

Monetary Policy: Rules and Transmission Mechanisms

Norman Loayza
Klaus Schmidt-Hebbel
editors



Central Bank of Chile / Banco Central de Chile

MONETARY POLICY FUNCTIONS AND TRANSMISSION MECHANISMS: AN OVERVIEW

Norman Loayza
World Bank

Klaus Schmidt-Hebbel
Central Bank of Chile

Monetary policy comprises the rules and actions adopted by the central bank to achieve its objectives. In most countries the primary goal of monetary policy is price stability. However, the mandate of many central banks also encompasses other objectives, including attainment of full employment, domestic financial stability, and normal operation of foreign payments. The priority of price stability over other policy goals tends to be politically accepted in most countries, if not actually enshrined in the laws governing the central bank.

Changes in monetary policy are triggered by domestic and external shocks that can imperil the attainment of policy objectives. Central banks implement policy changes by resetting their policy instrument, usually a short-term interest rate or a monetary or bank credit aggregate. These instruments affect the economy through various mechanisms of transmission to the ultimate policy goals.

Hence a useful way to understand monetary policy is to focus separately on central bank policy actions and the transmission mechanisms through which those actions work their effect. The central bank's policy rule or reaction function embodies its response to deviations in macroeconomic variables in order to achieve its ultimate policy objectives. Beyond the simple description of these policy rules, it is important to assess their efficiency (in the sense of achieving the desired combination of goals, subject to the structure of the

We are grateful to Francisco Gallego for his valuable contribution to the preparation of this overview.

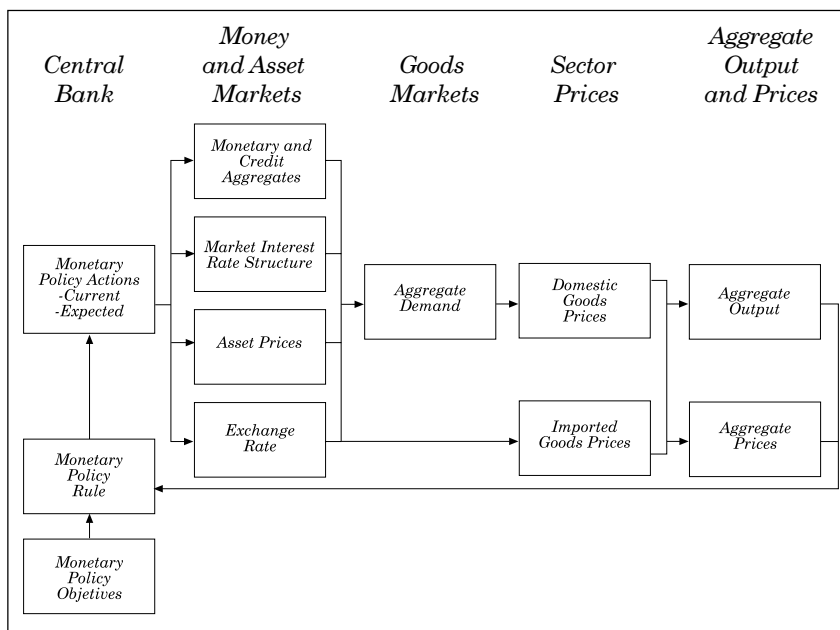
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economy and prevailing economic conditions) and their optimality (in the sense of maximizing a given social welfare function).

The transmission mechanisms of monetary policy work through various channels, affecting different variables and different markets, and at various speeds and intensities. Identifying these transmission channels is important because they determine the most effective set of policy instruments, the timing of policy changes, and hence the main restrictions that central banks face in making their decisions.

Figure 1 depicts the relationship between monetary policy rules and transmission mechanisms. Policy actions (both current and expected) taken on the basis of the central bank's policy rules are directly transmitted to money and asset markets. Changes in these markets in turn affect goods and labor markets, and ultimately aggregate output and prices. Finally, changes in current and projected output and inflation feed back into the monetary policy rules. This reflects the central bank's aim and strategy to attain its policy

Figure 1. Monetary Policy Rule and Transmission Mechanisms



objectives, given policymakers' understanding of the economy's structure and its response to policy actions.¹

The papers in this volume present and discuss some recent advances in theoretical and empirical research on monetary transmission mechanisms and monetary policy rules. Most are substantially revised versions of papers presented at the Third Annual Conference of the Central Bank of Chile, on "Monetary Policy: Rules and Transmission Mechanisms," held in Santiago in September 1999. Some of the papers analyze the properties of different types of central bank reaction functions. They link the objectives of the monetary authority to its reaction rules for different categories of shocks affecting the economy. These papers not only describe actual rules that central banks use or have used in the past, but also evaluate their efficiency and, in some cases, their optimality. Implicitly—and sometimes explicitly—these papers adopt a normative perspective, discussing how central banks *should* react to various shocks in order to achieve their goals, given the specific features of the economy in question. Other papers, mostly country studies, relate policy reaction functions to monetary transmission channels, emphasizing their interdependence in the actual conduct of monetary policy. These papers report on the transmission mechanisms in place in the various countries, allowing a comparison of their relative importance for economies that differ significantly in their structure.

1. TRANSMISSION MECHANISMS

The literature identifies five channels of monetary policy transmission.² John Taylor, in his paper in this volume, provides a summary review of these channels, and the authors of the case studies analyze in depth the transmission mechanisms most relevant to their

1. The arrows in figure 1 depict causality as running from monetary policy to money and asset markets, labor and goods markets, and sectoral as well as aggregate prices and output. For simplicity, feedback effects from prices and output to goods markets and ultimately to asset and money markets are not depicted. Moreover, the sequence of causality does not suggest precedence in time.

2. Mishkin (1995) provides an exposition of the main channels of transmission and the role of each in the context of the U.S. experience. A recent Bank of England (2001) document provides a qualitative analysis of monetary transmission in the United Kingdom. A similar document by the Central Bank of Chile (2000) describes monetary transmission in Chile.

respective countries. The description of the monetary transmission channels that follows here assumes that the central bank pursues an expansionary monetary policy by resetting its policy instrument, either increasing a monetary aggregate under its control or reducing its policy interest rate.³

The first transmission channel is the interest rate channel, the traditional mechanism and the one often regarded as the main channel of monetary policy transmission.⁴ An expansionary policy leads to a reduction in longer-term real interest rates, which in turn affects business investment, investment in residential housing, and consumer expenditure on durable goods. The corresponding shift in aggregate demand is eventually reflected in aggregate output and prices.

This transmission mechanism depends on several links, all of which are supported by various strands of the macroeconomic literature. Thus the relationship between nominal and real interest rates is explained by theories based on price and wage rigidities, the link between short- and long-term real rates follows from the expectational hypothesis of the term structure of interest rates, and the relationship between aggregate demand, on the one hand, and output and prices, on the other, is explained by combining a Phillips curve with temporary nominal price rigidities. The interest rate channel lies at the core of the current understanding of the “science of monetary policy [from] a new Keynesian perspective” (Clarida, Galí, and Gertler, 2000). This approach models the dynamic effects of monetary policy—temporary output effects and permanent price effects—in a framework based on optimizing dynamic behavior, rational expectations, and temporary price rigidities.⁵

3. The basic equivalence between an increase in money supply and a reduction in the policy interest rate—or the notion that the former leads to the latter (the liquidity effect)—has been empirically reconfirmed by Bernanke and Mihov (1998) for the United States. For welfare comparisons of money growth rules and interest rate rules, see Carlstrom and Fuerst (1995) and Végh (2002). Svensson (1999) compares inflation targeting with money growth targeting and nominal GDP targeting.

4. For example, this is the position taken by Taylor (1995), but strongly disputed by Bernanke and Gertler (1995).

5. The New Keynesian story as told by Clarida, Galí, and Gertler (2000) hinges on the existence of temporary price rigidities. Benhabib and Farmer (2000) provide an alternative model in which monetary policy also has temporary real effects but markets clear continuously. In their model, money enters the production function, and the possibility of multiple rational expectations equilibria arises.

In principle, there is no reason to focus on only one asset price—the interest rate—as a channel of monetary transmission. Monetary policy can also have important effects on the prices of equity, bonds, real estate, and foreign exchange. Considering these asset prices can lead to the identification of alternative channels of transmission. Given the special features of the transmission of monetary policy through the exchange rate, it is convenient to group equity, bonds, and real estate into a single, asset price channel and to consider the exchange rate mechanism separately.

According to the theory of the asset price channel, an expansionary monetary policy leads to higher equity prices, which make investment more attractive (through Tobin's q), thus raising aggregate demand. Higher equity prices also entail increased wealth, which raises consumption and thus also raises aggregate demand. The link between an increased money supply and higher equity prices can be argued from either a monetarist or a Keynesian perspective. In the former, an increase in money raises consumer wealth and asset prices, and hence spending on household and enterprise assets (as discussed by Meltzer, 1995), whereas in the latter, the increase in money lowers interest rates and makes equity markets more attractive.

The exchange rate channel works through both aggregate demand and aggregate supply effects. On the demand side, a monetary expansion lowers the domestic real interest rate, which, through the foreign interest parity condition, brings about a real depreciation of the domestic currency. This in turn leads to higher net exports and stronger aggregate demand.⁶ On the supply side, the real depreciation that results from a monetary expansion raises the domestic prices of imported goods, raising inflation directly. Moreover, the higher price of imported inputs contracts aggregate supply, reducing output and increasing inflation.

A fourth channel of policy transmission focuses on monetary and credit aggregates. The classical monetarist view emphasizes the role of narrow or broad monetary aggregates in determining asset, goods, and factor prices; this is still a relevant theory for long-run inflation. A different approach, and one that has received considerable attention in recent years, emphasizes the credit channel (Bernanke and Gertler, 1995). Its basic notion is that monetary policy can have price and output effects through the credit

6. Obstfeld and Rogoff (1995) emphasize this form of the exchange rate channel.

rationing that arises from information asymmetries between financial institutions and the firms and consumers to which they lend. This occurs because monetary policy affects the extent of adverse selection and moral hazard that constrain credit provision. It is argued that a monetary expansion alleviates adverse selection and moral hazard by increasing firms' net worth (through higher equity prices), reducing perceived loan risks (through lower real interest rates), improving firms' cash flow (through lower nominal interest rates), and decreasing the burden of nominal debt contracts (by raising inflation). All these considerations tend to make banks willing to supply more credit—*pari passu* with the monetary expansion—thus financing a rise in aggregate demand.⁷

Up to now we have considered four main transmission mechanisms, all of which focus on money and asset markets (second column of figure 1). The literature identifies a separate, fifth channel, based on private sector expectations about the future stance of monetary policy and, more generally, about all future-related variables. According to this “expectations” channel, all variables that have intertemporal implications, and are therefore determined in a forward-looking way, are affected by agents' beliefs about future shocks to the economy and how the central bank will react to them. The specific mechanisms for the expectations channel are intertemporal versions of the static interest rate, asset price, exchange rate, and monetary and credit mechanisms. For example, consider an announcement of future central bank policy that is not supported by a change in current policy. Such an “open-mouth operation” exerts real effects by modifying market expectations, which in turn trigger current changes in money and asset markets and lead ultimately to changes in output and inflation. Announcements of future policies may have the desired effect, however, only if the monetary authorities are perceived as committed to

7. Much work has been done recently on the credit channel. Li (2000) uses a general-equilibrium model to show that a monetary expansion can generate a liquidity effect that increases credit to households and increases aggregate activity. Repullo and Suarez (2000) develop a model of heterogeneous firms and banks in which the latter engage in monitoring to alleviate the moral hazard problem. These authors show that monetary expansion increases bank lending and aggregate investment, narrows the spreads between rates charged to borrowers and the risk-free rate, and causes a shift in the extension of credit toward more risky firms. The credit channel is empirically confirmed for the United States by Kashyap and Stein (2000), who find that the impact of monetary expansion on bank lending is stronger for banks with less liquid balance sheets.

their policies. Hence, as the political economy literature emphasizes, the credibility of monetary policy becomes relevant.⁸

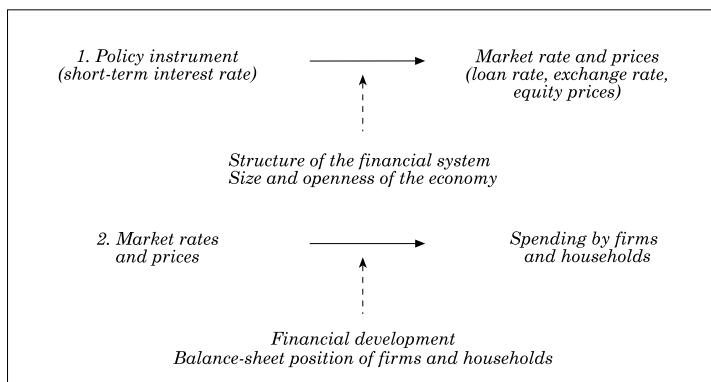
Various issues related to transmission mechanisms are worth discussing in more detail. For example, are different transmission channels functionally equivalent in terms of their effects on the economy? And what structural features of particular economies influence the relative importance of the various transmission mechanisms, and how do they do so?

(i) *Equivalence of transmission channels.* In the textbook example of a classical, fully flexible economy, a monetary shock translates into an equiproportionate and instantaneous increase in all nominal aggregates (including money and credit), asset prices, the exchange rate, factor prices, and goods prices. Hence aggregate demand expands but aggregate supply remains unchanged, precluding any real effects. Under such conditions it makes no sense to identify separate transmission mechanisms, much less attempt to measure their relative importance. All such mechanisms are observationally equivalent, reflecting the same transmission of money to prices in a fully flexible economy. Similar arguments can be made when moving away from a fully flexible economy, pointing out observational equivalence among transmission channels in a real-world economy characterized by temporary price rigidities. Discussing different transmission mechanisms makes sense only if it provides a better understanding of the relative dominance, speed, and intensity of the different channels, that is, if it helps to clarify how the dynamic response of output and prices is conditioned by the workings of specific asset, goods, and factor markets. But this requires an all-encompassing econometric model in order to engage in precise differentiation among competing transmission mechanisms, and such a model is not typically found in the empirical literature on transmission channels.

(ii) *Structural features and transmission mechanisms.* Not all economies react in the same way to changes in monetary policy. The choice of transmission mechanisms and their effectiveness in the conduct of monetary policy depend on the specific features of the economy in question. For purposes of illustration, we can divide monetary transmission into two steps (figure 2): first, the

8. See Persson and Tabellini (1997) for a survey of the credibility literature.

Figure 2. Factors that Influence the Transmission of Monetary Policy



policy instrument affects various asset markets and prices, and second, these changes affect spending decisions by firms and households. Each step is affected by the economy's specific features, and in particular its stage of financial development and openness to international trade and capital. The effect that changes in market prices can have on aggregate demand is also determined by the solvency and liquidity of firms and households.

(iii) *Depth and structure of the financial system.* Several characteristics of the financial system—whether it is based primarily on banks or comprises a variety of financial institutions, whether it is run publicly or privately, and whether it offers a large range of financial products—affect the effectiveness of monetary policy. First, monetary policy changes are more quickly and closely translated into changes in market interest rates and other financial prices if the financial system is well diversified in terms of its institutions and products. Conversely, when a few financial institutions have effective monopoly power and the supply of financial alternatives is poor, these institutions can to some extent determine market rates and prices independent of the actions of the central bank. Second, consumption and investment decisions by households and firms are more responsive to market rates and prices when those households and firms are not financially constrained

but can exercise their choices both intertemporally and across goods and services. The depth and structure of the financial system also determine which transmission mechanisms are the most relevant. When the financial system is shallow and poorly diversified (that is, dependent on a few banks), the asset price channel is of little importance (because of the low capitalization of the stock market) and the interest rate channel is weak (because of banks' monopoly power). The credit channel instead dominates, given the moral hazard and adverse selection problems that characterize shallow financial systems. The exchange rate channel is usually not very relevant in financially underdeveloped economies, because such economies tend to impose controls on foreign exchange transactions, whether related to international trade or capital flows. As the financial system develops and becomes deeper and more diversified, however, the asset price, interest rate, and exchange rate channels become more important.

(iv) *Size and openness of the economy.* The size of an economy and its openness to external transactions determine the importance of the exchange rate channel and the ability of monetary policy to determine domestic interest rates. The exchange rate channel receives much attention in this volume because the case studies focus on open and mostly small economies. In some of the studies, estimation of the pass-through from exchange rate changes to domestic inflation under different regimes takes center stage.

We turn now to a review of the findings on transmission mechanisms presented by the country case studies included in this volume. (Subsequent sections of this introduction discuss their findings on monetary reaction functions.) The economies studied—Australia, Canada, Chile, Israel, South Africa, and the United Kingdom—share several features: all are open, all except the United Kingdom are relatively small, and all follow a monetary regime based on inflation targeting with largely flexible exchange rates.

All the case studies develop models of varying complexity to analyze the interaction between the central bank and the economy. They apply various empirical techniques to identify the main transmission channels. Janine Aron and John Muellbauer (South Africa) and Leonardo Leiderman and Hadas Bar-Or (Israel) estimate simple structural equations. Alastair Cunningham and Andrew Haldane (United Kingdom) and Adam Cagliarini and Guy Debelle (Australia) rely on the calibration of simulated economies. Ángel Cabrera and Luis Felipe Lagos (Chile) estimate vector autoregression (VAR)

models. David Longworth and Brian O'Reilly (Canada) combine some of these techniques.

Table 1 summarizes the importance of each of the transmission channels in these six case studies.⁹ Most relevant are the traditional interest rate and exchange rate channels. In Chile and Israel, where financial market imperfections are likely to be prevalent, the credit channel is also important. In Canada and the United Kingdom, two seasoned practitioners of inflation targeting, expectations about future monetary policy are found to be a relevant transmission mechanism. The asset price channel appears to be unimportant in the economies considered here. However, in some of the studies the conditions used to identify the transmission mechanisms were unable to differentiate among the interest rate, credit, and asset price mechanisms. Hence the variables used to estimate the interest rate channel may be proxying for the other two channels as well. This is a limitation shared not only by some of the other country studies in this volume but indeed by most papers on transmission mechanisms, as discussed above.

Some of the country studies pay special attention to the effect of nominal currency devaluations on inflation. This is only natural given the importance of the exchange rate mechanism in these economies. Table 2 shows that, in the United Kingdom and Israel, the pass-through from a depreciation to inflation is incomplete: the average pass-through is estimated at 70 percent and 40 percent, respectively. Both studies also find evidence that the pass-through effect

Table 1. Main Monetary Policy Transmission Mechanisms in Six Countries

<i>Country</i>	<i>Interest rate</i>	<i>Credit</i>	<i>Asset prices</i>	<i>Exchange rate</i>	<i>Expectations</i>
Australia	Yes	No	No	Yes	No
Canada	Yes	No	No	Yes	Yes
Chile	Yes	Yes	No	Yes	No
United Kingdom	Yes	No	No	Yes	Yes
Israel	Yes	Yes	No	Yes	No
South Africa	Yes	No	No	Yes	No

Source: Papers in this volume by Cagliarini and Debelle, Longworth and O'Reilly, Cabrera and Lagos, Cunningham and Haldane, Leiderman and Bar-Or, and Aron and Muellbauer.

9. For a review of the importance of different transmission mechanisms in a broader sample of emerging economies, see Bank for International Settlements (1998).

Table 2. Estimated Pass-Through of a One Percentage Point Nominal Depreciation to Inflation

<i>Country</i>	<i>Average impact on inflation (percentage points)</i>	<i>Cyclical adjustment</i>
United Kingdom	+0.7	If output is 1% below (above) potential, pass-through falls (rises) by 0.2 percentage points
Israel	+0.4	If unemployment is 1% above (below) its average, pass-through falls (rises) by 0.1 percentage points

Source: Cunningham and Haldane, and Leiderman and Bar-Or, this volume.

is influenced by the economy's cyclical position: it is smaller in recessions, and larger in a boom, than in normal times.

2. MONETARY POLICY RULES: POSITIVE ANALYSIS

Monetary policy rules or reaction functions describe the response of policy instruments to deviations in key macroeconomic variables from levels the monetary authorities deem optimal. The study of monetary policy rules made a qualitative leap with the path-breaking work of Taylor (1993); in fact, the policy rules by which interest rates respond to output and inflation gaps are now known as "Taylor rules." Actually, many central banks throughout the world use a short-term interest rate as their policy instrument, and this is also true in most of the cases considered in this volume. Some exceptions are noted in the papers by Laurence Ball (New Zealand uses a monetary conditions index) and by Longworth and O'Reilly (Canada uses the difference between short- and long-term rates as its instrument).

Central banks typically respond to deviations, or gaps, in inflation and output from desired levels—these gaps are the two standard arguments in monetary reaction functions. Some central banks also react to a key open-economy variable, such as the exchange rate or the current account deficit, in setting policy. Another argument often included in policy rules is the lagged value of the interest rate itself, reflecting some degree of inertia in central bank behavior.

The time dimension of the variables included in the reaction function varies from central bank to central bank. In some cases only the current values of the gaps are included; in others their

lags or future projected levels, or both, are also considered.¹⁰ The variables included in the reaction function do not necessarily correspond to the ultimate policy objectives. Depending on its economic model, the central bank may react to changes in other variables that affect its objectives. For example, even when the authorities' only objective is price stability, they may have to respond not only to inflation gaps but also to output gaps.¹¹

Table 3 summarizes the estimates from the studies included here of the reaction coefficients associated with inflation gaps. The paper by Vittorio Corbo in this volume describes the monetary reaction functions in five Latin American countries and arrives at several findings. First, the difference between actual inflation and its policy target is a significant variable in the policy rules of all five countries; output gaps are also important arguments in the policy rules of most. Second, only in Chile does the central bank react "aggressively" to inflation deviations; that is, in Chile the implied nominal interest rate is adjusted more than proportionately to a change in inflation, whereas in other countries nominal interest rates rise less than proportionately with inflation gaps.¹² Third, there is mixed evidence regarding whether structural changes occur in central banks' reaction functions when they become independent. Finally, Latin American central banks exhibit considerable inertia in their policy instruments.

Among the other papers in this volume, Leiderman and Bar-Or show that the Bank of Israel follows a rule by which the policy interest rate responds to inflation gap projections and the lag in

10. Clark, Laxton, and Rose (2001) compare an interest rate policy rule that responds to contemporaneous inflation with an alternative rule that responds to the forecast of future inflation. They show, in the context of an empirical model for the United States that allows for asymmetries, that the forward-looking rule yields lower output volatility and a higher equilibrium output.

11. Most models of monetary transmission and policy rules assume that economic agents have full information about the central bank's policy rules. Tetlow and von zur Muehlen (2001) develop an empirically plausible model in which agents must learn the policy rule, and show that the real costs of learning may be substantial.

12. Benhabib, Schmitt-Grohé, and Uribe (2001a) dispute the notion that policy rules that respond to increases in inflation with a more than one-for-one increase in the nominal interest rate are stabilizing. They show that once the zero bound on nominal interest rates is taken into account, "the peril of (a stabilizing) Taylor rule" is that there exist an infinite number of equilibrium trajectories that converge to a liquidity trap, that is, a steady state in which the nominal interest rate is close to zero and inflation is possibly negative. In a separate paper, Benhabib, Schmitt-Grohé, and Uribe (2001b) show that Taylor-type policy rules induce aggregate instability by generating multiple equilibria. Moreover, active monetary policy can give rise to multiple equilibria, whereas passive monetary policy renders the equilibrium unique.

Table 3. Estimates of the Inflation Coefficient in Nominal Interest Rate Reaction Functions, Selected Countries and Periods

<i>Country</i>	<i>Study</i>	<i>Estimation period</i>	<i>Estimated coefficient</i>
Canada	Longworth and O'Reilly	Calibrated model	1.65
Chile	Cabrera and Lagos	1986-96	1.10-1.14
	Corbo	1985-90	1.20
		1990-99	1.21
Colombia	Corbo	1985-90	0.41
		1991-98	0.50
Costa Rica	Corbo	1990-98	0.69
		1990-95	0.67
El Salvador	Corbo	1992-98	0.40
		1994-98	0.46
Israel	Leiderman and Bar-Or	1994-99	0.90
Peru	Corbo	1993-98	0.80
South Africa	Aron and Muellbauer	1986-97	0.20
United Kingdom	Cunningham and Haldane	Calibrated model	1.00
United States	Taylor (1993)	1987-92	1.50

Source: Papers in this volume; Taylor (1993).

output. The central bank appears to adjust to, rather than oppose, inflation increases; that is, the Bank of Israel raises the policy rate less than proportionately in reaction to inflation shocks. Aron and Muellbauer apply the framework of basic reaction functions to South Africa. They also control for elements of importance to open economies, including the world interest rate and a measure of international financial liberalization, and find that these factors are relevant to the South African central bank's reaction function.

The high degree of inertia in policy rules that characterizes most central banks' reaction functions is addressed in several of the papers. Ball suggests that policy inertia is the result of political economy considerations: central banks wish to maximize their credibility by keeping policies stable and systematic. Debelle and Cagliarini show that in Australia's case the inertia in the policy instrument is due to uncertainty about the economy's reaction to changes in the interest rate. When central banks are unsure of the impact of their policies, they tend to resist changes in their current policy stance. More generally, Juan Pablo Medina and Rodrigo Valdés, in the first of

their two papers in this volume, rationalize policy inertia in their theoretical model by including interest rate volatility as a negative argument in the central bank's objective function.

In their cross-country study in this volume, Stephen Cecchetti and Michael Ehrmann find that central banks that have adopted explicit inflation targets have evolved from being less averse to inflation before adopting the target to more averse than otherwise similar countries without inflation targets.¹³ In fact, these authors estimate that eight of the nine inflation-targeting countries they study have become more hawkish: that is, their reaction functions feature significantly larger coefficients on the inflation gap.¹⁴ Cecchetti and Ehrmann also conclude that countries that use this monetary policy framework have been able to reduce significantly both the level and the volatility of inflation compared with a control group of countries. On the other hand, these authors also find that output volatility is greater in countries with inflation targets than in countries without them. This raises the question as to whether policy actions can somehow soften the trade-off between output variability and inflation variability. Using Canada as an example, Longworth and O'Reilly make the case that credibility gained by the central bank in the pursuit of its objectives can result in a less pronounced sacrifice in terms of output volatility for a given reduction in inflation volatility.

According to Cecchetti and Ehrmann, Chile is one of the inflation-targeting countries with a stronger reaction to inflation surges, having become gradually more averse to inflation throughout the past decade. This finding for Chile is consistent with Corbo's results, which show that the relative coefficient on inflation variability in the monetary reaction function has become larger since the central bank became independent in 1990.

3. MONETARY POLICY RULES: NORMATIVE ANALYSIS

The conceptual framework guiding the debate on normative aspects of monetary policy rules has been established by the "new

13. Increasing aversion toward inflation is not a unique feature of inflation-targeting central banks. For example, as Clarida, Gali, and Gertler (2000) show, U.S. interest rate policy in the Volcker-Greenspan period appears to have been much more sensitive to changes in expected inflation than in the pre-Volcker period.

14. The nine countries are Australia, Canada, Chile, Finland, Israel, New Zealand, Spain, Sweden, and the United Kingdom.

normative macroeconomics,” as discussed in the paper by Taylor in this volume. According to this framework, policy rules are analyzed in reference to a process of objective optimization carried out by the monetary authorities. Following this approach, some of the papers included in this volume address, first, which monetary rules are most efficient at achieving the monetary authority’s objectives and, second, what is the optimal policy response from a social welfare perspective.

Taylor compares the performance, in terms of macroeconomic stability, of model-specific optimal rules with that of simple rules under a variety of models and transmission mechanisms. He concludes that simple rules in which the policy instrument responds solely to deviations in output and inflation (Taylor rules) perform well under several *different* transmission mechanisms. For example, even when the transmission channel via the exchange rate is strong, simple rules perform very similarly to model-specific optimal rules that include reactions to deviations in the exchange rate. Taylor warns that, unlike simple rules, complex rules—those that include reactions to economic variables over and above inflation and output, or establish dynamic specifications within their reactions—can have disappointing results, depending on the economy’s transmission channel. Since these optimal complex rules are model specific, a different characterization of the economy can render the complex rules far inferior to simple rules.

Using a theoretical model, the paper by Charles Carlstrom and Timothy Fuerst in this volume arrives at a conclusion similar to Taylor’s. These authors also conclude that when central banks use rules based on future expectations of inflation, prices and monetary aggregates may become indeterminate (that is, the nominal anchor is lost); this does not occur when rules are based on current and past inflation gaps with respect to the target rate.

Another group of issues that can be analyzed from a normative viewpoint deals with rules for open economies. In their case study of the United Kingdom, Cunningham and Haldane quantify the optimal horizon for the central bank’s future planning, that is, how far into the future inflation rates are noticeably affected by the monetary authorities’ reaction. They argue that, in an economy where the pass-through from currency depreciation to domestic inflation is complete, the optimal planning horizon ranges between two and four quarters. In addition, in economies where the amount of pass-through varies with the business cycle, the optimal reaction should consider even shorter periods.

Working in a small, open economy setting, Medina and Valdés, in their paper described previously, derive optimal rules for various preferences on the part of the monetary authorities. They conclude that, if the current account balance is one of the objectives of monetary policy—as seems to have been the case for the Central Bank of Chile in the early 1990s—the optimal reaction function is similar even among central banks with varying degrees of inflation aversion. In addition, if the central bank is averse to current account deficits and not (or is averse to a lesser degree) to surpluses, it will respond more aggressively to inflation gaps than in the previous case.

Also focusing on open economies, Ball analyzes the case where the central bank prefers to fix its policy instrument for long periods. In particular, Ball compares rules that fix the interest rate with those that set a monetary conditions index (that is, a combination of the interest rate and exchange rate depreciation). His main conclusion is that setting the interest rate is optimal when the economy suffers mainly from real shocks to demand for its exports, whereas the monetary conditions index is superior when the economy is affected by international financial shocks.

In their second paper in this volume, Medina and Valdés study optimal monetary policy rules under inflation range targeting (sometimes called zone targeting). They compare the reaction rules that result when the central bank targets a single point, when it establishes a zone with “hard edges” (that is, when the central bank’s loss function gives a large weight to inflation deviations beyond the range), and when the zone has “soft edges.” They find that inflation range targeting produces a less aggressive optimal monetary policy than point targeting. However, optimal policy under range targeting is virtually never inactive and depends on how “hard” the edges are. Monetary policy behaves in a preemptive way: given that the probability of keeping inflation within the range is maximum when inflation is at the middle of the range, policy interest rates would always react when inflation is not at the center of the range.

Finally, this volume presents some findings regarding the relationship between fiscal and monetary policies. The paper by Herman Bennett and Norman Loayza argues that when monetary and fiscal authorities have different preferences for output and inflation gaps and conduct their policies without coordination, the policy reactions of each can become more radical. Combining a game-theoretical model with empirical evidence for industrialized countries, Bennett and Loayza find that if the central bank has a greater preference for inflation

control while the government cares more about unemployment reduction, public sector deficits (the government's instrument) and interest rates (the central bank's instrument) will both be biased upward. They conclude that, without prejudice to the gains associated with central bank independence, there are potential benefits to generating institutional incentives that permit coordination between monetary and fiscal authorities. They stress, however, that this process should not involve reducing the priority attached to inflation in the central bank's objective function.

4. CONCLUSIONS AND POLICY IMPLICATIONS

This volume presents original research on monetary policy rules and transmission mechanisms. The contributing authors take a variety of approaches in addressing these issues, from country studies to cross-country empirical analysis, and from theoretical models to historical narrative. Although the papers do not provide definitive answers to the questions of optimality and efficiency of monetary policy, they do produce relevant results that have policy implications.

Little is yet known about the empirical importance of different monetary policy transmission mechanisms. This is generally due to the lack of an all-encompassing macroeconomic model as well as to complexities derived from uncertainty, structural change, asymmetries, and nonlinearities in the response of an economy to changes in policy instruments. Nonetheless, this volume provides some evidence that the traditional mechanism, based on the direct impact of interest rates on aggregate demand, output, and inflation, remains the most relevant. The exchange rate channel is also found to be important—although not dominant—in open economies. Depreciations are not passed through fully to domestic inflation; rather, pass-through coefficients are found to range between 40 and 70 percent and are lower during recessions than during expansions. Finally, in countries with credible inflation targeting regimes, the expectations channel may be important in reinforcing the monetary authorities' intended policies, because economic agents know that the central bank's commitment to its target strongly influences the current and future policy stance.

Simple Taylor rules—rules consisting of the reaction of the monetary policy instrument to deviations from target inflation and potential

output—generally describe central bankers' behavior well. From a normative perspective, these rules perform robustly—and in many cases adequately—under different transmission mechanisms. That is, Taylor rules generate a similar level of macroeconomic stability under different monetary policy transmission scenarios. Moreover, simple rules seem to provide results similar to those of more model-specific complex rules, particularly when the exchange rate channel is important.

Finally, regarding the general framework of monetary policy, there is evidence that countries with explicit inflation targets have achieved inflation rates that are lower and less volatile than in countries without them; however, output in these inflation-targeting countries is somewhat more volatile than in nontargeting countries. In countries where the central bank becomes more credible in the pursuit of its objectives over time, a reduction in the volatility of inflation may be achieved at a lower cost in terms of output volatility.

REFERENCES

- Bank for International Settlements. 1998. "The Transmission of Monetary Policy in Emerging Markets." BIS Policy Paper 3. Basle.
- Bank of England. 2001. *The Transmission Mechanism of Monetary Policy*. London.
- Benhabib, J., and R. Farmer. 2000. "The Monetary Transmission Mechanism." *Review of Economic Dynamics* 3(3): 523-50.
- Benhabib, J., S. Schmitt-Grohé, and M. Uribe. 2001a. "The Perils of Taylor Rules." *Journal of Economic Theory* 96(1-2): 40-69.
- . 2001b. "Monetary Policy and Multiple Equilibria." *American Economic Review* 91(1): 167-86.
- Bernanke, B. S., and M. Gertler. 1995. "Inside the Black Box: The Credit Channel of Monetary Policy Transmission." *Journal of Economic Perspectives* 9(4): 27-48.
- Bernanke, B., and I. Mihov. 1998. "The Liquidity Effect and Long-Run Neutrality." *Carnegie Rochester Conference Series on Public Policy* 49: 149-94.
- Carlstrom, C. T., and T. S. Fuerst. 1995. "Interest Rate Rules vs. Money Growth Rules: A Welfare Comparison in a Cash-in-Advance Economy." *Journal of Monetary Economics* 36(2): 247-67.
- Central Bank of Chile. 2000. *Monetary Policy of the Central Bank of Chile: Objectives and Transmission*. Santiago (May).
- Clarida, R., J. Galí, and M. Gertler. 2000. "Monetary Policy Rules and Macroeconomic Stability: Evidence and Some Theory." *Quarterly Journal of Economics* 115(1): 147-80.
- Clark, P., D. Laxton, and D. Rose. 2001. "An Evaluation of Alternative Monetary Policy Rules in a Model with Capacity Constraints." *Journal of Money, Credit, and Banking* 33(1): 42-64.
- Kashyap, A. K., and J. C. Stein. 2000. "What Do a Million Observations on Banks Say about the Transmission of Monetary Policy?" *American Economic Review* 90(3): 407-28.
- Li, V. E. 2000. "Household Credit and the Monetary Transmission Mechanism." *Journal of Money, Credit, and Banking* 32(3): 335-56.
- Meltzer, A. H. 1995. "Monetary, Credit, and (Other) Transmission Processes: A Monetarist Perspective." *Journal of Economic Perspectives* 9(4): 49-72.
- Mishkin, F. 1995. "Symposium on the Monetary Transmission Mechanism." *Journal of Economic Perspectives* 9(4): 3-10.

- Obstfeld, M., and K. Rogoff. 1995. "The Mirage of Fixed Exchange Rates." *Journal of Economic Perspectives* 9(4): 73-96.
- Persson, T., and G. Tabellini. 1997. "Political Economics and Macroeconomic Policy." NBER Working Papers 6329. Cambridge, Mass.: National Bureau of Economic Research (December).
- Repullo, R., and J. Suarez. 2000. "Entrepreneurial Moral Hazard and Bank Monitoring: A Model of the Credit Channel." *European Economic Review* 44(10): 1931-50.
- Svensson, L. 1999. "Inflation Targeting as a Monetary Policy Rule." *Journal of Monetary Economics* 43: 607-54.
- Taylor, J. 1993. "Discretion versus Policy Rules in Practice." *Carnegie Rochester Conference Series on Public Policy* 39: 195-214.
- . 1995. "The Monetary Transmission Mechanism: An Empirical Framework." *Journal of Economic Perspectives* 9(4): 11-26.
- Tetlow, R. J., and P. von zur Muehlen. 2001. "Simplicity versus Optimality: The Choice of Monetary Policy Rules When Agents Must Learn." *Journal of Economic Dynamics and Control* 25 (1-2): 245-79.
- Végh, C. 2002. "Monetary Policy, Interest Rate Rules, and Inflation Targets." In *Indexation, Inflation, and Monetary Policy*, edited by F. Lefort and K. Schmidt-Hebbel. Santiago: Central Bank of Chile.

THE MONETARY TRANSMISSION MECHANISM AND THE EVALUATION OF MONETARY POLICY RULES

John B. Taylor

Treasury Department, USA and Stanford University

This paper explores the connection between the monetary transmission mechanism—the channel through which a change in monetary policy affects the economy—and the choice of monetary policy rules to guide central bank decisions. Different views of the monetary transmission mechanism are readily apparent in the many different models that monetary economists use to evaluate monetary policy. For example, a symposium on “The Monetary Transmission Mechanism” in the *Journal of Economic Perspectives* in the fall of 1995 contains five papers representing alternative views. The question is: Do these different views lead to substantial differences in the optimal rules for monetary policy? To answer this question, I draw on evidence obtained in recent and ongoing research on the quantitative evaluation of monetary policy rules. In fact, there has been an explosion of this type of normative macroeconomic research in recent years, reflecting both an increase in supply by researchers and an increase in demand by policymakers. Most of the *new normative macroeconomics* takes as given that the central bank has an explicit or implicit inflation target, and this assumption immediately makes the research useful to many central bankers. The purpose of this research is then to find policy rules to guide policymakers in setting the policy instruments so as to bring the inflation rate close to the target and keep it there, while taking account of the short-run trade-offs that impinge on output, employment, and exchange rate variability.

By an inflation target I simply mean a numerical value (usually near zero) for the inflation rate in the objective function used for policy evaluation; the “target rate of inflation is therefore given” (Taylor, 1979, p. 1276). Having an inflation target, however, does not necessarily mean a particular *operating procedure* for the central bank, such as setting the instruments of policy so as to bring a forecast of inflation into equality with the target, or so that the instruments react in a certain way to real output or the exchange rate. The choice of an operating procedure (a policy rule) is an outcome of the normative macroeconomic research, not an input into it. Although having an inflation target does not necessarily mean that the central bank is explicit rather than implicit in announcing the target, there is wide agreement about the benefits of a more transparent policy.

This new normative macroeconomics is ideally suited for answering questions about the connection between the monetary transmission mechanism and the policy rule. First, the recommendations for policy rules that emerge from this research are highly specific and usually expressible in the form of precise algebraic equations. Second, the recommendations are derived from explicit structural models of the economy in which the researchers have taken clear positions on the monetary transmission mechanism. Hence it is possible to trace the connection between views of the monetary transmission mechanism and policy choices in a way that was not possible before. The results are therefore new and in some cases quite surprising. One possible disadvantage of this approach should be mentioned at the start. By focusing on quantitative research, the approach does not deal with less formal or “verbal” descriptions of the monetary transmission mechanism, or with more basic theoretical models that have not yet been specified quantitatively for empirical work.

The paper proceeds as follows. I first briefly summarize different views of the monetary transmission mechanism. Because understanding the results of this paper requires an appreciation of the novel nature of the new normative macroeconomics, I next describe the methodology of the policy research in some detail. I then endeavor to classify eighteen policy models according to the approach they take to the monetary transmission mechanism, distinguishing between aggregate demand and price adjustment effects. In the remainder of the paper, I examine how these different views affect the estimated performance of different policy rules.

I look at a simple benchmark rule, at policy rules with inertia, and at policy rules designed for small, open economies. In cases where the results seem surprising or paradoxical, I examine and compare the different monetary transmission mechanisms in more detail. One by-product of this approach might therefore be a better understanding of how the different views compare. I summarize and discuss the results in the last section of the paper.

1. TERMINOLOGY AND A SUMMARY OF THE DIFFERENT VIEWS

Some terminology is needed to distinguish among the different views of the monetary transmission mechanism. One view, very common in new normative macroeconomic research, is the *financial market price* view (see Taylor, 1995, for details). This view stresses the impact of monetary policy on the prices of and rates of return on financial assets—including bond prices, interest rates, and exchange rates—and thereby on the spending decisions of firms and households. There are different versions of the financial market view. For example, different degrees of emphasis are placed on the exchange rate versus other asset prices; these differences are partly a matter of the degree of openness of the economy being studied. In smaller, more open economies the exchange rate is, of course, quantitatively more important than in larger economies. How does a greater influence of the exchange rate affect the optimal policy rule?

Another view of the monetary transmission mechanism, frequently put forth as an alternative to the financial market price view, is the *credit* view (see Bernanke and Gertler, 1995, for details). The credit view emphasizes changes in lending by banks and other financial intermediaries as an alternative to internal finance. Quantitative measures of credit and corporate cash flows are therefore an important input to this view. Does it matter for the choice of a monetary policy rule whether one thinks the financial market price view or the credit view dominates?

There are also different views about what *rigidities* are needed to explain why a change in a nominal quantity like the money supply affects real variables. Most of the research evaluating policy rules uses some variant of a *staggered price* or *wage setting* theory

to generate the impact of policy. A distinguishing feature of these models is that expectations of future inflation affect price setting. They differ in the degree of backward looking that is mixed in with the forward looking, and whether or not it is the expected inflation rate or the expected price level that affects decisions.

Another, completely different type of rigidity that has been used in normative macroeconomic research is that of the *limited participation* model (see Christiano, Eichenbaum, and Evans, 1997, for a review). In these models investors are limited in the amount of funds they can transfer from one financial account to another each period. How much difference do these different models make for the choice of an optimal policy rule?

Finally, despite broad agreement that expectations are very important in financial markets, and therefore in the monetary transmission mechanism, there is disagreement about the best way to model expectations. How different is the performance of policy rules in models that assume rational expectations from that of policy rules in models that do not?

2. THE NATURE OF THE MODELS AND THE POLICY RESEARCH

The approach of this paper is to first classify different models used for policy evaluation into structural types based on the approach they take to the monetary transmission mechanism, and then to see whether these different structures affect the evaluation of policy rules in systematic ways. All the quantitative models of the monetary transmission mechanism examined in this paper are stochastic, dynamic, and economy-wide. The models are also used in the same way for analysis and policy evaluation. Hence the differences are not in the methodology, but rather in the economic structure. It is helpful to discuss these methodological similarities and review their rationale before examining the structural differences.

The models must be stochastic if one is to predict how effective policy rules are at cushioning the economy from unanticipated shocks. The stochastic shocks are added to equations of the model, and their stochastic properties (variances and covariances) are matched with historical experience just as other parameters of the models are.

The models must be dynamic for two reasons: first, because there are lags in the monetary transmission mechanism, and second, because expectations of the future are important in financial markets. The most common—although not universal—expectations assumption used in these models is the rational expectations assumption, in which people's expectations of the future are equal to the model's mathematical conditional expectations.

The models are economy-wide or general-equilibrium models because monetary policy has impacts on the whole economy. Moreover, the rational expectations assumption requires a complete model of the economy in order to explain how expectations are formed. Some researchers prefer to use the term "model consistent" rather than "rational expectations," to emphasize that expectations depend on a complete model of the economy (see Brayton and others, 1997a and b, for example).

Stochastic, dynamic, economy-wide macroeconomic models with rational expectations give rise to mathematical structures that involve systems of difference equations in which both past and expected future values of variables appear. A typical model of the transmission mechanism used for policy evaluation can be written in the form

$$f_i \left(y_t, y_{t-1}, \dots, y_{t-p}, E_t y_{t+1}, \dots, E_t y_{t+q}, a_i, x_t \right) = u_{it} , \quad (1)$$

for $i = 1, \dots, n$, where y_t is an n -dimensional vector of endogenous variables at time t , x_t is a vector of exogenous variables at time t , u_{it} is a vector of stochastic shocks at time t , and a_i is a parameter vector.

The simplest rational expectations model of the monetary transmission mechanism is the case where the model in equation (1) is a single linear equation ($i = 1$) with one lead ($q = 1$) and no lags ($p = 0$). This is the well-known rational expectations version of the Cagan model (see Sargent, 1987, for example) in which the endogenous variable (y_t) is the current price level, the expected future variable ($E_t y_{t+1}$) is the one-period-ahead price level, and the exogenous variable (x_t) is the money supply (the instrument of policy). Of course, models used to evaluate policy in realistic situations (other than hyperinflations) need to be more complex than the Cagan model, and indeed all the models examined in this paper have more than one equation and values of p or q greater than one. In many applications the system of equation (1) is linear, although nonlinear versions of equation (1) are not uncommon.

A solution to equation (1) is a stochastic process for y_t .¹ Obtaining such a solution in a rational expectations difference equation system is much more difficult than doing so in a simple backward-looking difference equation with no expectations variables. This difficulty makes the new normative macroeconomics difficult to teach and requires more expertise than is needed for conventional policy evaluation methods. This complexity is one reason why the methods are not explained in detail in textbooks in macroeconomics.

How do researchers use the model in equation (1) for policy evaluation? Alternative monetary policies are characterized by rules that stipulate how the instruments of policy (usually the short-term interest rate) react to observed variables in the economy. The rules may be simple or complex, but in general they contain some feature that one is interested in investigating, such as how reactive policy should be to the exchange rate or to real output. In particular, one might want to know the optimal response of the policy instrument to these variables.

The method used to answer the question can be described in the following series of steps:

- Place the candidate policy rule into model $f_i(\cdot)$.
- Solve the model using one of the solution algorithms.
- Look at the properties of the stochastic steady-state (stationary) distribution of the variables (inflation, real output, and unemployment).

1. Many papers have been written on algorithms for obtaining solutions to systems like equation (1). In the case where $f_i(\cdot)$ is linear, Blanchard and Kahn (1980) showed how to get the solution to the deterministic part of equation (1) by finding the eigenvalues and eigenvectors of the system. Under certain conditions the model has a unique solution. Many macroeconomists have proposed algorithms to solve equation (1) in the nonlinear case (see Taylor and Uhlig, 1990, for a review). The simple iterative method of Fair and Taylor (1983) has the advantage of being very easy to use even in the linear case but is less efficient than other methods. Brian Madigan at the Federal Reserve Board has developed a very fast algorithm to solve such models. I have found that the iterative methods work very well in teaching advanced undergraduates and beginning graduate students. The algorithms are easy to program within existing user-friendly computer programs such as Eviews. I use such iterative methods to solve my multicountry rational expectations model (Taylor, 1993b). I think more emphasis on solving and applying expectational difference equations should be placed in the economics curriculum, especially at the graduate level but also at the undergraduate level. Many graduate students come to economics knowing how to solve difference and differential equations, but *expectational* difference equations such as equation (1) are not yet standard and require time and effort to learn well. It is difficult to understand, let alone do, modern macroeconomic policy research without a basic knowledge of how these expectational stochastic difference equations work.

- Choose the rule that gives the most satisfactory performance (a loss function may be useful here to help compare points on the trade-off between the variance of one target variable and another).
- Check the results for robustness using other models.

The use of policy rules in this way is the most noticeable characteristic of policy evaluation research in macroeconomics today, especially when compared with the days before the rational expectations revolution.² The introduction of the rational expectations assumption into macroeconomics significantly increased the advantages of using policy rules in this way to evaluate policy. With rational expectations, people's expectations of policy matter greatly for the impact of changes in the instruments of policy, as demonstrated forcefully by Lucas (1976). Hence, in order to evaluate the impact of a policy, one must state what that future policy will be under different contingencies. Such a contingency plan is nothing more than a policy rule.

Woodford (1999b) emphasizes the importance of the "timelessness" aspect of the above approach to policy evaluation. By focusing on a stationary policy rule and the stationary distribution, one is ensuring that the policy rule is no different than the one that the policymaker would follow under the same conditions at any other time. This timelessness, or stationarity, feature makes the evaluation of the policy rule much more accurate and less subject to serious errors. In effect, it assumes away any credibility problems that plague the evaluation of policy rules when people are forward-looking, as discussed in McCallum (1999).

3. DIFFERENT VIEWS OF THE MONETARY TRANSMISSION MECHANISM AS SEEN FROM THE POLICY MODELS

Several of the quantitative models that I examine in this study consist of only two structural equations. The first is an *aggregate demand* or *IS equation* showing how real GDP (aggregate demand) depends on the interest rate and the exchange rate, and the second is

2. Of course, there are examples of policy rules research that predate the rational expectations assumption (see Phillips, 1954, for example). Policy rules have always had considerable appeal for researchers interested in applying engineering control methods to macroeconomics; rules have also had the advantage of less uncertainty and greater accountability, as stressed by Milton Friedman.

a *price adjustment equation* showing how inflation evolves over time in response to changes in capacity utilization or in exchange rates. When combined with a policy rule, these simple models make up a three-equation system. These systems include such models as the Fuhrer and Moore (1995) rational expectations model, the Rudebusch and Svensson (1999) time-series model, the Ball (1997, 1999) models of closed or open economies, and the Woodford (1999b) or Clarida, Gali, and Gertler (1999) simplified “new Keynesian” models.³ Other models used for policy evaluation (for example, Taylor, 1993a, or the Federal Reserve’s FRB/US model) involve many more than three equations. These models have either a more detailed description of aggregate demand (with consumption, investment, net exports, and government purchases modeled separately, for example) or a more detailed description of price adjustment (with both wages and prices being modeled separately, for example). However, even these larger models can be described conceptually as “three relationship” systems (one relationship being the policy rule). Equations relating consumption, investment, and net exports to interest rates and the exchange rate combine to form an IS block of equations; wage and price setting equations with exchange rate pass-through combine to form a price adjustment block of equations. Hence, for both small models and large models, it is possible to classify differences in the monetary transmission mechanism according to whether they pertain to aggregate demand or price adjustment, and such a distinction is useful for the purposes of this paper.

Tables 1 and 2 use this framework to classify eighteen different models that have been used for policy evaluation in the last few years. The tables show several ways in which the models differ in their treatment of the monetary transmission mechanism as defined above. Table 1 focuses on differences relating to aggregate demand, and table 2 focuses on differences relating to price adjustment.

3. The use of the term “new Keynesian” is not universal and may be confusing because it has been associated with particular microeconomic foundations of price and wage adjustment such as menu costs. These types of models are also called “dynamic new Keynesian” models by Bernanke, Gertler, and Gilchrist (1999) and “new neoclassical synthesis” models by Goodfriend and King (1997). In my view the key characteristic of the models is that they are dynamic, stochastic, economy-wide models with forward-looking behavior and some rigidities that make them useful for policy evaluation along the lines defined in this paper.

Table 1. Classification of Selected Models according to the Approach Taken to the Aggregate Demand Component of the Monetary Transmission Mechanism

<i>Model</i>	<i>Size</i>	<i>Price or credit view^a</i>	<i>Interest rate^b</i>	<i>Partial adjustment^c</i>	<i>Exchange rate^d</i>
Ball (1997)	Small	Price	Short-term	Yes	No
Ball (1999)	Small	Price	Short-term	Yes	Yes
Bernanke, Gertler, and Gilchrist (1999)	Medium	Credit	Long-term	No	No
Batini and Haldane (1999)	Medium	Price	Short-term	Yes	Yes
FRB/US: Brayton and others (1997a and b)	Large	Price ^e	Long-term	Yes	Yes
Chari, Kehoe, and McGrattan (2000)	Medium	Price	Long-term	No	No
Christiano and Gust (1999)	Medium	Price	Long-term	Yes	No
Clarida, Gali, and Gertler (1999)	Small	Price	Long-term	No	No
Fuhrer and Moore (1995)	Small	Price	Long-term	Yes	No
King and Wolman (1999)	Small	Price	Long-term	No	No
McCallum and Nelson (1999a)	Small	Price	Long-term	No	No
McCallum and Nelson (1999b)	Small	Price	Long-term	No	Yes
MSR: Levin, Wieland, and Williams (1999)	Medium	Price	Long-term	No	No
Rotemberg and Woodford (1999)	Medium	Price	Long-term	No	No
Rudebusch and Svensson (1999)	Small	Price	Short-term	Yes	No
Svensson (1999a)	Medium	Price	Long-term	Yes	Yes
TaylorMCM: Taylor (1993b)	Large	Price	Long-term	Yes	Yes
Woodford (1999a)	Small	Price	Long-term	No	No

a. "Price" indicates that the model incorporates a financial market price view, and "credit" a credit view, of the transmission mechanism.

b. The measure of the interest rate that, through a rational expectations model of the term structure, influences demand.

c. "Yes" indicates that there is some type of delayed or partial adjustment in response to changes in interest rates.

d. "Yes" indicates that the exchange rate affects aggregate demand.

e. The presence of corporate cash flow in the investment equations of this model may suggest that a "credit" view coexists with a "financial market price" view, but the latter is a much more powerful channel of monetary policy in this model.

Table 2. Classification of Models according to the Staggered Price Adjustment Component of the Monetary Transmission Mechanism

<i>Model</i>	<i>Backward- or forward-looking^a</i>	<i>Type of staggering^b</i>	<i>Exchange rate a factor in price determination</i>
Ball (1997)	Backward		No
Ball (1999)	Backward		Yes
Bernanke, Gertler, and Gilchrist (1999b)	Forward	Price level	No
Batini and Haldane (1999)	Forward	Inflation rate	Yes
FRB/US: Brayton and others (1997a and b)	Forward	Price level	Yes
Chari, Kehoe, and McGrattan (2000)	Forward	Price level	No
Christiano and Gust (1999)	Neither ^c	Price level	No
Clarida, Gali, and Gertler (1999)	Forward	Price level	No
Fuhrer and Moore (1995)	Forward	Inflation rate	No
King and Wolman (1999)	Forward	Price level	No
McCallum and Nelson (1999a)	Forward	Price level	No
McCallum and Nelson (1999b)	Forward	Price level	Yes
MSR: Levin, Wieland, and Williams (1999)	Forward	Price level	No
Rotemberg and Woodford (1999)	Forward	Price level	No
Rudebusch and Svensson (1999)	Backward		No
Svensson (1999a)	Forward	Price level	Yes
TaylorMCM: Taylor (1993b)	Forward	Price level	Yes
Woodford (1999a)	Forward	Price level	No

a. “Backward” indicates that the staggered price adjustment mechanism is purely backward-looking, and “forward” that it is at least partly forward-looking.

b. “Price level” indicates that price setting and forward-lookingness are in terms of levels of prices, as in the staggered contract model in Taylor (1979) or the random geometric version of Calvo (1983); “inflation rate” indicates that it is in terms of the inflation rate, as in Fuhrer and Moore (1995).

c. The model is a limited participation model.

It is not possible to consider all the models that have been developed to date, but I think the eighteen models in tables 1 and 2 are representative. Because research at central banks is ongoing at this time, only two models actually in use at central banks (the Federal Reserve Board models FRB/US and MSR) are included in tables 1 and 2. It would be useful to consider models used at the Bank of Canada (Black, Macklem, and Rose, 1998), the Reserve Bank of New Zealand (Drew and Hunt, 1998), the Swedish Riksbank (Dillen and Nilsson, 1998), the Bank of England (King, 1999), and other central banks where research is under way.

I realize that it is difficult to evaluate my classification method without a direct knowledge of all these models. For each model I give a reference to a paper that describes the model and/or uses it for the purpose of evaluating monetary policy rules. It is through the model listings and descriptions in these references—descriptions in the form of equation (1)—that I have classified each model according to several characteristics, such as whether the credit view is used or whether the exchange rate is a channel for monetary policy. (The exact characteristics are defined in the notes to each table and are repeated in the text.) Of course, tables 1 and 2 do not include all the differences among the models. For example, some models use more explicit optimization methods to derive their equations than do other models, some models fit the data better than others, and some models describe exchange rate behavior differently from others (for example, Ball, 1999, and Svensson, 1999, differ in this regard). However, I think the two tables capture the key differences in the monetary transmission mechanism that might affect the evaluation of monetary policy rules. In any case, it seems clear from tables 1 and 2 that a variety of approaches have been taken to modeling the monetary transmissions mechanism. Now the question is whether the differences identified in tables 1 and 2 make a difference for the evaluation of policy rules.

4. A CLASS OF POLICY RULES

To answer the question just posed, I consider policy rules of the form

$$i_t = g_\pi \pi_t + g_y y_t + g_{e0} e_t + g_{e1} e_{t-1} + \rho i_{t-1} , \quad (2)$$

where i_t is the interest rate, π_t is the inflation rate (usually smoothed over four quarters for quarterly models), y_t is the deviation of output from potential, and e_t is the exchange rate (defined such that an increase represents an appreciation of the local currency).

The g parameters and ρ are policy choices. The interest rate is the instrument of monetary policy for all values of the policy parameters in this equation.⁴ The form of this simple policy rule allows for several of the major differences of opinion about policy rules. For example, the question of whether there should be interest rate smoothing (or inertia) in interest rate setting is captured by whether ρ is zero or not. I have suggested (Taylor, 1993a) that ρ should be zero, but others (Woodford, 1999a, for example) have recently argued that it should be greater than zero and even close to one. How much of this difference of opinion about policy is explained by differences of opinion about the monetary transmission mechanism? Similarly, the question about whether monetary policy—especially in a small, open economy—should react to the exchange rate is captured by whether g_{e0} or g_{e1} should be zero or not.

Of course, focusing on the functional form in equation (2) does not capture all differences in policy. In fact, fully optimal policy rules will be much more complex than equation (2). However, policy rule research has suggested that the simpler rules are close approximations to fully optimal policy rules in many cases. One might also wonder whether the *forecast* of inflation should be in the policy rule, rather than the four-quarter smoothed inflation rate. In my view (supported by simulations reported in Taylor, 1999b) there does not appear to be much difference between the impacts of policy rules that use forecasts of inflation in equation (2) rather than smoothed values of inflation over a few quarters. At least if the forecast is not too far out in the future, such forecast-based rules are in the spirit of equation (2). Moreover, it is difficult to compare different monetary transmission mechanisms for forecast-based rules because the forecasts themselves depend on the monetary transmission mechanism.

4. I could also have considered the impact of the monetary transmission mechanism on the choice of the policy instrument in the policy rule, for example, whether the instrument should be the monetary base or the overnight interest rate. That the interest rate is, in fact, the instrument in most of the policy evaluation research is an obvious indication that the monetary transmission mechanism in these models does not focus on the money supply, largely because of uncertainty about velocity. Hence one of the biggest differences in monetary transmission mechanisms (money versus interest rates) has already had a big impact on policy rules.

5. EFFECTS OF THE MONETARY TRANSMISSION MECHANISM ON A BENCHMARK RULE

Consider a version of the simple rule in equation (2) for which there is no reaction to the lagged interest rate and no reaction to the exchange rate. This is the type of rule I suggested in Taylor (1993a) as a guideline for the Federal Reserve, and I refer to it here as a benchmark rule, because many researchers have examined this rule in comparison with other possible rules or with actual policy performance. A natural question to ask is whether the performance of the benchmark rule is affected by the different views of the monetary transmission mechanism.

5.1 Effects of Different Views on Financial Market Prices

Simulations of the benchmark rule with a coefficient on inflation of 1.5 and a coefficient on output of 0.5 (Taylor, 1993a) show reasonably good performance—or at least no great depression or great inflation—across the range of models that use a financial market price and a sticky or staggered price adjustment view of the monetary transmission mechanism. Evidence for this comes from simulations of nine of the models in tables 1 and 2 (see Taylor, 1999a). These simulations indicate that when this simple rule is used, the variance of inflation and the variance of real output are small for the models that incorporate a financial market price view of the monetary transmission mechanism. To be sure, there is some preference for a weight on output above 0.5 in the policy rule if the objective function places more weight on output. However, there is no dominance—in terms of both output and price stability—of a rule with a weight on output of 1.0 rather than 0.5. In fact, a rule with a coefficient on output of 1.0 is just as reasonable as a rule with 0.5; the results say more about the use of rules of this general type than about specific coefficients.

The result—that the form of the monetary transmission mechanism does not have much effect on the performance of the benchmark rule—does not mean that no other policy rules will work better in some of the models. Indeed, as I discuss below, a policy rule with a reaction to the exchange rate may work better in models of small, open economies. Rather, the result is more like a robustness property that says the benchmark rule works pretty well; it

does not lead to poor performance across a range of models that incorporate a financial market price view of the monetary transmission mechanism. Evidently, the range of different approaches to the financial market price view—a short-term rate focus, a long-term rate focus, complete forward-looking behavior, complete backward-looking behavior, more or less disaggregation—generate a similar policy-relevant relationship among interest rates, inflation, and output. Hence the same benchmark rule works well for this range of models. But does this robustness result carry over to other models of the monetary transmission mechanism?

5.2 Effect of the Limited Participation View versus the Staggered Price Setting View

Consider the radically different theory of the transmission mechanism based on limited participation. Surprisingly, a stability analysis of the limited participation model of Christiano and Gust (1999) indicates that replacing sticky prices with limited participation does not lead to deterioration in the performance of the benchmark rule. As long as the weight on output is not too high, this simple rule also performs well in keeping the inflation rate and real output stable. (A weight on output of 0.5 works very well, but for some model parameters a weight of 1.0 is too large.)

Again, this is a robustness result. The benchmark rule is robust to a very different view of the monetary transmission mechanism. The result appears paradoxical simply because the limited participation view is so different structurally from the sticky-prices view. The explanation for the paradox comes from looking at how a change in monetary policy affects the economy. Most important is that a change in monetary policy can temporarily affect the real rate of interest—just as in the sticky-prices models. This change in the real interest rate then affects spending and employment for the same reasons it does so in other models of monetary transmission. As described by Christiano and Gust (1999), “The household’s date t decision about Q_t [the amount spent on goods] must be made before the date t realization of the shocks, while all other decisions are made afterwards. This assumption is what guarantees that... the equilibrium rate of interest falls, and output and employment rise.” Thus the paradox is explained by the fact that a monetary policy-induced decline in the real interest rate affects aggregate demand, much as in the sticky-prices models.

5.3 Effects of the Credit (Financial Accelerator) View versus the Traditional Market Price View

Now consider the model of Bernanke, Gertler, and Gilchrist (1999), which is the one model in table 1 incorporating an explicit credit view. This credit view is embodied in what the authors call a *financial accelerator*: “The idea that fluctuations in borrowers’ net worth lead to fluctuations in real activity is what we mean by the financial accelerator” (Bernanke, Gertler, and Gilchrist, 1996, p. 3). The key assumption—the one that gives the financial accelerator its credit view flavor—is that internal borrowing is cheaper than external borrowing. Hence an increase in net worth, which would accompany a reduction in the interest rate, increases firms’ ability to finance investment internally, and thus stimulates investment much as with the typical interest rate channel. As stated by Bernanke, Gertler, and Gilchrist (1999, p. 1369), “The unanticipated increase in asset prices raises net worth, forcing down the external finance premium, which in turn further stimulates investment.” The financial accelerator amplifies the impact of the interest rate. “With the financial accelerator mechanism present ...smaller counter-cyclical movements in interest rates are required to dampen output fluctuations” (Bernanke, Gertler, and Gilchrist, 1999, p. 1364).

Bernanke and Gertler (1999) report simulations of a policy rule like that in equation (2) in an estimated model with a financial accelerator. The rule they simulate is not exactly the one obtained by setting the coefficients on the exchange rate terms and the coefficient on the lagged dependent variable to zero, because they also set the coefficient on output to zero and use a forecast of the inflation rate rather than a smoothed value of the exchange rate. They find that this rule, which is similar to the benchmark rule, works reasonably well in their model. The variances of both inflation and output are small. Hence it appears that if one held a credit view of the monetary transmission mechanism—at least as embodied in the financial accelerator—it would have little effect on one’s assessment of the usefulness of a simple benchmark rule for policy.

As in the case of the limited participation model, this robustness may appear paradoxical.⁵ However, the explanation for the

5. Because Bernanke and Gertler (1999) report simulations of a rule without a weight on output and with a forecast of inflation, the results are not strictly comparable with the other simulation results reported here. In my view the rule is close enough to warrant the conclusions stated here, but until additional simulations are done, one cannot know for sure.

paradox is already contained in the above explanation of the financial accelerator. The change in the interest rate and its effect on spending is still the main story of how monetary policy works. The one change that could make a difference—that the financial accelerator increases the sensitivity to the interest rate—either is not large enough to damage the performance of the benchmark rule, or in the process of estimation the parameters are chosen so that the net effect of an interest rate change on spending is similar to other models of the monetary transmission mechanism.

5.4 Robustness to the Exchange Rate Channel in a Small, Open Economy

An important question about the benchmark rule is how the exchange rate channel affects its performance. Svensson's (1999) simulations of a small, open economy model are directly relevant to this question. He reports that the benchmark rule (without the exchange rate terms) performs well in reducing the variability of output around its potential. In assessing these results with the benchmark rule, Svensson (1999) concludes that the rule "appears somewhat robust; perhaps surprisingly robust." Again, this robustness finding does not mean that no better rule exists for Svensson's model; in fact, the benchmark rule leaves the variability of the real exchange rate higher than do other rules.⁶ The main point is that even a small, open economy view of the monetary transmission mechanism does not change the assessment that the simple benchmark rule—responding systematically only to inflation and output—works well and is robust.

As with the other views of the monetary transmission mechanism, the explanation of this finding is that the exchange rate channel effectively makes a connection from the interest rate to aggregate spending. Rather than simply changing the real interest rate, a change in monetary policy changes the real exchange rate as well. The exchange rate change magnifies the real interest rate effect but does not affect its direction. Hence a reaction of the policy rule only to inflation and output works just fine in stabilizing output and inflation.

6. In a small, open economy the exchange rate has direct effects on the inflation rate, so that choosing the correct measure of the target inflation rate is important.

5.5 Toward Improved Monetary Policy Rules

Thus far I have focused on the benchmark policy rule in equation (2) for which there is no inertia ($\rho = 0$) and no response to the exchange rate ($g_{e0} = g_{e1} = 0$). The conclusion is that this rule is robust across the range of views of the monetary transmission mechanism that are represented in current policy evaluation models. Stated differently, none of the current alternative views of the monetary transmission mechanism have a significant negative effect on the performance of this rule.

As I have emphasized, however, one cannot conclude from these findings that there are no better monetary policy rules. Moreover, from a very practical perspective, although there were successes in monetary policy in the 1990s, various kinds of monetary crises did occur, suggesting that there is a lot of room for improvement. Many suggestions for improving on the benchmark rule have been made. For example, several researchers (Woodford, 1999a; Williams, 1999) have suggested introducing inertia. Others have considered incorporating a response to the exchange rate (Ball, 1999; Svensson, 1999) in order to improve on the benchmark rule. In the next two sections I consider these two suggestions for improvement from the perspective of different views of the monetary transmission mechanism.

6. HOW THE MONETARY TRANSMISSION MECHANISM AFFECTS POLICY RULES WITH INERTIA

Simulation results for policy rules with inertia for nine of the models in tables 1 and 2 (Taylor, 1999a) indicate that the monetary transmission mechanism has a big effect on the performance of such rules. For example, consider the case where $\rho = 1$, $g_{\pi} = 1.2$, and $g_y = 1.0$. The simulation results show that whether this inertial rule improves performance (in terms of the variability of inflation and output) over the benchmark rule ($\rho = 0$, $g_{\pi} = 1.5$, and $g_y = 0.5$) depends on the monetary transmission mechanism used in the model. The inertial rule leads to improved performance in five of the nine models in tables 1 and 2 for which results are available: McCallum and Nelson (1999a), Rotemberg and Woodford (1999), the MSR model (Levin, Wieland, and Williams, 1999), the FRB/US model (Brayton and others, 1997a and b), and the TaylorMCM model (Taylor, 1993b).

The same rule leads to poorer performance in two of the models (Ball, 1999, and Rudebusch and Svensson, 1999), with the inertial rule becoming completely unstable for the latter. The two rules cannot be ranked for the other two of the nine models (Batini and Haldane, 1999, and Fuhrer and Moore, 1995).

There is a systematic difference between the monetary transmission mechanism in models for which inertia enhances performance and that in models for which it detracts from performance. A glance at table 1 shows that the difference is not whether the model assumes an open versus a closed economy. Inertia makes things better for both some closed- and some open-economy models, and it makes things worse for some other closed- and some other open-economy models. Nor is the difference in whether the model takes the financial market price view versus the credit view. The key difference, rather, is in the degree of forward-looking behavior. The two models for which performance deteriorates are *not* rational expectations models, whereas the five models for which performance improves *are* rational expectations models. Moreover, in the rational expectations models the long-term interest rate affects spending (through an expectations theory of the term structure; see table 1); they also assume forward-looking behavior in staggered price setting. One might worry that these rational expectations models are too forward-looking, with insufficient rigidities. However, some of the rational expectations models have many backward-looking terms as well. Indeed, the Taylor multicountry model, for which the inertial rule dominates the benchmark rule, has a considerable number of rigidities in wage setting and in the pass-through of exchange rate changes.

That rational expectations are the essential difference explaining the effects of inertial policy rules is bolstered by the fact that things get worse with inertia for all the non-rational expectations models. To be sure, things do not get better with inertia for all the rational expectations models. Both of the models that do not allow a ranking between the two rules (because inflation and output variances move in opposite directions) are rational expectations models. However, both employ a staggered price setting theory in which the rate of inflation rather than the price level is the effective decision variable (see table 2). Although it would be useful to look into this alternative explanation, the comparative results are at least consistent with rational expectations being a necessary, if not sufficient, condition for an inertial rule to improve performance.

There are good theoretical reasons why an inertial rule requires rational expectations to generate an improvement over the benchmark rule. The lagged interest rate in the rule means that interest rates will rise for many periods in the future if inflation does not come back to target. Expectations of such rising interest rates raise long-term interest rates today in a rational expectations model and have an anti-inflationary spending effect, thereby mitigating the need for a rise in future interest rates. In a non-rational expectations model there is no way for these expectations to have a dampening effect, and it is quite possible for the model to become unstable.

Even though the improvement in performance that can come from inertial rules is not robust to the expectations component of the monetary transmission mechanism, it is worthwhile pursuing ways in which using forward-looking expectations can improve monetary policy. If the gains from such inertial policies are great enough, they might even provide more incentives to institutionalize the rules. Moreover, as hinted at in the next series of results, the payoffs may be even greater when the exchange rate is considered in addition to the interest rate.

7. THE TRANSMISSION MECHANISM AND THE USE OF THE EXCHANGE RATE IN POLICY RULES

Open-economy issues have not been ignored in the research on policy evaluation. The exchange rate is part of the transmission mechanism in six of the models listed in tables 1 and 2. The exchange rate enters both in the determination of net exports and in the determination of inflation, as changes in the prices of foreign goods are passed through in part to domestic prices. Moreover, there is a link between the exchange rate and the interest rate through the capital markets. In general, the models used for policy evaluation assume perfect capital mobility, by specifying either an *ex ante* interest rate parity condition or a reduced-form relationship between the real interest rate and the real exchange rate.

Before discussing the implications of the monetary transmission mechanism for the use of the exchange rate in policy rules, it is important to point out that the policy evaluation research that informed my (1993a) proposal for a policy rule did consider the role of the exchange rate. Simulations of my multicountry model and other models (see Bryant, Hooper, and Mann, 1993) led me to

believe that if the Federal Reserve reacted strongly to the exchange rate, inflation-output performance in the United States would deteriorate. It was for that reason that I omitted the exchange rate in the rule I proposed in Taylor (1993a) as a guideline for the United States. However, it is clear that the same conclusion would not necessarily be reached for other countries, especially small, open economies. A country's size, openness, capital mobility, market completeness, and elasticities would matter greatly.

Work by Ball (1999) and Svensson (1999) on small, open economy models is therefore most welcome. Ball (1999) proposed a policy rule of the form of equation (2), without inertia but with the exchange rate included, for small, open economies. For his (1999) open-economy model, Ball found that such a rule would improve on the benchmark rule. For example, for the same standard deviation of output (1.4 percent), the interest rate rule that reacts to the exchange rate (with g_{e0} negative and g_{e1} positive) as well as to output and inflation reduces the standard deviation of the inflation rate around its target from 2.0 percent to 1.9 percent (Ball, 1999, p. 134). However, although this illustrates the effect that an open-economy view of the transmission mechanism has on the policy rule, it is not a very big improvement.

Svensson (1999) considers a rule very similar to that of Ball (1999) in a more forward-looking open-economy model. Although the motivation for this rule is not optimality (the rule is not optimal in his model), Svensson (1999) finds that this rule reduces the standard deviation of CPI inflation from 2.1 to 1.8. However, it increases slightly the variance of output, from 1.7 to 1.8, and therefore does not even dominate the benchmark rule. Again it seems that the open-economy aspect of the monetary transmission mechanism is not finding major improvements in the policy rule.

In another study (Taylor, 1999b) I considered the use of such a rule for the European Central Bank (ECB). I simulated my multicountry model to try it out. The exchange rate (e) relevant to the ECB is the dollar-euro exchange rate. I found that, compared with the benchmark rule, the rule with the exchange rate rule led to better performance for France and Italy, but had countervailing effects in Germany. Because the ECB does not have the freedom to set different interest rates in the different member countries, the policy rule cannot, of course, be aimed at different countries. However, the bloc of countries participating in European Monetary Union is similar in size to the United States, and findings for this group of countries might not be relevant for smaller open economies.

For comparison I list the policy parameters in equation (2) for these three studies:

	g_{e0}	g_{e1}
Ball (1999)	-0.37	0.17
Svensson (1999)	-0.45	0.45
Taylor (1999b)	-0.25	0.15

Each parameter has the same sign in all three studies. An appreciation of the domestic currency leads to a cut in the interest rate, followed in the next period by an offsetting increase in the interest rate. In the Ball (1999) model, the negative response is called for because the appreciation is contractionary, and a cut in interest rates offsets this contraction. The positive offset in the next period occurs because the favorable effects of the appreciation on inflation will be followed by unfavorable effects, which will raise inflation and require an increase in the interest rate.

The implication of these simulations is that although an open-economy emphasis on the monetary transmission mechanism makes a difference for policy rules, in practice it does not seem to have a big effect. At least this is so with respect to the current models and the focus on the variability of inflation and output. Taken at face value, the results imply that simple policy rules that focus on a smoothed inflation measure and real output and do not try to react to the exchange rate might actually work well. However, in my view it is likely that the current models probably understate the exchange rate effects in small, open economies and therefore tend to underestimate the costs of exchange rate fluctuations. This suggests the need for future research to look at the effects of exchange rate variability. The costs of such fluctuations may be very high for countries where there is a mismatch of assets by currency or duration (see Eichengreen and Hausmann, 1999) or where there may be large swings in the current account. Moreover, the forward-looking nature of the exchange rate suggests that there may be significant gains from policies that utilize rational expectations in the same way that inertial rules for the interest rate do in the closed-economy models discussed in the previous section.

8. CONCLUSION

The results of this paper can be summarized with three major conclusions. First, some of the biggest and most widely discussed differences in views of the monetary transmission mechanism seem to have only a small effect on the evaluation of simple policy rules. More specifically, within the range of views now represented in quantitative models used for policy evaluation—and that includes financial market price views, credit views, staggered price setting, limited participation, and exchange rate channels—the monetary transmission mechanism seems to lead to very similar choices about simple monetary policy rules. In particular, a simple benchmark rule seems to be robust to all these views about how monetary policy works.

Second, more-complex policy rules that incorporate inertial factors are more dependent on the particular form of the monetary transmission mechanism; in particular, they depend on a rational expectations assumption to improve economic performance. Although this suggests a lack of robustness, the estimated gains in rational expectations models may be large enough to motivate further research on the performance of such rules. Such rules may be particularly useful in small, open economies.

Third, although monetary transmission mechanisms with strong exchange rate channels do affect the choice of policy rule—and suggest the need for the central bank to adjust the interest rate in response to the exchange rate, as well as to inflation and real output—the gains from such rules over simple rules that react only to smoothed inflation and output seem surprisingly small. This result suggests the need for more research on the effect of exchange rate fluctuations on small, open economies, and for policy rules that take account of the forward-looking feature of exchange rates.

REFERENCES

- Ball, L. 1997. "Efficient Rules for Monetary Policy." NBER Working Paper 5952. Cambridge, Mass.: National Bureau of Economic Research.
- . 1999. "Policy Rules for Open Economies." In *Monetary Policy Rules*, edited by J. B. Taylor. Chicago: University of Chicago Press.
- Batini, N., and A. Haldane. 1999. "Forward-looking Rules for Monetary Policy." In *Monetary Policy Rules*, edited by J. B. Taylor. Chicago: University of Chicago Press.
- Bernanke, B., and M. Gertler. 1995. "Inside the Black Box: The Credit Channel of the Monetary Policy Transmission." *Journal of Economic Perspectives* 9(4): 27-48.
- . 1999. "Monetary Policy and Asset Price Volatility." In *New Challenges for Monetary Policy*. Kansas City, Mo.: Federal Reserve Bank of Kansas City.
- Bernanke, B., M. Gertler, and S. Gilchrist. 1996. "The Financial Accelerator and the Flight to Quality." *Review of Economics and Statistics* 78(1): 1-15.
- . 1999. "The Financial Accelerator in a Quantitative Business Cycle Framework." In *Handbook of Macroeconomics*, edited by J. B. Taylor and M. Woodford. Amsterdam: North-Holland.
- Black, R., T. Macklem, and D. Rose. 1998. "On Policy Rules for Price Stability." In *Price Stability, Inflation Targets and Monetary Policy*. Ottawa: Bank of Canada.
- Blanchard, O. J., and C. M. Kahn. 1980. "The Solution of Linear Difference Equations under Rational Expectations." *Econometrica* 48: 1305-11.
- Brayton, F., A. Levin, R. W. Tryon, and J. C. Williams. 1997a. "The Evolution of Macro Models at the Federal Reserve Board." *Carnegie-Rochester Conference Series on Public Policy* 47 (December): 43-81.
- Brayton, F., E. Mauskopf, D. Reifschneider, P. Tinsley, and J. Williams. 1997b. "The Role of Expectations in the FRB/US Macroeconomic Model." *Federal Reserve Bulletin* (April): 227-45.
- Bryant, R., P. Hooper, and C. Mann. 1993. *Evaluating Policy Regimes: New Empirical Research in Empirical Macroeconomics*. Washington: Brookings Institution Press.
- Calvo, G. A. 1983. "Staggered Prices in a Utility-Maximizing Framework." *Journal of Monetary Economics* 12(3): 983-98.

- Chari, V. V., P. Kehoe, and E. McGrattan. 2000. "Sticky Price Models of the Business Cycle: Can the Contract Multiplier Solve the Persistence Problem?" *Econometrica* 68(5): 1151-79.
- Christiano, L., M. Eichenbaum, and C. Evans. 1997. "Sticky Price and Limited Participation Models: A Comparison." *European Economic Review* 41(6): 1201-49.
- Christiano, L., and C. Gust. 1999. "Taylor Rules in a Limited Participation Model." NBER Working Paper 7017. Cambridge, Mass.: National Bureau of Economic Research.
- Clarida, R., J. Gali, and M. Gertler. 1999. "The Science of Monetary Policy: A New Keynesian Perspective." *Journal of Economic Perspectives* 37(4): 1661-1707.
- Dillen, H., and J. Nilsson. 1998. "Transparency, Uncertainty and Monetary Policy." Paper presented at a workshop on Monetary Policy Uncertainty, sponsored by the Reserve Bank of New Zealand, June 29-30.
- Drew, A., and B. Hunt. 1998. "The Forecasting and Policy System: Preparing Economic Projections." Discussion Paper G98-7. Wellington: Reserve Bank of New Zealand (October).
- Eichengreen, B., and R. Hausmann. 1999. "What International Monetary Arrangements are Appropriate in Light of the New Environment?" In *New Challenges for Monetary Policy*. Kansas City, Mo.: Federal Reserve Bank of Kansas City.
- Fair, R. C., and J. B. Taylor. 1983. "Solution and Maximum-Likelihood Estimation of Dynamic Nonlinear Rational-Expectations Models." *Econometrica* 51(4): 1169-85.
- Fuhrer, J. C., and G. R. Moore. 1995. "Inflation Persistence." *Quarterly Journal of Economics* 110: 127-59.
- Goodfriend, M. S., and R. G. King. 1997. "The New Neoclassical Synthesis and the Role of Monetary Policy." In *NBER Macroeconomics Annual*, edited by B. Bernanke and J. Rotemberg. Cambridge, Mass.: MIT Press.
- King, M. 1999. "Challenges Facing Monetary Policy: New and Old." Paper presented at the Federal Reserve Bank of Kansas City Conference, Jackson Hole, Wyoming, August.
- King, R., and A. Wolman. 1999. "What Should the Monetary Authority Do When Prices are Sticky?" In *Monetary Policy Rules*, edited by J. B. Taylor. Chicago: University of Chicago Press.

- Levin, A., V. Wieland, and J. C. Williams. 1999. "Robustness of Simple Monetary Policy Rules under Model Uncertainty." In *Monetary Policy Rules*, edited by J. B. Taylor. Chicago: University of Chicago Press.
- Lucas, R. E., Jr. 1976. "Econometric Policy Evaluation: A Critique." *Carnegie Rochester Conference Series on Public Policy* 1: 19-46.
- McCallum, B. 1999. "Issues in the Design of Monetary Policy Rules". In *Handbook of Macroeconomics*, edited by J. Taylor and M. Woodford. Amsterdam: North Holland.
- McCallum, B., and E. Nelson. 1999a. "Performance of Operational Policy Rules in an Estimated Semi-Classical Structural Model." In *Monetary Policy Rules*, edited by J. B. Taylor. Chicago: University of Chicago Press.
- . 1999b. "Nominal Income Targeting in an Open-Economy Optimizing Model." *Journal of Monetary Economics* 43(3): 553-78.
- Phillips, A. W. 1954. "Stabilization Policies in a Closed Economy." *Economic Journal* 64: 290-323.
- Rotemberg, J., and M. Woodford. 1999. "Interest Rate Rules in Estimated Sticky Price Models." In *Monetary Policy Rules*, edited by J. B. Taylor. Chicago: University of Chicago Press.
- Rudebusch, G., and L. O. E. Svensson. 1999. "Policy Rules for Inflation Targeting." In *Monetary Policy Rules*, edited by J. B. Taylor. Chicago: University of Chicago Press.
- Sargent, T. J. 1987. *Macroeconomic Theory*, 2nd ed. New York: Academic Press.
- Svensson, L. E. O. 1999. "Open-Economy Inflation Targeting." *Journal of International Economics* 50(1): 155-83.
- Taylor, J. B. 1979. "Estimation and Control of a Macroeconomic Model with Rational Expectations." *Econometrica* 47(5): 1267-86.
- . 1993a. "Discretion Versus Policy Rules in Practice." *Carnegie-Rochester Conference Series on Public Policy* 39: 195-214.
- . 1993b. *Macroeconomic Policy in a World Economy: From Econometric Design to Practical Operation*. New York: W.W. Norton.
- . 1995. "The Monetary Transmission Mechanism: An Empirical Framework." *Journal of Economic Perspectives* 9(4): 11-26.
- . 1999a. "Introduction." In *Monetary Policy Rules*, edited by J. B. Taylor. Chicago: University of Chicago Press.
- . 1999b. "Robustness and Efficiency of Monetary Policy Rules as Guidelines for Interest Rate Setting by the European Central Bank." *Journal of Monetary Economics* 43(3): 655-79.

- Taylor, J. B., and H. Uhlig. 1990. "Solving Nonlinear Stochastic Growth Models: A Comparison of Alternative Solution Methods." *Journal of Business and Economic Statistics* 8(1): 1-17.
- Williams, J. C. 1999. "Simple Rules for Monetary Policy." Unpublished paper. Washington: Board of Governors of the Federal Reserve System.
- Woodford, M. 1999a. "Optimal Monetary Policy Inertia." Paper presented at the Federal Reserve Bank of San Francisco-Stanford Institute for Economic Policy Research Conference, March.
- . 1999b. "Commentary: How Should Monetary Policy Be Conducted in an Era of Price Stability?" In *New Challenges for Monetary Policy*. Kansas City, Mo.: Federal Reserve Bank of Kansas City.

POLICY RULES AND EXTERNAL SHOCKS

Laurence Ball

The Johns Hopkins University

The decade since 1990 has been a period of innovation in monetary policy. Around the world, many countries have adopted inflation targeting as their basic policy framework. Different countries have tried different techniques for achieving inflation targets, such as different choices of policy instruments. Most central banks use a short-term interest rate as their instrument, but some have experimented with monetary conditions indexes, which are based on both interest rates and exchange rates. A rapidly growing literature discusses the merits of these different approaches to policy.

Most recent research on monetary policy rules uses models of closed economies. In the real world, however, open-economy issues such as the behavior of exchange rates are central to monetary policy. The experience of the world economy since 1997 has reminded us of this fact. The major macroeconomic shocks hitting many countries have been external, originating in the Asian and Russian financial crises. Industrial countries such as Australia and New Zealand as well as developing countries such as Brazil and Chile have been buffeted by shifts in exchange rates, exports, and world commodity prices. Policy rules developed for closed economies are inadequate for responding to such shocks.

This paper discusses policy rules for open economies, and especially the appropriate responses to large external shocks. The starting point for my analysis is my previous theoretical work on open-economy policy rules (Ball, 1999). But I conclude that some of the analysis in that paper must be modified in light of recent events. I address several specific questions about policy rules. First, what

The author is grateful for suggestions from Francisco Gallego, David Gruen, Norman Loayza, Christopher Smith, and conference participants at the Third Annual Conference of the Central Bank of Chile.

Monetary Policy: Rules and Transmission Mechanisms, edited by Norman Loayza and Klaus Schmidt-Hebbel, Santiago, Chile. ©2002 Central Bank of Chile.

variable should policymakers target? Closed-economy models support the practice of inflation targeting, but I argue that the target variable should be modified for open economies. Specifically, the inflation measure that is targeted should be adjusted to remove the transitory effects of exchange rate movements.

Second, what kind of reaction function should policymakers use to set policy instruments? Closed-economy models support the use of Taylor rules relating interest rates to inflation and output. In open economies such rules must be modified to give a role to the exchange rate.

Finally, what should policymakers use as their instrument? In other words, what variable should be on the left-hand side of the policy rule? I focus on the choice between an interest rate and a monetary conditions index. I examine this choice theoretically and use the results to interpret the recent experiences of countries that have used different instruments.

1. A SIMPLE MODEL

I base the analysis on my 1999 model and extensions of it. I therefore begin by summarizing the model, which is intended to capture the key interactions of macroeconomic variables. There are three equations:

$$y = \lambda y_{-1} - \beta U_1 - \delta H_1 + \varepsilon , \quad (1)$$

$$\pi = \pi_{-1} + \alpha y_{-1} - \gamma (H_1 - H_2) + \eta , \quad (2)$$

$$e = \theta r + v , \quad (3)$$

where y is output, π is inflation, r is the real interest rate, e is the real exchange rate (defined such that a higher e means an appreciation), and ε , η , and v are shocks. All variables are defined as deviations from equilibrium levels, and all coefficients are positive.

Equation (1) is an open-economy IS curve. Output is decreasing in the real interest rate and the real exchange rate and depends on lagged output and a demand shock. Equation (2) is an open-economy, accelerationist Phillips curve. The change in inflation depends on output and the change in the real exchange rate, which affects inflation

through import prices. Equations (1) and (2) include time lags: it takes one period for interest rates and exchange rates to affect output, and it takes output and exchange rate changes one period to affect inflation.

Finally, equation (3) posits a positive relation between interest rates and exchange rates. The idea behind this equation is that higher interest rates encourage capital inflows, which lead to an appreciation. Other determinants of exchange rates, such as investor confidence and expectations, are captured by the error term v . Obviously equation (3) is at best a simple reduced form. Later I derive this equation from somewhat deeper foundations; this proves important for comparing alternative policy instruments.

2. WHAT VARIABLE SHOULD POLICYMAKERS TARGET?

There is a growing consensus worldwide that monetary policymakers should target inflation. More and more countries are adopting inflation targets, and recent theoretical research suggests that this policy is effective at stabilizing both inflation and output. However, many of the arguments for inflation targeting assume a closed economy either explicitly or implicitly. In open economies, inflation targeting is suboptimal unless it is modified in an important way.

My 1999 paper argues that policymakers should target “long-run inflation,” a measure of inflation that filters out the transitory effects of exchange rate fluctuations. In the notation of my model, this variable is defined as

$$\pi^* = \pi + \gamma e_{-1} \quad , \quad (4)$$

where again e is the real exchange rate and γ is the coefficient on the change in the real exchange rate in the Phillips curve. Using the model in equations (1) through (3), I show that targeting π^* leads to stable output and stable inflation. In contrast, targeting ordinary inflation, π , keeps inflation stable but produces much more output variability than is necessary.

Rather than repeat the formal derivation of these results, I will discuss the intuition of what the variable π^* measures and why it is a good target for policy. This variable can be interpreted as the level of inflation adjusted for the temporary effects of exchange rates. In the definition of π^* , e is the deviation of the exchange rate from its

equilibrium level. If e_{-1} is positive, for example, the exchange rate has risen above its long-run level in the previous period. From the Phillips curve, this appreciation has directly reduced inflation by γe_{-1} . Thus π^* is what inflation would be now if there had not been this direct exchange rate effect.

The variable π^* also tells us about the future path of inflation. If e_{-1} is above its equilibrium level, then at some point, either in the current period or in the future, it must fall by an amount e_{-1} . At this point the disinflationary effects of the appreciation will be reversed, and inflation will rise by γe_{-1} . Thus π^* tells us where inflation will go in the long run. (More precisely, π^* is the level that inflation will approach if the output gap is held at zero. Inflation can go anywhere, of course, if there are large enough rises or falls in output.)

There are two reasons why it is better to target long-run inflation, π^* , than ordinary inflation, π . First, targeting π^* means that policy does not induce output contractions unless they are essential for long-run inflation stability. Increases in inflation often leave policymakers with a nasty job to do. Given the inertia in inflation, increases that arise when the economy overheats or there is an adverse supply shock will persist indefinitely if policy is accommodative. To prevent inflation from wandering away from its target, policymakers must tighten policy and slow down the economy. In an open economy, however, there is an exception to this rule: policy need not tighten to offset inflation rises to the extent they are caused by temporary exchange rate depreciation. Tightening is then not necessary because, as discussed above, the inflationary effects of exchange rate movements will eventually reverse themselves. Targeting π^* rather than π means that policymakers tighten only when there is an inflation increase that would otherwise be permanent. This approach allows some short-run volatility in inflation, but it keeps inflation stable over the longer run and greatly reduces output variability.

There is a second reason for targeting long-run inflation rather than current inflation. In open economies, a danger with pure inflation targeting is that policymakers will move exchange rates too aggressively to control inflation. The effect of exchange rates on import prices is the fastest channel from monetary policy to inflation, faster than the channel through speedups or slowdowns in output. As a result, if policymakers are given a mandate to keep inflation as close as possible to its target, they may respond by moving exchange rates aggressively to offset inflation movements. This in turn requires large

shifts in interest rates. The problem with large interest rate and exchange rate movements is that they cause large fluctuations in output. Targeting π^* rather than π avoids this problem and therefore keeps output more stable. By construction, π^* is unaffected by temporary exchange rate movements, so π^* targeters have no incentive to move exchange rates aggressively.

Targeting π^* means that it is important for policymakers to distinguish temporary from permanent shifts in exchange rates. So far my discussion has focused on deviations of the exchange rate from its long-run equilibrium—that is, on temporary changes. Policymakers can safely ignore the direct inflationary effects of these fluctuations. Exchange rates can also change, however, because fundamentals shift, changing the long-run equilibrium. Recall that the variable e is defined as the deviation of the exchange rate from its long-run level. If the actual exchange rate falls but the long-run equilibrium exchange rate falls by the same amount, e does not change. This implies that long-run inflation π^* rises by as much as actual inflation π . In this case policymakers cannot accommodate any of the increase in inflation; instead they must tighten policy and reduce output. Since the fall in the exchange rate reflects a change in fundamentals, it is not likely to be reversed in the future. There will be no disinflationary appreciation to take the place of a policy tightening.

Of course, it is not easy in practice to tell whether a change in exchange rates is permanent or temporary. To put it differently, it is not easy to measure the long-run equilibrium exchange rate. A disadvantage of π^* targeting is that it requires policymakers to estimate this unknown parameter. It also requires an estimate of the parameter γ in the Phillips curve. In contrast, pure inflation targeting is relatively easy to carry out, because measuring ordinary inflation does not require knowledge of equilibrium exchange rates or Phillips curve parameters. Defenders of pure inflation targeting can argue that moving to π^* targeting would reduce the simplicity and transparency of policy.

An important question for future research is whether the practice of π^* targeting can be simplified. Perhaps there is some target variable that is easier to measure than π^* but still avoids the problems with pure inflation targeting. One such variable mentioned by a number of authors is the inflation rate for prices of domestically produced goods. Targeting this inflation rate is not identical to targeting π^* , but it may be a good approximation: temporary exchange rate fluctuations have little direct effect on domestic price inflation.

And one can compute inflation in domestic goods prices without estimating the parameters in the π^* formula.

3. WHAT POLICY RULE?

Once policymakers have chosen a variable to target, they must also choose a strategy for meeting the target. Many economists advocate the use of a Taylor rule for adjusting short-term interest rates. Under this approach, a central bank raises interest rates when inflation rises above its target, or when output rises above its long-run level, and reduces interest rates in the opposite cases. The idea is that “leaning against the wind” in this way will keep output and inflation as stable as possible. So far no central bank has adopted a Taylor rule as a formal policy, but the data suggest that many move interest rates in a way that mimics such a rule.

The case for Taylor rules, like the case for inflation targets, is strong if one assumes a closed economy. But once again, the rule must be modified to account for openness. In particular, the Taylor rule must be extended to give a role to the exchange rate—a variable of central importance to policymakers that the basic Taylor rule ignores.

The model in equations (1) to (3) implies that a specific modification of the Taylor rule is desirable. Formally, the modified rule minimizes a weighted sum of the variances of output and inflation. The new rule is

$$\omega r + (1 - \omega)e = a y + b \pi^* . \quad (5)$$

This equation differs from the usual Taylor rule in two ways. First, on the right-hand side, inflation (π) is replaced by long-run inflation (π^*). This result is unsurprising given the earlier result that π^* is a better target variable than π .

Second, the variable on the left-hand side is no longer the interest rate, as in the basic Taylor rule. Instead, it is a weighted average of the interest rate and the exchange rate. Such an average is known as a monetary conditions index (MCI). The weights ω and $1 - \omega$ are roughly proportional to the effects of r and e , respectively, on aggregate spending—the coefficients β and δ in the IS equation. For a number of small, open economies, this means weights in the neighborhood of 0.75 on the interest rate and 0.25 on the exchange rate.

The intuition for putting an MCI in the policy rule is straightforward. In the underlying macro model, monetary policy affects spending through both the interest rate and the exchange rate. The overall stimulus to spending depends on the average of these two variables, with weights given by the IS coefficients. Since this average measures the overall stance of policy, it is the variable that should be adjusted when inflation or output goes off track.

There has been much debate recently about whether MCIs should appear in policy rules. To some degree, this issue is merely semantic. Trivial algebra allows us to move the exchange rate from the left to the right side of equation (5), yielding

$$r = \left(\frac{a}{\omega} \right) y + \left(\frac{b}{\omega} \right) \pi^* - \left[\frac{(1-\omega)}{\omega} \right] e . \quad (6)$$

Here the interest rate is on the left-hand side, as in the basic Taylor rule. The modification of the rule is that e is on the right-hand side: policymakers adjust interest rates in response to exchange rates as well as in response to output and inflation. Equation (6) may look like a less radical departure from the basic Taylor rule than equation (5), which introduces the concept of an MCI. But in substance, equations (5) and (6) are identical.

Later I discuss why, in the real world, the choice between rule (5) and rule (6) may be more than semantic. Here the point is just that e should appear somewhere in the rule—either on the left or on the right. If the rule simply ignores the exchange rate, policymakers will miss opportunities to adjust interest rates to offset the effects of exchange rates on spending. The result is unnecessarily large fluctuations in output and inflation.

4. THE CHOICE OF POLICY INSTRUMENT: WHY DOES IT MATTER?

There has been much recent debate about the choice of an instrument for monetary policy, that is, the variable that central banks should adjust to influence output and inflation. In the model I have described, we can interpret the instrument as the variable on the left-hand side of the policy rule. Most central banks use an interest

rate as their instrument, but Canada and New Zealand have experimented with an MCI like the one in equation (5). Which instrument is best?

As discussed above, my simple model suggests that this question lacks substance. Policymakers who follow rule (5) use an MCI as their instrument, and those who follow (6) use an interest rate. But rules (5) and (6) imply identical responses to any event. Suppose, for example, that there is a shock to the exchange rate equation (3): e falls for a given r . If y and π^* are constant, both rule (5) and rule (6) imply that r should be raised. Policymakers using rule (5) will say they are keeping the policy stance constant: they are adjusting the e/r mix to maintain the same MCI. Policymakers using rule (6) will say they are tightening policy in response to the expansionary effects of depreciation. But these are just two ways of saying the same thing.

Despite this theoretical point, the choice of policy instrument does matter in practice. The difference between theory and reality is in policymakers' degree of flexibility in adjusting their instruments. My theoretical argument assumes that the instrument, whatever it is, moves instantly to the optimal level when a shock occurs. In practice, policymakers adjust their instruments slowly over time. As we will see, this fact breaks the equivalence of interest rate and MCI targets.

Why don't instruments adjust instantly? There are at least two reasons. One is the fact that central bankers reevaluate their policy stances periodically rather than continuously. In some countries, for example, the procedure for analyzing recent data and choosing a policy setting occurs once per quarter. That policy setting is then held constant between policy reviews. Thus, within a quarter, an interest rate target means the interest rate is constant, and an MCI target means the interest rate is adjusted to offset exchange rate movements. Therefore the rules produce different outcomes when there are shocks to the exchange rate.

Many discussions of instrument choice emphasize the intervals between policy resettings. But these intervals are not the most important reason why the choice matters. The intervals are fairly short: sometimes they last a quarter, as in New Zealand, and sometimes less, as in the United States, where the Federal Open Market Committee meets every six weeks. Given the relatively slow evolution of output and inflation, delaying the optimal instrument adjustment for such short periods is unlikely to add substantially to macroeconomic volatility. (And if it did, the frequency of adjustments could be

increased. If the Federal Reserve hired additional staff, it could redo its policy analysis every four weeks rather than every six.)

The most important reason why the choice of an instrument matters is that it affects policy for periods much longer than the interval between instrument adjustments. In principle, these adjustments are an opportunity to adjust policy flexibly in response to all new information. If this were truly the case, my earlier argument would apply, and the labeling of one variable as the instrument would be semantic. But the labeling matters in reality because, whatever the “instrument” is, policymakers are reluctant to change it by large amounts. This is true even for reviews when in theory the entire stance of policy is on the table.

In countries with interest rate targets, policymakers’ aversion to large instrument shifts has a common name: “interest rate smoothing.” According to most theories, optimal interest rate rules imply that news about output and inflation produces large, one-time adjustments in rates. But empirical work on many countries shows that such adjustments seldom occur. If the economy overheats, for example, policymakers usually respond slowly: they raise interest rates by a quarter of a percentage point at a time at a series of meetings, even if it appears likely from the beginning that a large change is needed. It can take a long time before the interest rate reaches its optimal level.

There is no consensus about the reasons for interest rate smoothing. I am sympathetic to the view that there are political incentives for smoothing, even though its economic effects are undesirable. For example, Lowe and Ellis (1997) suggest that policymakers are embarrassed by reversals in the direction of interest rate movements, because the public interprets these reversals as repudiations of previous actions. In contrast, a series of interest rate changes in the same direction looks like a well-planned program. If policymakers respond to a shock with the full interest rate adjustment they think is optimal, their next move is equally likely to be in the same direction or the opposite direction. A concern for appearances may lead policymakers to underreact to shocks initially, to make it more likely that future interest rate changes are in the same direction.

Whatever the explanation for interest rate smoothing, it is a fact of life. And I suspect that it is a special case of a more general phenomenon of instrument smoothing. Just as central banks with interest rate targets smooth interest rates, so do those with MCI targets smooth MCIs. This is less clear-cut empirically, because we have

observed fewer experiences with MCI targets. But as discussed below, the recent experience of New Zealand is consistent with the idea of MCI smoothing. And Lowe and Ellis's logic carries over to this case. A policymaker who announces a big instrument shift is going out on a limb regardless of whether he or she is announcing a large interest rate change or a large MCI change. Either way, the policymaker may be embarrassed if he or she later has to take back some of the adjustment.

With instrument smoothing, interest rate targeters and MCI targeters react differently to shocks. Recall my example of a shock that reduces the exchange rate for a given interest rate. This leads to a higher interest rate under either the MCI rule (5) or the interest rate rule (6). But instrument smoothing dampens the interest rate rise of the interest rate targeter. The behavior of the MCI targeter is not affected, because the full interest rate adjustment does not require a change in the MCI. Both policymakers may consider themselves "cautious" or "conservative," because they avoid large shifts in their instruments. But caution has different implications in the two cases. In this example, policy is tighter with an MCI target.¹

5. A MODEL OF THE OPTIMAL INSTRUMENT

I now consider the choice of a policy instrument in a variation on my 1999 model. To focus on this issue, I simplify the model in two ways. First, I consider a static setting, thereby ignoring time lags in the effects of policy. Dynamics are crucial for some of the issues discussed earlier, but not for the issue of instrument choice. Second, I model only the real side of the economy and define the optimal instrument as the one that minimizes the variance of output; I do not explicitly consider inflation. This shortcut is possible because one can show that the instrument choice that minimizes output variability also minimizes inflation variability. Intuitively, the wrong choice causes unnecessary output fluctuations, which cause inflation fluctuations through the Phillips curve.

Having simplified the model along some dimensions, I now enrich the specification of how exchange rates are determined. Many commentators argue that the appropriate role of exchange rates in

1. David Gruen has made a similar argument about instrument smoothing with MCI and interest rate targets (personal communication with the author).

policy rules depends on the sources of exchange rate fluctuations. My 1999 model has a single exchange rate shock, v in equation (3). In the new model, two shocks affect exchange rates: a shock to exports and a shock to financial markets. The shock to exports also affects aggregate spending, so I modify the IS equation as well.

The new model starts with two accounting identities:

$$Y = D + X , \quad (7)$$

$$X = F , \quad (8)$$

where Y is output, D is domestic spending, X is net exports, and F is net foreign investment (that is, net capital outflows).

I assume the variables in equations (7) and (8) are determined by

$$D = -\beta U + u_1 , \quad (9)$$

$$X = -\delta H + u_2 , \quad (10)$$

$$F = -\phi U + \rho H + u_3 . \quad (11)$$

Domestic spending thus depends on the real interest rate and on shocks such as shifts in fiscal policy or consumer confidence (u_1). Net exports depend on the real exchange rate and on shocks such as shifts in trade policy or the strength of foreign economies (u_2). Finally, net foreign investment falls when the interest rate rises (because domestic assets become more attractive) and rises when the currency appreciates (because this implies a future depreciation, raising the return on foreign assets). The shock u_3 arises in financial markets. For example, if investors suddenly decide that a country's assets are risky, there is a capital outflow—a positive u_3 .²

Substituting equations (10) and (11) into equation (8) yields a reduced-form relation between the interest rate and the exchange rate:

$$e = \left[\frac{\phi}{(\delta + \rho)} \right] r + \left[\frac{1}{(\delta + \rho)} \right] u_2 - \left[\frac{1}{(\delta + \rho)} \right] u_3 . \quad (12)$$

2. This model draws on the model of a “large open economy” in Mankiw’s (1999) intermediate macroeconomics text.

Like the exchange rate equation in my 1999 model, this equation gives a positive relation between e and r . This version of the equation makes it clear that the relation is shifted by two kinds of shocks.

I use the model in equations (7) through (12) to consider the choice between an interest rate and an MCI as policy instrument. I assume that the weights on e and r in the MCI are proportional to δ and β , which give the variables' effects on aggregate spending. To capture the idea of instrument smoothing, I assume that the central bank must set its policy instrument in advance and can make no adjustment in response to shocks. With this assumption, I ask which choice of instrument keeps output more stable. This approach is similar to Poole's (1970) comparison of money and interest rate targets. The results would be similar if I allowed instruments to adjust partially in response to shocks.

Like Poole, I find that different instruments stabilize output depending on which shock hits the model. Specifically, there are three results:

Result 1: When there is a shock to domestic spending as in equation (9), output is the same under an interest rate or an MCI target. That is, when consumer confidence or fiscal policy shifts, it does not matter whether policy holds the interest rate or the MCI fixed. The explanation is simple. A domestic spending shock does not change the relation between the exchange rate and the interest rate: u_1 does not enter equation (12). Thus a constant interest rate implies a constant exchange rate and hence a constant MCI. Fixing the interest rate and fixing the MCI are the same policy in this case.

Result 2: When there is a shock to net foreign investment as in equation (11), an MCI target keeps output more stable than does an interest rate target. To see this result, consider a rise in net foreign investment—a case of capital flight. In this case, the shock u_3 is positive. A fixed-MCI policy fully insulates output from the shock, whereas a fixed interest rate does not.

Consider first a fixed interest rate. Under this policy, equation (12) implies that the positive u_3 lowers e : capital flight causes a depreciation. Equation (10) implies that the depreciation raises net exports. Domestic spending does not change, because the interest rate is held fixed. Thus the rise in net exports implies a rise in aggregate output.

With a fixed MCI, by contrast, the interest rate is raised when there is capital flight, to prevent the MCI from falling. In equilibrium, the shock produces a higher r , a lower e , and no change in a weighted average of the two. Specifically, the assumed weights in the MCI imply that the sum $\beta r + \delta e$ is unaffected by the shock. Equations (7) through (10) imply that this sum determines aggregate output; thus output is unaffected. Domestic spending falls because of the higher r , but this is offset by higher net exports caused by the lower e .

Result 3: When there is a shock to net exports as in equation (10), an interest rate target keeps output more stable than does an MCI target. Here suppose that net exports fall because of recession in a country's trading partners. This is a negative u_2 . Output falls under either an interest rate rule or an MCI rule, but the fall is larger under the latter.

With a fixed interest rate, the negative u_2 reduces net exports. It also reduces the real exchange rate, through equation (12), but the resulting rise in net exports is outweighed by the direct negative effect of the shock. Domestic spending does not change, so lower net exports imply lower output.³

Once again, a fixed MCI means that policymakers raise r to offset the fall in e . Thus r is higher than with a fixed interest rate, and e is also higher through equation (12). The higher r and higher e mean that both domestic spending and net exports are lower than with an interest rate target. Thus fixing the MCI magnifies the output loss from the negative net export shock.

To summarize, these results imply that the right choice of an instrument depends on the relative importance of shocks to net foreign investment and net exports. If different economies are susceptible to different kinds of shocks, different instruments may be appropriate. To illustrate these points, I now examine some recent country experiences.

6. SOME COUNTRY EXPERIENCES

In debating the choice of an instrument, many observers cite the recent experiences of Australia and New Zealand. The Asian financial

3. To see that net exports go down despite the lower e , recall that net exports equal net foreign investment. The combination of a lower e and a fixed r implies that net foreign investment falls by equation (11).

crisis of 1997 hit these two countries in broadly similar ways, yet in the aftermath of the crisis, New Zealand experienced a recession whereas Australia did not. At the time of the shock, New Zealand had recently adopted an MCI as an instrument, whereas Australia used an interest rate. Some commentators (such as *The Economist*, 1999) draw a connection between these facts: they interpret the Australasian experience as evidence that countries are better off with interest rate targets.

It is, of course, an oversimplification to attribute the experiences of Australia and New Zealand entirely to their choices of instruments. Other factors contributed to the recession in New Zealand. For example, policy in New Zealand was already tight when the Asian crisis began, because of inflationary pressures. In addition, a drought in 1998 reduced output in the country's large agricultural sector. On the other hand, the use of an MCI probably did make the recession deeper than it otherwise would have been. To explain why and to illustrate my model, I will tell a story about New Zealand and Australia that focuses on instrument choices.

My model implies that interest rate targets are the right choice in the presence of shocks to the net export function. This result is relevant because both Australia and New Zealand experienced large shifts in net exports during the Asian crisis. These countries trade heavily with East Asia, and so exports fell sharply when the region entered a recession.

This is not the whole story, however, because the East Asian crisis affected the Australasian countries through more than one channel. At the time of the crisis, investors fled countries that they deemed risky. Rightly or wrongly, these countries included New Zealand and Australia. Capital flight meant that these countries experienced a positive shock to net foreign investment as well as a negative shock to net exports.

Given this particular combination of shocks, Australia's policy of interest rate targeting worked brilliantly. Recall that a negative shock to net exports reduces output under interest rate targeting, although not as much as under MCI targeting. In Australia, the contractionary effects of the fall in net exports were offset by an additional depreciation resulting from the rise in net foreign investment. The stimulus from this additional depreciation was enough to leave total spending roughly constant. New Zealand suffered a recession after similar shocks because its policy was tighter: to maintain a constant MCI, it had to raise its interest rate.

The Reserve Bank of New Zealand recognized the contractionary effects of the Asian crisis and reduced its MCI target in late 1997 and 1998. However, the policy easing was not large or fast enough to prevent a recession. This experience is consistent with the practice of instrument smoothing: policy is adjusted slowly even though shocks make a large change optimal. It is easy to imagine the New Zealand central bank (like everyone else) being surprised by the Asian crisis and uncertain of the ideal response, and therefore erring on the side of adjusting its instrument “cautiously.” Australia was also cautious: there was almost no change in its instrument. The nature of the shocks determined which kind of caution was more successful.

Thus there was an element of luck behind the relative success of interest rate targets after the Asian crisis. If the contractionary shock to net exports had been smaller, or the expansionary shock to net foreign investment larger, output would have been higher in Australia. With a fixed interest rate, the economy might have overheated, causing inflation to rise. In such a scenario we would now be celebrating New Zealand’s wisdom in targeting an MCI: the higher interest rates implied by that policy would have prevented overheating.

Policy makers would like to know what instrument keeps output most stable on average, not just in particular episodes. Determining this requires more research on the relative importance of shocks to net exports and net foreign investment. The right choice of instrument may be different in different countries. It appears likely that an interest rate target is indeed best for Australia. Research by the Reserve Bank of Australia concludes that fluctuations in the Australian dollar are driven mainly by terms-of-trade shocks, which are less important in other countries. In my model, terms-of-trade shocks should be interpreted as shocks to the net export equation, since they change the value of exports for given physical quantities. These shocks are best handled through an interest rate target.

Are there countries that should use MCIs as instruments? One candidate is Canada, the country that pioneered their use. Research at the Bank of Canada suggests that fluctuations in the Canadian dollar—unlike the Australian dollar—are driven primarily by shocks to financial markets. In the terms of my model, these are net foreign investment shocks, which means they are best handled by an MCI target.

7. CONCLUSION

Monetary policy in open economies is different from that in closed economies. Open-economy policymakers should target a measure of inflation that filters out the transitory effects of exchange rate fluctuations. They should also include the exchange rate in their policy reaction function. Whether the exchange rate should appear on the left- or the right-hand side of the rule—that is, whether the policy instrument should be an interest rate or an MCI—is a question that requires further research.

I will conclude by mentioning another topic for further research: the benefits of stable exchange rates. In all the models I have discussed, optimal policy rules allow considerable variability in exchange rates. Real-world policymakers, however, seem averse to such variability. Rigid exchange rate pegs are becoming less popular, but many countries still seem to stabilize exchange rates more than is justified by current models. Is there some cost of exchange rate fluctuations that the models miss? One possibility is output fluctuations at the sectoral level. Exchange rate fluctuations cause reallocations of resources across the tradable and nontradable sectors, and these may be inefficient. Current models cannot capture this idea because they focus on aggregate variables. Progress might be made by evaluating policy rules in models that disaggregate output into tradables and nontradables.

REFERENCES

- Ball, L. 1999. "Policy Rules for Open Economies." In *Monetary Policy Rules*, edited by John B. Taylor. Chicago: University of Chicago Press.
- Lowe, P. and L. Ellis. 1997. "The Smoothing of Official Interest Rates." In *Monetary Policy and Inflation Targeting, Proceedings of a Conference*. Sydney: Reserve Bank of Australia.
- Mankiw, N. G. 1999. *Macroeconomics*, 4th ed. New York: Worth Publishers.
- Poole, W. 1970. "Optimal Choice of Monetary Policy Instrument in a Simple Stochastic Macro Model." *Quarterly Journal of Economics* 84: 197-216.
- The Economist. 1999. "Australia and New Zealand. G'day, Goldilocks" (March 6).

OPTIMAL MONETARY POLICY RULES WHEN THE CURRENT ACCOUNT MATTERS

Juan Pablo Medina

University of California, Los Angeles

Rodrigo O. Valdés

Ministry of Finance, Chile

Polymakers and the academic community have reached an increasing consensus during the last two decades: the primary objective of monetary policy should be to control inflation (see, for example, King, 1999). A less settled issue is the appropriate role of the central bank regarding other, secondary objectives. Some countries have explicitly included unemployment (or the output gap) among the central bank's objectives, whereas others make explicit reference to the output gap when explaining policy to the public. For example, the U.S. Federal Reserve has among its goals "to promote maximum employment," and the Reserve Bank of Australia has "the maintenance of full employment" as an explicit objective in addition to price stability. The Sveriges Riksbank, the Bank of England, and even the European Central Bank have identified output gap volatility as a reason to follow a gradualist approach to controlling inflation. For example, the Bank of England has stated that, in choosing among various alternative paths to achieving the inflation target, the monetary authority should be concerned about deviations of the level of output from capacity (see Svensson, 1999).

This paper was written while Medina and Valdés were affiliated with the Central Bank of Chile. We thank P. García, L. O. Herrera, J. Marshall, K. Schmidt-Hebbel, R. Vergara, and participants in the Third Annual Conference of the Central Bank of Chile, "Monetary Policy: Rules and Transmission Mechanisms", for helpful comments. All remaining errors are our responsibility. This paper presents the views of the authors and does not necessarily represent in any way the positions or views of the Ministry of Finance, Chile.

Monetary Policy: Rules and Transmission Mechanisms, edited by Norman Loayza and Klaus Schmidt-Hebbel, Santiago, Chile. © 2002 Central Bank of Chile.

But the output gap and inflation are not the only relevant objectives of monetary policy from a practical point of view. The law that establishes the Central Bank of Chile sets as a formal objective the stability and proper functioning of the country's external payments system. Operationally, this objective has been interpreted as maintaining a sustainable current account deficit. Specifically, there is an operational objective of keeping this deficit, measured at trend terms of trade, between 4 and 5 percent of GDP.¹ Behind this objective is the idea that an excessive current account deficit can easily jeopardize the normal functioning of the external payments system, including access to external financing.

Including a target for the current account deficit in the objective function of the central bank has potentially important consequences for the formulation of monetary policy, particularly regarding the optimal reaction to various shocks. Both the magnitude and the persistence of appropriate movements in interest rates following a specific shock can change when this objective is considered. This paper investigates this issue, deriving and comparing optimal policy rules using a simple macroeconomic model of the Chilean economy. It further analyzes what happens to optimal monetary policy when the current account objective is asymmetric, that is, when it is considered that positive deviations are relatively more undesirable than negative ones.²

The paper first studies the problem of a central bank that chooses interest rates so as to minimize the expected discounted loss of a quadratic loss function in an economy described by linear equations and in which there are some forward-looking variables. Although it makes use of standard dynamic programming, the paper departs from previous work by explicitly incorporating the current account in the objective function and by considering a macroeconomic model whose structure and lags are chosen to realistically represent the Chilean

1. See Massad (1998) for a description of the central bank's objectives and of the way monetary policy is conducted in Chile based on an inflation target. One important feature of the Chilean economy in this regard is the widespread practice of indexing for inflation, including indexing of financial assets. In addition, before September 1999 the central bank used a target zone framework as the basis of its exchange rate policy.

2. Of course, it is quite difficult to argue from first principles that the current account should be an objective in its own right. Ultimately, its inclusion is a short cut to avoid a very complex model in which inflation and output are severely affected by highly nonlinear events such as balance of payments crises.

economy.³ The model structure is similar to that of a simple central bank macroeconomic projection model. It includes equations for the output gap, the absorption-output gap, a Phillips curve, uncovered interest rate parity, and a term structure. Using this model, we investigate how optimal policy reactions change when the current account matters, and the implications of incorporating the output gap among the central bank's objectives.

The paper then studies the consequences of having an asymmetric objective for the current account. This is done within a considerably simpler framework, as otherwise it would be difficult to solve the central bank's problem. The economy is described by a central bank loss function that depends on inflation and the absorption-output gap, with two linear equations describing their evolution. Again, the central bank has to choose interest rates so as to minimize the expected discounted loss, this time of a nonquadratic loss function. The solution method we use in this case is based on standard dynamic programming using a convenient discretization of the economy. We investigate how optimal policy reactions change both with the asymmetry in objectives and with uncertainty about future shocks.⁴

It is important to clarify at the outset that by an *optimal reaction* we mean the best possible policy rule in terms of maximizing the objective function in the context of the model under analysis. It is not necessarily the best policy for day-to-day policymaking, because, by definition, any model is an incomplete description of reality. Actual policymaking might take into account these rules—indeed, they are quite appealing as they give precise answers to a quite complex problem of combined lagged effects. However, policymakers should also evaluate the implications of developments that are not considered in the model. In other words, the optimality of the rules we study is model-specific.

The main results of the paper yield relevant policy conclusions. For example, we find that including the current account among the objectives of the central bank has important consequences for optimal policy reactions. Interest rates react vigorously (and without much persistence) to shocks that affect the current account deficit, but are

3. Svensson (2000), Ryan and Thompson (1999), and many others study optimal policy rules in inflation targeting frameworks for open economies. Among other issues, these papers analyze the usefulness of monetary conditions indexes and the merits of targeting inflation of nontraded goods.

4. Because with asymmetric objectives the problem is not linear-quadratic, there is no certainty equivalence.

less responsive to output gap and inflation shocks when the current account is among the objectives. If the current account does not matter, optimal policy rules change considerably when the central bank cares about the output gap. However, these changes are far less dramatic if the central bank already has the current account among its objectives. An asymmetric current account objective does not greatly change the optimal reactions to demand shocks, but it makes monetary policy clearly more aggressive toward positive inflation shocks. The change in this policy reaction is economically relevant. Finally, when there is an asymmetric current account objective, a higher volatility in current account shocks generates a more aggressive monetary policy.

The paper is organized as follows. Section 1 describes the structure of the economy as modeled, as well as monetary policy objectives in a standard linear-quadratic framework. Section 2 presents the method for solving the central bank's problem and compares optimal policy rules for alternative central bank preference parameters using a realistic model estimate. Section 3 studies policy rules in a simpler economy but one in which current account objectives are asymmetric. Finally, section 4 presents some concluding remarks.

1. THE ECONOMY

The economy is described by a series of state variables, some of which are exogenous, while others are endogenous, predetermined, and subject to stochastic shocks, and the rest are endogenous and forward-looking. These variables evolve according to a simple linear macroeconomic model in which monetary policy affects some variables instantaneously and others with a lag.⁵ The exogenous variables represent the fundamentals for the economy and follow simple stochastic processes. The economy is endowed with a central bank, which has an explicit objective function. The frequency of the empirical counterpart of the model is quarterly, and we assume that variables are observed contemporaneously.⁶

5. The model we consider is not immune to the Lucas critique, although expectations are completely rational and the public knows the central bank's objectives. However, the Lucas critique is not that relevant when policy shocks are small (which is the case considered in this paper).

6. One way of interpreting this assumption is to consider that monetary policy chooses end-of-period interest rates. An alternative is to consider that actual (off-model observed) short-term projections are very good (within a quarter).

All variables in the model are measured as deviations from their (possibly stochastic) long-run trend and consequently are stationary. For example, r_t represents deviations of the interest rate with respect to its long-run trend.⁷

1.1 Monetary Policy Objectives

The central bank has three objectives: to keep inflation close to the target, to maintain the current account deficit close to a preannounced value, and to keep the output gap close to zero. In addition, the central bank dislikes large and sudden movements in interest rates.⁸ These objectives are summarized in the following quadratic loss function of period t :

$$l_t = \mu_\pi \pi_t^2 + \mu_{cc} cc_t^2 + \mu_y y_t^2 + \mu_r (r_t - r_{t-1})^2, \quad (1)$$

where π_t is the gap between actual and target inflation, cc_t is the gap between the actual and the target current account (as a proportion of GDP), and y_t is the gap between actual and potential output.⁹ The term $(r_t - r_{t-1})^2$ captures the costs for the central bank of frequent and sudden changes in monetary policy. Lastly, μ_π , μ_{cc} , μ_y , and μ_r are nonnegative constants that together characterize the central bank type.

The central bank is forward looking and in each period t chooses the level of the real (indexed) interest rate that minimizes the expected discounted sum of future losses:

$$L_t = E \left(\sum_{\tau=0}^{\infty} \delta^\tau l_{t+\tau} \mid \Omega_t \right), \quad (2)$$

where Ω_t represents the information set available in period t . Moreover, because there are forward-looking variables, both the central

7. See note 13.

8. See Woodford (1999a) for a derivation from first principles of these preferences for smooth movements in the policy instrument. Massad (1998) makes the case for instrument stability in Chile. The concern of the central bank regarding the normal functioning of the domestic payments system gives another argument for such an objective.

9. In this framework the authority recognizes that monetary policy can have only temporary effects on output. Moreover, there are no intertemporal inconsistency problems of the Barro-Gordon type. See note 13.

bank and the public know that the former can reoptimize in each period. Hence, the only possible solution is a discretionary one.¹⁰ Therefore, the optimal policy rule has the form $r_t = FX_t$, where X_t is the vector of predetermined variables and F is a vector of constants to be endogenously determined (see Backus and Driffill, 1986, and Söderlind, 1999a, for further details).

1.2 State Variables

There are three fundamental exogenous variables in this economy: the terms of trade (in logarithms) (tot), the country risk premium (φ), and the international real interest rate (r_t^*). We assume that these three variables are stationary (or that they are transformed so as to eliminate any trend). Their law of motion is given by the following equations:

$$tot_t = \rho_{tot} tot_{t-1} + \rho_{tot}^r r_{t-1}^* + \xi_t^{tot}, \quad (3)$$

$$r_t^* = \rho_r r_{t-1}^* + \xi_t^r, \quad \text{and} \quad (4)$$

$$\varphi_t = \rho_\varphi \varphi_{t-1} + \xi_t^\varphi, \quad (5)$$

respectively, where $0 < \rho_j < 1$ and ξ_t^j are i.i.d. shocks ($j = tot, r^*$, and φ).¹¹

Domestic inflation moves according to inflation in traded goods and in nontraded goods. Traded goods inflation, in turn, depends on international prices and the exchange rate, and nontraded goods inflation depends (because of indexation) on previous inflation, on inflation expectations in previous periods, and on the output gap

10. A solution involving a commitment would attain a better outcome (see Woodford, 1999b). However, like Svensson (1999), we assume that a commitment technology is not available. Thus, the only realistic solution is discretionary.

11. A more realistic approach would be to model the risk premium as an endogenous variable that depends on domestic variables such as the current account. Then an increase in the current account deficit would cause a nominal devaluation following a rise in the risk premium. However, considering this possibility would only add an additional, indirect concern of the central bank regarding the current account, without substantially changing the main results.

(according to a standard accelerationist Phillips curve). In particular, the (annualized) inflation gap evolves according to

$$\pi_t = (1 - \omega) \pi_t^T + \omega \pi_t^N - \bar{\pi}, \quad (6)$$

where π_t^T is tradables inflation, π_t^N is nontradables inflation, $\bar{\pi}$ is the inflation target, and ω is a constant parameter. Tradables inflation is determined as follows:

$$\pi_t^T = \alpha'_T(L) (\hat{e}_t + \pi_{t-1}^*) + \xi_t^T, \quad (7)$$

where $\alpha'(L)$ is a polynomial in the lag operator L , $\hat{e}_t$ is the nominal devaluation, π_t^* is international inflation, and ξ_t^T is an i.i.d. shock. This specification assumes that the weak version of purchasing power parity obtains for tradables (controlling for changes in value-added taxation and tariffs) and that there is no instantaneous pass-through. On the other hand, nontradables inflation evolves according to

$$\pi_t^N = \alpha'_{\pi L}(L) \pi_{t-1} + E[\alpha'_{\pi F}(F) \pi_{t+1} | \Omega_{t-1}] + \alpha'_y(L) y_t + \xi_t^N, \quad (8)$$

where $\alpha'_{\pi F}(F)$ is a polynomial in the forward (lead) operator. This means that $E(\pi_{t+1} | \Omega_{t-1})$ is a predetermined variable in period t .¹²

Let us define the real exchange rate (RER) as $q_t = e_t p_t^* / p_t$ and assume, without loss of generality, that $\bar{\pi} = 0$. Then the inflation gap equation can be written as

$$\begin{aligned} \pi_t = & \alpha_T(L) \hat{q}_{t-1} + \alpha_{\pi L}(L) \pi_{t-1} + E[\alpha_{\pi F}(F) \pi_{t+1} | \Omega_{t-1}] \\ & + \alpha_y(L) y_t + \xi_t^\pi, \end{aligned} \quad (9)$$

where $\alpha_T(L) = (1 - \omega) \alpha'_T(L)$, $\alpha_{\pi L}(L) = \omega \alpha'_{\pi L}(L) + (1 - \omega) \alpha'_T(L)$, $\alpha_{\pi F}(F) = \omega \alpha'_{\pi F}(F)$, $\alpha_y(L) = \omega \alpha'_y(L)$ and $\xi_t^\pi = \omega \xi_t^N + (1 - \omega) \xi_t^T$. Furthermore,

12. This structure is based on one of the projection models used at the Central Bank of Chile and is similar to the price equation derived from first principles in Svensson (2000).

in order to preserve homogeneity in prices we assume that $\omega[\alpha'_{\pi L}(1) + \alpha'_{\pi F}(1)] + (1 - \omega)\alpha'_T(1) = 1$. Notice that in this framework monetary policy affects inflation through three different channels: the output gap, the exchange rate, and lagged expectations of future monetary policy (and hence future inflation).

The RER is a forward-looking variable that is determined by the uncovered interest parity condition:

$$q_t = E(q_{t+1} \mid \Omega_t) + 0.25(r_t^* - r_t + \phi_t). \quad (10)$$

Besides the short-term real interest rate controlled by the central bank, there is a long-term interest rate determined as a forward-looking variable in the bond market. According to the expectation hypothesis of the term structure, the behavior of the long-term interest rate R_t can be approximated by

$$R_t = \lambda r_t + (1 - \lambda)E(R_{t+1} \mid \Omega_t), \quad (11)$$

where λ is a constant that negatively depends on the bond duration.

The output gap has some persistence and reacts with lags to the interest rates, the terms of trade, and the RER:

$$y_t = \beta_y(L)y_{t-1} + \beta_R(L)R_{t-1} + \beta_r(L)r_{t-1} + \beta_{tot}(L)tot_{t-1} + \beta_q(L)q_{t-1} + \xi_t^y, \quad (12)$$

where ξ_t^y is an i.i.d. shock. This equation represents a standard dynamic IS curve.

To construct the ratio of the current account (proxied by the trade balance) to GDP, we consider a linear approximation that depends on the gap between absorption and output (denoted by y_t^d), the terms of trade, the output gap, and the RER. A first-order (log) Taylor expansion of the trade balance yields the following approximation:

$$cc_t = -y_t^d - k_0 q_t + k_0 y_t + k_1 tot_t, \quad (13)$$

where k_0 is the ratio of the trade balance to GDP during the expansion year (2 percent in 1997), and k_1 is the ratio of exports to GDP

during that year (30 percent in 1997). The current account deficit during the expansion year was 4.8 percent of GDP.

Finally, we assume that the absorption-output gap has some persistence and depends on interest rates, the terms of trade, and the RER. In particular, this gap is determined by the following equation:

$$y_t^d = \gamma_d(L)y_{t-1}^d + \gamma_R(L)R_{t-1} + \gamma_r(L)r_{t-1} + \gamma_{tot}(L)tot_{t-1} + \gamma_q(L)q_{t-1} + \xi_t^d, \quad (14)$$

where ξ_t^d is an i.i.d. shock. In order to be consistent with our prior definition of y_t , we consider y_t^d as the gap between, on one hand, the difference between actual and trend absorption and, on the other, the output gap.¹³ Of course, because both equations include output in the left-hand side, and both represent cyclical movements of the economy, equations (14) and (12) are closely related. Thus the shocks ξ_t^y and ξ_t^d need not be orthogonal. In the exercises below we consider both independent and common shocks to both equations.

In sum, the economy is described by equations (3) to (5) and (9) to (14). Appendix A presents the estimation and calibration results of these equations using Chilean quarterly data. We choose a lag structure in each equation so as to maximize the realism and fit of the model, even though this strategy generates several state variables.

2. SOLUTION

The solution of the model requires us to rewrite the model so as to represent it in the state-space form. Once it is represented in this way, one can apply directly the algorithms described in Backus and Drifill (1986), Svensson (1994), and Söderlind (1999b). As mentioned before, we consider a discretionary solution.

2.1 State-Space Representation

Following the same notation as Svensson (2000), let X_t be the (column) vector of predetermined variables, Y_t the (column) vector of

13. In this framework, therefore, we study the effects of monetary policy on the current account without considering secular trends in the expenditure-output gap. This is consistent with the idea that the central bank is only capable of choosing (temporary) deviations of the real interest rate with respect to its long-run trend. The latter is actually endogenous and responds to the aforementioned secular trend.

variables that enter as arguments in the central bank's loss function, x_t the (column) vector of forward-looking variables, and ξ_t the (column) vector of shocks. Considering the lag structure embedded in the model estimation presented in appendix A, one has

$$X_t = \begin{pmatrix} tot_t, tot_{t-1}, tot_{t-2}, r_t^*, \Phi_t, q_{t-1}, q_{t-2}, q_{t-3}, \pi_t, \pi_{t-1}, \pi_{t-2}, \pi_{t-3}, y_t, y_{t-1}, \\ r_{t-1}, R_{t-1}, y_t^d \end{pmatrix}',$$

$$Y_t = (\pi_t, cc_t, y_t, r_t - r_{t-1})',$$

$$x_t = [R_t, q_t, E(\pi_{t+1} | \Omega_{t-1}), E(\pi_{t+2} | \Omega_{t-1})]', \text{ and}$$

$$\eta_t = (\xi_t^{tot}, 0, 0, \xi_t^r, \xi_t^\Phi, 0, 0, 0, \xi_t^\pi, 0, 0, 0, \xi_t^y, 0, 0, 0, \xi_t^d)'$$

Let n_1 , n_2 , n_3 , and $n = n_1 + n_2$ be the dimensions of X_t , x_t , Y_t , and Z_t , respectively. In the particular model we consider, $n_1 = 17$, $n_2 = 4$, and $n_3 = 4$. Let $Z_t = (X_t', x_t')$ be the vector that describes the state of the economy. Using these definitions, the model can be written in the following way (in the state-space):

$$\begin{bmatrix} X_{t+1} \\ E(x_{t+1} | \Omega_t) \end{bmatrix} = AZ_t + B\eta_t + \begin{bmatrix} \eta_{t+1} \\ 0 \end{bmatrix}, \quad (15)$$

$$Y_t = C_z Z_t + C_r r_t, \quad (16)$$

$$l_t = Y_t' K Y_t, \quad (17)$$

where A is a $n \times n$ matrix, B is a $n \times 1$ column vector, C_z is a $n_3 \times n$ matrix, C_r is a $n_3 \times 1$ column vector, and K is a $n_3 \times n_3$ diagonal matrix with $(\mu_\pi, \mu_{cc}, \mu_y, \mu_r)$ in the diagonal. Appendix B describes the construction of these matrices in detail.

The solution to the central bank's problem is characterized by a policy function of the following form:

$$r_t = FX_t, \quad (18)$$

where F is a $1 \times n_1$ row vector to be endogenously determined.

The solution also characterizes the evolution of the forward-looking variables according to the following linear function:

$$x_t = HX_t, \quad (19)$$

where H is a $n_2 \times n_1$ matrix to be endogenously determined.

Hence the dynamics of the economy are given by equations (18) and (19) and the following pair of equations:

$$X_{t+1} = M_{11}X_t + ?_{t+1}, \quad \text{and} \quad (20)$$

$$Y_t = (C_{z1} + C_{z2}H + C_rF)X_t, \quad (21)$$

where M_{11} , C_{z1} , C_{z2} are $n_1 \times n_1$, $n_3 \times n_1$ and $n_3 \times n_2$ matrices, respectively, corresponding to the partitions of

$$M \equiv A + B \begin{bmatrix} F \\ 0 \end{bmatrix} = \begin{bmatrix} M_{11} & M_{12} \\ M_{21} & M_{22} \end{bmatrix}, \quad \text{and}$$

$$C_z = \begin{bmatrix} C_{z1} & C_{z2} \end{bmatrix},$$

according to X_t and x_t .

In order to find the matrices F and H we use the algorithm mentioned above.

2.2 Optimal Reaction Functions

The optimal policy rule depends both on the structure of the economy and on the preferences of the central bank. These preferences, in turn, are described by a discount rate and by a set of relative weights for the loss function in equation (1). We consider a discount factor of 0.99 and four sets of weights for equation (1) and thus define four types of central banks. The “hawk” type (H) has inflation as its almost unique objective; the “dove” type (D) has as its

objectives both inflation and the output gap; the objectives of the “strict condor” type (SC) are inflation and the current account deficit; and those of the “flexible condor” type (FC) include inflation, the current account deficit, and the output gap. We assume that all four central bank types dislike large changes in interest rates and therefore have $\mu_r > 0$. Table 1 presents the weights (μ s) of the loss function for each of these central bank types.¹⁴

Table 2 presents the optimal reaction functions for each of the four types. Each column corresponds to the vector F' , which, multiplied by the vector X_t , yields the optimal interest rate deviation for period (quarter) t . For example, if the central bank is of the hawk type, it will increase the (indexed) interest rate by 0.45 percentage point after a 1-percentage-point upward shock to inflation.¹⁵

Examining the dynamic reaction of the interest rate to alternative shocks is another way of analyzing optimal policy rules. These reactions show the path of interest rates that would prevail if the rule is followed and no other shocks occur, and thereby include reactions to expected future movements in other endogenous variables.

Figure 1 presents the path of interest rates between quarter 0 (on impact) and quarter 7 following different exogenous shocks. Besides the six basic (structural) shocks of the model, we consider a combined shock to output and the absorption-output gap, which can be thought of as the case of an overheated economy. The figure presents the reactions of the four central bank types to such a shock. The panels on the left show the reactions of central bank types H and P, whereas those on the right ones show the reactions of types SC and FC.

Table 1. Preference Parameters for the Four Central Bank Types

Type of central bank	μ_π	μ_{cc}	μ_y	μ_r
Hawk	0.95	0.00	0.05	0.10
Dove	0.50	0.00	0.50	0.10
Strict condor	0.65	0.30	0.05	0.10
Flexible condor	0.35	0.30	0.35	0.10

Source: Authors' definitions.

14. The central bank preferences are “deep” parameters unaffected by the structure of the economy (for example, the degree of indexation). The structure of the economy modifies the optimal reaction functions, not preferences.

15. Notice that the interest rate persistence depends on both the parameter for r_{t-1} and that for R_{t-1} .

Table 2. Optimal Policy Functions by Central Bank Type

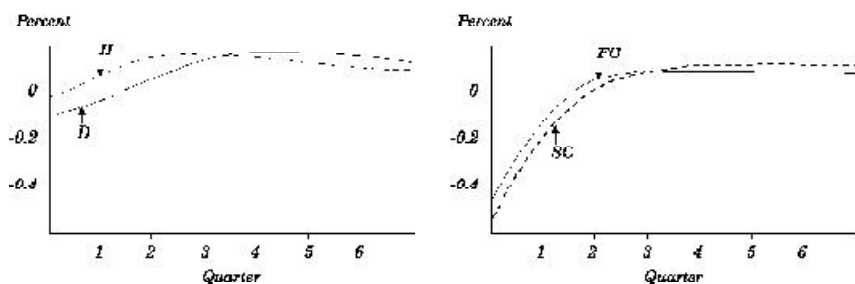
Variable	Central bank type			
	Hawk	Dove	Strict condor	Flexible condor
tot_t	-0.02	-0.01	-0.11	-0.10
tot_{t-1}	0.02	0.03	0.05	0.05
tot_{t-2}	0.01	0.02	0.01	0.01
r_t^*	0.87	0.43	0.52	0.34
Φ_t	0.72	0.32	0.43	0.27
q_{t-1}	-0.13	-0.06	-0.09	-0.06
q_{t-2}	-0.09	-0.04	-0.07	-0.04
q_{t-3}	-0.11	-0.05	-0.06	-0.04
π_t	0.45	0.28	0.24	0.17
π_{t-1}	0.32	0.19	0.17	0.11
π_{t-2}	0.19	0.11	0.10	0.07
π_{t-3}	0.09	0.05	0.04	0.03
y_t	0.57	0.60	0.31	0.33
y_{t-1}	0.12	0.07	0.06	0.04
r_{t-1}	0.28	0.12	-0.04	-0.07
R_{t-1}	-0.27	-0.37	-0.15	-0.20
y_t^d	0.00	0.00	0.13	0.12

Source: Authors' calculations.

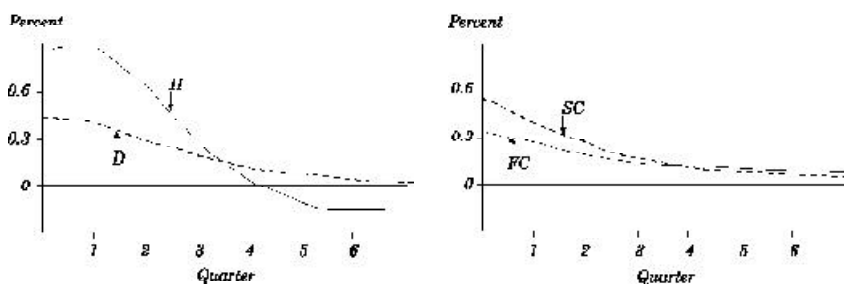
The results of table 2 and figure 1 have implications in at least three dimensions (besides the numerical results, which may be useful as a benchmark for policymaking). First, once the current account is part of the central bank's objectives, optimal policy reactions change in many respects, sometimes substantially. As expected, the SC and FC types respond to shocks to the absorption-output gap and to the terms of trade in a very different way than do types H and D. These two shocks have direct effects on the current account, for which the latter two central banks do not care. Interestingly, types SC and FC are less responsive to shocks to the international interest rate and the risk premium than types H and D, respectively. More important, when there is a target for the current account, monetary policy is clearly less aggressive in responding to shocks to inflation (compare type H with type SC) and to the output gap. All these differences are economically relevant.

Figure 1. Reaction Functions of Four Central Bank Types

5 percent shock to the terms of trade



1 percent shock to the real interest rate



1 percent shock to the country-risk premium

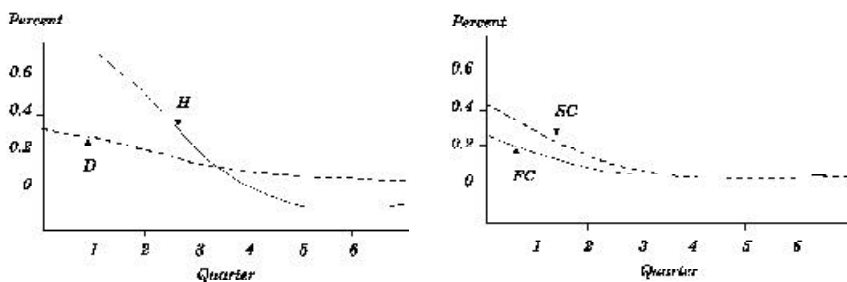
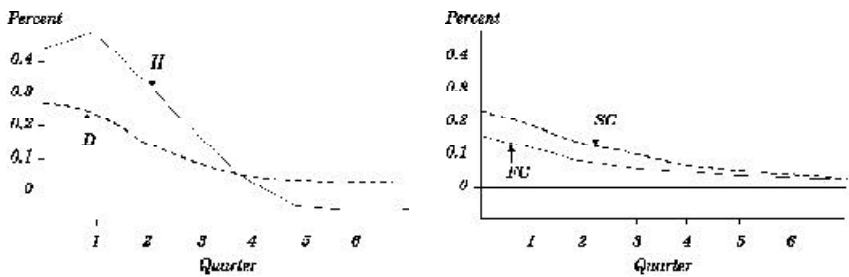
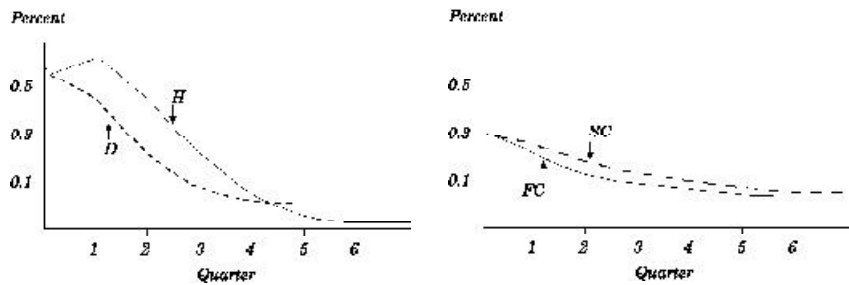


Figure 1. (Continued)

1 percent shock to the inflation gap



1 percent shock to the output gap



1 percent shock to the absorption-output gap

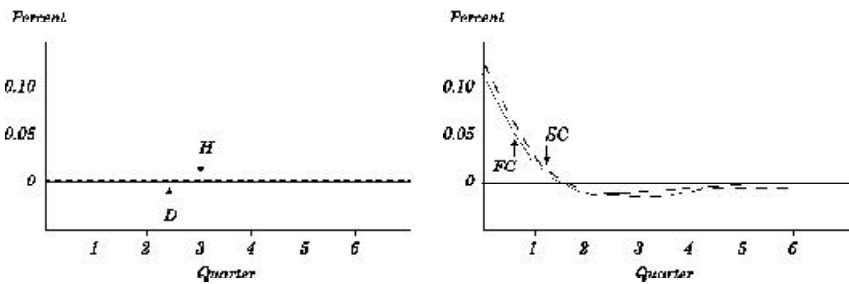
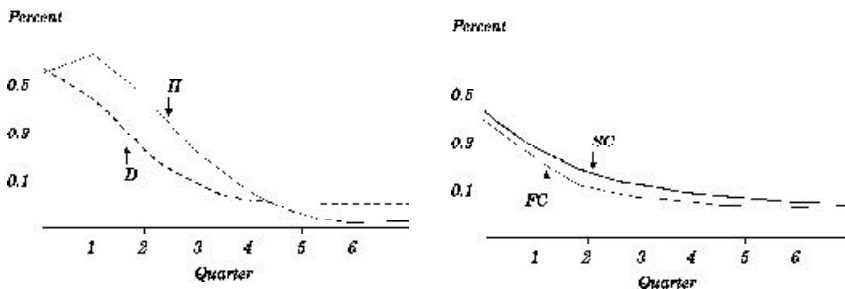


Figure 1. (Continued)

Simultaneous 1 percent shock to the output gap and the absorption-output gap



Source: Authors' calculations.

Second, the results show that, in general, reactions are less persistent for shocks that directly and indirectly affect the current account when the current account matters. This is probably due to the relatively lower persistence in the absorption-output gap in comparison to other variables. However, the reaction to inflation and output shocks is more persistent in types SC and FC than in types H and D.

Finally, the differences in optimal rules that arise when the central bank incorporates the output gap among its objectives are far less dramatic when the current account is already one of its objectives. Indeed, the differences between the reactions of types H and D are considerably more important than the differences between those of types SC and FC. One case in which this difference appears most clearly is in the dynamic central bank reaction to an inflation shock—probably the key issue in monetary policymaking. In this case type SC is only marginally more hawkish than type FC. Thus one can conclude that incorporating the output gap into the central bank's objectives does not appear to be crucial when the current account already matters. The intuition for this result is simple: the current account also presents a trade-off for monetary policy, because a more aggressive response to an inflation shock generates a larger current account deviation. However, for this result to hold, it is necessary to have a symmetric current account objective. The next section analyzes optimal policy reactions when this objective is asymmetric.

3. OPTIMAL MONETARY POLICY WITH AN ASYMMETRIC CURRENT ACCOUNT OBJECTIVE

Ultimately, behind the objective of keeping the current account under control is the notion that an “excessive” deficit usually brings about a serious balance of payments crisis, in which voluntary financing disappears and the economy enters a deep recession. The converse, however, is not true: too small a deficit is not considered to be a threat to external stability. But the loss function described by equation (1) is symmetric, treating positive and negative deviations as equally undesirable. Therefore the rules we have derived are, by construction, symmetric. This section investigates the implications for monetary policy of having an asymmetric loss function for the current account.

We analyze two issues that arise with asymmetric objectives. First, we investigate how much optimal reactions change, in response to both price and demand (current account) shocks. Second, we analyze whether optimal monetary policy changes when the volatility of shocks increases. We evaluate both how policy changes and the economic relevance of these changes.

Departing from the linear-quadratic framework (that is, from a symmetric current account objective) has the benefit of allowing for a more realistic loss function, but at the same time, it seriously complicates the problem. In the linear-quadratic problem we were able to find closed-form solutions of the form $r_t = FX_t$, whereas in this case we have to resort to numerical simulations. To be able to solve the central bank’s problem, we have to simplify the model of the economy substantially. In particular, we calibrate a simple stochastic, two-equation, backward-looking economy with two state variables, namely, inflation and the absorption-output gap, and directly associate the latter with the current account deficit. For simplicity, we assume that a positive absorption-output gap has inflationary consequences.¹⁶ Moreover, we do not consider any preferences over interest rate variability, nor do we consider bounds for possible interest rate values. Thus the rules we derive will in general prescribe a more aggressive

16. It should be stressed that this is a simplification. There is no reason for this gap to have direct inflationary consequences. What happens is that this gap is usually highly correlated with the output gap, which does affect inflation.

monetary policy than what a central bank would normally follow. Accordingly, rather than taking the quantitative results we derive at face value, they should be analyzed relative to the baseline scenario of rules for a symmetric current account objective (derived from a standard quadratic loss function).

3.1 A Simpler Economy

The economy is described by the following two equations:

$$\pi_t = \pi_{t-1} + \alpha_y y_{t-1}^d + \varepsilon_t^\pi, \quad \text{and} \quad (22)$$

$$y_t^d = \beta_y y_{t-1}^d + \beta_r r_{t-1} + \varepsilon_t^y, \quad (23)$$

where, as before, π_t is the inflation gap in period t , y_t^d is the absorption-output gap, r_t is the real (or indexed) interest rate (again measured as a deviation from its long-run trend), and ε_t^π and ε_t^y are serially uncorrelated mean-zero stochastic shocks. The quantities α_y , β_r , and β_y are constant parameters.

As before, the central bank's problem at time t is to choose a sequence of interest rates $\{r_{t+\tau}\}_{\tau=0}^\infty$ so as to minimize the intertemporal loss function in equation (2). Let x_t be the vector with the state variables, $x_t = (p_t, y_t^d)'$. We seek to characterize the interest rate sequence through a time-invariant (and probably nonlinear) policy function for a loss function of the following type:

$$l(x_t) = \begin{cases} a\pi_t^2 + b_L (y_t^d)^2 & \text{for } y_t^d \in (-\infty, 0) \\ a\pi_t^2 + b_H (y_t^d)^2 & \text{for } y_t^d \in (0, \infty), \end{cases} \quad (24)$$

where a , b_L , and b_H are positive constants. The asymmetric current account objective is described by $b_L < b_H$.

Therefore the central bank's problem is to set interest rates in order to minimize equation (2) with equation (24) subject to equations (22) and (23). We consider three alternative central bank types: quadratic, asymmetric, and one-sided. Table 3 presents the preference parameters of each. The quadratic central bank has the standard symmetric loss

Table 3. Loss Functions of Alternative Central Bank Types

Variable	Central bank type		
	Quadratic	Asymmetric	One-sided
a	1.00	1.00	1.00
b_L	0.50	0.20	0.00
b_H	0.50	0.80	1.00
δ	0.95	0.95	0.95

Source: Authors' definitions.

function, the asymmetric central bank cares considerably more about positive deviations of the current account from its target than about negative ones, and the one-sided central bank dislikes positive current account deviations (and inflation) only. In all cases, on average, there is a 2:1 weight relation between inflation and current account gap deviations.

We calibrate the model using the following parameter values: $\alpha_y = 0.5$, $\beta_y = 0.6$, $\beta_r = -0.5$, S.D. (ϵ_t^π) = 0.8 percent, S.D. (ϵ_t^y) = 0.8 percent, and zero covariance between shocks (where S.D. represents the standard deviation). These parameters are approximately in line with the estimation of equations (22) and (23) with Chilean data, with the caveat that we use the output gap in the former equation (see note 16).¹⁷ The frequency of the real-world counterpart of the model can be thought of as being either quarterly or semiannual.

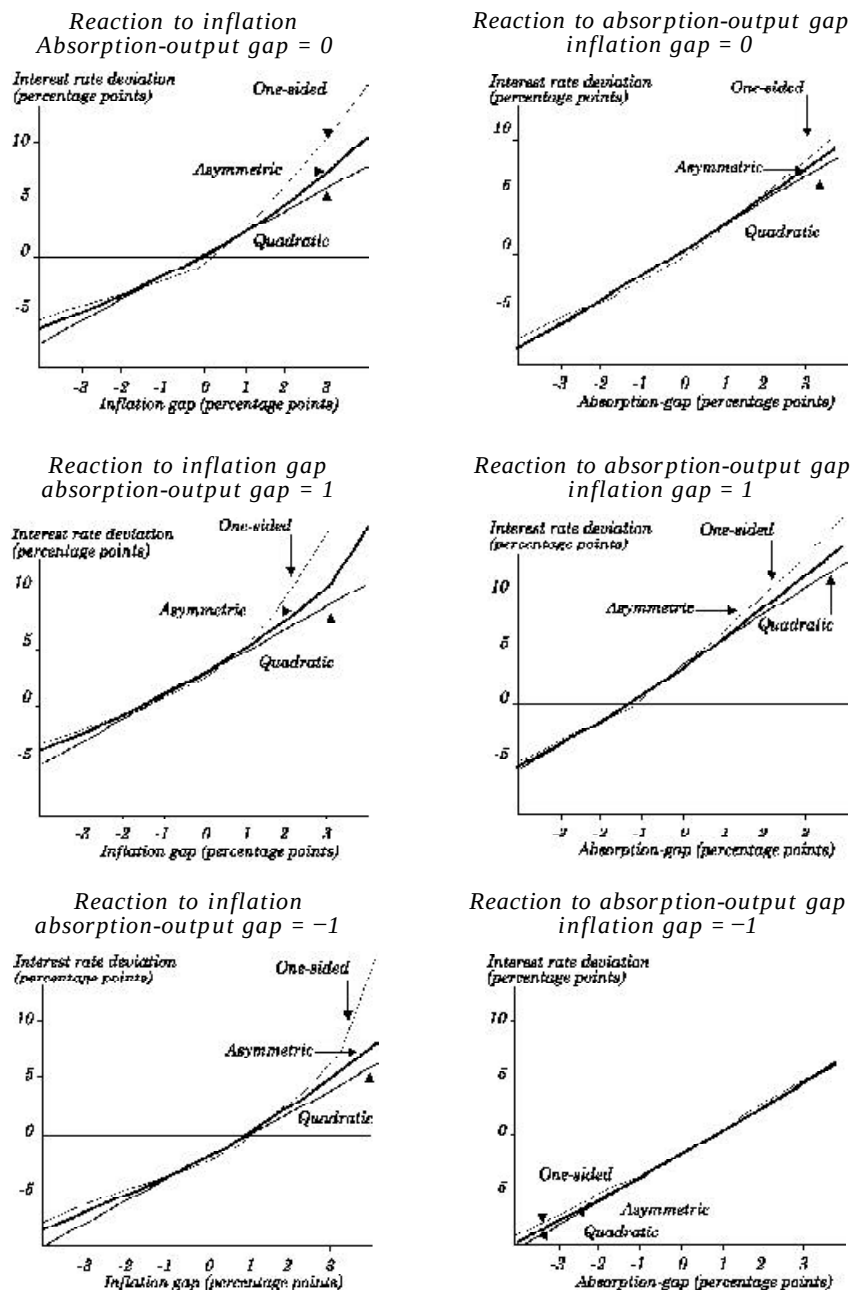
3.2 Solution

To solve the problem we discretize the economy along the lines followed by Medina and Valdés (2002) and apply standard dynamic programming techniques. It should be mentioned that this approximation yields quite accurate solutions for the linear-quadratic case.

Figure 2 shows the optimal policy functions for the central bank's problem under alternative combinations of inflation and the absorption-output gap. In each panel the x-axis shows a gap deviation, and the y-axis shows the optimal policy reaction (given by the interest rate deviation) of each of the central bank types.

17. The estimation of equation (22) yields a considerably higher inflation volatility. However, as shown by Magendzo (1998), in Chile there is close relation between the level and the volatility of inflation. The estimation of the same equation using the difference between actual and long-run trend inflation yields a standard deviation of 0.2 percent.

Figure 2. Optimal Policy Functions with an Asymmetric Current Account Objective



Source: Authors' calculations.

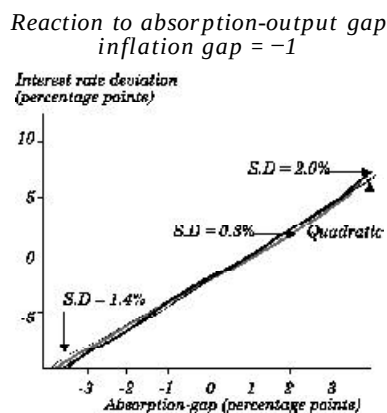
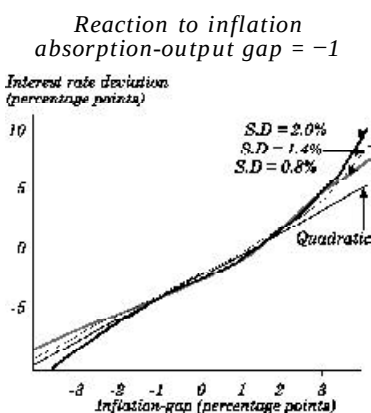
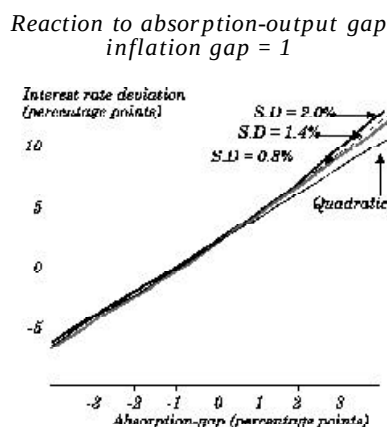
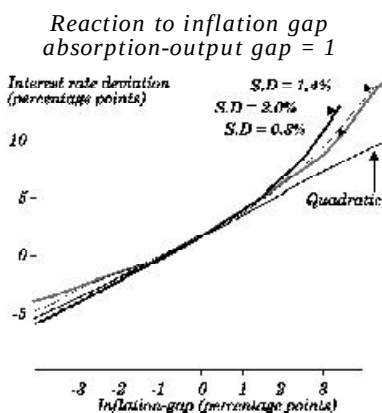
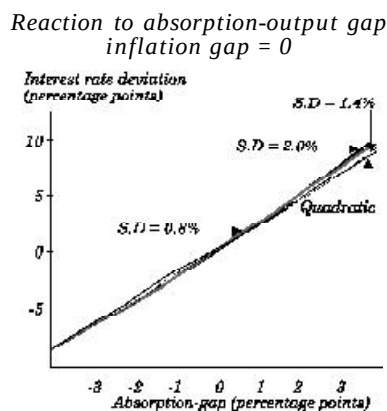
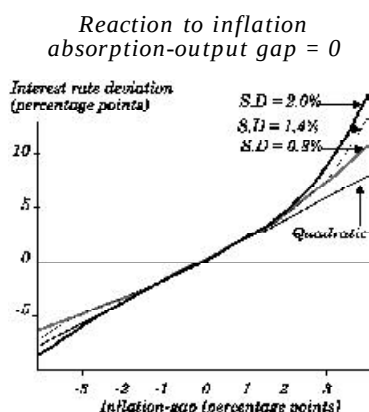
The results show two interesting features. First, and more important, the asymmetric current account objective generates a more aggressive response to positive inflation shocks. The intuition for this is straightforward: there is no trade-off involved. The differences are quite large. For example, if the current account gap is zero while the inflation gap is 3 percent, a one-sided central bank will increase interest rates by almost twice as much as the symmetric one, and an asymmetric central bank will increase them by one-third more than the symmetric one. In the case of negative inflation shocks, the asymmetry generates a less aggressive monetary policy (higher interest rates). Hence the two effects together imply that a central bank with an asymmetric current account objective can end up having inflation, on average, below its target.¹⁸

Second, at least for the case in which there is a negative or a zero inflation gap, the asymmetric current account objective does not greatly affect the optimal policy response to demand (current account) shocks. The reason for this result is that even if an expenditure gap does not matter directly, it can matter indirectly through its future impact on inflation, especially when inflation has a unit root. This is not the case if there is a positive absorption-output gap and a positive inflation gap. In this case monetary policy is more aggressive because the no-trade-off argument applies.

Figure 3 illustrates what happens to optimal policy reactions when the standard deviation of current account shocks increases. As one might expect, when the standard deviation rises from 0.8 percent (the baseline case) to 1.4 percent, the reactions of the central bank are more aggressive against inflation. However, these changes are not of great economic relevance. Only when the standard deviation rises to 2 percent do the differences start to become important, although they still are less important than the differences created by the asymmetry itself. In the case of negative inflation shocks, we find that a higher volatility of shocks also makes monetary policy more aggressive. One possible explanation is that when the inflation gap is very negative, a higher demand volatility risks a movement toward an even more negative gap (through a Phillips curve effect). Acting preemptively, when volatility is higher, monetary policy tries to return inflation to its target faster. Again, however, the differences are not that relevant from an economic perspective.

18. Of course, one can argue that the bias is for (not against) inflation if the counterfactual is a central bank with no current account objective at all.

Figure 3. Effects of Volatility on Optimal Policy Functions with an Asymmetric Current Account Objective



Source: Authors' calculations.

4. CONCLUDING REMARKS

This paper has presented two different models in order to analyze the implications for monetary policy of having a target for the current account deficit among the central bank's objectives. The first model is a simple linear-quadratic model estimated (or calibrated) for the Chilean economy with several state variables, some of which are forward-looking. The second model is a simple two-equation model in which the monetary authority has an asymmetric objective for the current account.

The analysis of this realistic linear-quadratic economy indicates that including the current account in the central bank's objectives has important consequences for optimal policy reactions. Interest rates become less reactive to shocks to inflation and the output gap and, as expected, more reactive to shocks that directly affect the current account. For example, the optimal reaction to a terms-of-trade shock is completely different once the central bank cares about the current account.

Furthermore, the results show that optimal monetary rules change much less when the central bank incorporates the output gap among its objectives if it already has a target for the current account among those objectives. Therefore, although the discussion of incorporating unemployment in the central bank's objectives is highly relevant in Chile, it is considerably less so than in a country in which the central bank has no current account objectives. Of course, this result hinges on having a symmetric objective for something that offers a trade-off to rapid inflation control.

The asymmetric nature of the current account objective has important consequences for optimal policy reactions against inflation shocks. Compared with the case of a symmetric current account objective, monetary policy is considerably tighter when the objective is asymmetric. When the volatility of current account shocks increases and the central bank has an asymmetric current account objective, monetary policy becomes more aggressive (that is, more reactive). This last change, however, is quantitatively less important from an economic perspective.

APPENDIX A

Model Estimation and Calibration

This appendix describes the estimation results and calibration for the Chilean economy of the model presented in the text. The data are of quarterly frequency, and the sample size varies according to data availability.

For the risk premium equation, we assume an AR(1) parameter of 0.90, equal to that estimated for the international interest rate. We calibrate the current account gap equation with a log Taylor expansion in 1997 (see text for details). We estimate the inflation equation using a specification in terms of levels, with international inflation (which includes nominal depreciation, foreign inflation, and changes in value added taxes and tariffs) among the explanatory variables, and we impose homogeneity in prices. We then modify the equation incorporating the inflation target and the RER. In the output equation we assume elasticities with respect to the RER and estimate the rest of the parameters. Here and in appendix B we denote the conditional expectation $E(x_{t+\tau} | \Omega_t)$ as $x_{t+\tau|t}$.

A.1 Terms of Trade

The estimated equation for the terms of trade is

$$\begin{aligned} tot_t &= \rho_{tot} tot_{t-1} + \rho_{tot}^r r_{t-1}^* + \xi_t^{tot} . \\ 0.86 &\quad -0.53 \\ (21.4) &\quad (-3.7) \end{aligned}$$

The method of estimation is ordinary least squares (OLS), the sample period is 1977 Q2 to 1998 Q2, and robust Newey-West t tests are used. The $\bar{R}^2$ of the equation = 0.85, the F statistic = 237.4, and the Durbin- h statistic = 1.19.

A.2 International Real Interest Rate

The estimated equation for the international real interest rate is

$$\begin{aligned} r_t^* &= \rho_r r_{t-1}^* + \xi_t^r . \\ 0.90 & \\ (18.8) & \end{aligned}$$

The estimation method is OLS, the sample period is 1977 Q2 to 1998 Q2, and robust Newey-West t tests are used. The $\bar{R}^2$ of the equation = 0.84, the F statistic = 443.0, and the Durbin- h statistic = 2.30.

A.3 Country Risk Premium Calibration

The country risk premium is calibrated as follows:

$$\varphi_t = \rho_{\varphi} \varphi_{t-1} + \xi_t^{\varphi}.$$

0.90

A.4 Inflation (Levels)

The estimated equation is

$$\begin{aligned} \pi_t - \pi_{t-1} = & \psi_0 \left[(\pi_{t-2} + \pi_{t-3} + \pi_{t-4}) / 3 - \pi_{t-1} \right] \\ & + \psi_1 \left[(\pi_{t+1|t-1} + \pi_{t+2|t-1}) / 2 - \pi_{t-1} \right] \\ & + \psi_2 \left[(p_{t-1}^* + e_{t-1} - p_{t-4}^* - e_{t-4}) / 3 - \pi_{t-1} \right] \\ & + \psi_3 (y_{t-1} + y_{t-2}) / 2 + \psi_4 D912 + \psi_5 DTax + \xi_t^{\pi}. \end{aligned}$$

0.41
(3.4)
0.29
(2.0)
0.15
(2.3)
0.39 0.08 1.97
(2.1) (6.2) (2.1)

The method of estimation is two-stage least squares (TSLS), the sample period is 1988 Q3 to 1998 Q4, and robust Newey-West t tests are used. The $\bar{R}^2$ of the equation = 0.59, and the F statistic = 11.52. The inflation target, wages, R_{t-1} , and lags are used as instruments.

A.5 Inflation Gap (Transformation)

The equation is as follows:

$$\pi_t = \alpha_{\pi L}^0 \pi_{t-1} + \alpha_{\pi L}^1 (\pi_{t-2} + \pi_{t-3})/2 + \alpha_{\pi L}^2 \pi_{t-4} + \alpha_{\pi F} (\pi_{t+1|t-1} + \pi_{t+2|t-1})/2 \\ + \alpha_q (q_{t-1} - q_{t-4})/3 + \alpha_y (y_{t-1} + y_{t-2})/2 + \xi_t^\pi .$$

0.20 0.37 0.14 0.29

0.60 0.39

A.6 Long-Term Real Interest Rate

The estimated equation is as follows:

$$R_t = \lambda r_t + (1 - \lambda) R_{t+1|t} .$$

0.13 0.87

(2.1) (18.8)

The estimation method is TSLS, the sample period is 1987 Q3 to 1998 Q4, and robust Newey-West t tests are used. The $\bar{R}^2$ of the equation = 0.74, the F statistic = 110.1, and the Durbin-Watson statistic = 1.64. Instruments used are π_t , y_t^d , tot_t , and lags.

A.7 Output Gap

The estimated equation is as follows:

$$y_t = \beta_y y_{t-1} + \beta_R (R_{t-1} + R_{t-2})/2 + \beta_r r_{t-2} + \beta_{tot} (tot_{t-2} + tot_{t-3})/2 \\ + 0.005 q_{t-1} + 0.010 q_{t-2} + 0.015 q_{t-3} \\ + 0.020 q_{t-4} + \xi_t^y .$$

0.61 -0.97 -0.28 0.04

(11.1) (-3.3) (-1.7) (4.2)

The method of estimation is OLS, the sample period is 1987 Q3 to 1998 Q4, and robust Newey-West t tests are used. The $\bar{R}^2$ of the equation = 0.57, the F statistic = 16.1, and the Durbin- h = -0.72.

A.8 Absorption-Output Gap

The estimated equation is as follows:

$$\begin{aligned}
 y_t^d = & \gamma_d y_{t-1}^d + \gamma_r (r_{t-1} + r_{t-2})/2 + \gamma_{q1} q_{t-1} + \gamma_{q2} q_{t-2} + \gamma_{q3} q_{t-3} + \gamma_{q4} q_{t-4} \\
 & 0.29 \quad -0.91 \quad \quad \quad -0.02 \quad -0.02 \quad -0.03 \quad -0.02 \\
 & (2.4) \quad (-3.3) \quad \quad \quad (-0.05) \quad (-0.08) \quad (-2.0) \quad (-0.3) \\
 & + \gamma_{tot} tot_{t-2} + \xi_t^d . \\
 & 0.08 \\
 & (4.2)
 \end{aligned}$$

The method of estimation is OLS-PDL for q , the sample period is 1986 Q2 to 1998 Q4, and robust Newey-West t tests are used. The $\bar{R}^2$ of the equation = 0.49, the F statistic = 11.1, and the Durbin- h = 0.85.

A.9 Current Account Gap Calibration

The calibration of the current account gap is as follows:

$$\begin{aligned}
 cc_t = & -y_t^d + k_0 q_t - k_0 y_t + k_1 tot_t . \\
 & 0.02 \quad 0.02 \quad 0.30
 \end{aligned}$$

The calibration is based on a log Taylor expansion with 1997 as the base year.

A.10 Uncovered Interest Rate Parity

The equation is as follows:

$$q_t = q_{t+1|t} + 0.25(r_t^* + \varphi_t - r_t) .$$

APPENDIX B

State-Space Representation

This appendix shows how to write the model in the state-space form. As noted by Svensson (2000), given rational expectations, the inflation gap has the following behavior:

$$\pi_{t+1} = \pi_{t+1|t} + \xi_{t+1}^\pi.$$

Moreover, shifting the inflation equation one period forward and taking expectations based on information up to time t , one arrives at an equation that can be solved for $\pi_{t+3|t}$ as a function of known variables and of $\pi_{t+2|t}$ and $\pi_{t+1|t}$. With these considerations one can write the matrix A of equation (15) in the following way:

$$A = \begin{bmatrix} \rho_{tot} E_1 + \rho_{tot}^r E_4 \\ E_1 \\ E_2 \\ \rho_r E_4 \\ \rho_\phi E_5 \\ E_{19} \\ E_6 \\ E_7 \\ E_{20} \\ E_9 \\ E_{10} \\ E_{11} \\ A_{13} \\ E_{13} \\ 0 \\ E_{18} \\ A_{17} \\ [1/(1-\lambda)] E_{18} \\ E_{19} - 0.25 E_4 - 0.25 E_5 \\ E_{21} \\ A_{21} \end{bmatrix},$$

where E_j represents a $1 \times n$ row vector with 1 in position j and zeros otherwise, and $A_{j\cdot}$ is row j of matrix A . Furthermore,

$$A_{13} = \beta_y E_{13} + \beta_R (E_{16} + E_{18})/2 + \beta_r E_{15} + \beta_{tot} (E_2 + E_3)/2 + \beta_{q1} E_{19} \\ + \beta_{q2} E_6 + \beta_{q3} E_7 + \beta_{q4} E_8 ,$$

$$A_{17} = \gamma_d E_{17} + \gamma_r E_{15}/2 + \gamma_q (E_6 + E_{19})/2 + \gamma_{tot} E_2 + \gamma_{q1} E_{19} + \gamma_{q2} E_6 \\ + \gamma_{q3} E_7 + \gamma_{q4} E_8 ,$$

and

$$A_{21} = \frac{2}{\alpha_{\pi F}} \left[\frac{E_{20} - \alpha_{\pi L}^0 E_9 - \alpha_{\pi L}^1 (E_{10} + E_{11})/2 - \alpha_{\pi L}^2 E_{12} - \alpha_{\pi F} E_{21}/2}{-\alpha_q (E_{19} - E_8)/3 - \alpha_y (E_{13} + E_{14})/2} \right] .$$

The B vector, in turn, is given by

$$[0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, \gamma_r/2, -\lambda(1-\lambda), 0.25, 0, 0]' .$$

The C_Z matrix and the C_r vector of equation (16) are given by

$$C_Z = \begin{bmatrix} E_9 \\ -E_{17} - k_0 E_{19} + k_0 E_{13} + k_1 E_1 \\ E_{13} \\ -E_{15} \end{bmatrix} \quad y \quad C_r = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 1 \end{bmatrix} .$$

Finally, the K matrix of equation (17) is given by

$$K = \begin{bmatrix} \mu_\pi & 0 & 0 & 0 \\ 0 & \mu_{cc} & 0 & 0 \\ 0 & 0 & \mu_y & 0 \\ 0 & 0 & 0 & \mu_r \end{bmatrix} .$$

REFERENCES

- Backus, D., and J. Driffill. 1986. "The Consistency of Optimal Policy in Stochastic Rational Expectations Models." CEPR Discussion Paper 124. London: Centre for Economic Policy Research.
- King, M. 1999. "Challenges for Monetary Policy: New and Old." Paper presented at a symposium on New Challenges for Monetary Policy, sponsored by the Federal Reserve Bank of Kansas City, August.
- Magendzo, I. 1998. "Inflación e Incertidumbre Inflacionaria en Chile." *Economía Chilena* 1(1): 29-42.
- Massad, C. 1998. "La Política Monetaria en Chile." *Economía Chilena* 1(1): 7-27.
- Medina, J. P., and R. Valdés. 2002. "Optimal Monetary Policy Rules Under Inflation Range Targeting". In this volume.
- Ryan, C., and C. Thompson. 1999. "The Exchange Rate and Monetary Policy Rules." Unpublished paper. Sydney: Reserve Bank of Australia (August).
- Söderlind, P. 1999a. "Solution and Estimation of RE Macromodels with Optimal Policy." *European Economic Review* 43: 813-23.
- . 1999b. "Algorithms for RE Macromodels with Optimal Policy—Lecture Notes." Unpublished paper. Stockholm: Stockholm School of Economics.
- Svensson, L. E. O. 1994. "Why Exchange Rate Bands? Monetary Independence in Spite of Exchange Rate Bands." *Journal of Monetary Economics* 33(1): 157-99.
- . 1999. "How Should Monetary Policy Be Conducted in an Era of Price Stability?" Paper presented at a symposium on New Challenges for Monetary Policy, sponsored by the Federal Reserve Bank of Kansas City, August.
- . 2000. "Open-Economy Inflation Targeting." *Journal of International Economics* 50: 155-83.
- Woodford, M. 1999a. "Optimal Monetary Policy Inertia." NBER Working Paper 7261. Cambridge, Mass.: National Bureau of Economic Research.
- . 1999b. "Commentary: How Should Monetary Policy Be Conducted in an Era of Price Stability?" Paper presented at a symposium on New Challenges for Monetary Policy, sponsored by the Federal Reserve Bank of Kansas City, August.

OPTIMAL MONETARY POLICY RULES UNDER INFLATION RANGE TARGETING

Juan Pablo Medina

University of California, Los Angeles

Rodrigo O.Valdés

Ministry of Finance, Chile

Central banks resort to a variety of alternative arrangements in formulating, conducting, and communicating monetary policy. One increasingly popular type of arrangement is based on a target range for inflation.¹ In this setup the conduct of monetary policy is oriented to keeping inflation within preannounced boundaries. For example, the central banks of Brazil, Canada, Israel, New Zealand, and Sweden all have target zones for inflation, whose width ranges from 2 to 3 percentage points. Chile recently announced an inflation target range of 2 to 4 percent, to begin in 2001. One can further distinguish two alternative arrangements for the target range, namely, soft-edged and hard-edged ranges. Under the former, deviations from the edges of the range are considered as adverse as a deviation from a point target, whereas in the latter, deviations from the target range are considered to be relatively more undesirable.² In other words, a soft-edged regime could be understood as a “thick” point target regime.

This paper was written while Medina and Valdés were affiliated with the Central Bank of Chile.

The authors thank Pablo García, Luis Oscar Herrera, and Felipe Morandé and seminar participants at the Central Bank of Chile for useful comments and accept responsibility for all remaining errors. This paper presents the views of the authors and does not necessarily represent in any way the positions or views of the Ministry of Finance, Chile.

1. This arrangement is part of a broader movement in monetary policy design in which the anchor of monetary policy is a target for inflation. See, for example, Bernanke and others (1999).

2. One reason for considering a deviation from a target range as being relatively more costly is its impact on credibility.

Monetary Policy: Rules and Transmission Mechanisms, edited by Norman Loayza and Klaus Schmidt-Hebbel, Santiago, Chile. ©2002 Central Bank of Chile.

Other central banks (for example, that of the United Kingdom and that of Chile until 2000) organize monetary policy around a point target, and some implicitly regard upward deviations of inflation as more costly than downward deviations. The latter is typically the case of a country trying to disinflate (examples include Brazil, Colombia, and Israel today and Chile during the 1990s).

In this paper we investigate how optimal monetary policy rules change under these alternative formulations. In particular, we compare optimal policy rules derived under alternative policy objectives or loss functions for a simple, backward-looking, dynamic model of the economy. We are interested in answering four related questions: First, does range targeting yield optimal monetary policy reactions that are less aggressive than otherwise?³ Second, are there relevant nonlinearities for monetary policy under range targeting (for example, are there zones in which the optimal policy is inaction)? Third, what happens to optimal monetary policy reactions if the range edges are harder, that is, if deviations from the range are considered highly undesirable events? Finally, what are the implications of having an asymmetric objective, in which positive inflation deviations are relatively more undesirable than negative ones? Our purpose is not only to answer these questions but also to provide some quantitative measures so as to evaluate their economic relevance. For that purpose we consider a simple but realistic model of the economy calibrated with Chilean data.

The economy for which we calculate optimal policy rules is extremely simple, described by two linear equations: an accelerationist Phillips curve and an output gap equation. Monetary policy directly controls the real interest rate, which, in turn, affects output with a lag, and output affects inflation with another lag. For simplicity we consider neither any central bank preferences regarding interest rate variability nor any bounds for possible interest rate values. In general, the rules we derive will prescribe a more aggressive monetary policy than what a central bank would normally follow. Accordingly, rather than taking the quantitative results we derive at face value, they should be analyzed relative to the baseline scenario of rules for a symmetric point inflation target (derived from a standard quadratic loss function).

3. Other ways to make monetary policy less aggressive include the incorporation of interest rate smoothness among the central bank's objectives and the measurement of inflation over longer horizons (see, for example, Nessén, 1999).

This paper is closely related to the literature on optimal monetary policy rules developed by Svensson (2000), Ball (1999), McCallum (1998), and Woodford (1999), among many others. It departs from an otherwise standard analysis by comparing the implications of alternative nonquadratic loss functions. It is closely related to Orphanides and Wieland (1999), who also study the effects of range targets for inflation. The key difference between that paper and this one is that Orphanides and Wieland consider no lags in the effects of the output gap on prices, whereas we model this effect as taking one period. In their model, monetary policy has a one-period control lag (that is, it affects inflation after one period), whereas in ours it has a two-period lag. Although this extra lag makes the model more realistic, it poses the difficulty of having a second state variable.⁴

The main results we find are the following: Compared with a quadratic loss function, range targeting yields a less aggressive optimal monetary policy. For example, after a 1-percentage-point inflation shock, interest rates increase by approximately one-third less when there is range targeting with soft edges than when there is point targeting. Optimal monetary policy in this setup is always active, however. That is, even if inflation is well inside the range, unless it is squarely in the middle of the target, interest rates should not be at their neutral level. Monetary policy moves in a preemptive way: because the likelihood that a shock will move the economy out of the range increases when it is not in the middle of the range, it is optimal to move back the economy toward the center of the range. If range edges are relatively hard, range targeting implies a more aggressive monetary policy than when they are soft.⁵

If the loss function is the same as with point targeting, but with a discrete jump to zero in the inflation target range, optimal monetary policy does not change in any important way. If the loss function is asymmetric, penalizing positive inflation deviations more than negative ones, optimal monetary policy involves higher average interest rates. This implies that this loss function generates (on average) a negative output gap.⁶

4. Orphanides and Wieland (1999) also include in their analysis a nonlinear Phillips curve and model uncertainty. We, in turn, focus our analysis on the implications of having alternative loss functions.

5. Thus, there is an apparent trade-off between the width of the range and the form of its edges. The width generates less aggressive responses, whereas harder edges generate more aggressive responses.

6. A negative output gap is defined as one in which potential output exceeds actual output.

The paper is organized as follows. Section 1 presents the basic model of the economy, discusses the procedure we use to transform a continuous economy into a discrete one, and reviews the dynamic programming framework we use to solve for the optimal policy rules. Section 2 compares the optimal policy rules derived under alternative loss functions. Section 3 concludes.

1. GENERAL FRAMEWORK

This section presents the framework we use to calculate and compare optimal monetary policy rules under alternative loss functions. It describes the economy, the central bank's preferences, and the method we use to find optimal monetary policy rules.

1.1 The Economy

We consider a simple, dynamic, backward-looking economy described by the following two equations:

$$\pi_t = \pi_{t-1} + \alpha_y y_{t-1} + \varepsilon_t^\pi, \quad \text{and} \quad (1)$$

$$y_t = \beta_y y_{t-1} + \beta_r r_{t-1} + \varepsilon_t^y, \quad (2)$$

where π_t is the gap between inflation in period t and its long-run target, y_t is the output gap, r_t is the real (or indexed) interest rate (measured as a deviation with respect to its long-run level), and ε_t^π and ε_t^y are (possibly correlated) serially uncorrelated mean-zero stochastic shocks. In the equations α_y , β_r , and β_y are constant parameters.

These two equations are similar to those presented in Ball (1999) and Svensson (1997). Equation (1) is a standard accelerationist Phillips curve, and equation (2) is a standard output gap equation (a dynamic IS curve). Below we present an estimation of these equations using data for the Chilean economy. Notice that in this setup monetary policy has a two-period control lag over inflation.

At time t the central bank's problem is to choose a sequence of interest rates $\{r_{t+\tau}\}_{\tau=0}^{\infty}$ so as to minimize the following expected intertemporal loss function:

$$L_t = E \left[\sum_{\tau=0}^{\infty} \delta^{\tau} l(x_{t+\tau}) \right], \quad (3)$$

where δ is a discount factor, $l(\cdot)$ is an instantaneous loss function, and x_t is a vector of state variables $x_t = (\pi_t, y_t)'$.

We seek to characterize the interest rate sequence through a time-invariant (and probably nonlinear) policy function for alternative instantaneous loss functions. In particular, we seek to characterize and compare optimal policy (reaction) functions when the loss function is of the following type:

$$(4)$$

where b, c, a_j and $\bar{\pi}_j$ ($j = L, H$) are constants.

This loss function includes the standard quadratic function with weights a and b in inflation and output gap variability, respectively. In this case $\pi_t = \bar{\pi}_H = 0$ and $a_L = a_H$. It also includes less standard setups such as target zone (for example, $\bar{\pi}_L < 0, \bar{\pi}_H > 0$, and $c = 1$) and asymmetric weights (for example, $a_L < a_H$). Table 1 summarizes the five baseline cases we consider.⁷

Figures 1 and 2 show the alternative loss functions described in table 1. The quadratic case is meant to represent the standard point-target framework, whereas those with a zero value in the $(-1, +1)$ range represent alternative range targeting setups. We also include an asymmetric objective function to represent higher costs of positive inflation deviations.⁸

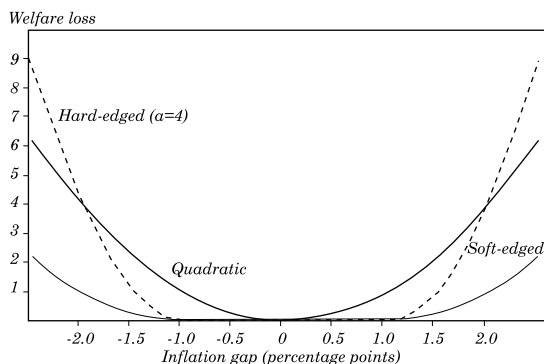
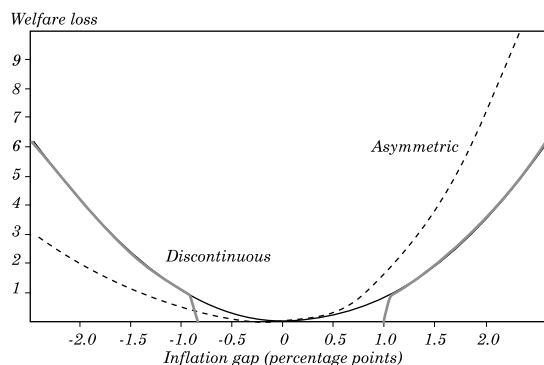
In sum, the problem is to choose a sequence $\{r_{t+\tau}\}_{\tau=0}^{\infty}$ that minimizes equation (3) subject to equations (1) and (2). Under some regularity conditions, this problem has a solution that can be represented by a time-invariant policy function mapping the inflation and output gaps onto the real interest rate, $r_t = h(x_t)$, where x_t is the vector of

7. Of course, one could also consider other parameters. Medina and Valdés (2002) considers the case of a one-sided objective.

8. Other asymmetries that may in general arise include asymmetric shocks and asymmetric responses of the economy.

Table 1. Parameter Values in Alternative Loss Functions

Parameter	Definition	Loss function				
		Quadratic	Range with soft edges	Range with hard edges	Range with discrete edges	Asymmetric "hawk"
a_L	Weight on downward inflation variability	1.0	1.0	1.25 or 4.0	1.0	0.5
a_H	Weight on upward inflation variability	1.0	1.0	1.25 or 4.0	1.0	2.0
b	Weight on output variability	0.5	0.5	0.5	0.5	0.5
c	Weight on inflation variability inside the range	1.0	1.0	1.0	0.0	1.0
$\bar{\pi}_L$	Distance of lower bound of range from center (percentage points)	0	-1	-1	-1	0
$\bar{\pi}_H$	Distance of upper bound of range from center (percentage points)	0	+1	+1	+1	0
δ	Discount factor	0.95	0.95	0.95	0.95	0.95

Figure 1. Loss Functions under Alternative Definitions of Range-Targeting**Figure 2. Asymmetric and Discontinuous Loss Functions**

state variables (see, for example, Sargent and Ljungqvist, 1999). In this case $\mathbf{x}_t = (\pi_t, y_t)'$.

Unfortunately, for the class of loss functions we consider, it is not possible to find a closed-form solution for the function $h(\cdot)$. Only in the well-known case of a quadratic problem it is possible to find a vector F such that $r_t = F \mathbf{x}_t$ yields the optimal solution. We therefore have to resort to numerical methods. In particular, we change the original problem to one in which we constrain the states and control variables to be a discrete and finite set of points. We then apply standard dynamic programming techniques.⁹

9. Judd (1998) analyzes discrete-state space dynamic programming.

1.2 Discretization of the Continuous-State Space

We proceed as follows to transform the continuous economy described by equations (1) and (2) and the control variable r_t into a discrete-state space economy. We first assume that the economy can be in any of m possible states collected in a set $\Gamma = \{(\pi_1, y_1), (\pi_2, y_2), \dots, (\pi_m, y_m)\}$. We further assume that the interest rate r_t can take n different values arranged in a set $\psi = (r_1, r_2, \dots, r_n)$.

To preserve the dynamic and stochastic properties embedded in equations (1) and (2), we calculate transition probabilities between states that depend on the interest rate. In this way monetary policy can be thought of as choosing alternative transition matrices of a Markov chain of the economy.

Assume that the shocks ε_t^x and ε_t^y follow a bivariate normal distribution with variance-covariance matrix Σ . It is then straightforward to calculate the conditional distribution of the vector $x_t = (\pi_t, y_t)'$ conditional on (π_{t-1}, y_{t-1}) and r_{t-1} as the bivariate normal distribution with mean of

and the following variance-covariance matrix:

$$\text{Var}(x_t | \pi_{t-1}, y_{t-1}, r_{t-1}) = \Sigma.$$

To construct the transition matrix associated with each interest rate in ψ , we divide a rectangle $(a_\pi, b_\pi) \times (a_y, b_y) \subseteq \mathfrak{R}^2$ into m equal-size rectangles $\theta_1, \theta_2, \dots, \theta_m$ and consider that the centers of each of these rectangles form the set Γ . For each feasible interest rate $r_k \in \psi$ we can define the transition probability p_{ij}^k as the likelihood of a movement from state (π_i, y_i) at time $t-1$ to state (π_j, y_j) one period ahead, given that $r_{t-1} = r_k$. This probability is given by

$$\begin{aligned} p_{ij}^k &= \Pr \left[(\pi_t, y_t)' \in \theta_j | (\pi_{t-1}, y_{t-1}) = (\pi_i, y_i), r_{t-1} = r_k \right] \\ &= \left\{ \int_{\theta_j} \frac{1}{2\pi(\Sigma)^{1/2}} \exp \left[-\frac{(x - \bar{x}_i^k)' \Sigma (x - \bar{x}_i^k)}{2} \right] dx \right\} \\ &\quad \div \int_{(a_\pi, b_\pi) \times (a_y, b_y)} \frac{1}{2\pi(\Sigma)^{1/2}} \exp \left[-\frac{(x - \bar{x}_i^k)' \Sigma (x - \bar{x}_i^k)}{2} \right] dx, \end{aligned}$$

where

$$\bar{x}_i^k = E \left[\left(\begin{array}{c} \pi_t \\ y_t \end{array} \right) \middle| \pi_{t-1} = \pi_i, y_{t-1} = y_i, r_{t-1} = r_k \right].$$

Armed with this set of transition matrices, we next find a solution of the original problem using standard dynamic programming. Clearly, because we consider a subset of the possible states of the economy, this discretization is only an approximation. Moreover, it should be clear that in the neighborhood of the borders of the rectangle $(a_\pi, b_\pi) \times (a_y, b_y)$ the approximation is far from accurate, for two reasons. One is that the probability of moving further away from the center of the rectangle is assumed to be zero, and the other is that the centers of the small rectangles θ_j at the borders do not properly represent the values that the system can take outside the (large) rectangle. When we calculate optimal policy rules, we use the complete rectangle, but we only consider the neighborhood of its center when we analyze and compare the implications of alternative loss functions.

1.3 Discrete-State Space Dynamic Programming

With the economy represented in a discrete-state space, the original problem of the central bank becomes:

$$\text{Min}_{(r_{t+\tau})_{\tau=0}^{\infty}} E \sum_{\tau=0}^{\infty} \delta^\tau l(\pi_t, y_t),$$

subject to:

$$\begin{aligned} (\pi_{t+1}, y_{t+1}) &\in \Gamma = [(\pi_1, y_1), \dots, (\pi_m, y_m)], \\ r_t &\in \Psi = (r_1, \dots, r_k), \\ \text{Pr}[(\pi_t, y_t) = (\pi_j, y_j) | (\pi_{t-1}, y_{t-1}) = (\pi_i, y_i), r_{t-1} = r_k] &= p_{ij}^k, \end{aligned}$$

where $\sum_{j=1}^m p_{ij}^k = 1$, for all $i = 1, \dots, m$ and for all $k = 1, \dots, n$.

The Bellman equation associated with this problem is

$$V(\pi_t, y_t) = \min_{r' \in \Psi} \left\{ l(\pi_t, y_t) + \delta E \left[V(\pi_{t+1}, y_{t+1}) | (\pi_t, y_t), r' \right] \right\}, \quad (5)$$

which, given the transition probabilities, can be written as

$$V(\pi_i, y_i) = \min_{r_k \in \Psi} \left[l(\pi_i, y_i) + \delta \sum_{j=1}^m p_{ij}^k V(\pi_j, y_j) \right], \quad (6)$$

for all $i = 1, \dots, m$ and for all $k = 1, \dots, n$. Here $V(\pi_t, y_t)$ is the optimal value of the objective function starting from an inflation π_t and output gap y_t . The solution of the central bank's problem is characterized by a value function $V(.,.)$ that satisfies equation (6) and an associated policy function $r' = h(\pi, y)$ mapping the state of the economy (π, y) onto an optimal choice of interest rate. Since equation (6) satisfies Blackwell's sufficient conditions for a contraction (see Stockey and Lucas, 1989, p. 54), it has a unique solution $V^*(.,.)$.

In cases in which the discrete-state space is small, it is not difficult to solve the Bellman equation applying an iterative algorithm. Define $\mathbf{v}$ to be a vector in $\mathbb{R}^m$ and $T[.]$ to be an operator that maps vector $\mathbf{v}$ into a new vector $T(\mathbf{v}) = (tv_1, tv_2, \dots, tv_m)'$ in which each element tv_i is given by

$$tv_i = l(\pi_i, y_i) + \min \left(\sum_{j=1}^m p_{ij}^1 v_j, \sum_{j=1}^m p_{ij}^2 v_j, \dots, \sum_{j=1}^m p_{ij}^n v_j \right). \quad (7)$$

Thus the Bellman equation can be represented by

$$\mathbf{v} = T(\mathbf{v}),$$

which can be solved by iterating until convergence the following recursion:

$$(\mathbf{v})_{s+1} = T[(\mathbf{v})_s].$$

If $\mathbf{v}^*$ is the value function of the problem, then the optimal policy function h satisfies

$$r' = h(\pi, y) \in \arg \min_{r_k \in \Psi} \left(\sum_{j=1}^m p_{ij}^k v_j^* \right).$$

That is, for each pair (π_t, y_t) , the function h yields the optimal interest rate r_t such that the central bank's discounted intertemporal loss function is minimized.

2. COMPARISON OF ALTERNATIVE LOSS FUNCTIONS

This section calculates and compares optimal monetary policy rules for different loss functions using the methodology described above. In order to provide realistic results, it uses an estimation of the economy described by equations (1) and (2) using Chilean data. We then use the model presented above to calculate policy functions for alternative objective functions and compare them against the standard quadratic loss function.

2.1 Estimation and Calibration

We estimate equations (1) and (2) using Chilean quarterly and semiannual data on core inflation and the output gap (calculated with a Hodrick-Prescott filter) from 1986 to 1998. Table 2 presents the basic results.¹⁰ It also presents the values of the parameters that we finally use in the simulations. The interest rate is the short-term indexed rate that the Central Bank of Chile used for monetary policy during the period (the rate on its own ninety-day indexed securities in 1986-95 and the overnight interbank interest rate thereafter).

Although we broadly use the ordinary least-squares estimates for elasticities, we consider a lower innovation volatility in our simulations. In the case of inflation, the main reason for this assumption is that this variable displays significant ARCH (autoregressive conditional heteroskedasticity) effects. In fact, a standard ARCH-LM test on the equations in table 2 yields a p value of 0.06. Furthermore, as Magendzo (1998) has documented, this volatility has a positive and stable relationship with the inflation level. To verify this effect, we estimate the same equation (1) but use the ratio of actual to trend inflation instead of the value of actual inflation. The estimate still shows a significant effect of the output gap on changes in (relative)

10. We also considered in the estimation a one-period-lagged direct effect of interest rates on inflation. This was meant to capture the standard open-economy transmission mechanism from monetary policy to inflation through the exchange rate. The results, however, cannot be considered different from zero.

Table 2. Estimates of Parameters in Inflation and Output Gap Equations for Chile, 1986-98, and Values Chosen for Model Calibration^a

Parameter	Parameter estimates		Calibration
	Using quarterly data	Using semiannual data	
Inflation (Phillips curve)			
α_y	0.49 (0.20)	0.54 (0.16)	0.50
$\sigma(\varepsilon_t^{\pi})$	0.030	0.011	0.008
$\overline{R}^2$	0.08	0.43	
Output gap			
β_y	0.61 (0.07)	0.32 (0.11)	0.60
β_r	-0.43 (0.16)	-0.55 (0.32)	-0.50
$\sigma(\varepsilon_t^g)$	0.015	0.015	0.010
$\overline{R}^2$	0.46	0.23	
Correlation ($\varepsilon_t^g, \varepsilon_t^y$)	-0.05	0.21	0.00

Source: Authors' calculations.
a. Estimation method is ordinary least-squares. Newey-West-consistent standard errors in parentheses.

inflation. More important, the standard error of the innovations in this estimation is approximately 0.25. Considering this standard deviation and an annual trend inflation of around 3 percent, we calibrate the model using a quarterly standard deviation of 0.8 percent (for annualized inflation). For output we consider a standard deviation of 1.0 percent, to broadly take into account the effect of other known output determinants in Chile, such as conditions in the mining sector and fiscal policy.

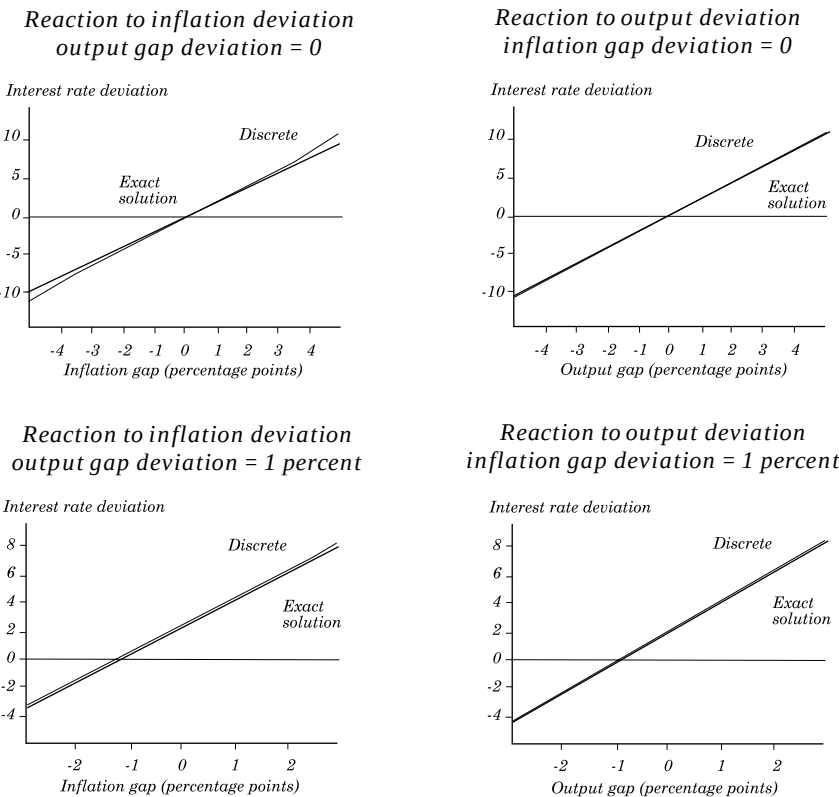
2.2 Quadratic Preferences

To evaluate the accuracy of our discretization of the economy, we compare the optimal policy rules for a quadratic loss function that results from using the algorithm presented in the previous section with the results from a standard dynamic programming procedure using the continuous-state space economy. For the latter we use the standard linear regulator problem solution (see, for example, Sargent and Ljungqvist, 1999).

Notice that because output is not that persistent, monetary policy has to be quite active in order to affect inflation. We construct grids for inflation and output in the $[-5, +5]$ range with increments of 0.25 and 0.5, respectively. We search for optimal interest rates in the $[-17, +17]$ range with increments of 33 basis points at each point of the grid.¹¹

Figure 3 presents the results of this exercise. The top left and top right panels show the optimal interest rate deviation for given deviations of inflation and the output gap, respectively. Each panel assumes

Figure 3. Optimal Policy Functions with a Quadratic Loss Function



Source: Authors' calculations.

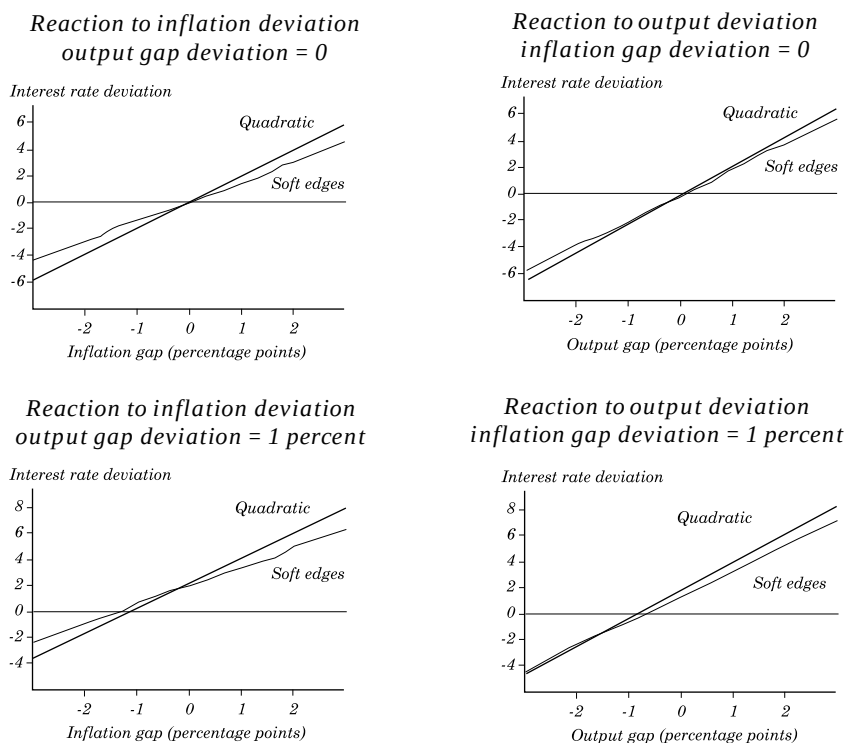
11. These grids imply that there are more than 58 million p_{ij}^k 's.

that the other variable has a deviation equal to zero. The bottom panels show the same functions but assume a positive (1 percent) deviation of the other variable. As mentioned above, the accuracy of the results is limited at the borders of the grid we consider. However, they are surprisingly accurate once we move away from these borders. Indeed, only in the policy response to extreme inflation deviations do the two reaction functions diverge. In what follows we present results using deviations for the $[-3, +3]$ range.

2.3 Range Targeting

Is monetary policy more or less aggressive with point or range targets? The answer obviously depends on how hard are the edges of the range under consideration. Figure 4 shows optimal policy reaction

Figure 4. Optimal Policy Functions under Soft-Edged Range Targeting



Source: Authors' calculations.

functions for a soft-edged target range with a 2-percentage-point width. To facilitate comparisons, it also presents the optimal reaction functions for a quadratic loss function. The soft-edged range is represented by a loss function with quadratic losses in the edges with the same parameters as in the quadratic case (see table 1 and figures 1 and 2 for details). It can be thought of as a “thick” point target.

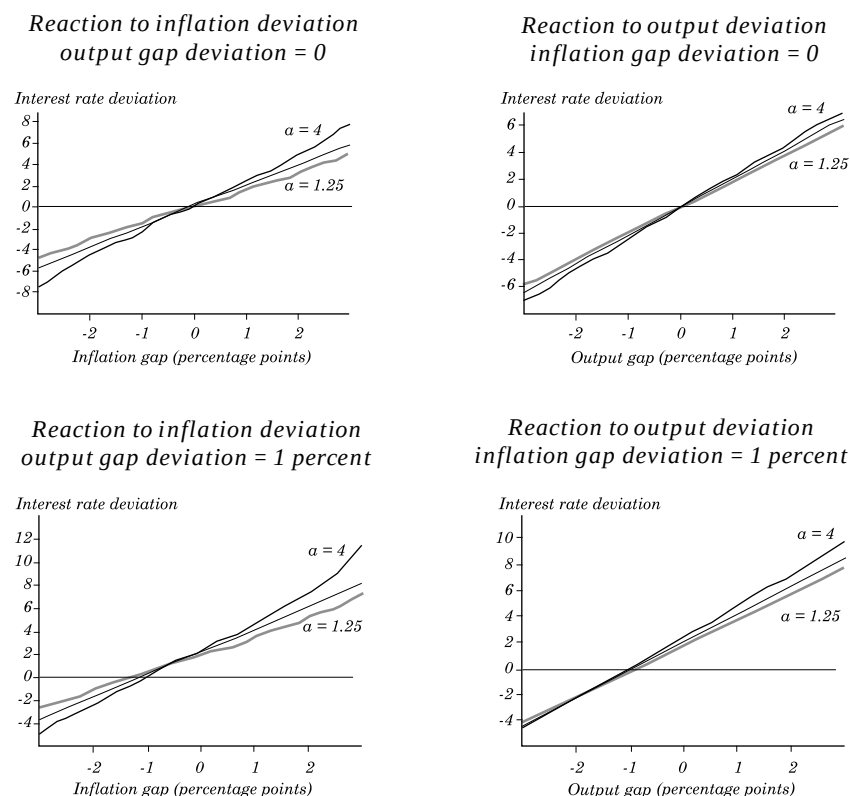
The results show that, indeed, monetary policy is less aggressive with a range target with soft edges. For all practical purposes, the reaction functions are piecewise linear: when the inflation gap lies in the $[-1.5, +1.5]$ range, the policy rule is a line with a slope 30 percent less steep than in the quadratic case. This means that monetary policy is one-third less aggressive when there is a target range. Outside the $[-1.5, +1.5]$ range the monetary policy reaction function is still linear, with a similar slope, but it starts at a higher level (in absolute value). The reaction function against output shocks is also piecewise linear. It is almost equal to the policy function in the quadratic case for gaps in the $[-1.5, +1.5]$ range and less aggressive outside that range (by approximately 80 basis points). The magnitude of these differences is not large, but it is economically meaningful.

The results also show that monetary policy is always active. Even when an inflation shock leaves the economy well inside the target range, if it is not right at the middle of that range, interest rates should not be equal to their neutral level. The intuition behind this result is that monetary policy has to move in a preemptive way: because new shocks are coming in the future, being close to the borders of the range is risky. Thus the central bank has to adjust interest rates in such a way that the economy moves closer to the middle of the target range.

Figure 5 shows the results for two alternative cases in which the range edges are harder ($a = 1.25$ and $a = 4$). In these cases the optimal policy functions have some nonlinearities, although these are not substantial. When $a = 1.25$, that is, when a range deviation is considered 25 percent worse than a point deviation, optimal policy is still less aggressive with a target range than with a point target. When range deviations are considered four times as bad as point deviations, policy is more aggressive. Numerically, following a 2-percentage-point inflation shock, interest rates respond by approximately 10 percent more than in the quadratic case. When shocks are in the neighborhood of the target, differences are less important, and alternative loss functions using the relatively harder edges yield similar outcomes.

Figure 6 presents the case of a range with discontinuous edges, in which the loss function is the standard quadratic function that collapses (discontinuously) to zero inside the range $(-1, +1)$. This could be thought of as a range that permits some limited flexibility, although outside the range, losses are the same as in the point target case. In other words, small deviations are not considered undesirable, whereas larger deviations are as costly as in the case of a quadratic loss function. The result shows that from an economic point of view this range

Figure 5. Optimal Policy Functions under Harder-Edged Range Targeting

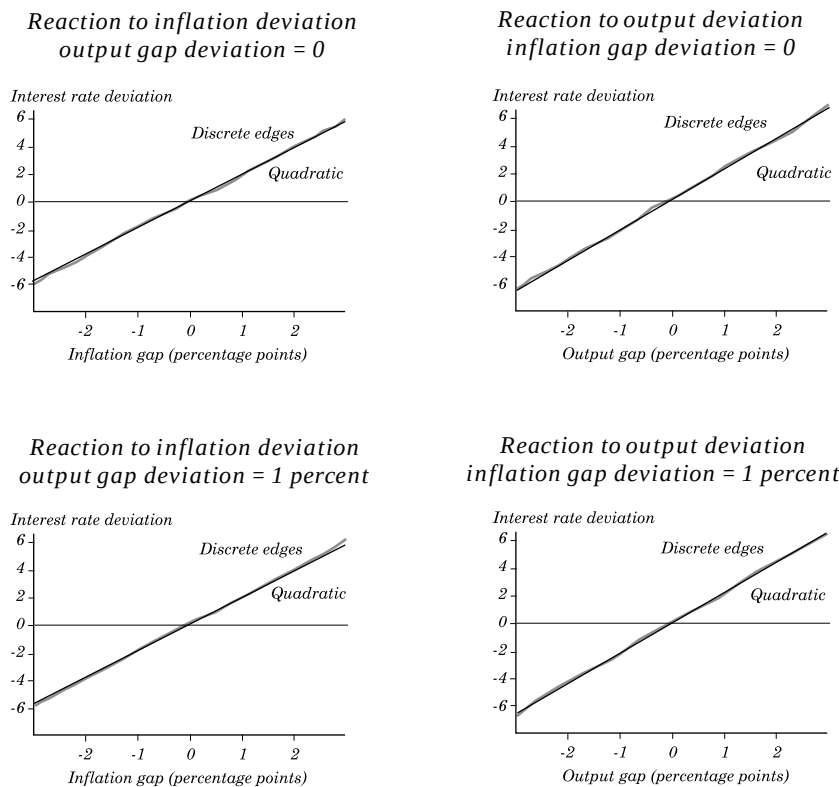


Source: Authors' calculations.

does not yield any room for a less aggressive monetary policy. Indeed, the reaction functions in both cases are practically equal.

The intuition behind this result is simple. Because the economy is subject to continuous shocks, it is very unlikely that the economy will be very close to the middle of the range on a period-by-period basis. Therefore it is immaterial whether inflation deviations are considered neutral inside the target range. As a way to prevent movements out of this range, monetary policy has to be equally active.

Figure 6. Optimal Policy Functions with a Discrete Loss Function

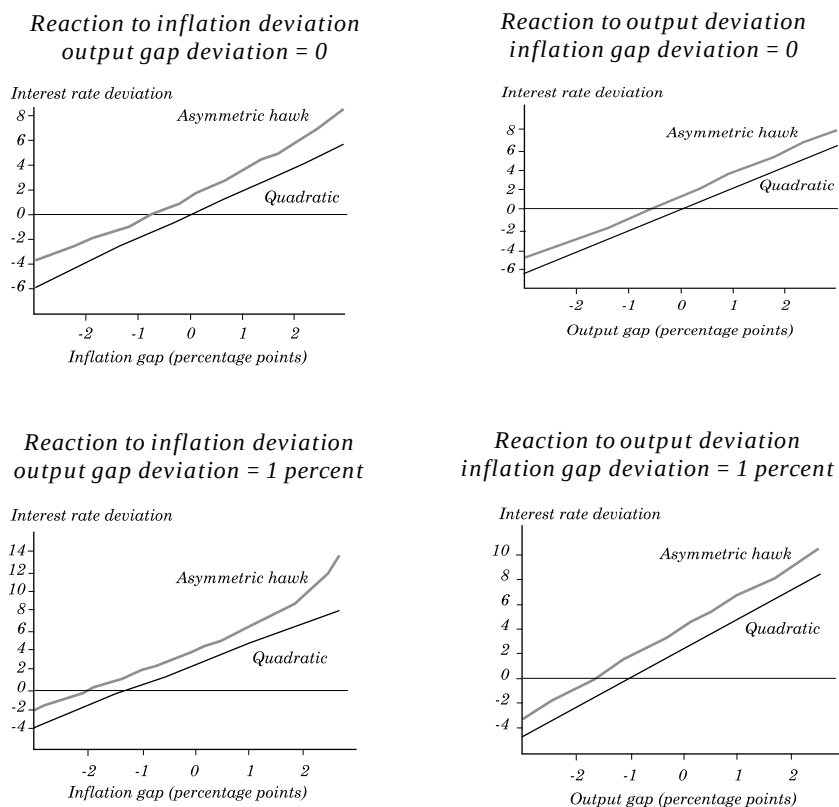


Source: Authors' calculations.

2.4 Asymmetric Losses

If positive inflation deviations are considered more costly than negative ones (for example, because of credibility problems or because the authorities are following a disinflation strategy), the loss function will be asymmetric, penalizing positive deviations more than negative ones. Figure 7 plots the policy functions for the case in which there is a point target but positive deviations are considered twice as costly as negative deviations (that is, $a_L = 1$, $a_H = 2$).

Figure 7. Optimal Policy Functions with an Asymmetric Loss Function



Source: Authors' calculations.

The result, as expected, is that monetary policy is, on average, tighter than in the quadratic (symmetric) case. Even when inflation is on target and the output gap is zero, interest rates have a positive bias. In general, reaction functions are still linear with respect to output deviations (although at a higher level), whereas they are clearly nonlinear with respect to inflation, especially for large positive inflation deviations. When inflation is very low, the reaction function is parallel to that in the quadratic case (in this case, because $a_L = 1$, they are practically equal). But when inflation is positive, interest rates are increasingly higher in the former case.

Because interest rates are on average higher in the economy with asymmetric preferences, it is also the case that the output gap is, on average, smaller. That is, there is a bias against output.

3. CONCLUDING REMARKS

This paper has investigated how optimal monetary policy rules change when the central bank considers alternative loss functions. In particular, it has evaluated the implications of considering a range target for inflation in a simple model calibrated to the Chilean economy.

The answers that this paper provides to the four questions posed in the introduction are the following. First, inflation range targeting indeed produces a less aggressive monetary policy response only when the range edges are not hard. If these edges are sufficiently hard, a range target involves more aggressive optimal monetary policy reactions. Specifically, a soft-edged range implies that interest rates move a third less than in the case of a point target. If the loss function is the same as in the case of a point target, but with losses equaling zero when inflation lies inside the target range, then optimal monetary policy does not change.

Second, there are some nonlinearities, but their economic relevance is not great. Interestingly, there are no inaction zones for monetary policy when there is range targeting. That is, monetary policy should always react to shocks, even if inflation is well inside the target range.

Third, if inflation deviations from the target range are considered highly undesirable events—that is, if the target range has hard edges—optimal monetary policy will be more aggressive than in the

case of a point target, in which deviations are always undesirable, but to a lesser extent. Therefore range targeting does not imply a less active monetary policy. The optimal policy will be more or less aggressive, depending on how hard the range edges are.

Finally, if positive inflation deviations are considered relatively more undesirable than negative ones, optimal monetary policy will be tighter than when the objective is symmetric. This means that in this environment the average output gap will be negative.

REFERENCES

- Ball, L. 1999. "Policy Rules for Open Economies." In *Monetary Policy Rules*, edited by J. Taylor. Chicago: University of Chicago Press.
- Bernanke, B., T. Laubach, F. Mishkin, and A. Posen. 1999. *Inflation Targeting: Lessons from the International Experience*. Princeton, N.J.: Princeton University Press.
- Judd, K. 1998. *Numerical Methods in Economics*. Cambridge, Mass.: MIT Press.
- Magendzo, I. 1998. "Inflación e Incertidumbre Inflacionaria en Chile." *Economía Chilena* 1(1): 29-42.
- Medina, J.P. and R. Valdés. 2002. "Optimal Monetary Policy Rules when the Current Account Matters". In this volume.
- McCallum, B. T. 1998. "Robustness Properties of a Rule for Monetary Policy." *Carnegie-Rochester Conference Series on Public Policy* 29: 173-204.
- Nessén, M. 1999. "Targeting Inflation over the Short, Medium, and Long Term." Unpublished paper. Stockholm: Sveriges Riksbank (August).
- Orphanides, A., and V. Wieland. 1999. "Inflation Zone Targeting." Unpublished paper. Washington: Board of Governors of the Federal Reserve System (June).
- Sargent, T. J., and L. Ljungqvist. 1999. "Recursive Macroeconomic Theory." Unpublished paper. Stanford, Calif.: Stanford University.
- Stokey, N., and R. Lucas. 1989. *Recursive Methods in Economic Dynamics*. Cambridge, Mass.: Harvard University Press.
- Svensson, L. E. O. 1997. "Inflation Forecast Targeting: Implementing and Monitoring Inflation Targets." *European Economic Review* 41: 1111-46.
- . 2000. "Open-Economy Inflation Targeting." *Journal of International Economics* 50: 155-83.
- Woodford, M. 1999. "Optimal Monetary Policy Inertia." Working Paper 7261. Cambridge, Mass.: National Bureau of Economic Research.

MONETARY POLICY IN LATIN AMERICA IN THE 1990s

Vittorio Corbo

Pontificia Universidad Católica de Chile

For decades until the early 1990s, Latin America was the region of the world with the highest average level of inflation. High inflation was the cumulative result of a long history of activist economic policies based on a disregard for macroeconomic stability. These policies culminated in large government deficits that ended up being monetized by the central bank, or in balance of payments crises that resulted in sharp adjustments in exchange rates. The period was one of fiscal dominance, in the sense that monetary policy was primarily dictated by fiscal considerations. Then, in a substantial departure from previous policies, the quest for greater stability that had begun in the industrial countries in the early 1980s reached Latin America by the end of that decade. As a result, in the 1990s country after country put in place mechanisms aimed at reducing inflation toward single-digit annual levels.

The results have been dramatic. In the 1980s four Latin American countries experienced average rates of inflation over 200 percent per year, and the average for the region had reached 145 percent. But by the end of the 1990s the average inflation rate for the region was below 10 percent. Among the larger countries, only two, Mexico and Venezuela, had inflation rates above 15 percent per year. And of these two, Mexico is well on the way toward achieving single-digit annual inflation.

This paper was prepared in collaboration with Andrés Elberg and José A. Tessada. This revised version was completed while Corbo was a Visiting Scholar in the Research Department of the IMF. A preliminary version was presented at the Third Annual Conference of the Central Bank of Chile, "Monetary Policy: Rules and Transmission Mechanisms", Santiago, Chile, September 20-21, 1999. We are grateful to the Central Bank of Chile and the Faculty of Economics and Administration of the Pontificia Universidad Católica de Chile for financial support; to the authorities of the Central Banks of Chile, Colombia, Costa Rica, El Salvador and Peru for facilitating information, and to Francisco Gallego, Alvaro Rojas, Patricio Rojas, Rodrigo Valdés and Rodrigo Vergara for their comments.

Monetary Policy: Rules and Transmission Mechanisms, edited by Norman Loayza and Klaus Schmidt-Hebbel, Santiago, Chile. ©2002 Central Bank of Chile.

Many factors lay behind the decision to make a frontal attack on inflation. First, the poor inflation record of the 1980s entailed high political and economic costs. Second, an overwhelming amount of analytical and empirical evidence had shown that trying to achieve a permanent reduction of unemployment through loose monetary policy results, eventually, in an acceleration of inflation with little permanent effect on the unemployment rate.¹ That is, the short-term Phillips curve trade-off between inflation and unemployment, so popular in the 1960s and early 1970s, tends to vanish in the long run. Third, there was an increasing awareness that, with forward-looking expectations and credible policies, the cost of reducing inflation is much lower than previously thought (Sargent, 1982). Fourth, the consensus became widespread among economists that sensible macroeconomic policy contributes to sustainable growth, although it does not ensure it. As a corollary, there is today widespread agreement that the best contribution that monetary policy can make to long-term growth is to make inflation low and predictable.² Fifth, it became increasingly clear that inflation gives rise to a form of regressive taxation and results in nonnegligible welfare effects. These mainly affect the poorest groups in the population, who are less able to deal with inflation and tend to hold an unusually high ratio of non-interest-earning monetary assets to income (Bulir and Gulde, 1995). Sixth, it was realized that the costs of inflation are highly nonlinear with respect to the level of inflation, making the reduction of high inflation a worthwhile undertaking (Bruno, 1991). Finally, a seventh factor was the emergence of a large group of well-trained Latin American economists and their success in reaching high-level positions in the governments of their countries.

Once the decision to reduce inflation to single-digit annual levels has been made, the issue is how to go about getting the job done. This question of anti-inflation strategy is directly related to the question of the most appropriate monetary policy regime or framework. Here there are three options to be considered: an exchange rate anchor, a money anchor, and an inflation target anchor. Section 1 of this paper studies the elements to be considered in the choice of

1. For recent discussions of these developments, see Goodhart (1994) and Fischer (1995, 1996).

2. Some of the same factors have also been behind policy changes in developed countries geared to achieving price stability. See Fischer (1996) and Bernanke and others (1999).

a monetary framework. Once a framework has been chosen, it has to be decided how to conduct monetary policy within the chosen framework. This is the subject of section 2. The section begins by analyzing the institutional underpinnings of monetary policy in five countries: Chile, Colombia, Costa Rica, El Salvador, and Peru, and then turns to the practice of monetary policy in a wider group of nine countries: the five just named plus Argentina, Bolivia, Brazil, and Mexico. Section 3 then investigates empirically how the central banks of Chile, Colombia, Costa Rica, El Salvador, and Peru have conducted monetary policy in recent years, and in particular whether the central bank's behavior changed after it became independent. For this purpose monetary policy reaction functions are estimated for the five countries. Finally, section 4 presents the main conclusions.

1. THE CHOICE OF A MONETARY POLICY REGIME

Three basic strategies can be envisaged for the choice of a monetary policy regime to anchor inflation.³ The first is fully orthodox: monetary targeting relies on a precommitted path for the money supply to anchor inflation. The second, exchange rate targeting, uses the exchange rate as the nominal anchor. The third, increasingly popular strategy is inflation targeting, where the anchor for inflation is the publicly announced inflation target and the commitment of the central bank to gear monetary policy toward achieving this target.

In all three cases, but especially the first and the third, the attempt at stabilization probably induces slower economic growth at first. The exchange rate anchor, in contrast, is usually first accompanied by an expansion, followed by a recession (Calvo and Végh, 1999). In choosing among these three approaches, it is important to take into account the degree of openness of the economy and the stability of the relationship between monetary aggregates and inflation.

1.1 The Exchange Rate Anchor

Setting a value for the exchange rate in a small, open economy provides an anchor for the price level by exerting a direct effect, through

3. On monetary anchors see Calvo and Végh (1999), Bernanke and Mishkin (1997), and Bernanke and others (1999).

arbitrage forces, on the prices of tradable goods.⁴ That is, tradable goods prices become the nominal anchor for the whole economy.⁵ If the exchange rate is fixed with respect to the currency of a low-inflation country, and the peg is credible, it also serves to reduce inflation expectations toward the level of inflation in the low-inflation country. Another advantage of using an exchange rate anchor is that it is directly observable, and therefore the public at large can understand it much more easily than a monetary rule.

However, an exchange rate anchor also has some disadvantages. The first is that, if it has an open capital account, the pegging country cannot run an independent monetary policy. It loses the ability to use monetary policy to respond to domestic and external shocks, especially those that affect aggregate demand. This is not an insignificant cost for large and medium-size countries that are exposed to frequent aggregate demand shocks (mostly to the terms of trade) and that have the technical and institutional capacity to carry out an independent monetary policy. But the cost may be less important for countries that cannot practically carry out an independent monetary policy in any case. This would include countries with extensive currency substitution, and countries where a large proportion of the liabilities of the financial system is denominated in foreign currency.⁶ Second, domestic interest rates (adjusted for country risk) become determined by the interest rate of the anchor country, and therefore interest rate shocks in the anchor country are transmitted directly to the pegging country. In cases where the economic cycles in the two countries are far out of phase, such a monetary shock would have real costs in the pegging country. Third, with perfect capital mobility the use of an exchange rate anchor exposes the country to speculative attacks. This has become increasingly clear in the recent crises in emerging markets. The defense against these attacks involves the

4. Following the Mexican crisis of 1994-95 and the Asian crises of 1997-98, the debate on the most appropriate exchange rate system has taken a new twist, with the discussion today framed more in terms of feasibility than of optimality (see, in particular, Obstfeld and Rogoff, 1995, and Eichengreen, 1999).

5. In this system, given a trajectory for the price of tradable goods (and assuming that they obey the law of one price), the trajectory of domestic inflation is obtained by dividing the nominal price of tradable goods (expressed in local currency) by the real exchange rate (a real variable).

6. In some countries the central bank may lack the technical capacity to carry out an independent monetary policy *other* than one based on an exchange rate anchor. This could be the result of a deliberate decision based on the advantages expected from operating within an optimal currency area as described by Mundell (1961).

use of high interest rates for a protracted period, and this is costly in terms of the resulting high unemployment and the deterioration of bank portfolios. High interest rates also set the stage for the abandonment of the peg, as economic agents come to believe that the high cost of defending the peg will eventually lead the pegging country to abandon it. There are also, in most cases, high and highly nonlinear costs when a peg is abandoned in favor of a large devaluation (Obstfeld and Rogoff, 1995; Eichengreen, 1999).

But this is not all. The fixing of the exchange rate also requires that other indexation mechanisms in the economy be discarded and that an appropriate institutional structure be developed to prevent the financial system from becoming too vulnerable to an eventual exchange rate correction. Such a structure can be developed through appropriate financial sector regulation. Potential problems along these lines are best illustrated by the experience of Chile in the late 1970s (Corbo and Fischer, 1994), Mexico in 1994-95 (Dornbusch and Werner, 1994), the Asian countries in 1997-98 (International Monetary Fund, 1997), and Russia in 1998. Brazil in 1999 is the exception that confirms the rule. In Brazil, the early-1999 devaluation corrected an accumulated real appreciation that had built up while the exchange rate was being used as an anchor to reduce high inflation. Rather than triggering a severe crisis, it set the stage for a recovery.

Another potential side effect of fixing the exchange rate in the presence of an open capital account is undue risk taking and, as a consequence, an unsustainable expansion of credit. This can result in a financial bubble, increasing financial fragility in the process (Corbo and Fischer, 1995; Edwards and Végh, 1997; Mishkin, 1997). This problem is illustrated by the experience of Chile in the early 1980s and of Mexico in the first half of the 1990s, and by the recent experience of Asia (especially Indonesia, Korea, Malaysia, and Thailand). In all these cases, following the fixing of the exchange rate, the initial spread between the domestic and the foreign interest rate—adjusted for the expected rate of devaluation—rose sharply, providing substantial encouragement for capital inflows and credit expansion. This increase in the spread could also have been due to an inconsistent fiscal policy. But in all these countries the final result was a combination of large capital inflows, an expenditure boom, and a sharp real appreciation. A sudden reversal of capital flows was then all it took to precipitate a major crisis. Also, fixing the exchange rate in the presence of nominal rigidities can distort resource allocation if the real exchange rate then departs from its equilibrium level.

In practice, an exchange rate anchor usually takes the form of a predetermined nominal path for the rate of currency devaluation (that is, a crawl), but it could also be a fixed rate against the currency of another country.⁷ Fixed rates come in three varieties: simply fixed, without any supporting institutional changes; fixed within a stronger institutional framework; and the abandonment of the local currency in favor of a common currency or the currency of another country. Examples of the second type are the currency boards adopted in Argentina and Hong Kong. Examples of the third type are the European countries that have decided to participate in monetary union, and Panama's abandonment of its local currency in favor of the U.S. dollar. In the latter case, the probability of an adjustment in the "peg" is negligible. Preconditions for successful implementation of the last two types are order in the fiscal accounts, a robust financial system, and sufficient foreign reserves to back the monetary and financial (local currency denominated) liabilities of the central bank (International Monetary Fund, 1999). It could be argued, however, that if all these conditions are fulfilled, there is little to be gained from a currency board or full dollarization.

For medium-size and large economies that have rigid labor and commodity markets, fixed rates may make the adjustment to a demand shock unduly costly. In particular, for this type of country a real depreciation, when required by a change in the fundamentals, could become too costly, given that it depends on the downward flexibility of nontradable goods prices. In this case a more flexible exchange rate regime would be preferable. Indeed, as the adjustment to the external shocks of 1999 has illustrated, the combination of prudent monetary policy and exchange rate flexibility has facilitated adjustment in most countries in the Latin American region. But a properly functioning flexible exchange rate system also requires a well-capitalized, well-regulated, and well-supervised financial system. Otherwise, changes in the market value of the exchange rate could result in serious difficulties due to a mismatch in the currency denomination of assets and liabilities, with severe macroeconomic consequences. But this is not all. It is also necessary to have in place the institutions and procedures for the development of a market for hedging exchange rate risks.

7. Predetermined rates of devaluation were used in the 1970s in the ill-fated "tablita" experiments of the Southern Cone countries (Corbo and de Melo, 1987).

Even assuming all these actions are taken, many questions remain open with regard to the most appropriate monetary arrangement for a particular country. Following the early success of Argentina's currency board system, some countries in the region have given serious consideration to doing likewise. But before jumping into such a rigid system, it is important to understand that Argentina, a country with a long history of abusing its monetary and exchange rate policies, essentially had no alternative. Countries thinking of following Argentina's path should also remember that a currency board is not a panacea. To start with, a country has to have sufficient foreign reserves to finance the short-term monetary liabilities of the monetary system; otherwise the system will not be credible. Furthermore, the financial system must be strong enough to survive without a lender of last resort. If this is not possible, arrangements must be made for access to emergency lending from foreign commercial banks, as Argentina has done, or from an external official institution, most likely the U.S. Federal Reserve or the European Central Bank. Moreover, wage flexibility and labor mobility must be high enough to facilitate changes in relative prices between tradable and nontradable goods when called for by a change in the macroeconomic fundamentals. Otherwise price rigidities will give rise to substantial welfare losses. Ultimately, the discipline of a currency board requires that the government be ready and have the political support to live with the high interest and unemployment rates that are an integral part of adjustment when the country faces a shock that requires a real depreciation.

Countries that are not ready or willing to go the route of currency boards or full dollarization, and decide instead to use a flexible exchange rate system, need to choose an appropriate monetary framework capable of generating low and predictable inflation. Such a framework requires giving sufficient independence to the central bank to allow it to focus its monetary policy on the ultimate objective of low inflation without resorting to the exchange rate peg as an anchor. Here the options are the use of a money anchor or some other explicit nominal anchor as an inflation target.

1.2 A Money Anchor

Effective use of a monetary aggregate as a nominal anchor for inflation depends, first of all, on the authority and capacity of the central bank to carry out an independent monetary policy aimed at

achieving and maintaining low inflation. But this is not all. At a more technical level, the effectiveness of a monetary anchor depends on the stability of demand for the monetary aggregate to be used as the anchor. It is this stability that provides the link between the monetary aggregate and the rate of inflation. Instability of the demand for money presents a problem in cases where there is considerable financial innovation or a sudden change in the rate of inflation.

In particular, in an economy that has experienced a period of high and variable inflation, the demand for money becomes very unstable as economic agents develop ways to economize on the use of money balances. When inflation is finally reduced, hysteresis effects emerge, generating a breakdown in the old demand-for-money relationship. In cases like these, predicting the quantity of money demanded becomes very difficult, and the use of a monetary target may be a very ineffective way to achieve a given inflation objective. It may be more appropriate to use an exchange rate anchor in the initial stages of the stabilization program, to be followed later by a more flexible exchange rate system accompanied by a monetary or inflation target.

1.3 Inflation Targeting

Given the problems with the use of an exchange rate or a monetary anchor, in recent years some countries have moved to a third type of anchor: inflation targeting. This type of monetary framework was initially introduced in certain industrial countries with the objective of keeping inflation close to a desired low long-run level. New Zealand introduced an inflation targeting system for this purpose in March 1990. Similar systems have since been introduced in Canada (February 1991), the United Kingdom (October 1992), Sweden (January 1993), and Australia (September 1994). The European Central Bank adopted the approach in October 1998. Variants on this system, aimed at adjusting inflation first toward single-digit annual levels and eventually toward a steady-state low level, have been introduced in a series of nonindustrial economies, starting with Chile in September 1990 and Israel in March 1991.⁸

In inflation targeting, the target rate of inflation is the monetary anchor, and both monetary and fiscal policies are geared toward achieving the target. The attractiveness of this system is that

8. See Fry and others (1999).

its effectiveness does not depend on a stable relationship between a monetary aggregate and inflation, and at the same time it avoids the problems associated with the fixing of the exchange rate reviewed above. An additional advantage for emerging market countries is that the trajectory of the market exchange rate provides important information on the market evaluation of present and future monetary policy; the exchange rate thus plays the same role that nominal yields on long-term government paper play in industrial countries (Bernanke and others, 1999).

A well-defined inflation targeting framework goes well beyond just setting a target for the inflation rate; rather, it requires a series of actions (Svensson, 1999a; King, 2000). First, there should be a public announcement of a strategy of medium-term price stability and of an intermediate target for inflation for a time period over which monetary policy can realistically claim to affect the level of inflation. Second, there should be an institutional commitment to price stability in the form of rules of operation for the monetary authority. Third, a clear strategy is needed, delineating how monetary policy, through the adjustment of interest rates, is going to operate to bring inflation close to the announced target. A full inflation targeting strategy usually starts from a conditional interval forecast of inflation for the period utilized for setting the target. It also has to specify an operational procedure for the central bank to follow when the inflation forecast is above or below the target. These procedures should be transparent, and the monetary authorities should be made accountable for reaching the objective that has been set.

Given the normal lags in the operation of monetary policy, the inflation target has to be set for a period far enough into the future that monetary policy can actually have an effect. In practice, central banks in industrial countries announce a target for the next twelve or twenty-four months. They then develop a conditional forecast of inflation, based on existing monetary policy and a forecast of the relevant exogenous variables, and set a strategy and communicate to the public what they will do if the range forecast for inflation does not include the targeted value. In emerging market economies, however, where financial markets are not as well developed and liquidity constraints are widespread, there is some evidence that the lags of monetary policy are shorter (Fry and others, 1999).

In this framework, the established inflation target is the ultimate objective of policy, and an inflation forecast, sometimes not made public, is the intermediate objective. Monetary policy, with

appropriate fiscal underpinnings, is the main instrument used to pursue the target. In particular, when the conditional inflation forecast is above the inflation target, the level of the intervention interest rate is raised so as to achieve an increase in the real interest rate that will bring inflation closer to the target. One advantage of inflation targeting is that inflation itself is made the target, committing monetary policy to achieve the set target and thus helping to shape inflation expectations. Here, too, however, resides the main disadvantage of inflation targeting. Because inflation is an endogenous variable that depends also on factors that go beyond the stance of monetary policy (for example, on shocks to the terms of trade and to aggregate supply and demand), the authorities cannot control inflation directly. As a result, it becomes difficult to evaluate the stance of monetary policy on the basis of just the observed path of inflation. Furthermore, because monetary policy works with a substantial lag, if the authorities precommit to an unconditional inflation target independently of changes in external factors that also affect the inflation rate, it can be costly to change monetary policy to bring inflation back to the set target. In particular, to persist in aiming for the inflation target when a shock has resulted in a (temporary) rise in the inflation rate can produce a severe slowdown or increased output volatility (Cecchetti, 1998). On the other hand, accommodating the external shock could result in a loss of credibility for the inflation targeting regime.

To address some of these problems, several options have been proposed. The first is to set the inflation target in terms of a range rather than a point estimate. A second is to set a target for core inflation rather than for some broader measure of inflation. A third is to exclude from the price index the effects of changes in indirect taxes and in the terms of trade. A fourth is to set the target for a horizon long enough that short-term shocks to the inflation rate do not require a monetary response (on these point see, in particular, the discussion in Bernanke and others, 1999).

2. THE PRACTICE OF MONETARY POLICY IN LATIN AMERICA

As mentioned in the previous section, a successful exchange rate anchor system requires, first of all, a credible peg. In contrast, operating a successful monetary target or inflation targeting strategy requires a central bank with sufficient autonomy to operate monetary

policy as called for by the strategy. Given the crucial role of an independent central bank within a monetary policy framework, this section begins by reviewing the progress made by some Latin American countries in providing greater autonomy to their central banks.

Table 1 presents information obtained from the charters of five Latin American central banks (Chile, Colombia, Costa Rica, El Salvador, Perú). As the table shows, the reforms aimed at enhancing central bank independence in these countries were mostly implemented during the first half of the 1990s. Chile, where a law creating an independent central bank was enacted in October 1989, was the pioneer in introducing this type of reform, both within the region and among emerging market economies worldwide. Elsewhere in Latin America, similar steps were taken later in Colombia (1991), El Salvador (1991), Peru (1993), and Costa Rica (1995). Although in all these countries the reforms had as their common aim to provide a greater degree of central bank independence, they varied considerably in how far they pursued that objective. Following Cukierman (1992), one can identify four broad dimensions of legal central bank autonomy: the clarity of the mandate; the procedures for appointment and dismissal of members of the board of directors; the provisions for resolving conflicts between the executive branch and the central bank and the degree of the latter's influence in formulating monetary policy, exchange rate policy, and the budget; and the existence of legal restrictions on the ability of the public sector to borrow from the central bank.

A review of central bank charters with respect to these four dimensions helps to clarify how far these five Latin American countries have progressed in enhancing central bank autonomy. As table 1 shows, in all five countries price stability is today established by law as one of the key objectives of the central bank. However, in only one country (Peru) is this the central bank's sole legal objective. In the others the central bank also has other objectives, which to varying degrees could conflict with the price stability objective. At one extreme is the objective of promoting the stability of the financial system. This provision, found in the charters of the central banks of Colombia and El Salvador, does not represent an explicit conflict with the price stability objective, if it is interpreted as seeking an appropriate regulatory and supervisory framework. However, there could be a conflict if the provision is interpreted as requiring the central bank to avoid too high a level of the (real) interest rate or to restrict the adjustment of the nominal exchange rate in order to preserve financial system

Table 1. Features of Central Bank Charters in Selected Latin American Countries

	<i>Chile</i>	<i>Colombia</i>	<i>Costa Rica</i>	<i>El Salvador</i>	<i>Peru</i>
Year of central bank reform	1989	1991	1995	1991	1993
Legal objectives of the central bank	Price stability Normal functioning of the internal and external payments systems	Price stability Strength of the financial system	Price stability Multiple other objectives, including full employment	Price stability Stability and competitiveness of the financial system	Price stability
Is the finance minister a member of the board?	No	Yes	Yes	No	No
Does the central bank have final authority to formulate monetary policy?	Yes	Yes	Yes	Yes	Yes
Does the central bank have final authority to formulate exchange rate policy?	Yes	In part; the exchange rate regime is defined by the legislature	Yes	Yes	Yes
Is the central bank authorized to finance the government?	No	No	No	No	No

Source: Corbo et al., 1999

stability. At the other extreme, the objective of full employment, which appears only in the charter of the Costa Rican central bank, could conflict with the price stability objective if full employment is defined as a short-term objective.

The five countries also vary significantly in terms of the second dimension of central bank independence: the appointment and dismissal procedures for the board of directors. In all of the countries except Chile, the president of the board is named directly by the president of the republic for a term of office that coincides with the latter's term of office. Furthermore, in Colombia the president of the central bank board is also the finance minister.⁹ Only in Chile and Peru must the president of the board be approved by the legislature; in the other countries the decision is left entirely to the chief executive. How the president of the central bank's board is chosen becomes particularly important when one considers that, in all five countries, the law establishes that in case of conflict within the board, it is the president's vote that resolves the dispute. Thus the president of the board has considerable influence over the monetary policy resolutions made by the board.

All of the five central bank charters provide for the removal of directors. These provisions differ across countries, however, both in terms of the causes that may be invoked for removal and in terms of the institution legally empowered to do so. Of the five countries, only in Costa Rica does the law prohibit removing a director for reasons of policy. In Chile, Colombia, and Peru, although a board member may be removed because of his or her vote on a policy resolution, this can only be done under severely restrictive conditions. For example, in the case of Peru, the legislature may only proceed to dismiss a director when a serious fault has been committed and duly proved, and even then a two-thirds majority is required. El Salvador has probably the least restrictive conditions for removal: the central bank charter establishes that the council of ministers has the authority to dismiss a director who has voted favorably on a resolution that implies a flagrant deviation from the central bank's objectives or from any other responsibility that the law imposes.

Another important dimension of autonomy has to do with the authority given to the central bank to formulate monetary and exchange rate policy. All of the five countries have final authority to

9. In Costa Rica the finance minister is a member of the board but not the president.

decide the course of monetary policy, and only in Colombia are monetary policymakers constrained by the legislature in the choice of exchange rate regime. In all the other countries the decision about the exchange rate system is left entirely to the central bank.

Finally, none of the five countries allows its central bank to finance the government's budget. This represents an important step toward establishing the central bank's independence from fiscal authority.

This examination of the central bank charters of these five Latin American central banks shows that they have gained increasing independence in running monetary policy. The next step is to examine how they have carried out that policy in practice. As discussed in the previous section, three choices of anchor for a monetary policy regime can be distinguished: an exchange rate anchor, a money anchor, or an inflation target. Table 2 provides a broad overview of the monetary policy regimes used by nine Latin American countries. As can be seen, the monetary mechanisms utilized vary a great deal from country to country, but inflation targeting is the predominant framework used in these countries today. Four of the nine countries (Brazil, Chile, Colombia and Mexico) adopted this framework during the 1990s. All four countries went through a transition period, during which credibility was built and inflation was gradually reduced. During this period the inflation target was not explicit, but rather was usually stated in terms of achieving a gradual reduction of inflation toward levels in industrial countries. Neither any interim target nor the duration of the transition was spelled out. Once they had made sufficient progress in reducing inflation, most countries then started to use explicit targets, in the form of annual targets (a point or a range) publicly announced at the end of the previous year.

However, only Brazil and Chile have revealed a well-articulated inflation targeting procedure. That is, they publish information on their conditional inflation forecasts and on the procedures to be followed when the inflation forecast lies outside the announced target range. These are similar to the inflation reports published by industrial countries' central banks (and now by Israel's central bank as well).

Three countries (Bolivia, Costa Rica, and Peru) use some sort of monetary target to conduct monetary policy. What is somewhat striking is the fact that two of these countries (Bolivia and Peru) have experienced hyperinflationary episodes in the past, which might have introduced considerable instability in the demand for money through hysteresis and currency substitution effects. Also, in all three cases the development of financial markets—with the associated innovations

Table 2. Features of Monetary Policy Targeting in Selected Latin American Countries

<i>Country</i>	<i>Type of target</i>	<i>Is the target implicit or explicit?</i>	<i>Who sets the target?</i>	<i>Is the target single or multiple?</i>
Argentina	Exchange rate	Explicit	Congress	Single
Bolivia	Monetary	Implicit	Central bank alone	Single
Brazil	Inflation	Explicit	Central bank and finance ministry	Single
Chile	Inflation	Explicit	Central bank and finance ministry	Single
Colombia	Inflation	Explicit	Central bank alone	Single
Costa Rica	Monetary	Implicit	Central bank alone	Single
El Salvador	Exchange rate	Implicit	Central bank alone	Single
Mexico	Inflation	In transition from implicit to explicit	Central bank alone	Single
Peru	Monetary	Implicit	Central bank alone	Single

Source: Author's elaboration in base of information provided by central banks.

in financial instruments and intermediaries— followed the introduction of broadly based reforms, and this might have contributed to weakening the link between monetary aggregates and inflation. Another interesting point is that all of the countries that rely on a monetary target do not announce publicly what that target will be for the next period. As Mishkin (1999) has pointed out, this lack of transparency leads to “confusion in the market place, a lack of accountability of the central bank, and a missed opportunity to focus the public and politicians on the need for a long-run orientation of monetary policy.” Several authors have emphasized the importance of transparency of the monetary framework as a way to control discretionary behavior by authorities that could lead to poor long-run outcomes. As King (2000) recently put it, “The communication of policy makers’ intentions with a view to enhancing their credibility has come to play a central role in monetary policy.”

Two countries (Argentina and El Salvador) have adopted an exchange rate target, although under radically different institutional frameworks. The Argentinean authorities are committed by law to maintain one-to-one parity between the peso and the U.S. dollar and have established a currency board to comply with that legal mandate. In contrast, policymakers in El Salvador have adopted a *de facto* fixed exchange rate with no clear commitment to maintain the parity.¹⁰ The circumstances that led these two countries to adopt their monetary policy regimes also differ. In Argentina the currency board system was adopted in 1991 as a way to deal with the monetary authority’s lack of credibility in the context of a long history of high and variable inflation. In contrast, El Salvador adopted its fixed exchange rate system in 1993, when inflation was moderate (the annual inflation rate was near 20 percent).

3. MONETARY POLICY RULES: THE CASES OF CHILE, COLOMBIA, COSTA RICA, EL SALVADOR, AND PERU

This section investigates empirically how monetary policy has been conducted in these five countries in recent years. For this purpose we follow closely the reaction function methodology developed by Taylor (1993) and extended by Clarida, Galí, and Gertler (1998a).

10. However, recently (early 2001) El Salvador has been making preparations towards the introduction of a currency board.

In general, the monetary authority's reaction function results from an optimization problem, where it is assumed that the authority minimizes a loss function on the squared differences of inflation and its target, and of observed and potential output. The basic specification used here has the central bank adjusting the interest rate (the real rate in Chile, and the nominal rate in the other countries) in response to the gap between expected inflation and its target value. We then add as additional regressors other variables that are spelled out as additional objectives in the central bank's charter (as reviewed in the previous section). Then we investigate empirically whether, in setting monetary policy, the authorities have also considered other variables. Given that the effects of monetary policy appear with a lag, monetary policy responds to lead values of the inflation gap. When choosing additional variables that could have played a role when setting monetary policy, we draw on others' work on the transmission mechanism for an open economy (Ball, 1999 and Svensson, 1999b).

Following Clarida, Galí, and Gertler (1998b), the interest rate is set in accordance with the following reaction function:

$$U_t = U + \beta \left[(\pi_{t+n} | \Omega_t) - \pi_t^* \right] + \gamma_1 \left[(y_{t+k} | \Omega_t) - y_{t+k}^* \right] + \gamma_2 \left[(z_{t+j} | \Omega_t) - z_{t+j}^* \right], \quad (1)$$

where the bar over r denotes the long-run equilibrium interest rate, π_{t+n} is the expected rate of inflation between periods t and $t + n$, y_t is (the logarithm of) output, and z_t is a generic variable that we measured in different ways. This variable may be measured as the gap between expenditure and GDP as a share of the latter; as the gap between the rate of growth of expenditure and the rate of growth of GDP; as the current account deficit as a share of nominal GDP; as the foreign interest rate; or as the deviation of the real exchange rate from its trend. The variable r_t^* is the target interest rate set by the central bank, π_t^* is the target rate of inflation (which may be time-variant for a country whose objective is to reduce inflation gradually toward industrial-country levels), and y_t^* is the logarithm of potential output, measured as the trend of GDP.

In this framework the presence of the output gap in the reaction function could arise directly from a concern of the authorities with output volatility, so that monetary policy is adjusted in order to reduce deviations of output from its trend; in this case the output gap is a separate final objective in the policymakers' loss function.

Alternatively, it may arise because the monetary authorities use the information provided by the output gap in their forecast of future inflation; in this case the output gap enters the reaction function as an intermediate objective. To distinguish between these two motives, we used lagged values of the output gap as an instrument for the inflation gap, using the generalized method of moments (GMM) estimation procedure.

When the main objective of monetary policy is to keep inflation close to its target level, the real interest rate should be raised when the inflation gap becomes positive. In a standard transmission mechanism from aggregate demand to price dynamics, it is through an increase in the real interest rate that observed inflation is brought back to its target level when the former exceeds the latter. Thus, in the above model, when monetary policy is carried out using the real interest rate, as in Chile, the value of β should be positive. When monetary policy is carried out using the nominal interest rate, as in the other four countries studied, its value should be also greater than one.¹¹ Thus the value of β turns out to be a key parameter in assessing the central bank's response.

To complete the model, a partial adjustment equation is added to accommodate the observed propensity of central banks to make smooth and slow, rather than sudden, adjustments of interest rates toward the desired level:

$$U_t = \rho U_t^* + (1 - \rho) U_{t-1} + v_t, \quad (2)$$

where it is assumed that v_t is i.i.d. $(0, \sigma^2)$.

From equations (1) and (2) one obtains the following relation:

$$r_t = \rho \left\{ \bar{r} + \beta [E(\pi_{t+n} | \Omega_t) - \pi_{t+n}^*] + \gamma_1 [E(y_{t+k} | \Omega_t) - y_{t+k}^*] \right\} + \gamma_2 [E(z_{t+j} | \Omega_t) - z_{t+j}^*] + (1 - \rho) r_{t-1} + v_t. \quad (3)$$

Finally, assuming that expectations are rational, we replace expected values with realized values, obtaining the following equation:

11. The key assumption here is that the real interest rate is an argument in the real expenditure equation.

$$r_t = \rho [\bar{r} + \beta(\pi_{t+n} - \pi_{t+n}^*) + \gamma_1(y_{t+k} - y_{t+k}^*) + \gamma_2(z_{t+j} - z_{t+j}^*)] + (1 - \rho)r_{t-1} + \varepsilon_t, \quad (4)$$

where the error term, ε_t , is a linear combination of the forecast errors of inflation, output, z_{t+j} , and the true disturbance v_t . Because some of the variables considered in the right-hand side of the equation are also endogenous, the model is estimated using a method—the GMM method—that yields consistent estimates in the presence of simultaneity problems.¹²

3.1 Chile

As we saw in section 1, since the beginning of the 1990s Chile's monetary policy has had as its main objective the gradual achievement of a level of inflation similar to that in the industrial countries. That level has been defined recently as a steady-state annual inflation rate in the range of 2 to 4 percent, starting in 2001. In moving toward this steady-state level, the central bank announces, in September of each year, an annual inflation target for the following year.

To study how much of a trend change in the rate of inflation (which could also affect expectations) has been implied by the set target, we built a multivariate model to forecast inflation. The model is estimated using a rolling regression, and then a forecast is made for the following year. A comparison of the forecast of inflation with the target set by the central bank (figure 1) shows that only in 1993 was the target rate well below the value predicted by the model; however, from 1992 until the end of 1996 it was below the forecasted value. From this we conclude that through most of the 1990s the central bank pursued the objective of a gradual reduction of inflation.

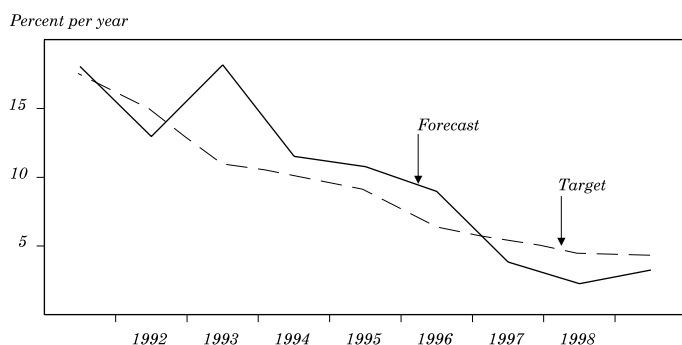
As we saw in table 1, the charter of the Central Bank of Chile assigns it the objective not only of reducing inflation but also of ensuring that the internal and external payments systems function properly. This can be interpreted as saying that, for a given gap between expected inflation and its target, the central bank should also care for other objectives.¹³

12. For descriptions of this method see Hamilton (1994), Enders (1995), Mátyás (1999), and Greene (2000).

13. Corbo (1998) and Rosende (1998) present two different explanations for the mechanism of transmission of monetary policy and for the effective role played by the central bank in the reduction of inflation.

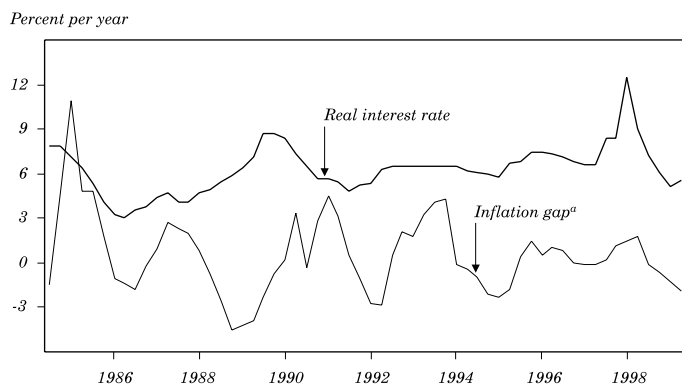
Figure 2 compares the trajectories of the inflation gap and the real interest rate in Chile. It appears that interest rates were raised in advance of increases in the inflation gap. But because monetary policy works with a lag of around three quarters, we also compare the gap between actual inflation and the inflation target with a three-quarter lag in the real rate of interest (figure 3). This figure illustrates quite clearly that monetary policy is adjusted to keep expected inflation close to its target.

Figure 1. Inflation Targets and Inflation Forecasts in Chile



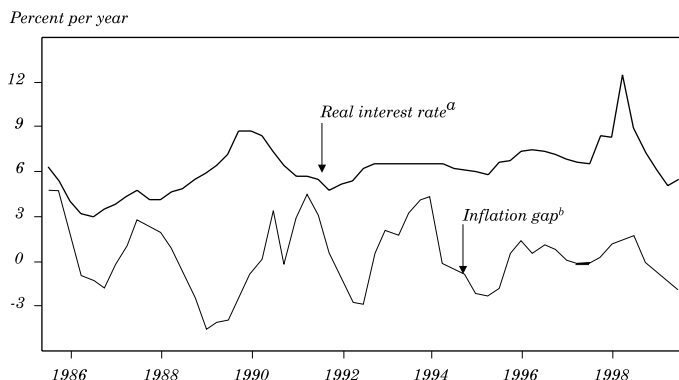
Source: Author's calculations based on Central Bank of Chile data.

Figure 2. Inflation Gap and Real Interest Rate in Chile



Source: Author's calculations based on Central Bank of Chile data.

a. Difference between inflation and its target.

Figure 3. Inflation Gap and Lagged Real Interest Rate in Chile

Source: Author's calculations.

a. The real interest rate is shown with a lag of three quarters.

b. Difference between inflation and its target.

We proceed now to investigate how monetary policy in Chile was carried out in the 1990s and to compare monetary policy during this period with that in the 1985-89 period, immediately before the central bank became independent. In the model that we estimate for Chile, the dependent variable is the real interest rate, because monetary policy is carried out using bonds issued by the central bank that are indexed to the consumer price index (CPI). We used as a baseline an equation in which the only explanatory variable is the expected inflation gap. To accommodate lags in the operation of monetary policy, we explored different leads for the inflation gap and found that monetary policy responds to a three-quarter lead of the expected inflation gap.

The estimations were carried out using quarterly data for the period from 1990Q1 to 1999Q4. A two-period partial adjustment model was used to accommodate the smoothing of interest rates, and a dummy variable was introduced to account for the large increase in the interest rate that took place in the third quarter of 1998, when the exchange rate band came under attack. When this mechanism is used to model the behavior of actual interest rates, the model estimated is a slight departure from the general specification outlined above. The general equation, analogous to equation (4), is given by

$$r_t = (1 - \rho_1 - \rho_2) \left[\bar{r} + \beta (\pi_{t+n} - \pi_{t+n}^*) + \gamma_1 (y_{t+k} - y_{t+k}^*) \right] + \gamma_2 (z_{t+j} - z_{t+j}^*) + \rho_1 r_{t-1} + \rho_2 r_{t-2} + \varepsilon_t \quad (4')$$

The set of instruments used in the GMM estimation includes one-period and two-period lags of the interest rate, the rate of growth of nominal money, the rate of nominal depreciation, the rate of growth of nominal wages, the output gap, and external inflation.

The results of the estimation of the baseline are presented in the bottom panel of table 3. In the baseline model, presented in the first row of this panel, the coefficient on the inflation gap (β) is positive but not statistically significant. This result could be due to a specification error, as the central bank has a separate declared objective to keep the size of the current account deficit, computed at a “normal” level of the terms of trade, below 4 percent of GDP. To incorporate this second objective we extended the basic model by adding as a separate regressor the difference between the fourth-quarter moving average of the current account deficit (as a ratio to GDP) and 0.04. The results are reported in the third row of the bottom panel. The coefficient on the inflation gap is again positive, but now it is statistically different from zero. The coefficient on the current account gap is also positive and statistically significantly different from zero. These findings provide some support to the idea that an equation that includes only the inflation gap is wrongly specified. The estimated coefficient of the inflation gap implies that, for a 1-percentage-point gap between expected and target inflation, the central bank raises the real interest rate by 68 basis points to bring inflation close to the target. In the same way, the estimated coefficient of the current account gap implies that a 1-percentage-point difference in this variable results in an increase of 61 basis points in the real interest rate. We also considered, as an alternative specification, a forward-looking version of the Taylor rule that includes, instead of the current account gap, the gap between the logarithm of GDP and the logarithm of its trend (measured using a Hodrick-Prescott filter). However, as can be seen in the second row of the panel, this measure of the output gap was not statistically significant, nor was the inflation gap in this specification.

We also tested for a nonlinear response of monetary policy to the inflation gap by introducing the square of the inflation gap as a separate regressor. However, its coefficient (fourth row of the bottom panel) was not statistically significant, and the coefficients on the inflation gap and the current account gap changed little. Finally, we also tested for asymmetries in the response of monetary policy. For this purpose we introduced a multiplicative dummy for those observations where the inflation gap was negative (fourteen out of thirty-eight observations in the second period), but again, as

Table 3. Estimates of the Central Bank of Chile Reaction Function^a

Specification	Parameter						J-test	R ²
	ρ ₁	ρ ₂	α	β	γ ₁	γ ₂		
Sample period 1985Q3 to 1989Q4								
Baseline	1.864 (43.54)	−1.037 (−19.67)	7.000 (18.97)	0.550 (3.26)			0.27	0.79
Adding output gap	1.436 (14.02)	−0.713 (−7.83)	4.960 (33.85)	0.560 (4.75)	1.400 (6.95)		0.24	0.87
Adding square of inflation gap	0.869 (9.89)	−0.005* (−0.04)	6.440 (7.41)	0.001* (0.005)	0.698 (3.32)	−0.520* (−1.022)	0.02	0.86
Adding dummy for negative inflation gap	1.161 (7.47)	−0.494 (−3.89)	5.225 (33.39)	0.324 (4.58)	1.461 (9.22)	0.163 (4.28)	0.20	0.88
Sample period 1990Q1 to 1999Q4								
Baseline	1.219 (8.96)	−0.322 (−3.35)	6.540 (11.73)	1.440* (1.16)			0.06	0.83
Adding output gap	1.162 (12.55)	−0.325 (−3.5)	6.240 (24.99)	0.236* (1.28)	0.360* (1.11)		0.11	0.88
Adding current account deficit	0.726 (9.87)		6.827 (15.63)	0.676 (2.31)	0.610 (2.56)		0.05	0.80
Adding square of inflation gap	0.72 (9.99)		6.962 (10.76)	0.742 (2.21)	0.559 (2.57)	−0.066* (−0.41)	0.05	0.81
Adding dummy for negative inflation gap	0.699 (8.93)		7.018 (13.61)	0.675 (2.62)	0.581 (2.73)	−0.350* (−0.66)	0.04	0.77

a. In the regression equation, ρ_1 and ρ_2 are the coefficients on one- and two-period lags of the real interest rate, α is the constant term, β is the coefficient on the inflation gap, and γ_1 and γ_2 are coefficients on additional regressors as indicated in the table. Numbers in parentheses are *t* statistics.

* Not significant at the 10 percent level. All the other variables are significant at the 5 percent level.

reported in the bottom row of the table, the coefficient of the dummy variable was not statistically significant.

As a further test of the model, we also estimated it for the period before the central bank became independent. Because there was no explicit inflation target during this period, we used a forward-looking, four-quarter moving average of the annual inflation rate as the target. The results of these estimations appear in the top panel of table 3. The inflation gap by itself (in the baseline regression, shown in the top row) is statistically significant, as is the gap between the log of GDP and the log of its trend value (second row).

For this period also, we tested for the existence of asymmetries in the response of monetary policy. For this purpose we introduced a quadratic term of the inflation gap, and a multiplicative dummy for those periods when the inflation gap was negative. The coefficient of the nonlinear term turned out not to be statistically significant (third row of the top panel), but the coefficient of the dummy variable was statistically significant and had the expected sign (fourth row). That is, for a given size of the inflation gap, the monetary authority adjusts the interest rate by a larger amount when the gap is negative.

A first reading of these results could make them appear surprising, as they suggest that well before the central bank became independent it was already operating under rules that tried to keep inflation close to its forward-looking trend value. But this finding is also consistent with the view that the independence of the central bank, which was granted in 1989, only institutionalized procedures that were already in operation well before (Fontaine, 1991).

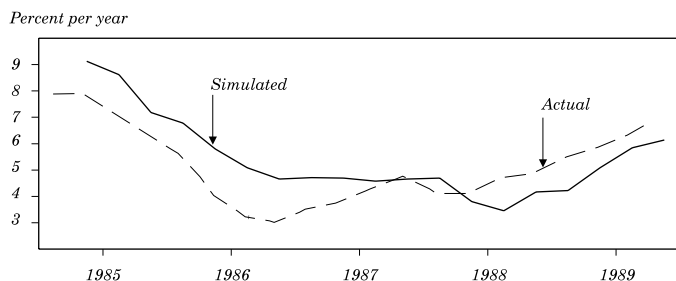
Returning to the results for the 1990s, another result that should be mentioned is the high persistence of the interest rate. This can be appreciated by calculating the sum of the two coefficients of the lagged values of the interest rate, which lies between 0.7 and 0.9. A value in this range implies that, for a given change in the target interest rate, the proportion that is reflected in the rate for the same quarter is between 10 and 30 percent of that change.

Because the central bank obtained its independence only in late 1989, we can investigate how the actual monetary policy followed before 1990 differed from what it would have been if monetary policy during that period had been governed by the reaction function of the second period. Figure 4 compares, for the period from 1985Q1 to 1989Q4, the actual and simulated values of the real interest rate. The latter were obtained using the second-period reaction function. The figure shows that, up to the first quarter of 1988, the fitted values were above the actual values, implying that during this period

monetary policy was more expansionary than it would have been under the policy of the second period. Thereafter the fitted values are below the actual values; this period was one where the central bank adopted a very tight monetary policy to slow down the acceleration of inflation (Corbo and Fischer, 1994).

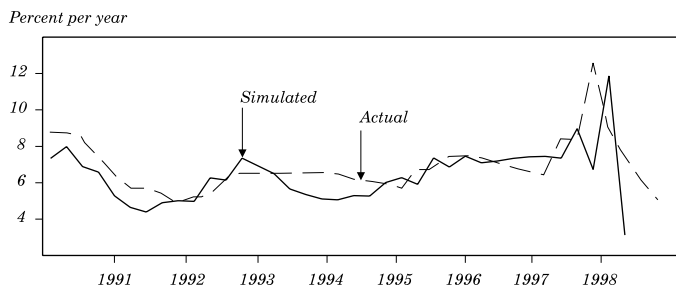
Figure 5 presents, for the second period, the fitted and actual values of the real interest rate. The fitted values were obtained using the equation reported in the third line in the bottom panel of table 3. The figure shows that the model tracks the actual rate quite closely.

Figure 4. Actual and Simulated Values for the Real Interest Rate in Chile 1985-89



Source: Author's calculations.

Figure 5. Actual and Simulated Values for the Real Interest Rate in Chile 1990-99



Source: Author's calculations.

The main exceptions are the period from 1994Q1 to 1995Q2, when the equation underestimates the actual values, and the end of the sample, when interest rates were set more to defend the exchange rate band than to achieve the inflation target.

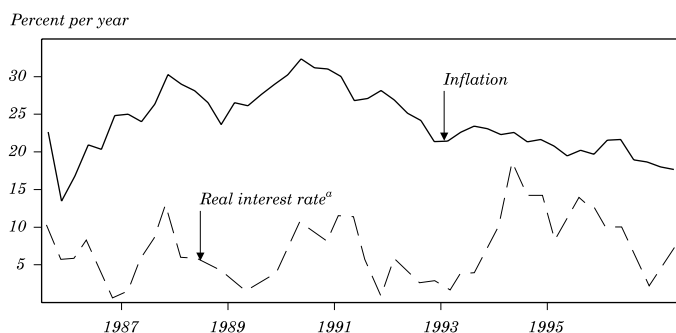
3.2 Colombia

As we saw in section 2, the crucial reform of monetary policy in Colombia took place in 1991. This was accomplished through a new constitution enhancing the legal independence of the central bank. This event provides a natural breakpoint in the sample period, in that one would expect, in general, different behavior before and after the central bank became independent. Before describing the estimation, in figure 6 we present the paths of inflation and of a three-quarter lag of the real interest rate.

The estimation uses quarterly data for the period from 1986Q1 to 1998Q4. In a first stage, a baseline reaction function was estimated using GMM, in which the only right-hand-side variable was the deviation of expected inflation from its trend, obtained as a Hodrick-Prescott filter of observed inflation. To account for the empirically observed smoothing of movements in short-term interest rates, we used a one-period partial adjustment model for the adjustment of the observed interest rate toward its desired level. The dependent variable was measured as the interest rate on certificates of deposit (CD), because it is through this instrument that the central bank carries out its monetary policy.

We started by estimating a reaction function for the whole period. The results of this estimation, using a two-quarter lead for the inflation gap, are shown in the top panel of table 4. The vector of instruments included one to four lags of the inflation gap, of the unemployment gap, and of short-term interest rates. The unemployment gap was measured as the deviation of the unemployment rate with respect to a trend value obtained using a Hodrick-Prescott filter. All the estimated coefficients were found to be statistically significant at the 1 percent level, with the exception of the inflation gap, which was significant only at the 10 percent level (the corresponding *p*-value is 0.065). The coefficient on the deviation of observed inflation from its target value is greater than one. This result suggests that the Central Bank of Colombia would have moved the interest rate aggressively in order to avoid a deviation of inflation from its target, defined here as a smooth trend of observed inflation.

Figure 6. Inflation and Lagged Real Interest Rate in Colombia.



Source: Authors' calculations.

a. The real interest rate is defined as the ex post difference between nominal interest rate and inflation. The rate is shown with a lag of three quarters.

Nonetheless, using a Wald test, the null hypothesis that $\beta = 1$ cannot be rejected at the 5 percent significance level. In other words, the data do not support “hawkish” behavior on the part of the Colombian authorities during the sample period as a whole. This is not surprising, because this period includes the second half of the 1980s, a period during which Colombia’s monetary policy has usually been described as accommodative (Cárdenas and Partow, 1998). We confirm that monetary policy was accommodative in the sense that the central bank adopted a neutral position, accommodating expected shocks to inflation through monetary policy by holding the real interest rate constant.

The estimated coefficient on the partial adjustment process of the actual toward the desired interest rate level also shows that the Colombian authorities were reluctant to introduce abrupt changes in monetary policy. In particular, only one-fifth of a given desired adjustment in the interest rate was accomplished during one quarter.

In Colombia the only legal objective of the central bank other than monetary stability is the stability of the financial system. Therefore we proceeded directly to search for other, hidden objectives. These could be more important for the first half of the sample, when the central bank was not yet independent. Thus we proceeded to introduce other possible objectives of monetary policy as arguments in the reaction function. In particular, we added the

Table 4. Estimates of the Central Bank of Colombia Reaction Function^a

Specification	Parameter					J-test	R ²
	ρ	α	β	γ ₁	γ ₂		
Sample period 1986Q1 to 1998Q4							
Baseline	0.176 (3.61)	31.15 (22.11)	2.84* (1.89)			0.10	0.61
Sample period 1986Q1 to 1990Q4							
Baseline	0.78 (14.21)	33 (357.3)	0.71 (11.4)			0.25	0.66
Adding unemployment gap	0.81 (15.9)	32.85 (427.22)	0.6 (14.1)	-7.85 (-2.53)		0.24	0.60
Adding real exchange rate	0.74 (17.24)	32.7 (870.51)	0.67 (16.3)	-7.46 (-3.21)	1.75 (2.34)	0.31	0.61
Sample period 1991Q1 to 1998Q4							
Baseline	0.32 (3.41)	25.62 (22.56)	2.73 (4.37)			0.15	0.44
Adding unemployment gap	0.27 (5.2)	25.57 (13.94)	2.19 (2.43)	-32.86* (-1.82)		0.15	0.56

a. Parameters are as described in table 3 except that ρ is the partial adjustment parameter and the interest rate is the nominal instead of the real rate. Numbers in parentheses are *t* statistics.

* Significant at the 10 percent level. All the other variables are significant at the 5 percent level.

unemployment gap. As lagged values of the unemployment gap were already used as instruments in the estimation, introducing the unemployment gap as an additional regressor in the reaction function is equivalent to testing whether it enters as a separate objective of monetary policy. The unemployment gap was measured as the difference between the actual rate of unemployment and its quadratic trend.

This specification yielded poor results (not shown). The coefficient of the unemployment rate was either not statistically significant or had the wrong sign. Similar results were obtained when the deviation of the real exchange rate from its trend was introduced as an alternative variable (not shown). The lack of a satisfactory relationship to explain the responses of monetary policy to economic shocks during the whole sampling period (1986-98) may be due to the existence of a structural break. Such a break might have occurred in terms of the objective function of the central bank, as it gained legal independence only in the early 1990s, and the objective of price stability was only then introduced as its main priority. Or there may have been a change in the type of shocks that hit the economy: access to external financing improved significantly during the 1990s, when a broadly based reform program was put into practice. Thus we proceeded to separate the sample into two periods: 1986Q1 to 1990Q4, and 1991Q1 to 1998Q4.

The results of the estimation for the first of these two periods are shown in the middle panel of table 4. As in the regressions for the whole period, we started by estimating a baseline equation in which only the deviations of the observed inflation from its trend—again obtained as a Hodrick-Prescott filter—entered as a regressor. The results show that all the variables are statistically significant at the 1 percent level and have the expected signs. The coefficient on the deviation of inflation from its (implicit) target is significantly less than one, suggesting that the Colombian authorities during this period tended to accommodate expected shocks to inflation, letting the real interest rate fall when a rise in future inflation was forecasted. The partial adjustment coefficient also shows that, during this period, movements in short-term interest rates showed less persistence than over the whole period. One must keep in mind, however, that the magnitude of the estimated partial adjustment coefficient for the whole period could be subject to some kind of specification error. In any case, the estimated coefficient for the period from 1986Q1 to 1990Q4 seems to be particularly high: almost four-fifths of the desired adjustment in the observed interest rate was achieved in one quarter.

We then introduced the unemployment gap as an additional regressor. The results of an estimation in which this variable enters the equation with a one-quarter lead are shown in the second row of the panel. All the coefficients are statistically significant at the 1 percent level (with the exception of the coefficient on the unemployment gap, which has a p-value of 0.02) and are very similar to those obtained under the baseline specification. Again the coefficient on the deviation of inflation from its target is significantly less than one. The coefficient on the unemployment gap suggests that, during this period, the monetary authorities also gave some weight to this variable as an additional objective. In particular, the results imply that the authorities reduced short-term interest rates when a rise in the gap between unemployment and its trend was expected, and increased rates when a fall in the gap was expected.

As a next step, we introduced the deviation of the real exchange rate from its trend as an additional variable to the above specification. The results, shown in the last row of the middle panel of table 4, are for a specification in which the deviation of the real exchange rate from its trend value enters the equation with a four-period lead. The instruments utilized include the first to the fourth lag of the deviation of inflation from its target, of the unemployment gap, of the short-term interest rate, and of the exchange rate variable. As the table shows, all the coefficients are statistically significant and have the expected sign. Excluding the coefficient on the real exchange rate variable itself, all the results are very similar to those obtained when the reaction function included only the inflation gap and the unemployment gap as arguments. As a test of the plausibility of this specification, one can estimate, under the assumption of a constant inflation target, the coefficient of the “long run” interest rate. The estimated value turns out to be 32.7 percent, which is very close to the average for the sample period (32.97 percent). The coefficient on the deviation of the real exchange rate from its trend suggests that the Colombian authorities were not just concerned about price stability and unemployment volatility. Rather, they also tried to stabilize expected movements in the real exchange rate, presumably to avoid putting the competitiveness of the tradable sector at risk.

As a final step we included the interest rate on three-month U.S. Treasury bills to the last specification, to investigate how

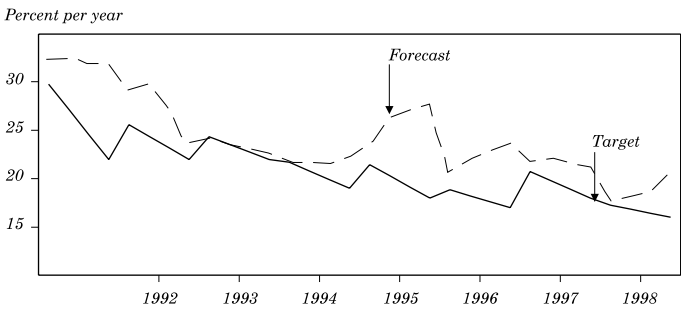
independent domestic monetary policy in Colombia was from the stance of foreign monetary policy. The results, not reported here, were very poor, which is not surprising in that, during the sample period (1986-90), Colombia was relatively closed to international capital movements.

Next we studied how monetary policy was conducted after the central bank became independent, by estimating a reaction function for the period from 1991Q1 to 1998Q4. During this period, under the law, the overriding objective of the central bank was to achieve monetary stability. In the transition toward monetary stability the central bank announced annual inflation targets. Thus for this period we define the inflation gap as the deviation of observed inflation from the (linearized) annual targets established by policymakers. The estimation of the baseline equation for this subperiod yielded the results shown in the bottom panel of table 4. The coefficient for the inflation gap, when this variable enters the equation with a two-period lead, is statistically significantly greater than one, which supports the idea that the authorities were determined to avoid deviations of observed inflation from its target. However, this does not necessarily imply that policymakers were hawkish; the observed result could well be explained by the setting of "soft" annual inflation targets. Indeed, if one compares an inflation forecast made with an autoregressive model with the announced target, one finds that only in 1995 was the inflation forecast a hard target (figure 7).

We next extended the arguments of the reaction function to include the unemployment gap. The results obtained when the unemployment gap enters the equation with four leads provide some (weak) evidence that the Colombian authorities considered unemployment stability as a final objective during the period of central bank independence. The coefficient on the unemployment gap is statistically significant at the 10 percent level (the corresponding p-value is 0.08). When the deviation of the real exchange rate from its trend was included as an additional argument in the reaction function (not shown), the results were very poor. Finally, as in the regressions for the first subperiod, the inclusion of the three-month U.S. treasury bill rate did not provide evidence that foreign monetary policy imposed a constraint on the Colombian authorities during the 1990s (results not shown).

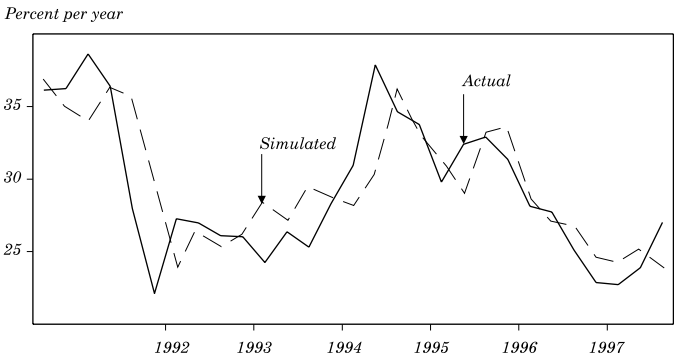
Figure 8 compares the paths of the observed and the predicted nominal interest rate in Colombia, where the latter is computed using the second regression equation in the bottom panel of table 4. As the figure shows, the model tracks the trajectory of the actual rate quite closely.

Figure 7. Inflation Targets and Inflation Forecasts in Colombia.



Source: Author's calculations.

Figure 8. Actual and Simulated Values for the Nominal Interest Rates in Colombia.



Source: Author's calculations.

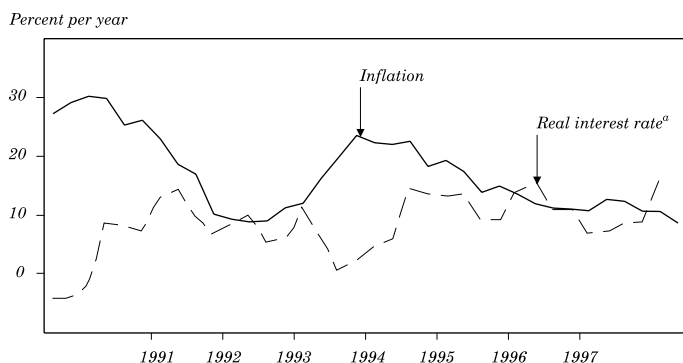
3.3 Costa Rica

As discussed in section 2, Costa Rica's central bank became independent only in 1995 and has, in addition to its main objective (the achievement of price stability), a secondary objective of achieving full employment. However, like its Chilean counterpart, the Central Bank of Costa Rica has been concerned with reducing inflation since before it became independent. Therefore we study the way in which the central bank has conducted monetary policy throughout the 1990s.

In Costa Rica monetary policy is carried out using what are called monetary stabilization bonds (whose abbreviation in Spanish is BEM). These have a typical maturity of six months, and therefore the six-month interest rate of the BEM is used as the interest rate intervention variable in the estimation of a reaction function. The trajectories of inflation and of the real interest rate lagged three quarters are presented in figure 9. Some evidence emerges that the central bank adjusted interest rates so as to affect the future course of inflation.

As in the other countries, we used a one-period partial adjustment mechanism for the adjustment of the actual interest rate toward its desired level. Also, because Costa Rica does not have an explicit inflation

Figure 9. Inflation and Lagged Real Interest Rate in Costa Rica



Source: Author's calculations.

a. The real interest rate is defined as the ex post difference between nominal interest rate and inflation. The rate is shown with a lag of three quarters.

targeting framework, the target inflation rate is unknown, and we assume that the objective was to keep inflation around its trend value. The latter is measured using a Hodrick-Prescott filter. Alternatively, we could have followed Clarida, Galí, and Gertler (1998b) and assumed that the inflation target is a constant, which can then be estimated from the constant of the regression. However, this procedure could introduce a specification error in cases when the country is pursuing the objective of reducing inflation gradually toward a long-run steady-state level.

The reaction function for Costa Rica is estimated using quarterly data for the period from 1990Q1 to 1998Q4. The results of estimation of a baseline equation, which includes only the inflation gap as an explanatory variable, are presented in the first row of table 5. The inflation gap is measured using a two-quarter lead, and the equation is again estimated using GMM. The instruments used are four lags of the inflation gap, of the BEM interest rate, and of the output gap.

As can be observed from the table, the coefficient on the inflation gap in the baseline specification is positive and greater than one. Thus it appears that the Central Bank of Costa Rica was trying to keep inflation close to its trend, reacting to a 1-percentage-point increase in the gap between expected inflation and its trend with a 47-basis-point increase in the real interest rate. Nonetheless, as in the Colombian case, the estimated parameter of the inflation gap is not significantly different from one. Thus policymakers could well have in fact been neutral in the face of expected inflation shocks.

The low value of the partial adjustment coefficient shows that interest rates have a lot of persistence, moving very slowly toward their desired value. The persistence of interest rate movements is of the same order of magnitude as in the Colombian case. Finally, as an indicator of the validity of the model, the estimated value of the “long run” nominal interest rate turns out to be 22.8 percent, very close to the mean of the interest rate series over the sampling period (24.95 percent).

The results obtained so far could be subject to a specification error, because the Central Bank of Costa Rica has other objectives besides achieving a gradual reduction of inflation. Therefore we also considered the addition of other variables that appear as legal objectives of the central bank. As mentioned in section 2, the Central Bank of Costa Rica’s charter establishes several secondary objectives for

Table 5. Estimates of the Central Bank of Costa Rica Reaction Function^a

<i>Specification</i>	<i>Parameter</i>					<i>J-test</i>	R ²
	ρ	α	β	γ ₁	γ ₂		
<i>Sample period 1990Q1 to 1998Q4</i>							
Baseline	0.38 (4.4)	22.80 (24.4)	1.47 (5.68)			0.15	0.61
Adding output gap	0.68 (15.9)	25.49 (43.48)	0.79 (10.89)	73.77 (7.54)		0.21	0.61
Adding real exchange rate	0.64 (11.49)	25.59 (92.88)	0.82 (32.31)	58.85 (9.60)	60.29* (2.49)	0.22	0.61

a. Parameters are as described in table 3 except that ρ is the partial adjustment parameter and the interest rate is the nominal instead of the real rate. Numbers in parentheses are *t* statistics.

* Significant at the 5 percent level. All the other variables are significant at the 1 percent level.

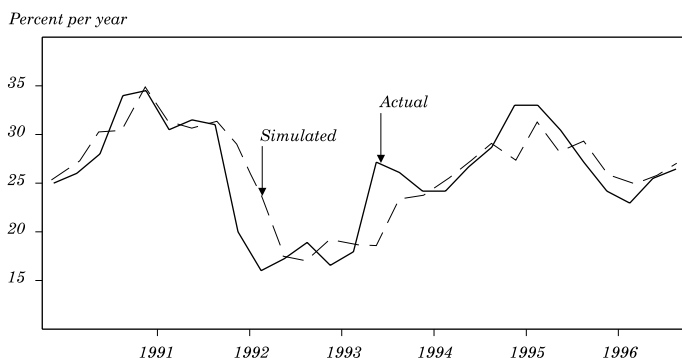
monetary policy. These include the achievement of full employment, the promotion of efficiency in the internal and external payments systems, the appropriate management of international reserves, and the stability of the financial system. The only one of these objectives that could play an independent role is the full employment objective. To account for this objective we introduced the output gap as an additional explanatory variable. This was measured as the deviation of an industrial output index from its trend, the latter obtained using a Hodrick-Prescott filter. Thus we estimated a sort of forward-looking version of the Taylor rule. In this specification the inflation gap enters the equation with a two-period lead and the output gap with an eight-period lead.¹⁴ It appears from the results (second row of table 5) that the monetary authorities did try to stabilize output over the sample period. Another interesting finding is that, in this second specification, the coefficient on the inflation gap falls to less than one. A Wald test confirms that the coefficient is significantly less than one, suggesting that during the 1990s the authorities accommodated expected shocks to inflation.

To introduce the objective of promoting efficiency of the internal and external payments system, we added to the above specification the expected deviation of the real exchange rate from its trend. The new variable enters the equation with an eight-period lead. The results (shown in the third row of table 5) show that the stabilization of the real exchange rate was also considered as a separate objective by the Costa Rican authorities. Again the inflation gap coefficient is statistically significantly less than one, confirming the finding that the monetary authorities followed an accommodative policy with respect to shocks to expected inflation. We also introduced as a separate argument the level of foreign reserves, but the results, not reported here, were very poor. Finally, we also considered the six-month U.S. Treasury bill rate as another variable that might have played a role in setting monetary policy, but the results were also very poor.

Figure 10 compares the paths of the actual and estimated values of the interest rate, the latter obtained from the last equation in table 5. As the figure shows, with the exception of 1992, the model tracks the behavior of the observed interest rate fairly closely.

14. The lead utilized for the output gap is much longer than one would have expected a priori, as monetary policy works in emerging market countries with a much shorter lag than in industrial countries (Fry and others, 1999).

Figure 10. Actual and Simulated Values for the Nominal Interest Rate in Costa Rica



Source: Author's calculations.

3.4 El Salvador

In El Salvador the main objective of the central bank is price stability. A secondary objective, as noted in section 2, is to ensure the stability and competitiveness of the financial system. However, in setting monetary policy, El Salvador uses a framework closer to a fixed exchange rate: the exchange rate has been de facto fixed since the early 1990s. El Salvador also allows the free movement of capital and therefore comes close to the textbook model of a fixed exchange rate with perfect capital mobility. In this Mundell type of setting, monetary policy has no role to play in stabilization, and therefore the exercise of estimating a reaction function for monetary policy would appear to make no sense. Nonetheless, it may be claimed that capital mobility in El Salvador is far from perfect, and consequently, it should be worthwhile to analyze the extent to which policymakers have room to conduct an independent monetary policy. Indeed, a similar point is made by Clarida, Galí, and Gertler (1998b), who study the reaction functions for France, Italy, and the United Kingdom at a time when these three countries fixed their currencies within the Exchange Rate Mechanism (ERM) of the European Monetary System.¹⁵ In their framework the stance of monetary

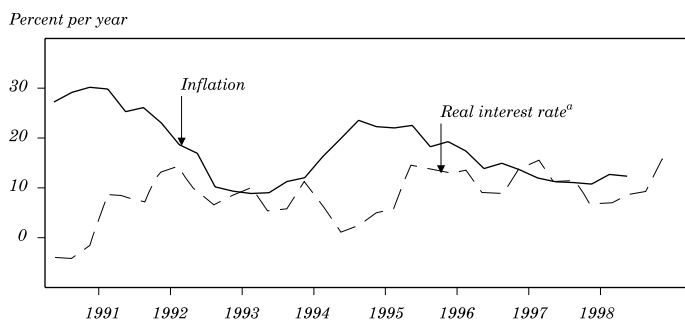
15. Clarida, Galí, and Gertler (1998b) assess the degree of independence of monetary policy for the members of the ERM by adding the Bundesbank policy rate to a baseline specification for the reaction function that includes only domestic variables.

policy is a weighted average of the interest rate desired by the authorities and the foreign interest rate. In the context of El Salvador, an analogous exercise can be performed by adding to a baseline specification the interest rate on U.S. Treasury bills as a measure of the external constraints faced by the Salvadorian monetary authorities.

As in the case of the other countries, we proceeded to estimate a baseline specification in which monetary policy reacts only to expected future deviations of inflation from its trend. Then we added the foreign interest rate as a separate regressor. Thus two explanatory variables entered the extended model: the inflation gap and the six-month U.S. Treasury bill rate. For the dependent variable we used the financial system deposit rate. Figure 11 shows the trajectory of the inflation rate and of the real interest rate lagged three quarters. There is some evidence that interest rate adjustment is related to the inflation rate. In the estimation, as in the case of the other countries, we assumed a first-order partial adjustment process for the adjustment of the domestic interest rate. The estimations were carried out using quarterly data for the period 1991Q1 to 1998Q4. The results appear in the top row of table 6. The coefficient on the U.S. Treasury bill (γ_2) is not statistically significant, implying that foreign monetary policy was not an effective constraint on the conduct of monetary policy in El Salvador.

Given this finding, we focused on estimating a reaction function for the Central Bank of El Salvador in the same way as we did for the other countries of the sample. The second line of table 6 presents the results from estimation of a baseline specification in which only the

Figure 11. Inflation and Lagged Real Interest Rate in El Salvador



Source: Author's calculations.

a. The real interest rate is defined as the ex post difference between nominal interest rate and inflation. The rate is shown with a lag of three quarters.

Table 6. Estimates of the Central Bank of El Salvador Reaction Function^a

Specification	Parameter					J-test	R ²
	ρ	α	β	γ ₁	γ ₂		
Sample period 1991Q1 to 1998Q4							
Baseline plus U.S. Treasury bill rate	0.06 (2.4)	10.07 (2.52)	0.98* (1.84)		0.05** (1.1)	0.12	0.92
Baseline	0.09 (2.62)	14.05 (22.8)	1.11 (2.34)			0.10	0.91
Adding output gap	0.06 (2.26)	13.49 (18.8)	1.39 (2.1)	3.72* (1.92)		0.10	0.93

a. Parameters are as described in table 3 except that ρ is the partial adjustment parameter and the interest rate is the nominal instead of the real rate. Numbers in parentheses are *t* statistics.

* Significant at the 10 percent level.

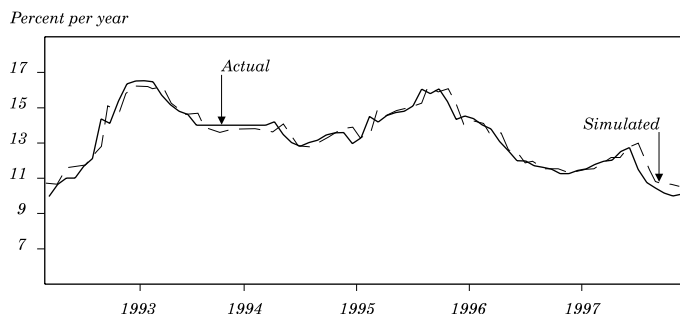
** Not significant at the 10 percent level. All the other variables are significant at the 5 percent level.

six-month-forward inflation gap enters as an explanatory variable. The instruments considered included one to four lags of the inflation gap, the output gap, and the short-term (six-month) interest rate. All the coefficients are statistically significant and have the expected signs (second row of table 6). The coefficient for the inflation gap is slightly greater than one, but a Wald test confirms that it is not statistically different from one. This result suggests that monetary authorities were not particularly determined to control inflation shocks; policymakers would have let the real interest rate remain constant when faced with shocks to inflation. Another interesting result is given by the partial adjustment coefficient. Over 90 percent of the current short-term interest rate is explained by the lagged interest rate, reflecting a high degree of persistence in interest rate movements.

We then proceeded to add other variables as regressors in the reaction function. First, we introduced the output gap to find out whether the monetary authorities considered output stability as a final objective. We found (bottom row of table 6) that policymakers had at least some concern about output stability during the 1990s. The output gap appears to be significant at the 10 percent level and almost significant at the 5 percent level (the p-value is 5.9 percent). When we added the real exchange rate as another regressor, either in addition to the output gap or as an alternative to it, we found that it did not enter the reaction function of the Salvadorian authorities (results not shown).

Finally, figure 12 shows the paths of the observed and fitted values of the nominal interest rate, where the latter was obtained using the model reported in the last row of table 6. The model tracks the trajectory of the observed interest rate quite well.

Figure 12. Actual and Simulated Values for the Interest Rate in El Salvador



Source: Author's calculations.

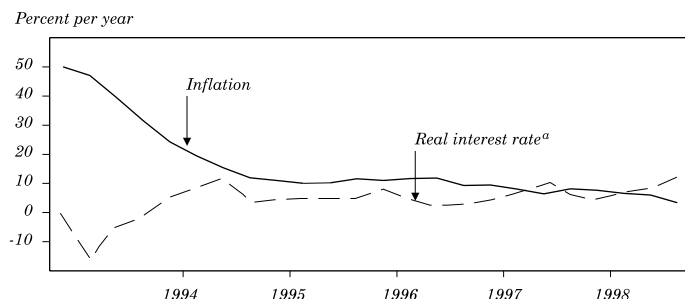
3.5 Peru

In Peru the 1980s were characterized by substantial macroeconomic disequilibria and financial repression, including interest rate controls. During the 1990s, however, substantial progress was made in restoring macroeconomic stability. As we saw in section 2, in January 1993 a new legal framework was introduced giving more independence to the central bank and making price stability the central bank's only objective.

In carrying out monetary policy, the Peruvian authorities have used the rate of growth of the monetary base as an intermediate target. The main instrument used to pursue this policy has been certificates of deposits of the central bank, which are bought and sold in open market operations. To investigate how monetary policy is carried out in Peru, we estimated reaction functions with quarterly data for the period from 1993Q1 to 1999Q1, the period of increased legal independence for the central bank. In a first stage we used the rate of change in the monetary base as the dependent variable. The results with this dependent variable were very poor, however, and therefore we switched to using the nominal interest rate on thirty-day certificates of deposit as the dependent variable.¹⁶ Figure 13, which presents the paths of the real interest rate, with an four-period lag, and the rate of inflation, indicates that nominal interest rates were adjusted in response to inflation.

As in the other countries, we began by estimating a baseline specification in which the only regressor is the inflation gap. Given that Peru did not have an explicit inflation target, the inflation gap is defined as the difference between observed inflation and its trend, which is measured using a Hodrick-Prescott filter. Nonetheless, the estimation yielded poor results: the inflation gap either was not statistically significant or had the wrong sign. The same result was obtained when the trend of inflation was measured using a four-quarter moving average of quarter-to-quarter inflation rates. However, a stable relation was found when the inflation gap entered the equation as the difference between observed inflation and the average inflation rate for the sample period or, equivalently, when the target inflation rate was assumed to be a constant. The results of the estimation using this specification are reported in the first row of table 7. Here the

16. This series presented a problem of missing observations for March and May 1997. To overcome this problem, a least squares regression was estimated in which the certificate rate was regressed on its first lag and the discount rate. A first-order partial adjustment model was assumed and was supported by data.

Figure 13. Inflation and Lagged Real Interest Rate in Peru

Source: Author's calculations.

a. The real interest rate is defined as the ex post difference between nominal interest rate and inflation. The rate is shown with a lag of three quarters.

inflation gap enters the equation with a four-period (one year) lead, and the vector of instruments used in the estimation includes one to four lags of inflation, of the output gap, and of the short-term interest rate. The results show that monetary policy appears to have accommodated shocks to expected inflation. The coefficient of the inflation gap is also statistically significantly less than one. The estimated parameter of the partial adjustment process for interest rates implies a high degree of persistence of monetary policy: over 70 percent of the level of the short-term interest rate is explained by its lagged value.

As noted in section 2, the charter of the Central Reserve Bank of Peru establishes monetary stability as the only objective of monetary policy. Therefore one could conclude from these results that the monetary authority has not been fully committed to its legal objective.

In the next stage we added the output gap to the baseline equation. This variable, with a two-period lead, is statistically significant at the 1 percent level (second row of table 7). Again the coefficient of the inflation gap is significantly less than one, pointing to accommodative behavior on the part of the authorities. Finally, the deviation of the real exchange rate from its trend was introduced as a third regressor. This variable, too, is statistically significant at the 1 percent level (last row of table 7). This suggests that, during the sample period, Peruvian policymakers were concerned not only with output stability but also with the stability of the real exchange rate. Thus, despite the mandate to achieve price stability, other macroeconomic considerations also appear to have had a bearing on the course of monetary policy.

Table 7. Estimates of the Central Bank of Peru Reaction Function^a

<i>Specification</i>	<i>Parameter</i>					<i>J-test</i>	<i>R</i> ²
	ρ	α	β	γ ₁	γ ₂		
<i>Sample period 1993Q1 to 1999Q1</i>							
Baseline	0.29 (10.18)	28.72 (42.81)	0.75 (10.81)			0.27	0.72
Adding output gap	0.26 (5.34)	28.25 (46.00)	0.73 (14.95)	23.93 (3.04)		0.27	0.73
Adding real exchange rate	0.28 (30.33)	28.00 (126.6)	0.65 (25.62)	4.52 (3.92)	73.29 (12.66)	0.30	0.76

a. Parameters are as described in table 3 except that ρ is the partial adjustment parameter and the interest rate is the nominal instead of the real rate. Numbers in parentheses are *t* statistics. All variables are significant at the 1 percent level.

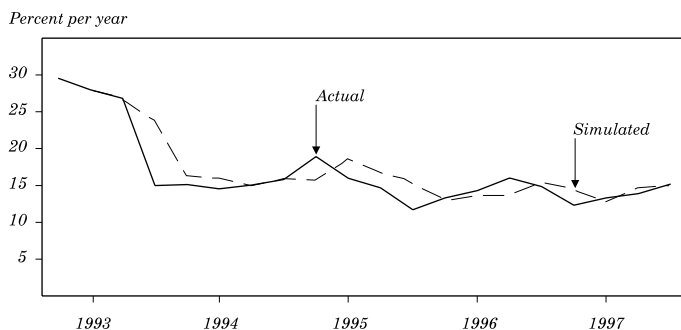
Finally, figure 14 shows the paths of the actual and fitted nominal interest rates, where the latter is obtained using the last equation in table 7. The model tracks the trajectory of the actual rate fairly closely.

To sum up the empirical findings, in two of the five cases studied (Chile and Colombia), monetary policy has clearly been geared, since the central bank gained independence, toward moving inflation closer to its target value. In El Salvador there is some evidence that monetary policy is at least neutral; that is, shocks to the inflation rate do not result in a change in the real interest rate. In the other two countries (Costa Rica and Peru), however, a higher real interest rate is not the mechanism utilized to bring inflation close to its target.

Of the five countries, Chile has made the most progress in reducing inflation toward its target level and in achieving a level of inflation close to those in the industrial countries. This is not surprising, because progress in reducing inflation depends on factors other than just monetary policy. Among these, one should consider the evolution of the equilibrium real exchange rate and the trajectory of imported inflation.

Finally, one can compare our results with results obtained by others for industrial countries. The most direct comparison can be made with the results of Clarida, Galí, and Gertler (1998b). In their empirical work, they find that interest rate policy in Germany, Japan, and the United States is mostly determined by the expected

Figure 14. Actual and Simulated Values of the Nominal Interest Rate in Peru



Source: Authors' calculations.

inflation gap, measured as the difference between expected inflation and a constant steady-state inflation target. These authors find that the real interest rate increases in response to shocks to expected inflation ($\beta > 1$ in their framework, where the dependent variable is the nominal interest rate). In contrast, the output gap was significant only for Germany and Japan and not for the United States. Thus, for the United States, the output gap is used only to get a forecast of future inflation. In our empirical results we found that, in Chile and Colombia, the output gap and the unemployment gap, respectively, were not statistically significant in the reaction function, and therefore did not play a role beyond the information they provide in forecasting future inflation.

For the smaller countries—Costa Rica, El Salvador, and Peru—our results show that foreign interest rates do not play an important role in setting the stance of monetary policy. For El Salvador this result is surprising, inasmuch as the nominal exchange rate did not change much during the 1990s, with its central bank using a combination of a money and an exchange rate anchor.

4. CONCLUSIONS

After a long tradition of high fiscal deficits and high inflation, Latin America made a major effort during the last decade to achieve a sustainable reduction of inflation. These efforts have paid off: whereas the average annual inflation rate in Latin America in the 1980s exceeded 100 percent, by 1999 annual inflation in the region was down to the single-digit level. Inflation strategies were initially based on getting the fiscal situation under control, as a way of liberating monetary policy from the need to finance fiscal deficits; since then strategies have moved to more formal uses of nominal anchors. The choice of a nominal anchor as the cornerstone of the stabilization effort has changed over time, as rigid exchange rate mechanisms have been replaced by more flexible arrangements. The exceptions are Argentina's currency board and the de facto fixed exchange rate arrangement of El Salvador. The other countries use either a monetary anchor or an inflation target.

To facilitate the reduction of inflation, and as a way of protecting the central bank from the political pressures that typically give rise to time-inconsistency problems, most Latin American countries have now granted their central banks independence. Central banks

in the region have also been given a clear mandate to achieve a sustainable reduction in inflation and appropriate instruments for doing so.

Although the results in terms of inflation reduction have been spectacular, the costs in terms of output are not in evidence. This result could be due, in large part, to the effect of the credibility of the new policies on inflation expectations, allowing inflation to be reduced at a much lower cost than anticipated from standard models with high inflation inertia. Moreover, the beneficial effect on growth is not surprising, as most studies of the costs of inflation show that these costs are highly nonlinear and become very high at high levels of inflation, such as those typical of Latin America in the 1980s.

In general, it is found that, in setting monetary policy, central banks look beyond just inflation to take into account other variables, which often are spelled out in their charter. These other variables are considered not because of their predictive power for expected inflation but as separate objectives of monetary policy. Thus, in the case of Chile, we found that the ratio of the current account deficit to GDP is also taken into account in deciding the stance of monetary policy. In contrast, the output gap was significant only in the second half of the 1980s, and not in the 1990s after the central bank became independent. A similar result is found for Colombia, where the unemployment rate is significant only in the 1980s and not in the 1990s. In Costa Rica and Peru, both the output gap and the real exchange rate are statistically significant, whereas in El Salvador only the output gap is statistically significant. Of the five countries, Chile has made the most progress in reducing inflation toward its target level and in achieving a level of inflation close to those in industrial countries. This is not surprising, because progress in reducing inflation depends on factors other than monetary policy alone. Among these, one should consider the path of the equilibrium real exchange rate and the trajectory of imported inflation.

REFERENCES

- Ball, L. 1999. "Policy Rules for Open Economies." In *Monetary Policy Rules*, edited by John B. Taylor. Chicago: University of Chicago Press.
- Bernanke, B., and F. Mishkin. 1997. "Inflation Targeting: A New Framework for Monetary Policy?" *Journal of Economic Perspectives* 11: 97-116.
- Bernanke, B., T. Laubach, F. Mishkin, and A. Posen. 1999. *Inflation Targeting*. Princeton, N.J.: Princeton University Press.
- Bruno, M. 1991. "High Inflation and the Nominal Anchors of an Open Economy." Princeton Essays in International Finance 183. Princeton, N.J.: Princeton University Press.
- Bulir, A., and A. M. Gulde. 1995. "Inflation and Income Distribution: Further Evidence on Empirical Links." IMF Working Paper 95/86. Washington: International Monetary Fund.
- Calvo, G., and C. Végh. 1999. "Inflation Stabilization and BOP Crises in Developing Countries." In *Handbook of Macroeconomics*, Vol. 1C, edited by J. Taylor and M. Woodford. Amsterdam: North Holland.
- Cárdenas, M., and Z. Partow. 1998. "Does Independence Matter? The Case of the Colombian Central Bank." Unpublished paper. Bogotá: Fedesarrollo.
- Cecchetti, S. 1998. "Policy Rules and Targets: Framing the Central Banker's Problem." *Federal Reserve Bank of New York Economic Policy Review* 4(2): 1-14.
- Clarida, R., J. Galí, and M. Gertler. 1998a. "Monetary Policy Rules and Macroeconomic Stability: Evidence and Some Theory." NBER Working Paper 6442. Cambridge, Mass.: National Bureau of Economic Research (March).
- . 1998b. "Monetary Policy Rules in Practice: Some International Evidence." *European Economic Review* 42: 1033-68.
- Corbo, V. 1998. "Reaching One-Digit Inflation: The Chilean Experience." *Journal of Applied Economics* 1(1): 123-63.
- Corbo, V., and J. de Melo. 1987. "Lessons from the Southern Cone Policy Reforms." *World Bank Research Observer* 2(2): 111-42.
- Corbo, V., A. Elberg, and J. A. Tessada. 1999. "Monetary Policy in Latin America: Underpinnings and Procedures." *Cuadernos de Economía* 109 (December): 897-927.
- Corbo, V., and S. Fischer. 1994. "Lessons from the Chilean Stabilization and Recovery." In *The Chilean Economy: Policy Lessons and Challenges*, edited by B. Bosworth and others. Washington: Brookings Institution.

- . 1995. "Structural Adjustment, Stabilization and Policy Reform: Domestic and International Finance." In *Handbook of Development Economics*, Vol. III, edited by J. Behrman and T. Srinivasan. Amsterdam: Elsevier Science.
- Cukierman, A. 1992. *Central Bank Strategy, Credibility, and Independence: Theory and Evidence*. Cambridge, Mass.: MIT Press.
- Dornbusch, R., and A. Werner. 1994. "Mexico: Stabilization, Reform and No Growth." *Brookings Papers on Economic Activity* 1: 253-315.
- Edwards, S., and C. Végh. 1997. "Banks and Macroeconomic Disturbances under Predetermined Exchange Rates." *Journal of Monetary Economics* 40: 239-78.
- Eichengreen, B. 1999. "Kicking the Habit: Moving from Pegged Rates to a Greater Exchange Rate Flexibility." *Economic Journal* 109: C1-C14.
- Enders, W. 1995. *Applied Econometric Time Series*. New York: John Wiley & Sons.
- Fischer, S. 1995. "Central Bank Independence Revisited." *American Economic Review* 85(2): 201-06.
- . 1996. "Why Are Central Banks Pursuing Long-Run Price Stability?" In *Achievement of Price Stability: A Symposium Sponsored by the Federal Reserve Bank of Kansas City*. Kansas City, Mo.: Federal Reserve Bank of Kansas City.
- Fontaine, J. A. 1991. "La Administración de la Política Monetaria en Chile, 1985-1989." *Cuadernos de Economía* 83: 109-29.
- Fry, M., D. Julius, L. Mahadeva, S. Roger, and G. Sterne. 1999. "Monetary Policy Frameworks in a Global Context." Unpublished paper. London: Bank of England (June).
- Goodhart, C. 1994. "Central Bank Independence." *Journal of International and Comparative Economics* 3: 1-12.
- Greene, W. 2000. *Econometric Analysis*, 4th ed. New York: Prentice Hall.
- Hamilton, J. 1994. *Time Series Analysis*. Princeton, N.J.: Princeton University Press.
- International Monetary Fund. 1997. *World Economic Outlook*. Washington.
- . 1999. *Exchange Rate Arrangements and Currency Convertibility: Developments and Issues*. Washington.
- King, M. 2000. "Monetary Policy: Theory in Practice." Address to a joint luncheon of the American Economic Association and the American Finance Association.

- Mátyás, L., ed. 1999. *Generalized Method of Moments Estimation*. Cambridge, U.K.: Cambridge University Press.
- Mishkin, F. 1997. "Strategies for Controlling Inflation." NBER Working Paper 6122. Cambridge, Mass.: National Bureau of Economic Research (August).
- . 1999. "International Experiences with Different Monetary Policy Regimes." NBER Working Paper 7044. Cambridge, Mass.: National Bureau of Economic Research (March).
- Mundell, R. 1961. "A Theory of Optimum Currency Areas", *American Economic Review* 51 (September): 657-664.
- Obstfeld, M., and K. Rogoff. 1995. "The Mirage of Fixed Exchange Rates." *Journal of Economic Perspectives* 9(Fall): 73-96.
- Rosende, F. 1998. "Política Monetaria en Chile en los Noventa: Un Ejercicio no Neutral." *Perspectivas* 2(1), November: 157-175.
- Sargent, T. 1982. "The End of Four Big Inflations." In *Inflation: Causes and Effects*, edited by R. Hall. Chicago: University of Chicago Press.
- Svensson, L. E. O. 1999a. "Inflation Targeting as a Monetary Policy Rule." *Journal of Monetary Economics* 43: 607-54.
- . 1999b. "Open-Economy Inflation Targeting." NBER Working Paper 6545. Cambridge, Mass.: National Bureau of Economic Research.
- Taylor, J. 1993. "Discretion versus Policy Rules in Practice." *Carnegie-Rochester Conference Series on Public Policy* 39: 195-214.

THE EFFECT OF UNCERTAINTY ON MONETARY POLICY: HOW GOOD ARE THE BRAKES?

Adam Cagliarini
Reserve Bank of Australia

Guy Debelle
Reserve Bank of Australia

In most industrial countries, official interest rate changes tend to be “smooth.” That is, rates are adjusted relatively infrequently and in small steps. Yet the path of interest rates that emerges as optimal from macroeconomic models is, in general, considerably more volatile. So are the paths of interest rates implied by simple Taylor-type rules, unless a sufficiently large weight is put on an interest rate smoothing term that penalizes large movements in the policy interest rate. Do these contrasting outcomes imply that policymakers in industrial countries are adopting suboptimal monetary policy strategies, or are there factors not captured in the models that justify the strategies pursued in practice?

One possible explanation for the divergence between the models and observed practice is that the former fail to adequately capture the uncertainty that impinges on the monetary policy decision. Most notably, Brainard (1967) highlighted the fact that uncertainty about model parameters can induce less aggressive actions on the part of the policymaker than those that result when uncertainty is ignored. This paper investigates the extent to which different forms of

The authors thank Alexandra Heath for helpful discussions, Geoff Shuetrim and Chris Thompson for developing the optimization routine, Nargis Bharucha for assistance in refining the programs, Lyndon Moore for research assistance, and David Gruen, Geoff Shuetrim, and colleagues at the Reserve Bank of Australia for comments. The views expressed in this paper are those of the authors and are not necessarily those of the Reserve Bank of Australia.

Monetary Policy: Rules and Transmission Mechanisms, edited by Norman Loayza and Klaus Schmidt-Hebbel, Santiago, Chile. ©2002 Central Bank of Chile.

uncertainty affect the optimal path of interest rates. It does so by incorporating uncertainty into a simple model of the Australian economy and examining the impact of various forms of uncertainty on the volatility of the monetary policy instrument.

This paper complements that of Rudebusch (1999), who conducts a similar analysis for the U.S. economy. One difference between his analysis and ours is the inclusion of another transmission channel of monetary policy, namely, the effect of monetary policy-induced changes in the exchange rate on output and inflation. It also extends Shuetrim and Thompson's (1999) analysis of uncertainty in the Australian context.

Before investigating the smoothness of monetary policy changes in Australia, we document, in section 1, the practice of interest rate smoothing by industrial-country central banks, and we review some possible explanations that have been advanced for this behavior. Section 2 focuses explicitly on uncertainty as an explanation for smoothing and summarizes the growing literature that examines the impact of various types of uncertainty on the monetary policy process. Section 3 describes briefly a simple model of the Australian economy and the methodology that will be used to examine the effect of uncertainty. Section 4 presents the empirical results, and section 5 concludes.

The main finding of the paper is that the introduction of uncertainty does not necessarily explain the divergence between model-derived optimal policy and observed outcomes. Rather, different types of uncertainty have differing effects on the smoothness of the path of official interest rates implied by the model of the Australian economy used here. General parameter uncertainty does not have much impact on smoothness. Shuetrim and Thompson (1999) find that the incidence and persistence of the uncertainty determine whether it results in more or less smoothness. Soderstrom (1999), using an analytical model, obtains results similar to those in this paper. These findings, however, are in contrast to recent results for the United States (Sack, 1998) and the United Kingdom (Martin and Salmon, 1999), and some possible explanations for the difference are discussed.

However, uncertainty about the average interest rate sensitivity of the economy—that is, how good the policy brakes are—is shown to have a significant impact on smoothness. Increasing the mean interest rate sensitivity of the economy by one standard deviation results in a much higher degree of smoothness but one that is still less than that observed in practice.

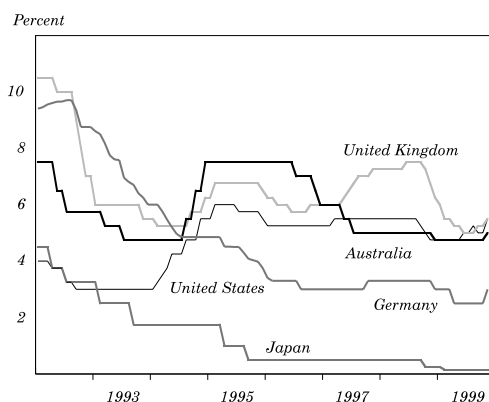
1. FACTS AND THEORIES OF SMOOTHING

1.1 Facts

The path of short-term interest rates that results from the monetary policy decisions of most industrial-country central banks tends to be smooth. Table 1 documents the fact that central banks tend to change their policy settings relatively infrequently and in small steps.¹ The table also shows that a series of policy moves in the same direction is more common than a policy reversal and that a relatively long period of inaction tends to precede a reversal.² The smooth path of official interest rates that underpins table 1 is illustrated in figure 1.

The central banks of Germany (and later the European Central Bank under European Monetary Union) and Canada appear to move interest rates more frequently than the others in the sample.

Figure 1. Official Interest Rates in Selected Industrial Countries



Source: Reserve Bank of Australia.

1. The table refers to nominal rather than real rates. Although the former are generally the policy instrument of central banks, the latter are often the instrument of monetary policy in empirical models, including the one used in this paper. If inflation and inflation expectations are relatively persistent, this distinction will not greatly affect the comparison of theory and practice.

2. Rudebusch (1995) documents the pattern of changes in the federal funds rate in the United States in more detail and estimates hazard functions for continuations and reversals.

Table 1. Policy Adjustments in Selected Industrial Countries, January 1992-November 1999^a

<i>Country</i>	<i>Interest rate</i>	<i>Number of changes</i>		<i>Average number of days between changes</i>			<i>Average size of change (basis points)</i>		
		<i>Continuations^b</i>	<i>Reversals</i>	<i>All</i>	<i>Continuations</i>	<i>Reversals</i>	<i>All</i>	<i>Continuations</i>	<i>Reversals</i>
Australia	Cash rate	12	3	195	134	438	63	67	50
United States	Federal funds rate	15	5	144	68	374	33	35	25
United Kingdom	Repo rate	25	5	99	84	179	42	44	30
Germany ^c	Repo rate	80	10	32	20	123	10	9	20
Japan	Call	8	0	326	326	NA	54	54	NA
Sweden	Discount	49	5	47	32	195	27	27	28
Canada	Overnight	33	5	51	40	123	34	35	25

Source: Authors' calculations.

NA, not applicable.

a. Data for Sweden begin in December 1992 and those for Canada in July 1994.

b. A continuation is a change in interest rates in the same direction as the previous change.

c. Data are for countries participating in European Monetary Union after January 1999.

Recently, however, both those central banks have tended to adjust rates less frequently. In the three years ending in November 1999, policy rates were adjusted only thirteen times in Canada and four times in Germany and the euro area.

In identifying whether these paths of policy interest rates are smooth, it is necessary to determine what the appropriate benchmark is. In the literature to date, two such benchmarks have been proposed. One is to compare the observed pattern of official interest rates with the optimal policy path derived from a macroeconomic model of the economy, where the policymaker has the standard objective function, which does not include an interest rate smoothing term. This benchmark may be misleading, however, because it ignores the effect of information available to the policymaker that is not captured in the model. For example, the model captures the average performance of the economy over time, whereas at any point in time the policymaker may consider that he or she has some knowledge about the residuals of the equations in the model, particularly with regard to future exogenous shocks (elections, for example). Even so, this does not explain the relative frequency of continuations and reversals, that is, the high degree of autocorrelation of official interest rates.

A second benchmark used is the path of interest rates derived from a policy rule, generally a Taylor-type rule. In macroeconomic models of small, closed economies (such as that in Svensson, 1997), the Taylor rule and optimal policy are nearly equivalent, because all the state variables are in the rule. However, in larger models the Taylor rule provides only an approximation to the path of interest rates derived from optimizing the model. Certainty equivalence does not apply once uncertainty is introduced (Orphanides, 1998). Thus a Taylor rule that is close to optimal in a deterministic world is not necessarily so in a stochastic one.

One commonly adopted approach used to reconcile the differences between the degrees of interest rate smoothing in theory and in practice is to simply impose interest rate smoothing on the model. This can be done by including a lagged interest rate term in a Taylor-type rule or by including the variance of interest rate changes in the policymaker's objective function. Although such modifications reduce the volatility of interest rates, they do not explain the observed serial correlation. These modifications are also somewhat unsatisfactory in that they are somewhat ad hoc (although Woodford, 1999, derives a rationale for interest rate smoothing from first principles).

Consequently, in this paper we try to identify more explicitly the factors that might induce less aggressive policy changes in practice, focusing primarily on uncertainty.

1.2 Theories

Eijffinger, Schalling, and Verhagen (1999) break down the above pattern of behavior into two facets. First, they describe as interest rate “stepping” the adjustment of policy rates in discrete steps rather than continuously, despite new, policy-relevant information arriving almost constantly.³ Second, they describe smoothing as the process whereby policy is adjusted only gradually toward the desired position. For much of this paper, the term “interest rate smoothing” will be used to include both forms of behavior.

Lowe and Ellis (1997) discuss three possible explanations for this pattern of interest rate smoothing.⁴ First, smooth changes in policy interest rates may have the maximum effect on long-term interest rates. This argument was made by Goodfriend (1991) and is developed more theoretically by Woodford (1999). Goodfriend argues that the central bank is able to communicate its intentions more clearly to participants in the market by generating a smooth path of short-term interest rates, thereby allowing participants to infer future policy actions and build them into long-term rates. The forward-looking behavior of market participants effectively undoes the policymaker’s smoothing behavior (Goodhart, 1999). This suggests that a model that directly incorporates long-term interest rates and accurately reflects the formation of market participants’ expectations may generate a smoother path for policy interest rates.

Similarly, the relative infrequency of policy changes may increase the impact of policy announcements when they do occur. Lowe and Ellis (1997) provide some support for this hypothesis by finding that the effect of policy announcements on consumer sentiment in Australia is nonlinear. That is, the announcement of the policy change itself has an effect on consumer sentiment, irrespective of the size of

3. Conventionally, the decisionmaking bodies of most central banks meet at most once a month, thereby providing a bound on the frequency of policy changes. Multiple intermeeting policy changes are extremely rare.

4. Other strands of literature consider smoothing in terms of the seasonal movements in interest rates (Mankiw and Miron, 1991) and in terms of the optimal inflation tax (Mankiw, 1987, and Barro, 1989), which will not be discussed here.

the change. They also find some evidence that the shift to explicit policy announcements in Australia in the early 1990s was associated with a larger impact on consumer sentiment than previously.

The second explanation for smoothing that Lowe and Ellis consider is that policymakers may dislike frequent reversals in the path of official interest rates because such behavior might undermine public confidence in the monetary authorities and create instability in financial markets (Goodfriend, 1987, and Cukierman, 1996). For example, Goodhart (1999) cites a description of the recent behavior of the Bank of England's Monetary Policy Committee (itself far from the near random walk implied by economic models) as "almost laughable... like a drunk staggering from side to side down the street." Furthermore, the criticism that the committee's actions were "fickle" and "influenced by the latest anecdotal or statistical evidence, swaying its opinions one way or the other and back again" would be an accurate description of the policy outcomes if the committee were to follow the dictates of an optimizing macroeconomic model.

This rationale for smoothing is difficult to test because few instances are recorded of central banks pursuing a policy that resulted in volatile rates.⁵ Nevertheless, to investigate this hypothesis, Lowe and Ellis (1997) examine whether long-term bond yields are more volatile around periods when there are policy reversals. They find that there is some evidence of increased volatility in Australia, the United Kingdom, and the United States, but that it is generally short-lived. However, if central banks were to move to a regime where reversals were more commonplace, volatility might decline. This would particularly be the case if financial market participants had a good understanding of the central bank's reaction function.

The third explanation is that the nature of the monetary policy decision process requires that the central bank build a consensus before a change in interest rates can be adopted (Goodhart, 1996). As the evidence to defend a particular action may often only accumulate slowly, the consensus building process might likewise be drawn out. This may particularly be the case where the monetary policy decision is made by a committee rather than by a single policymaker (Blinder, 1995b).

5. The disinflation in the United States in the early 1980s is one such period, although the instrument of monetary policy at the time was nonborrowed reserves rather than a short-term interest rate. Interestingly, Mayer (1999) cites fears of generating instability in financial markets as a possible explanation for "excessive" smoothing by the Federal Reserve in the 1970s.

More formally, this infrequency of policy changes can also be motivated by Dixit-Pindyck uncertainty considerations. If there are costs in implementing policy changes, then in an uncertain world there is an option value to waiting and not reacting to each piece of economic information as it comes to hand (Eijffinger, Schalling, and Verhagen, 1999).

Nevertheless, if policymakers took the evidence of the economic model at face value, that evidence should be sufficient to justify a policy decision. The fact that this does not occur suggests that the economic models are lacking some critical ingredients. In the next section we discuss the ingredient of uncertainty.

2. UNCERTAINTY AND SMOOTHING

The long-standing explanation for the observed smoothness of official interest rates is that policy decisions are made under uncertainty. Until recently this factor was rarely taken explicitly into account in policy models, because additive (mean-zero) shocks were generally the only form of uncertainty considered. Because most models assumed a quadratic objective function for policy (most commonly, squared deviations of inflation from target and of output from potential) and that the economy is linear and its structure known to the policymaker, certainty equivalence implied that the policymaker's uncertainty about future shocks would not affect the policy decision.

More recently, however, Brainard's (1967) discussion of uncertainty has been seriously reconsidered. Brainard noted that although certainty equivalence implies that additive uncertainty provides no justification for smooth adjustment of policy, multiplicative uncertainty can. In this section we discuss four different forms of multiplicative uncertainty—parameter uncertainty, model uncertainty, mean-parameter uncertainty, and data uncertainty—and their impact on policy outcomes. There is not much difference among the first three forms of uncertainty, but the small distinction is useful for expository purposes.

2.1 Parameter Uncertainty

Brainard focused explicitly on uncertainty about the parameters in the model that describes the economy. In particular, there may be uncertainty about the impact of interest rate changes on output and

inflation. In this environment the policymaker has to trade off, on the one hand, the desire to return these variables to their target values as quickly as possible, and on the other, the desire to minimize the risk of increased volatility in output and inflation that arises because policy changes might have a larger impact than expected. As a consequence, in the one-period model that Brainard uses, the policymaker moves interest rates by less to return inflation and output to their targets than if there were no uncertainty.

The presence of parameter uncertainty does not necessarily imply that the policymaker should be less aggressive (that is, produce a smoother path of official rates), particularly when there is uncertainty about more than one parameter. Whether or not it does is essentially an empirical question. Using a model of the Australian economy, Shuetrim and Thompson (1999) find that uncertainty about the economy's dynamics can increase the activism of policy, depending on the location of the uncertainty. In the U.S. context, Weiland (1998) also argues that uncertainty-induced caution does not allow the policymaker the benefit of experimentation to better learn the true structure of the economy. In a nonlinear world, such experimentation may be particularly costly.

In contrast, Sack (1998) finds that introducing parameter uncertainty into a vector autoregressive (VAR) model of the U.S. economy reconciles much of the difference between the observed path of the federal funds rate and that implied by a VAR model without such uncertainty. Martin and Salmon (1999) replicate these results for the United Kingdom. In each case, however, as the aim of the exercise was to reconcile the estimated path of official interest rates with the path that actually occurred, although parameter uncertainty was taken into account, only the observed path of additive shocks was considered.

2.2 Model Uncertainty

More fundamentally, the policymaker may be uncertain about the model that best describes the economy. One could regard this as encompassing parameter uncertainty. The omitted variables in the model should have insignificant coefficients. A general form of model uncertainty would then consider the possibility that these parameters are in fact significant.

Blinder (1995a) provides a simple solution to this dilemma: "use a wide variety of models and don't ever trust any one of them too much."

Sargent (1998) and Onatski and Stock (1999) address this proposal more technically and find that such uncertainty generally results in a more aggressive approach, as the policymaker seeks to avoid worst-case outcomes.

Both the latter analyses address the issue of “robust” control across a range of possible models of the economy rather than optimal control within one particular model. Sargent describes the policymaker’s decision process in such a world as “planning against [the worst, thereby] assuring acceptable performance under a range of specification errors” (1998, p. 5). That is, the policymaker practices disaster avoidance. Whether this cautious approach implies more or less aggressive policy actions, Sargent argues, depends on the nature of the disasters to be avoided. Of relevance to the results obtained below, Onatski and Stock (1999) find that the possibility that monetary policy might have almost no effect prompts a more aggressive response.

A similar consideration of robust control in the context of monetary policy rules has long been advocated by McCallum (see especially McCallum, 1988). He argues that the robustness of a monetary policy rule across different economic models is a crucial characteristic in determining the rule that the central bank should follow. However, robustness of this sort has generally been examined in an environment of additive uncertainty; the parameter uncertainty within each model has not been taken into account (see, most notably, the volume edited by Bryant, Hooper, and Mann, 1993).

2.3 Mean-Parameter Uncertainty

A variant on the two previous forms of uncertainty is mean-parameter uncertainty (Rudebusch, 1999). Here the focus is on the significant parameters within a particular model. Parameter uncertainty implies that, for example, the effect of interest rates on economic activity is (normally) distributed about a given mean. Thus there is only a small possibility that interest rates will have an impact that is surprisingly large. In practice, however, the policymaker may believe that the average impact of interest changes is considerably larger than that implied by the model, perhaps because the model is misspecified.

In a deterministic world, the higher mean effect of policy implies that policy will be less aggressive than that implied by the (misspecified) model. If there is also parameter uncertainty, the result is not so

clear cut. This is most easily seen in the following variant of the Svensson (1997) model discussed by Batini, Martin, and Salmon (1999):

$$y_t = -\bar{E}i_{t-1} + \varepsilon_t ,$$

$$\pi_t = D\pi_{t-1} + y_{t-1} ,$$

where y is output, i is the policy interest rate, and π is inflation.

If reducing inflation is the sole objective of monetary policy, the optimal interest rate is given by

$$i_t = \frac{\bar{a}\bar{b}}{\bar{b}^2 + \sigma_b^2} \pi_t ,$$

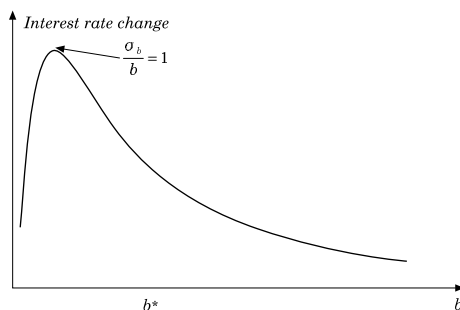
where $\bar{a}$ and $\bar{b}$ are the means of the parameters in the two equations, and σ_b^2 is the variance of b .

In this model, whether an increase in average interest rate sensitivity (an increase in $\bar{E}$) increases or decreases the aggressiveness of monetary policy depends on whether the coefficient of variation $\sigma_b/\bar{b}$ (the inverse of the t -statistic) is greater than or less than one. If the interest rate term is significant (b^* in figure 2), the coefficient of variation is less than 1, and hence an increase in interest rate sensitivity (an increase in b) decreases the aggressiveness of monetary policy.

Conversely, if we decrease the interest rate sensitivity parameter (while maintaining the same degree of uncertainty about it), initially this will increase the aggressiveness of monetary policy. However, once the mean of the parameter is less than one standard deviation from zero, further declines in it will actually decrease policy aggressiveness. This comes about because the costs of “perverse” outcomes, whereby an increase in interest rates leads to an increase in inflation, are large enough to offset the benefits of the “normal” case of an increase in interest rates leading to a decrease in inflation. These arguments are illustrated in figure 2, which plots the interest rate change against the mean value of the interest rate sensitivity parameter b .

In a number of countries, the estimated effect of changes in official rates on output and inflation might be regarded as small, particularly given the media exposure that surrounds each small change in interest rates. This suggests that the general public and financial

Figure 2. Mean Parameter Uncertainty and Interest Rate Changes



markets, as well as policymakers, may believe that the effect is indeed larger than empirically estimated.

Table 2 summarizes the effect of a sustained 50-basis-point change in policy rates as estimated in representative macroeconomic models of the United States, the United Kingdom, and Australia. The individual impact of any one change is not particularly large. However, as discussed in section 1, if the public or financial markets see such a change as the first of a sequence of changes in the same direction, their perception of the effect of the change may incorporate the expected impact of the future changes as well.

The existing empirical work has generally not addressed the issue of mean-parameter uncertainty. Rudebusch (1999) finds that mean uncertainty about the interest rate sensitivity of output or about the persistence of inflation has some impact on the aggressiveness of policy, but that mean uncertainty about the slope of the Phillips curve or output persistence has little impact.

2.4 Data Uncertainty

Finally, data revisions may imply that the policymaker is uncertain about the current economic situation. In the absence of other uncertainty, data revisions are just another source of additive uncertainty, and hence certainty equivalence implies that they should have no impact on the policy decision. Thus the inclusion of data uncertainty will not affect the optimal policy benchmark. However, if Taylor rules are used as the benchmark for policy, data revisions

Table 2. Effect of a Sustained 50-Basis-Point Reduction in the Policy Interest Rate in Australia, the United States, and the United Kingdom (percentage points, relative to baseline)

<i>Country</i>	<i>After four quarters</i>	<i>After eight quarters</i>
Australia		
Effect on GDP growth	0.26	0.35
Effect on inflation	0.18	0.33
United States		
Effect on GDP growth	0.30	0.55
Effect on inflation	0.10	0.30
United Kingdom		
Effect on GDP growth	0.23	0.53
Effect on inflation	0.13	0.51

Source: For the United States, Reifschneider, Tetlow, and Williams (1999); for the United Kingdom, Bank of England (1999); for Australia, derived from the model described in Lowe and Ellis (1997).

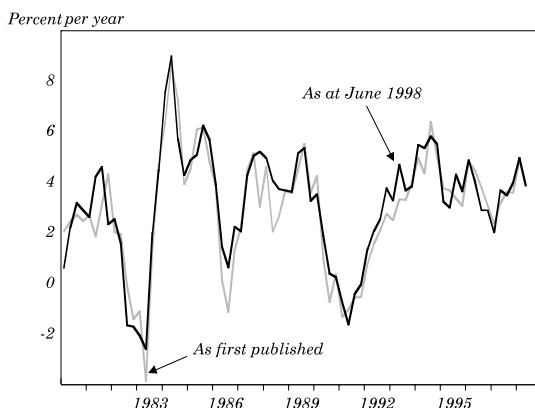
will play a role, because certainty equivalence no longer applies (Orphanides, 1998).

In Australia, as in most countries, one important source of data uncertainty is revisions to GDP. Figure 3 shows the divergence between the first published estimate of GDP growth over the preceding four quarters and the current estimate for the same period.⁶ If one were to compare the first published estimate of the *level* of GDP with the most recent estimate, the divergence would be even greater, because in Australia revisions to GDP are, on average, upward.

For the policymaker and for policy models that incorporate a Phillips curve-type supply side, this poses particular problems for the estimate of the output gap. Estimating potential output is problematic even in the absence of revisions to the estimate of actual GDP. Orphanides (1998) shows that introducing real-time output gap uncertainty into a model of U.S. monetary policy results in a policy that is considerably less aggressive than that implied by a policy rule that ignores such considerations. Rudebusch (1999) finds that data uncertainty reduces the aggressiveness of policy toward deviations of inflation and output from target in a Taylor rule. More fundamentally, Isard, Laxton, and Eliasson (1999) consider the performance of various monetary policy rules in a nonlinear model of the U.S. economy with uncertainty about the output gap and find that Taylor-type rules are generally not robust.

6. This draws on work by Lyndon Moore, Reserve Bank of Australia.

Figure 3. Initial and Revised Estimates of GDP Growth in Australia^a



Source: Reserve Bank of Australia.

a. Estimates are for the four quarters preceding the initial estimate.

3. MODEL AND METHODOLOGY

To investigate the impact of the various forms of uncertainty just described, we use as our benchmark the path of interest rates that results from the optimization of a small macroeconomic model of the Australian economy. (See the appendix for a full description of the model.) The model is a slightly simpler version of that used in Lowe and Ellis (1997), although the impacts of interest rate changes on output and inflation are comparable.

The objective function for monetary policy is the standard weighted average of squared deviations of inflation from the target, and of output from potential. In adopting this as the objective function, we assume that the paths of official interest rates described in section 1 were set by policymakers with such an objective function in mind.

The transmission of monetary policy occurs through two channels: directly through the impact of short-term interest rates on output,⁷ and indirectly through the impact of exchange rate changes on

7. Empirical work has generally been unable to uncover any significant link between long-term interest rates and economic activity in Australia. Hence the rationale for smoothing discussed by Goodfriend (1991) and Woodford (1999) is not captured in this model.

output and on imported-goods prices. In the model, short-term interest rates affect output with a two-quarter lag. In more fully specified models of Australian GDP, the lag tends to be between two and six quarters (Gruen, Romalis, and Chandra, 1999). The output gap, in turn, affects inflation directly one quarter later, and indirectly through its impact on unit labor costs in a wage Phillips curve. The effect of the output gap on unit labor costs is larger than that directly on inflation, so that the effect of the output gap on unit labor costs is the main channel through which monetary policy can have permanent effects on the inflation rate.

The exchange rate responds to changes in interest rates with a lag of one quarter. This then causes a contemporaneous movement in imported-goods prices, which feeds into inflation a further quarter later. Imported-goods prices account for around 40 percent of the consumer price basket. A 10 percent depreciation of the domestic currency leads to about a 1-percentage-point increase in the year-ended inflation rate after one year.

To introduce multiplicative and additive uncertainty into the model, we need distributions for the parameters in the model and the shocks to each equation, respectively. The parameter distributions⁸ were formed from the variance-covariance matrix for each equation. The distribution of the shocks for each equation was derived from the residuals obtained from estimating each equation over the sample period 1985-98, allowing for covariance in the residuals across equations.

The optimal policy response could, in theory, be calculated at this stage. However, as this was not analytically tractable, we derived numerical solutions. To examine the effect of parameter uncertainty, a set of fifty parameter draws was taken from a normal distribution for each of the parameters of interest.⁹ Then the economy was subjected to an additive shock in each equation, every period for a total of fifty periods. Using the approach outlined in Shuetrim and Thompson (1999), we calculated the optimal stance of policy every period under the assumption that there were no future shocks.¹⁰ This

8. We did not allow for covariance across the equations in the parameter distributions, so the system variance-covariance matrix of the parameters is block-diagonal.

9. We do not allow for learning by the policymaker about the parameters of the model.

10. The zero bound on nominal interest rates was not enforced during the simulations. Orphanides and Wieland (1998) investigate the implications of such a constraint.

procedure was then repeated for another forty-nine sets of additive shocks, thereby generating fifty simulated paths for the official interest rate, each fifty periods long.

To summarize the smoothness of official interest rates, we are interested in the average absolute change in short-term interest rates in each path. The variability of interest rates is measured by the standard deviation of the absolute change in the short-term official interest rate. The distribution of this statistic is not normal; hence we report the median absolute change in the interest rates, in addition to the average change.

4. RESULTS

The benchmark for interest rate variability we use is that which results from the inclusion in the model of additive uncertainty only. As can be seen in table 3, under additive uncertainty, the path of official interest rates generated by the model is extremely volatile compared with that observed in practice. The average change in official interest rates is also considerably greater than observed in practice. Official interest rates were changed by an average of 8 percentage points each quarter, and the standard deviation of these changes was around 5.6 percentage points.¹¹ Figure 4 shows the distribution of the average absolute interest rate change that resulted from each of the fifty draws and illustrates the positive skew in the distribution. Here, as in all the other simulations discussed in this section, the paths of official interest rates that are generated exhibit minimal (if any) serial correlation, in contrast to what is observed in practice. That is, none of the forms of uncertainty discussed here are able to explain the relative frequency of continuations and reversals in policy changes.

4.1 Parameter Uncertainty

Table 4 summarizes the results of analyses in which uncertainty about the parameters is incorporated into the model. At this stage there is no mean uncertainty: the policymaker assumes that the mean

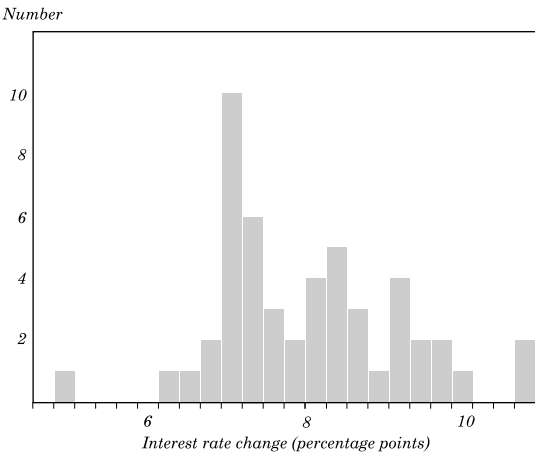
11. Arguably, other parameters in the model might change quite significantly if such a volatile pattern of interest rate changes were the norm.

Table 3. Effect of Additive Uncertainty on Interest Rate Variability (percentage points)

	<i>Observed volatility^a</i>		<i>Model with additive uncertainty only</i>
	<i>Real</i>	<i>Nominal</i>	
Absolute change in official interest rates $ \Delta r $			
Mean	0.85	0.87	8.0
Median	0.57	0.71	6.8
Standard deviation of change in official interest rates			
Mean	0.9	0.9	5.8
Median	0.9	0.9	5.6

Source: Authors' calculations.
a. Over the period 1985-99.

Figure 4. Frequency Distribution of Average Absolute Interest Rate Changes in Australia



Source: Authors' calculations.

Table 4. Effect of Parameter Uncertainty on Interest Rate Variability (percentage points)

	Form of uncertainty					
	Additive only	Full parameter	Interest rate sensitivity of output	Phillips curve term in wage equation	Relative importance of domestic and imported inflation	Adjustment of output to potential in output equation
Absolute change in official interest rates $ \Delta r $						
Mean	8.0	8.4	7.7	8.0	8.0	8.1
Median	6.8	7.1	6.5	6.8	6.8	6.8
Standard deviation of change in official interest rates						
Mean	5.8	6.1	5.6	5.8	5.8	5.8
Median	5.6	6.1	5.5	5.6	5.6	5.7

Source: Authors' calculations.

of each parameter is as estimated in the model. We did not allow for uncertainty about every parameter in the model, but rather focused on the ten main parameters of the model in the output, inflation, unit labor cost, import price, and real exchange rate equations. The table shows that the introduction of "full" parameter uncertainty does not greatly affect the variability in policy interest rates compared with that when only additive uncertainty is considered; in fact, that variability marginally increases. Uncertainty about the sensitivity of output to interest rate changes seems to decrease interest rate variability only slightly.

These results are in contrast to those in Sack (1998) and Martin and Salmon (1999), where parameter uncertainty increased the smoothness of policy substantially. One possible explanation for the difference in findings is that, as Shuetrim and Thompson (1999) demonstrate empirically and Soderstrom (1999) demonstrates analytically, whether parameter uncertainty increases smoothness depends on the nature of the uncertainty and its interaction with the lag structure of the economy. In addition, Sack and Martin and Salmon use the actual path of shocks (according to their models) that affected the U.S.

and U.K. economies to derive their results, whereas here we use multiple paths.

Consequently, we conducted an exercise similar to that of Sack and of Martin and Salmon by simulating the model with the observed residuals over the sample period, and then introducing the various forms of uncertainty. Table 5 summarizes the results. Interest rate variability is considerably reduced when only the path of historical shocks is considered. The second column of the table shows that, in this instance, full parameter uncertainty increases interest rate volatility, but if there is only uncertainty about the sensitivity of output to the interest rate, interest rate volatility is approximately unchanged.

Interest rate variability is lower with the historical shocks than with most of the draws shown in figure 4, because the actual path of the shocks matters. The historical shocks are not completely random, unlike those that underpin figure 4. The draws in our simulations are taken from a normal distribution with no serial correlation. The historical shocks have no significant serial correlation and are not significantly different from a normal distribution (in most cases), but have sufficient nonnormality and serial correlation to generate the results in table 5.

To further narrow down the interaction of additive and parameter uncertainty, we performed a set of simulations in which there was uncertainty only about the interest rate sensitivity parameter

Table 5. Effect of Parameter Uncertainty with Historical Shocks on Interest Rate Variability (percentage points)

	<i>Form of uncertainty</i>		
	<i>Additive only</i>	<i>Full parameter</i>	<i>Interest rate sensitivity of output</i>
Absolute change in official interest rates $ \Delta r $			
Mean	4.3	4.8	4.3
Median	3.9	4.0	4.1
Standard deviation of change in official interest rates			
Mean	2.8	3.0	2.9
Median	2.8	3.0	2.9

Source: Authors' calculations.

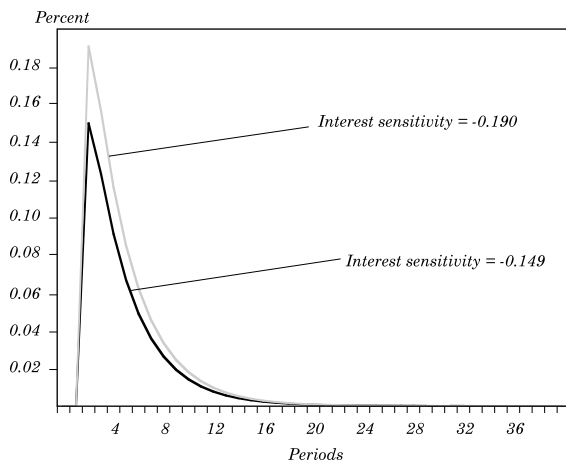
and the shock in the output equation (results not shown). In this instance, interest rate variability was reduced when there was uncertainty about the interest rate parameter, a result similar to that found by Rudebusch (1999). This again highlights that the exact nature of the uncertainty affects the conclusions that can be drawn about the implications of uncertainty for interest rate volatility.

4.2 Mean-Parameter Uncertainty

The above results assume that the policymaker believes that the mean effect of interest rate changes on, say, output is the same as that implied by the model estimated with the historical data. Next we allow the parameters in the economy to have different means from those in the estimated model and allow the policymaker to realize this fact, while still maintaining the same degree of uncertainty (that is, the variance of the parameter is not affected by a shift in its mean).

We focus particularly on the effect of interest rate changes on output. First, we increase the impact of interest rate changes on output by one standard deviation. That is, interest rate changes are now more powerful, and the policymaker is aware of that fact. Figure 5 shows the impulse response of output to a 1-percentage-point change

Figure 5. Impulse Response of Output in Australia with Differing Interest Rate Sensitivities



Source: Authors' calculations.

in official rates under the estimated and the new parameter values: -0.15 and -0.19 , respectively.

As noted in section 2, whether increases in mean interest rate sensitivity increase policy smoothness depends on the coefficient of variation. Here, because the interest rate term is significant, one would expect that an increase in interest rate sensitivity would increase smoothness. The third and fourth columns of table 6 suggest that this is certainly the case. Interest rate volatility is reduced by around 25 percent with a one-standard-deviation increase in interest rate sensitivity. A two-standard-deviation increase in interest rate sensitivity decreases interest rate volatility even further. If, on the other hand, interest rate sensitivity is *reduced* by two standard deviations, interest rate volatility is substantially increased. The reason is that, in this instance, the economy is extremely insensitive to interest rate changes (the coefficient is close to zero).

These results illustrate the analysis in section 2.3. As further evidence of this, figure 6 traces out the optimal interest rate response to a temporary 1 percent increase in output as the interest rate parameter is varied, that is, as the interest rate sensitivity of the economy is changed. The graph traces out a curve similar to that obtained analytically in figure 2.

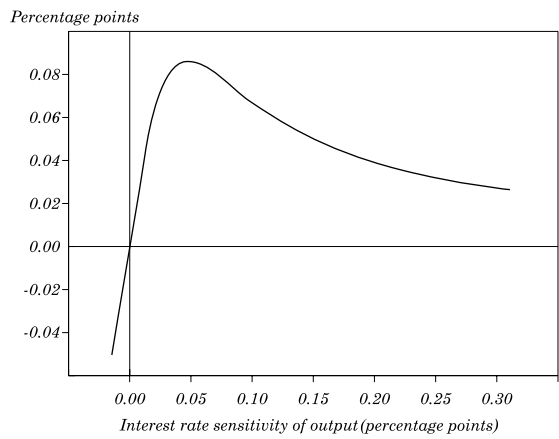
Figure 7 shows the frequency distribution of the average absolute change in official interest rates in each path. It shows the lower interest rate volatility in each of the paths compared with that illustrated in figure 4.

Table 6. Effect of Mean-Parameter Uncertainty on Interest Rate Variability (percentage points)

			<i>Change in mean interest rate sensitivity</i>		
	<i>Additive only</i>	<i>Interest rate sensitivity parameter</i>	<i>One standard deviation larger</i>	<i>Two standard deviations larger</i>	<i>Two standard deviations smaller</i>
Absolute change in official interest rates $ \Delta r $					
Mean	8.0	7.6	6.0	5.0	14.4
Median	6.8	6.5	5.1	4.2	12.2
Standard deviation of change in official interest rates					
Mean	5.8	5.6	4.6	3.6	10.4
Median	5.6	5.5	4.3	3.6	10.4

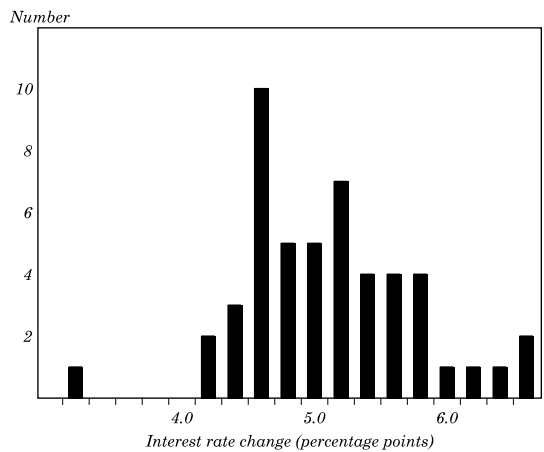
Source: Author's calculations.

Figure 6. Percentage Points Interest Rate Response to an Output Shock in Australia at Varying Interest Rate Sensitivities



Source: Authors' calculations.

Figure 7. Frequency Distribution of Interest Rate Changes in Australia under Mean-Parameter Uncertainty



Source: Authors' calculations.

One caveat to these results is that we have confined mean-parameter uncertainty to the interest rate sensitivity of output. A shift in the mean of this parameter may be associated with changes in other equations in the model, thereby offsetting the impact on interest rate volatility. However, reestimating the output equation while imposing the higher interest rate coefficient did not affect the other coefficients significantly, but rather only resulted in larger residuals.

5. CONCLUSION

Policy changes in practice tend to produce a smooth path for interest rates, whereas the optimal path of official interest rates generated by models or policy rules is often considerably more volatile. This paper has investigated whether the inclusion of uncertainty can help reconcile theory with practice. It has shown that, in general, parameter uncertainty does not induce much smoothness when its effects are directly incorporated in the model. However, particular forms of parameter uncertainty may have some impact.

The main finding of the paper is that mean-parameter uncertainty about the interest rate sensitivity of output can reduce the aggressiveness of optimal policy in the model. Thus, if the effectiveness of monetary policy is greater than that suggested by the estimated model *and* the policymaker knows that, policy is likely to be less aggressive. However, the path of policy interest rates is still more volatile than that observed in practice.

An issue not addressed here is whether there are any losses from a smooth path of interest rates. Lowe and Ellis (1997) tentatively conclude that smoother policy does not generate much of an increase in the volatility of inflation and output. Thus, even if the policy approach adopted in most industrial countries has not been optimal because it has been excessively smooth, the costs have not been great. Moreover, there may be costs to increased volatility in interest rates that the model does not capture, which would further reinforce that conclusion.

Finally, the results in this paper are unable to explain the frequency of reversals in the direction of policy, relative to continuations, that is observed in practice. The forms of uncertainty discussed in this paper are unlikely to provide an explanation. A more likely explanation might involve the potential adverse effects on the credibility of the central bank of frequent reversals in the direction of policy.

APPENDIX

A Small Macroeconomic Model of Australia

The model used in this paper is a simplified version of that used by Lowe and Ellis (1997). The motivation for each equation is provided there, along with additional references. The specification of each equation of the model, with diagnostics, is given below. All variables except for the interest rate are expressed as logarithms; interest rates are expressed in annualized terms. Each equation is estimated over the period from 1985 Q1 to 1998 Q4. In our simulations the constants in each equation were calibrated so that the model possessed certain steady-state properties. All numbers in parentheses are standard errors.

Endogenous Variables

The output equation in the model is

$$\Delta y_t = \alpha_1 - \underset{(0.085)}{0.244}(y_{t-1} - y_{t-1}^*) + \underset{(0.120)}{0.064}\Delta y_{t-1} - \underset{(0.041)}{0.149}r_{t-2} ,$$

$$\begin{array}{ll} \text{Adjusted } R^2 = 0.255 , & \text{SE} = 0.007 , \\ \text{Jarque-Bera test: } 1.97 \text{ (p} = 0.37) , & \text{LM(4) test: } 1.09 \text{ (p} = 0.37) , \\ \text{DW} = 2.09. & \end{array}$$

where y is real nonfarm output, y^* is potential output, and r is the real cash rate.

The price equation is

$$\begin{aligned} \Delta p_t = & \alpha_2 - \underset{(0.010)}{0.088}p_{t-1} + \underset{(0.013)}{0.068}ulc_{t-1} + \underset{(0.004)}{0.020}pm_{t-1} \\ & + \underset{(0.021)}{0.107}(y_{t-1} - y_{t-1}^*) , \end{aligned}$$

$$\begin{array}{ll} \text{Adjusted } R^2 = 0.864 , & \text{SE} = 0.002 , \\ \text{Jarque-Bera test: } 1.12 \text{ (p} = 0.57) , & \text{LM(4) test: } 0.93 \text{ (p} = 0.45) , \\ \text{DW} = 1.68 & \end{array}$$

where p is the level of the underlying consumer price index, ulc is a measure of unit labor costs, and pm is import prices. Prices are modeled as a markup on unit labor costs and imported-goods prices.

The restriction that the coefficients on prices, unit labor costs, and import prices sum to zero was imposed.

The unit labor costs equation is

$$\Delta ulc_t = \underset{(0.475)}{0.848} \Delta p_{t-1} + \underset{(0.475)}{0.152} \Delta p_{t-2} + \underset{(0.078)}{0.303} (y_{t-1} - y_{t-1}^*) \\ + \underset{(0.197)}{0.135} \Delta (y - y^*)_{t-4} ,$$

Adjusted $R^2 = 0.221$, SE = 0.010 ,
 Jarque-Bera test: 0.368 (p = 0.83) , LM(4) test: 0.57 (p = 0.68) ,
 DW = 2.32.

The unit labor cost equation is a linear Phillips curve incorporating adaptive expectations. The assumption of adaptive expectations has historically provided the best fit for Australian data. The equation was estimated with the restriction that the coefficients on lagged inflation sum to one. This restriction is not rejected by the data. The final term in the equation captures “speed-limit” effects. That is, the speed with which the output gap is closed affects wage pressures in addition to the size of the gap itself.

The import price equation is

$$\Delta pm_t = \alpha_3 - \underset{(0.079)}{0.137} (pm_{t-1} + e_{t-1}) - \underset{(0.045)}{0.601} \Delta e_t ,$$

Adjusted $R^2 = 0.798$, SE = 0.015 ,
 Jarque-Bera test: 2.22 (p = 0.33) , LM(4) test: 0.42 (p = 0.79) ,
 DW = 1.75.

where e is the nominal exchange rate. We assume unitary passthrough of movements in the exchange rate in the long run and that world inflation is zero.

The real exchange rate equation is

$$\Delta rer_t = \alpha_4 - \underset{(0.108)}{0.331} (rer_{t-1} - tot_{t-1}) + \underset{(0.195)}{0.377} r_{t-1} \\ + \underset{(0.121)}{0.749} \Delta cpsdr_t ,$$

Adjusted $R^2 = 0.537$, SE = 0.031 ,
 Jarque-Bera test: 1.64 (p = 0.44) , LM(4) test: 1.25 (p = 0.30) ,
 DW = 1.78.

where rer is the real exchange rate measured using the real trade-weighted index, tot is the terms of trade, and $cpsdr$ is the commodity price index measured in special drawing rights.

Exogenous Variables

The equation for potential output is

$$y_t^* = \alpha_5 + \underset{(0.051)}{0.115} tot_t^* - \underset{(0.035)}{0.075} rer_t^* + \underset{(0.014)}{1.361} y_t^{US} ,$$

where tot^* is the steady-state level of the terms of trade, rer^* is the steady-state level of the real exchange rate, and y^{US} is the level of U.S. real output. For other exogenous variables we assume

$$\Delta tR_t = 0 ,$$

$$\Delta cpsGU = 0 ,$$

$$\Delta y_t^{US} = 0.00625 .$$

Identities and Definitions

Assuming foreign inflation is zero, the nominal exchange rate is

$$\Delta e_t = \Delta \mathcal{E}U - \Delta p_t .$$

The real cash interest rate is defined as

$$U_t = i_t - \Delta_4 p_t ,$$

where $\Delta_4 p_t = p_t - p_{t-4}$.

REFERENCES

- Bank of England. 1999. *Economic Models at the Bank of England*.
- Barro, R. 1989. "Interest-Rate Targeting." *Journal of Monetary Economics* 23(1): 3-30.
- Batini, N., B. Martin, and C. Salmon. 1999. "Monetary Policy and Uncertainty." *Bank of England Quarterly Bulletin* 39(2): 183-89.
- Blinder, A. 1995a. "Central Banking in Theory and Practice. Lecture I: Targets, Instruments, and Stabilization." Washington: Board of Governors of the Federal Reserve System.
- . 1995b. "Central Banking in Theory and Practice. Lecture II: Credibility, Discretion, and Independence." Marshall Lecture presented at Cambridge University.
- Brainard, W. 1967. "Uncertainty and the Effectiveness of Policy." *American Economic Review* 57(2): 425-41.
- Bryant, R., P. Hooper, and C. Mann. 1993. *Evaluating Policy Regimes*. Washington: Brookings Institution.
- Cukierman, A. 1996. "Why Does the Fed Smooth Interest Rates? In *Monetary Policy on the 75th Anniversary of the Federal Reserve System*, edited by M. Belongia. Norewell, Mass.: Kluwer Academic Publishers.
- Eijffinger, S., E. Schalling, and W. Verhagen. 1999. "A Theory of Interest Rate Stepping: Inflation Targeting in a Dynamic Menu Cost Model." CEPR Discussion Paper 2168. London: Centre for Economic Policy Research.
- Goodfriend, M. 1987. "Interest Rate Smoothing and Price Level Trend-Stationarity." *Journal of Monetary Economics* 19: 335-48.
- . 1991. "Interest Rates and the Conduct of Monetary Policy." *Carnegie-Rochester Conference Series on Public Policy* 34: 7-30.
- Goodhart, C. 1996. "Why Do the Monetary Authorities Smooth Interest Rates?" LSE Financial Markets Group Special Paper 81. London: London School of Economics.
- . 1999. "Central Bankers and Uncertainty." *Bank of England Quarterly Bulletin* 39(1): 102-14.
- Gruen, D., J. Romalis, and N. Chandra. 1999. "The Lags of Monetary Policy." *Economic Record* 75: 280-94.
- Isard, P., D. Laxton, and A-C. Eliasson. 1999. "Simple Monetary Policy Rules Under Uncertainty." IMF Working Paper 75. Washington: International Monetary Fund.

- Lowe, P., and L. Ellis. 1997. "The Smoothing of Official Interest Rates." In *Monetary Policy and Inflation Targeting*, edited by P. Lowe. Sydney: Reserve Bank of Australia.
- Mankiw, G. 1987. "The Optimal Collection of Seigniorage: Theory and Evidence." *Journal of Monetary Economics* 20(2): 327-41.
- Mankiw, G., and J. Miron. 1991. "Should the Fed Smooth Interest Rates? The Case of Seasonal Monetary Policy." *Carnegie-Rochester Conference papers on Public Policy* 34: 41-70.
- Martin, B., and C. Salmon. 1999. "Should Uncertain Monetary Policy-Makers Do Less?" Bank of England Working Paper 99. London: Bank of England.
- Mayer, T. 1999. *Monetary Policy and the Great Inflation in the United States*. London: Edward Elgar.
- McCallum, B. 1988. "Robustness Properties of a Rule for Monetary Policy." *Carnegie-Rochester Conference papers on Public Policy* 29: 173-203.
- Onatski, A., and J. Stock. 1999. "Robust Monetary Policy under Model Uncertainty in a Small Model of the U.S. Economy." Paper presented at the CEPR-Stanford University Conference on Monetary Policy and Monetary Institutions, March 5-6.
- Orphanides, A. 1998. "Monetary Policy Evaluation with Noisy Information." Federal Reserve System Finance and Economics Discussion Series 1998-50. Washington: Federal Reserve.
- Orphanides, A., and V. Weiland. 1998. "Price Stability and Monetary Policy Effectiveness When Nominal Interest Rates are Bounded at Zero." Federal Reserve System Finance and Economics Discussion Series 1998-35. Washington: Federal Reserve.
- Reichsneider, D., R. Tetlow, and J. Williams. 1999. "Aggregate Disturbances, Monetary Policy, and the Macroeconomy: The FRB/US Perspective." *Federal Reserve Bulletin* 85(1): 1-19.
- Rudebusch, G. 1995. "Federal Reserve Interest Rate Targeting, Rational Expectations and the Term Structure." *Journal of Monetary Economics* 35(2): 245-74.
- . 1999. "Monetary Policy in an Uncertain World." Federal Reserve Bank of San Francisco Working Papers in Applied Economic Theory 99-05. San Francisco: Federal Reserve Bank of San Francisco.
- Sack, B. 1998. "Does the Fed Act Gradually? A VAR Analysis." Federal Reserve System Finance and Economics Discussion Series 1998-17. Washington: Federal Reserve.

- Sargent, T. 1998. "Discussion of Policy Rules for Open Economies." In *Monetary Policy Rules*, edited by J. Taylor. Chicago: University of Chicago Press.
- Shuetrim, G., and C. Thompson. 1999. "The Implications of Uncertainty for Monetary Policy." Reserve Bank of Australia Research Discussion Paper 1999-10. Sydney: Reserve Bank of Australia.
- Soderstrom, U. 1999. "Monetary Policy with Uncertain Parameters." Sveriges Riksbank Working Paper 83. Stockholm: Sveriges Riksbank.
- Svensson, L. 1997. "Inflation Forecast Targeting: Implementing and Monitoring Inflation Targets." *European Economic Review* 41(6): 1111-46.
- Weiland, V. 1998. "Monetary Policy and Uncertainty about the Natural Unemployment Rate." Federal Reserve System Finance and Economics Discussion Series 1998-22. Washington: Federal Reserve.
- Woodford, M. 1999. "Optimal Monetary Policy Inertia." Paper presented at the CEPR-Stanford University Conference on Monetary Policy and Monetary Institutions, March 5-6.

MONETARY POLICY IN CHILE: A BLACK BOX?

Ángel Cabrera
FORECAST S.A.

Luis Felipe Lagos
Pontificia Universidad Católica de Chile

During the 1990s the Chilean economy gradually cut its inflation rate from figures in the thirties to 4.7 percent in 1998. Central bank authorities have declared that the main objective of monetary policy is to reduce inflation to levels comparable to those in industrial countries. The designated instrument of that monetary policy has been an indexed interest rate,¹ through which the central bank has sought to influence the path of real market rates over different time horizons. These market rates, in turn, are believed to have influenced the behavior of spending and aggregate production, thereby managing the inflationary process in a manner consistent with the proposed stabilization goals. This apparent success deserves a closer look, because, in the words of Robert Lucas (1996), “Central bankers and even some monetary economists talk knowledgeably of using high interest rates to control inflation, but I know of no evidence from even one economy linking these variables in a useful way.”

Several earlier studies of the Chilean economy have confirmed the lack of solid empirical evidence of a systematic relationship between inflation and interest rates (see appendix B). Also, in those cases where some statistical support exists for such a relationship,

The authors thank Sergio Quintana for his cooperation in econometric issues and data processing. They also appreciate the comments of Klaus Schmidt-Hebbel and the attendees of the Third Annual Conference of the Central Bank of Chile and of a seminar at the Pontifical Catholic University's Economics Institute.

1. The central bank's ninety-day rate was used until 1995. The one-day interbank rate has been in use since then.

Monetary Policy: Rules and Transmission Mechanisms, edited by Norman Loayza and Klaus Schmidt-Hebbel, Santiago, Chile. ©2002 Central Bank of Chile.

the transmission mechanism is not specified satisfactorily. It is frequently argued that increases in policy interest rates allow the gap between the growth rates of aggregate spending and GDP, or between actual and potential GDP, to be reduced, thereby decelerating inflation. However, monetary theory states that the path of inflation must be linked to a nominal variable. Therefore, in order to understand the connection between interest and inflation rates, it is necessary to study the transmission mechanism of monetary policy, including the relevant nominal variables.

This paper analyzes Chilean monetary policy during the 1986-97 period, identifying the instruments, intermediate targets, and goals defined by the central bank. This analysis allows us to determine and study the central bank's reaction function empirically. Different transmission mechanisms are reviewed in an effort to reach a better understanding of the central bank's reaction function; these mechanisms are empirically evaluated using the structural vector autoregressive (VAR) methodology. We have chosen VAR as our econometric tool in this paper in order to make our results comparable with those of a number of earlier studies. However, as will be explained in detail below, recent international literature shows categorically the need to complement the traditional VAR approach with identification assumptions based on theory and on institutional considerations, thereby creating what are now known as structural VAR systems.

The paper is organized as follows. Section 1 is a conceptual discussion of monetary policy administration and the reaction function used by the central bank during 1986-97. Section 2 analyzes different possible transmission mechanisms of Chilean monetary policy. Section 3 reviews the structural VAR methodology, presents empirical results, and offers some interpretations. Section 4 concludes.

1. MONETARY POLICY MANAGEMENT IN CHILE: INSTRUMENTS AND GOALS

During the 1986-98 period Chilean monetary policy considered the use of various instruments and intermediate objectives in order to achieve certain goals. Instruments are those variables that the central bank can control directly. Intermediate objectives, in turn, are those variables not controlled closely by the monetary policymakers, but whose behavior may be altered, with a certain lag, by using

the instruments. These intermediate objectives are supposedly closely related to the end goals that the central bank would like to achieve.

1.1 Goals

According to the law governing the central bank's operations, the goals of the central bank are currency stability, a stable internal payments system, and the normal operation of the external payments system. The first goal has been construed as meaning control of inflation, even though the law suggests that it should be conceived as price level stability.

The objective of a stable domestic payments system has been addressed through explicit guarantees granted to bank deposits (up to a certain limit). These guarantees, although not provided directly by the central bank, are backed by it as the lender of last resort.

Finally, external payments stability has been thought of as meaning the maintenance of a sustainable current account deficit.² Given the past experience of the Chilean and other economies, the central bank has theorized that this deficit should not exceed 3 to 4 percent of GDP on average. To do otherwise, the central bank believes, would sooner or later result in speculative attacks against the domestic currency and a capital outflow, forcing the country into a costly adjustment. In addition, the goal of external payments stability has been interpreted as maintaining a certain level of stability of the real exchange rate—the other side of the current account deficit coin.

Over the years the central bank has changed the relative importance it assigns to each of these goals, along with some degree of what might be called a "crisis mentality," which is a common element in monetary policy management.³ Thus, after the debt crisis of 1982-83, the primary objective was to reduce the current account deficit, and this effort led to a huge adjustment of both private and public spending. At the same time, the objective of a "high and stable" real exchange rate was decided on, to strengthen the export sector and allow the country's huge foreign debt to be repaid. As a result, during the 1980s the objective of low inflation was secondary, subordinated

2. Such an interpretation is questionable. For example, Rosende (1998) argues that this objective cannot be achieved through monetary policy, and that therefore it should be interpreted as having a monetary policy that will not generate an exchange rate crisis or a balance of payments crisis.

3. See Bernanke and Mishkin (1992).

to that for the real exchange rate, until by the end of the decade voluntary capital flowed back in, thereby relaxing the external constraint.

Later, during the 1990s, the central bank's principal objective became the control and gradual reduction of inflation. However, the objectives for the real exchange rate and the current account have remained in place, as demonstrated by the central bank's sustained sterilized intervention in the exchange market during the period, together with the active implementation of controls on capital inflows. Nevertheless, the current account deficit, as corrected by the long-term trend in the terms of trade, has been continually deteriorating since 1993 (table 1).

1.2 Instruments

The variable selected by the central bank for its monetary policy instrument from the mid-1980s to April 1995 was the "UF" or past-CPI-indexed interest rate on its ninety-day obligations, which were auctioned at a fixed rate. The case for using an interest rate as an instrument, and in particular a real rate as opposed to the common central bank practice of using a nominal rate, is related to the variability of the demand for money and to the desire of the central bank to disclose certain information, as argued by Fontaine (1991). Fontaine argues that if the monetary policy objective is informational, then in an indexed economy the best instrument is a real interest rate, since it is clear that nominal rate movements are not always matched by changes in the real rate. Using the nominal rate as a monetary policy instrument in such a situation may give misleading signals to private economic agents. In contrast, the real interest rate is expected not only to determine the path of spending, but also to communicate the central bank's perceptions of the state of the economy in terms of domestic and external equilibrium. Although Fontaine recognizes that the demand for money is stable, its velocity is believed to be highly variable given the huge fluctuations in nominal interest rates caused by the UF mechanism. This makes the use of a monetary aggregate as a monetary policy instrument infeasible and therefore is believed to bias the decision in favor of the real interest rate.⁴

4. However, because the UF rate reflects lagged inflation, interest rates using this indexing mechanism do not strictly correspond to the real interest rate. See Calvo and Mendoza (1997).

Table 1. Current Account Deficit in Chile

Percent of GDP		
<i>Year</i>	<i>Actual</i>	<i>Trend^a</i>
1990	1.9	1.4
1991	-0.4	-1.1
1992	2.0	0.7
1993	5.6	3.6
1994	3.2	3.8
1995	2.1	5.0
1996	5.5	5.3
1997	5.3	6.5
1998	6.5	5.8

Source: Authors' calculations based on Central Bank of Chile data.

a. Using long-term trend in the terms of trade.

Most authors recognize that the instrument actually used has been an interest rate (see appendix A). However, Rosende and Herrera (1991) find that money supply movements are a better predictor of transitory fluctuations in GDP growth than is interest rate variation (see appendix B). This result suggests that, even when it is using the interest rate as an instrument, the central bank monitors the evolution of the money supply. In this regard, Rojas (1993) holds that the monetary authorities have not used a monetary aggregate as an intermediate objective because, although money does affect output in the short run, a stable relationship between money and nominal output exists only for the M2A and M3 aggregates, whose use as intermediate objectives is considered limited by the imperfect control that the central bank has over them.

In May 1995 the central bank decided to change its monetary policy instrument, dropping the ninety-day rate in favor of a shorter-term rate: the interbank one-day rate. The goal was to give the market a greater role in determining medium- and long-term interest rates. Thus the central bank auctions out its ninety-day obligations so that the market determines the interest rate. In this way, expected capital gains (or losses) are prevented from generating sharp changes in term composition, as used to occur when the ninety-day rate was fixed, causing liquidity management problems for the central bank.⁵

5. For a detailed analysis see Budnevich and Pérez (1995).

1.3 Intermediate Objectives

In accordance with the monetary policy transmission mechanisms discussed below, the central bank has used as its main intermediate objectives the spending-output gap and the gap between actual and potential output, both their levels and their growth rates (appendix A). The then-president of the central bank, Roberto Zahler, justified the 1995 interest rate increase with the following argument: "...we must not forget that both aggregates, that is the economic activity and the demand, continue to grow now for the fifth quarter in a row, significantly above conservative estimations on the economy's productive potential increase and, therefore, above its trend level, with the resulting pressures over domestic prices."⁶

On another occasion Zahler stated:

"...it is important to differentiate between output and spending levels and growth rates. When the economy has had several years of growth above its potential, and it is also very near it, it is not enough to go back to growing at the potential output rate. If the appropriate levels are to be recovered, it is necessary to grow at a below-potential pace for some time.... This will permit us to return to the desired path in terms of output and spending levels and reduce inflationary pressures.... Regarding domestic demand, we must note that it has grown so strongly in the past few years that it has gone over the potential output level, pushing prices up and generating pressures on foreign accounts. An adjustment is needed, then, to take the domestic demand to more reasonable levels... we use all kinds of indicators to predict price behavior, such as the aforesaid gap between potential and actual output, the evolution of wages, exchange rates, government spending, credits, money supply, and others." (Zahler, 1994).

For these intermediate instruments to be operational, they must respond to the policy instrument in a predictable way. In other words, an interest rate increase must decelerate the growth rate of spending by more than that of output, in the case of the spending-output gap, and it must decelerate the growth rate of output directly or through slowing spending, in the case of the actual-potential output gap. Thus, for example, Eyzaguirre and Rojas (1996) argue that "Monetary policy

6. Speaking at a seminar on Latin American World Trade and Perspectives for the Year 2000, Santiago, May 9, 1996.

has been based, for over a decade, on the control of the interest rate of some of the financial instruments offered by the Chilean Central Bank. The grounds for this policy have been the influence that these rates have, directly or indirectly, over the expansion rhythm of aggregate spending and thereby on prices, especially of non tradables.”

1.4 Intermediate Objectives and the Central Bank’s Reaction Function

When setting its annual inflation goals and its implicit goals for the trend deficit in the current account (a maximum of 4 percent of GDP at trend prices), the central bank adjusts the interest rate instrument according to the evolution of the intermediate objectives just described. As already noted, the central bank has used as its intermediate objectives the rate of growth of spending with respect to the growth in output (the spending-output gap), and the evolution of actual GDP with respect to potential GDP, considering both their levels and their growth rate. Thus, whenever the monetary authorities have found spending to be growing faster than GDP, or actual GDP to be growing faster than potential GDP, over a few quarters, they have sought to adjust growth in spending through the interest rate instrument. In recent years the manipulation of the interest rate has been related to the application of the well-known Taylor rule (Taylor, 1993). According to this rule, the interest rate is adjusted upward when the inflation rate exceeds the target and/or output is above its potential level, and downward in the contrary case. This rule can be represented by the following equation:

$$dR = aY + b(\Pi - \Pi^*), \quad (1)$$

where dR is the first difference of the interest rate, Y is the output gap,⁷ Π and Π^* stand for the inflation rate and the inflation target, respectively, and a and b are positive parameters.

On the other hand, the literature on inflation targeting emphasizes that the central bank’s expected inflation (that is, its inflation forecast) is the intermediate objective par excellence (Masson, Savastano, and Sharma, 1997). Thus the monetary policy instrument responds to the

7. Measured as the percentage deviation from potential output, or as the spending-output gap.

difference between projected inflation and the inflation target for a specified period. Within this context, the central bank's reaction function is forward-looking, as distinguished from a reaction policy that responds to intermediate objectives as represented by past readings of certain variables. In this approach, the monetary policy's operating method can be depicted by the following function:

$$dI_t = \beta (\Pi_{t+j}^e - \Pi_{t+j}^*), \quad (2)$$

where dI_t is the change in the monetary policy instrument in period t , Π_{t+j}^e and Π_{t+j}^* and represent expected inflation and the inflation target for period $t+j$, respectively. Within this analytical framework, expected inflation is generated from a series of statistical models combining several indicators. Thus the basic difference between this monetary policy model and that described by equation (1) is that the former uses expected rather than past or present inflation to manage the policy instrument.

However, this inflation targeting scheme is compatible with Taylor's monetary rule inasmuch as it can be argued that the output gap is the principal determinant of the central bank's inflation forecasts. Massad (1998) suggests that monetary policy may actually be managed nowadays according to an inflation targeting scheme, considering activity and employment indicators, the spending-output gap, the current account balance, monetary aggregates, wage growth, and the yield curve. This set of indicators supposedly permits the central bank to develop a forecast of the path of core inflation and thereby adjust its instrument according to the gap between the forecasted and the targeted inflation rates.

2. MONETARY POLICY TRANSMISSION MECHANISMS

The channels whereby the real interest rate can affect the final targets for inflation, the current account, and the real exchange rate can take a number of forms. Here we identify five possible transmission mechanisms: the Australian mechanism, the Phillips curve mechanism, the interest rate parity mechanism, the monetarist mechanism, and the credit mechanism.

2.1 The Australian Mechanism

The Australian mechanism takes the so-called Australian model as its theoretical framework.⁸ The model's main assumptions are the following: the economy is a small, open economy that produces and consumes tradable and nontradable goods; capital is a specific factor in both sectors; labor is mobile between sectors and is subject to diminishing returns; the domestic price of the tradable good is determined according to purchasing power parity, the nominal exchange rate, and the international price; and the relative price of nontradables is determined by their supply and demand equilibrium. Within this context, the real exchange rate, defined as the relative price of tradables to nontradables, depends inversely on the level of aggregate spending with respect to output.⁹ The reason is that an increase in spending over output will result in an increase in demand for both tradables and nontradables, thereby creating excess demand in both markets. In the tradable goods market, this will merely result in increased net imports and therefore in a drop in the trade account balance. The excess demand for nontradables, on the other hand, requires an increase in the relative price of those goods in order to achieve equilibrium in the nontradable sector, with a resulting appreciation in terms of the real exchange rate.

Taking a closer look at the version of this model presented in Kamin (1996), these considerations can be expressed algebraically as follows:

$$TCRE_t = a_0 - a_1 \left(\frac{G}{Y} \right)_t, \quad a_1 > 0, \quad (3)$$

$$\pi_t^n = b(TCR_{t-1} - TCRE_{t-1}), \quad b > 0. \quad (4)$$

Substituting equation (3) into equation (4), we have

$$\pi_t^n = -ba_0 + bTCR_{t-1} + ba_1 \left(\frac{G}{Y} \right)_t. \quad (5)$$

8. See, for example, Dornbusch (1980).

9. The equilibrium real exchange rate here is the one that clears the nontradables sector. From a long-term perspective, however, it should also meet the prerequisite that the current account be equal to the sustainable capital account.

Equation (3) reflects the fact that the equilibrium real exchange rate ($TCRE$) in the Australian model is inversely related to the spending-output ratio (G/Y). Equation (4), in turn, indicates that, in the context of a predetermined nominal exchange rate and slow price adjustment, the convergence of the actual real exchange rate (TCR) toward equilibrium takes place through variations in the inflation of nontradables (π^n). From this it follows that inflation of nontradables will depend on the gap between TCR and $TCRE$. Finally, equation (5) shows that the evolution of nontradables inflation is determined by the spending-output ratio and by the actual real exchange rate lagged one period.

Within this analytical framework the exchange rate system will determine how the real exchange rate will adjust, and therefore the effect on the price-level path associated with changes in relative prices. Thus, in a fixed exchange rate system, the appreciation in terms of the real exchange rate takes place through the acceleration of inflation of nontradables.¹⁰ In contrast, if the exchange rate floats, the reduction in the real exchange rate occurs through a nominal appreciation, reducing tradable goods inflation. Therefore the relationship between the spending-output gap and the inflation rate may be either positive or negative, depending on the exchange rate system.

Accordingly, in the context of this model, the relationship between the monetary policy instrument and the inflation rate must go through the spending-output relationship. Thus, if the long-term real interest rate determines the evolution of investment expenses and durable goods consumption, then the manipulation of the short-term interest rate by the central bank, through its effect on long-term rates, can reduce the spending-output gap and increase the equilibrium real exchange rate.¹¹ This, in turn, within a pre-fixed or indexed exchange rate system, will result in reduced inflationary pressures. In this sense it must be kept in mind that during the past

10. Strictly speaking, the exchange rate adjustment to a transitory demand shock may take place through an increase in the price level without a variation in trend inflation. However, in an indexed economy inflation has an inertial component, and therefore any price-level adjustment manifests itself in an increase in inflation. In particular, the inflationary effect associated with a relative price correction will appear especially strong in those cases where indexation affects the nominal exchange rate.

11. In the short run the deceleration in the growth of spending will also translate into reduced GDP growth.

ten years Chilean exchange rate policy has consisted of an exchange rate band whose midpoint adjusts to past inflation, together with corrections for foreign inflation and productivity. This introduces a significant degree of indexing of the nominal exchange rate.

As shown in figure 1, variation in the nominal exchange rate trended downward between the first quarter of 1990 and the second quarter of 1995, reflecting the gradual reduction in inflation and sporadic discrete revaluations through adjustments in the band's midpoint or in its width.¹² These corrections to the exchange rate rule permitted a growing fraction of the relative price correction associated with the evolution of the spending-output gap to be accomplished through the nominal exchange rate, instead of through inflation of nontradable goods.

The above analysis suggests that the gradual decline in inflation is tied to the path of the nominal exchange rate. In fact, as figure 2 shows, whenever the spending-output gap narrows, a deceleration of nontradables inflation follows, but in periods where the gap increases, inflation remains constant. This behavior can be explained by the fact that, whenever the gap increases, the growth rate of the nominal exchange rate decreases and even becomes negative in some periods, as can be seen in figure 1.

Figure 1. Changes in the Nominal Exchange Rate in Chile^a

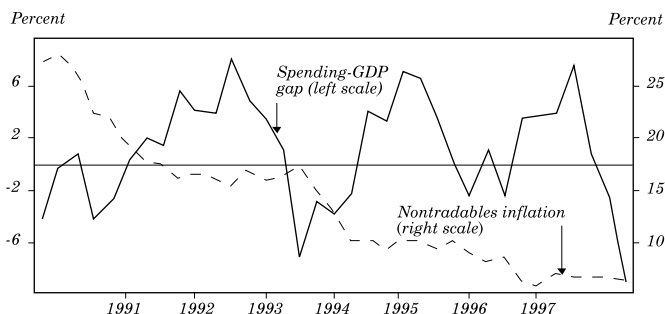


Source: Authors' calculations based on Central Bank of Chile data.

a. Change over the preceding twelve months.

12. The band's midpoint also takes into account the evolution of the Deutsche mark-dollar and Japanese yen-dollar parities. For a detailed analysis of Chile's exchange rate policy see Vergara (1994).

Figure 2. Changes in Inflation of Nontradables and the Spending-GDP Gap^a



Source: Authors' calculations based on Central Bank of Chile data.
a. Change over the preceding twelve months.

2.2 The Phillips Curve Mechanism

The second transmission mechanism is based on the famous Phillips curve, augmented by inflation expectations (Friedman, 1976). According to this approach, if actual output (y) exceeds the economy's potential output (y_p), or if the natural rate of unemployment exceeds actual unemployment, then in the short run, actual inflation of wages and prices (π) will accelerate with respect to the expected rate (π^e). The inverse relationship, where causality goes from the inflation rate to the unemployment rate, results from a slow adjustment of inflation expectations, rigid prices and wages, or lack of policy credibility. Actually, a short-run Phillips curve is possible only if actual inflation differs from expected inflation. In the long run, therefore, there is no trade-off between unemployment and inflation, because the adjustment of expected inflation to actual inflation results in an unemployment rate equal to the natural rate and in actual GDP in line with potential GDP.

Equation (6) shows the Phillips curve augmented by inflation expectations:

$$\pi_t = \pi_t^e + c(y - y_p), \quad c > 0. \quad (6)$$

Assuming static expectations (the basis of the accelerationist hypothesis of the Phillips Curve), $\pi_t^e = \pi_{t-1}$, and therefore the change in inflation will equal.¹³

$$d\pi_t = c(y - y_p). \quad (7)$$

What counts here is the level of actual output compared with its potential, because an economy can grow faster than its potential for some time without inflationary pressures emerging, if initial output is below potential.¹⁴

The transmission mechanism of monetary policy in this theoretical context can be described as follows. Whenever the trend of GDP growth is above that of potential GDP growth, after a while GDP will rise above its potential. Then an increase in the interest rate permits spending growth to decelerate, which in turn slows the growth of GDP until its level returns to that of potential GDP. In addition, the higher interest rate may have a direct effect on actual output by making working capital more expensive. Thus the deceleration of GDP growth may also reduce the inflation rate to the level determined by the nominal anchor (this may be the exchange rate, a monetary aggregate, or the inflation target determined by policymakers), which in steady state will equal expected inflation.

The output gap approach is widely used in the empirical literature on inflation determinants. As pointed out by Coe and McDermott (1997), the available evidence on industrial countries suggests that such a gap is an important determinant of inflation. For the Asian emerging economies as well, these authors find that the output gap plays a significant role in the evolution of inflation. However, for a large number of developing countries, the evidence shows no relationship between the output gap and inflation.¹⁵ As for the Chilean case, Mendoza and Fernández (1994) show evidence favoring this relationship.

13. Naturally, expectations may be rational; however, the simplifying assumption of static expectations captures the essence of the transmission mechanism to be applied to empirical studies. See Coe and McDermott (1997).

14. Zahler (1994) has argued in favor of the levels of actual and potential output being more important than the growth rates. See the previous section.

15. On this matter see International Monetary Fund (1996).

2.3 The Interest Rate Parity Mechanism

The interest rate parity mechanism is based on international arbitrage of interest rates. Thus, whenever a country's domestic interest rate exceeds the foreign rate (corrected for devaluation expectations and country risk), it induces a capital inflow, a nominal appreciation of the domestic currency, a drop in inflation, and an increased current account deficit financed by a capital account surplus. Capital mobility thus ensures that the domestic interest rate cannot remain out of line with the foreign rate, and in a fixed exchange rate system, that same mobility also implies that the central bank loses its ability to set monetary policy autonomously. Here the question for policymakers is whether to stabilize the exchange rate and abandon monetary policy independence, or to retain the interest rate as a monetary policy instrument and settle for greater exchange rate variability.

In Chile during the 1990s the domestic real interest rate, adjusted for real exchange rate expectations and country risk, stayed consistently above the foreign rate. The resulting massive capital inflows were partially sterilized, in such a way that the central bank accumulated substantial reserves. This imposed significant losses on the central bank, because it issued bonds at a UF rate that was above the rate it obtained on its dollar-denominated assets. In order to reduce the effect of capital inflows, the central bank imposed a 30 percent reserve requirement on foreign credits and investments not of a "productive" nature. However, as Valdés and Soto (1998) concluded, this reserve requirement did not reduce the total amount of short-term capital but only affected its composition.¹⁶

According to the above, interest rate arbitrage has resulted in a changed portfolio composition, with the private sector borrowing in foreign currency and acquiring UF-denominated assets, while the opposite has happened with the central bank's portfolio. So, supposedly, there has been no direct effect on the level of aggregate spending, and therefore the real exchange rate has not been affected by the spending-output gap mechanism.¹⁷ However, this did not necessarily prevent a transitory real appreciation of the peso through a nominal

16. Recently, in the wake of the Asian crisis, the central bank has reduced the reserve requirement to zero.

17. In the medium and the long run, the increase in the domestic interest rate should increase the real exchange rate, in accordance with the spending-output relationship.

appreciation, and thus a drop in tradables inflation may have been generated. Actually, the accumulation of international reserves may have led to the currency appreciating within its band.¹⁸ This, together with a relatively slower price adjustment of goods than of the exchange rate, may have caused, in the short run, a real appreciation and a deflationary trend in the prices of nontradable goods.

On the other hand, with the exchange rate remaining close to the band's floor for long periods, the resulting continued accumulation of reserves and a number of discrete modifications to the exchange rate band have taken their toll on its credibility. This has led to expectations of a nominal revaluation, which, in the presence of price inflexibilities, would also mean a real appreciation, at least in the short run. This has further strengthened the incentives for capital inflows, causing the central bank to have to endure several episodes of speculative attacks. Often it has been forced to validate the market's expectations, either by extending the band's limits or by realignment of its midpoint. For example, toward the end of 1994 the central bank accumulated over \$2 billion in just two months, requiring it to modify the exchange rate band in November, thereby permitting a substantial appreciation.

In addition, to the extent that the announcement of a decreasing inflation target determines a certain expected path for nominal exchange rate variation, implying a reduced real exchange rate, high domestic interest rates become irresistibly attractive for capital inflows.¹⁹ In this context, short-term real exchange rate swings induced by the nominal appreciation will be out of equilibrium, and therefore the actual and the equilibrium exchange rate will become misaligned. This, in turn, will introduce new deflationary pressures on nontradables.

However, an alternative hypothesis cannot be ruled out, namely, that nominal appreciation only accommodates the equilibrium real appreciation. In this case individuals would expect a real appreciation based on the evolution of fundamental variables (relative sector productivity, the spending-output ratio, government spending, the terms of trade, and the like). The result would be to increase the gap

18. On the effects of sterilized intervention on the exchange rate, see Edison (1993).

19. On this matter see Rosende (1998).

between domestic and foreign interest rates and to stimulate capital inflows to validate these expectations.²⁰

2.4 The Monetarist Mechanism

The monetarist transmission mechanism is based on the monetarist hypothesis of the economic cycle, according to which an unanticipated change in the nominal money supply affects inflation and output in the short run. In contrast to the Keynesian approach, this theoretical scheme not only considers the interest rate as a transmission mechanism, but also contemplates the effects thereof through a set of asset prices and real wealth. Thus, in this approach, variations in the money supply affect interest rates and the prices of stocks, land, and durable goods. All these variations in relative prices will affect consumption and investment through multiple wealth effects and substitution effects.

Under the interest rate policy that the central bank has been following over the last fifteen years, an interest rate increase results in a smaller monetary expansion during the process of adjusting to the new equilibrium. This has a negative effect on prices of other assets and, ultimately, on spending, output, and the rate of inflation.

It is often argued that, whenever monetary policy uses the interest rate as its instrument, nominal money will be endogenous, so that observed variations in the nominal money supply will respond to movements in the demand for money. However, whenever the central bank chooses to change the level of the interest rate, it does so through exogenous changes in the money supply. Certainly, once the new equilibrium has been reached, money supply movements become endogenous again.²¹

20. Zahler (1997) argues in favor of this hypothesis: "we cannot overstate that the real appreciation of the Chilean peso during the nineties, around 4.5% per year, was the result of an equilibrium process, that responded to the structural changes of the Chilean economy over the past years, and not to an exchange rate manipulation with the purpose of artificially reducing the inflationary trend." On the other hand, Rosende (1998) believes that the interest rate policy stressed the downward trend of the real exchange rate.

21. Unpublished results of the authors indicate that some correlation exists between money market imbalances and an acceleration of GDP. For Rosende and Herrera (1991), money market imbalances can be attributed to the fact that the relative prices that the central bank attempts to stabilize (the interest rate or the exchange rate) are far from their equilibrium, thereby generating endogenous movements in the money supply.

2.5 The Credit Mechanism

Empirical findings of international studies have not supported the hypothesis of a negative relationship between the interest rate and aggregate spending. Therefore research on the monetary policy transmission mechanism has turned to what has been termed the credit mechanism.²² This approach emphasizes the role of the banking system as a source of financing for small and medium-sized companies, for which the problem of asymmetric information is most important. Two transmission channels are proposed, namely, the bank credit channel and the balance sheet channel.

In the credit channel model, an interest rate increase resulting in reduced money growth, bank reserves, and deposits will have a contractionary effect on bank credits, depressing investment expenditure and, in turn, GDP. However, as explained above, in an open economy a higher domestic interest rate may generate an incentive for capital inflows, which can be intermediated by the banking sector, thus leading to an increase in loans.

The balance sheet channel operates through a deterioration of companies' cash flow resulting from the interest rate increase. This magnifies problems of adverse selection and moral hazard, thereby reducing corporate lending.²³ This, in turn, has a negative effect on investment and, as a result, on GDP. This transmission mechanism, together with the Phillips curve or the Australian mechanism, suggests that an increase in the interest rate will reduce inflationary pressures by reducing the spending-output gap or the gap between actual and potential output.

One example of the application of this approach is Edwards and Végh (1997). These authors hold that, in both Chile and Mexico, the banking sector played a fundamental role in intermediating capital flows, which ended in an explosive growth in consumption (in Chile in the 1980s and in Mexico in the 1990s). When capital withdrew from these countries, banks were left with severe financial problems, which deepened the recessions the countries were then suffering. The authors build a model in which fixed exchange rate stabilization generates output and employment cycles through changes in deposit-credit spreads and in bank

22. Examples can be found in Mishkin (1995) and Bernanke and Gertler (1995).

23. Bernanke and Gertler (1995) argue that this effect should be applied not only to corporate investment expenses but also to individuals' expenditure on durable goods.

credits. In their empirical analysis, the authors use a widening of the spread between interest rates for credits and for deposits as a proxy for a shock to the banking system, and they find that such a shock negatively affects economic activity.

3. EMPIRICAL EVALUATION OF ALTERNATIVE TRANSMISSION MECHANISMS

3.1 Methodology

A review of the relevant literature indicates that a large majority of recent studies on the effects of monetary policy use vector autoregression (VAR) as their econometric tool of choice.²⁴ However, this methodology has been subjected to strong criticism, on the grounds that it lacks a sufficient theoretical basis and on the grounds that its identification procedure is questionable. With respect to the first criticism, it is arguably a matter of personal preference, since none of the econometric methodologies currently in use is totally immune from criticism on this score. Although economic theory does establish certain relationships between variables, it seldom provides accurate predictions of the dynamics of those relationships or distinguishes between endogenous and exogenous variables. This forces a choice between imposing “arbitrary” constraints on the joint dynamics of the set of variables and in selecting endogenous variables, on one hand, and adopting a totally empirical approach on the other, whereby the data “reveal” their joint dynamic process and all variables are treated symmetrically.²⁵ The latter is the option implicit in the VAR methodology.

To understand the nature of the second type of criticism, consider the following example:

$$y_t + b_{12} z_t = b_{10} + \gamma_{11} y_{t-1} + \gamma_{12} z_{t-1} + \varepsilon_y, \quad (8)$$

$$z_t + b_{21} y_t = b_{20} + \gamma_{21} y_{t-1} + \gamma_{22} z_{t-1} + \varepsilon_z, \quad (9)$$

24. Some examples are the works of Rosende and Herrera (1991), Bernanke and Blinder (1992), Mendoza and Fernández (1994), Leeper, Sims, and Zha (1996), Valdés (1997), Bernanke and Mihov (1998), Cochrane (1998), and Garretsen and Swank (1998).

25. On this matter the classic reference is Sims (1980).

where variables y and z follow a stochastic process as described by equations (8) and (9) and ε_y and ε_z are innovations or “white noise.” This system of equations, known as the structural VAR, may be described as shown below:

$$B_0 x_t = \Gamma_0 + \Gamma_1 x_{t-1} + \varepsilon_t, \quad (10)$$

where $E(\varepsilon_t \varepsilon_t') = \Sigma$.

When both sides of equation (10) are premultiplied by B_0^{-1} , the autoregressive vector is obtained in its reduced form:

$$x_t = A_0 + A_1 x_{t-1} + e_t, \quad (11)$$

where

$$x_t' = [y_t \quad z_t],$$

$$A_0 = B_0^{-1} \Gamma_0,$$

$$A_1 = B_0^{-1} \Gamma_1,$$

$$e_t = B_0^{-1} \varepsilon_t,$$

$$\Omega = E(e_t e_t') = B_0^{-1} \Sigma (B_0^{-1})'.$$

Here the main fact worth singling out is that, given $e_t = B_0^{-1} \varepsilon_t$, every element in the residuals vector of the reduced system is a linear combination of all the structural innovations that affect the endogenous variables that make up the system. Therefore, the dynamic response (impulse response function) of these endogenous variables to a shock to one of the system's error vector components in its reduced form cannot be linked to any structural innovations in particular.

In the traditional VAR methodology the identification problem is solved by placing constraints on the contemporary effects of the variables and on their variance-covariance matrix. These constraints,

associated with Cholesky's decomposition, assume a recursive process, where the first variable included in the VAR system is not affected contemporaneously by any of the remaining endogenous variables, the second one is affected contemporaneously only by the first, and so on.

If the theoretical constraints applicable to the structural dynamic model are such that the B_0 matrix is inferior triangular, with unit coefficients in the principal diagonal, and matrix Σ is diagonal, where the values in its diagonal are the structural innovations' variances, this model will be appropriately identified using the traditional procedure. In this case, estimates of the parameters (B_0 , Γ , Σ) through the full-information maximum likelihood (FIML) method can be obtained by maximizing the likelihood function with respect to the estimated parameters of the reduced form. The FIML estimation of B_0 allows us to calculate the orthogonalized residuals through the relationship $\varepsilon_t = B_0 e_t$, which corresponds to the vector of structural disturbances. Similarly, the orthogonalization of the impulse response function's coefficients will generate the dynamic consequences of structural innovations. In general, however, the constraints will not be the "true constraints" imposed by economic theory. Thus a more flexible identification procedure is needed, to allow the incorporation of constraints consistent with the theoretical model being tested.²⁶

Given the above, in a second development stage of the VAR methodology more attention was paid to the identification of variables based on economic theory; the result was the so-called structural VAR. The leaders of this line of research were Christopher Sims, Olivier Blanchard, Mark Watson, and Ben Bernanke. The rationale of the structural VAR methodology is that any identification constraints being imposed on matrixes B_0 and Σ must come from economic theory. Once such constraints are established, it is possible to estimate values of the structural coefficients that will both satisfy and meet the condition given by the last of the equations above. For that purpose the FIML method is used.²⁷

One last methodological issue worth noting relates to the existence of conflicting ideas about whether the variables included in a

26. For further details of the VAR estimation methodology, see Hamilton (1994).

27. See Hamilton (1994).

VAR system must be previously filtered so that they are all stationary, or whether they must simply be included in their “natural form.” Some authors, such as Sims (1980) and Doan (1992), argue against variable differentiation even when the variables have a unit root. Their main argument is that the objective of the structural VAR is to find any interrelationships that may exist between the variables included in the system, and not the estimated values of parameters per se. Similarly, they argue against variable filtering because this may imply a loss of information about joint movements of the variables, such as the possible existence of cointegration relationships between them. However, the majority of the other authors hold that the variables must be used in such a way that the VAR can imitate the true data-generating process, and therefore the variables included must be stationary.

3.2 Identification Criteria Used

In keeping with the arguments in the previous section, the characteristic element of the structural VAR methodology adopted here is the use of identification assumptions explicitly based either on economic theory or on institutional aspects inherent in the economy under analysis. Therefore we first describe in detail the identification assumptions used to estimate the various models considered here:

- Because the data being used are monthly, the first assumption is that the monetary policy instrument (the rate on the central bank's ninety-day instrument) does not respond contemporaneously to variables that are not observable within the month, such as activity variables (production and spending). However, the instrument can respond contemporaneously to variables observed in the very short term, such as monetary and financial variables and prices.
- Financial variables (such as the exchange rate, market interest rates, and asset prices) can respond contemporaneously to any information, including nonobservable information.²⁸

28. Because financial variables are not the result of the decision of any one player but arise from the interaction of many actors within their respective markets, they can be affected by variables that, without being directly observable, do alter the equilibrium of those markets. They can also be affected by the actors' expectations regarding the future path of the relevant variables.

- Activity variables (such as spending, output, and the spending-output gap) respond to all the other variables with a lag; exceptions are days worked and, in the case of GDP, the response to spending itself.²⁹
- Prices of goods (as reflected in the overall CPI and the CPI for nontradables) respond contemporaneously only to those variables that affect them directly, such as the exchange rate and international prices.³⁰
- The real exchange rate responds contemporaneously only to variables affecting it directly (the nominal exchange rate, international prices, and the CPI for nontradables). This assumption is a direct extension of the previous one.
- In the case of the monetary credit model, credit from the financial sector is assumed to respond contemporaneously to interest rates and money (which affect the credit supply), because this is the central transmission mechanism of monetary policy according to this model. Credit may also respond contemporaneously to aggregate spending, which affects the demand for credit.

3.3 Principal Results

As we have seen, the need for the variables included in a structural VAR to be stationary remains controversial. Therefore, as a way to check the robustness of the results obtained, all the estimated models were estimated in three versions (except for the reaction function and the Phillips curve, which were estimated only in two versions): as levels, as levels and growth rates over twelve months,³¹ and as levels and first differences (of levels or of the twelve-month variation rate, depending on the type of variable).³² This also allows

29. This assumption is intended to incorporate into the models' empirical estimation the existence of lags in the production and spending decisionmaking processes or in their implementation. Such lags may arise from delays in the generation and disclosure of information on which the decisions are based, from difficulties in their interpretation because of uncertainties (for example, with respect to whether shocks are permanent or transitory), or from the presence of rigidities (contractual or other) that may hinder instantaneous reactions.

30. This is one of the standard assumptions used in Keynesian models to allow for the existence of real effects in response to nominal shocks.

31. The twelve-month variation was used in those cases where it makes economic sense, for example with price indexes and production and spending figures.

32. This version of the models attempted to make all the variables included comply with the seasonality condition; this was checked using the Dickey-Fuller and Phillips-Perron tests.

our results to be compared with a broader range of previous studies. Appendix B summarizes the main results for the Chilean economy reported by other authors.

For reasons of space, only the results of the version with the most theoretical basis (the one combining variables in levels and twelve-month growth rates) are shown, since these results are easier to interpret. Also, and for the same reasons, only the impulse response functions considered to be the central hypotheses associated with each of the models estimated are discussed.³³

The Central Bank's Reaction Function. Table 2 describes the estimated model. The upper panel of figure 3 shows the response of the monetary policy rate to a 1-percentage-point increase in the cyclical component of GDP. As the figure shows, the response is positive and strongly significant after the fifth month from the shock. The response peaks around 13 basis points, 15 months after the shock.

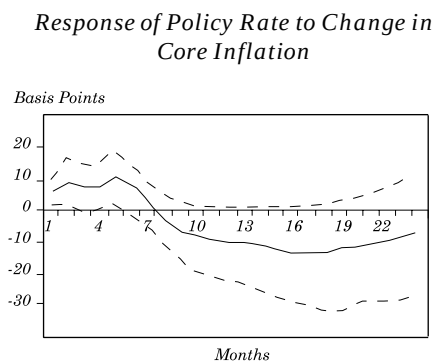
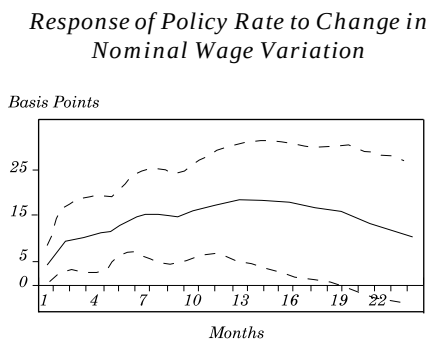
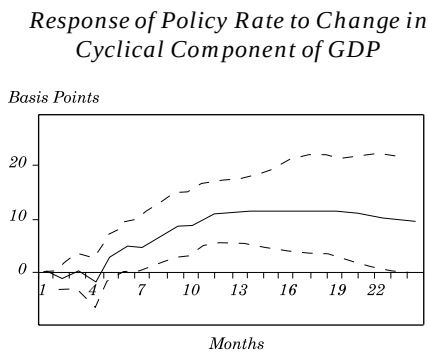
Table 2. Characteristics of the Models

<i>Model</i>	<i>Variables included^a</i>	<i>Lags</i>	<i>Sample period</i>
Central bank's reaction function	TASA BC; CICLO; V12WUC; V12IPCSUB; seasonal dummies; deterministic trend	Five	January 1986 to December 1996
Australian model	LTTUC; TASABC; TBE; CICLO; LTCN; LIPCNT; LTCRINE; seasonal dummies; deterministic trend	Four	April 1989 to June 1997
Credit model	LTTUC; TASABC; TBE; V12M1A; V12COLOC; V12GASTO; V12PIB; V12TCN; V12IPCSUB; V12DHAB; seasonal dummies; deterministic trend	Three	January 1987 to June 1997
Monetary model: asset prices	LTTUC; TASABC; TBE; V12M1A; V12IGPA; V12GASTO; V12PIB; V12TCN; V12IPCSUB; V12DHAB; seasonal dummies; deterministic trend	Three	January 1987 to June 1997
Phillips curve model	LTTUC; TASABC; TBE; CICLO; DV12TCN; DV12IPCSUB; seasonal dummies; deterministic trend	Five	February 1986 to December 1996
Interest rate parity model	TASABC; LIBOR; VTCREXPOST; V3TCN; V3IPC; seasonal dummies; deterministic trend	Six	January 1987 to December 1997

a. See appendix C for definitions of the variables.

33. A complete report of the impulse response functions of this and the other models estimated is available from the authors.

Figure 3. Impulse Response Functions for the Central Bank's Reaction Function



Source: Authors' calculations.

The middle panel of figure 3 shows the response of the monetary policy rate to a 1-percentage-point increase in the twelve-month variation rate of nominal wages. A positive, strongly significant response of the policy rate to a positive shock to this variable is observed. This response reaches its maximum intensity, nearly 20 basis points, fifteen months after the shock.

Finally, the bottom panel of figure 3 depicts the response of the monetary policy rate to a 1-percentage-point increase in core inflation. It can be concluded that the response is positive and significant in the period from one to seven months after the shock, and that the maximum response appears around month 5 after the shock, when it amounts to slightly more than 10 basis points.

The Australian Model. Table 2 again describes the main characteristics of the model. The top left panel of figure 4 shows the response of the spending-output gap to a positive shock of 50 basis points in the monetary policy interest rate. Three conclusions can be drawn. First, the response is negative but not large enough to be significant. Second, this negative response extends from month 1 to month 13 after the shock. And third, at its maximum, the reduction in the gap is 1 percentage point.

On the other hand, the next two panels of figure 4 shows the response of the CPI for nontradables to an increase of 50 basis points in the monetary policy interest rate. The results indicate that when the *level* of the CPI for nontradables is used, the response is negative and significant (at the 10 percent level). However, when the twelve-month variation in the CPI for nontradables is used, the familiar “price puzzle” appears,³⁴ in that the response is positive. However, this response is not large enough to be statistically significant.

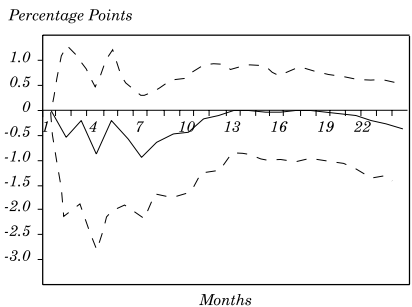
The next panel of figure 4 depicts the response of the (logarithm of the) real exchange rate to a 50-basis-point shock to the monetary policy interest rate. A first main conclusion is that the level of the real exchange rate increases after the fourth month, and this response is marginally significant (at the 10 percent level). A second is that after two years the real exchange rate is about 2 percentage points above its trend level.

The last panel of figure 4 shows the response of the real exchange rate to a 5-percentage-point shock in the spending-output gap. The response is negative and significant. Two years after the shock, the real exchange rate is 1.3 percentage points below its trend level.

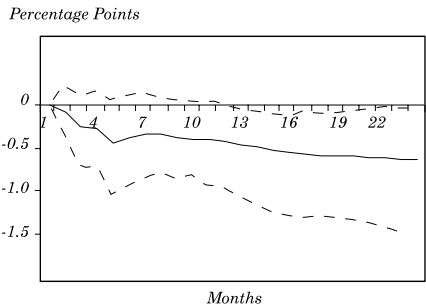
34. See Bernanke and Blinder (1992) and Leeper, Sims and Zha (1996) for more on this subject.

Figure 4. Impulse Response Functions for the Australian Model

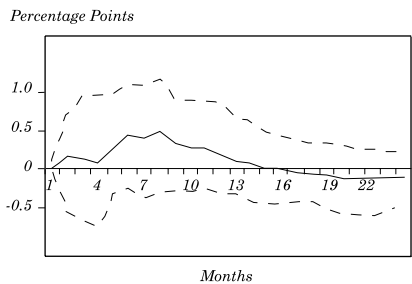
Response of Spending-Output Gap to Change in Policy Rate



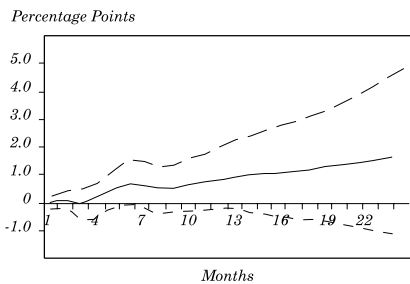
Response of Nontradables CPI to Change in Policy Rate



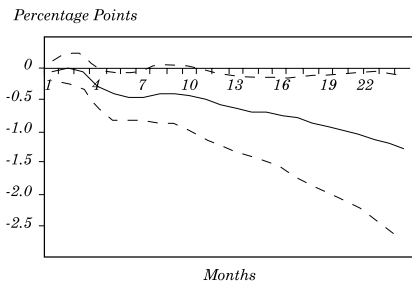
Response of Change in Nontradables CPI to Change in Policy Rate



Response of Real Exchange Rate to Change in Policy Rate



Response of Real Exchange Rate to Change in Spending-Output GAP



The Credit Model. Table 2 again describes the main characteristics of the model. The top left panel of figure 5 shows the response of the monetary aggregate M1A to a 50-basis-point increase in the monetary policy interest rate. It can be concluded that the response is negative, that the largest effect is reached six months after the shock, and that at its maximum the response is marginally significant at the 10 percent level.

The top right panel in figure 5 depicts the response of annual growth in financial system credit to a 50-basis-point increase in the monetary policy rate. The response is negative, very persistent, and significant at the 10 percent level. The response is at its greatest eighteen months after the shock, at which point the annual growth rate of credit has been reduced by 0.60 percentage point.

The left-hand panel in the second row of figure 5 shows the response of aggregate spending to a 50-basis-point shock in the monetary policy rate. A lagged negative response is detected beginning in the fourth month after the shock. However, this response is not significant at the 10 percent level.

The right-hand panel in the second row of figure 5 shows the response of the core CPI to an increase of 50 basis points in the monetary policy rate. The response is positive, revealing again the presence of the "price puzzle," which has been found in other studies of the Chilean economy.³⁵ However, the response is not significant at the 10 percent level.

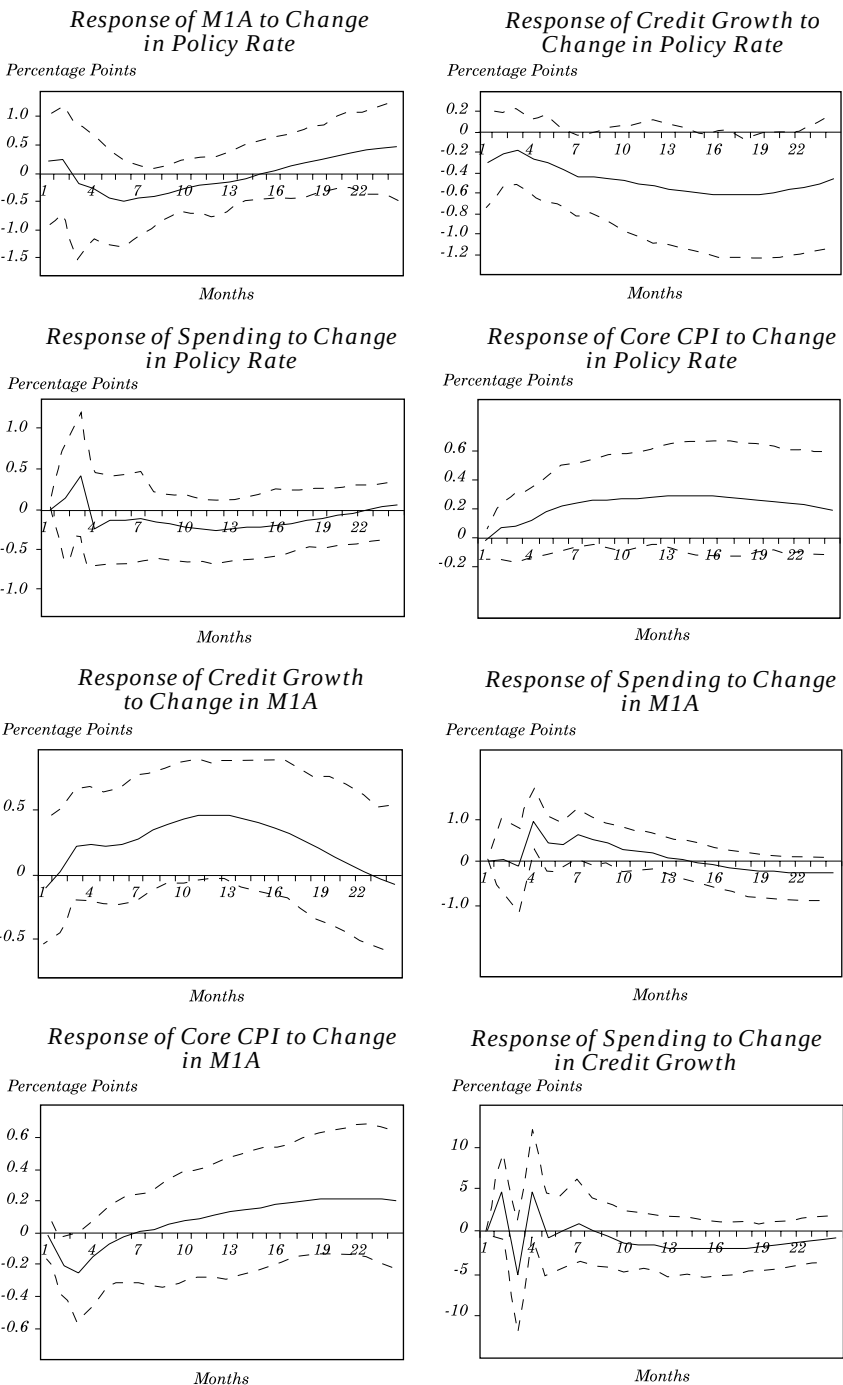
The left-hand panel in the third row of figure 5 depicts the response of financial system credit to a positive shock to M1A of 5 percent. The response is positive and achieves significance at the 10 percent level between ten and thirteen months after the shock. The response peaks at twelve months after the shock, at which point it is near 0.5 percentage point.

The right-hand panel in the third row of figure 5 shows the response of aggregate spending to a positive shock to M1A of 5 percent. The response is positive and significant at the 10 percent level and occurs between four and thirteen months after the shock, peaking near 1 percentage point.

The bottom left panel of figure 5 shows the response of core CPI to a positive shock to M1A of 5 percent. A negative response is observed between the second and the fourth month after the shock, which is

35. See Valdés (1997) and Mendoza and Fernández (1994).

Figure 5. Impulse Response Functions for the Credit Model



Source: Authors' calculations.

significant at the 10 percent level. This result can be interpreted as another indication of the so-called price puzzle. Subsequently, at the fifth month after the shock a positive response from prices appears, but it is not large enough to be significant.

Finally, the bottom right panel of figure 5 shows the response of aggregate spending to a 5 percent positive shock to annual growth in financial system credit. The response is somewhat erratic, but it is positive in the second and fourth months after the shock, and marginally significant at the 10 percent level. The magnitude of the response is relatively large, peaking at around 5 percentage points.

The Monetary-Asset Price Model. Table 2 shows the main characteristics of the model that we have labeled the “monetary-asset price model.” The top left panel of figure 6 shows the response of M1A to an increase of 50 basis points in the monetary policy interest rate. The response becomes negative at month 5 after the shock. The largest negative effect is reached at seven months; it is significant at the 10 percent level and amounts to almost 1.5 percentage points.

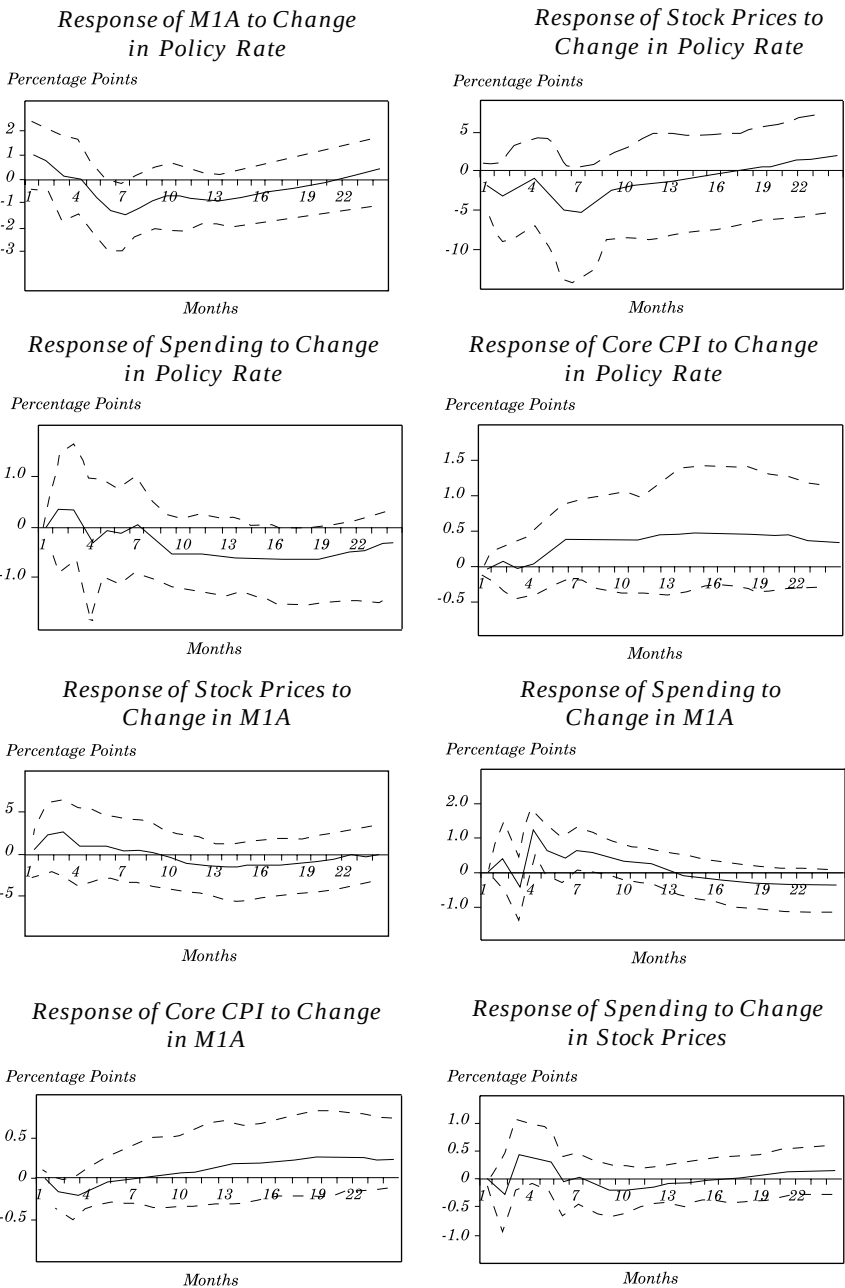
The top right panel of figure 6 shows the response of the Chilean general stock price index (IGPA) to a positive shock of 50 basis points in the monetary policy rate. The response is negative and significant at the 10 percent level. The maximum response is achieved between six and seven months after the shock, when it equals 5 percentage points.

The left-hand panel in the second row of figure 6 shows the response of aggregate spending to a positive shock of 50 basis points to the monetary policy rate. A negative response appears at month 8 after the shock and is significant at the 10 percent level. The maximum effect is reached between fifteen and eighteen months after the shock and amounts to 0.6 percentage point.

The right-hand panel in the second row of figure 6 shows the response of the core CPI to a 50-basis-point increase in the monetary policy rate. As in the credit model case, this model finds a positive response indicative of the traditional “price puzzle.” However, in this case as well, the response does not reach significance at the 10 percent level.

The left-hand panel in the third row of figure 6 shows the response of the IGPA to a positive shock of 5 percentage points to M1A. A positive response is observed between one and nine months after the monetary shock, but it is not significant.

Figure 6. Impulse Response Functions for the Monetary-Asset Price Model



Source: Authors' calculations.

The right-hand panel in the third row of figure 6 depicts the response of aggregate spending to a 5 percent positive shock to M1A. The response is positive and significant at the 10 percent level. It occurs between four and thirteen months after the shock and peaks at about 1 percentage point.

The bottom left panel of figure 6 shows the response of the core CPI to a 5 percent positive shock to M1A. A negative response is observed between the second and the fourth month after the shock, which is marginally significant at the 10 percent level. Once again this result can be interpreted as a manifestation of the "price puzzle." Subsequently, a positive response of prices appears, but it is not significant.

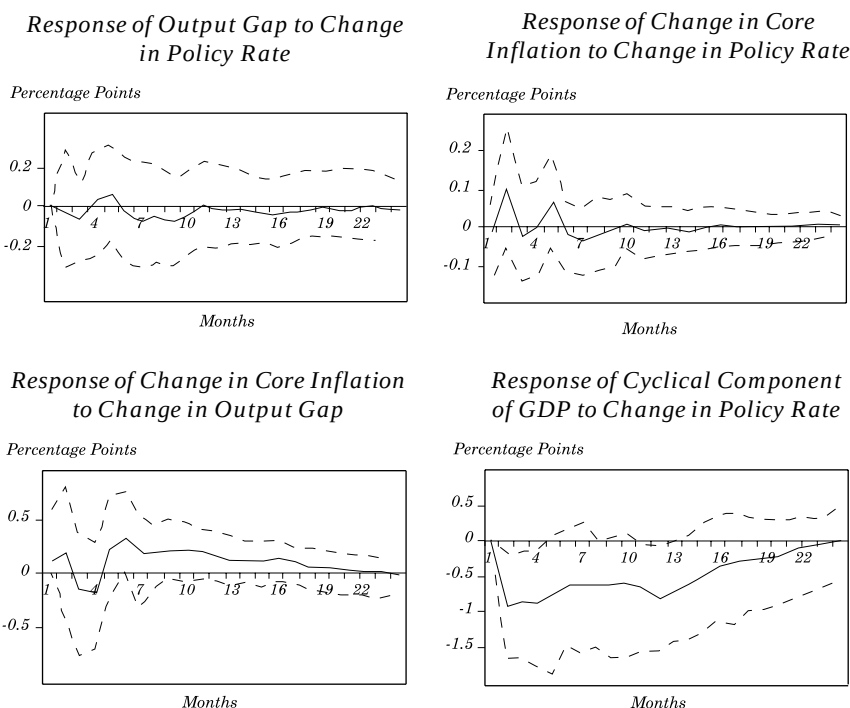
Finally, the bottom right panel of figure 6 shows the response of aggregate spending to a positive shock of 10 percent to the IGPA. A positive response is observed, which is marginally significant between months 3 and 6 after the shock.

The Phillips Curve Hypothesis. Table 2 again describes the main characteristics of the model. The top left panel of figure 7 shows the response of the discrepancy between actual and potential output (that is, the business cycle) to an increase of 50 basis points in the monetary policy rate. The response is far from significant, and so, under this specification of the model, no systematic response of the cyclical component of GDP to a shock in the monetary rate can be identified.

The top right panel of figure 7 shows the acceleration in core inflation in response to a 50-basis-point increase in the monetary policy rate. Although the observed response is basically positive during the periods immediately following the shock, it is far from significant. Thus, in this case the "price puzzle" that appears is of a lesser degree than in the other models estimated.

The bottom left panel of figure 7 shows the acceleration in core inflation in response to a 5-percentage-point increase in the discrepancy between actual and potential output. Although at the beginning (between months 3 and 4 after the shock) a negative response is detected, it is not significant, and from month 5 onward a clearly positive and marginally significant (at the 10 percent level) response can be seen. This indicates the presence of a positive effect from the cyclical component of GDP on core inflation, and therefore of

Figure 7. Impulse Response Functions for the Phillips Curve Model



Source: Authors' calculations.

what is commonly called “overheating.”³⁶ The graph also shows that, at its peak in month 6, the magnitude of this response is about 0.40 percentage point, and this positive effect remains until the eighteenth month after the shock.

Finally, the bottom right panel of figure 7 shows the response of the cyclical component of GDP to a 5-percentage-point increase in inflation acceleration. A clearly negative response is observed, which is significant at the 10 percent level. At its peak, this response reaches almost 1 percentage point, and it stays negative

36. On this matter see Zahler (1994). The international academic literature generally uses the term “gap model” to describe the empirical inflation models that emphasize the existence of this effect. One example is Coe and McDermott (1997). The existence of this effect supports the use of the GDP’s cyclical component as one of the elements in the central bank’s reaction function.

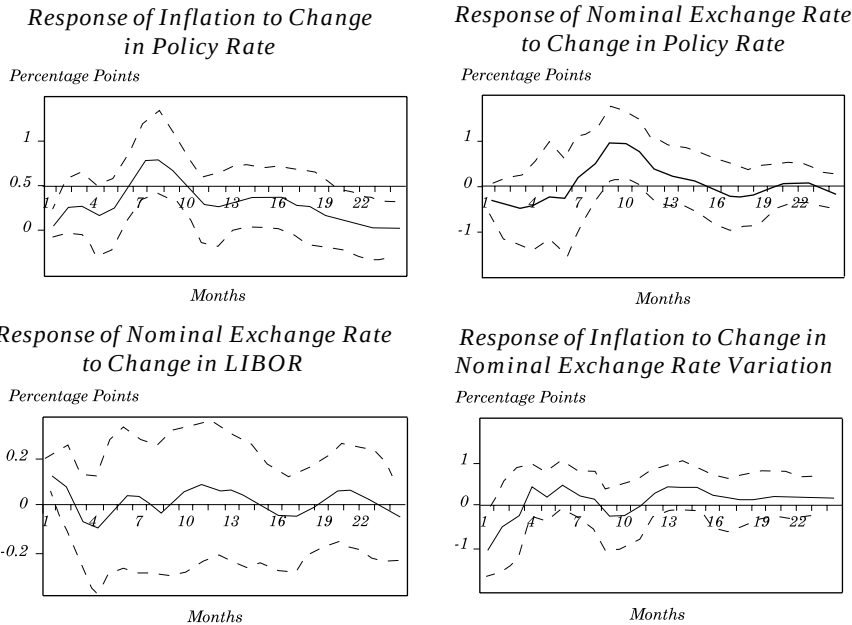
during the first twenty-four months following the shock. This evidence runs counter to the hypothesis implicit in the so-called Lucas supply model, according to which innovations in the inflation rate will have a positive effect on aggregate output.

The Interest Rate Parity Model. The results for this model must be interpreted carefully. Lack of sufficient information made it impossible to include in the estimated model either a country risk premium or an adjustment for foreign credit reserves held less than one year. Therefore a model specification problem may have arisen because of omitted variables, which could alter the results.

Table 2 again describes the main characteristics of the model. The top left panel of figure 8 shows the response of inflation to an increase of 50 basis points in the policy interest rate. Again there is strong evidence of a “price puzzle,” since the estimated response is positive and highly significant.

The top right panel of figure 8 shows the response of the nominal exchange rate to a 50-basis-point increase in the policy interest rate.

Figure 8. Impulse Response Functions for the Interest Rate Parity Model



Source: Authors' calculations.

Although, as predicted by the interest rate arbitrage hypothesis, the initial response of the exchange rate is negative, it is far from significant. By the seventh month after the shock, moreover, a significant positive response of the exchange rate is detected, which parallels the behavior of the inflation response. This reveals that some degree of nominal exchange rate indexation exists.

Similarly, the bottom left panel of figure 8 shows the response of the nominal exchange rate to an increase of 50 basis points in the London interbank offered rate (LIBOR). In this case some slight evidence in favor of the interest rate arbitrage hypothesis is detected, since in the month of the shock itself there is a positive, significant response. Afterward, however, the response fluctuates around zero and is far from significant.

Finally, the bottom right panel of figure 8 shows the response of the rate of inflation to a positive 5-percentage-point shock in the rate of variation of the nominal exchange rate. A positive, marginally significant response is seen after three months. This reveals that exchange rate fluctuations have affected the path of inflation over the period under study.

3.4 Lessons for the Effectiveness of Monetary Policy

The results just presented lead to a number of conclusions with respect to the effects of monetary policy on several macroeconomic variables. Here we will focus on the effects on four such variables: inflation, output, spending, and the real exchange rate.

Monetary Policy and Inflation. The results associated with the Australian model indicate that a positive innovation of 50 basis points in the monetary policy interest rate will provoke a negative deviation of the CPI for nontradable goods from its trend. The magnitude of this deviation is around 0.4 percentage point after one year and 0.6 percentage point after two years. These results are similar to those obtained by Rosende and Herrera (1991). They estimate that an increase of 120 basis points in the interest rate on bank deposits provokes a global price-level deviation from its trend in the range of 0.43 to 0.75 percentage point, with an

estimated duration of roughly six quarters.³⁷ Our results also seem generally consistent with those of Eyzaguirre and Rojas (1996), who estimate that a 100-basis-point increase in the interest rate on bank credit will reduce inflation of nontradables by 0.3 percentage point after one year, and by 1 percentage point after one year and a half.³⁸

In contrast, the papers by Valdés (1997) and Mendoza and Fernández (1994) find a positive response of inflation to a shock of the same sign in the interest rate. Mendoza and Fernández point out that, although there appears to be no systematic effect of the interest rate on inflation, sharp increases in that rate (such as that observed in Chile between 1988 and 1992) have a negative effect on inflation with a nine-month lag. On the other hand, Valdés finds a negative effect of the interest rate on the difference between actual and targeted inflation. However, in our opinion the procedure Valdés used is inadequate, because the reported result implies that an increase in the interest rate would provoke an increase in the targeted rate of inflation, which makes no economic sense. (Moreover, this increase would be larger than that observed in actual inflation, in such a way as to reduce the differential.) Another problem is Valdés' use of inflation projections by a local consulting firm as a proxy for target inflation, which is very questionable. Therefore we reconstructed the inflationary differential using the targets reported by the central bank itself from 1991 on (see Magendzo, 1997) and incorporated it into different VAR systems; we found no systematic effect of the interest rate on this variable.

A "price puzzle" emerges in many of the models estimated in this paper. However, a global evaluation of our results suggests that, as stated by Leeper, Sims, and Zha (1996), this puzzle may

37. Considering that the magnitude of the shock used in our estimate is only about four-tenths that of Rosende and Herrera's shock, and that the share of nontradables in the overall CPI is 50 percent, it can be concluded that the responses calculated in both studies are very similar in size. However, this conclusion holds only if the CPI for tradables is independent from that for nontradables, a condition that is not met in the presence of any degree of exchange rate indexation.

38. In both Rosende and Herrera (1991) and Eyzaguirre and Rojas (1996), the shock analyzed does not originate from the true monetary policy instrument; hence interpreting these shocks as monetary is dubious.

be the result of wrong identification assumptions and of specification problems in the VAR system.³⁹

Monetary Policy and Economic Activity. As for the monetary policy effects on activity indicators, our results show very weak negative responses of aggregate spending, GDP, and the cyclical component of GDP to positive shocks in the interest rate used as a monetary policy instrument. Only in the case of the gap between the growth rates of spending and output is a stronger negative response detected. That response lasts 13 months and reaches a maximum (around month 8) of somewhere between 1 and 2 percentage points, in response to an increase of 50 basis points in the policy interest rate.

On the other hand, our results show significant positive responses of both GDP and aggregate spending to positive innovations in the nominal money supply. In the case of aggregate spending, the response is observed between the fourth and the thirteenth month after a shock of 5 percentage points to M1A and reaches a magnitude of 0.5 to 1 percentage point.

Rosende and Herrera (1991) find a positive effect of nominal money on the deviation of GDP from its trend. According to their estimates, a 3.2-percentage-point increase in the money supply will generate a positive deviation of GDP ranging between 0.36 and 0.89 percentage points over four quarters. Similarly, they find that an increase of 120 basis points in the interest rate on price-level-adjustable one-year bank deposits reduces the deviation in output by an estimated 0.97 to 1.25 percentage points after four quarters, an effect that fades out in the seventh quarter after the shock.⁴⁰ More consistent with our results on this matter, Mendoza and Fernández (1994) find no systematic effect of the interest rate on one-year bank credits on the gap between actual and potential GDP, but they do observe Granger causality from M1A to this gap.

39. When identifying assumptions consistent with our results are used, a substantial mitigation of the anomalous response of inflation appears in comparison with the VAR systems with the traditional recursive identification (nonstructural VAR). In addition, our results show that the strength of the "price puzzle" varies inversely with the estimated model's global adjustment.

40. Unfortunately, Rosende and Herrera do not report the significance bands associated with the impulse response functions, so it is not possible to determine whether or not these effects are statistically significant.

Along the line of Rosende and Herrera's results, Eyzaguirre and Rojas (1996) find that an increase of 100 basis points in the interest rate on one-year bank credits reduces the growth rate of aggregate spending by an estimated 1 percentage point in the short run. This effect reaches an estimated 1.5 percentage points after five to six quarters.

Finally, Valdés (1997) also finds a negative effect of the interest rate on ninety-day central bank obligations on the growth rate of output (specifically, on an approximation of IMACEC, a monthly indicator of economic activity). Such an effect is observed for an estimated four to fifteen months after the shock and amounts to about 0.5 percentage point following an increase of 30 basis points in the interest rate.

A global evaluation of these results leads to the conclusion that the estimated response of spending and aggregate production to shocks in the interest rate appears to be strongly influenced by the VAR system specification used. In contrast, the effects of monetary innovations appear to be more robust.

Monetary Policy and the Real Exchange Rate. The version of the Australian model reported here shows that a positive shock of 50 basis points in the monetary policy rate provokes a positive deviation of the real exchange rate from its trend. After a year this deviation amounts to 1 percentage point, and after two years it is near 2 percentage points.

The results reported by Eyzaguirre and Rojas (1996) tend to support our own. They find a positive effect of the interest rate on the real exchange rate and state that, after three quarters from the shock to the interest rate, it explains around an estimated 20 percent of the forecast error of the model with respect to the real exchange rate.⁴¹ In contrast, Mendoza and Fernández (1994) and Valdés (1997) find no significant response of the real exchange rate to shocks in the interest rate.⁴²

41. Unfortunately, these authors report no estimates of the magnitude of the real exchange rate response.

42. It must be noted that the real exchange rate definitions used by these authors differ from the one used here, which is the same as that used by Eyzaguirre and Rojas. Rosende and Herrera (1991) report no results on the effect of monetary policy on the real exchange rate.

4. CONCLUSIONS

The most robust results of our research are those on the central bank's reaction function. Here the evidence shows that, during the period analyzed, the monetary authorities responded systematically to signs of "overheating" (a discrepancy between actual and potential GDP, or a spending-output gap),⁴³ and to direct inflation indicators (nominal wages and the CPI), by increasing the interest rate used as an instrument.

Paradoxically, the results yield weak evidence in favor of hypotheses whereby spending and output respond negatively to the monetary policy instrument. Here the greatest response is found for the spending-output gap. However, spending and output do seem to respond systematically to shocks to the nominal money supply. An obvious question arises about the possible convenience of redefining the variable used as the monetary policy instrument.

Still more paradoxical is the evidence showing that, in the large majority of the models estimated, inflation responds positively to an increase in the monetary policy rate (the "price puzzle"). However, regarding the results offered by traditional VAR systems, the use of "structural" identification assumptions allows this anomaly to be reduced substantially, making it insignificant in most cases. Also, within the context of the Australian model, a response that has the expected negative sign and is significant is detected. One can therefore speculate that the "price puzzle" phenomenon is associated not only with the wrong selection of identification assumptions, but also with specification problems in the VAR system. The anomalous result is observed with greater strength in those models that tend to be rejected by the data in general terms.

As for the theoretical transmission mechanisms, the one that gets the most support is that associated with the Australian model, in that the results show a (weak) negative effect of the monetary policy rate on the spending-output gap.⁴⁴ Also, a negative effect of

43. Although this report of our analyses shows only the results obtained regarding the response of the monetary instrument to innovations in the cyclical component of GDP, the impulse response functions obtained with the Australian model give evidence of a positive and significant response to shocks to the spending-output gap.

44. However, from a strict econometric point of view, the correct way to compare the estimated models is to use nested tests. Unfortunately, this could not be done because of lack of data.

monetary policy on the price level of nontradables and a positive effect on the level of the real exchange rate are detected. Finally, the evidence shows a negative effect of the spending-output gap on the real exchange rate (both its level and its rate of acceleration).

Monetary models, in contrast, get mixed support under both the credit approach and the asset price approach. Consistent with the models' predictions, the empirical evidence shows that the monetary policy rate has a negative effect on M1A, on financial system credit in real terms, and on stock prices (real IGPA). However, the evidence also shows that the positive relationships between monetary shocks (M1A), real financial system credit, and stock prices are weak.

Also consistent with the monetarist hypotheses, most of the models estimated show a strong positive effect of a shock in nominal money balances on aggregate spending. Moreover, the results obtained consistently show positive effects on aggregate spending associated with shocks to both financial system credit and stock prices.

Nevertheless, the monetarist view does not receive full support for its predictions, because the evidence provides weak support of the presumption of a negative effect of the monetary policy rate on aggregate spending. Also, the results show the existence of a "price puzzle," although the anomalous response is insignificant more often than not.

The evidence reported here is adverse for the Phillips curve hypothesis. The results do not allow one to propose that a "Lucas supply" phenomenon exists, since innovations in inflationary acceleration provoke a clearly negative effect on the cyclical component of GDP. Nor is a significant effect of shocks to the monetary policy instrument detected in the cyclical component of GDP. In addition, the same evidence shows the presence of a "price puzzle," but as in most of the other cases where this result appears, it is not statistically significant.

However, the evidence on the model that we call the Phillips curve model does show a strong positive effect on the acceleration of core inflation resulting from a shock to the cyclical component of GDP. This is the primary prediction arising from the empirical inflation models based on the "overheating" hypothesis (the gap model), which for many is another version of the Phillips curve.⁴⁵

45. See Coe and McDermott (1997).

The hypothesis that gets the least empirical support from the models estimated is the interest rate parity hypothesis.⁴⁶ The results show that the sign of the nominal exchange rate's response to shocks to the domestic interest rate is the opposite of the expected one. In addition, its response to shocks to the foreign interest rate is very weak. Finally, in the estimated versions of this model the presence of the "price puzzle" is strong.

Finally, the above comparison of the models indicates that there is no presumption that the transmission mechanisms analyzed are intrinsically incompatible with each other. Indeed, theory shows that, in general, they can appear simultaneously. Rather the true purpose of our comparison has been to determine which of the theoretical transmission channels have manifested themselves with the greatest strength over a specific period of Chile's economic history.

46. As mentioned above, this may be due to specification problems in the model because of the limited data available.

APPENDIX A

Essential Features of Monetary Policy according to Selected Authors

<i>Author(s)</i>	<i>Instrument</i>	<i>Intermediate objective</i>	<i>Goal</i>	<i>Transmission mechanism</i>
R. Valdés (1997)	90-day PRBC interest rate (1985 to April 1995); interbank rate (from May 1995 on)	Gap between growth rates of actual and potential output	Current account (1985-89); inflation (from 1989 on)	Not disclosed
Mendoza and Fernández (1994)	90-day PRBC interest rate	M1A growth rate; gap between actual and potential output (trend)	Inflation	PRBC rate affects market rates and M1A growth rate. This affects the spending-output gap, thereby determining inflation. The authors propose as an alternative mechanism one whereby unexpected inflation affects output trend deviations and inflation
Eyzaguirre and Rojas (1996)	90-day PRBC interest rate (1985 to April 1995); interbank rate (from May 1995 on)	Spending expansion rate	Current account deficit no greater than 3 to 4 percent of GDP; gradual reduction of inflation	PRBC rate affects market credit rates, which influence the expansion of aggregate spending. This ultimately affects price and wage inflation
Budnevich and Pérez (1995)	90-day PRBC interest rate (1985 to April 1995); interbank rate (from May 1995 on)	Spending-potential output gap	In the 1980s, real exchange rate; in the 1990s, real exchange rate, current account deficit no greater than 3 to 4 percent of GDP, and inflation	Market rates are closely linked to central bank's short rate. Market rates affect spending and thereby affect the inflation rate
Magendzo (1997)	90-day PRBC interest rate (1985 to April 1995); interbank rate (from May 1995 on)	Spending-output gap	"High" real exchange rate and current account (1985-89); medium- and long-term equilibrium of real exchange rate (1990s); inflation; current account deficit no larger than 3 to 4 percent of GDP	The rate has informational properties and affects the spending-output gap, which determines the inflationary trend
Zahler (1994)	90-day PRBC interest rate.	Actual output-potential output gap; gap between growth rates of spending and potential output.	Inflation; medium- and long-term current account deficit no larger than 3 to 4 percent of GDP.	Interest rate affects spending growth, which in turn affects inflation.

APPENDIX B

Empirical Results of Selected Studies of Monetary Policy in Chile

Author	<i>Effect of monetary policy</i>			<i>Methodology</i>
	<i>On inflation</i>	<i>On economic activity</i>	<i>On the real exchange rate</i>	
Rosende and Herrera (1991)	A 120-basis-point increase in the interest rate has a negative effect on price-level deviation from trend in the range of 0.43 to 0.75 percentage point and lasts around six quarters After four quarters, 45 percent of the variance in price-level deviations is attributable to shocks on real exchange rate, and 12 percent to shocks to the interest rate. Money explains a mere 0.64 percent of variance	A 120-basis-point increase in the interest rate reduces the deviation of output from its trend by 0.97 to 1.25 percentage points after four quarters. This effect is transitory, lasting roughly six quarters A positive 3.2-percentage-point shock to the money supply increases the deviation of output from its trend by an estimated 0.36 to 0.89 percentage point over four quarters. After four quarters, shocks to money explain an estimated 22 percent of the variance of GDP, whereas shocks to the interest rate explain 14 percent. In the medium run (eight to sixteen quarters) the real exchange rate explains nearly 43 percent of output variance	No results from the VAR relating to the effects of monetary variables on the real exchange rate are reported.	The 90- to 365-day inflation-adjustable deposit rate is used as a proxy for the monetary policy instrument Quarterly data are used for the period from 1978 Q1 to 1990 Q4 A VAR system is estimated that includes the exchange rate, interest rate, the real exchange rate (central bank), CPI, M1A, GDP Variable deviations from the trend are used (Kydland and Prescott's filter)
Mendoza and Fernández (1994)	The interest rate has no Granger causality on the inflation rate for twelve months M1A has no Granger causality on inflation, but inflation does cause M1A. Weak evidence exists that the gap between actual and potential output has a Granger causality on inflation	The interest rate has no Granger causality on the output gap The M1A's twelve-month growth rate has Granger causality on the output gap, but not vice versa Unexpected inflation has Granger causality on the output gap (impulse response analyses show that the relationship is negative) No systematic effect is found of the UF interest rate on the output gap Only sharp interest rate increases (1988-92) induce an output gap reduction, with a lag of nine months	No systematic responses to shocks in the UF interest rate or to the growth-rate of M1A are reported.	The 90- to 365-day inflation-adjustable deposit rate is used as a proxy for the monetary policy instrument Quarterly data are used for the period from January 1986 to March 1994 Granger causality test: interest rate-intermediate objectives (money, output gap); intermediate objectives- inflation; interest rate- inflation. VAR: interest rate;

APPENDIX B (continued)

Author	<i>Effect of monetary policy</i>			
	<i>On inflation</i>	<i>On economic activity</i>	<i>On the real exchange rate</i>	<i>Methodology</i>
Mendoza and Fernández(1994) (continued)	No systematic effect is found on inflation from an increased interest rate (in fact, the VAR shows an initial positive response) Only sharp interest rate increases (1988-92) induce a drop in inflation, with a nine-month lag			twelve-month variation rate of M1A; actual seasonally adjusted output gap-trend; twelve-month inflation rate; real exchange rate; terms of trade (exogenous variable)
Eyzaguirre and Rojas(1996)	A 1-percentage-point increase in the spending-output gap increases nontradables inflation by 0.25 percentage point during the two to three months following the shock. This effect amounts to an estimated 0.5 to 0.6 percentage point after five to six quarters A 100-basis-point increase in the credit interest rate reduces nontradables inflation by 0.3 percentage point after one year, accumulating a 1-percentage-point reduction after eighteen months from the shock Innovations in the spending-output gap explain an estimated	An increase of 100 basis points in the credit rate is expected to reduce the growth rate of spending by 1 percentage point in the short run. This effect increases to 1.5 percentage points after five to six quarters. Innovations in the credit rate explain 25 percent of variance in spending, and the greatest impact occurs after the third quarter	After three quarters, innovations in productivity, the credit rate, and the spending-output gap explain 20 to 24 percent each of the variance of the real exchange rate. In contrast, the differential between domestic and foreign rates explains no significant fraction of the variance	The 30- to 90-day inflation-adjustable deposit rate is used as a proxy for the monetary policy instrument Quarterly data from 1998 Q1 to 1995 Q4 Simple correlation analysis between the 90-day PRBC rate, the 30- to 365-day bank credit rate, and a hybrid foreign interest rate (looking for association) Decomposition of the variance of the 90-day PRBC rate, the 90- to 365-day bank credit rate, and a hybrid foreign interest rate (looking for causality) OLS regression of first difference of spending against own lags and disposable income, the credit rate, and the foreign rate. Variance analysis of spending forecast error OLS regression of nontradables inflation against own lags and lags of the

APPENDIX B (continued)

<i>Author</i>	<i>Effect of monetary policy</i>			<i>Methodology</i>
	<i>On inflation</i>	<i>On economic activity</i>	<i>On the real exchange rate</i>	
Eyzaguirre and Rojas (1996) (continuation)	50 percent of variance in nontradables inflation after four quarters			spending-output gap, wages, the exchange rate, and tradables inflation; variance analysis of nontradables inflation forecast errors OLS regression of real exchange rate against mean productivity lags, the credit rate, the domestic-foreign rate differential, and the spending-output gap; variance analysis of the real exchange rate forecast error
R. Valdés (1997)	The monetary policy rate has a reported negative transitory effect (between months 6 and 12) on the gap between core and target inflation. A 30-basis-point rise in the rate reduces the gap by 0.4 percentage point after nine months Insignificant positive effect on the level of core inflation.	Transitory negative effect (between months 4 and 15) on the growth rate of the IMACEC. A 30-basis-point increase in the interest rate reduces the IMACEC's growth rate by 0.5 percentage points (maximum effect after seven months) Transitory negative effect (between months 7 and 18) on spending-output gap.	No significant effect	Monthly data: January 1985 to August 1996 The 90-day PRBC rate and the interbank rate are used as a proxy for the monetary policy instrument “Semistructural” VARs: interest rate; core-target inflation gap; IMACEC twelve-month variation rate; real exchange rate twelve-month variation rate; M1A twelve-month variation rate; spending's twelve-month variation rate.

APPENDIX C

Variable Nomenclature and Description

BRECHA	Difference between the twelve-month percentage variation of spending and output (from the Central Bank of Chile)
CICLO	Difference between the logarithms of seasonally adjusted GDP and potential GDP
DTASABC	First difference of ninety-day PRBC
DTBE	First difference of eight-year PRC
DV12IPCSUB	First difference of the twelve-month percentage variation in the IPCSUB
DV12TCN	First difference of the twelve-month percentage variation in the TCN
DV12IPCNT	First difference of the V12IPCNT variable
DV12TCRINE	First difference of the V12TCRINE variable
LCOLOC	Logarithm of real actual credit of the financial system (from the Superintendency of Banks and Financial Institutions)
LDHAB	Logarithm of working days (authors' calculations)
LGASTO	Logarithm of aggregate spending in millions of 1986 pesos (from the Central Bank of Chile)
LIBOR	Ninety-day London interbank offered rate deflated by U.S. inflation (from the Central Bank of Chile)
LIGPA	Logarithm of the real general stock price index (IGPA)
LIPCNT	Logarithm of the nontradables price index (from the National Institute of Statistics)
LM1A	Logarithm of the money aggregate M1A (from the Central Bank of Chile)
LIPCSUB	Logarithm of the core price index (from the Pontifical Catholic University data base)
LPIB	Logarithm of GDP in millions of 1986 pesos (from the Central Bank of Chile)
LTCN	Logarithm of the nominal exchange rate (from the Central Bank of Chile)
LTCRINE	Logarithm of the real exchange rate, defined as the ratio of the price index for tradables to that for nontradables (from the National Institute of Statistics)
LTTUC	Logarithm of the terms of trade (from the Pontifical Catholic University data base)
TASABC	Ninety-day PRBC rate (from the Central Bank of Chile)

APPENDIX C (continued)

TBE	Eight-year PRC rate (from the Central Bank of Chile)
VTCREXPOST	Ninety-day ex post variation of the real exchange rate, defined as the ninety-day ex post variation of the TCN, plus the ninety-day variation of the U.S. CPI, less the ninety-day ex post variation of the Chilean CPI ("ex post" refers to the variables being advanced by one quarter)
V3IPC	Ninety-day percentage variation in the CPI
V3TCN	Ninety-day percentage variation in the TCN
V12COLOC	Twelve-month variation in actual credit in real terms
V12DHAB	Twelve-month variation in working days
V12GASTO	Twelve-month variation in spending
V12IGPA	Twelve-month variation in the real IGPA
V12IPCNT	Twelve-month percentage variation in the nontradables CPI
V12IPCSUB	Twelve-month variation in the core CPI
V12M1A	Twelve-month variation in the money aggregate M1A
V12PIB	Twelve-month variation in GDP
V12TCN	Twelve-month variation in the nominal exchange rate
V12TCRINE	Twelve-month variation in the real exchange rate
V12WUC	Twelve-month variation in nominal wages (from the National Institute of Statistics)

REFERENCES

- Bernanke, B., and A. Blinder. 1992. "The Federal Funds Rate and the Channels of Monetary Transmission." *American Economic Review* 82(4): 901-21.
- Bernanke, B., and M. Gertler. 1995. "Inside the Black Box: The Credit Channel of Monetary Policy Transmission." *Journal of Economic Perspectives* 8(4):27-48.
- Bernanke, B., and A. Mihov. 1998. "Measuring Monetary Policy." *Quarterly Journal of Economics* 113 (3): 869-902.
- Bernanke, B., and F. Mishkin. 1992. "Central Bank Behavior and the Strategy of Monetary Policy: Observations from Six Industrialized Countries." In *NBER Macroeconomics Annual*, edited by O. Blanchard and S. Fischer. Cambridge, Mass.: MIT Press.
- Budnevich, C., and J. Pérez. 1995. "Política Monetaria: La Reciente Experiencia Chilena." *Estudios Públicos* (Winter): 283-322.
- Calvo, G., and E. Mendoza. 1997. "Empirical Puzzles of Chilean Stabilization Policy." Paper prepared for the conference on Chile: Development Lessons and Challenges, organized by the Development Institute of the World Bank, Washington, December 17-18.
- Cochrane, J. 1998. "What do the VARs Mean? Measuring the Output Effects of Monetary Policy." *Journal of Monetary Economics* 41 (2): 277-300.
- Coe, D., and C. McDermott. 1997. "Does the Gap Model Work in Asia?" *International Monetary Fund Staff Papers* 44(1): 59-80.
- Doan, T. 1992. *RATS User's Manual*. Evanston, Ill.: Estima.
- Dornbusch, R. 1980. *Open Economy Macroeconomics*. New York: Basic Books.
- Edison, H. 1993. "The Effectiveness of Central Bank Intervention: A Survey of the Literature after 1982." Special Papers in International Economics18. Princeton, N.J.: Princeton University (July).
- Edwards, S., and C. Végh. 1997. "Banks and Macroeconomic Disturbances under Predetermined Exchange Rates." NBER Working Paper 5977. Cambridge, Mass.: National Bureau of Economic Research.
- Eyzaguirre, N., and P. Rojas. 1996. "Restricciones al Flujo de Capitales y Política Macroeconómica: El Caso Chileno." Paper prepared for a conference on "El Retorno de los Capitales Privados a América Latina" (The Return of Private Capital to Latin America), Santiago, Chile, July 30-31.

- Fontaine, J. A. 1991. "La Administración de la Política Monetaria en Chile, 1985-89." *Cuadernos de Economía* 28(83): 109-129.
- Friedman, M. 1976. *Price Theory*. Chicago: Aldine.
- Garretsen, H., and J. Swank. 1998. "The Transmission of Interest Rate Changes and the Role of Bank Balance Sheets: A VAR-Analysis for the Netherlands." *Journal of Macroeconomics* 20(2): 325-339.
- Hamilton, D. 1994. *Time Series Analysis*. Princeton, N.J.: Princeton University Press.
- International Monetary Fund. 1996. *World Economic Outlook*. Washington.
- Kamin, S. 1996. "Real Exchange Rate and Inflation in Exchange Rate Based Stabilization: An Empirical Examination." International Finance Discussion Papers 554. Washington: Board of Governors of the Federal Reserve System (June).
- Leeper, Eric, C. Sims, and T. Zha (1996): "What Does Monetary Policy Do?" *Brookings Papers on Economic Activity* 2: 1-78.
- Lucas, R. 1996. "Nobel Lecture: Monetary Neutrality." *Journal of Political Economy* 104(4): 661-82.
- Magendzo, I. 1997. La Política Monetaria en Chile en la Década de los Noventa: Objetivos, Herramientas e Indicadores. Serie Estudios Económicos 41. Santiago: Banco Central de Chile
- Massad, C. 1998. "La Política Monetaria en Chile." *Economía Chilena* 1 (1): 7-28.
- Masson, P., M. Savastano, and S. Sharma. 1997. "The Scope for Inflation Targeting in Developing Countries." IMF Working Paper 130. Washington: International Monetary Fund.
- Mendoza, E., and F. Fernández. 1994. "Monetary Transmission and Financial Indexation: Evidence from the Chilean Economy." IMF Paper on Policy Analysis and Assessment. Washington: International Monetary Fund.
- Mishkin, F. 1995. "Symposium on the Monetary Transmission Mechanism." *Journal of Economic Perspectives* 9(4): 3-10.
- Rojas, P. 1993. "El Dinero como un Objetivo Intermedio de Política Monetaria en Chile: Un Análisis Empírico." *Cuadernos de Economía* 30 (90): 139-78.
- Rosende, F. 1998. "Política Monetaria en Chile en los Noventa: Un Ejercicio "no Neutral." *Perspectivas en Política, Economía y Gestión*. 2 (1): 157-185.
- Rosende, F., and L. Herrera. 1991. "Teoría y Política Monetaria: Elementos Para el Análisis." *Cuadernos de Economía* 28 (83): 55-93.

- Sims, C. 1980. "Macroeconomics and Reality." *Econometrica* 48(1): 1-48.
- Taylor, J. 1993. *Macroeconomic Policy in the World Economy: From Econometric Design to Practical Operation*. New York: W. W. Norton.
- Valdés, R. 1997. "Efectos de la Política Monetaria en Chile." *Cuadernos de Economía* 35 (104): 97-125.
- Valdés, S., and M. Soto. 1998. "The Effectiveness of Capital Controls: Theory and Evidence from Chile." *Empirica* 25(2): 133-164.
- Vergara, R. 1994. "Política Cambiaria en Chile: La Experiencia de una Década (1984-1994)." *Estudios Públicos* 56: 133-164.
- Zahler, R. 1994. Speech at a meeting of the Asociación de Industrias Metalúrgicas, Santiago (July).
- . 1997. "La Política Macroeconómica de Chile en los Años Noventa: La Visión del Banco Central." Unpublished manuscript Santiago: Comisión Económica para América Latina y el Caribe.

DOES INFLATION TARGETING INCREASE OUTPUT VOLATILITY? AN INTERNATIONAL COMPARISON OF POLICYMAKERS' PREFERENCES AND OUTCOMES

Stephen G. Cecchetti

Ohio State University

Michael Ehrmann

European Central Bank

Monetary policy regimes around the world changed dramatically over the decade of the 1990s. Central banks have become more transparent, more independent, more accountable, and (apparently) more successful. The biggest transformation has been the move away from focusing on intermediate objectives, such as money and exchange rates, and toward the direct targeting of inflation. In their survey of central banks worldwide, Fry and others (1999) find that in 1990 only four of seventy central banks had either an explicit monitoring range or an actual target for inflation. By 1998 that number had risen to forty out of seventy-seven.

This profound change in institutional structure has been accompanied by an equally impressive improvement in economic performance. Across the set of twenty-three industrialized and developing countries that we study here, average inflation fell from 8.7 percent per year for the five years ending in 1990 to an average of 3.5 percent per year for the most recent five years for which we have data. Over these same intervals, real growth in industrial production rose from 3.2 percent per year to 4.3 percent per year.

This paper was written while Ehrmann was affiliated to the European University Institute.

The authors are grateful to Henrik Hansen and Anders Warne for sharing their RATS code, to Meg McConnell and Gabriel Perez Quiros for useful discussions, and to Valerie LaPorte for editorial assistance. The views expressed are authors own and not necessarily those of the European Central Bank.

Monetary Policy: Rules and Transmission Mechanisms, edited by Norman Loayza and Klaus Schmidt-Hebbel, Santiago, Chile. ©2002 Central Bank of Chile.

The most interesting part of the story, however, concerns inflation targeting, which one might call the monetary policy framework of the 1990s. Included in our sample of twenty-three countries are nine that have targeted inflation explicitly, beginning, in nearly all cases, in the first few years of the decade. Table 1 shows that inflation in these countries fell by more than 7 percentage points on average, from 10.8 percent in the late 1980s to 3.4 percent in the latter part of the 1990s. The average reduction among nontargeting countries was 3.6 percent. To a very real extent, inflation targeting has achieved its primary objective: the lowering of inflation.

Table 1. Output Growth and Inflation and Their Variability before and after 1990 in Inflation-Targeting and Nontargeting Countries (percent per year)

Country group	Average		Standard deviation ^b	
	Real output growth ^a	Inflation	Real output growth	Inflation
<i>1985-89</i>				
All countries	3.21	8.65	9.08	10.44
All inflation targeters ^c	2.26	10.83	7.47	15.01
All nontargeters ^d	3.81	7.24	10.12	7.49
All EU countries	2.35	10.22	7.35	13.69
EU nontargeters	3.23	3.83	10.65	3.60
Non-EU nontargeters	4.86	13.38	9.17	14.51
<i>1993-97</i>				
All countries	4.28	3.53	7.22	3.68
All inflation targeters	4.80	3.41	6.92	3.31
All nontargeters	3.95	3.60	7.41	3.92
All EU countries	4.84	3.32	7.09	3.25
EU nontargeters	3.82	2.44	8.29	1.90
Non-EU nontargeters	4.18	5.68	5.83	7.55
<i>Difference between 1985-89 and 1993-97</i>				
All countries	1.08	-5.12	-1.87	-6.75
All inflation targeters	2.54	-7.42	-0.55	-11.70
All nontargeters	0.13	-3.64	-2.71	-3.57
All EU countries	2.49	-6.90	-0.26	-10.44
EU nontargeters	0.59	-1.38	-2.36	-1.69
Non-EU nontargeters	-0.68	-7.70	-3.35	-6.95

Source: See the appendix B for details

a. Output growth is measured by industrial production (quarterly data at an annual rate).

b. Average of standard deviations for all countries in the group. The standard deviation of real growth is computed as the deviation from the full sample trend. The standard deviation of inflation is computed as the deviation from 2 percent. Sample periods vary slightly by country.

c. The nine countries, as classified by Morandé and Schmidt-Hebbel (1999), where inflation targets are explicit and clearly dominate any other possible secondary target or objective: Australia, Canada, Chile, Finland, Israel, New Zealand, Spain, Sweden, and the United Kingdom.

d. Austria, Belgium, Denmark, France, Germany, Ireland, Italy, Japan, Korea, Mexico, Netherlands, Portugal, Switzerland, and the United States.

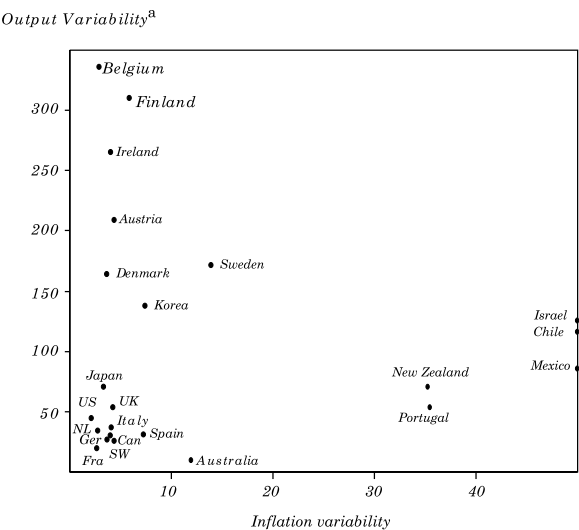
There are many ways to portray a shift in monetary regime. One is to note that, if the regime shift is real, it must represent a change in the preferences of the central bank. This means that, if we can use the outcomes of policy to infer the objectives of the policymaker, these objectives should have changed following the regime shift. More specifically, we might think of policymakers as choosing a point on a trade-off between output variability and inflation variability, assuming that such a trade-off exists. If there is a stable trade-off, a move to inflation targeting would be expected to result in a move along this frontier to a point where inflation is less variable and output more variable than they otherwise would have been. It is also possible that operating on the frontier is difficult, and that a shift in the policy framework could act as a commitment mechanism, increasing credibility and allowing policymakers to achieve better outcomes overall.

The breakdown of output and inflation statistics in table 1 supports the view that inflation-targeting countries have reduced inflation variability at the expense of an increase in output variability. Comparing the late 1980s with the mid-1990s, we see first that volatility in both output and inflation fell in all countries in our sample, suggesting that the 1990s were a relatively shock-free decade; thus overall performance has been better in all countries. That is, aggregate supply shocks, which move output and inflation in opposite directions and force monetary policymakers to make choices, may have been on average smaller (in absolute value) during the 1990s.¹ For this reason, it is important to compare inflation-targeting and nontargeting countries. The table shows that the standard deviation of inflation fell more for the targeters, and output variability fell less.

Figures 1 and 2 present the same information in a slightly different way. Figure 1 plots the variance of inflation (as measured by consumer prices) and the volatility of output (as measured by industrial production) about its trend for our sample of twenty-three countries. (Extremely high values of inflation or output variability are truncated.) These outcomes depend on many things, including a country's economic structure, its policy regime, and the pattern of shocks it has faced. Nevertheless, the pattern of inflation and output variability suggests the existence of a trade-off, because there seem to be groups of countries along concentric curves that move radially outward from the origin.

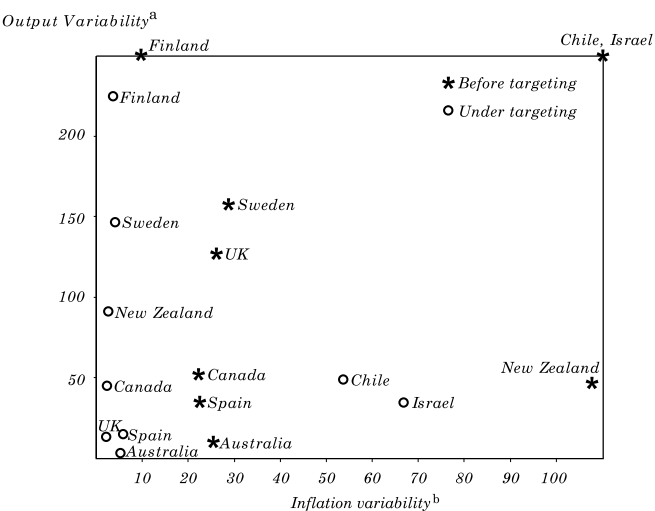
1. Fry and others (1999, p. 66) also make this point.

Figure 1. Trade-off between Output and Inflation Variability in Twenty-Three Countries



Source: Authors' calculations.
a. Deviations from trend.

Figure 2. Trade-off between Output and Inflation Variability in Inflation-Targeting Countries, before and after Implementation



Source: Authors' calculations.
a. Deviations from trend.
b. Deviations from 2 percent per year.

Figure 2 reports the experience of the inflation-targeting countries. We examine the outcomes for five years before (indicated by asterisks) and five years after inflation targeting was implemented (indicated by circles). The figure shows the squared deviation of annual inflation from 2 percent, which we assume to be a likely long-run target. If a country were initially operating on a stationary inflation-output variability trade-off, the shift to inflation targeting would be expected to move the point on the plot upward (toward higher output variability) and to the left (toward lower inflation variability). This is the case, however, for only one of the nine countries we examine, New Zealand. For the remaining eight countries, performance suggests that the move to inflation targeting came with an overall improvement in efficiency.

Unfortunately, presenting the evidence in this way has a significant drawback. If, in the aggregate, the shocks hitting the economy decline between the two periods we compare, both inflation and output variability will fall, and the country's point on the plot will move toward the origin (downward and to the left). For this reason we must develop a more disciplined approach to the data, one based on an economic model.

The remainder of this paper pursues this approach, estimating the changes in policymakers' revealed preferences to see whether the outcomes in inflation-targeting countries are likely to have come from an increase in the weight attached to inflation variability in policymakers' objective function. We do this using the technique described in Cecchetti, McConnell, and Perez Quiros (1999), who note that if we assume policymakers are acting optimally, their actions reveal their objectives. The method is as follows. Beginning with a simple loss function that represents combinations of output and inflation variability, we can treat policy as a solution to a control problem in which the interest rate path is chosen so as to place the economy at the point on the variability frontier that minimizes this loss. In effect, we deduce from the data what policymakers' preference must be. The data are used to go backward. First, we estimate the structure of the economy in each country. This tells us the country's available frontier. From this and the actual output and inflation outcomes, we can estimate the relative weight that national central banks implicitly have placed on output and inflation variability in formulating their policies.

The remainder of the paper is in four sections. Section 1 presents a simple model that allows us to relate output and inflation outcomes,

together with the economic structure, to a policymaker's preferences. Section 2 reports estimates of the structural vector autoregressions that give us the raw material we need to estimate preferences. Section 3 then reports estimates of the policymaker's implied objective function in a sample of twenty-three countries. Most important, we see how these objective functions vary across targeting and nontargeting countries and how they have changed over time. Our conclusion is that the targeting countries have, on average, moved along the available frontier in a way that reduces inflation variability significantly and increases output variability slightly from what they might otherwise have been. Interestingly, the same is true of the nontargeting EU countries, which necessarily increased their focus on inflation as they approached the start of monetary union on January 1, 1999.

1. FORMULATING THE POLICYMAKER'S PROBLEM

When making policy, central bankers consider large masses of information in an effort to meet what are often multiple objectives. It is impossible to describe the process in terms that are amenable to analytical study. To make any progress at all, we must begin with a number of assumptions that clearly result in a model that is unrealistic. Our hope is that our results capture some critical aspect of the problem actually being addressed.

We follow textbook analyses at the outset by assuming that a central banker's objectives can be written as a simple quadratic loss function.² That is, the policymaker seeks to minimize the discounted sum of squared deviations of output and prices from their target paths. The general form of such a loss function (measured over a medium-term horizon of three or four years) can be written as

$$L = E \left[\alpha (\pi - \pi^*)^2 + (1 - \alpha) (y - y^*)^2 \right], \quad (1)$$

where E denotes the mathematical expectation, π is inflation, y is the logarithm of aggregate output, π^* and y^* are the desired levels of inflation and output, and α is the relative weight given to squared

2. The model here was first presented in Cecchetti, McConnell, and Perez Quiros (1999) and is based on Cecchetti (1998).

deviations of output and inflation from their desired levels.³ The parameter α is the crucial quantity of interest, and we will call it the policymaker's aversion to inflation variability.

Equation (1) immediately gives rise to several issues. First, the objective function is symmetrical, including only quadratic terms. The implication is that policymakers are equally averse to extremely positive and extremely negative events. This is surely not the case: we would expect policymakers to take action when the mean and the variance of forecast distributions are likely to stay the same but the probability of some extreme bad event increases. That is, even if the variance is unchanged, an increase in the probability of a severe economic downturn is likely to prompt action.

Also, the loss function includes only output and inflation and not exchange rates. The rationale for this is our belief that domestic inflation and output are the fundamental concerns of policymakers. The decision to focus on the exchange rate path in the formulation of policy is, in our view, the choice of an intermediate target. Policymakers are concerned not with the behavior of intermediate targets per se, but with the domestic inflation and growth outcomes produced by their use. Exchange rate targeting is analogous to monetary aggregate targeting. Both imply a certain behavior for output and inflation and an objective function such as equation (1).

Returning to the issues at hand, we contend that the policymaker's problem cannot be solved without knowledge of the dynamics of output and inflation and their relationship to the interest rate (r_t) instrument controlled by the policymaker. We write these in the following simple way:

$$y_t = \gamma(r_t - d_t) + s_t, \quad (2)$$

$$\pi_t = -(r_t - d_t) - \omega s_t, \quad (3)$$

where d_t and s_t are shocks to aggregate demand and aggregate supply, respectively. These are the fundamental sources of exogenous disturbances to the economy.⁴ The parameter γ gives the ratio of the

3. This loss function can be written in a more complex, dynamic form in which a discount factor and a time horizon appear explicitly. In addition, we could add a term that makes changes in interest rates explicitly costly. These refinements do not add to the analysis here.

4. Equations (2) and (3) can be thought of as the time averages of the vector-moving-average representation of a structural vector autoregressive model. Thus our model, although apparently simple, does not restrict short-run dynamics.

responses of output and inflation to a policy shock and can be thought of as the inverse of the slope of the aggregate supply curve. The parameter ω is the slope of aggregate demand.

The relationship linking output, inflation, and interest rates can be described in many ways, most of them very complex. What is important for our purposes here, and is captured in equations (2) and (3), is the notion that two kinds of disturbances buffet the economy and require policy responses. The first—the aggregate demand shock—moves output and inflation in the same direction; the second—the aggregate supply shock—moves output and inflation in opposite directions. Policy can only move output and inflation in the same direction and so is analogous to an aggregate demand shock. It is the movements in aggregate supply that create the essential dilemma for policy, because they force a choice.

The fact that the policymaker's objectives are assumed to be a simple function of the variances of output and inflation, and that the structure of the economy is assumed to be linear, means that the optimal policy response to demand and supply shocks is a simple linear rule. We write this as

$$r_t = ad_t + bs_t. \quad (4)$$

It is now straightforward to solve for the rule. The result is that policy offsets aggregate demand shocks one for one, and so a is equal to 1. As expected, the response to supply shocks is more complex, because they create a trade-off for policy. The extent of the reaction depends on the economic structure as measured by the slopes of the aggregate demand (ω) and aggregate supply curves (γ), as well as the policymaker's aversion to inflation variability (α).⁵

The optimal policy has several implications for the variability of output and inflation. First, both depend only on the variance of aggregate supply shocks, not on the variance of demand shocks.⁶ This follows immediately from the fact that the optimal policy rule dictates that demand shocks be offset completely by interest rate moves. Second, changes in the volatility of aggregate supply shocks shift the

5. The resulting expression is given by $b^* = [-\alpha\omega + (1 - \alpha)\gamma]/[\alpha + (1 - \alpha)\gamma^2]$. It would be possible to rewrite equation (4) in the form used by Taylor (1993). To accomplish this, simply note that, using equations (2) and (3), the supply shock s_t can be written in terms of output, y_t , and inflation, π_t . Simple substitution would then allow us to rewrite the policy rule in terms of output and inflation directly—the form of a Taylor rule.

6. The resulting expressions are $\sigma_y^2 = (1 - \gamma b^*)^2 \sigma_s^2$ and $\sigma_\pi^2 = (\omega + b^*)^2 \sigma_s^2$, where σ_s^2 is the variance of the supply shocks and b^* is the optimal reaction to s_t given in note 5.

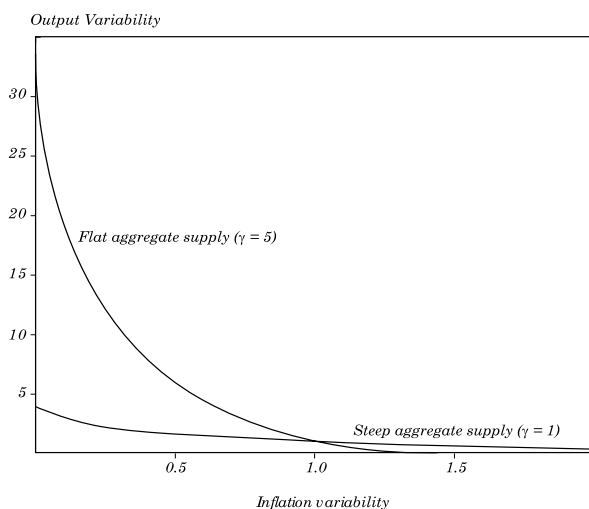
variance of output and inflation in the same proportion.⁷ As a result, we can derive the following ratio:

$$\frac{\sigma_y^2}{\sigma_\pi^2} = \left[\frac{\alpha}{\gamma(1-\alpha)} \right]^2. \quad (5)$$

This expression has several interesting properties. First, we note that when $\alpha = 0$ (that is, the policymaker cares only about output variability), $\sigma_y^2 / \sigma_\pi^2 = 0$. Likewise, for $\alpha = 1$ (the policymakers cares only about inflation variability), $\sigma_y^2 / \sigma_\pi^2 = \infty$. Significantly, varying α between 0 and 1 allows us to trace out the entire output-inflation variability frontier, the shape of which is related to the slope of the aggregate supply curve ($1/\gamma$) and is unaffected by the slope of the aggregate demand curve (ω) and the variance of aggregate supply shocks.

Figure 3 plots two representative frontiers to show how the slope depends on γ . The solid line plots a frontier for a country with a relatively flat aggregate supply curve ($\gamma = 5$), whereas the dashed line depicts the frontier for a country with a steeper aggregate supply

Figure 3. Representative Frontiers of the Trade-off between Inflation and Output Variability



Source: Authors' calculations.

7. This means that the variability frontier as drawn in figures 1 and 2 does shift with the variance of supply shocks, making those figures more difficult to interpret.

curve ($\gamma = 1$).⁸ The implication is that if a country faces a relatively flat aggregate supply curve, reductions in inflation variability will be accompanied by relatively large increases in output variability, making inflation targeting more difficult.

We will use equation (5) to estimate the policymaker's revealed aversion to inflation variability, α . First, however, we need to know γ , which we will estimate in section 2, and the ratio of the variances of output and inflation, which we will obtain from the data. With these two quantities in hand, we can estimate α .

2. MEASURING THE IMPACT OF POLICY

The next task is to measure the impact of policy on output and inflation. That is, we need to identify and estimate a model that allows us to measure the monetary transmission mechanism. Numerous studies report such estimates for various sets of countries.⁹ We choose to apply the methodology used by Ehrmann (2000), in his study of European countries, to a broader cross section of countries. This approach yields a series of estimates, all based on the same methodology, for a set of twenty-three countries, including nine that target inflation explicitly. Also, the estimated models can be carefully tested for structural stability and adjusted to ensure that they are stable over the samples for which we estimate them. It is also important that our models yield a complete set of responses to the shocks we identify and that these models conform to our priors with regard to the type of shock being identified.¹⁰ In practice, these last requirements are extremely difficult to meet.

Methodologically, our approach is based on the structural vector autoregression (VAR) techniques devised by King and others (1991) to identify monetary shocks from a combination of long-run and short-run restrictions. For each country the model has either four or five variables, including output, inflation, an interest rate, and (with the exception of Japan, Switzerland, and the United States) an exchange rate. When a fifth variable is present, it is either a monetary aggregate, a second interest rate, or a commodity price index. The methods

8. Table 3 below reports the estimates of γ for the countries we study. The case of $\gamma = 5$ is close to that of Australia, France, Germany, Italy, and Switzerland. The second case, $\gamma = 1$, is close to that of Chile, Denmark, Israel, Korea, Japan, Mexico, New Zealand, Spain, and the United States.

9. See the references in Cecchetti (2001) for a representative sample.

10. In particular, it is important for our purposes that all shocks in the system, and not just the money shock, produce plausible impulse response functions.

and model specifications are described in detail in the appendixes A and B. Here we simply report the results.

Figure 4 plots the responses of output and inflation to an interest rate increase of 100 basis points for the twenty-three countries in our sample. For purposes of comparison, we have plotted all the results on the same vertical scale. The patterns vary quite dramatically, with the interest rate changes eliciting a much larger response in Germany and Switzerland, for example, than in Israel or Mexico.

Figure 4. Responses of Output and Inflation to a 100-Basis Point Interest Rate Increase in Twenty-Three Countries

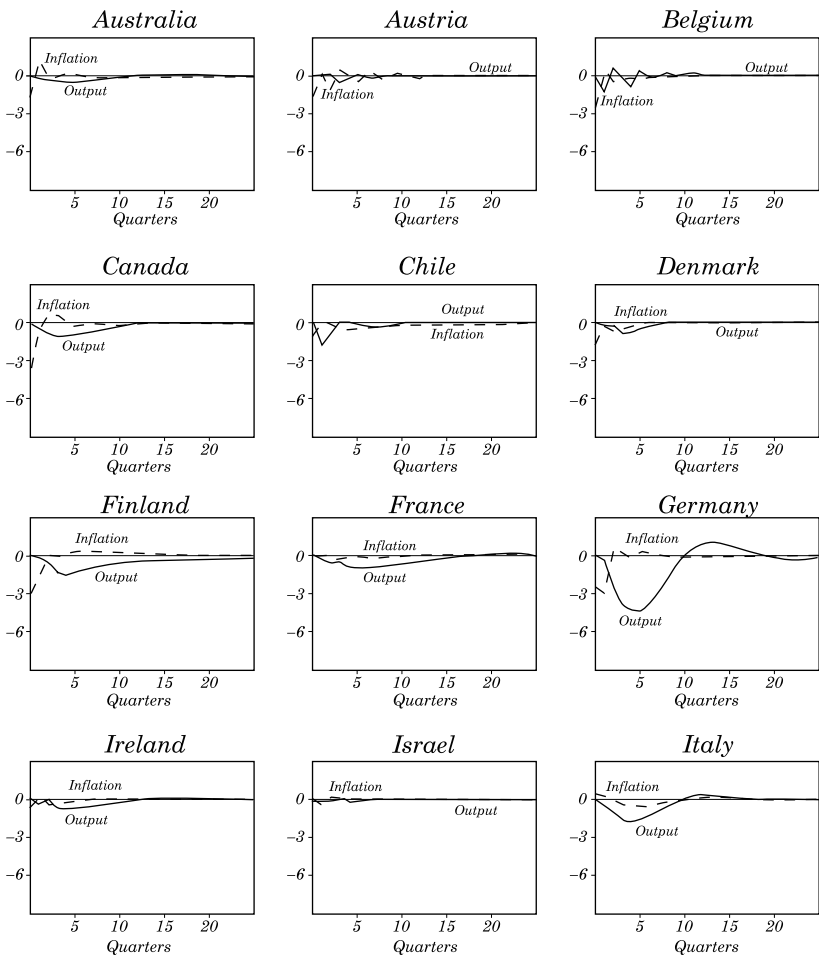
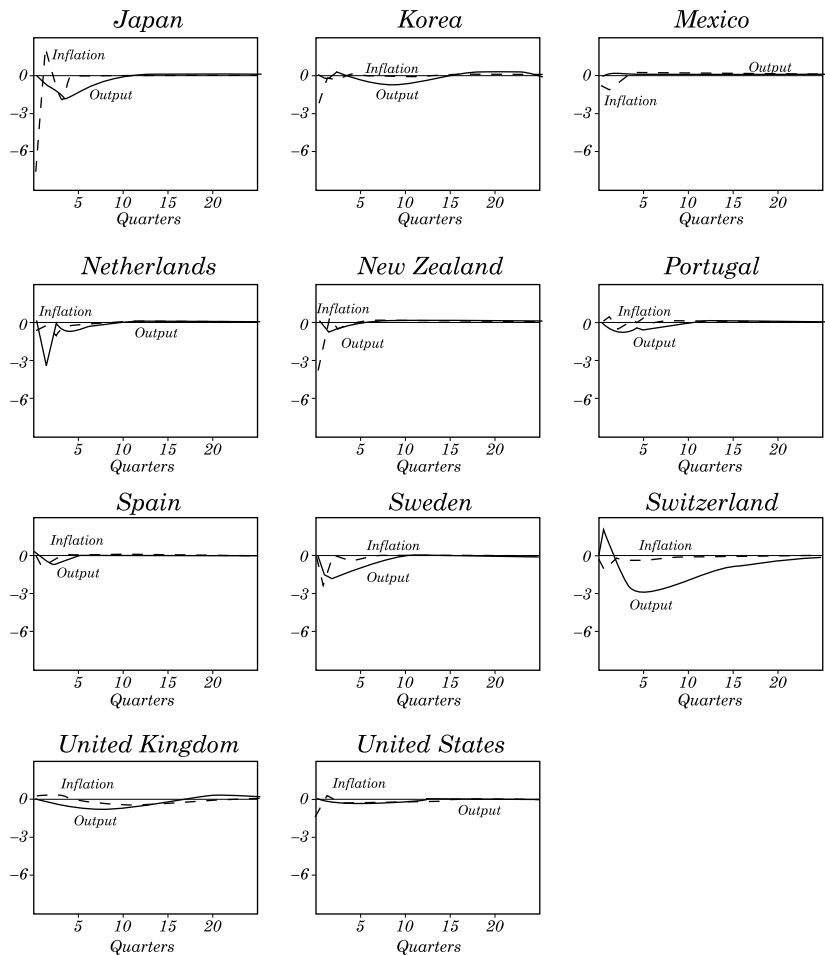


Figure 4. (continued)



Source: Authors' calculations.

Table 2 summarizes the results from the figure. For each country the table also reports estimates of the sacrifice ratio and an estimate of the inverse slope of the aggregate supply curve (γ), which we need to infer the policymaker's preferences. The sacrifice ratio is the cumulative percentage loss in output for a 1-percentage-point reduction in inflation. Here we report the sacrifice ratio over a horizon of twelve quarters.

Table 2. Impulse Response Functions in Inflation-Targeting and Nontargeting Countries

Country	Maximum impact		Sacrifice ratio ^a	Inverse aggregate supply slope (γ) ^b
	On output	On inflation		
<i>Inflation-targeting countries</i>				
Australia	-0.48	-1.78	7.90	4.65
Canada	-0.96	-3.96	3.11	1.80
Chile	-1.78	-1.03	1.79	0.84
Finland	-1.51	-3.05	5.92	3.76
Israel	-0.11	-0.51	2.90	1.42
New Zealand	-0.93	-3.41	1.36	0.67
Spain	-0.68	-0.95	3.29	1.22
Sweden	-1.92	-2.58	4.68	2.35
United Kingdom	-0.84	-0.36	18.17	13.76
Average	-1.02	-1.96	5.46	3.38
<i>Other countries</i>				
Austria	-0.51	-1.58	0.40	0.22
Belgium	-1.21	-2.72	0.66	0.13
Denmark	-0.80	-1.68	1.52	0.70
France	-0.93	-0.28	8.65	6.15
Germany	-4.39	-3.05	10.37	5.72
Ireland	-0.73	-0.67	4.62	2.83
Italy	-1.82	-0.52	9.27	4.89
Japan	-1.76	-8.41	2.14	1.09
Korea	-0.73	-2.29	1.38	1.35
Mexico	-0.15	-1.19	0.83	0.69
Netherlands	-3.56	-1.23	4.76	2.03
Portugal	-0.82	-0.90	230.2	122.55
Switzerland	-3.04	-1.34	5.65	5.08
United States	-0.36	-1.30	1.75	1.10
Average ^c	-1.53	-2.02	4.00	2.46

Source: Authors' calculations.

a. Computed as the cumulative output loss per percentage-point reduction in inflation over a horizon of twelve quarters.

b. Twelve-quarter average of the impact of policy innovations on output, divided by the twelve-quarter average impact on inflation. See appendixes A and B for details.

c. Excludes Portugal.

The numbers appear to be both reasonable and similar across the targeting and nontargeting countries. With the exception of those for Portugal, all of the numbers are plausible. For the remaining countries the sacrifice ratio ranges from 0.4 for Austria to 18.2 for the United Kingdom. The estimate of γ has a similar variation, from 13.8 for the United Kingdom to 0.1 for Belgium (again ignoring Portugal). Although there is modest evidence that interest rate increases yield a bigger output response and a smaller implied sacrifice ratio in the inflation-targeting countries, the results are far from conclusive.

3. POLICYMAKERS' AVERSION TO INFLATION VARIABILITY

We are now ready to estimate policymakers' aversion to inflation variability (α). Equation (5), together with estimates of the aggregate supply slope and the ratio of the variance of output and inflation, yields an estimate of α . In calculating the ratio of inflation volatility to output volatility, we must make an assumption about the paths of desired inflation and output, π^* and y^* in equation (1). Throughout the analysis we take desired output to be the actual trend in the sample. This assumption tends to minimize the estimated "variance" of output, and so measures of α will be higher than they otherwise would be. Table 3 reports results for two assumptions about the desired level of inflation: that it is equivalent to average inflation in the sample, and that it is fixed at 2 percent. The results for the second assumption are always higher, because the use of the sample mean inflation reduces the squared deviations.

The first thing to notice about the results is that most of the α s are quite large, suggesting that many of these countries took the goal of inflation stability very seriously over this period. When desired inflation is assumed to be 2 percent, fourteen of the twenty-three countries have estimated α s of higher than 0.70, and half of these exceed 0.9.¹¹ The only country that appears not to be averse to inflation variability at all is Mexico, with an estimated α of 0.08. Beyond this, the average for the inflation-targeting countries is no different from that for the nontargeting countries.

The estimates in table 3 are interesting, but since they are computed over the full samples for which data are available, they do not allow us to infer the effects of changes to inflation targeting. For this reason we now shift to computing estimates of α using subsamples of the data. Figures 5 through 7 plot the results of an exercise in which we computed the value of α for five-year moving windows. Throughout we assume that desired inflation is 2 percent and that the estimate of

11. As noted in Cecchetti, McConnell, and Perez Quiros (1999), the use of industrial production to measure output is likely to produce values of α for these countries that are upper bounds on the true value. We would expect that a shift to GDP, which is nearly uniformly less volatile, would raise our estimate of the absolute value of γ and reduce our estimate of σ_y^2/σ_π^2 . For any given value of σ_y^2/σ_π^2 , a higher γ will imply a higher value of α , since the slope of the output-inflation variability frontier at that point will be steeper. Thus both of these effects serve to raise the value of α relative to what we would obtain using GDP.

γ is unchanged.¹² On each graph we include a horizontal line for the value of α computed from using the full sample, as reported in table 4. For the inflation-targeting countries in figure 5, the vertical line represents the date at which the new regime was introduced.

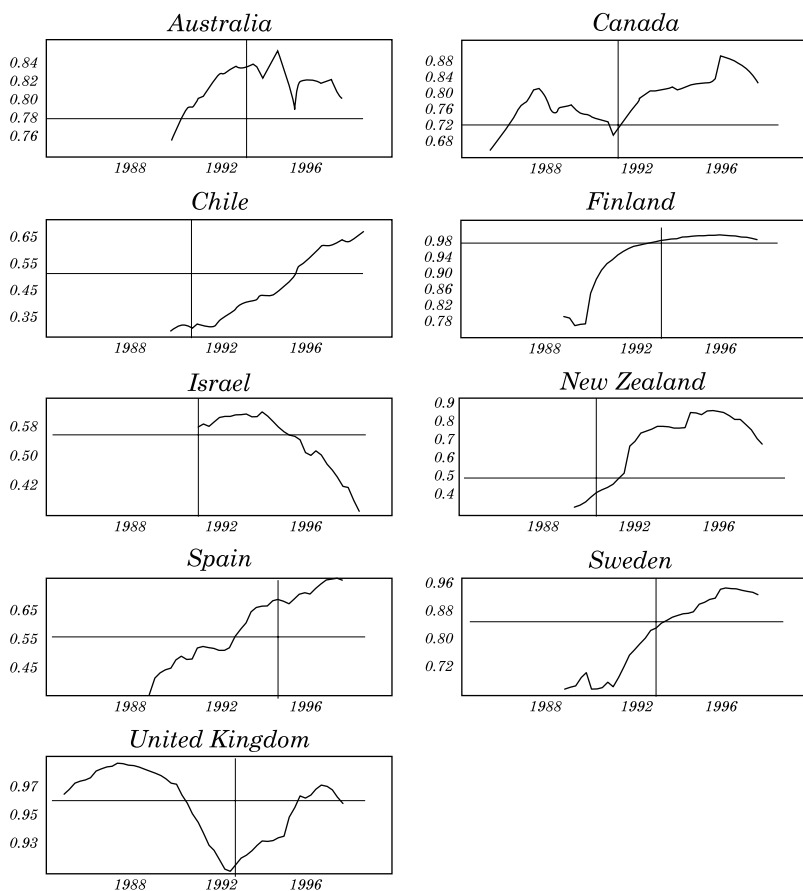
Table 3. Estimated Aversion to Inflation Variability in Inflation-Targeting and Nontargeting Countries

Country	Aversion to inflation variability (α)	
	Assuming desired output = trend output, and desired inflation = average inflation	Assuming desired output = trend output, and desired inflation = 2 percent per year
<i>Inflation-targeting countries</i>		
Australia	0.81	0.78
Canada	0.75	0.72
Chile	0.55	0.49
Finland	0.96	0.96
Israel	0.72	0.56
New Zealand	0.53	0.49
Spain	0.67	0.55
Sweden	0.86	0.84
United Kingdom	0.97	0.96
Average	0.76	0.71
<i>Other countries</i>		
Austria	0.50	0.49
Belgium	0.43	0.43
Denmark	0.61	0.59
France	0.95	0.94
Germany	0.94	0.93
Ireland	0.94	0.93
Italy	0.91	0.85
Japan	0.84	0.83
Korea	0.79	0.71
Mexico	0.12	0.08
Netherlands	0.84	0.84
Portugal	0.99	0.99
Switzerland	0.92	0.92
United States	0.74	0.70
Average ^c	0.75	0.73

Source: Authors' calculations.

12. As noted in section 2, we took care to examine each of our structural models for stability, and so we are reasonably confident that we have obtained stable estimates of the aggregate supply slope. Even so, small changes in γ would not affect our results, as this simply serves to scale the level of α , not affecting the changes.

Figure 5. Five-Year Rolling Sample Estimates of Aversion to Inflation Variability in Inflation-Targeting Countries



Source: Authors' calculations.

The results in the figures are quite striking. For seven of the nine inflation-targeting countries, the estimate of the aversion to inflation variability rises substantially either *before* or immediately after the targeting regime is implemented (figure 5). The exceptions are Israel, where the estimate of α falls following implementation, and the United Kingdom, where there is no material change.

Table 4. Shift in Implied Weight Attached to Inflation Variability in Inflation-Targeting Countries

Country	Aversion to inflation variability in full sample period	Date of shift to inflation targeting	Aversion to inflation variability	
			Before shift ^a	After shift ^b
Australia	0.78	1993Q2	0.83	0.80
Canada	0.72	1991Q2	0.73	0.87
Chile	0.49	1990Q4	0.27	0.52
Finland	0.96	1993Q2	0.96	0.97
Israel	0.56	1991Q1	0.58	0.51
New Zealand	0.49	1990Q2	0.34	0.83
Spain	0.55	1994Q4	0.65	0.74
Sweden	0.84	1993Q1	0.76	0.91
United Kingdom	0.99	1992Q4	0.93	0.96
Average	0.71	1992Q1	0.67	0.79

Source: Authors' calculations.

a. Five years ending one year before the shift to explicit inflation targeting.

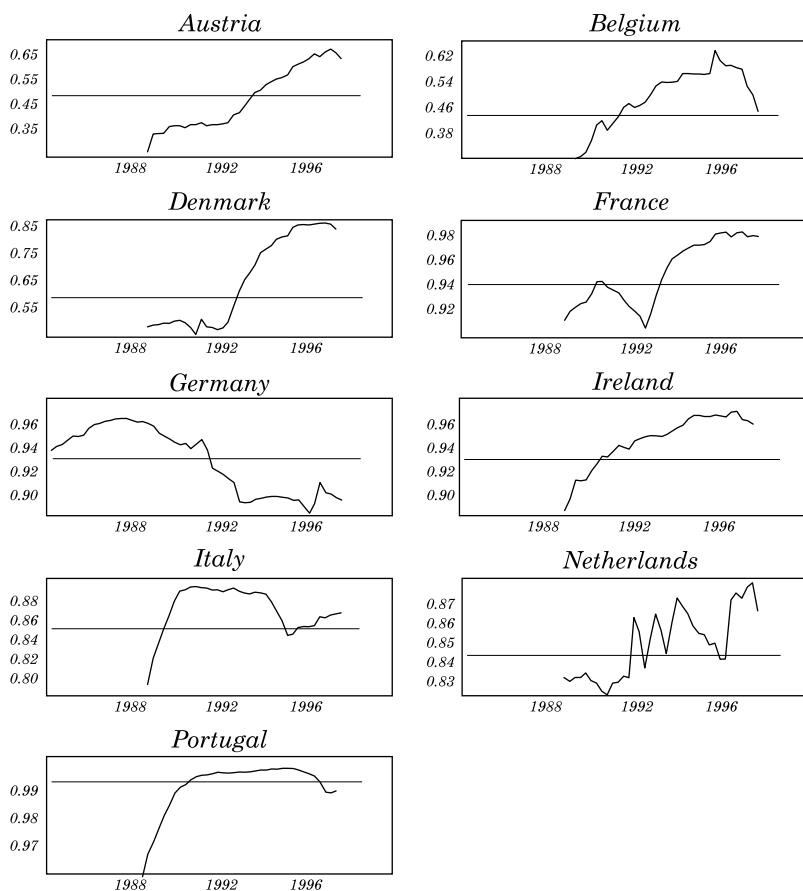
b. Five years following the shift to explicit inflation targeting, or the last five-year period for which data are available.

Of the nine EU countries that did not explicitly target inflation in the 1990s, all but one show an increase in the estimate of α beginning in the early 1990s similar to the increase for the inflation targeters (figure 6). Interestingly, the exception is Germany. We surmise that, in preparation for monetary union, the countries of the European Union were forced to behave more like inflation-targeting countries throughout the 1990s. Germany, however, softened its previous hard-line view toward inflation, both because of the implications of unification with the former East Germany and as a compromise in the direction of its future colleagues in monetary union.

For the remaining five countries in our data set, the results are mixed (figure 7). The estimates of the aversion to inflation variability for the United States and Mexico rise, but the estimates for the other countries show declines of varying degrees.

Table 4 complements figure 5, reporting the aversion to inflation variability for five-year periods before and after the explicit announcement of a move to inflation targeting. Of the nine countries in the sample, seven show an increase in the estimate of α . For the other two there are modest declines.

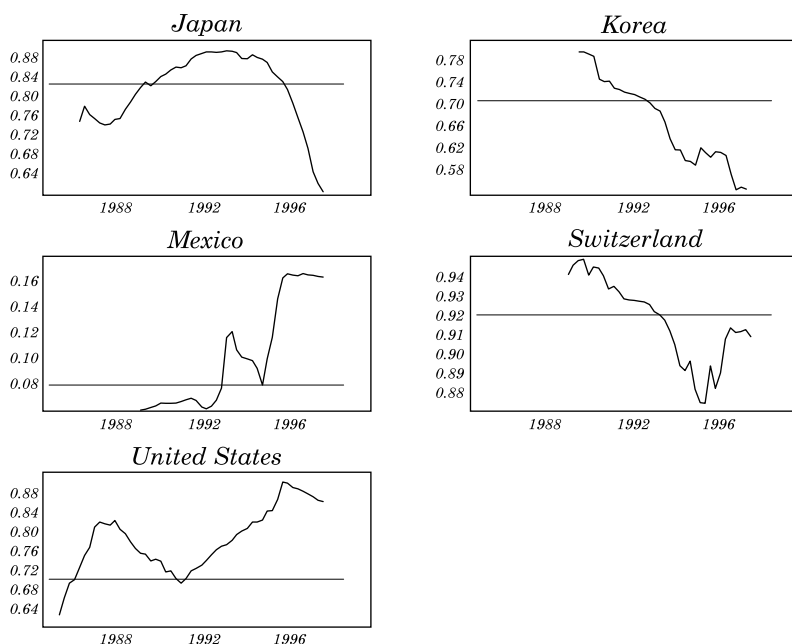
Figure 6. Five-Year Rolling Sample Estimates of Aversion to Inflation Variability in Other EU Countries



Source: Authors' calculations.

We conducted one final test to determine whether the changes in the inflation-targeting countries can in fact be ascribed to the targeting regime. For this test we used the remaining fourteen countries in our sample as a control and examined the values of α as they changed from 1990 to the end of the available sample. The results, reported in table 5, show that, over the full sample for which we have data, the values of α are highest in the nontargeting EU countries.

Figure 7. Five-Year Rolling Sample Estimates of Aversion to Inflation Variability in Other Countries



Source: Authors' calculations.

Table 5. Changes in Average Aversion to Inflation Variability in Inflation-Targeting and Nontargeting Countries

Country group ^a	Full sample period	1984-89	Last 5 years
All countries	0.72	0.69	0.76
All inflation targeters	0.71	0.63	0.76
All nontargeters	0.73	0.72	0.75
EU nontargeters	0.78	0.75	0.83
Non-EU nontargeters	0.65	0.67	0.62

Source: Authors' calculations.

a. Non-EU nontargeters are Japan, Korea, Mexico, Switzerland, and the United States. Other groups are defined as in table 1.

The principal finding, however, is that the inflation-targeting countries show a significant increase, from an average of 0.63 to an average of 0.76. In addition, the nontargeting EU countries show an increase in α from 0.75 to 0.83. The non-EU nontargeting countries show a modest decrease.¹³

4. CONCLUSIONS

This paper asks whether inflation targeting increases the volatility of output. Most macroeconomists assume that in the presence of aggregate supply shocks—short-run disturbances that move output and inflation in opposite directions—monetary policy must allow either output or inflation to move away from its desired long-run level. In other words, there is a variability trade-off. One interpretation of a move to inflation targeting is that the preferences of monetary policymakers have changed, with many central banks exhibiting increasing aversion to inflation variability and decreasing aversion to output variability. It is natural to conclude that the outcome should be higher output volatility than would otherwise have occurred.

We estimated the change in the preferences of monetary policymakers in a cross section of twenty-three countries, including nine that target inflation explicitly. We found evidence that in all countries, whether they target inflation or not, aversion to inflation variability increased during the decade of the 1990s. Furthermore, we conclude that the inflation targeters increased their aversion to inflation volatility by more than the nontargeters, although the difference is modest.

13. A simple regression of the change in α on dummy variables for inflation-targeting and EU nontargeting countries shows that these declines are statistically significant at the 5 percent level for the targeters, and at the 10 percent level for the nontargeting EU countries.

APPENDIX A

Estimation and Identification Strategy

To estimate the structural responses of each economy to a monetary policy shock, we used structural vector autoregressions (SVARs). A detailed discussion of our methodology can be found in Ehrmann (2000), so we provide here only a quick overview of the estimation strategy. We apply a procedure set forth in King and others (1991).¹⁴ Their identification strategy is based on the implications of the cointegrating relations, in a multivariate system. Complete identification of an n -variable structural system requires $[n(n-1)/2]$ restrictions. In a system with m cointegrating relations there will be k common trends, where $k = n - m$, and thus k shocks that are assumed to have long-term effects on the variables in the system (and are therefore interpretable as supply shocks). This structural assumption imposes $k * m$ of the necessary restrictions. For complete identification of the effects of supply shocks we need $[k(k-1)/2]$ additional restrictions. The methodology of King and others employs a triangular specification, allowing the first shock to have a contemporaneous effect on all the dependent variables, the second on the last $n - 1$, and so on. In order to identify the transitory shocks (interpretable as demand shocks), we need a set of additional $[m(m-1)/2]$ restrictions. We again use a triangular specification, and we identify the monetary policy shock by assuming that it has no contemporaneous (within-quarter) effect on output.

14. For the analytical derivation of their procedure, see King and others (1991) or Warne (1993).

APPENDIX B

The Models

Table A1 contains detailed descriptions of each model. Briefly, for each country our model consists of four or five variables. For each country we include a short-term interest rate (the policy variable) as well as a measure of output and a measure of inflation (the quantities in the policymaker's objective function). In addition, for all countries but Japan, Switzerland, and the United States, we add the exchange rate of the national currency against the currency of a large trading partner. In the case of the members of the European Exchange Rate Mechanism, this is the exchange rate with the deutsche mark. For the remaining countries it is either the Japanese yen or the U.S. dollar exchange rate. When a four-variable system creates puzzling responses, a fifth variable is chosen from a pool of candidates: long-term interest rates, U.S. or German short-term interest rates (for countries strongly influenced by U.S. or German monetary policy, respectively), commodity prices as a leading indicator for inflation,¹⁵ or monetary aggregates. All data are quarterly at annual rates and seasonally adjusted using deterministic dummy variables.

The models are tested for structural breaks with the help of one-step Chow tests and breakpoint (N down) Chow tests, both at the equation and the vector level. Especially for some European countries, the tests reveal structural breaks around 1984, coinciding with the emergence of the "hard" European Monetary System. To ensure that the models are stable and well specified, for most countries the sample period is restricted to 1984-97. In some cases the results of the stability tests led us to shorten the sample period. To avoid distorting the evidence, we thus have to accept small samples.

The lag length for the reduced-form vector autoregressions is found using the London School of Economics general-to-specific modeling strategy. In all cases a lag length of at most two is sufficient. We perform a number of additional diagnostic tests to ensure that the models are well specified. We test the residuals of both the individual equations and the

15. Since they are determined in auction markets, commodity prices react much faster to news about future inflation than do industrial or consumer prices. Econometric evidence supports their value as leading indicators of inflation (Boughton and Branson, 1991). Christiano, Eichenbaum, and Evans (1996) discuss the usefulness of commodity prices in estimating the responses of output and inflation to monetary policy shocks.

systems as a whole for serial correlation, nonnormality, heteroskedasticity, and autoregressive conditional heteroskedasticity.¹⁶

In most cases we must introduce dummy variables for our models to pass this battery of stringent specification tests. This is especially true of the tests for normality of the residuals. We introduce dummy variables in periods where indirect taxes are increased, under the presumption that central banks do not generally tighten policy at these times, even though measured inflation is normally observed to rise. We also include dummy variables at the times of the 1992-93 and 1995 exchange rate crises, when many countries' central banks changed their behavior drastically, albeit briefly. Finally, dummy variables are put into the models at times of extraordinary national events, such as labor strikes. Table A2 reports the full list of dummy variables included for each of the countries we study.

Table A1. Specification of the Model

Country	Variables	Cointegration		
		rank	Lags	Sample period
Australia	OECD-MEI short-term interest rate, industrial production (seasonally adjusted), CPI inflation, Australian dollar-yen exchange rate, IMF commodity price index	3	2	1985Q1-1997Q4
Austria	Three-month money market rate, industrial production, CPI inflation, Schilling-DM exchange rate, German short-term interest rate	2	2	1984Q1-1997Q1
Belgium	Three-month treasury bill rate, industrial production, CPI inflation, Belgian franc-DM exchange rate, German short-term interest rate	3	2	1984Q3-1997Q4
Canada	OECD-MEI short-term interest rate, industrial production (seasonally adjusted), CPI inflation, Canadian dollar-U.S.dollar exchange rate, real M3	2	2	1980Q3-1997Q4
Chile ^a	Thirty-to-ninety-day deposit rate, industrial production (seasonally adjusted), CPI inflation, Peso-U.S.dollar exchange rate, U.S. short-term interest rate	3	2	1985Q1-1998Q4

16. For a detailed description of the tests, see the help function in PcFIML9.0; the test statistics are available from the authors upon request.

Table A1. (continued)

Country	Variables	Cointegration		
		rank	Lags	Sample period
Denmark	Three-month interbank market rate, industrial production (seasonally adjusted), CPI inflation, Krone-DM exchange rate	2	2	1984Q1-1997Q3
Finland	Call money rate, industrial production, CPI inflation, Markka-U.S. dollar exchange rate	2	2	1984Q1-1997Q4
France	Three-month money market rate, industrial production, CPI inflation, French franc-DM exchange rate, long-term rate on government bonds	3	2	1984Q1-1997Q4
Germany	Three-month money market rate, industrial production (seasonally adjusted), CPI inflation, DM-U.S. dollar exchange rate, IMF commodity price index	3	2	1979Q3-1997Q4
Ireland	Three-month treasury bill rate, industrial production, CPI inflation, Punt-DM and Punt-Sterling exchange rates	3	2	1984Q1-1997Q3
Israel	Short-term treasury bill rate, industrial production (seasonally adjusted), CPI inflation, Shekel-U.S. dollar exchange rate, real money	3	2	1986Q2-1998Q3
Italy	Three-month treasury bill rate, industrial production, CPI inflation, Lira-DM exchange rate, IMF commodity price index	3	2	1984Q1-1997Q4
Japan	OECD-MEI short-term interest rate, industrial production (seasonally adjusted), CPI inflation, real M3	2	2	1981Q1-1997Q4
Korea	Daily money market rate, industrial production (seasonally adjusted), CPI inflation, Won-U.S. dollar exchange rate	2	2	1984Q3-1997Q3
Mexico	OECD-MEI short-term interest rate, industrial production (seasonally adjusted), CPI inflation, Peso-U.S. dollar exchange rate, IMF commodity price index	3	2	1984Q1-1997Q4
Netherlands	Three-month interbank market rate, industrial production, CPI inflation, Guilder-DM exchange rate, German short-term interest rate	3	2	1984Q1-1997Q4
New Zealand	OECD-MEI short-term interest rate, industrial production, CPI inflation, New Zealand dollar-U.S. dollar exchange rate	2	2	1984Q3-1997Q4
Portugal	Five-day money market rate, industrial production, CPI inflation, Escudo-DM exchange rate, German short-term interest rate	3	2	1983Q4-1997Q3

Table A1. (continued)

Country	Variables	Cointegration		
		rank	Lags	Sample period
Spain	Three-month money market rate, industrial production, CPI inflation, Peseta-DM exchange rate, real ALP ^b	2	2	1984Q1-1997Q4
Sweden	Three-month treasury bill rate, industrial production, CPI inflation, Krona-U.S. dollar exchange rate, interest rate on nine-year government bonds	3	2	1984Q1-1997Q4
Switzerland	OECD-MEI short-term interest rate, industrial production (seasonally adjusted), CPI inflation, real M3	2	2	1984Q1-1997Q4
United Kingdom	Three-month treasury bill rate, industrial production, RPIX inflation, ^c Sterling-DM exchange rate, IMF commodity price index	3	1	1980Q1-1997Q4
United States	OECD-MEI short-term interest rate, industrial production (seasonally adjusted), CPI inflation, IMF commodity price index	2	2	1980Q1-1997Q4

Sources: Data for Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, the Netherlands, Portugal, Spain, Sweden, and the United Kingdom are from Datastream; those for Australia, Canada, Japan, Mexico, New Zealand, Switzerland, and the United States are taken from the OECD Main Economic Indicators (MEI). Data for Chile are from International Monetary Fund, *International Financial Statistics* (the deposit rate), the Central Bank of Chile's World Wide Web site (inflation), and DRI (industrial production and the exchange rate); Israeli data are from DRI (exchange rate, industrial production, and inflation) and from *International Financial Statistics* (interest rate and money); data for Korea are from *International Financial Statistics* (money market rate and industrial production) and DRI (inflation and exchange rates).

a. The model for Chile looks at parts of the transmission mechanism only, because the interest rate in use is a deposit rate. This assumes that the transmission from monetary policy shocks to the deposit rate has already taken place.

b. ALP is a monetary measure of active liquidity in private hands. It is a broader aggregate than M3. To construct real ALP, the natural logarithm of the consumer price index (CPI) is subtracted from the natural logarithm of ALP.

c. RPIX is a measure of retail prices on all items except mortgage interest. Because the U.K. CPI includes mortgage interest payments, CPI inflation is biased upward following an interest rate increase. To avoid a price puzzle, the interest payments must be excluded from the price index.

Table A2. Dummy Variables

Country	Dummy variables
Australia	None
Austria	For the inflation equation: increase in the value-added tax in 1986Q1 and of indirect taxes in 1996 (in order to achieve the Maastricht criteria). For the industrial production equation: general economic downturn in 1992. For the interest rate equation: tightening by the central bank in 1986 Q1, which followed a period of massive capital outflows, central bank interventions, and reserve losses
Belgium	Exchange rate and interest rate equations: exchange rate crisis in 1993 (restricted to lie in the cointegration space). The Belgian franc came under downward pressure with the widening of the exchange rate bands in the Exchange Rate Mechanism to 15 percent. Industrial production: output decline in 1987Q1; the central bank linked

Table A2. (continued)

<i>Country</i>	<i>Dummy variables</i>
	the decline to efforts to trim the public deficit and therefore did not take any corrective steps. Inflation: in 1986Q1 inflation fell too sharply to be explained by the monetary policy framework alone. Indeed, lower fuel prices are mentioned by the central bank as a reason for the marked improvement in inflation performance
Canada	Exchange rate: exchange rate crisis in 1992-93. Interest rate: in 1981Q4 and 1994Q2, strong influence of U.S. interest rate changes; since U.S. interest rates do not enter as a separate variable, these influences have to be dummied out here
Chile	Inflation: in 1988Q3 the value-added tax and fuel prices fell, whereas in 1990 both were increased. System: in 1992Q1, money growth exploded to a 55 percent annual rate
Denmark	Exchange rate and interest rate: exchange rate crisis in 1992-93. Inflation: increase in indirect taxes in 1986
Finland	Exchange rate and interest rate: exchange rate crisis in 1992-93. Industrial production: recession from 1990 to 1994
France	None
Germany	Interest rate: stock market crash in 1987, in the aftermath of which the Bundesbank loosened its monetary policy stance until 1988Q3 to offset some of the consequences of the crash on the real economy. Industrial production: strike in 1984Q2. Inflation: first round of rent rises in East Germany 1992Q1; linear trend, restricted to lie in the cointegration space
Ireland	Interest rate: speculative crises in 1986 and 1992. Inflation: increase in excise duties, removal of food subsidies and other taxation measures to reduce the budget deficit in 1987Q1. Exchange rate: crises in 1992 and 1995
Israel	Exchange rate: devaluations in 1987Q1, 1989Q2, and 1991Q2
Italy	Exchange rate and interest rate: crises in 1992-93 and 1995. Inflation: jump in 1990
Japan	Interest rate: focus of monetary policy on exchange rate after the 1985 Plaza Accord leads to a tightening of the policy stance in 1985Q4. Inflation: increase in consumption tax in 1997Q2
Korea	Inflation: acceleration in 1990Q2. Exchange rate: acceleration of depreciation in 1996Q3
Mexico	Interest rate: tight monetary policy stance under the Economic Solidarity Pact reduces inflation by over 100 percentage points in 1988. Industrial production: oil shock in 1986, steep increase in the growth rate in 1994 coinciding with the coming into force of the North American Free Trade Agreement. Exchange rate: crisis in 1994-95
Netherlands	Industrial production: after a cut in the value-added tax, a fall in social security contributions, and nominal wage increases, households' disposable income rose by 5 percent in real terms in 1989, leading to a steep increase in private consumption and industrial production

Table A2. (continued)

<i>Country</i>	<i>Dummy variables</i>
New Zealand	Exchange rate: 20 percent devaluation in 1984Q3, wide swings after the float in March 1985. Inflation: indirect tax increases in 1985Q1, 1986Q4, and 1989Q3
Portugal	Exchange rate: speculative attacks in 1992-93
Spain	Exchange rate: speculative attacks in 1993 and 1995. Massive interest rate increase in the Bank of Spain lending rate in 1987. After an overshooting of ALP by nearly 100 percent with respect to its target, and after an increasing government deficit had to be financed by the Bank of Spain, driving liquidity up even further, the Bank of Spain increased its lending rate from 11.5 percent in December 1986 to 20.5 percent in May 1987. Inflation: value-added tax introduced in 1986Q1; linear trend, restricted to lie in the cointegration space
Sweden	Exchange rate and interest rate: crisis in 1992-93. The central bank increased its marginal lending rate to 500 percent in September 1992. Inflation: tax reform in 1990Q1 widened the value-added tax base substantially; subsequent change in the value-added tax in 1991
Switzerland	Interest rate: after the stock market crash in 1987, the central bank lowered interest rates to their lowest level since 1979
United Kingdom	Industrial production: miners' strike in 1984. Exchange rate: currency crisis in 1992. Interest rate: in 1985Q1 the Bank of England drastically increased interest rates after an exchange rate depreciation to indicate that it was in earnest about the newly declared change in orientation toward exchange rate goals; linear trend, restricted to lie in the cointegration space
United States	Interest rate: high volatility of short-term rates at the beginning of Paul Volcker's chairmanship of the Federal Reserve; linear trend, restricted to lie in the cointegration space

Source: Authors' construction.

REFERENCES

- Boughton, J. M., and W. H. Branson. 1991. "Commodity Prices as Leading Indicators of Inflation." In *Leading Economic Indicators: New Approaches and Forecasting Records*, edited by K. Lahiri and G. H. Moore. Cambridge, England: Cambridge University Press.
- Cecchetti, S. G. 1998. "Policy Rules and Targets: Framing the Central Banker's Problem." *Federal Reserve Bank of New York Economic Policy Review* 4 (June): 1-14.
- . 2001. "Legal Structure, Financial Structure and the Monetary Transmission Mechanism. In *The Monetary Transmission Process*. Recent Developments and Lessons for Europe, edited by Deutsche Bundesbank. New York: Palgrave
- Cecchetti, S. G., M. M. McConnell, and G. Perez Quiros. 1999. "Policymakers' Revealed Preferences and the Output-Inflation Variability Trade-off: Implications for the European System of Central Banks." Unpublished manuscript. New York: Federal Reserve Bank of New York.
- Christiano, L. J., M. Eichenbaum, and C. L. Evans. 1996. "Identification of the Effects of Monetary Policy Shocks. In *Financial Factors in Economic Stabilization and Growth*, edited by M. I. Blejer. New York: Cambridge University Press.
- Ehrmann, M. 2000. "Comparing Monetary Policy Transmission Across European Countries." *Weltwirtschaftliches Archiv* 136(April): 58-83.
- Fry, M., D. Julius, L. Mahadeva, S. Rogers, and G. Sterne. 1999. "Monetary Policy Framework in a Global Context." Unpublished manuscript. London: Bank of England Centre for Central Banking Studies (June).
- King, R. G., C. I. Plosser, J. H. Stock, and M. W. Watson. 1991. "Stochastic Trends and Economic Fluctuations." *American Economic Review* 81(June): 819-40.
- Morandé, F., and K. Schmidt-Hebbel. 1999. "The Scope for Inflation Targeting in Emerging Market Economies." Unpublished manuscript. Santiago: Central Bank of Chile.
- Taylor, J. B. 1993. "Discretion Versus Policy Rules in Practice." *Carnegie-Rochester Conference Series on Public Policy* 39 (December): 195-214.
- Warne, A. 1993. "A Common Trends Model: Identification, Estimation and Inference." University of Stockholm IIES Seminar Paper 555. Stockholm.

OPTIMAL MONETARY POLICY IN A SMALL, OPEN ECONOMY: A GENERAL-EQUILIBRIUM ANALYSIS

Charles T. Carlstrom

Federal Reserve Bank of Cleveland

Timothy S. Fuerst

*Bowling Green State University
and Federal Reserve Bank of Cleveland*

The two central issues in monetary policy are separated by time horizon. The first relates to the short run: what is the appropriate monetary policy across the business cycle? The second relates to the long run: what is the optimal long-run rate of inflation? This paper explores these classic issues from the vantage point of a small, open economy. "Smallness" opens up both possibilities and pitfalls for the policymaker, because several important variables (such as the foreign interest rate, the real exchange rate, and the worldwide real rate of interest) are now exogenous from the perspective of the home country.

The short-run focus of monetary policy is to determine how best to respond to real shocks buffeting the economy. These real shocks include fiscal disturbances, fluctuations in multifactor productivity, and movements in real exchange rates. The central banker must make decisions in real time in the face of severe data problems. In particular, it is typically unlikely that the central bank can respond directly to fundamental shocks; instead it must respond to movements in endogenous variables. For example, the central bank will not immediately observe movements in productivity but instead must respond to movements in the rate of inflation.

These informational restrictions imply that the central bank must use a fairly simple policy rule, namely, a reaction function linking movements in the nominal interest rate to these movements in endogenous variables. One such rule is the celebrated Taylor (1993)

rule. The last several years have seen numerous theoretical analyses of the welfare advantages of different policy rules. Papers include Carlstrom and Fuerst (1995), Ireland (1997), King and Wolman (1996), and Rotemberg and Woodford (1999). These papers posit structural models of the real economy and the monetary transmission mechanism. A principal conclusion of this line of research is that the welfare gain from operating under the first-best rule rather than the second- or even the tenth-best rule is small. For example, in a limited participation model, Carlstrom and Fuerst (1995) report that the welfare gain from switching from a money growth peg (a seemingly disastrous policy in the posited model) to an interest rate peg (the second-best policy) equals only 0.017 percent of the steady-state capital stock. (A limited participation model assumes that only a subset of the economy directly participates in open market operations, and thus only this subset has immediate access to the new cash injected into the economy by the central bank.)

As a consequence of these small welfare numbers, the focus of recent research has shifted to a related question: how to avoid doing harm. Relevant papers include Clarida, Galí, and Gertler (1997), Kerr and King (1996), Benhabib, Schmitt-Grohe, and Uribe (1998), Carlstrom and Fuerst (1998, 2000, and forthcoming), and Christiano and Gust (1999). A central bank that follows a rule in which it responds to endogenous variables may introduce real indeterminacy and sunspot equilibria into an otherwise determinate economy.¹ These sunspot fluctuations are welfare-reducing and potentially quite large. An important focus of this paper is to isolate the conditions sufficient to ensure that the monetary policy rule does not introduce sunspot equilibria into the economy.

The paper's analysis is conducted in the context of a fully articulated general-equilibrium model of a small, open economy. The underlying real model is essentially that of Mendoza (1991). Money is

1. There are actually two types of indeterminacy that may arise. The first is *nominal indeterminacy*: are the initial values of the price level and all other nominal variables pinned down? In our notation this corresponds to the question of whether $\pi \equiv P_t/P_{t-1}$ is determined (where t is the initial time period). Nominal determinacy is a typical occurrence under many interest rate operating procedures, the most celebrated example being an interest rate peg. It is of no consequence in and of itself, but rather is important only if it leads to *real indeterminacy*. By this we mean a situation in which the behavior of one or more real variables is not pinned down by the model. This possibility is of great importance as it immediately implies the existence of *sunspot equilibria*, which in the present environment are necessarily welfare reducing. Sunspots are purely extraneous variables that alter the equilibrium because economic agents believe that they will alter the equilibrium.

introduced by assuming that it is required to facilitate certain transactions. The paper considers both a flexible-price economy in which anticipated inflation effects are paramount, and a limited participation model as in Lucas (1990), Christiano, Eichenbaum, and Evans (1997), and Fuerst (1992), in which unanticipated money supply shocks have real effects.² The “smallness” assumption manifests itself in the assumptions of perfect capital markets an exogenous worldwide real rate of interest, and an exogenous real exchange rate. From a theoretical point of view, the “smallness” assumption is particularly attractive, because many of the results that are obscured in a closed economy are more readily apparent here. In addition, certain other shocks (such as to the real exchange rate) are not relevant to a closed economy.

The first two sections of the paper address the issue of real indeterminacy in a small, open economy with flexible prices (section 1) and with limited participation (section 2). A principal conclusion is that to avoid real indeterminacy the central bank must respond aggressively to *past* movements in inflation. It is well known that basing policy responses on market expectations can generate nonuniqueness of equilibria. For this reason, “looking forward” tends to create indeterminacy because monetary policy is driven by an endogenous variable that in turn depends on policy.³

A standard argument in the literature is that, to avoid real indeterminacy, the central bank must respond aggressively to either expected inflation (see Clarida, Galí, and Gertler, 1997) or current inflation (see Kerr and King, 1996). These analyses all use reduced-form, sticky-price models, where the underlying structural model is a labor-only economy and money is introduced through a money-in-the-utility function (MIUF) model with a zero cross-partial between consumption and real balances. In sharp contrast, we argue that a necessary and sufficient condition for determinacy is for the monetary authority to react aggressively to past movements in inflation.⁴

2. Open-economy limited participation models include those of Baier (1997), Grilli and Roubini (1992), and Schlagenhauff and Wrase (1995).

3. These questions are of more than academic interest. Several central banks around the world currently use inflation forecasts as an important part of their decisionmaking on policy issues. The recent federal funds rate increases in the United States are evidence that such forecasts are used. Although there were few signs that current inflation was increasing, interest rates were raised at the August and November 1999 meetings of the Federal Open Market Committee because it was feared that higher inflation might well be in the offing.

4. Carlstrom and Fuerst (1998) demonstrate that these results on indeterminacy are robust to a closed-economy model with a more elaborate production technology.

The fundamental differences between our model and the others just described are twofold. As demonstrated in Carlstrom and Fuerst (forthcoming), one major difference comes from the assumption about which money balances enter the utility function. The traditional MIUF assumption is that it is end-of-period balances that enter. But a direct extension of a typical cash-in-advance economy suggests that the money the household has left after leaving the bond market and before entering the goods market is more appropriate. Remarkably, this distinction in timing is critical for questions of determinacy. As argued in Carlstrom and Fuerst (forthcoming), cash-in-advance timing is a more natural choice, and so we adopt it here. We utilize a rigid cash-in-advance constraint, but following the arguments of our earlier paper, the results generalize to an arbitrary MIUF setup with cash-in-advance timing.

The second major difference is in the type of nominal rigidity analyzed. The earlier papers assume a sticky price environment adopted from Calvo (1983). The assumption in that model is that a fixed fraction of firms adjust their prices every period. This implies that, for any arbitrarily long but finite period, not all prices will have adjusted to the levels implied by a flexible-price model. Equivalently, for arbitrary initial conditions, the deterministic dynamics converge to the flexible-price steady state only in the infinite limit. This pricing arrangement is problematic for issues of determinacy. For example, in Clarida, Galí, and Gertler (1997), an equilibrium is indeterminate if perturbations from the equilibrium path lead to explosive inflation dynamics. But surely the Calvo pricing arrangement would not continue to hold along such a path, so that imposing this arrangement along the path seems quite artificial. In this paper we consider an alternative nominal rigidity, namely, the limited participation model mentioned above. But more important, we assume that this nominal rigidity arises for only a finite and definite time period. That is, for arbitrary initial conditions, the model converges to the flexible-price steady state within a *finite* period. This assumption is more appropriate for the analysis of the limiting behavior that is so important for stability analysis.⁵

The final section of the paper turns to the long-run issue of monetary policy: what is the optimal long-run rate of inflation? By positing a Taylor rule in sections 1 and 2, we assume that it is not optimal

5. Carlstrom and Fuerst (2000) demonstrate that these same indeterminacy results hold for a sticky-price model in which prices are sticky for only a finite time period.

for the central bank to follow Friedman's (1969) advice and engineer a long-run deflation that will peg the nominal rate of interest to zero. There is an enormous literature concerning the robustness of Friedman's optimum quantity of money result (see, for example, Woodford, 1990). This paper provides a novel explanation for a positive long-run rate of inflation that is unique to a small, open economy. This "smallness" implies that the country takes the foreign nominal rate of interest as given. To the extent that this foreign rate distorts domestic behavior, there is a rationale for positive domestic nominal interest rates.

1. A FLEXIBLE-PRICE MODEL

The economy in the model consists of households, firms, and financial intermediaries, with the latter accepting deposits from households and lending to firms. The firms borrow cash to finance their wage bill. The households consume a single good that is produced abroad, and the firms produce a single good that is sold abroad at the real exchange rate e_t . The economy is small in that the real exchange rate is taken as given and households' foreign asset accumulation earns a constant real rate of return r .

Households are infinitely lived, with preferences given by

$$E_0 \sum_{t=0}^{\infty} \beta^t U(c_t, 1 - L_t),$$

where E_0 denotes the expectations operator conditional on time-zero information, $\beta \in (0,1)$ is the personal discount factor, c_t is consumption at time t , and L_t is labor supply at time t . To purchase consumption goods, households are subject to the following cash-in-advance constraint:

$$P_t c_t \leq M_t + P_t w_t L_t - N_t,$$

where P_t is the price level, M_t denotes beginning-of-period cash balances, w_t denotes the real wage, and N_t denotes the household's choice of one-period bank deposits. These deposits earn nominal rate R_p , which is paid out at the end of the period. The household's intertemporal budget constraint is given by

$$M_{t+1} = M_t + P_t (w_t L_t + r A_t) - P_t c_t - P_t (A_{t+1} - A_t) + \Pi_t + N_t (R_t - 1).$$

Here A_t denotes the household's investment in foreign assets that earn the constant real rate of return r , with $\beta(1 + r) = 1$. We assume that asset accumulation occurs at the household level and that cash in advance is not needed to finance its purchase. Π denotes the profit flow from firms and financial intermediaries.

Firms in this economy produce an export good using a production function employing domestic labor:

$$y_t = e_t \theta_t f(H_t),$$

where θ_t is a measure of aggregate productivity, and H_t denotes hired labor. One can imagine that f is constant returns or that land is an additional fixed factor in the production function. In the former case there are no profits to distribute, whereas in the latter case the profit flow to equity owners is simply the rents on land. To finance its wage bill the firm must acquire cash and does so by borrowing short term from the financial intermediary at (gross) rate R_t .

The intermediary in turn has two sources of cash: cash deposited by households and new cash injected into the economy by the central bank. Hence the loan constraint is

$$P_t w_t H_t \leq N_t + M_t^s (G_t - 1),$$

where G_t denotes the (gross) money supply growth rate, $G_t \equiv M_{t+1}^s / M_t^s$. Note that monetary injections are carried out as lump-sum transfers to the financial intermediary.

We restrict our attention to equilibria with strictly positive nominal interest rates so that the two cash constraints are binding. A recursive competitive equilibrium is given by stationary decision rules that satisfy these two binding cash constraints and the following:

$$E_t \left(\frac{P_t U_{ct+1}}{P_{t+1}} \right) = \beta E_t \left[(1 + r) \frac{P_{t+1} U_{ct+2}}{P_{t+2}} \right], \quad (1)$$

$$\frac{U_{Lt}}{U_{ct}} = \frac{e_t \theta_t f'(L_t)}{R_t}, \quad (2)$$

$$\frac{U_{ct}}{P_t} = \beta E_t \left(R_t \frac{U_{ct+1}}{P_{t+1}} \right), \quad (3)$$

$$c_t + A_{t+1} = e_t \theta_t f(L_t) + (1 + r) A_t. \quad (4)$$

The social resource constraint, equation (4), comes from imposing market clearing and netting out firm and intermediary profits from the household's intertemporal budget constraint.

Note that, using equation (3), we can rewrite equation (1) as

$$\frac{U_{ct}}{R_t} = \beta E_t \left[(1 + r) \frac{U_{ct+1}}{R_{t+1}} \right]. \quad (5)$$

The system given by equations (2), (4), and (5) is isomorphic to Mendoza's (1991) corresponding real business cycle economy except that, because of the cash-in-advance constraint, it is distorted by a consumption tax rate of $(1 + tc_t) = R_t$. Because of this implicit consumption tax, the rate of return on foreign assets does not equal the usual consumption Euler equation, equation (5), and the marginal rate of substitution is not equal to the marginal product of labor, equation (2).

This public finance interpretation is key in what follows. For example, Carlstrom and Fuerst's (1995) result that a constant nominal interest rate is preferred to a variable one is a manifestation of the standard result that constant taxes are better than fluctuating ones (holding the mean distortion fixed).⁶ However, as demonstrated by Carlstrom and Fuerst (1995) in a calibrated model, these welfare gains are quite small, and so our attention is shifted to issues of indeterminacy.

Below we consider monetary policy rules in which the nominal rate (the consumption tax) is endogenous, responding to movements in the economy. In a real economy, Schmitt-Grohe and Uribe (1997) demonstrate that the endogenous tax rate movements implied by a balanced-budget rule can lead to real indeterminacy. An important issue below is whether interest rate operating procedures can have the same effect.

The small-economy assumption makes stability analysis particularly transparent. Without loss of generality, we now limit the discussion to the deterministic version of the model. As is well known, if the deterministic dynamics are not unique, it is possible to construct sunspot equilibria in the model economy. Substituting equation (3) into equation (1) yields

$$\frac{R_{t+1}}{\pi_{t+1}} = (1 + r). \quad (6)$$

6. Such an interest rate smoothing policy is exactly the typical central bank policy over the seasonal cycle.

As mentioned above, this relationship is not the standard Fisherian relationship. The above nominal interest rate is the rate between $t + 1$ and $t + 2$, *not* between t and $t + 1$. The inflation rate, however, is between t and $t + 1$ ($\pi_{t+1} \equiv P_{t+1}/P_t$). The reason for this distortion is that the cash-in-advance constraint is on consumption but not investment. It is this distortion that gives rise to the potential for indeterminacy.

Proposition 1: Suppose that monetary policy is given by the forward-looking interest rate rule given by

$$R_t = R_{ss} \left[\prod_{n=0}^{\infty} \left(\frac{\pi_{t+n+1}}{\pi_{ss}} \right)^{\lambda^n} \right]^{\tau(1-\lambda)}, \quad (7)$$

where $\tau \geq 0$, $R_{ss} = \pi_{ss}/\beta$, and $\lambda \in [0,1)$.

Then, in the flexible-price model, there is real determinacy if and only if $0 \leq \tau < 1$. In any event there is always nominal indeterminacy as π_t is free.

Proof: Since equation (6) starts at $t + 1$, we scroll equation (7) ahead one period. Taking the logarithms of equation (7), expressing R and the π s as log deviations, we have

$$\tilde{R}_{t+1} = (1 - \lambda)\tau \sum_{n=0}^{\infty} \lambda^n \tilde{\pi}_{t+n+2}. \quad (8)$$

Exploiting the recursion in equation (8), we have

$$\lambda \tilde{R}_{t+2} = \tilde{R}_{t+1} - (1 - \lambda)\tau \tilde{\pi}_{t+2}. \quad (9)$$

Using equation (6), this then implies that

$$\lambda \tilde{\pi}_{t+2} = \tilde{\pi}_{t+1} - (1 - \lambda)\tau \tilde{\pi}_{t+2}, \quad (10)$$

or

$$\tilde{\pi}_{t+2} = \left[\frac{1}{\lambda + (1 - \lambda)\tau} \right] \tilde{\pi}_{t+1}. \quad (11)$$

For real determinacy we need this mapping to be explosive. Hence there is real determinacy if and only if $0 \leq \tau < 1$. If this is the case,

then π_{t+j} is determined for $j \geq 1$. From equation (7), this pins down R_{t+j} for $j \geq 0$, so that equations (1) through (4) uniquely pin down the inflation rate and real behavior. Since equation (11) starts with π_{t+1} , the initial price level, π_t , is free (QED).

An immediate corollary to the above theorem is that an interest rate peg ($\tau = 0$) delivers real determinacy but, like the other rules, has nominal indeterminacy.

Under the policy rule given by equation (8)—the linearized version of equation (7)—the monetary authority responds with an elasticity of τ to a geometric weighted average of all future expected inflation rates, where more weight is placed on the near future. A special case of such a rule is that where $\lambda = 0$ and all the weight is placed on the inflation rate between t and $t + 1$:

$$R_t = R_{ss} \left(\frac{\pi_{t+1}}{\pi_{ss}} \right)^\tau.$$

Under this policy rule, increases in expected inflation increase the nominal rate. But for active policies ($\tau > 1$), these nominal rate increases are also associated with increases in the real rate of interest. Thus we have an implicit consumption tax (the nominal rate) correlated tightly with expected consumption growth (the real rate). The self-fulfilling circle goes something like this. An increase in expected inflation increases investment demand, lowering current consumption. The decline in current consumption increases the real rate of interest; with $\tau > 1$, the nominal rate (consumption tax) rises sharply with this real rate movement; this tax movement implies that the initial increase in expected inflation and the decline in current consumption are rational.

The fact that π_t is free for all values of τ is just a manifestation of nominal indeterminacy; that is, there is nothing to pin down the initial growth rate of money. This innocent remark has some interesting implications.

Proposition 2: Suppose that monetary policy is given by a forward-looking rule that includes the current inflation rate:

$$R_t = R_{ss} \left[\prod_{n=0}^{\infty} \left(\frac{\pi_{t+n}}{\pi_{ss}} \right)^{\lambda^n} \right]^{\tau(1-\lambda)}, \quad (12)$$

where $\tau \geq 0$, $R_{ss} = \pi_{ss}/\beta$, and $\lambda \in [0,1)$.

Then in the flexible-price model there is real indeterminacy for all values of $\tau \neq 0$.

Proof: The proof proceeds as before, leading to the following difference equation:

$$\tilde{\pi}_{t+2} = \frac{1 - (1 - \lambda)\tau}{\lambda} \tilde{\pi}_{t+1} .$$

Under appropriate conditions this is explosive, so that π_{t+j} is pinned down for $j \geq 1$. But even in this case π_t is free and hence so is R_t . Thus we have real indeterminacy. Once again, if $\tau = 0$, we have an interest rate peg and there is no real indeterminacy (QED).

The nominal indeterminacy from before is now real. Before, π_t being free had no real effect, but now, given our interest rate rule, R_t is free. Since R_t acts like a tax on consumption, the fact that R_t is not pinned down implies that real behavior is indeterminate. The reason for this indeterminacy is that our policy rule is responding to endogenous variables. This is why an interest rate peg ($\tau = 0$) is determinate.

This discussion suggests that the central bank should look further backward so that it only responds to exogenous variables. Remarkably, by looking backward the conditions for determinacy are (almost) entirely flipped on their head from when the Taylor rule is forward looking.

Proposition 3: Suppose that monetary policy is given by the backward-looking interest rate rule given by

$$R_t = R_{ss} \left[\prod_{n=0}^{\infty} \left(\frac{\pi_{t-n-1}}{\pi_{ss}} \right)^{\lambda^n} \right]^{\tau(1-\lambda)} , \quad (13)$$

where $\tau \geq 0$, $R_{ss} = \pi_{ss}/\beta$, and $\lambda \in [0, 1)$.

Then in the flexible-price model there is real determinacy if and only if $\tau = 0$ or $\tau > 1$. In the case of $\tau > 1$, there is also nominal determinacy.

Proof: Following the strategy pursued in proposition 1, we are led to the following difference equation:

$$\tilde{R}_{t+2} = [\lambda + (1 - \lambda)\tau] \tilde{R}_{t+1} .$$

For real determinacy we thus need $\tau > 1$, which then implies that π_{t+j} is pinned down for $j \geq 0$ (QED).

An interest rate peg is determinate but, like before, has nominal indeterminacy. Notice, however, that if the monetary authority responds aggressively to past inflations ($\tau > 1$), initial inflation and hence the initial money stock are pinned down. This result is a general-equilibrium generalization of McCallum's (1981) earlier result. McCallum argued that because an interest rate peg suffered from nominal indeterminacy, the monetary authority needed a nominal anchor, which could be accomplished by responding to a nominal variable. Proposition 3 confirms this but shows that merely responding to a nominal variable, like past inflation, is not enough. The monetary authority has to aggressively respond to past inflation to ensure nominal determinacy.

For completeness, we consider a backward-looking rule in which the central bank also considers the current inflation rate:

Proposition 4: Suppose that monetary policy is given by a backward-looking interest rate rule that also includes the current inflation rate:

$$R_t = R_{ss} \left[\prod_{n=0}^{\infty} \left(\frac{\pi_{t-n}}{\pi_{ss}} \right)^{\lambda^n} \right]^{\tau(1-\lambda)}, \quad (14)$$

where $\tau \geq 0$, $R_{ss} = \pi_{ss} / \beta$, and $\lambda \in [0, 1)$.

Then in the flexible-price model there is real determinacy if and only if $\tau = 0$ or $1 < \tau < (1 + \lambda)/(1 - \lambda)$. In the case of $1 < \tau < (1 + \lambda)/(1 - \lambda)$, there is also nominal determinacy.

Proof: Following the strategy pursued in proposition 3, we are led to the following difference equation:

$$\tilde{R}_{t+1} = \left[\frac{\lambda}{1 - (1 - \lambda)\tau} \right] \tilde{R}_t.$$

For determinacy, the term in brackets must be outside the unit circle. There are two regions to consider. First, if $\tau(1 - \lambda) < 1$, the bracketed term exceeds unity whenever $\tau > 1$. If $\tau(1 - \lambda) > 1$, we must consider the other side of the unit circle. Now for determinacy we must have

$$\tau < \frac{1 + \lambda}{1 - \lambda}.$$

Combining the two regions, we have the region noted in the proposition (QED).

With an active policy, looking backward can render the economy determinate. Yet the more weight is placed on the distant past (the larger is λ), the more the bounds for determinacy shrink.

Although at this stage nominal indeterminacy is merely a nuisance, its presence becomes critical in the next section when we consider how the presence of a particular type of nominal rigidity, namely, sluggish portfolios, affects the above results.

2. A LIMITED PARTICIPATION MODEL

A natural criticism of the previous analysis is that it was conducted in a monetary model in which only anticipated inflation has real effects. For example, under most of the policies considered there is nominal indeterminacy in the flexible-price model, implying that an independently and identically distributed shock to the money supply has no effect on any real variables.⁷ This section extends the analysis to a more compelling model of monetary nonneutrality in which iid shocks have real effects.

The model we choose to examine is the limited participation model (see, for example, Lucas, 1990, Christiano, Eichenbaum, and Evans, 1996, and Fuerst, 1992). There are at least two reasons for this choice. First, in contrast to sticky-price models, there has been very little work on indeterminacy issues in this type of model.⁸ Second, there is a compelling empirical reason to consider such a model. A well-known empirical phenomenon is that, in response to a positive monetary policy innovation (a movement downward in the nominal interest rate), aggregate real behavior displays a hump-shaped time profile, while prices rise slowly to a higher level. A hump-shaped consumption

7. This exception is a backward-looking Taylor rule when $\tau > 1$. Otherwise the fact that initial money growth is free implies that iid shocks to money growth will also achieve the interest rate directive.

8. A notable exception is Christiano and Gust (1999). There are two important differences between their analysis and the model presented here. First, they assume that investment purchases are subject to a cash-in-advance constraint, whereas this paper makes the more standard assumption that investment is a credit good. Second, in their model the portfolio rigidity is forever rigid in that the deterministic dynamics converge to the flexible-price model only in the limit. This is analogous to a Calvo (1983) pricing arrangement.

profile implies an increase in the real rate of interest, whereas an upward movement in prices implies that expected inflation cannot fall. But then we are left with a puzzle: how can nominal interest rates fall? The obvious answer is that over some time horizon the standard Fisherian interest rate determination is broken; that is, equation (3) must not hold over some time interval.

This is exactly the assumption made in limited participation models. In particular, these models assume that the (nominal) portfolio choice (N_t) is made one period in advance, so that equation (3) is replaced with

$$E_{t-1} \left(\frac{U_{ct}}{P_t} \right) = \beta E_{t-1} \left(R_t \frac{U_{ct+1}}{P_{t+1}} \right).$$

The positive implications of these models are well-known. For example, suppose that

$$U(c_t, L_t) = \ln(c_t) - \frac{L_t^{1+\eta}}{1+\eta}.$$

Then straightforward calculations imply

$$L_t = \left(\frac{N_t + G_t - 1}{G_t} \right)^{\frac{1}{1+\eta}}.$$

With N_t predetermined, this implies that monetary shocks increase employment and domestic output, while driving down the domestic nominal interest rate. From a policy perspective, the more important observation is that employment does not respond to productivity or real exchange rate shocks, because these shocks drive the nominal interest rate upward. This sluggishness makes a clear case for monetary policy: money growth should be varied to accommodate these shocks. Carlstrom and Fuerst (1995) use this as a starting point to make the case for interest rate pegging in this model. Once again, the welfare gains are small.

Because of this we turn to stability analysis. The attractive feature of the limited participation model is that it breaks the rigid Fisherian interest rate determination. But for the stability properties of interest rate operating procedures, this turns out to be somewhat disastrous since the interest rate is no longer linked to underlying real variables such as consumption growth and expected inflation.

As before, we need only consider the deterministic dynamics. After one period, portfolios can adjust, implying that for stability analysis we must replace equation (3) with its counterpart scrolled forward:

$$\left(\frac{U_{ct+1}}{P_{t+1}} \right) = \beta \left(R_{t+1} \frac{U_{ct+2}}{P_{t+2}} \right). \quad (15)$$

Combining this with the asset accumulation equation (1), we have

$$\frac{R_{t+1}}{\pi_{t+1}} = (1 + r), \quad (16)$$

$$\left(\frac{U_{ct+1}}{\pi_{t+1}} \right) = \left(\frac{U_{ct+2}}{\pi_{t+2}} \right). \quad (17)$$

For stability analysis, the system of equations includes equations (16) and (17), the labor equation (2), and the resource constraint equation (4).

Equation (16) is familiar from before. Under suitable conditions on the interest rate operating procedure it will pin down inflation and interest rate dynamics. The novelty is in equation (17): the limited participation constraint implies that there is little to pin down the initial U_{ct} and thus the initial asset accumulation decision, even if the initial nominal interest rate is determined.

To have any hope of determinacy we need an extra restriction. The limited participation constraint provides one: N_t is a predetermined nominal variable. Combining the two binding cash constraints, and using the household's labor choice decision, we have

$$M_t - N_t = P_t \left(c_t - \frac{U_{Lt} L_t}{U_{ct}} \right). \quad (18)$$

Since M_t and N_t are predetermined, this provides an additional restriction; in the flexible price model N_t is free and equation (18) does not restrict real behavior. In particular, if a policy rule pins down the current price level P_t , then the additional restriction in equation (18) will pin down the initial consumption-asset-accumulation decision. Hence the only way of achieving determinacy is if the interest rate operating procedure pins down the current $\pi_t \equiv P_t/P_{t-1}$. This immediately implies the following:

Proposition 5: Suppose that monetary policy is given by either a forward-looking rule as in equation (7) or a current/forward-looking

Taylor rule as in equation (12). Then in the limited participation model there is real indeterminacy for all values of τ .

It also implies its corollary:

Proposition 6: Suppose that monetary policy is given by a backward-looking Taylor rule as in equation (13). Then in the limited participation model there is real determinacy if and only if $\tau > 1$. Suppose that monetary policy is given by the current/backward-looking Taylor rule given in equation (14). Then there is real determinacy if and only if $1 < \tau < (1 + \lambda)/(1 - \lambda)$.

Notice that a forward-looking Taylor rule and an interest rate peg both suffer from real indeterminacy, because both had nominal indeterminacy in the corresponding flexible-price economy.⁹ An active backward-looking Taylor rule, however, pins down the price level. Since portfolios are predetermined in nominal terms, this price-level determination pins down an extra real variable.

3. A FLEXIBLE-PRICE MODEL WITH TWO CURRENCIES

This section changes the nature of the analysis from the short run (policy across the business cycle) to the long run (the long-run rate of inflation). Given this focus, we ignore dynamic issues and instead concentrate on steady-state analysis.

In terms of modeling, this section builds on the earlier model by assuming that the home-country agent has preferences over both the imported and the exported good and that the imported good must be paid for with foreign currency accumulated in advance.¹⁰ Hence we have a model with two cash constraints and thus two implicit consumption taxes. The imported good is taxed at the foreign interest rate, whereas the domestically produced good is taxed at the domestic interest rate. In section 1, domestic currency could be used for all transactions, so that there was only one implicit tax—the domestic interest rate. But now there are two taxes, one of which the domestic central bank takes as exogenous. In this environment it may not be optimal for the home country to follow Friedman's dictum and drive the domestic nominal interest rate to zero.

9. Carlstrom and Fuerst (1995) show that an interest rate peg suffers from real indeterminacy in a closed-economy limited participation model.

10. This more complicated modeling environment would not affect the earlier conditions for real determinacy.

Household preferences over the imported good (good 2), the domestically produced good (good 1), and work effort are given by

$$\sum_{t=0}^{\infty} \beta^t U(c_{1t}, c_{2t}, L_t) . \quad (19)$$

To finance its consumption purchases, the household uses cash accumulated in advance and thus faces the following cash constraints:

$$P_{1t}c_{1t} \leq M_{1t} + W_t L_t - N_{1t} , \quad (20)$$

$$P_{2t}c_{2t} \leq M_{2t} - N_{2t} , \quad (21)$$

where M_{it} denotes holdings of the home ($i = 1$) and the foreign ($i = 2$) currency; P_{it} denotes the nominal price of goods $i = 1, 2$; W_t denotes the nominal wage expressed in home currency; and N_{it} denotes bank deposits denominated in the two currencies $i = 1, 2$. The intertemporal constraint (expressed in home currency) is thus given by

$$M_{1t+1} + s_t M_{2t+1} = s_t M_{2t} + M_{1t} + W_t L_t - P_{1t}c_{1t} - s_t P_{2t}c_{2t} + \Pi_t \\ + N_{1t}(R_{1t} - 1) + s_t N_{2t}(R_{2t} - 1) + s_t X_t ,$$

where R_{it} denotes the nominal interest rate denominated in the two currencies $i = 1, 2$; s_t is the end-of-period nominal exchange rate; and X_t is a currency transfer from the foreign government. Since this is a small, open economy, we need to exogenously impose an equilibrium condition on domestically owned bank deposits of foreign currency. For simplicity we assume that these are in zero net supply, so that one equilibrium condition imposed below will be $N_{2t} = 0$. Similarly, since our focus is on steady-state issues, we abstract from real foreign asset accumulation (A_t). This is done without loss of generality.

The first-order conditions to the household's problem include

$$\frac{U_{2t}}{U_{1t}} = \frac{s_t P_{2t} R_{2t}}{P_{1t} R_{1t}} , \quad (22)$$

$$\frac{U_{L_t}}{U_{1t}} = \frac{W_t}{P_{1t}} . \quad (23)$$

As for the firm, it produces good 1 using the production technology from before, and subject to the need to borrow domestic

currency to finance its wage bill. In addition, it imports good 2 at exogenous terms of trade. (As before, the imported good is the numeraire, so that e_t is the real price of good 1 in terms of good 2.) The firm then sells the two goods at their respective prices P_{it} . Since the firm does not distribute dividends until the end of the period, it maximizes its end-of-period profits. Hence purchasing power parity is in terms of the end-of-period exchange rate:

$$e_t = \frac{P_{1t}}{s_t P_{2t}} . \quad (24)$$

Interest rate parity is given by

$$\hat{s}_t = \frac{s_t R_{2t}}{R_{1t}} ,$$

where $\hat{s}_t$ is the beginning-of-period, or spot, exchange rate. The fact that equation (24) does not hold with the spot exchange rate, but instead with the end-of-period exchange rate, is a manifestation of the cash-in-advance distortion.

Substituting the firm's optimization conditions into the household first-order conditions yields

$$\frac{U_{L_t}}{U_{1t}} = \frac{\theta_t f'(L_t)}{R_{1t}} , \quad (25)$$

$$\frac{U_{1t}}{U_{2t}} = \frac{e_t R_{1t}}{R_{2t}} . \quad (26)$$

As noted earlier, this is now a model with two implicit consumption taxes, both of which are manifested in equations (25) and (26). The home-produced good (good 1) is taxed at the domestic nominal rate, whereas the imported good (good 2) is taxed at the foreign rate of interest. For a given foreign interest rate it is clear that the central bank faces a second-best problem. Setting the domestic rate to match the foreign rate may alleviate one distortion, equation (26), but exacerbates another, equation (25).

The social resource constraint comes from imposing the equilibrium decision rules and market-clearing conditions on the household's intertemporal constraint. As previously, we assume that only domestic households hold domestic currency. Hence we need only adjust the earlier resource constraint in equation (4) for domestically held foreign cash balances:

$$\frac{M_{2t+1}^a - M_{2t}^a}{P_{2t}} + e_t c_{1t} + c_{2t} = e_t \theta_t f(L_t) + \frac{X_t}{P_{2t}}, \quad (27)$$

where M_{2t}^a denotes foreign cash balances per capita held by the representative domestic household (in the earlier model, domestic households held no foreign cash).

In the steady state, domestic labor supply and purchases of the two goods are constant. Since we are uninterested in the wealth effects coming from exogenous foreign price movements, we assume that

$$X_t \equiv (P_{2t+1} - P_{2t})c_2, \quad (28)$$

where c_2 is the steady-state level of the imported good.¹¹ The household takes this transfer as exogenous so that it does not affect marginal decisionmaking but is only felt at the aggregate resource level. In particular, with the transfer given by equation (28), the binding cash-in-advance constraint implies that foreign money holdings drop out of the resource constraint, so that the steady-state resource constraint is given by

$$ec_1 + c_2 = e\theta f(L). \quad (29)$$

The steady-state welfare problem is to maximize equation (19) subject to equations (25), (26), and (29).

We must utilize numerical methods to make any headway. Hence assume the following functional forms:

$$U(c_1, c_2, L) = \frac{(c_1^{1-\delta} + \mu c_2^{1-\delta})^{\frac{1-\sigma}{1-\delta}}}{1-\sigma} - \frac{\nu L^{1+\eta}}{1+\eta},$$

$$f(L) = L^\alpha.$$

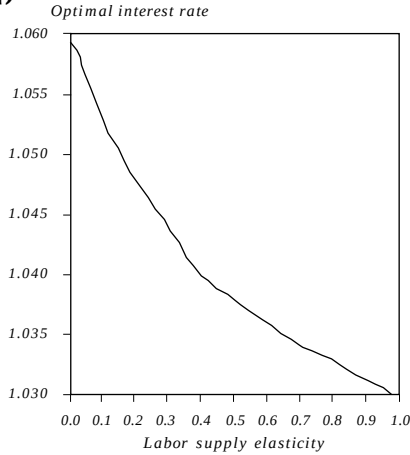
For our benchmark calibration, we set to 1 both the intertemporal elasticity of substitution ($1/\sigma$) and the elasticity of substitution between the two consumption goods ($1/\delta$); we set the labor supply elasticity ($1/\eta$) to 0.333 and the labor share to $\alpha = 2/3$. We also normalize $\theta = 1$, $e = 1$, and $\mu = 1$. The latter implies an import share of $[c_2/(c_2 + c_1)] = 0.47$.

11. Thus this assumption is in the spirit of Lucas (1982), who assumes that domestic and foreign households are insured against "seigniorage risk." Without this assumption the analysis would proceed with an inflation tax term in the aggregate resource constraint in equation (29).

The foreign interest rate is set at $R_2 = 1.06$. We then choose v so that, with $R_1 = 1.06$, we have $L = 1/3$.

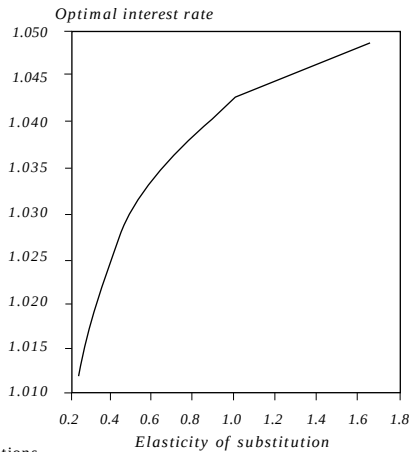
Figures 1 through 3 present the results for differing values of the elasticity of substitution between differing values of the labor supply elasticity ($1/\eta$), the two consumption goods ($1/\delta$), and differing import shares (variations in μ). Across all three figures all other parameters are held constant except the one being analyzed.

Figure 1. Optimal Interest Rate and Labor Supply Elasticity ($1/\eta$)



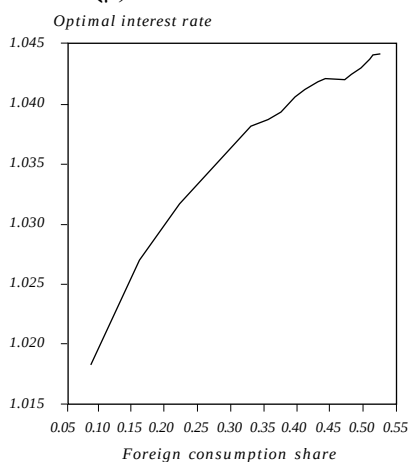
Source: Author's calculations.

Figure 2. Optimal Interest Rate and Elasticity of Substitution Between c_1 and c_2 ($1/\delta$)



Source: Author's calculations.

Figure 3. Optimal Interest Rate and Foreign Consumption Share (μ)



Source: Author's calculations.

The figures reveal standard second-best intuition. When there are two distorted margins, the benevolent planner will choose to more heavily distort the margin that is less elastic or less important. The two margins here are the labor-leisure choice in equation (25) and the choice between good 1 and good 2 in equation (26). The first distortion is eliminated with a zero nominal rate (a gross rate of unity), and the second is eliminated by matching the foreign interest rate.

Figures 1 through 3 have the qualitative shape that one would expect. As $1/\delta$ goes to zero and demands become highly inelastic, the distortionary impact of divergent nominal interest rates declines. Hence the optimal response is to lower the distortion on the labor margin by lowering the domestic interest rate. As labor supply becomes highly inelastic and $1/\eta$ goes to zero, just the opposite is true, and the optimal response is to more closely match the foreign rate. Figure 3 reveals that as the importance of the foreign sector rises, the cost of this distortion rises. Hence as the foreign share rises, the optimal response is to move closer to the foreign rate. Notice that, except under extreme parameter values, the optimal domestic rate is significantly different from Friedman's zero.

Before closing, it is instructive to compare this steady-state analysis with the corresponding dynamic Ramsey problem (see, for example, Chari, Christiano, and Kehoe, 1996). In the present context the key

issue is the form of the aggregate resource constraint. For the household budget constraint to collapse into the form given by equation (29), one needs to preclude an initial and one-time flight from the foreign currency (a possibility that, by assumption, cannot arise in a steady-state analysis). That is, if the Ramsey planner began with the level of foreign cash balances given by the steady-state problem, he would encourage a one-time drop in these currency holdings by setting the domestic nominal rate to zero. This lower domestic rate would lead the household to decrease its consumption of foreign goods and thus lower its holdings of foreign currency. For all future periods this flight would leave the domestic household at a period-by-period utility level lower than that under the steady-state problem (as consumption of the imported good would be forever lower). To rule out this type of behavior, we must replace equation (28) with the stronger condition

$$X_t \equiv (P_{2t+1}c_{2t+1} - P_{2t}c_{2t}) . \quad (30)$$

This transfer scheme imposes an implicit tax on currency flight. Once again the domestic household takes this transfer as exogenous, and thus it does not enter private marginal conditions. However, the Ramsey planner is affected by these transfers, and they lead to an aggregate resource constraint like that in equation (29). Hence, under the assumption made in equation (30), the steady-state analysis and the dynamic Ramsey problem are equivalent.

4. CONCLUSION

This paper has used a standard open-economy model to address two classic questions in monetary policy: What is the appropriate monetary policy across the business cycle? And what is the optimal long-run rate of inflation?

Recent research suggests that an important issue for the first question is what policy restrictions ensure that the central bank's policy rule does not introduce real indeterminacy and sunspot fluctuations into an otherwise stable economy. The message is clear: the central bank should respond aggressively to lagged inflation rates. From the standpoint of indeterminacy issues, a policy that targets current and future expected inflation is disastrous. Responding "passively" to only future expected inflation or targeting the nominal interest rate may

avoid real indeterminacy in a flexible-price model. However, these policies are disastrous when the economy is subject to a nominal rigidity such as that implied by limited participation. In terms of exchange rates, to the extent that a pegged exchange rate implies that the domestic nominal interest rate is given exogenously by the foreign country, a pegged exchange rate is also subject to real indeterminacy and sunspot fluctuations.

As for the second question, concerning the long-run rate of inflation, a small, open economy faces an exogenous foreign interest rate. Almost certainly this rate distorts domestic behavior. Hence the central bank immediately faces a second-best problem. One distortion (a positive foreign rate) can be worse than two (a positive domestic and foreign interest rate). This is a novel reason to stay clear of Friedman's zero nominal rate.

This paper's general-equilibrium or structural approach to policy evaluation has many advantages, including an obvious welfare criterion (lifetime utility of the typical agent) and a clear articulation of what parameters are invariant to policy. General-equilibrium analysis forces one to be specific, and as always the devil is in the details. An example illustrates this point. King and Wolman (1996) analyze a sticky-price general-equilibrium model and conclude that strict price-level targeting is the optimal monetary policy. In contrast, the results of Carlstrom and Fuerst (forthcoming) imply that a plausible alteration in their modeling of money demand implies that an aggressive price-level target is actually destabilizing and introduces sunspot equilibria into the economy. Which conclusion is correct? One must examine the details, all of which a simple reduced-form model obscures.

REFERENCES

- Baier, S. L. 1997. "Optimal Monetary Policy in a Two Country, Two Currency Limited Participation Model." Unpublished manuscript, Notre Dame University.
- Benhabib, J., S. Schmitt-Grohe, and M. Uribe. 1998. "Monetary Policy and Multiple Equilibria." Working paper 37. New York University (June).
- Calvo, G. A. 1983. "Staggered Prices in a Utility-Maximizing Framework." *Journal of Monetary Economics* 12(3): 983-98.
- Carlstrom, C., and T. Fuerst. 1995. "Interest Rate Rules vs. Money Growth Rules: A Welfare Comparison in a Cash-in-Advance Economy." *Journal of Monetary Economics* 36: 247-67.
- . 1998. "Real Indeterminacy in Monetary Models with Nominal Interest Rate Distortions." Federal Reserve Bank of Cleveland Working Paper 1818. Cleveland, Ohio: Federal Reserve Bank of Cleveland (December).
- . 2000. "Forward vs. Backward-Looking Taylor Rules." Federal Reserve Bank of Cleveland Working Paper 0009. Cleveland, Ohio: Federal Reserve Bank of Cleveland (August).
- . Forthcoming. "Timing and Real Indeterminacy in Monetary Models." *Journal of Monetary Economics*.
- Chari, V. V., L. Christiano, and P. Kehoe. 1996. "Optimality of the Friedman Rule in Economies with Distorting Taxes." *Journal of Monetary Economics* 37(2): 203-23.
- Christiano, L., M. Eichenbaum, and C. Evans. 1996. "The Effects of Monetary Policy Shocks: Evidence from the Flow of Funds." *Review of Economics and Statistics* 78: 16-34.
- . 1997. "Sticky Price and Limited Participation Models: A Comparison." *European Economic Review* 41(6): 1201-49.
- Christiano, L., and C. J. Gust. 1999. "Taylor Rules in a Limited Participation Model." NBER Working Paper 7017. Cambridge, Mass.: National Bureau of Economic Research.
- Clarida, R., J. Galí, and M. Gertler. 1997. "Monetary Policy Rules and Macroeconomic Stability: Evidence and Some Theory." Unpublished manuscript. New York University.
- Friedman, M. 1969. *The Optimum Quantity of Money and Other Essays*. Chicago: Aldine.
- Fuerst, T. S. 1992. "Liquidity, Loanable Funds, and Real Activity." *Journal of Monetary Economics* 29: 3-24.

- Grilli, V., and N. Roubini. 1992. "Liquidity and Exchange Rates." *Journal of International Economics* 32: 339-52.
- Ireland, P. 1997. "A Small, Structural, Quarterly Model for Monetary Policy Evaluation." *Carnegie-Rochester Conference Series on Public Policy* 47: 83-108.
- Kerr, W., and R. King 1996. "Limits on Interest Rate Rules in the IS-LM Model." *Federal Reserve Bank of Richmond Economic Quarterly* (Spring): 47-75.
- King, R. G., and A. L. Wolman. 1996. "Inflation Targeting in a St. Louis Model of the 21st Century." *Federal Reserve Bank of St. Louis Review* 78(3): 83-107.
- Lucas, R. E., Jr. 1982. "Interest Rates and Currency Prices in a Two Country World." *Journal of Monetary Economics* 10: 335-59.
- . 1990. "Liquidity and Interest Rates." *Journal of Economic Theory* 50: 237-64.
- McCallum, B. 1981. "Price Level Determinacy with an Interest Rate Policy Rule and Rational Expectations." *Journal of Monetary Economics* 8: 319-29.
- Mendoza, E. G. 1991. "Real Business Cycles in a Small Open Economy." *American Economic Review* 81(4): 797-818.
- Rotemberg, J., and M. Woodford. 1999. "Interest Rate Rules in an Estimated Sticky Price Model." In *Monetary Policy Rules*, edited by J. Taylor. Chicago: University of Chicago Press.
- Schlagenhauff, D. E., and J. Wrase. 1995. "Liquidity and Real Activity in a Simple Open Economy Model." *Journal of Monetary Economics* 35: 431-61.
- Schmitt-Grohe, S., and M. Uribe. 1997. "Balanced Budget Rules, Distortionary Taxes, and Aggregate Instability." *Journal of Political Economy* 105(5): 976-1000.
- Taylor, J. B. 1993. "Discretion versus Policy Rules in Practice." *Carnegie-Rochester Series on Public Policy* 39: 195-214.
- Woodford, M. 1990. "The Optimum Quantity of Money." In *Handbook of Monetary Economics*, volume 2, edited by B. M. Friedman and F. H. Hahn. New York: Elsevier.

POLICY BIASES WHEN THE MONETARY AND FISCAL AUTHORITIES HAVE DIFFERENT OBJECTIVES

Herman Bennett

Massachusetts Institute of Technology

Norman Loayza

The World Bank

Until recently, the debate on the relationship between monetary and fiscal authorities centered on the inflationary consequences of monetary financing of the fiscal deficit. The moderately high inflation of the 1970s in some industrialized countries and, particularly, the recurring episodes of very high inflation in several developing countries justified this focus. The main policy recommendation for countries seeking to avoid high and variable inflation has been to institute an independent monetary authority whose main mandate is the control of inflation (see Cukierman, 1992; Walsh, 1993). In fact, in recent years several central banks around the world have adopted inflation targeting as the cornerstone of their monetary policy (see Bernanke and others, 1999).

For their part, fiscal authorities in many countries have also come to recognize the harmful effects of inflation and have taken measures to control their deficits. This has been achieved both by rationalizing fiscal expenditure (for example, eliminating price subsidies and privatizing public enterprises) and by raising tax revenue, particularly through the adoption of value-added taxes. Fiscal authorities are also using domestic and international financial markets to better manage the public debt, to avoid the need to collect an inflation tax from outstanding monetary assets.

We are grateful to Guillermo Larraín, Daniel Lederman, and Rodrigo Valdés for useful discussions and helpful comments. All remaining errors are our responsibility.

At the time of writing, Herman Bennett and Norman Loayza were affiliated with the Central Bank of Chile.

Monetary Policy: Rules and Transmission Mechanisms, edited by Norman Loayza and Klaus Schmidt-Hebbel, Santiago, Chile. ©2002 Central Bank of Chile.

Thus, in many countries around the world, there is a new policy environment, one in which monetary authorities are committed to controlling inflation, and fiscal authorities do not rely on the inflation tax to finance their deficits and debt service. In this new context, a different set of policy issues and questions arises. This paper is devoted to one of these, namely, what effect a lack of coordination between monetary and fiscal authorities has in achieving the goal of minimizing business cycle fluctuations.

Coordination (or the lack thereof) is a relevant issue because monetary and fiscal authorities have different policy instruments, different objectives and preferences, and sometimes different perceptions of how the economy functions. In this paper we concentrate on the effects of having monetary and fiscal authorities with dissimilar objectives and with control of different policy instruments. In this sense the paper is closely related to Nordhaus (1994), Loewy (1988), and Perry and Lederman (1997). Following these studies, we use a game-theoretic approach to analyze the effects of a lack of policy coordination on fiscal deficits and domestic real interest rates.

To introduce the main issues and results of the paper, we present a simple fiscal-monetary game modeled after the well-known prisoners' dilemma. We use this game to analyze the possible responses of the monetary and fiscal authorities in the face of a negative shock that raises inflation and lowers employment. Figure 1 presents the main assumptions and the outcomes. The monetary and the fiscal authorities each have two options: they can follow either a loose or a tight policy. When both "play tight," the resulting inflation is low, but so is the resulting employment. When both play loose, both inflation and employment are high. And when only one of them plays tight and the other loose, the result is employment and inflation that are somewhere in between.

The interesting feature of this fiscal-monetary game is that the two authorities have different preferences for both inflation and employment (see the payoff schedules in figure 1). Whereas the monetary authority places greater value on achieving low inflation than on achieving high employment, the fiscal authority regards the latter as more important than keeping inflation low. (We have arbitrarily made these differences in the preference schedules sufficiently large to obtain the result we would like to stress.)

The only Nash equilibrium in this game consists of a tight monetary policy and a loose fiscal policy. All of the other alternatives present opportunities for one of the players to benefit by unilaterally deviating from it. Thus the equilibrium of this game exposes the paradigmatic conservatism of central banks and liberalism of fiscal

authorities. It also illustrates why the response of each of them is optimal given their differing preferences. If the monetary authority were to follow a loose policy and accept a pledge from the fiscal authority for stricter restraint, the fiscal authority would find it optimal to renege on its pledge and adopt a loose policy. By the same token, if the fiscal authority were to conduct a tight policy, given an offer from the central bank to follow a loose policy, the monetary authority would benefit by deviating from its offer and following a tight policy instead. Finally, in terms of the payoffs to both authorities, the Nash equilibrium is equivalent to the combination of loose monetary and tight fiscal policies. From a long-run perspective, however, it can be argued that this combination of policies is healthier than the Nash equilibrium, given that it does not compromise fiscal sustainability and does not weaken the investment capacity of the private sector.

Figure 1. A Monetary-Fiscal Game: Outcomes and Payoffs

		<i>Central bank</i>	
		<i>Tight monetary policy</i>	<i>Loose monetary policy</i>
<i>Fiscal authority</i>	<i>Tight fiscal policy</i>	<i>Outcome:</i> Low inflation Low employment <i>Payoff:</i> Central bank: $6 + 1 = 7$ Fiscal authority: $3 + 1 = 4$	<i>Outcome:</i> Medium inflation Medium employment <i>Payoff:</i> Central bank: $4 + 2 = 6$ Fiscal authority: $2 + 4 = 6$
	<i>Loose fiscal policy</i>	<i>Outcome:</i> Medium inflation Medium employment <i>Payoff:</i> Central bank: $4 + 2 = 6$ Fiscal authority: $2 + 4 = 6$	<i>Outcome:</i> High inflation High employment <i>Payoff:</i> Central bank: $1 + 3 = 4$ Fiscal authority: $1 + 6 = 7$

<i>Payoff schedule</i>			
	<i>Low</i>	<i>Medium</i>	<i>High</i>
Central bank	6	<i>Inflation</i> 4	1
Fiscal authority	3	2	1
Central bank	1	<i>Employment</i> 2	3
Fiscal authority	1	4	6

Although it illustrates the major themes of the paper, this simple game has some obvious shortcomings. One is that it requires an arbitrary, ad hoc payoff schedule to achieve the desired result. We may want to clarify the preference conditions under which policy biases occur. The second shortcoming is that the game does not consider the possibility for negotiation between the fiscal and monetary authorities, which may result in policy coordination.

Section 1 of this paper presents a more fully elaborated monetary-fiscal game in which the potential advantages of policy coordination can be clearly seen. Through this model we also clarify the conditions under which looser fiscal policy (represented by higher primary fiscal deficits) is accompanied by tighter monetary policy (represented by higher real interest rates), as predicted by our version of the prisoners' dilemma. Our basic conclusion from the model is that increasing the divergence in preferences between the monetary and fiscal authorities for output and inflation gaps results in higher primary fiscal deficits and higher real interest rates.

Section 1 also compares the Nash equilibrium solution to this model with a Stackelberg solution. By allowing one of the authorities to take the lead in choosing policy, the Stackelberg solution introduces a dynamic dimension into the game, creating the possibility for one player (the leader) to act in a way that elicits a mutually beneficial response from the other (the follower). The Stackelberg game results in the same basic conclusion as the Nash equilibrium; however, due to its potential for beneficial interaction, the Stackelberg equilibrium comes closer to the coordination solution than the Nash equilibrium does.¹

Section 2 brings some empirical evidence to bear on the question. We use annual data over the period 1970-94 from a sample of industrialized countries to test the main hypothesis of our model: in a context where fiscal and monetary authorities are independent and do not effectively coordinate their policy responses, those countries whose fiscal and monetary authorities have more divergent preferences for the output and inflation gaps will exhibit larger primary deficits and higher real interest rates. Given the simplified nature of

1. We acknowledge that the coordination solution against which we compare the Nash and Stackelberg equilibria is not derived endogenously in the model. This is because the game we analyze is a "one-shot" game. Endogenous coordination, which is beyond the scope of this paper, may arise in the context of a game played in a series of consecutive rounds, where the coordination solution would be sustained by reputation, commitment, and credibility.

our game-theoretic model, this conclusion would apply only after controlling for other factors affecting the level of primary deficits and domestic real interest rates.

We run separate regressions for the primary deficit (as a ratio to GDP) and the real domestic interest rate (more precisely, its deviation from the international interest rate). Then we assess whether proxies for the divergence in preferences between fiscal and monetary authorities are positively related to these primary deficits and real interest rates. The proxies we use are indexes for each country of the importance of price stability for the central bank. In these regressions we control for a number of effects that may influence (or be influenced by) the dependent variables, such as business cycle effects, international conditions, and Ricardian equivalence effects.

Using a seemingly-unrelated-regression estimator and accounting for country random effects, we find that, *ceteris paribus*, the greater the importance placed on inflation control by the monetary authority, the larger is the primary deficit and the higher the domestic real interest rate. We conclude that, without prejudice to the gains from central bank independence, there are gains to be had from policy coordination by the monetary and fiscal authorities. Central bank independence has helped achieve price stability and has induced fiscal discipline in many countries. As mentioned above, this is a necessary, first-generation reform. A policy implication of this paper is that a second-generation reform consisting of institutional incentives for domestic policy coordination can also be beneficial, but only for countries that have already achieved price stability and fiscal discipline.

1. A GAME-THEORETIC MODEL

This section presents a one-period model of a simple game played by monetary and fiscal authorities. It builds on the trade-off that each authority has to face in the short run between changes in the inflation rate and in the output gap (that is, the Phillips curve). The model emphasizes the effects on the level of fiscal deficits and real interest rates that result from different preferences by the monetary and fiscal authorities with respect to deviations of inflation and output from their optimal levels.

This game-theoretic approach is based on Frankel (1988), Loewy (1988), and Nordhaus (1994). The main difference between Frankel's model and ours is that Frankel assumes a world where the authorities have the same preferences with respect to inflation

and output deviations but disagree on the model that best represents the economy.² With respect to Nordhaus's model, the main difference is that we assume that the monetary authority dislikes changing the real interest rate from its optimal level. As we show below, under this assumption it is possible to reverse Nordhaus's conclusion that lack of coordination between monetary and fiscal authorities necessarily implies higher fiscal deficits and higher real interest rates. Also, extending Nordhaus's work, we analyze the Stackelberg equilibrium, which allows us to assess whether the main conclusions change if the monetary-fiscal game is played sequentially. Two other important differences with respect to previous work are that, first, we assume asymmetric preferences and, second, we analyze aggregate supply and demand shocks separately (the latter are presented in an earlier version of this paper: Bennett and Loayza, 2000).

1.1 The Model

We assume that policymakers seek to maximize an asymmetric utility function. Both fiscal and monetary authorities dislike falls in output and rises in inflation; however, they do not mind rises in output or drops in inflation. In addition, we assume that each authority dislikes changing its policy instrument from its equilibrium level.

The utility level for the fiscal authority is denoted by U^F , and its relative preference between objectives is given by the coefficients α^F , β^F , and δ . These measure, respectively, the cost associated with output falling below a certain threshold ($y - y^*$), with inflation rising beyond a desired level ($\pi - \pi^*$), and with deviations of the deficit from a socially optimal level ($D - D^*$).

$$U^F = V^F \left[(y - y^*), (\pi - \pi^*), (D - D^*) \right],$$

$$U^F = -\alpha^F \left[\min(y - y^*, 0) \right]^2 - \beta^F \left[\max(\pi - \pi^*, 0) \right]^2 - \delta (D - D^*)^2. \quad (1)$$

Note that $\alpha^F, \beta^F, \delta > 0$.³

2. Frankel concludes that policy coordination may not be welfare improving if it means a departure from the "true" model. However, coordination is more likely to be welfare improving if it involves sharing information so as to arrive at that "true" model.

3. More precisely, D represents the primary deficit (the overall deficit minus interest payments).

The monetary authority's utility function is modeled with the same structure, but instead of the deficit deviation it has an intrinsic preference with respect to its instrument, the real interest rate (r). Analogously to equation (1), U^M represents the monetary authority's utility, and α^M , β^M , and τ measure, respectively, the cost associated with output falling below a certain threshold ($y - y^*$), with inflation rising beyond a desired level ($\pi - \pi^*$), and with deviations of the real interest rate from its socially optimal level ($r - r^*$).

$$U^M = V^M \left[(y - y^*), (\pi - \pi^*), (r - r^*) \right],$$

$$U^M = -\alpha^M \left[\min(y - y^*, 0) \right]^2 - \beta^M \left[\max(\pi - \pi^*, 0) \right]^2 - \tau (r - r^*)^2. \quad (2)$$

Again, $\alpha^M, \beta^M, \tau > 0$.

The assumption that $\tau > 0$ reflects the observation that central banks dislike large and sudden movements in policy interest rates. For example, in the recent literature on monetary policy, the lagged interest rate has been widely used as an argument of the policy reaction function (see Woodford, 1999, for a model that formalizes the optimality of interest rate smoothing rules). Similarly, the assumption that $\delta > 0$ reflects the fact that the fiscal authorities dislike deviations in their instrument from an established target. This may result from the political costs and financing difficulties involved in moving away from an agreed-upon fiscal budget.

We assume that the monetary authority cares more about a rise in inflation than the fiscal authority does. Conversely, the fiscal authority is more concerned about drops in output than its monetary counterpart is. That is, $\beta^M > \beta^F$ and $\alpha^F > \alpha^M$. These divergent preferences reflect both the central bank's mission to contain inflation and the fiscal authority's need to deal with voters' aversion to unemployment. We assume that the socially optimal levels y^* , π^* , D^* , and r^* are perceived to be the same by both authorities.

The forces that rule the economy are modeled as follows:

$$y - y^* = \gamma_D (D - D^*) - \gamma_r (r - r^*) + \gamma_0, \quad (3)$$

$$\pi - \pi^* = \lambda_y (y - y^*) - \lambda_0. \quad (4)$$

Equation (3) gives the aggregate demand function, and equation (4) gives aggregate supply (or the Phillips curve). The term $(y - y^*)$ represents the output gap; $(\pi - \pi^*)$ represents the deviation of inflation from the optimal rate; γ_D and γ_r represent, respectively, the elasticity of the output gap with respect to fiscal deficits and the real interest rate; and λ_y represents the elasticity of inflation with respect to the output gap. Shocks to aggregate demand and supply are represented, respectively, by γ_0 and λ_0 . For simplicity, we set $D^*, r^* = 0$.

In what follows we concentrate on aggregate supply shocks, which in our model create a trade-off between output and inflation for both authorities. In Bennett and Loayza (2000) we study the fiscal and monetary response to aggregate demand shocks and show that the central hypothesis of the model, tested in section 2 of this paper, holds for this type of shock as well.

The solution for the case of a positive aggregate supply shock ($\lambda_0 > 0$) is trivial. This results from the type of asymmetric loss functions that we have assumed. A positive supply shock leaves inflation lower than π^* and output higher than y^* , in which case neither authority suffers a loss, and thus there is no policy response. On the other hand, a negative supply shock lowers output and increases inflation, thus inducing a policy reaction by both authorities. It is this case that we study in detail.

Given a negative supply shock, the loss functions in equations (1) and (2) can be written as follows:

$$U^F = -\alpha^F (y - y^*)^2 - \beta^F (\pi - \pi^*)^2 - \delta (D - D^*)^2, \quad (5)$$

$$U^M = -\alpha^M (y - y^*)^2 - \beta^M (\pi - \pi^*)^2 - \tau (r - r^*)^2. \quad (6)$$

This simplification is correct because, as we show below, the resulting equilibrium level of output is lower than y^* , and inflation is higher than π^* . In other words, the solution is interior to the range $y < y^*$ and $\pi > \pi^*$.

1.2 Optimization under a Single Economic Authority

First we determine the optimal levels of D and r in the two cases where the monetary or the fiscal authority is able by itself to determine both instruments (in other words, there is a single economic authority). This will give us their respective “bliss points.” We can

then compare the situation where each authority determines its own instrument under lack of coordination with alternative scenarios such as, first, a single economic authority managing both monetary and fiscal policies, and, second, the two authorities working to coordinate policy.⁴

When the fiscal authority also determines the interest rate, the first-order conditions are

$$\frac{\partial U^F}{\partial D} = -2\alpha^F (y - y^*) \gamma_D - 2\beta^F (\pi - \pi^*) \lambda_y \gamma_D - 2\delta D = 0, \quad (7)$$

$$\frac{\partial U^F}{\partial r} = 2\alpha^F (y - y^*) \gamma_r + 2\beta^F (\pi - \pi^*) \lambda_y \gamma_r = 0. \quad (8)$$

From equation (7), and substituting equations (3) and (4), we obtain the fiscal reaction function (FRnFn):

$$D = \left[\frac{1}{1 + \frac{\delta}{\gamma_D^2 (\alpha^F + \beta^F \lambda_y^2)}} \right] \frac{\gamma_r}{\gamma_D} r + \left[\frac{\lambda_y \lambda_0}{\frac{\delta}{\beta^F \gamma_D} + \gamma_D (\alpha^F / \beta^F + \lambda_y^2)} \right]. \quad (9)$$

From equation (8) we obtain what we call the fiscal cross-maximization function (FCrMx), because it results from the fiscal authority's optimization with respect to the instrument of the other (monetary) authority (the real interest rate):

$$D = \frac{\gamma_r}{\gamma_D} r + \left[\frac{\lambda_y \lambda_0}{\gamma_D (\alpha^F / \beta^F + \lambda_y^2)} \right]. \quad (10)$$

Figure 2 plots equations (9) and (10). Their intersection gives the optimal pair (D^F, r^F) , or bliss point, for the fiscal authority. This is

4. By coordination we mean a process through which the two independent authorities negotiate their strategies in order to improve the results for both.

achieved at the fiscal authority's optimal level of aggregate demand, with $D^F = 0$. This result is to be expected given the fiscal authority's dislike of having the public deficit deviate from its optimal level. From the fiscal authority's utility function in equation (5) we can see that it is costless to this authority to achieve the optimal aggregate demand level using r instead of D as the policy instrument.

The dotted lines in figure 2 and the figures that follow represent iso-aggregate demand levels (iso-AD). The slope of the aggregate demand function is γ_r/γ_D . From equation (10), the slope of FCrMx is γ_r/γ_D , so this line also represents an aggregate demand level, which in this case is the optimal fiscal activity level.

Analogously, we can obtain the monetary authority's bliss point. When the central bank determines both D and r , the first-order conditions are derived by maximizing the central bank's utility function in equation (6) with respect to both instruments. The monetary reaction function (MRnFn) is given by

$$\frac{\partial U^M}{\partial r} = 0 \Rightarrow$$

$$D = \left[1 + \frac{\tau}{\gamma_r^2(\alpha^M + \beta^M \lambda_y^2)} \right] \frac{\gamma_r}{\gamma_D} r + \left[\frac{\lambda_y \lambda_0}{\gamma_D(\alpha^M/\beta^M + \lambda_y^2)} \right], \quad (11)$$

and the monetary cross-maximization (MCMx) function is given by

$$\frac{\partial U^M}{\partial D} = 0 \Rightarrow$$

$$D = \frac{\gamma_r}{\gamma_D} r + \left[\frac{\lambda_y \lambda_0}{\gamma_D(\alpha^M/\beta^M + \lambda_y^2)} \right]. \quad (12)$$

The monetary authority's bliss point, (D^M, r^M) , is obtained in the same way as for the fiscal authority. Its optimal aggregate demand level is reached with its instrument unchanged, $r = 0$. Figure 2 shows that the level of aggregate demand at the monetary bliss point is lower than that reached at the fiscal bliss point. This comes from the relationship between α^F/β^F and α^M/β^M , the authorities' relative preferences for inflation and output ($\alpha^F/\beta^F > \alpha^M/\beta^M$).⁵

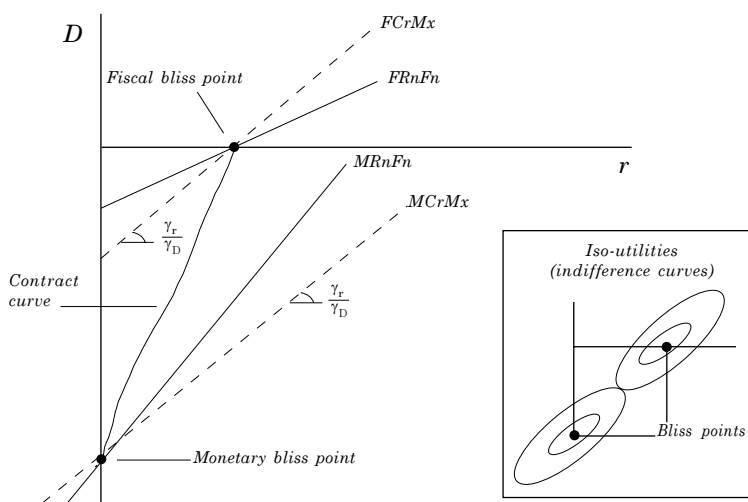
5. Remember that the dotted lines represent iso-AD curves. In this case, the MCMx function in equation (12) gives the bliss level of aggregate demand for the monetary authority.

What happens if the monetary authority presents a greater disutility from higher inflation (that is, a higher β^M)? The central bank's optimal aggregate demand will then decrease in order to achieve lower inflation. As discussed above, this change in the bliss point represents a downward movement along the D axis.

To summarize, these two simple scenarios of nonindependence (a single economic authority) show the effects on activity of different preferences in each authority's utility function. They also show the desire of each authority to use the other's instrument to adjust the output and inflation gaps and thus optimize its own utility function.

In addition to these cases of nonindependence, it is interesting to study the case where there is coordination between independent authorities. The contract curve shown in figure 2 describes the possible solutions for this scenario. It is the group of points for which there is no possibility of improving the situation of one authority without diminishing the utility of the other. In other words, the contract curve is the line that contains the tangent points between the two sets of iso-utility curves (see inset in figure 2).⁶

Figure 2. Fiscal and Monetary Bliss Points and the Contract Curve



6. The shape of the iso-utility curves depends on the authorities' utility function parameters: the relative preference for inflation and output gaps, and the relative cost associated with deviations of the respective instrument.

Even though, with independent authorities, points on the contract curve seem to be the best solution for both players, this coordinated equilibrium may be unenforceable and thus unlikely to be achieved. In the real world, the fact of independence, together with obstacles to enforcing commitments, the transactions costs that hinder coordination, and the practical inability to discern outcomes due to policies from those due to shocks, suggests that policy actions may be more realistically modeled as Nash or Stackelberg games.

1.3 The Nash Equilibrium

The Nash equilibrium applies when both players decide their strategies simultaneously and without coordination. In the monetary-fiscal game, this means that each authority has to decide the level of its instrument, knowing that its counterpart is rational and has a certain preference regarding the inflation and output gap. Then the Nash equilibrium will result in a pair (D^N, r^N) in which no player can reach a higher utility level by unilaterally deviating from that equilibrium.

The Nash solution is obtained when each authority maximizes its utility function with respect to its own instrument, taking the other policy instrument as given. Equations (7) and (11) represent the first-order conditions of the Nash solution. Thus, the reaction function of the fiscal authority is given by equation (9), and the monetary authority's reaction function by equation (11).

Comparing these two equations shows that, first, the slope of MRnFn is greater than γ_r/γ_D , and the slope of FRnFn is less than γ_r/γ_D , which reflects the loss associated with each authority allowing its respective policy instrument to deviate from its optimal level. Second, the intercept of MRnFn is more negative than that of FRnFn, which results from the fact that the monetary authority realizes a smaller loss from a given output gap (and a greater loss from a given inflation gap) than the fiscal authority (figure 3).

The intersection of MRnFn and FRnFn gives the Nash solution. After a fair amount of algebra, the solution of the Nash equilibrium is given by

$$D^N = \frac{-\gamma_r^2 \lambda_y (\alpha^F \beta^M - \alpha^M \beta^F) \lambda_0 + \tau \beta^F \lambda_y \lambda_0}{\gamma_r^2 \delta / \gamma_D (\alpha^M + \beta^M \lambda_y^2) + \tau \delta / \gamma_D + \gamma_D \tau (\alpha^F + \beta^F \lambda_y^2)}, \quad (13)$$

$$r^N = \frac{-\gamma_D^2 \lambda_y (\alpha^F \beta^M - \alpha^M \beta^F) \lambda_0 - \delta \beta^M \lambda_y \lambda_0}{\gamma_r \delta (\alpha^M + \beta^M \lambda_y^2) + \tau \delta / \gamma_r + \gamma_D^2 \tau / \gamma_r (\alpha^F + \beta^F \lambda_y^2)}. \quad (14)$$

Note from equation (13) that the sign of D^N is not strictly positive. In fact, D^N will be negative if the difference in preferences between monetary and fiscal authorities is small with respect to the central bank's loss from changing the interest rate from its target level. This case, however, is of limited empirical importance, because it would imply that, in the presence of a negative supply shock, central bank independence results in higher inflation than under the fiscal bliss point (figure 4). This makes little practical sense. Therefore in what follows we assume that the condition given in equation (15) holds, so that the Nash equilibrium always implies a larger deficit and a higher real interest rate than the solution under a single economic authority. Intuitively, this condition requires that the central bank values low inflation sufficiently more than the fiscal authority and sufficiently more than keeping the interest rate at its long-run level:

$$\alpha^F \beta^M - \alpha^M \beta^F > \tau \frac{\beta^F}{\gamma_r^2} . \quad (15)$$

The Nash equilibrium portrayed in figure 3 represents the conclusion arrived at in Loewy (1988) and in Nordhaus (1994): both the real interest rate and the fiscal deficit exceed their levels at either bliss point. In fact, the level of aggregate demand obtained at the Nash equilibrium can be achieved by a large number of combinations of lower deficits and interest rates. Thus the Nash equilibrium (D^N, r^N) is Pareto inferior to a large set of points, and in particular to any point on the contract curve.

Why does this "inefficiency" occur? The following example, presented in the inset in figure 3, may clarify the intuition behind this result. Starting from the fiscal bliss point (D^F, r^F), suppose that the central bank is granted independence and that no coordination is possible. The monetary authority could react to the initial level of aggregate demand by increasing r to a new level, allowing it to maximize its utility function for the fiscal deficit $D = 0$ (point 1). A rational fiscal authority will anticipate this reaction and the level of aggregate demand that it implies, and thus it may react with a level of D that maximizes its own utility function given the new real interest rate (point 2). The monetary authority, in turn, may reset its instrument to a new optimal level given the latest fiscal reaction (point 3). As the figure shows, each authority will continue to adjust its policy instrument until neither can improve its utility, given rational behavior by the other player. This equilibrium is represented by the optimal pair (D^N, r^N).

Figure 3. Nash Equilibrium

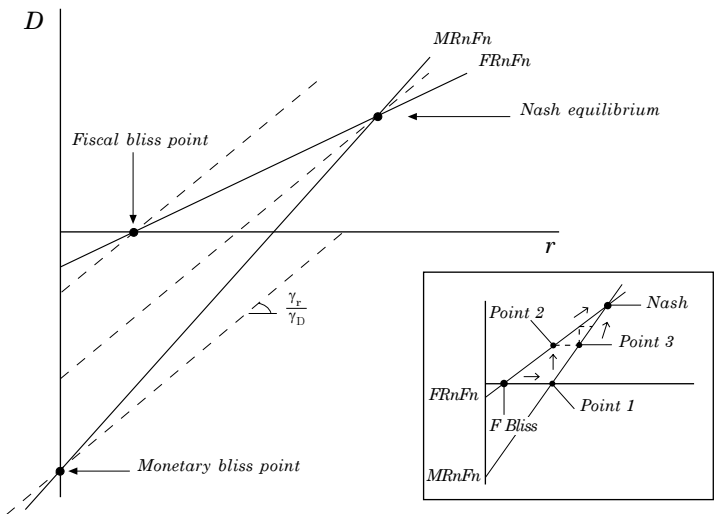
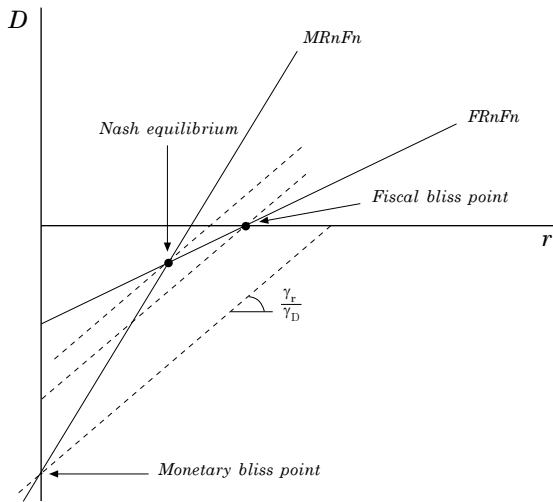


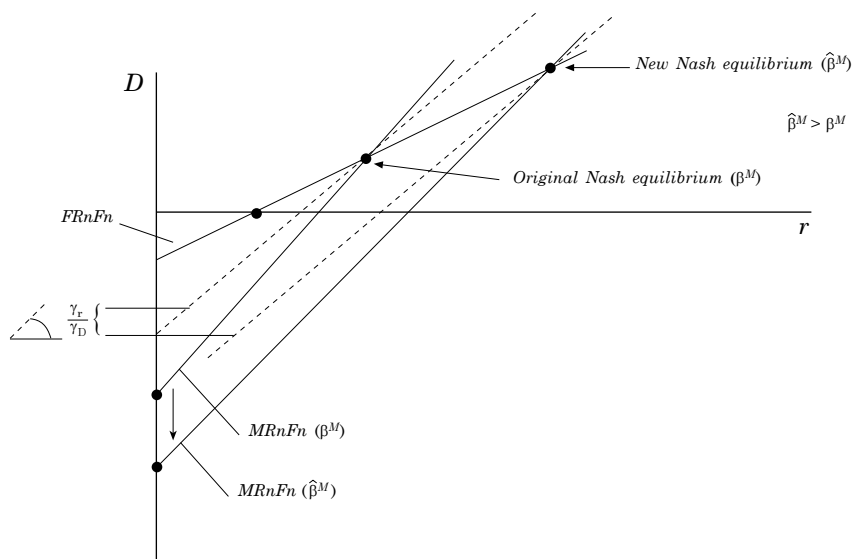
Figure 4. Nash Equilibrium when the Central Bank Sufficiently Dislikes Changing the Interest Rate



What happens if the difference in preferences between the two authorities becomes wider (that is, the difference between α^F/β^F and α^M/β^M increases)? Modeling this as a higher β^M ($\hat{\beta}^M > \beta^M$) in figure 5, we can see that the new equilibrium ($\hat{D}^N, \hat{r}^N$) will necessarily be located to the northeast of (D^N, r^N) , which means higher levels of both instruments, lower inflation, and lower aggregate demand. Both the intercept and the slope of MRnFn will be lower if β^M increases to $\hat{\beta}^M$, reflecting the lower desired aggregate demand that results from the stronger anti-inflation preference of the central bank.⁷ Note that this conclusion does not require the assumption made in equation (15).

To summarize, modeled as a Nash game, the uncoordinated policy reaction of the fiscal and monetary authorities to a negative supply shock results in higher fiscal deficits and higher real interest rates than those obtained when either authority alone determines both instruments. Moreover, when the divergence in the authorities' preferences for the output and inflation gaps widens, the resulting fiscal deficit becomes larger and the real interest rate becomes higher.

Figure 5. Shift in Nash Equilibrium with an Increase in the Central Bank's Preference



7. This result is maintained if we model the increased difference in preferences as a higher α^F , a lower α^M , or a lower β^F . The last two results can easily be derived from the resulting values of D^N and r^N .

Finally, substituting the resulting D^N and r^N in the output gap equation (3) and in the inflation equation (4), it can clearly be seen that equilibrium output is lower than y^* and inflation higher than π^* . In other words, the solution is interior to the range $y < y^*$ and $\pi > \pi^*$. Thus it is valid to assume that, given a negative supply shock, the authorities' utility function can be modeled as the simple quadratic form of equations (5) and (6).

1.4 The Stackelberg Equilibrium

Whereas the Nash equilibrium is obtained when both players move simultaneously, a sequential play of the game leads to the Stackelberg equilibrium. For the monetary-fiscal game this means that one of the authorities decides first the magnitude of its instrument and the other follows its lead. We begin by assuming that the monetary authority is the leader. The contrary case is analyzed at the end of this section.

In the Stackelberg game, when the central bank is the leader, the fiscal reaction will be governed by equation (9), the optimal response of the follower to a given real interest rate.

The central bank's first-order condition as the leader of the Stackelberg game is obtained by maximizing U^M with respect to r , taking into account that the central bank is now able to affect D according to the fiscal authority's reaction function in equation (9). We can then express the monetary authority's "action" function (MANFn) as follows:

$$D = \left[1 + \frac{\tau}{\Phi \gamma_r^2 (\alpha^M + \beta^M \lambda_y^2)} \right] \frac{\gamma_r}{\gamma_D} r + \left[\frac{\lambda_y \lambda_0}{\gamma_D (\alpha^M / \beta^M + \lambda_y^2)} \right], \quad (16)$$

$$\text{where } \Phi = \frac{1}{1 + \frac{\gamma_D^2 (1 + \beta^F \lambda_y^2)}{\delta}} < 1. \quad (17)$$

Substituting equation (9) into equation (16), we can determine the central bank's optimal magnitude for the real interest rate. Then, given r , the fiscal authority decides its deficit according to equation (9). The Stackelberg solution is given by

$$D^s = \frac{-\Phi \gamma_r^2 \lambda_y (\alpha^F \beta^M - \alpha^M \beta^F) \lambda_0 + \tau \beta^F \lambda_y \lambda_0}{\Phi \gamma_r^2 \delta / \gamma_D (\alpha^M + \beta^M \lambda_y^2) + \tau \delta / \gamma_D + \gamma_D \tau (\alpha^F + \beta^F \lambda_y^2)}, \quad (18)$$

$$r^s = \frac{-\Phi\gamma_D^2\lambda_y(\alpha^F\beta^M - \alpha^M\beta^F)\lambda_0 - \Phi\delta\beta^M\lambda_y\lambda_0}{\Phi\gamma_r\delta(\alpha^M + \beta^M\lambda_y^2) + \tau\delta/\gamma_r + \gamma_D^2\tau/\gamma_r(\alpha^F + \beta^F\lambda_y^2)}. \quad (19)$$

As in the Nash equilibrium, the resulting fiscal deficit, equation (18), does not strictly have to be positive. It could be negative if the authorities' preferences become very similar or if the relative cost to the central bank of a change in its instrument from the optimum rises considerably. As previously, the case of a negative equilibrium deficit has little practical importance, for it implies that central bank independence would result in a higher inflation rate with respect to the fiscal bliss point. Therefore in what follows we assume that the condition given in equation (20) holds, so that the Stackelberg equilibrium always implies larger deficits and higher real interest rates than the solutions under a single economic authority:

$$\alpha^F\beta^M - \alpha^M\beta^F > \frac{\beta^F}{\gamma_r^2\Phi}. \quad (20)$$

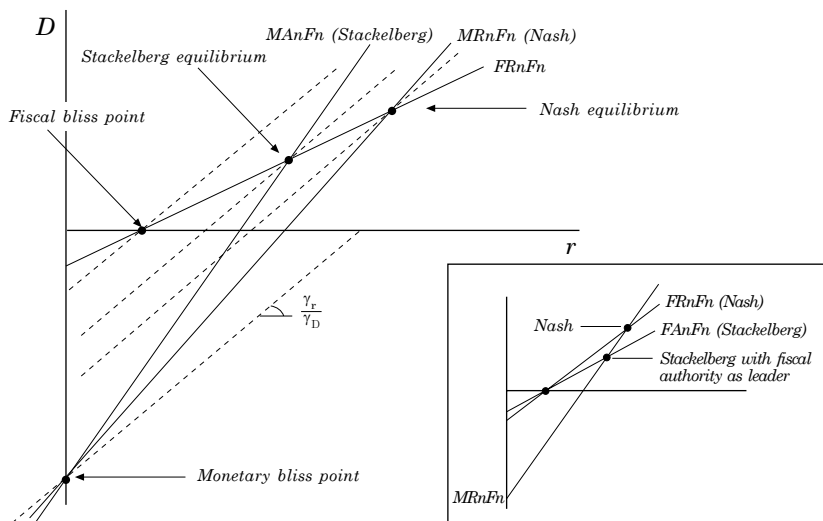
Figure 6 shows the Stackelberg equilibrium, which is the intersection between equation (16), the MAnFn (Stackelberg), and equation (9). As in the Nash solution, the lack of policy coordination, modeled as a Stackelberg game, results in larger fiscal deficits and higher real interest rates than when either authority controls both policy instruments.

What happens in this case if the difference in preferences between the two authorities becomes wider (that is, the difference between α^F/β^F and α^M/β^M increases)? As in the Nash game, modeled as higher β^M ($\beta^M > \beta^M$), the new equilibrium ($\hat{D}^S, \hat{\pi}^S$) will necessarily be located to the northeast of (D^S, r^S), which means higher levels of both instruments and lower inflation and aggregate demand.⁸ Note that this conclusion does not require the assumption in equation (20).

Relative to the Nash solution, the Stackelberg equilibrium produces smaller deficits and lower interest rates. When the monetary authority is the leader, it also implies a higher level of economic activity (and of inflation) and allows both authorities to reach a higher iso-utility curve than in the Nash equilibrium. The inset in figure 6 shows the alternative case in which the fiscal authority is the leader. Here the conclusions are similar except that the resulting level of aggregate demand is lower than in the Nash solution.

8. As in the Nash game, this result is maintained if we model the increased difference in preferences as a higher α^F , lower α^M , or lower β^F . The last two results can easily be derived from the resulting values of D^S and r^S .

Figure 6. Stackelberg Equilibrium with Central Bank as Leader



Finally, with the same procedure used as in the Nash game, it can clearly be seen that the Stackelberg solution is interior to the range $y < y^*$ and $\pi > \pi^*$. Thus it is valid to assume that, given a negative supply shock, the authorities' utility function can be modeled as the simple quadratic form of equations (5) and (6).

1.3 Conclusions

We have modeled the lack of coordination between fiscal and monetary authorities as, alternatively, a Nash or a Stackelberg game. Under the assumption that, compared with the fiscal authority, the monetary authority loses more from higher inflation than from a larger output gap, we reach three main conclusions. First, in the presence of a negative supply shock, lack of coordination results in a larger fiscal deficit and a higher interest rate than when either authority controls both instruments.⁹

9. This result requires, in addition, that the monetary authority be sufficiently willing to modify its instrument.

Second, when the difference in preferences between the monetary and fiscal authorities increases, so do the equilibrium fiscal deficit and interest rate. As we show in Bennett and Loayza (2000), this result holds not only for negative supply shocks, but also in the presence of aggregate demand shocks. Section 2 is devoted to testing this second conclusion of the theoretical model.

Third, when the relationship between the fiscal and monetary authorities can be represented as a leader-follower relationship, the Stackelberg solution applies. In this case the previous two conclusions are still valid, but in a milder form: the Stackelberg solution produces fiscal deficits and interest rates that are in between the policy coordination solution and the Nash equilibrium.

2. EMPIRICAL EVIDENCE

The main conclusion of section 1 can be summarized as follows. In a context where fiscal and monetary authorities are independent and do not effectively coordinate their policy responses, those countries and time periods where these authorities have more divergent preferences for the output and inflation gaps will exhibit larger primary deficits and higher real interest rates. Given the highly simplified nature of our game-theoretic model, this conclusion would apply only after controlling for other factors affecting the level of primary deficits and domestic real interest rates.

In this section we bring to bear some empirical evidence concerning our main conclusion. We base this evidence on regressions using both cross-country and time-series data. This choice is justified by the nature of our conclusion, which compares different policy regimes both within and between countries.

2.1 The Empirical Model

Let d be the primary deficit (properly normalized to be comparable across countries and over time) and r the real domestic interest rate (or more precisely, that portion of it subject to changes in policy). Then consider the following two reduced-form regression equations:

$$d_{i,t} = \beta_d X_{i,t} + \theta_d m f_{i,t} + \varepsilon_{i,t} , \quad (21)$$

$$r_{i,t} = \beta_r X_{i,t} + \theta_r m f_{i,t} + \mu_{i,t} , \quad (22)$$

where mf is an indicator of the difference in preferences between monetary and fiscal authorities regarding the inflation and output gaps, X is a set of control variables, and the subscripts i and t denote country and time, respectively. We assume cross-country homogeneity in the response of primary deficits and real interest rates to changes in mf and X ; thus the coefficients β and θ are the same across countries and over time.

Hypothesis Test

The test of our main hypothesis is based on the sign and significance of both θ_d and θ_r . If both are significantly positive, we conclude that an increase in the divergence of preferences between monetary and fiscal authorities raises, *ceteris paribus*, the primary deficit and the real interest rate, thus supporting our main hypothesis.

Sample

We use a pooled data set of annual observations for the period 1970-94 covering most industrialized countries. Since the paper focuses on the interaction of fiscal and monetary policies toward stabilization, we cannot use countries where the fiscal-monetary relationship has been dominated by inflationary financing of the fiscal deficit. We recognize that, in that case, the issues analyzed in this paper are of second-order importance. For that reason the sample does not include developing countries or industrial countries that have experienced relatively high inflation over the last three decades, such as Greece (where annual inflation over the period averaged 14 percent), Iceland (24 percent), and Portugal (14 percent.) For the remaining industrial countries the average inflation rate for the period has been below 10 percent. In the 1990s many developing and transition countries (notably, Argentina, Bolivia, Peru, and Poland) pursued stabilization policies that brought their inflation rates down to single digits. Insofar as these countries do not revert to using the inflation tax to finance their fiscal deficit, the issues and policy biases put forward in this paper are relevant for them. However, given that their period of stability is too recent, we do not include them in the empirical analysis. This leaves nineteen industrialized countries in the sample: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, the Netherlands, New Zealand, Norway, Spain, Sweden, Switzerland, the United Kingdom, and the United States.

Structure of the Error Terms and Method of Estimation

Regarding the characteristics of the error terms in the deficit and interest rate regressions, we work under two alternative sets of assumptions. First we assume joint endogeneity of d and r and no country random effects. We allow for the joint endogeneity of d and r by admitting a contemporaneous correlation between their respective error terms. However, we assume that each error term is uncorrelated both serially and across countries. In this case the method of estimation is Zellner's seemingly-unrelated-regression estimator (SURE) applied to pooled data:

$$E[\varepsilon_{i,t}, \mu_{j,s}] = \sigma_{\varepsilon\mu} \text{ for } i = j, t = s, \text{ and } 0 \text{ otherwise,} \quad (23)$$

$$E[\varepsilon_{i,t}, \varepsilon_{j,s}] = \sigma_{\varepsilon\varepsilon} \text{ for } i = j, t = s, \text{ and } 0 \text{ otherwise,} \quad (24)$$

$$E[\mu_{i,t}, \mu_{j,s}] = \sigma_{\mu\mu} \text{ for } i = j, t = s, \text{ and } 0 \text{ otherwise.} \quad (25)$$

Alternatively, we assume joint endogeneity of d and r and country random effects. We allow for the joint endogeneity of d and r as in the previous case, but in addition we allow the error terms corresponding to the same country to be correlated. However, we retain the assumption that the error terms of different countries are uncorrelated. In this case the method of estimation is SURE applied jointly with the random effects estimator to pooled data:

$$E[\varepsilon_{i,t}, \mu_{j,s}] = \sigma_{\varepsilon\mu} \text{ for } i = j, t = s, \text{ and } 0 \text{ otherwise,} \quad (26)$$

$$E[\varepsilon_{i,t}, \varepsilon_{i,t}] = \sigma_{\varepsilon\varepsilon}, \quad E[\varepsilon_{i,t}, \varepsilon_{i,s}] = \sigma_{Re} \text{ for } t \neq s \text{ and}$$

$$E[\varepsilon_{i,t}, \varepsilon_{j,s}] = 0 \text{ for } i \neq j, \quad (27)$$

$$E[\mu_{i,t}, \mu_{i,t}] = \sigma_{\mu\mu}, \quad E[\mu_{i,t}, \mu_{i,s}] = \sigma_{R\mu} \text{ for } t \neq s \text{ and}$$

$$E[\mu_{i,t}, \mu_{j,s}] = 0 \text{ for } i \neq j. \quad (28)$$

Dependent Variables

For the deficit regression, the dependent variable is the ratio of the central government's primary deficit (the overall deficit minus interest payments) to GDP; data are from the International Monetary

Fund's *Government Finance Statistics*. Dividing by GDP makes the scale (or metric) of the primary deficit such that it can be used for regressions across countries and over time. For the interest rate regression, the dependent variable is the domestic real interest rate minus the international rate; these are obtained, respectively, from Loayza and others (1998) and the International Monetary Fund's *International Financial Statistics*. We use the deviation from the international rate to account for the fact that domestic rates are heavily influenced by parity conditions in countries with open capital accounts.¹⁰

Control Variables

Our main hypothesis deals with only one of the many potential determinants of primary fiscal deficits and domestic real interest rates. Therefore, in order to test it we must control for other variables that influence or are influenced by primary deficits or domestic real interest rates. We use the same control variables for both regressions. To account for the real effects of the business cycle, we use both the current GDP growth rate and the deviation of that growth rate from its previous five-year average. We include the current inflation rate to control for seignorage-related factors, and its deviation from the previous five-year average to control for the price effects of the business cycle. In order to account for international conditions and shocks, we incorporate the terms of trade and the average growth rate of all industrialized countries. Finally, to control for Ricardian equivalence effects, we use the private saving rate. The data for all these variables were obtained from Loayza and others (1998).

Proxies for the Difference in Preferences

The variable whose effect on fiscal primary deficits and domestic interest rates we want to assess is the difference in preferences between monetary and fiscal authorities regarding the inflation and output gaps. We proxy for this variable with measures of the central bank's statutory commitment to control inflation, as expressed in its charter. This is appropriate under the maintained assumption that

10. Nominal domestic rates are deflated by an average of current and next-year inflation rates. The international real interest rate is the nominal Eurodollar London rate adjusted by the percentage change in the consumer price index for industrial countries.

the fiscal authorities' relative preference for output and inflation gaps does not vary much over time and across countries.

The first two proxies are based on the 1992 paper by Cukierman, Webb, and Neyapti (CWN). The first one ($\pi\ obj$) is their index of the importance of price stability as a central bank objective.¹¹ Data exist for this measure for most industrialized countries and many developing countries over the period 1970-89. The second proxy ($\pi\ obj-a$) results from updating the first index up to 1994. We did the update assuming that the central banks of the sample countries have not changed their stance toward inflation except when they explicitly adopted an inflation targeting regime.

The third proxy ($\pi\ targ$) is a dummy variable for whether the central bank has an explicit inflation targeting regime. Except for the case of Germany, explicit inflation targeting regimes have been adopted rather recently: in Australia (1993), Canada (1991), Finland (1993), New Zealand (1990), and Sweden (1993). In addition, we use CWN's index of central bank independence (cbi), exclusive of the price stability objective, in order to compare the effects of central bank independence with those of central bank preference for price stability.

2.2 Results

Tables 1, 2, and 3 present the estimation results. The first two tables use the proxies based on how important the inflation objective is for the central bank ($\pi\ obj$, $\pi\ obj-a$, and $\pi\ targ$). The third table presents the results using the index of central bank independence (cbi) as the explanatory variable of interest. Each table presents the regression results by pairs of the primary deficit and the real interest rate as dependent variables in each SURE system. The results reported in table 1 are for estimations performed under the assumption

11. CWN's index for the inflation objective of the central bank is based on explicit information contained in its charter. The index ranges from 0 to 1. Values are assigned according to the following criteria: 1 if price stability is mentioned as the only or major goal, and in case of conflict with the government the central bank has final authority to pursue policies aimed at achieving this goal; 0.8 if price stability is mentioned as the only goal but the central bank does not have explicit final authority in case of conflict; 0.6 if price stability is mentioned along with other objectives that do not seem to conflict with price stability (such as maintenance of a stable banking system); 0.4 if price stability is mentioned along with one or more potentially conflicting goals (such as full employment); 0.2 if the charter does not contain any objectives for the central bank; and 0 if some goals appear in the charter but stability is not one of them.

Table 1. Effects of Different Preferences between Fiscal and Monetary Authorities on Deficits and Real Interest Rates, Estimation without Country Random Effects^a

Explanatory variable	Dependent variable					
	SURE1		SURE2		SURE3	
	Primary deficit ^b	Interest rate ^c	Primary deficit	Interest rate	Primary deficit	Interest rate
Proxy for difference in preferences ^d						
π_{obj}	0.010 (2.50)	0.011 (2.29)				
π_{obj-a}			0.012 (2.85)	0.013 (3.06)		
π_{targ}					0.008 (1.56)	0.013 (2.52)
GDP growth rate	-0.114 (-0.99)	-0.002 (-0.02)	-0.350 (-3.12)	-0.162 (-1.38)	-0.315 (-2.77)	-0.110 (-0.93)
Deviation of GDP growth rate ^e	0.197 (1.52)	-0.192 (-1.25)	0.353 (2.81)	-0.126 (-0.96)	0.335 (2.62)	-0.163 (-1.22)
Inflation	0.366 (9.46)	-0.204 (-4.48)	0.374 (9.77)	-0.336 (-8.36)	0.377 (9.47)	-0.323 (-7.78)
Deviation of inflation ^e	-0.324 (-4.88)	-0.393 (-5.02)	-0.313 (-4.47)	-0.33 (-4.44)	-0.328 (-4.58)	-0.354 (-4.72)
Terms of trade	-0.05 (-3.77)	0.026 (1.68)	-0.039 (-2.72)	0.048 (3.21)	-0.04 (-2.8)	0.047 (3.11)

Table 1. (continued)

Explanatory variable	Dependent variable					
	SURE1		SURE2		SURE3	
	Primary deficit ^b	Interest rate ^c	Primary deficit	Interest rate	Primary deficit	Interest rate
Growth rate in OECD	-2.067 (-2.2)	-0.386 (-3.49)	-0.129 (-1.31)	-0.59 (-5.7)	-0.151 (-1.52)	-0.612 (-5.91)
Private saving	-0.351 (-9.8)	-0.036 (-0.86)	0.34 (9.42)	-0.013 (-0.34)	0.311 (8.99)	-0.043 (-1.20)
Constant	-0.042 (-2.59)	-0.014 (-0.73)	-0.048 (-2.75)	-0.017 (-0.92)	-0.037 (-2.18)	-0.007 (-0.36)
R^2	0.41	0.28	0.32	0.42	0.31	0.41
N	348	348	438	438	438	438

Source: Authors' calculations.

a. Data are annual data for nineteen industrial countries from 1970 to 1994. The estimator is Zellner's seemingly-unrelated-regression estimator. Numbers in parentheses are t statistics.

b. As a percentage of GDP.

c. Difference between the domestic and the international interest rates.

d. π_{obj} is an index of the importance of price stability as a central bank objective for the period 1970-89, taken from Cukierman, Webb, and Neyapti (1992); π_{obj-a} is the same index updated to 1994; π_{avg} is a dummy variable for whether the central bank has an explicit inflation targeting regime.

e. Deviation from its previous five-year average.

Table 2. Effects of Different Preferences between Fiscal and Monetary Authorities on Deficits and Real Interest Rates, Estimation with Country Random Effects^a

<i>Explanatory variable</i>	<i>Dependent variable</i>					
	<i>SURE1</i>		<i>SURE2</i>		<i>SURE3</i>	
	<i>Primary deficit^b</i>	<i>Interest rate^c</i>	<i>Primary deficit</i>	<i>Interest rate</i>	<i>Primary deficit</i>	<i>Interest rate</i>
Proxy for difference in preferences ^d						
π_{obj}	0.011 (1.39)	0.014 (1.90)				
π_{obj-a}			0.017 (2.52)	0.014 (2.37)		
π_{larg}					0.012 (1.85)	0.009 (1.46)
GDP growth rate	-0.189 (-1.62)	0.184 (1.37)	-0.518 (-4.44)	-0.016 (-0.13)	-0.51 (-4.24)	0.001 (0.01)
Deviation of GDP growth rate ^e	0.246 (1.92)	-0.371 (-2.50)	0.504 (3.92)	-0.303 (-2.31)	0.500 (3.83)	-0.309 (-2.30)
Inflation	0.377 (8.18)	-0.155 (-3.02)	0.382 (9.19)	-0.374 (-8.89)	0.388 (9.05)	-0.372 (-8.54)
Deviation of inflation ^e	-0.323 (-4.80)	-0.469 (-6.05)	-0.282 (-4.04)	-0.321 (-4.47)	-0.297 (-4.17)	-0.333 (-4.54)
Terms of trade	-0.05 (-3.51)	0.003 (0.16)	-0.04 (-2.74)	0.027 (1.78)	-0.04 (-2.72)	0.026 (1.72)

Table 2. (continued)

Explanatory variable	Dependent variable					
	SURE1		SURE2		SURE3	
	Primary deficit ^b	Interest rate ^c	Primary deficit	Interest rate	Primary deficit	Interest rate
Growth rate in OECD	-0.177 (-2.02)	-0.352 (-3.43)	-0.079 (-0.84)	-0.556 (-5.68)	-0.095 (-1.01)	-0.571 (-5.85)
Private saving	0.30 (5.99)	-0.108 (-2.04)	0.341 (6.90)	-0.044 (-6.60)	0.319 (8.99)	-0.068 (-1.46)
Constant	-0.03 (-1.68)	0.014 (0.69)	-0.046 (-2.48)	0.008 (0.41)	-0.036 (-1.99)	0.018 (1.01)
R^2	0.51	0.41	0.42	0.51	0.42	0.50
N	348	348	438	438	438	438

Source: Authors' calculations.
a. Data are annual data for nineteen industrial countries from 1970 to 1994. The estimator is Zellner's seemingly-unrelated-regression estimator. Numbers in parentheses are t statistics.
b. As a percentage of GDP.
c. Difference between the domestic and the international interest rate.
d. Proxy measures are defined as in table 1.
e. Deviation from its previous five-year average.

Table 3. Effects of Central Bank Independence on Deficits and Real Interest Rates^a

<i>Explanatory variable</i>	<i>Dependent variable</i>			
	<i>Without country random effects</i>		<i>With country random effects</i>	
	<i>Primary deficit^b</i>	<i>Interest rate^c</i>	<i>Primary deficit</i>	<i>Interest rate</i>
Index of central bank independence ^d	−0.004 (−0.44)	0.025 (2.31)	0.0003 (0.02)	0.014 (1.11)
GDP growth rate	−0.11 (−0.95)	0.082 (0.59)	−0.193 (−1.64)	0.231 (1.70)
Deviation of GDP growth rate ^e	0.204 (1.53)	−0.25 (−1.61)	0.257 (1.99)	−0.40 (−2.66)
Inflation	0.35 (8.15)	−0.16 (−3.18)	0.378 (7.87)	−0.122 (−2.23)
Deviation of inflation ^e	−0.317 (−4.49)	−0.455 (−5.53)	−0.327 (−4.73)	−0.51 (−6.38)
Terms of trade	−0.052 (−3.93)	0.025 (1.63)	−0.051 (−3.54)	−0.001 (−0.10)
Growth rate in OECD	−0.214 (−2.26)	−0.403 (−3.64)	−0.181 (−2.07)	−0.35 (−3.48)
Private saving	0.326 (9.41)	−0.069 (−1.70)	0.286 (5.83)	−0.153 (−2.78)
Constant	−0.028 (−1.67)	−0.016 (−0.83)	−0.023 (−1.22)	0.023 (1.06)
R^2	0.39	0.28	0.51	0.42
N	348	348	348	348

Source: Authors' calculations.

a. Data are annual data for nineteen industrial countries from 1970 to 1994. The estimator is Zellner's seemingly-unrelated-regression estimator. Numbers in parentheses are t statistics.

b. As a percentage of GDP.

c. Difference between the domestic and the international interest rate.

d. From Cukierman, Webb, and Neyapti (1992).

e. Deviation from its previous five-year average.

of homoskedasticity and independence across countries and over time, whereas those in table 2 are obtained using a country random-effects model. Table 3 presents both estimation methods for the case of *cbi* as the explanatory variable.

The estimation results presented in tables 1 and 2 broadly support our main hypothesis. When we control for shocks and economic conditions that influence primary deficits and the real interest rate, those countries and time periods where the central bank places greater importance on keeping inflation down are associated with both larger primary deficits and higher real interest rates. In the case of $\pi\text{ }obj\text{-}a$, the proxy with the largest coverage and signal variance, its effect on both the primary deficit and the real interest rate is positive and significant at the 5 percent level. The sign, significance, and even the size of the coefficients on this variable are virtually the same whether country random effects are ignored (table 1) or controlled for (table 2). The estimated coefficients with the random-effects model imply that a one-standard-deviation increase in $\pi\text{ }obj\text{-}a$ is associated with both an increase in the primary deficit of 0.56 percent of GDP and a rise in the domestic real interest rate by 0.46 percentage point over the international rate.

The results obtained with the other two proxies for the central bank's concern for price stability, $\pi\text{ }obj$ and $\pi\text{ }targ$, are fairly similar. The estimated coefficients are always positive. In most cases they are also statistically significant at conventional thresholds (5 or 10 percent), and in the rest they are at least marginally significant (the largest *p* value is 0.17).

In table 3 we study whether a measure of central bank independence renders the same results as measures of central bank's concern for price stability. We find no significant effects of central bank independence on primary deficits under either estimation method. Central bank independence does have a positive and significant effect on real interest rates when homoskedasticity and independence of the error term are assumed. However, the statistical significance of this result vanishes when country random effects are allowed for. Comparing the results of table 3 with those of tables 1 and 2, we conclude that having an independent central bank is not by itself conducive to the policy biases that result from lack of policy coordination. The key issue is the divergence of objectives (revealing different preferences) between fiscal and monetary authorities.

Finally, a note of caution. In the empirical exercises presented here, we have proxied the divergence in preferences between fiscal and monetary authorities with measures of the central bank's concern with price stability. However, policy implications should be derived with respect to the variable of interest (the difference in preferences) and not with respect to its proxy. We worked under the assumption that fiscal authorities' preferences are relatively constant across countries and over time. We adopted this empirical approach for convenience, given that it is easier to find empirical measures for central bank's objectives than for those of fiscal authorities. Thus, our empirical results should not be taken to imply that, in order to reduce the described policy biases, the central bank should unilaterally lower its standards for inflation control. Rather, the policy implication we favor is that coordination, both at the level of setting objectives and at the level of policy implementation, can alleviate the biases that move the economy to suboptimally higher fiscal deficits and real interest rates.

3. CONCLUSIONS

Central bank independence has contributed to the achievement of price stability and fiscal discipline in many countries. The conventional wisdom is that this is a necessary, first-generation reform of fiscal and monetary policy. The question this paper asks is whether a second-generation reform consisting of institutional incentives for domestic policy coordination could be beneficial. The paper presents a game-theoretic model in which the fiscal and monetary authorities interact to stabilize the economy, starting from dissimilar preferences with respect to the output and inflation gaps and controlling different policy instruments. It is assumed, realistically, that the monetary authority experiences a relatively larger utility loss from inflation than output gaps than the fiscal authority does.

Modeled as either a Nash or a Stackelberg equilibrium, the solution under the assumption of lack of policy coordination implies that, in the face of a negative supply shock, the fiscal authority acts more liberally and the monetary authority more conservatively than if either controlled both policy instruments. Moreover, we find that an increase in the divergence of preferences between the monetary and fiscal authorities leads to, *ceteris paribus*, larger public deficits (the fiscal authority's policy instrument) and higher real interest rates (the central bank's instrument).

The paper's empirical analyses attempt to test the latter conclusion on a pooled sample of nineteen industrial countries with annual data for the period 1970-94, using the seemingly-unrelated-regression estimator and allowing for country random effects. Working under the assumption that fiscal authorities' relative preference for output and inflation gaps varies little over time and across countries, we proxy for the divergence in preferences with measures of the central bank's commitment to control inflation. Controlling for other shocks and economic conditions, we find that countries and time periods where the central bank places a greater importance on keeping inflation low are associated with both larger primary deficits (as a ratio to GDP) and domestic real interest rates (as a deviation from international rates).

The empirical results of the paper should not be taken to imply that, in order to reduce these policy biases, which move the economy to suboptimally large fiscal deficits and high real interest rates, the central bank should unilaterally lower its standards for inflation control. Rather, the policy implication we favor is that, without prejudice to the gains from central bank independence, coordination both at the level of setting objectives and at the level of policy implementation can alleviate these biases. This goal must be achieved with "second generation" reforms. These must deal with the issues that hinder the process of coordination, such as contract enforceability, transactions costs, and the practical inability to discern outcomes due to policies from those due to shocks.

REFERENCES

- Bennett, H., and N. Loayza. 2000. "Policy Biases When The Monetary and Fiscal Authorities Have Different Objectives." Working Paper 66. Santiago: Central Bank of Chile.
- Bernanke, B. S., T. Laubach, F. Mishkin, and A. Posen. 1999. *Inflation Targeting. Lessons from the International Experience*. Princeton, N.J.: Princeton University Press.
- Cukierman, A. 1992. *Central Bank Strategy, Credibility, and Independence: Theory and Evidence*. Cambridge, Mass.: MIT Press.
- Cukierman, A., S. B. Webb, and B. Neyapti. 1992. "Measuring the Independence of Central Banks and Its Effect on Policy Outcomes." *World Bank Economic Review* 6(3): 353-98.
- Frankel, J. A. 1988. "The Implications of Conflicting Models for Coordination between Monetary and Fiscal Policymakers." In *Empirical Macroeconomics for Interdependent Economies*, edited by R. C. Bryant and others. Washington: Brookings Institution.
- Loayza, N., H. López, K. Schmidt-Hebbel, and L. Servén. 1998. "The World Saving Database." Washington: World Bank.
- Loewy, M. 1988. "Reganomics and Reputation Revisited." *Economic Inquiry* 26 (April): 253-63.
- Nordhaus, W. 1994. "Policy Games: Coordination and Independence in Monetary and Fiscal Policies." *Brooking Papers on Economic Activity* 2: 139-215.
- Perry, G., and D. Lederman. 1997. "The Importance of Macroeconomic Policy Coordination: A Note." Unpublished paper. Washington: Office of the Chief Economist, Latin America and the Caribbean, World Bank.
- Walsh, C. E. 1993. "Central Bank Strategies, Credibility and Independence: A Review Essay." *Journal of Monetary Economics* 32: 287-302.
- Woodford, M. 1999. "Optimal Monetary Policy Inertia." NBER Working Paper 7261. Cambridge, Mass.: National Bureau of Economic Research (August).

THE MONETARY TRANSMISSION MECHANISM IN THE UNITED KINGDOM: PASS-THROUGH AND POLICY RULES

Alastair Cunningham
Bank of England

Andrew G. Haldane
Bank of England

A number of recent papers have used policy simulations from small empirical macroeconomic models to assess the efficacy of inflation targeting or, more precisely, inflation forecast targeting (Svensson, 1997a). These include Rudebusch and Svensson (1999), Svensson (1997b), Ball (1999), and in a U.K. context, Batini and Haldane (1999). The models used to undertake these simulations often differ significantly, however. One important source of difference is the assumed degree of openness of the economy. Rudebusch and Svensson (1999) examine a closed-economy setting, whereas Svensson (1997b), Ball (1999), and Batini and Haldane (1999) use an open-economy framework.

The existing inflation-targeting countries—Australia, Canada, Chile, Israel, Sweden, and the United Kingdom, among others—are of course small, open economies. And the exchange rate channel of monetary transmission turns out to have important implications for the design of policy rules for inflation targeting. For example, recognizing the open-economy dimension, Svensson (1997b) prescribes rules that target some underlying or “domestically-generated” measure of inflation. This has the merit of excluding first-round import-price pass-through effects and hence preventing destabilizing high-frequency

The views expressed are those of the authors and not necessarily those of the Bank of England. The authors owe a debt of gratitude to Mike Chui and Richard Pierse, whose advice on solution of the models has been invaluable. We would also like to thank Nicoletta Batini, Erik Britton, Prasanna Gai, Steve Millard, Adrian Penalver, Joe Pearlman, and Paulo Freitas for helpful comments and suggestions. Any remaining errors are due to us.

Monetary Policy: Rules and Transmission Mechanisms, edited by Norman Loayza and Klaus Schmidt-Hebbel, Santiago, Chile. ©2002 Central Bank of Chile.

adjustments in monetary policy. Ball (1999) concludes in favor of a policy rule that targets something akin to a “monetary conditions index”—a weighted average of interest and exchange rates—for similar reasons. Batini and Haldane (1999) find that switching import prices on and off has implications for the shape of the frontier of the trade-off between output variability and inflation variability. Clearly, exchange rate pass-through, as one of the key open-economy monetary transmission channels, has important implications for policy rules for inflation forecast targeting.

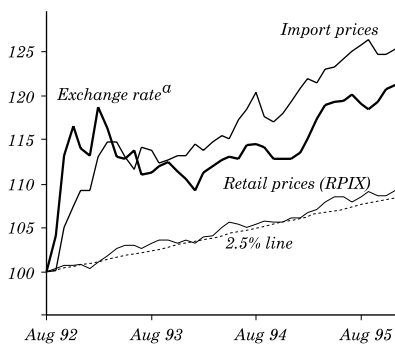
However, all three open-economy models outlined above share the feature that they model the pass-through process—from the exchange rate to import prices and ultimately to retail prices—in a rather stylized fashion. In particular, they assume that this pass-through is full and instantaneous.¹ So, for example, a given exchange rate change leads to an immediate jump in the price level (and hence the inflation rate) by an amount proportional to the share of imported goods in the consumption basket (see, for example, Batini and Haldane, 1999). This is clearly an oversimplification. It is also inconsistent with the experience of many countries recently. In many cases, exchange rate pass-through has not been immediate, nor, on occasion, has it been complete.

“Event studies” of countries undergoing large exchange rate changes can be used to illustrate. We first consider two U.K. events of the last decade: the roughly 15 percent depreciation of sterling following its exit from the European Exchange Rate Mechanism (ERM) in September 1992, and the roughly 15 percent appreciation of sterling between September 1996 and April 1997. These cases are illustrated in figures 1 and 2. The figures also show the path of import prices and retail prices, both again indexed to 100 on the base date.

Two features are significant. First, import-price pass-through was not immediate in either case. This was most notable in 1996-97, but even in 1992 import prices lagged behind the exchange rate for around six months. Second, the effects of the exchange rate change on retail prices were clearly small in both cases. Again, this was particularly notable following the 1996 appreciation. Retail-price inflation (excluding mortgage interest payments) was 2.8 percent in August 1996 and the same a year later, despite the appreciation. Of course, this exercise is partial, as other (domestic) factors will have acted on inflation

1. In Ball (1999) there is a one-period lag between a change in the exchange rate and its effect on consumer prices.

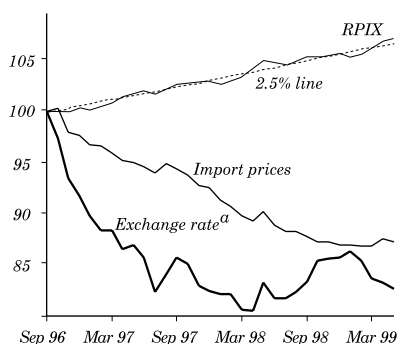
Figure 1. Exchange Rates, Import Prices, and Retail Prices in the United Kingdom after the 1992 Depreciation, Index, August 1992 = 100



Source: Bank of England.

a. An increase represents a depreciation.

Figure 2. Exchange Rates, Import Prices, and Retail Prices in the United Kingdom after the 1996 Appreciation, Index, September 1996 = 100



Source: Bank of England.

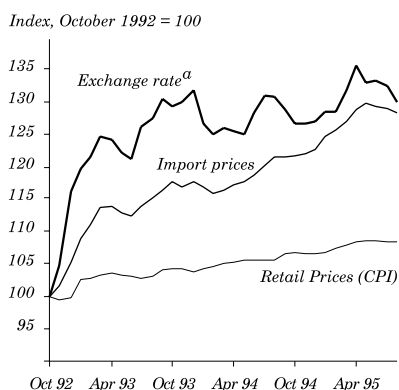
a. An increase represents a depreciation.

over the period. Nevertheless the U.K. experiences of 1992 and 1996-97 suggest that a simple model of full and immediate pass-through may overstate the direct (near-term) impact of exchange rate changes on import prices and, especially, retail-price inflation.

The same patterns are evident outside of the United Kingdom. Figures 3 and 4 consider the cases of Sweden and Brazil following their exit from fixed exchange rate arrangements (an ECU peg in the case of Sweden in 1992, and a crawling dollar peg in the case of Brazil in 1999). For Brazil we are not aware of a monthly data series for import prices and so instead show the path of an index of consumer, wholesale, and construction prices (the IGP-M). This measure might be expected to react more rapidly than consumer prices to an exchange rate shock, because tradable goods form a larger part of the basket. In both cases it is clear that pass-through effects were relatively limited in their downstream effects on import or output or, in particular, retail prices.

At a theoretical level, it is not surprising that pass-through of exchange rate shocks may take time. Whenever there are costs to changing prices—for example, menu costs or the potential to induce

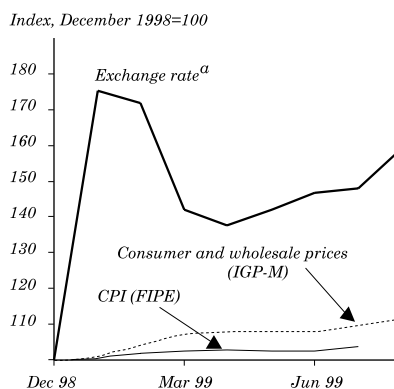
Figure 3. Exchange Rates, Import Prices, and Retail Prices in Sweden after Exit from Fixed Exchange Rates, Index, October 1992 = 100



Source: Bloomberg.

a. An increase represents a depreciation.

Figure 4. Exchange Rates, Import Prices, and Retail Prices in Brazil after Exit from Fixed Exchange Rates, Index, December 1998 = 100



Source: Bloomberg.

a. An increase represents a depreciation.

search behavior among consumers—suppliers may prefer to absorb any transient exchange rate perturbations in their markups or margins (see, for example, Britton, Larsen, and Small, 1999). Once the exchange rate change is seen to be lasting, it will be passed through, but it may take time for an exchange rate shock to be revealed as lasting. We seek to capture this lagged adjustment feature in the models of pass-through that we present below, by considering various types of *time-dependent* pass-through rules.

It is also possible that suppliers' pass-through decisions in the face of exchange rate shocks are affected by the state of the business cycle. Theoretical models can generate either pro- or counter-cyclical markups (see, for example, Britton, Larsen, and Small, 1999). But in the United Kingdom there is some evidence that pro-cyclicality has dominated (Small, 1997). The event studies are consistent with a similar pattern. Table 1 reports four-quarter GDP growth in the quarter preceding the various exchange rate changes for each country. All three depreciations occurred at times of weak growth, which with pro-cyclical markups would result in lower prices and perhaps help explain a part of the delayed or limited pass-through.

Table 1. GDP Growth Preceding Exchange Rate Shocks in Selected Countries and Episodes

<i>Country and period</i>	<i>Direction of exchange rate change</i>	<i>GDP growth in previous quarter (percent)^a</i>
United Kingdom, 1992Q2	Depreciation	-0.7
United Kingdom, 1996Q2	Appreciation	+2.7
Sweden, 1992Q3	Depreciation	-0.9
Brazil, 1998Q4	Depreciation	-2.1

Sources: Bloomberg; U.K. Office for National Statistics.

a. Growth over the previous four quarters.

The sterling appreciation of 1996, in contrast, followed a period of relatively rapid growth, which could again help explain the slow pass-through. We also seek to capture some of this possible cyclical-ity in markups in the models presented below, by experimenting with some classes of (business cycle) *state-dependent* pass-through rules.

The principal output of this paper is a set of stochastic simulations, which we use to assess the performance of various policy rules when the economy is subject to a (representative) set of shocks. Batini and Haldane (1999) argue that, when exchange rate perturbations are passed through fully and immediately to import prices, a strategy of inflation forecast targeting clearly dominates current inflation targeting, and that the “best” forecast feedback horizon is between three and six quarters ahead. In this paper we ask whether this and other conclusions are robust to alternative, more realistic models of pass-through. The paper is organized as follows. Section 1 sets out a simple macroeconomic model, calibrated to U.K. data and using a particular (restrictive) view of the pass-through process. Section 2 explores the various monetary transmission mechanism channels embedded within that model and evaluates the performance of policy rules based on inflation forecast targeting. Section 3 experiments with different, more plausible specifications of the import-price pass-through process, embodying degrees of state and time dependence. It evaluates the effect these different specifications have on the monetary transmission mechanism and on the design of inflation forecast targeting rules. Section 4 briefly draws some conclusions.

1. A SMALL MACROECONOMIC MODEL

This section sets out a baseline macroeconomic model and monetary policy rule. The treatment is brief because the baseline model is almost identical to that set out in Batini and Haldane (1999). In essence, the model is a linearized, open-economy IS-LM model, with rational expectations and Fuhrer-Moore wage contracting:

$$y_t = \alpha_1 y_{t-1} + \alpha_2 y_{t+1} + \alpha_3 U_{t-1} + \alpha_4 T_{t-1} + \varepsilon_{1t} , \quad (1)$$

$$m_t - p_t^c = \beta_1 y_t + \beta_2 i_t + \varepsilon_{2t} , \quad (2)$$

$$s_t = E_t(s_{t+1}) + i_t - i_t^f + \varepsilon_{3t} , \quad (3)$$

$$p_t^d = \frac{1}{2}(w_t + w_{t-1}) , \quad (4)$$

$$w_t - p_t^c = \chi_0 \left[(w_{t+1}) - (p_{t+1}^c) \right] + (1 - \chi_0)(w_{t-1} - p_{t-1}^c) + \chi_1 y_t + \varepsilon_{4t} , \quad (5)$$

$$p_t^c = \phi p_t^d + (1 - \phi) p_t^m , \quad (6)$$

$$U_t = i_t - (\pi_{t+1}) , \quad (7)$$

$$T_t = s_t + p_t^c - p_{t'}^c . \quad (8)$$

All variables except interest rates are in logarithms, and all behavioral relationships are expressed as deviations from equilibrium. For simplicity, and consistent with a small-economy representation, we normalize foreign prices and interest rates ($p_{t'}^c$ and i_t^f) to zero. We also normalize to zero the foreign exchange risk premium in equation (3) and the (implicit) markup in equation (4).

Equation (1) is a standard IS curve, with real output, y_t , depending negatively on the ex ante real interest rate and the real exchange rate, as defined by equations (7) and (8). A rise in the real exchange rate (q_t) represents an appreciation and hence pushes demand downward ($\alpha_4 < 0$), as does a rise in the real interest rate, r_t ($\alpha_3 < 0$). Output

also depends on lags of itself, reflecting adjustment costs.² ε_{1t} is a vector of aggregate demand shocks.

Equation (2) is an LM curve with conventional arguments: a nominal interest rate, capturing portfolio balance, and real output, capturing transactions demand.³ ε_{2t} is a vector of velocity shocks. Equation (3) is an uncovered interest parity condition, with $E_t(\cdot) = E(\cdot | \Omega_t)$, where Ω_t is the information set available at time t and E is the mathematical expectations operator. The shock vector ε_{3t} comprises foreign interest rate shocks and other noise in the foreign exchange market, including shocks to the exchange risk premium.

Equations (4) and (5) define the model's supply side. They take the form laid out in Fuhrer and Moore (1995a). Equation (4) is a markup equation, with domestic output prices (in logarithms, p_t^d) a constant markup over weighted-average contract wages (in logarithms, w_t) in the current and the preceding period. Equation (5) is the wage contracting equation. Wage contracts last two periods.⁴ Agents in today's wage cohort bargain over relative real consumption wages (where p_t^c are log consumer prices and $\pi_t = p_t^c - p_{t-1}^c$). Today's real contract wage is some weighted average of the real contract wage of the "other" cohort of workers: that is, those whose wages have already been agreed in the previous period and those whose wages are expected to be agreed in the next period. The benefit of this specification is that it generates inflation persistence, rather than price-level persistence as in the standard two-period Taylor (1979) contracting model.

We do not impose symmetry on the lag and lead terms in the contracting equation, as in the standard Fuhrer and Moore (1995b) model. Instead we allow a flexible, mixed lag-lead specification, which nests Fuhrer and Moore as a special case.⁵ The lag and lead weights are restricted to sum to unity, however, to preserve price homogeneity in the wage-price system (a vertical long-run Phillips curve).

2. We switch off the forward-looking term, setting $\alpha_2 = 0$ in the simulations.

3. McCallum and Nelson (1997) show that this form of the LM curve can also be derived as the reduced form of an optimizing stochastic general-equilibrium model. Because monetary policy operates through an interest rate rule, the money demand equation is essentially redundant.

4. We could have lengthened the contracting lag—for example, to four periods, which in our calibration is one year—to better match real-world behavior. But two lags appeared to be sufficient to generate the inflation persistence evident in the data, when taken together with the degree of backward-lookingness embodied in the Phillips curve.

5. See Blake and Westaway (1996). This flexible mixed specification is found in Fuhrer (1997) to be preferred empirically.

Also in the wage contracting equation is a conventional output gap term, capturing tightness in the labor market. The shock vector (ϵ_{4t}) captures disturbances to the natural rate of output and other supply shocks.

Equation (6) simply defines the consumption price index, comprising domestic goods (with weight ϕ) and imported foreign goods (with weight $1 - \phi$).

To close this system, we need to specify processes for import prices (p_t^m) and for nominal interest rates (i_t , the policy instrument). For import prices Batini and Haldane (1999) use the simplest possible closure rule:

$$p_t^m = -s_t, \quad (9)$$

so that exchange rate changes are immediately and fully passed through to retail prices, with a depreciation (a fall in s) raising import prices. This is clearly a restrictive specification, as evidenced in the introduction. In particular, it assumes that the markups of foreign exporters, domestic wholesalers, and domestic retailers do not change following an exchange rate adjustment. We explore the effects of relaxing these assumptions in section 3.

For interest rates we specify an inflation forecast-based policy rule of the form

$$U_t = \gamma U_{t-1} + (1 - \gamma) U_t^* + \theta (\pi_{t+j} - \pi^*), \quad (10)$$

where r_t^* denotes the equilibrium value of real interest rates and π^* is the inflation target. The equilibrium real interest rate and the inflation target are normalized to zero in the simulations.

According to the rule, the monetary authorities control nominal interest rates (i_t) so as to hit a path for the short-term real interest rate (r_t). Short-term real rates are in turn set relative to some steady-state value, determined by a weighted combination of lagged and equilibrium real interest rates. The novel feature of the rule, however, is the feedback term. Deviations of expected inflation (the feedback variable) from the inflation target (the policy goal) elicit remedial policy actions.

The policy choice variables for the authorities are the parameter triplet $\{\gamma, \theta, \gamma\}$. The parameter γ dictates the degree of interest rate

smoothing (see Williams, 1997). θ is a policy feedback parameter. Finally, j is the targeting horizon of the central bank when forming its forecast. The central bank sets interest rates in response to the expected deviation of inflation from target j periods ahead. This does not mean that rates are set to bring inflation back to target j periods out, since that depends on the smoothing and feedback coefficients as well. The horizon of the inflation forecast (j) and the size of the feedback coefficient (θ), as well as the degree of instrument smoothing (γ), dictate the speed at which inflation is brought back to target following inflationary disturbances. Because they influence the inflationary transition path, these policy parameters clearly also have a bearing on output dynamics.

The rule considered here differs from those in Svensson (1997b) in that it is a simple feedback rule for the policy instrument, rather than a complicated, optimal targeting rule. At the same time, however, the simple forecast-based rules we consider do have some clear similarities to Svensson's optimal inflation forecast targeting rules. Monetary policy under both rules seeks to offset deviations between expected inflation and the inflation target at some horizon.⁶ More concretely, even simple forecast-based specifications can be considered "encompassing" rules with respect to transmission lags, output, and information (Batini and Haldane, 1999).

The model set out in equations (1) through (10) is calibrated rather than estimated, with parameters chosen to match (loosely) the simulation properties of the Bank of England's medium-term forecasting model on a quarterly basis (see Bank of England, 1999). The baseline parameterization is shown in table 2.

Some of the parameter settings are worth touching on.⁷ In the wage contracting equation (5) we set the forward-looking component equal to 0.2. Up to a point, this weight is rather arbitrary, and indeed it may change over time. The weight we choose is close to that found empirically in the United States by Fuhrer (1997) and generates plausible paths from the impulse responses in the United Kingdom (Blake and Westaway, 1996). The import share in the consumption basket is

6. In particular, since the rules we consider allow flexibility over both the forecast horizon (j) and the feedback parameter (θ), both of which affect output stabilization, their closest analogue is Svensson's flexible inflation forecast targeting rule.

7. A more detailed explanation of the calibration is given in Batini and Haldane (1999).

Table 2. Model Parameters

<i>Parameter</i>	<i>Value</i>	<i>Description</i>
<i>IS curve</i>		
α_1	0.8	Autoregressive element
α_2	0.0	Forward-looking element
α_3	-0.5	Real interest elasticity of aggregate demand
α_4	-0.2	Real exchange rate elasticity of aggregate demand
<i>LM schedule</i>		
β_1	1.0	Output elasticity of money demand
β_2	-0.5	Nominal interest semielasticity of money demand
<i>Wage setting</i>		
λ_0	0.2	Forward-looking “weight” on wage bargain
λ_1	0.2	Short-run Phillips curve slope
<i>Consumer prices</i>		
ϕ	0.8	Share of domestically produced goods in the consumption basket
<i>Policy rule</i>		
θ	0.5	Forecast feedback parameter
γ	0.5	Smoothing parameter
j	8	Forecast horizon

Sources: Authors' calculations.

set at 0.2 ($\phi = 0.8$), broadly in line with existing shares.⁸ On the policy rule we set $\gamma = 0.5$ (some, but not too much, interest rate smoothing) and $\phi = 0.5$. For the forecast horizon we set $j = 8$ periods, which corresponds to a horizon of two years since the model is calibrated to match quarterly data. This is around the inflation forecast horizon that the Bank of England aims to align with the inflation target when setting interest rates in the United Kingdom (King, 1996).

2. THE MONETARY TRANSMISSION MECHANISM AND POLICY FRONTIERS

This section illustrates certain features of the model, specifically the channels of monetary policy transmission and the performance

8. An alternative calibration would weight import prices according to the (larger) share of consumption comprised of tradable goods. This calibration would reflect the potential impact of competition within the traded goods sector, but might be better developed in a more complex two-sector model. At a qualitative level, we would expect a higher weight on import prices to accentuate any differences between the simulation properties of the pass-through specifications discussed in section 3.

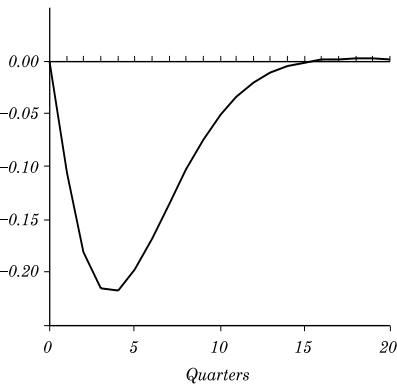
of various inflation forecast-based policy rules in the face of structural shocks. We begin with some deterministic impulse responses from the model before turning to stochastic analysis.

2.1 The Monetary Transmission Mechanism in the United Kingdom

Using the baseline parameterization and model, we can explore the dynamics of the monetary policy transmission mechanism in the United Kingdom by considering a one-time permanent displacement of the inflation target.⁹ Figures 5 and 6 show the paths of the output gap and inflation following a 1-percentage-point lowering of the inflation target; the responses are shown as percentage-point deviations from the base.

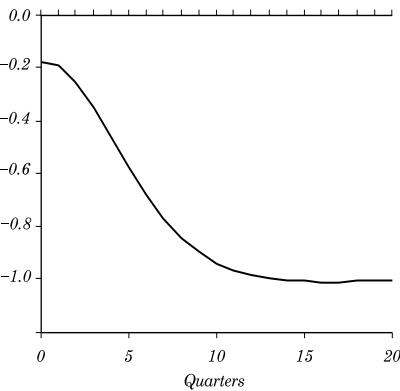
Several features are worth noting. First, the monetary transmission process embodies significant lags. It takes around fourteen to sixteen periods (or around four years) for inflation to reach its baseline

Figure 5. Impulse Response of the Output Gap to a 1-Percentage-Point Lowering of the Inflation Target^a
Percentage points



Source: Authors' calculations.
a. Change from baseline.

Figure 6. Impulse Response of the Inflation to a 1-Percentage-Point Lowering of the Inflation Target^a
Percentage points



Source: Authors' calculations.
a. Change from baseline.

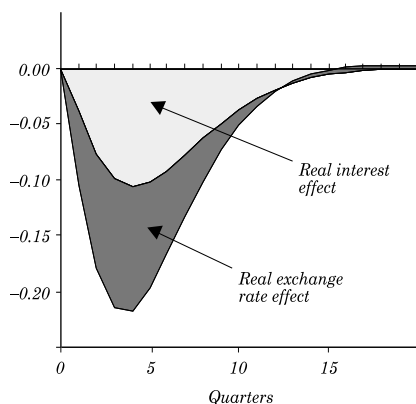
9. The model is solved using the Winsolve package designed by Richard Pierse and uses a stacked Newton solution algorithm.

and for the output gap, once opened, to be closed. This is roughly in line with vector autoregression (VAR)-based simulation results for the United Kingdom (see, for example, Dale and Haldane, 1995) and other developed countries (see, for example, Sims, 1992). Second, the sacrifice ratio implied by the model (the cumulative loss of output for a 1-percentage-point reduction of annual inflation) is around 0.4 percent. This is a little on the low side. Output responses are probably too small. Third, and by contrast, the response of the inflation rate is, if anything, too big. In particular, the step fall in the inflation rate in the first period is inconsistent with VAR-based studies of the historical price-level response following monetary policy tightenings. The size of this jump is the direct result of the restrictive (full and immediate) import-price pass-through assumption we have imposed.

The monetary transmission mechanism in this model comprises four channels: two operating directly on the price side (the aggregate supply curve), and two indirectly through the quantity side (the aggregate demand curve). The four channels are the real interest rate channel, the real exchange rate channel, the import-price pass-through channel, and the expectational channel. The first two are the quantity channels, operating through the aggregate demand equation (1), and the second two are the price channels. Figures 7 and 8 illustrate the marginal effects of these four channels on the impulse response paths of output and inflation, respectively, for the same 1-percentage-point disinflation experiment.¹⁰ Looking first at output effects, we see that the marginal contribution of the real interest rate and real exchange rate channels is roughly equal in the United Kingdom. The real exchange rate channel is marginally quicker. With regard to inflation effects, figure 8 presents a partial decomposition, switching off any feedback channels, such as the impact of import prices on expectations. Both import prices and forward-looking wage bargaining generate a jump in inflation in the first period. In subsequent periods the backward-looking elements dominate, and to an increasing extent. These backward-looking elements are essentially twofold: the backward-looking element to wage bargaining and the impact of the declining output gap on wages, operating through the short-run Phillips curve.

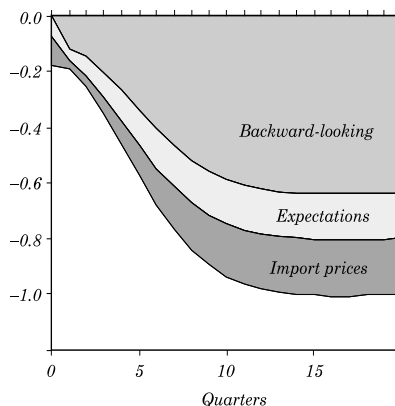
10. The decomposition exercise is partial, in the sense that we do not allow for any feedback effects when calculating the marginal impact of each component. So the figures show the impact of each element on output and inflation given the paths of *all* other variables in the disinflation experiment. An alternative approach would have been to solve the model setting selective parameters to zero. In this case the policy rule would ensure that inflation tended to its new target, so that adjusting the parameters merely alters the shape of the adjustment path.

Figure 7. Decomposition of Impulse Response Path of Output
Percentage points^a



Source: Authors' calculations.
a. Change from baseline.

Figure 8. Decomposition of Impulse Response Path of Inflation
Percentage points^a



Source: Authors' calculations.
a. Change from baseline.

2.2 Policy Frontiers

We now turn to some stochastic simulation analysis to evaluate the performance of various inflation forecast-based policy rules of the form of equation (10). In particular, following Taylor (1999), we look at the implications of different policy rules for the variability of the output gap and inflation—the two arguments typically believed to enter policymakers' loss function. Batini and Haldane (1999) experiment with each of the three parameters $\{j, \theta, \gamma\}$ that define the policy rule. Here we focus on the effects of the inflation forecast feedback horizon, setting $\theta = \gamma = 0.5$.

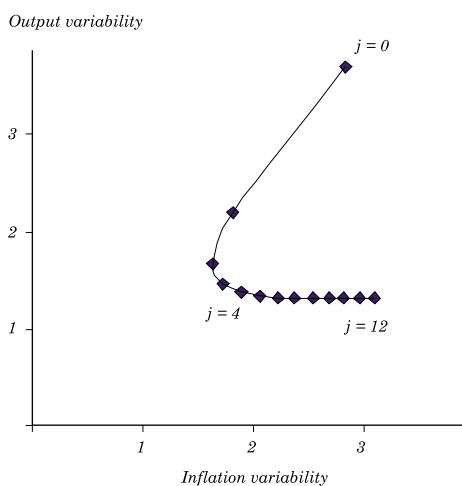
The economy is assumed to be subjected to unanticipated shocks for 100 periods.¹¹ The shocks are drawn randomly given a covariance matrix of shocks for demand, real wages, and the nominal exchange rate. We use a set of shocks derived from the Bank of England's structural medium-term forecasting model. Our results are an approximation, for two reasons. First, we have imposed a diagonal covariance

11. The simulations are solved over 180 periods, to enable the model to reequilibrate after shocks have finished. We only use results for the periods in which shocks are occurring.

matrix;¹² second, the set of shocks is drawn from a model that differs in several respects from the one used in this paper.¹³ Ideally, we would have drawn a set of shocks from an econometric representation of our model. This is an area of ongoing research within the Bank of England.

The behavior of various policy rules under stochastic simulation can be illustrated in a variety of ways. We plot a sequence of policy frontiers in output variability-inflation variability space, where variability is the average standard deviation across periods 21 to 100 and shocks exert their impact for 100 periods. This is designed to capture variability when the economy is subjected to a continuous stream of shocks; hence we exclude the early quarters when the initial shocks may not have had their full impact. Figure 9 illustrates such a frontier, using the parameterization of the model and policy rule described earlier, but varying the forecast horizon from zero periods (current-period inflation targeting) to twelve periods (three-year-ahead inflation forecast targeting).

Figure 9. Locus of Policy Frontiers in Output-Inflation Variability Space



Source: Authors' calculations.

12. This is a slight change from the original Batini and Haldane paper and follows from the change of solution software.

13. The Bank of England's medium-term forecasting model is considerably richer (with around twenty estimated equations to our five key behavioral equations). It is also essentially backward-looking, whereas our model contains forward-looking elements.

The resulting frontier is L-shaped.¹⁴ The shortest forecast horizons generate greater variability of both inflation and, especially, output, with current-period inflation targeting performing particularly poorly. After $j = 4$, inflation volatility increases without any significant reduction in output volatility. Between $j = 2$ and $j = 4$, there is some evidence of a trade-off between output variability and inflation variability. So the optimal forecast horizon would appear to lie between two and four quarters.¹⁵ In this sense, targeting an inflation forecast dominates setting policy reactively to current inflation. Once we allow for the fact that central banks in practice feed back from annual inflation rates, whereas our model-based feedback variable is a quarterly inflation rate, the optimal forecast horizon implied by our simulations is close to that used by inflation-targeting central banks in practice. That horizon is around six to eight quarters. Furthermore, it is worth noting that adopting a two-to-four-period optimal forecast horizon is not the same as saying that policymakers should aim to return inflation to target within a year. Instead, the horizon is the period at which policymakers should be concerned with deviations from the inflation target and start to react. Inflation will return to target some time later.

What explains these results? Monetary policy has its maximal marginal impact on output after about a year. When policymakers react to inflation with a shorter lag, the (integral of the) real interest and exchange rate changes necessary to hit the target is therefore high relative to other forecast horizons. So the result of focusing on short forecast horizons is that monetary policy is forced into overreacting, and as a result it introduces a dynamic of its own. The costs of this overreaction are felt particularly by output rather than by inflation. This stems partly from the full pass-through assumption, which means that, through the import-price channel, even late-reacting monetary policy can exercise significant leverage over inflation, through its influence on the exchange rate. The cost of these actions is a significant destabilization of output, however, as real interest rates and the real exchange rate are forced to overadjust.

14. Note that we do not perfectly replicate the j -loci of the original Batini and Haldane model. This follows from a combination of factors, such as our imposition of a diagonal variance-covariance matrix and the change in solution software (and in particular the software's treatment of unanticipated shocks).

15. Output variance continues to decline as we move beyond $j = 4$, but as the figure shows, this decline is negligible.

Longer horizons smooth out these adjustments in real interest and exchange rates. Monetary policy reacts preemptively, thereby damping output variability at the same time that it secures effective inflation control. Too long a forecast horizon, however, results in monetary policy doing too little to damp period-by-period inflation fluctuations. These fluctuations in inflation become embedded in the wage bargaining process, and inflation variability rises at lengthy forecast feedback horizons.

3. ALTERNATIVE MODELS OF PASS-THROUGH

The baseline model assumes full and immediate import-price pass-through, which we know from the event studies to be counterfactual. In this section we outline some alternative pass-through specifications and explore their implications for the transmission mechanism and policy rule frontiers. None of these specifications represent a well-articulated theoretical model of the margin behavior of foreign exporters, domestic wholesalers, or domestic retailers. Rather, they are meant as a summary statistic of the pass-through process, or “rules of thumb” for margin behavior motivated by some of the stylized facts outlined earlier.

3.1 Alternative Pass-Through Specifications

We consider four alternative pass-through specifications, replacing equation (9) with the following:

$$p_t^m = p_t^d, \text{ (identical import and domestic prices) }, \quad (9a)$$

$$p_t^m = p_{t-1}^m - \Psi_1 (s_t + p_{t-1}^m), \text{ (slow pass-through) }, \quad (9b)$$

$$p_t^m = p_{t-1}^m - \Psi_1 (s_t + p_{t-1}^m) - \Psi_2 \Delta s_t, \text{ (slow pass-through with dynamic error correction) }, \quad (9c)$$

$$p_t^m = p_{t-1}^m - \Psi_1 (s_t + p_{t-1}^m) - \Psi_2 \Delta s_t + \Psi_3 y_t, \text{ (slow pass-through with cyclical markup) }. \quad (9d)$$

Equation (9a) is the polar opposite of the base case and treats import prices identically to domestic prices. This variant was included in the original Batini-Haldane paper largely for expositional purposes and termed the “no pass-through” case. It might be justified in a world in which importers continuously adjust their margins to equate import and domestic prices in local currency terms, irrespective of exchange rate changes, perhaps because the economy is large, with significant domestic competition in the tradable goods market. There is some (indirect) pass-through, however, as any exchange rate shock affects output and, through output, domestic and import prices. We term this specification a large-economy pass-through variant.¹⁶

Equation (9b) allows for a graduated rather than an immediate response of import prices to exchange rate changes. This is an error-correcting specification, whereby the level of import prices adjusts gradually to the level of the exchange rate, at a rate of ψ_1 per period. In the simulations below we set $\psi_1 = 0.7$, which mimics the one-period-ahead response of import prices to a step change in the nominal exchange rate in the Bank of England’s medium-term macroeconomic model.

Equation (9c) adds to this specification the contemporaneous change in the exchange rate, to capture the effect of an exchange rate change. For the simulations below we set $\psi_1 = 0.15$ and $\psi_2 = 0.55$, to exactly mimic the impulse response from the macroeconomic model. Equations (9b) and (9c) collapse to the base case setting $\psi_1 = 1$ and $\psi_2 = 0$.

Finally, the variant in equation (9d) is designed to reflect the potential impact of output on supplier behavior. It builds on the dynamic error correction specification, as this mimics the specification of the Bank of England’s macroeconomic model, but in addition it allows for a cyclical effect on importers’ margins. When output is above potential, the upward pressure on import prices will augment any increase in import prices following a depreciation and reduce any decrease following an appreciation.

Of course, there is no reason to expect importers to be the only suppliers to set markups on a cyclical basis. So we also adjust the domestic price equation (4) to incorporate a pro-cyclical markup:

$$p_t^d = \frac{1}{2}(w_t + w_{t-1}) + \Psi_3 y_t \quad (4a)$$

16. Note, however, that the real exchange rate still exerts pressure on demand through equation (1).

Recent work at the Bank of England suggests some evidence of pro-cyclical margins behavior in the United Kingdom (Small, 1997). In the simulations below we set $\psi_3 = 0.15$. The calibration is based loosely on the Bank's medium-term macroeconomic model and draws on pro-cyclical elements of both the retail-price and import-price equations. ψ_1 is set equal to 0.15 and ψ_2 is 0.55, as in equation (9c). Of course, the evidence of pro-cyclical markups is not conclusive, and some theoretical models generate counter-cyclical markups. There is clearly scope for further experimentation with this specification, as empirical research provides firmer conclusions about the cyclicity of margin behavior.

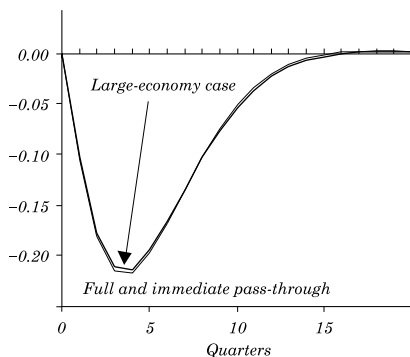
3.2 Impact on the Transmission Mechanism

The "large Economy" specification. Figures 10 and 11 compare the trajectories of inflation and output following a displacement of the inflation target under the immediate and large-economy pass-through cases. When import and domestic prices are equated, the initial jump in inflation all but disappears. This occurs because there is no direct effect on consumer prices from the spot exchange rate jump associated with the displacement of the inflation target. And the absence of a direct price effect holds back inflation expectations. The resulting trajectory is more in line with counterfactual VAR studies of the monetary transmission process in the United Kingdom. The output trajectories are similar in the two cases.¹⁷

slow Pass-Through. The delayed pass-through variants produce a smaller initial jump in inflation than in the base case, but a larger jump than under zero pass-through. This is unsurprising, since there is now some (limited) import-price response to the exchange rate jump. The effect of the delayed pass-through variants are better illustrated by considering the impulse response of consumer prices to a nominal exchange rate shock (here a 1-percentage-point appreciation). Figure 12 compares the inflation

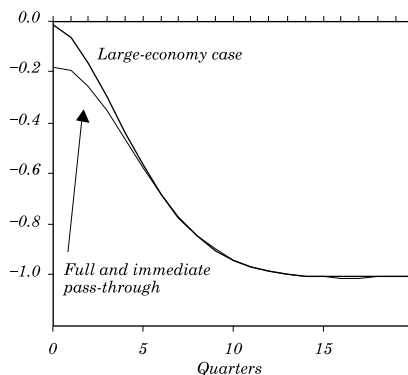
17. Output is driven by the real interest and exchange rates, as in equation (1). Real interest rates are driven by an inflation forecast, in this case eight periods ahead. By that horizon, any direct price-level effects of the exchange rate have fed through, so that the real interest rate response to the inflation target displacement is similar under the two specifications. And since the interest rate response is similar, the real exchange rate also follows a similar profile.

Figure 10. Impulse Response of the Output Gap in the Large-Economy Case
Percentage points^a



Source: Authors' calculations.
a. Change from baseline.

Figure 11. Impulse Response of Inflation in the Large-Economy Case
Percentage points^a

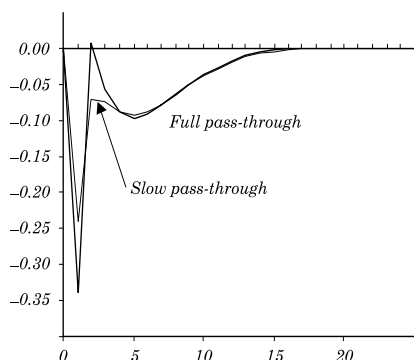


Source: Authors' calculations.
a. Change from baseline.

impulse under full pass-through and in the slow pass-through case in equation (9b). In the full pass-through base case, the exchange rate shock in period 1 leads to an immediate stepdown in import prices, as well as a jump in wages due to the contemporaneous and forward-looking elements of the nominal wage equation. In the second period the jump in inflation is reversed, as the spot exchange rate jumps back toward its initial value. When import prices adjust more slowly, the initial jump in consumer prices is smaller, but so is the subsequent reversal. So the variant generates a similar terminal price level, but a very different trajectory for inflation in the early periods—an initial overshoot, then an undershoot in the base case and a more graduated response in the variant.

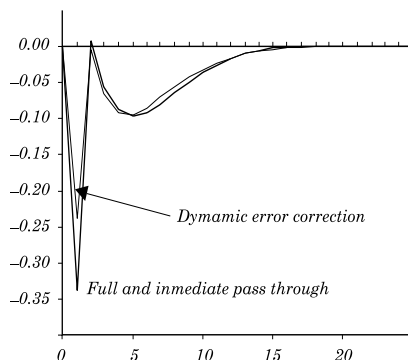
Figure 13 repeats the exercise for the dynamic error correction specification in equation (9c), which includes a term for the change in the spot exchange rate. The initial jump in consumer prices is the same as under the slow pass-through variant, but in period 2 consumer prices jump back further. This follows from the jump response of import prices to a change in the nominal exchange rate.

Figure 12. Impulse Response of Inflation in the Slow Pass-Through Case
Percentage points^a



Source: Authors' calculations.
a. Difference from baseline.

Figure 13. Impulse Response of Inflation in Case of Slow Pass-Through with Jump
Percentage points^a



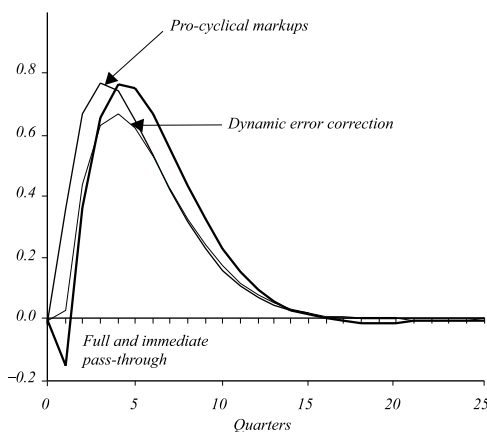
Source: Authors' calculations.
a. Difference from baseline.

Cyclical Markup. We illustrate the impact of the pro-cyclical mark-ups variant in equation (9d) by comparing the inflation impulse following a one-period shock to output (here a 1-percentage-point rise) with the impulse when import-price pass-through is full and immediate (baseline case), and under the dynamic error-correcting case, equation (9c), which forms the base for the new equations. The impulses are shown in figure 14.

When pass-through is full and immediate, the monetary policy tightening that follows the shocks leads to a nominal appreciation sufficient to reduce inflation in the first quarter. But thereafter the currency depreciates and the output shock takes time to unwind, so inflation rises. When pass-through is slow, inflation rises in the first quarter, as import prices do not fall sufficiently to offset the upward pressure on wages that operates via the Phillips curve. And when margins are pro-cyclical, there is further upward pressure on prices. Under this variant the initial rise in consumer prices is significant, at around a third of the initial output impulse, and far speedier than in the other pass-through cases.

In the long run, monetary policy adjusts to bring inflation to target, regardless of the specification. Similarly, import-price

Figure 14. Impulse Response of Inflation under Pro-Cyclical Markups
Percentage points^a



Source: Authors' calculations.

a. Difference from baseline.

pass-through is full in the long run, regardless of the specification. Pro-cyclicality of markups does not have a long-term impact on import prices, because policy adjusts to close any output gap.

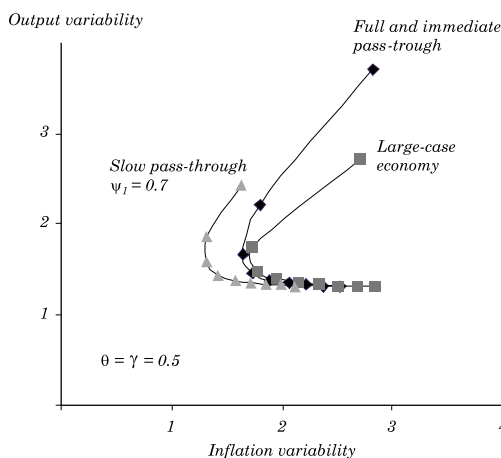
3.3 Impact on Policy Frontiers

Do the various pass-through specifications have a significant impact on the policy frontiers generated by stochastic simulations? We repeated the 100-period stochastic simulations for the various import-price variants, for $j = 0$ to $j = 8$.

Alternative Rates of Pass-Through. Figure 15 compares j -loci under the full and immediate pass-through (baseline) specification, the large-economy specification in equation (9a), and the slow pass-through specification in equation (9b). We also carried out stochastic simulations for equation (9c), but the results are qualitatively very similar to those in the simple slow pass-through case.

The main conclusion of the full and immediate pass-through model holds true in the large-economy case as well. So the optimal feedback horizon is greater than zero, and inflation forecast targeting is better

Figure 15. Loci of Policy Frontiers under Alternative Pass-Trough Models



Source: Authors' calculations.

than targeting current inflation. But the output cost of focusing on very short horizons is reduced somewhat. This happens because exchange rate disturbances (which have the greatest magnitude in our variance matrix) no longer feed through immediately to inflation and so do not “require” an interest rate response. As a result, real interest rates and hence output are less volatile. It remains the case, however, that responding to inflation forecasts rather than outturns delivers sizable benefits in terms of the trade-off between output variability and inflation variability.

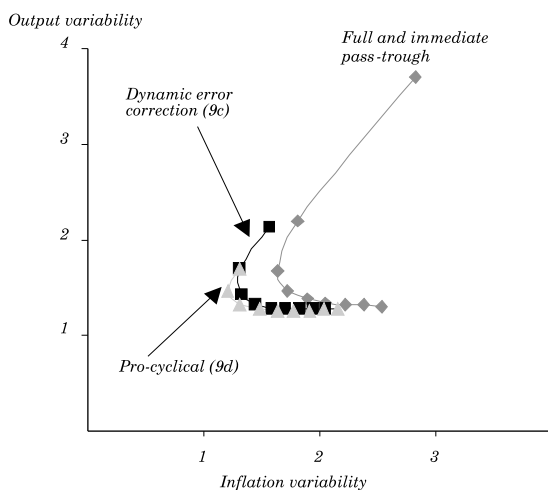
This is also the case when pass-through is slow. The j -loci remain L- (or even C-) shaped. However, in the slow-pass-through case both inflation and output variability are damped. The output cost of choosing short forecast horizons is lower because of the reduced impact of exchange rates on consumer prices (and hence monetary policy). Slowing the rate of pass-through also reduces the volatility of inflation at all horizons. Exchange rate shocks have a smaller impact on inflation (if not the price level), so less inflation becomes embedded in wages.

Cyclical Pass-Through. Finally, we consider j -loci when economy-wide markups (for both domestic and import prices) are pro-cyclical in

addition to import-price pass-through being slow, using the specifications in equations (9d) and (4d). We compare this with the full and-immediate-pass-through case and the slow-pass-through-with-jump case (9c).

When we add pro-cyclical markups, output variability becomes further compressed at short horizons (Figure 16). Output variance is compressed because output shocks now matter more for inflation and hence are subject to more of an offsetting policy response. So monetary policy implicitly attaches a relatively greater “weight” to output shocks as opposed to wage or exchange rate shocks. Interestingly, however, this output volatility gain comes without greatly disturbing inflation control. Inflation volatility is affected by offsetting factors. Pro-cyclical markups raise the inflation response to output shocks.¹⁸ But offsetting this, changes in the real interest rate now have a greater impact on inflation, making it easier to bring inflation back to target when forecast horizons are short. Because of this second effect, shorter forecast horizons—perhaps as little as two periods ahead—appear to be the “best.”

Figure 16. Loci of Policy Frontiers under Alternative Pass-Trough Models



Source: Authors' calculations.

18. They also increase the inflationary impact of any exchange rate shocks (via their impact on output).

4. CONCLUSIONS

We have considered alternative specifications of import-price pass-through in terms of their impact on the monetary policy transmission mechanism and on the operation of inflation forecast-based rules. Under these alternative specifications, it remains the case that looking forward—that is, responding to forecasts rather than inflation outturns—makes sense. However, pass-through assumptions do appear to have implications for the feasible sets of points on the inflation-output variability frontier. Moreover, in some circumstances, for example in the case of pro-cyclical markups, it may also suggest that a shorter forecast horizon may be appropriate.

We have focused on just one of the transmission channels for monetary policy, albeit an important one for inflation targeters in small, open economies. It would be interesting to consider the robustness of these conclusions to varying assumptions about the nature of the monetary policy transmission mechanism. For example, how are inflation forecast targeting rules affected by different assumptions about policy credibility? These and other questions are left for future research.

REFERENCES

- Ball, L. 1999. "Policy Rules for Open Economies." In *Monetary Policy Rules*, edited by J. B. Taylor. Chicago: University of Chicago Press.
- Bank of England. 1999. *Economic Models at the Bank of England*. London.
- Batini, N., and A. G. Haldane. 1999. "Forward-Looking Rules for Monetary Policy." In *Monetary Policy Rules*, edited by J. B. Taylor. Chicago: University of Chicago Press.
- Blake, A. P., and P. F. Westaway. 1996. "Credibility and the Effectiveness of Inflation Targeting Regimes." *The Manchester School* 64: 28-50.
- Britton, E., J. Larsen, and I. Small. 1999. "Imperfect Competition and the Dynamics of Mark-ups." Unpublished paper. London: Bank of England.
- Dale, S., and A. G. Haldane. 1995. "Interest Rates and the Channels of Monetary Transmission: Some Sectoral Estimates." *European Economic Review* 39: 1611-26.
- Fuhrer, J. C. 1997. "The (Un)Importance of Forward-Looking Behaviour in Price Specifications." *Journal of Money, Credit and Banking* 29(3): 338-50.
- Fuhrer, J. C., and G. R. Moore. 1995a. "Forward-Looking Behaviour and the Stability of a Conventional Monetary Policy Rule." *Journal of Money, Credit and Banking* 27: 1060-70.
- . 1995b. "Inflation Persistence." *Quarterly Journal of Economics* 110: 127-59.
- King, M. A. 1996. "Direct Inflation Targets." Paper presented at a symposium of the Geldpolitische in Europa, Frankfurt, April.
- McCallum, B. T., and E. Nelson. 1997. "An Optimising IS-LM Specification for Monetary Policy and Business Cycle Analysis." NBER Working Paper 5875. Cambridge, Mass.: National Bureau of Economic Research.
- Rudebusch, G. and L. E. O. Svensson. 1999. "Policy Rules for Inflation Targeting." In *Monetary Policy Rules*, edited by J. B. Taylor. Chicago: University of Chicago Press.
- Sims, C. A. 1992. "Interpreting the Macroeconomic Time-Series Facts: The Effects of Monetary Policy." *European Economic Review* 36: 975-1011.

- Small, I. 1997. "The Cyclicalities of Mark-ups and Profit Margins: Some Evidence for Manufacturing and Services." Bank of England Working Paper 72. London: Bank of England.
- Svensson, L. E. O. 1997a. "Inflation-Forecast-Targeting: Implementing and Monitoring Inflation Targets." *European Economic Review* 41: 1111-46.
- . 1997b. "Open-Economy Inflation-Targeting." Unpublished paper. Washington: Institute for International Economics.
- Taylor, J. B. 1979. "Aggregate Dynamics and Staggered Contracts." *Journal of Political Economy* 88: 1-24.
- . 1999. *Monetary Policy Rules*. Chicago: University of Chicago Press.
- Williams, J. 1997. "Simple Rules for Monetary Policy." Paper presented at the NBER Summer Institute, Cambridge, Mass.

THE MONETARY POLICY TRANSMISSION MECHANISM AND POLICY RULES IN CANADA

David Longworth

Bank of Canada

Brian O'Reilly

Bank of Canada

The inflation targeting regime in place in Canada requires a clear understanding of the monetary policy transmission mechanism and a way to exploit knowledge of that mechanism in making policy decisions. This paper describes the Bank of Canada's current understanding of the monetary policy transmission mechanism as well as our research, in the context of a model based on that understanding, to identify policy rules to help guide the formulation of monetary policy.

Section 1 discusses the Bank's view of the monetary policy transmission mechanism in Canada. It begins with the major linkages and then focuses in turn on transmission through financial variables, the impact of financial variables on aggregate demand, and the impact on inflation from the output gap, expectations, and the exchange rate. Because of the importance of inflation projections in the framework used at the Bank of Canada, section 2 reviews the range of approaches that have been investigated for generating such projections. These include the construction of small models of the Canadian economy, single-equation models of quarterly inflation, and a fully specified model, the Quarterly Projection Model (QPM). Section 3 outlines recent work at the Bank of Canada on policy rules. This section covers the QPM policy rule, simulation analyses comparing forward-looking

The authors have benefited from the technical assistance of Hope Pioro and from comments by their colleagues (especially Bob Amano, Tiff Macklem, and Dinah Maclean), by Pablo García, and by participants at the Third International Conference of the Central Bank of Chile. The views expressed in this paper are those of the authors. No responsibility for them should be attributed to the Bank of Canada.

Monetary Policy: Rules and Transmission Mechanisms, edited by Norman Loayza and Klaus Schmidt-Hebbel, Santiago, Chile. ©2002 Central Bank of Chile.

rules of the QPM type with Taylor rules, and some ongoing work on open-economy extensions of Taylor-type rules. Given that some of this work suggests that efficient policy rules can be affected by particular changes in economic behavior, section 4 outlines some evidence on such changes in Canada since the introduction of an inflation target. The final section concludes.

1. THE CANADIAN MONETARY POLICY TRANSMISSION MECHANISM

The monetary policy transmission mechanism is complex, and our understanding of it is imperfect.¹ At the Bank of Canada our mainstream paradigm is quite explicit and well known and contains three major sets of linkages. The first major linkage is from our instrument, the target band for the overnight interest rate,² to other financial variables: the term structure of market interest rates, rates on deposits and loans at financial institutions ("administered rates"), and the exchange rate. The second runs from financial variables to aggregate demand and the output gap. And the third runs from the output gap, the exchange rate, and inflation expectations to inflation.

The precise relationships that underlie these three linkages are probably not fixed. In particular, we find it important to bear in mind that the success and credibility of the monetary and fiscal policy frameworks will condition the way the transmission mechanism works in practice. We also find it useful to have a checklist of the exogenous shocks that typically hit the economy (figure 1).

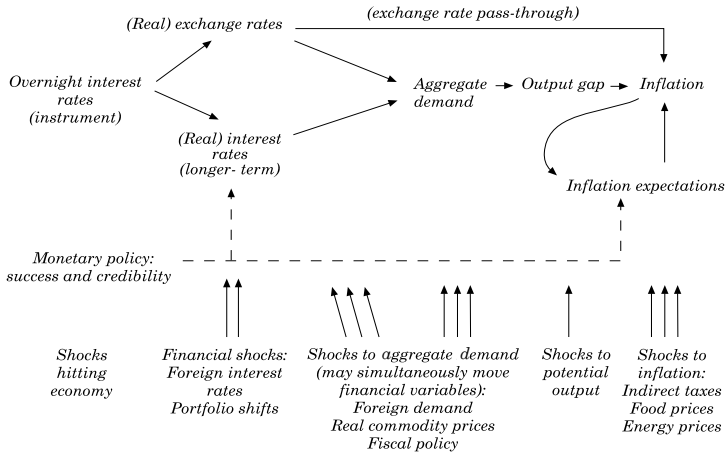
1.1 Transmission through Financial Variables

The Canadian term structure of interest rates is strongly influenced by the world term structure of real interest rates, risk premiums related to Canadian government debts and deficits (relative to those in the rest of the world), and domestic inflation expectations.

1. This section draws heavily on David Longworth's notes for a presentation on "Monetary Policy in Canada" to an IMF course in May 1997.

2. The target band for the overnight interest rate is 50 basis points wide, and the Bank aims to keep the rate in the middle of the band. Since February 1996, the Bank Rate, the rate at which directly clearing financial institutions borrow from the Bank of Canada, has been set at the top of the target band. Press releases are issued at the time of changes in the target band.

Figure 1. Monetary Policy Transmission Mechanism in Canada



However, it has generally been true in the past that a rise in nominal domestic short-term rates (and, more specifically in recent years, the target band for the overnight rate) has translated into a rise in nominal domestic rates all along the term structure, with the effects typically smaller the further along the maturity spectrum one is looking (see Clinton and Zelmer, 1997; Muller and Zelmer, 1999). One would expect, however, that this is due to the nature of the typical shocks experienced in the past. In the future, to the extent that a rise in short-term interest rates causes markets to raise their estimate of the probability of keeping future inflation within the inflation-control range, longer-term nominal interest rates may tend to fall or at least not rise.

Bank research has concluded that there has been an essentially stable (if not precise) relationship between administered interest rates (those set by deposit-taking financial institutions on loans and deposits) and market rates of similar maturities (see Clinton and Howard, 1994; Hendry, 1992). Moreover, the long-run relationship is one in which changes in administered rates move one for one with changes in similar market rates. And the adjustment is quite rapid—indeed, typically much more rapid than in the United States.

The exchange rate responds in an important way to unexpected changes in interest rate differentials between Canada and the other major industrial countries (Longworth and Murray, 1988; Khemani

and Murray, 1990). Given Canada's trade patterns, the United States has a very high weight (about 86 percent) in the trade-weighted exchange rate index (Lafrance and Antia, 1998-99).

1.2 Impact of Financial Variables on Aggregate Demand

At the Bank of Canada, the mainstream transmission mechanism is one in which aggregate demand depends on two variables. The first is the level of real interest rates (relative to equilibrium real interest rates), which affects consumption spending (especially on durable goods), and which also affects decisions to invest in housing and nonhousing capital. The second is the level of the real exchange rate, which affects exports and imports in the usual ways.

The empirical evidence for Canada suggests that it is short-term (or perhaps short- to medium-term) interest rates that matter the most for aggregate demand. This evidence comes basically from four sources:

- reduced-form equations for changes in output, as well as for changes in exchange rates, in which interest rates of various maturities are important explanatory variables,
- reduced-form equations for changes in output using the spreads between long-term and various short-term interest rates (Cozier and Tkacz, 1994; Clinton, 1994-95),
- evidence from the structure of household and business balance sheets (Longworth and Poloz, 1995; Montplaisir, 1996-97), and
- evidence that the components of aggregate demand that move first in the business cycle are consumer durables and housing, which are typically financed with debt at short- to medium-term interest rates, rather than business investment.

The effects of interest rates and exchange rates on aggregate demand build up only slowly over time. There is little contemporaneous effect. But by the third or fourth quarter the effect is economically significant, with the maximum effect reached after six to eight quarters.

There is as yet little evidence that direct credit channels (see Bank of Canada, 1995) are important in affecting aggregate demand. But empirical and theoretical work is ongoing at the Bank on a direct money channel (Hendry, 1995; Armour and others, 1996; Engert and Hendry, 1998; Hendry and Zhang, 1998).

In addition to knowing how monetary policy affects aggregate demand, it is important to identify the major areas where shocks to demand will arise. For the Canadian economy, the major sources of shocks are foreign demand (particularly U.S. demand, given the structure of Canadian trade), domestic fiscal policy, and the real world price of commodities. Canada is a major net exporter of commodities, and thus its terms of trade tend to move in the opposite direction from other major industrial countries when real commodity prices change.

1.3 Impact on Inflation from the Output Gap, Expectations, and the Exchange Rate

As figure 1 shows, monetary policy affects inflation through three channels: the output gap, inflation expectations, and the exchange rate pass-through. A key part of the mainstream view of the monetary transmission mechanism at the Bank of Canada is the effect of excess demand or supply in product markets on the rate of inflation. Thus, changes in monetary conditions work through their effect on the output gap to influence the inflation rate over time.

As is well known, inflation expectations also play a very important role in the inflation process. Although there is evidence that the backward-looking component in these expectations remains important, the concentration of the central bank on the achievement of its inflation target no doubt helps to condition the formation of the forward-looking components of these expectations. And the achievement of the inflation-control targets means that the backward-looking component of these expectations will come to play a stabilizing role at a rate close to the targeted rate.

Another element in the short-run inflation process is changing relative prices. Arising from a number of sources, these can have once-and-for-all price-level effects and therefore influence the measured inflation rate in the short run, but not necessarily the momentum of the inflation process. Because monetary policy can influence the exchange rate, exchange rate effects are particularly important to note in this regard (see Laflèche, 1996-97). Other specific shocks that have been important in the past include shocks to indirect taxes, energy prices, and food prices.

The Bank of Canada has relied on the output gap channel to influence inflation (including the induced effect that the change in actual inflation thus produced exerts through the backward-looking element of inflation expectations). The Bank did not count on expectations

being influenced by the target during the first few years of the inflation targeting regime. Nor has it relied on the exchange rate pass-through to consumer prices to guide inflation to its target (in strong contrast with the practice of the Reserve Bank of New Zealand in the early years of its inflation targeting regime). In principle, exploiting the effects of exchange rate pass-through could shorten the time necessary to hit the inflation target, but at the cost of greater volatility in the economy, including the volatility of real output. In recent years, as inflation expectations have become somewhat influenced by the targets themselves, exchange rate changes are now seen as affecting the price level, not the ongoing rate of inflation.

2. INFLATION PROJECTIONS

Although QPM is the main model and organizing framework for the medium-term projections that are constructed quarterly, both QPM and projections for inflation alone have been informed by a wide range of research with small models. These models have helped the Bank to better understand some of the workings of the economy, as well as to explore how to impose appropriate theoretical restrictions and grasp their implications. Thus, in moving from the overview of the transmission mechanism in the previous section to the description of QPM at the end of this section, it is useful to describe the range of approaches investigated. These include research with small, “complete” models of the economy, whether done as reduced forms, vector autoregressions (VAR), or vector error correction models (VECM); single-equation models of quarterly CPI inflation, which are generally Phillips curves; and models and methods that are useful in monitoring very short run monthly and quarterly movements in inflation (not discussed in this paper).

2.1 Small Models of the Canadian Economy

In the mid-1980s Longworth and Poloz (1986) constructed a small model to examine various policy rules. Its prominent feature was its simplicity: there were four behavioral equations (for output demand, a price Phillips curve, money demand, and the exchange rate) plus a policy rule and identities. Simplicity was desirable for a number of reasons. First, it allowed the model to be understood both by the modelers and by policymakers. Second, it allowed other key features

to be put in place without too much difficulty: a coherent flow framework with a well-defined steady state, expectations that were model-consistent in the long run despite being adaptive in the short run, and exchange rate behavior that was consistent with convergence to the steady state. Third, simplicity made it possible to reduce the time required to do stochastic simulations. The model was calibrated (rather than estimated), based on judgment using estimates by the modelers and others. This meant that the modelers could concentrate on the effects of key variables and their parameters rather than have to expend considerable effort in the estimation phase of model building to control for all the variables that might matter in explaining a given endogenous variable. Thus, for example, the output equation excluded foreign output, real commodity prices, and fiscal variables. The framework of the four behavioral equations plus the policy rule captured the mainstream model of monetary transmission in which the real interest rate and the real exchange rate affected the output gap and thus inflation. It also set the stage for subsequent estimated reduced-form or VAR models, many of which omitted money variables, since the stock of money did not enter the equations for other variables.

For example, Duguay (1994) estimated a reduced-form IS curve for output, in which changes in Canadian output depend on lags of changes in the real interest rate, the real exchange rate, U.S. output, real commodity prices, and a fiscal policy variable. He also presented a short-run Phillips curve, based on the previous work of Dupasquier and Girouard (1992).

In the construction of the calibrated QPM model, as well as in subsequent work designed to calibrate stochastic shocks for use with QPM, a number of VARs were estimated by Bank staff. Finally, Armour and others (1996) have constructed a VECM in which the deviation of money from its long-run demand plays an important role. The model contains equations for Canadian output, prices, money (M1), and interest rates.

2.2 Single-Equation Models of Quarterly Inflation

The archetypical Canadian model of inflation would have the following form:

$$\begin{aligned} \ln \pi_t = & \ln \pi_t^{\text{expect}} + D[\ln(gDp)] \\ & + E[\ln(chDnge \ln reDexchDnge rDe)] \\ & + F[\ln(chDnge \ln IndirectDces)] \\ & + G[\ln(chDnge \ln fRRl prIces)] \\ & + H[\ln(chDnge \ln energy prIces)] + UMGuDOHURU, \end{aligned}$$

where a , b , c , d , and e are parameters, f is a function, and L is the lag operator.

Equations have been estimated for the CPI, the core CPI (the CPI excluding food and energy and the effect of indirect taxes), the CPI excluding food and energy alone, and the CPI excluding changes in indirect taxes alone. Particular attention has been given to the formation of inflation expectations and to the measurement and relevant function of the output gap.

Until the last five years, most work at the Bank used inflation expectations that were modeled as backward looking, with the sum of the coefficients equal to one. (This was the case, for example, in Longworth and Poloz, 1986, and Dupasquier and Girouard, 1992.) But when inflation varies around a constant target, there is no longer a unit root in the inflation process. Then, as Thomas Sargent argued in the 1970s, it is inappropriate to model expectations with the unit restriction on the sum of the coefficients. As one moves from one inflation regime to another, one would expect a learning process, and thus quite a complicated formulation for inflation expectations. Initial steps in modeling such a learning process (as it applies to the actual evolution of Canadian inflation) have been undertaken by Laxton, Ricketts, and Rose (1994) and by Ricketts and Rose (1995) using a Markov switching process with three inflation regimes. Fillion and Léonard (1997) have used regimes similar to the ones captured in the Markov switching work in estimating a quarterly Phillips curve. Their model, which follows closely the archetypical model above, has inflation expectations in the current monetary regime that are close to $0.39 L(\text{inflation}) + 0.61(\text{inflation target})$.

When the monetary authorities act to achieve a given inflation target range, inflation expectations at all horizons should eventually fall in line with that range. This reflects an increase in credibility and will likely need to be taken into account in projecting inflation (see Perrier, 1998; Maclean, 1998; Amano, Coletti, and Macklem, 1999).

Potential output and therefore the output gap are not easily measured. The Bank of Canada has moved from estimating potential output as a linear trend, to constructing it using a Hodrick-Prescott filter on actual output, to estimating it using a multivariate filter that combines structural information with a filtering approach. The current procedure, which closely follows that of Butler (1996), decomposes potential output into the trend marginal product of labor, population, one minus the trend unemployment rate, the trend labor force participation rate, and trend hours worked, appropriately scaled by the

trend of the labor share. Multivariate filters are used to estimate each trend. It is recognized that these filters have problems at the end of the sample period. St-Amant and van Norden (1997) discuss various approaches to measuring the output gap that have been used at the Bank and assess their strengths and weaknesses. Kichian (1999) assesses measures of potential output (and consequently the output gap) using state-space techniques on a model that includes a Phillips curve.

Until the 1990s, modeling at the Bank typically assumed that Phillips curves were linear functions of the output gap. Work by Laxton, Rose, and Tetlow (1993a, b, and c) attempted to estimate the degree of nonlinearity of the Phillips curve and to identify its implications. Their Monte Carlo studies showed that nonlinearities should be difficult to find. And their empirical work showed that a given degree of excess demand has a larger absolute effect on inflation than the same degree of excess supply. Dupasquier and Ricketts (1998a and b) extended this work by examining the empirical robustness of various theories on the curvature of the Phillips curve. They concluded that there is some evidence that the slope of the Phillips curve gets flatter at lower and more stable rates of inflation.

2.3 The Quarterly Projection Model

The Bank of Canada has long been interested in developing structural macroeconomic models and using them for economic projections.³ In the late 1970s the RDuF (Research Department Experimental Forecasting) model became the organizing framework for the projection exercise. By the late 1980s, as the weaknesses of RDuF were becoming all too obvious, reduced-form aggregate demand and inflation equations were used to determine the important dynamics in the projection, which continued nominally to be performed with the RDuF framework. Then, in September 1993, QPM was introduced as the Bank's projection model.

The emphasis on structural models results from three main beliefs:

- that economic theory and empirical work suggest the major elements in the monetary transmission mechanism,

3. This section draws heavily on Longworth and Freedman (1995). See Duguay and Longworth (1998) for the history of macroeconomic models and their use in policymaking at the Bank of Canada.

- that there is enough stability in some of the major relationships in the economy that it is sensible to base an estimated or calibrated model on them, and
- that in order to conduct policy to achieve an inflation-control target (or other nominal target), it is necessary to have a way of quantifying the link between current changes in interest rates and future values of the targeted variable.

The use of structural models for economic projections has always been supplemented by judgment, particularly in the first few quarters of the projection. This judgment includes that based on information from variables that do not enter explicitly into the structural model, such as the monetary aggregates.

QPM, which built upon knowledge gained with reduced-form and VAR models, was designed to overcome the deficiencies of an earlier generation of models, including RDuF, by

- having a fully articulated, steady-state version of the model, to which the dynamic version converges,
- incorporating all necessary stock-flow relationships, with the key stocks being household financial wealth, the capital stock, government debt, and net foreign assets,
- basing household behavior on the Blanchard-Weil overlapping generations model, having firms choose the optimal stock of capital given the production function and the long-run labor supply, and having governments choose a desired long-run debt-to-GDP ratio, and
- incorporating both forward-looking (“model consistent”) and backward-looking elements in expectations.

It is virtually impossible to impose all the desired long-run restrictions in an estimated model with forward-looking expectations where the data are drawn from a number of different monetary policy regimes. Therefore it was decided that the best of the second-best ways of assigning coefficients would be to calibrate the model, largely on the basis of existing empirical evidence.

Because of the way in which the model was calibrated (which depended to an important extent on the information on dynamics found in VARs), the short-run dynamics of the model are similar in many ways to models without stock-flow dynamics. To understand the short-run dynamics of the model, the key parts of the model (which are described more fully below) are as follows:

- aggregate demand, which depends importantly on interest rates and exchange rates
- the price-wage nexus
- the monetary policy reaction function, and
- the behavior of the exchange rate and the long-term bond rate.

The major aggregate demand components in the model are consumption (which includes housing and inventory accumulation), business fixed investment, government expenditure on goods and services, and exports and imports. In the short run, consumption is negatively related to the term spread between short-term and long-term interest rates. Business fixed investment responds to the cost of capital, and exports and imports are influenced by the real exchange rate.

The price-wage nexus in the model is somewhat complicated, as future prices and future costs appear in both equations. In setting prices, firms use lagged prices, forward-looking expected costs (including indirect tax effects), and forward-looking expected prices. Output gaps also affect inflation, and the relationship is nonlinear, with a given amount of excess demand having a larger absolute effect on inflation than an equivalent amount of excess supply. In addition to these factors, the CPI excluding food and energy depends on import prices, and thus on the exchange rate. Costs depend largely on nominal wages, which in turn depend on expected future prices, expected future nominal wages, lagged nominal wages, the real-wage target (determined by the equilibrium marginal product of labor), and the labor market gap.

The monetary policy instrument in the model is the short-term interest rate. This rate is determined by a monetary policy reaction function which expresses the yield curve gap—the difference between the short-term (three-month) and the long-term (ten-year) interest rate minus its equilibrium value—as a function of the deviation of inflation (based on the CPI excluding food and energy) from the inflation-control target six to seven quarters in the future. The reaction function also includes a lagged dependent variable to smooth the movement of the yield curve gap. The equation can be written as

$$y\mathcal{L}\mathcal{A}gDp_t = \alpha_1 \left[\sum_{k=6}^7 \frac{1}{2} (\dot{p}_{t+k} - \dot{p}_{t+k}^{tar}) \right] + \alpha_2 y\mathcal{L}\mathcal{A}gDp_{t-1}, \quad (1)$$

where $yieldgap_t = (i_t^s - i_t^l) - (i_t^s - i_t^l)^{ss}$, $(\dot{p}_{t+k} - \dot{p}_{t+k}^{tar})$ is the deviation of inflation from its targeted rate, i^s and i^l are the short- and long-term interest rates, respectively, and ss denotes a steady-state value.

The ten-year interest rate is given by a weighted average of future short rates (adjusted by a term premium), the current short-term interest rate (adjusted by a term premium), and the foreign long-term interest rate (adjusted by a risk premium and the expected international inflation differential).

The exchange rate is determined by the uncovered interest parity condition, including a risk premium. In the long run the equilibrium real exchange rate adjusts so that the flow of net exports is sufficient to sustain the equilibrium net foreign asset position (which, in turn, is determined by household preferences, the desired stock of government debt, and the real interest rate).

3. POLICY RULES

Svensson (1999) describes a monetary rule as a “prescribed guide for monetary policy conduct.”⁴ The rule reacts in a mechanical way to a prespecified information set. In reality, as discussed in Svensson (2001), central banks, in forming policy, consider all the information available about the economy, attempt to distinguish which shocks are occurring, and then modify their tactics and strategy accordingly.

A monetary rule is important for the policy advice provided to senior management as part of a model-based projection exercise. For each projection the staff at the Bank of Canada try to identify, in the context of a model, the various shocks affecting the economy and to quantify their impact on inflation. To provide consistent policy advice, it is necessary to have a systematic response of movements in the policy instrument to the various shocks. If the policy reaction function used by the staff continually changed, policymakers would be unable to differentiate between changes in the outlook stemming from shocks and those arising from changes in the policy reaction function. A stable reaction function provides a consistent link from projection to projection, to help in analyzing the implications of new information. Similarly, a benchmark policy reaction function provides

4. This section draws heavily from Amano, Coletti, and Macklem (1999), Côté and Macklem (1996), and Maclean (1998).

a baseline comparison for assessing the implications of different policy reactions (delayed, preemptive, and so forth). Such assessments are often provided, for example, in the alternative scenarios generated as part of the projection exercise.⁵

An ideal policy rule, as encapsulated in a reaction function in a model, is one that captures the central bank's general preferences in terms of bringing inflation back to target within an acceptable time frame, without causing unacceptable deviations in output from potential or unacceptable movements in the monetary instruments. (That is, there is an implicit loss function.) The rule should be one that performs well *on average*, rather than just with respect to one particular set of shocks. Much of the early work on monetary rules in QPM looked at model responses to deterministic shocks, mainly because the size of the model and the computing resources then available did not allow us to consider stochastic simulations. This early approach was followed in full recognition that the results obtained from deterministic simulations are highly dependent on the particular shocks imposed. More recently, Bank researchers have been using stochastic simulations, as well as analytic work based on small theoretical models, to examine whether we can improve on the current monetary rule in QPM.

3.1 The Initial (and Current) QPM Policy Rule

In a forward-looking model like QPM, the role of the monetary authority is to provide a nominal anchor for the economy. Because inflation expectations depend, at least in part, on future monetary policy, a policy rule needs to be specified in terms of an attainable nominal objective. Without an endogenous policy response to economic developments, economic agents do not have enough information to form their expectations, and nominal values become undefined (in other words, the model does not solve). An endogenous policy rule or reaction function is therefore an essential part of QPM. As noted above, QPM uses the short-term interest rate as the policy variable that has to adjust to achieve the inflation target.

Although this reaction function is an ad hoc rule, in the sense that it is not derived from an optimal control problem, the choice of parameters and the degree of forward-lookingness were chosen in

5. Longworth and Freedman (1995) discuss the role of the staff economic projection in the conduct of monetary policy.

the context of what we had learned in previous work or by experience. The six-to-seven-quarter horizon approximates well the sort of horizon over which monetary policy has a meaningful effect on trend inflation. Trying to hit an inflation target over a very short period of time would imply considerable volatility in interest rates (and the exchange rate), possibly leading to instrument instability. Even though the reaction function does not allow for secondary objectives other than smoothing of the policy instrument, the magnitude of the key parameter, α_1 in equation (1), which is linked to the degree of inflation volatility that the authorities are ready to accept, was also chosen taking into consideration that the authorities care about the volatility of output as well.

The use of a forward-looking rule implies that the monetary authority has knowledge of the origin and nature of recent shocks. In a model in which private agents are assumed to be (at least partly) forward-looking, it would be hard to argue that the authorities should not be characterized by the same behavior. Because there is a lot of uncertainty, QPM is built with enough flexibility to allow the implications of different policy responses to be considered by changing the reaction function in various ways.

3.2 Forward-Looking versus Taylor Rules

Reaction functions, like that in QPM, that involve adjusting interest rates to the expected future deviation of inflation from its target level are considered to belong to the class of inflation forecast-based (IFB) policy rules. Although these rules can allow for interest rate smoothing (as in QPM) or include other terms, such as the contemporaneous output gap as discussed below, their main distinguishing feature is their forward-lookingness with respect to inflation.

Reaction functions in which interest rates respond both to deviations of inflation from its target level and to deviations of output from potential, but using only contemporaneous or past information, are considered to be Taylor-type policy rules (Taylor, 1993). The original Taylor rule was derived for the United States, a closed economy, but it can be extended into an open-economy form as shown by Ball (1999) and Srour (1999) and discussed below.

Black, Macklem, and Rose (1998) use a model of the Canadian economy called CPAM (Canadian Policy Analysis Model), which has many of the features of QPM but simulates much faster, to investigate the consequences of variants of these two types of policy rules

as well as a price-level rule.⁶ They first examine the stochastic behavior of the economy, drawing random shocks from those identified with VAR analysis. They find that the base-case CPAM reaction function produces inflation outcomes considerably better than historical outcomes, although roughly in line with the experience in Canada since 1992, when inflation targets came into effect. When these authors compare alternative parameterizations of IFB rules in terms of the root-mean-squared deviations (RMSDs) of inflation relative to the target and of the output gap, they discover rules that produce lower RMSDs of both inflation and output than the base-case rule. This result usually occurs for a more vigorous reaction to an expected deviation of inflation from the target, and therefore implies more interest rate volatility than the CPAMIQPM rule.

Their results highlight that, in an open economy, two channels exist through which the monetary authority can control inflation: the output gap and the exchange rate. These different channels produce IFB rules with quite different properties. Because the lags in the exchange rate channel are shorter than those through the output gap channel, the monetary authority can achieve substantially better inflation control using the exchange rate channel. This comes at the cost, however, of considerably greater variability in interest rates, the exchange rate, and output. Owing to the nonlinearity in the Phillips curve in CPAM (and QPM), the higher variance of output also results in a lower level of output. Controlling inflation through the output gap has the advantage that stabilizing inflation requires leaning against the output gap, which both reduces output variability and raises the average level of output.

In their simulations of Taylor-type rules, Black, Macklem, and Rose find (as have others) “optimal” coefficients to be much higher than those suggested by Taylor’s estimated rule characterizing historical U.S. Federal Reserve policy. They also find that Taylor rules produce results roughly similar to those of IFB rules if the comparison only focuses on the RMSDs of inflation and output. However, deeper analysis leads them to conclude that a Taylor rule is less appealing, for two reasons. First, it is not generally capable of achieving the inflation target on average in CPAM without an explicit modification to allow for a shift in the mean of output. Second, the

6. With respect to the latter type of rule, their results show a significant improvement in the trade-offs facing policymakers when they allow expectations to adjust to take account of the effects of price-level control.

volatility of interest rates is relatively high, sometimes high enough in absolute terms that a considerable proportion of observations have negative nominal interest rates. With IFB rules, where the dynamic structure of the model is taken into account, results are achieved with instrument settings that are much less volatile.

Recent work at the Bank of Canada by Dinah Maclean using stochastic simulations examines the performance of various policy rules from the perspective of their impact on inflation, output, and interest rate variability when the model economy is hit by stochastic shocks that approximate those that the Canadian economy normally experiences. Comparisons are made between the results from IFB-type rules, nonlinear rules that do not react until inflation falls outside the bands, and Taylor-type rules.

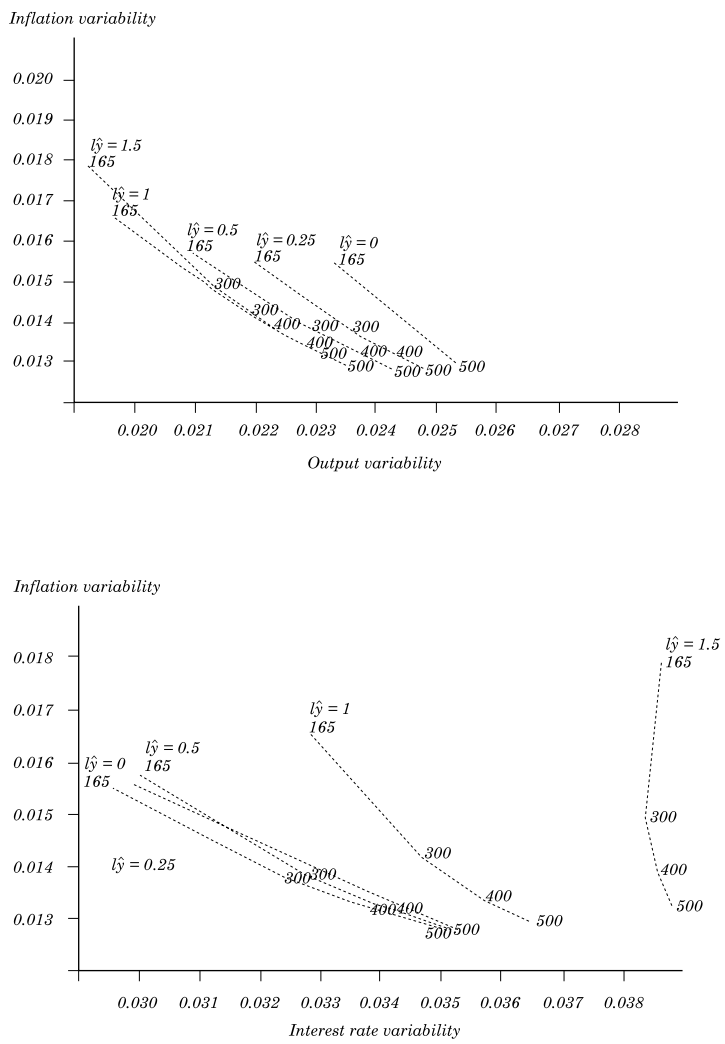
With respect to the IFB rules, the QPM reaction function described above is modified by adding a contemporaneous output gap term to the forward-looking inflation gap term.⁷ The nonlinear rules allow for the possibility of no or very little monetary policy reaction as long as inflation is moving within the target bands. This is done by adding a term to reflect an additional weight on the deviation of inflation from its target six to seven periods ahead if inflation is outside the target band. The Taylor-type rules have the standard (closed economy) formulation. Various rules in each of the three basic classes are obtained by varying the weights on the inflation and output gap terms.

Each reaction function being considered is incorporated into QPM in turn, and stochastic simulations of the resultant model economy are run. The shocks used for the stochastic simulations are calibrated to be generally representative of the historical distribution of shocks affecting the Canadian economy. The results of the experiments are summarized in terms of output, inflation, and interest rate variability. Not enough simulations were run to determine which rule might be an optimal one, but the results provide some indicative evidence on the relative performance of each class of rule considered.

For illustrative purposes, figure 2 (taken from Maclean's work) shows the outcomes from simulating the various monetary policy rules. Each curve or locus shows the outcome for rules with the same weight on the output gap term and varying weights on the inflation gap term.

7. The inflation gap term looks six to seven quarters ahead, whereas the output gap term is an average of the contemporaneous output gap and one lag of the gap.

Figure 2. Simulations of Monetary Rules with Historical Distribution of Shocks^a



Source: Bank of Canada.
a. $\hat{\gamma}$ is the coefficient on the output gap in the reaction function. The other numbers on the curves are 100 times the coefficient on the inflation term in the reaction function.

Outcomes are shown in terms of the variability of the deviations of inflation from target versus either the variability of the output gap or the variability of interest rates.

As the figure 2 shows, Maclean finds that, for relatively low weights on the output gap, increasing that weight reduces output variability without increasing inflation variability. This is the case, for example, in moving from a rule with a weight on the inflation gap of 1.65 and a zero weight on the output gap to a rule with the same weight on the inflation gap and a weight of 0.25 on the output gap. This is not true, however, for larger weights on the output gap, where more of a trade-off with inflation variability emerges. When the weight on the output gap reaches 1.5, output variability actually increases compared with a weight of 1. Too large a weight on the output gap term increases cycling in the real economy. For any given weight on the output gap, increasing the weight on the inflation gap (that is, moving along the locus) gives the expected clear trade-off between inflation and output variability.

With respect to the variability of inflation versus the variability of interest rates, when the absolute value of the weight on the output gap is small, the weight can be increased without increasing interest rate variability, but as the weight becomes larger, a clear trade-off starts to emerge. With respect to the former observation, increasing the weight on the output gap from zero to 0.25 reduces interest rate variability for all weights on the inflation gap. However, increasing the weight further, to 0.5, still leads to lower interest rate variability compared with the zero locus for many of the points.

Overall, Maclean's results support previous internal work at the Bank of Canada based on a stripped-down version of QPM with stochastic shocks. This work suggested that, by introducing a contemporaneous output gap term, the current rule can be improved in terms of reducing the variability of both output and inflation with little change in the variability of interest rates. To achieve this, there should be a greater weight on the inflation gap term than currently used in QPM and a small weight (rather than a zero weight as in QPM) on an output gap term.

The benefit of adding the output gap is that it allows the monetary authority to distinguish between price-level and demand shocks and thus to differentiate its policy response. Adding an output gap term into the rule does not mean that the monetary authority is targeting output. The role of the output gap is to provide more

information to the monetary authority about the source of movements in inflation.⁸

Although adding an output gap term to a forward-looking rule appears beneficial, placing too great a weight on the output gap is a problem. It causes increased cycling in both output and interest rates, possibly because it shifts too much weight away from the forward-looking term (the inflation gap six to seven periods ahead). This result contrasts with the properties of a Taylor rule where both the output gap and inflation gap terms are contemporaneous. With such a rule, it is the output gap term that has the more forward-looking information. However, in comparing the forward-looking rule with a closed-economy formulation of the Taylor rule, Maclean suggests that Taylor-type rules do not do as well as forward-looking rules in terms of average variabilities. She makes it clear that this conclusion is tentative, because there was no attempt to search over a wide range of coefficients or formulations to identify the most efficient Taylor rule.

Maclean also shows that pursuing a more opportunistic policy, where the monetary authority does not react greatly to deviations of inflation from the midpoint if inflation is still within the bands, but only reacts when inflation is expected to fall outside the bands, will increase the probability of falling outside the bands. This suggests that the monetary authority should actively try to move inflation back toward the midpoint, even when inflation is within the bands.

Finally, initial results with regard to an interest rate smoothing term in the reaction function suggest that smoothing causes greater variability of inflation and output, although the costs of small amounts of smoothing are low. The variability of inflation can be reduced, with no increase in the volatility of the change in interest rates, by adopting a rule with greater smoothing and more aggressive weights on the gap. This comes at the cost, however, of larger changes in the level of interest rates, as well as greater output variability. Again, at low rates of smoothing the costs are relatively low. Some degree of smoothing is likely beneficial, therefore, and in fact the degree of smoothing suggested by these results is consistent with the smoothing already incorporated in the current monetary rule in QPM.

8. In exploratory work on the sensitivity of monetary policy rules to shocks, Bob Amano discusses how monetary policy would respond to an adverse supply-side price shock under a Taylor rule to demonstrate how the increased information provided by the output gap is helpful.

3.3 Open-Economy Extensions

Some analytic work on the implications of being an open economy for the form of the policy rule has been done at the Bank of Canada (Srouer, 1999). Srouer considers the role of the exchange rate in policy formulation, extending the work of Ball (1999).

Ball (1999) uses a very simple model with constant coefficients to show that the optimal policy rule in a small, open economy is similar to the Taylor rule. It differs from the Taylor rule in that it is not expressed in terms of the interest rate, but rather in terms of an index that is a weighted average of the real interest rate and the real exchange rate. The weights are roughly proportional to the coefficients of the same variables in the IS curve. In addition, the inflation rate is adjusted to filter out direct but temporary effects of the exchange rate.

Srouer notes that Ball's results depend on the assumption that the shocks are white noise and, in particular, are uncorrelated across equations. He observes that this assumption is not valid in a small economy like Canada's, where variables such as commodity prices or foreign output affect both the exchange rate and demand. Therefore he extends Ball's model to include new exogenous explanatory variables, X_t , with the result that the optimal policy rule takes the form

$$Zr_t + (1 - Z)e_t = Ay_t + B(\pi_t + Ie_{t-1}) + CX_t,$$

where all variables are measured as deviations from their average values; $wr_t + (1 - w)e_t$ can be viewed as a monetary conditions index (MCI), with r_t the real interest rate and e_t the log of the real exchange rate (defined such that a greater e_t means an appreciation); y_t is the output gap; $(\pi_t + Ie_{t-1})$ is a measure of inflation that excludes the direct but temporary effects of exchange rate movements, hereafter referred to as "core-core inflation"; w , A , and B are positive constants with $0 < w < 1$; and C is a constant vector that depends on the parameters of the model excluding the coefficient on X_t in the exchange rate equation.

The implications for the response of the MCI to innovations in output or modified inflation are unaffected relative to Ball's model, since the effects of such innovations on future output and inflation have not changed. However, the MCI now must respond to innovations in X , since these will affect the future path of output and inflation. The extent to which the MCI must respond depends on the nature of the innovation.

Srour notes that an autonomous rise in the exchange rate would require constant monetary conditions, whereas a rise due to an increase in real commodity prices would require tighter monetary conditions. The reason for the latter response is that, other things equal, higher real commodity prices lead to more demand.

Bank of Canada staff would like to have a robust Taylor-type reaction function incorporating the extensions of Ball and Srour that could be substituted into QPM to generate results that would provide another perspective (to a model with an IFB reaction function) for internal discussions on monetary policy. A focused effort will be made to identify a suitable rule for this purpose. "Suitable" here means a reaction function that is robust across several models rather than one optimized for QPM only. Some preliminary simulation analysis is discussed below.

Exploratory simulation work at the Bank to date has considered a Ball-type open-economy Taylor rule and, for comparison purposes, two alternative formulations of the base Taylor rule, one using the core-core inflation measure and the other the core inflation measure. This work examines what happens to the responses of key variables under a standard set of shocks in deterministic simulations. It also examines what happens to the trade-off frontiers among the variances of inflation, interest rate, and output gaps when the weights on the output and inflation gaps in the reaction function are changed. For the latter simulations, the historical distribution of shocks to the Canadian economy was the same as that used by Maclean.

The exchange rate pass-through parameter is thought to be around 0.2 for core inflation. That is, a 1 percent depreciation in terms of the real exchange rate will result in a 0.2 percent increase in the price level after about eight quarters. The relative weight on the real exchange rate in the MCI in Canada is 0.33, versus 1.0 on the interest rate term. Note that although it is the yield spread gap rather than the real interest rate that affects real activity in QPM, other work at the Bank of Canada suggests that the relative weights on the real exchange rate and the real interest rate remain about the same in IS-curve estimations.

The measures of inflation and the output gap that are available for Canada are, or can be made to be, consistent with those in the theoretical models. A somewhat more difficult issue for an open economy that is not in equilibrium is how to measure the exchange rate gap, since the equilibrium exchange rate in the model's steady state is unlikely to be the relevant one for policy purposes. Since

the theoretical models make no distinction in the exchange rate term for the pass-through effect and for the MCI term, the year-to-year change in the exchange rate was used in our reaction functions.⁹ The reaction function was coded with the yield spread gap on the left-hand side and the real exchange rate, weighted by its MCI weight (0.33), on the right-hand side. The core-core inflation term was constructed using a parameter of 0.2 on the year-to-year change in the exchange rate.

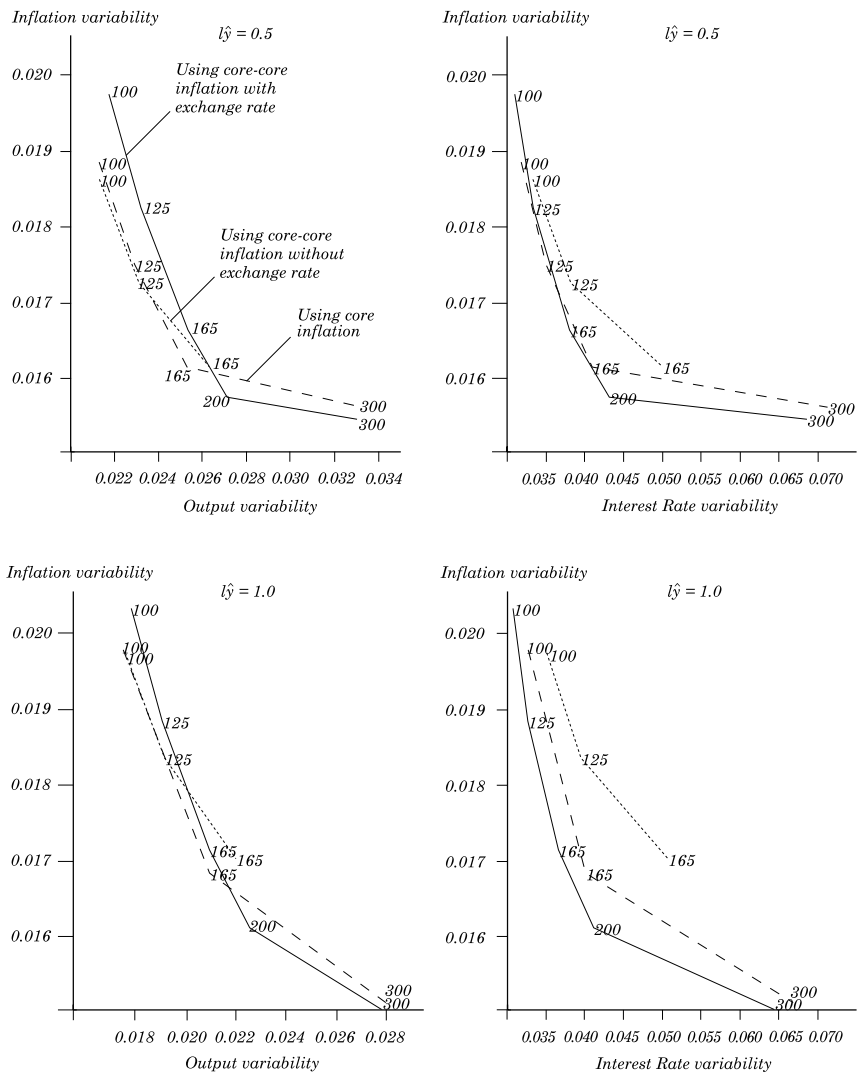
The initial experiments for variants of the Taylor rule were deterministic ones in which the standard simulations used at the Bank for assessing the implications of any change for the model's properties were undertaken to see how the model behaved under each form of the Taylor rule considered.¹⁰ Although more work needs to be done to refine and understand the results, the most general observation is that the results from the open-economy Taylor rule show less cycling for inflation, interest rates, the exchange rate, and the output gap than do the results for the other two forms of the Taylor rule considered.

These results should not be all that surprising given the more complete representation, relative to the variants of the base Taylor rule used, of how policy is actually formulated and implemented in Canada. The results from the two other Taylor rules do not differ enough to allow us to say that either one shows less cycling than the other when all of the simulation results are considered. The next set of experiments were stochastic ones that used the same three versions of the Taylor rule as for the deterministic simulations and the representation of historical shocks used by Maclean. As is typical in this work, results were generated for a range of coefficients on the inflation gap term (0.5, 1.0, 1.25, 1.65, 2.0, 3.0, and 4.0) and for a range of coefficients on the output gap term (0.0, 0.25, 0.5, 1.0, and 1.5). Only selected results will be considered here. Results are plotted for the variance of inflation against the variance of the output gap and for the variance of inflation against the variance of the interest rate gap. In figure 3, each graph has three curves, corresponding to the three Taylor rules considered. Two sets of graphs are shown.

9. That is, the exchange rate lagged one year is used to represent the short-term equilibrium. It is not clear that this is the appropriate thing to do. In an artificial economy, the long-run equilibrium is always constant, so it might be better to use the level of e in calculating the MCI and the year-to-year change in e in estimating the exchange rate pass-through.

10. The following types of shocks are considered: a disinflation shock, an inflation shock, a demand shock, an exchange rate shock, a commodity price shock, a productivity shock, an indirect tax shock, a corporate tax shock, a government size shock, a government debt shock, and a foreign shock.

Figure 3. Simulations of Taylor Rules with Historical Distribution of Shocks and Low Exchange Rate Rate Variability



Source: Bank of Canada.

Each set corresponds to a different weight on the output gap term l_y (0.5 and 1.0). The curves in each graph are constructed by joining the various points generated using the relevant output gap weight and a range of weights on the inflation gap term.

Figure 3 shows that using core-core inflation in the basic Taylor rule leads to a relatively worse (and more attenuated) trade-off frontier, especially for that between the variance of inflation and the variance of the interest rate, than either of the other two Taylor rules. It seems that using an underlying measure of inflation that removes the exchange rate effect without allowing the exchange rate to be directly considered in setting the instrument leads to a perverse dynamic. (Indeed, this dynamic ultimately causes the simulations to fail for larger weights on the inflation gap.)

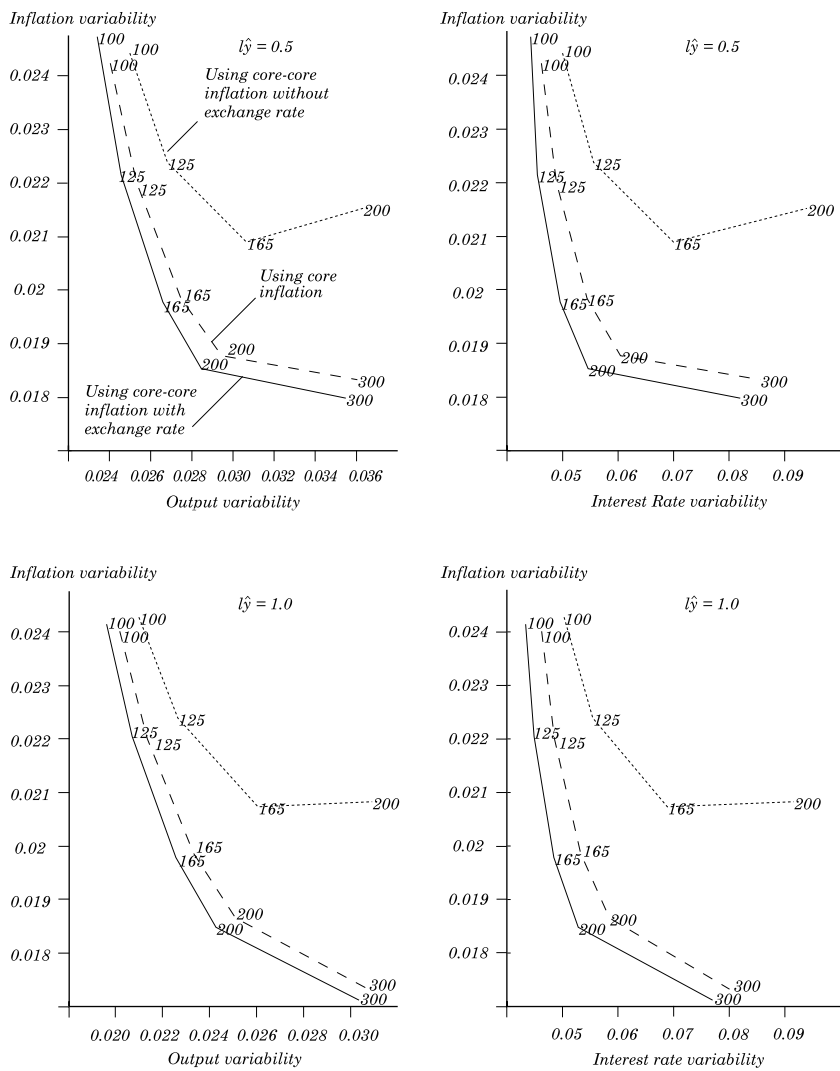
When movements in the exchange rate are taken into account as in the Ball-type open-economy Taylor rule, it seems that there might be some room for improving the relative performance of the trade-off frontiers from those obtained using a closed-economy formulation. With a higher weight (1.0) on the output gap, including the exchange rate does seem to reduce interest rate volatility (and presumably exchange rate volatility) and makes little difference for output variability.¹¹ However, this comes at the expense of greater inflation variability.

In calibrating the shocks to be used for stochastic simulations in Maclean's work and the preliminary investigations reported above, the variability of the exchange rate ended up below that seen historically. This trade-off was made to ensure that the variabilities of other key variables were consistent with historical experience. If the stochastic simulations are changed slightly to ensure that the resulting exchange rate variability is more in line with historical experience, the resulting trade-off frontiers, as shown in figure 4, are even more suggestive that it might be helpful to use a Ball-type open-economy Taylor rule.

Work at the Bank of Canada will continue to refine the conceptual underpinnings of an open-economy Taylor rule. At the same time, a concerted effort will be made, using simulation analysis and different models, to find a robust representation of a Taylor rule that can be used in the discussions on monetary policy formulation.

11. Exchange rate variability and interest rate variability resulting from these stochastic simulations are highly correlated.

Figure 4. Simulations of Taylor Rules with Historical Distribution of Shocks and Exchange Rate Variability as Experienced in Recent History



Source: Bank of Canada.

4. POLICY RULES AND RECENT CHANGES IN ECONOMIC BEHAVIOR IN CANADA

Economic behavior appears to have changed during the period over which inflation targeting has been in place in Canada in a way that has implications for our IFB policy rule. There is at least suggestive evidence of increasing monetary policy credibility (some of which is regularly reported in the Bank's semiannual *Monetary Policy Report*), a flattening of the Phillips curve, and greater room for countercyclical fiscal policy. The implications of each of these are addressed in Amano, Coletti, and Macklem (1999). They conclude that changes in credibility would require a recalibration of the IFB rule to avoid a worsening of outcomes, that a flatter Phillips curve would increase output volatility for a given level of inflation control, and that increased room for countercyclical fiscal policy seems to improve the trade-off between output and inflation variability.

4.1 More Firmly Anchored Expectations?

Overall, we interpret the results of several studies on this question as showing that credibility has improved during the inflation-reduction, inflation-control period.¹² Johnson (1998), for example, uses survey measures of expected inflation from 1984 to 1995 to examine the credibility of monetary policy across eighteen industrial countries, including Canada. He concludes that Canada and New Zealand have the most credible targets among the inflation targeting countries. Perrier (1998) uses survey data on expected inflation from the Conference Board of Canada. He concludes from these data that the Bank of Canada has developed increasing credibility over the inflation targeting period. These studies are based on formal regression analysis, but the flavor of their results can be captured by simply looking at the behavior of survey measures of inflation in the 1990s.

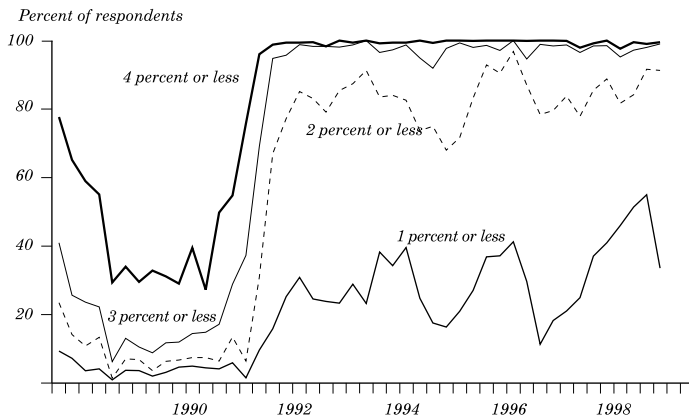
In the Conference Board of Canada's quarterly Survey of Forecasters for July 1999, the average forecast rates of inflation for 1999 and 2000 were 1.5 percent and 1.7 percent, respectively. The Conference Board also surveys businesses; from these surveys one can infer the distribution of expected year-to-year price increases over

12. Studies include Svensson (1994), Johnson (1997, 1998), Amano, Coletti, and Macklem, (1999), and Perrier (1998).

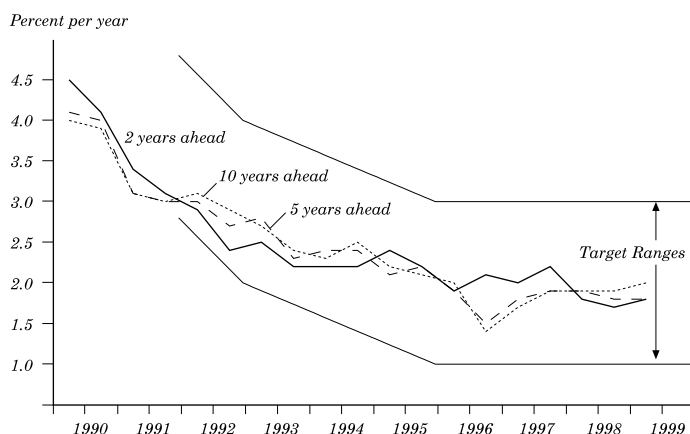
the next six months. Figure 5 (from data regularly available in the semiannual Monetary Policy Report) presents a time series of the percentage of business respondents who expected inflation to be at a certain level or less. As shown, close to 100 percent of the respondents expect Canadian inflation to be 3 percent (the upper band of the inflation range) or less over the near term. Longer-term inflation forecasts, reported by the Consensus Economics Inc. survey of forecasters, show a similar convergent trend. These forecasts suggest that longer-term (two, five, and ten years ahead) inflation expectations are in line with the midpoint (2 percent year-to-year) of the official inflation target band (figure 6).

Other measures suggestive of reduced monetary uncertainty are reviewed in Amano, Coletti, and Macklem (1999). They include the dispersion of inflation forecasts across forecasters; the average deviation of inflation forecasts from the inflation target; the difference between the yield on Government of Canada long-term Real Return Bonds and nominal bonds of comparable maturity (a proxy for long-term inflation expectations, also regularly included in the *Monetary Policy Report*); and the length of debt contracts.

Figure 5. Distribution of Expected Price Increases in Canada Over the Next Six Months



Source: Conference Board of Canada, *Index of Business Confidence*.

Figure 6. Consensus Forecasts of CPI Inflation in Canada

Source: Consensus Economics Inc.

Amano, Coletti, and Macklem show that the effect of increasing credibility is to shift the policy frontier closer to the origin. However, they also find that a rule (defined by the degree of forward-lookingness on inflation and by the weight on the inflation gap term in a reaction function) that was on the frontier initially is unlikely to still be on the frontier when credibility is increased. One reason is that, with increased credibility, the forecasting horizon of private sector agents shortens, and the monetary authority should take this into account by shortening the horizon in its reaction function. There is also some indication that increasing the weight on the inflation gap improves the trade-off frontier.

4.2 Changes in the Slope of the Phillips Curve

For Canada, Dupasquier and Ricketts (1998a and b) consider five different models of asymmetric price adjustment and examine the testable implications of each on aggregate price data. They find a significant and positive relationship between the expected rate of inflation and the slope of the Phillips curve. However, when the Lucas model (the misperceptions or signal extraction model) and the menu-cost (or costly adjustment) model are considered together, the authors find it difficult to discriminate empirically between whether the

flatter slope is due to a lower standard deviation of inflation, as implied by the Lucas model, or a lower mean of inflation, as implied by the menu-cost model. Nevertheless, their empirical evidence is suggestive of a flattening of the Phillips curve in an environment of low and stable inflation.

If the Phillips curve becomes flatter at lower rates of inflation, then disinflations that begin at lower inflation rates should be more costly. However, for demand shocks, a flatter Phillips curve means that inflation will move away from its target more slowly, so that the variance of inflation may fall. Debelle (1996) examines the last three Canadian disinflations and finds a negative relationship between the initial level of inflation and the resulting sacrifice ratio. In particular, he finds that the sacrifice ratio associated with the 1974-76 disinflation is 0.4 when the initial level of inflation was 11.5 percent; that the ratio for the 1981-85 disinflation is 2.0 when inflation was 12.9 percent; and that the sacrifice ratio of the 1990-93 disinflation is 3.5 when inflation was 5.3 percent.

For a given inflation expectations formation process, a flatter Phillips curve shifts the trade-off frontier (for inflation and output variability) such that output volatility is higher, especially for rules with a short forecasting horizon (Amano, Coletti, and Macklem, 1999). The latter is to be expected, as the stronger response of short-horizon rules, as opposed to longer-horizon rules, to prospective inflationary pressures creates more output variability. As the Phillips curve becomes flatter, the marginal cost, in terms of output variability, of better inflation control increases. Unlike changing credibility where there was a significant effect on the calibration of the rules, flattening the Phillips curve does not have a pronounced effect on which rules are good ones.

4.3 Changes in Fiscal Policy

From the mid-1970s to the mid-1990s, unsustainable structural deficits produced a steady increase in the ratio of net government debt to gross domestic product in Canada, from 5 percent in 1974 to 70 percent in 1996.¹³ Over this period, Canada's net debt-to-GDP ratio moved from fourth highest among the Group of Seven major industrial countries to second highest.

13. Unless otherwise specified, net government debt is net consolidated debt across federal, provincial, and municipal governments as measured on a national accounts basis.

In response, Canadian fiscal authorities launched a variety of measures in the 1990s that were intended to first stabilize and eventually reduce the debt ratio. Beginning with its 1994/95 budget, the Canadian federal government set short-term deficit targets to provide economic agents and financial markets with an anchor for where fiscal policy was going. Over the five years in which the deficit targets have been in place, the Canadian federal government has consistently overachieved its announced target. In addition, six of Canada's ten provinces and both of its territories have enacted either legislation or constitutional constraints on government deficits, taxes, expenditure, or debt (see Millar, 1997). These measures (together with cyclical improvements in economic activity) have reduced the overall government deficit from approximately 8.0 percent of GDP in 1992 to a small surplus in 1998. The overall government net debt-to-GDP ratio in Canada has fallen, with further reductions expected. As a result, the constraints on the federal government's ability to behave countercyclically in the recent past are becoming less and less binding.

A more countercyclical fiscal policy allows a beneficial shift in the efficient policy frontier in the sense that, for a given level of inflation volatility, output volatility is lower (and vice versa) with only small changes in which monetary policy rules are most efficient. When fiscal policy can be more countercyclical, the beneficial effects for the efficient frontier arise from the ability to use automatic stabilizers, with their faster effects than monetary policy on aggregate demand, and from the complementarity of fiscal and monetary policy in responding to most shocks.

5. SOME CONCLUDING REMARKS

This paper has discussed the Bank of Canada's current view of the monetary policy transmission mechanism in Canada and the research on which it is based, as well as some of the Bank's current and ongoing research on policy rules, or more accurately, policy reaction functions. The main objectives in the research on various elements of the monetary policy framework at the Bank of Canada is to find practical ways of addressing the major types of uncertainty in formulating monetary policy.

Uncertainty has become particularly important as a research and practical issue in recent years for several reasons. In Canada and

in many other countries, there has been a shift in focus from how to achieve low inflation to how to conduct monetary policy in an environment of low and stable inflation. In such an environment the treatment of risks has become more symmetric. At the same time, increased international linkages have added to the uncertainties, but on the other hand, technological advances have increased economists' capability to deal with uncertainty.

The major types of uncertainty facing policymakers are uncertainty about shocks, uncertainty about parameters, uncertainty about data, and uncertainty about models. Shock uncertainty has three elements: additive (random) uncertainty, uncertainty about the persistence of shocks, and uncertainty surrounding the results from deterministic simulations implying the need for confidence bands. Parameter uncertainty reflects the fact that the responses of key variables to changes in the monetary policy instrument are not known with certainty. Data uncertainty results from the difficulty of measuring precisely such things as inflation and the output gap. Model uncertainty arises because the true model of the economy can never be known for sure.

At the Bank of Canada, experience and research have led the staff to identify three actions that can help policymakers deal with uncertainty and provide a sharper focus to discussions at key meetings on monetary policy:

- The main reaction function used should capture the policymakers' trade-off among the variance of inflation relative to target, the variance of the output gap, and the variance of (changes in) interest rates, to address parameter and data uncertainty. However, to take account of model uncertainty, an alternative reaction function of the Taylor-Ball-Srouer type should be developed and used regularly.

- As to risks, it is helpful to follow a three-part approach. The first is to use confidence bands, based on past projection errors and simulation analysis, around inflation and output predictions in the base case and in alternative scenarios. The second is to develop alternative scenarios of key risks, which typically concern the size and persistence of additive shocks. The third is to develop no-change-in-policy scenarios (in which monetary conditions are held constant for two to four quarters), to highlight the cost of delaying policy actions.

- Other information should be reviewed for its consistency with the base case being presented for consideration by the policymakers.

In Canada this includes reports from the Bank's regional representatives on their reading of the economy, and the presentation of the implications for the path of monetary conditions of an alternative paradigm based on monetary and credit aggregates (to address model uncertainty).

REFERENCES

- Amano, R., D. Coletti, and T. Macklem. 1999. "Monetary Rules When Economic Behaviour Changes." Bank of Canada Working Paper 99-8. Ottawa: Bank of Canada.
- Armour, J., J. Atta-Mensah, W. Engert, and S. Hendry. 1996. "A Distant-Early-Warning Model of Inflation Based on M1 Disequilibrium." Bank of Canada Working Paper 96-5. Ottawa: Bank of Canada.
- Ball, L. 1999. "Policy Rules for Open Economies." In *Monetary Policy Rules*, edited by J. B. Taylor. Chicago: University of Chicago Press.
- Bank of Canada. 1995. *Credit, Interest Rate Spreads, and the Monetary Policy Transmission Mechanism: Proceedings of a Conference held at the Bank of Canada*. Ottawa: Bank of Canada.
- Black, R., T. Macklem, and D. Rose. 1998. "On Policy Rules for Price Stability." In *Price Stability, Inflation Targets, and Monetary Policy, Proceedings of a Conference held by the Bank of Canada*. Ottawa: Bank of Canada.
- Butler, L. 1996. "The Bank of Canada's New Quarterly Projection Model: Part 4—A Semi-Structural Method to Estimate Potential Output: Combining Economic Theory with a Time-Series Filter." Bank of Canada Technical Report 77. Ottawa: Bank of Canada.
- Clinton, K. 1994-95. "The Term Structure of Interest Rates as a Leading Indicator of Economic Activity: A Technical Note." *Bank of Canada Review* (Winter): 23-40.
- Clinton, K., and D. Howard. 1994. "From Monetary Policy Instruments to Administered Interest Rates: The Transmission Mechanism in Canada." Bank of Canada Technical Report 69. Ottawa: Bank of Canada.
- Clinton, K., and M. Zelmer. 1997. "Constraints on the Conduct of Canadian Monetary Policy in the 1990s: Dealing with Uncertainty in Financial Markets." Bank of Canada Technical Report 80. Ottawa: Bank of Canada.
- Côté, A., and T. Macklem. 1996. "The Determination of Interest Rates and the Exchange Rate in the Bank of Canada's Quarterly Projection Model." In *The Determination of Long-Term Interest Rates and Exchange Rates and the Role of Expectations, Conference Papers*, Vol. 2. Basle: Bank for International Settlements.
- Cozier, B., and G. Tkacz. 1994. "The Term Structure and Real Activity in Canada." Bank of Canada Working Paper 94-3. Ottawa: Bank of Canada.
- Debelle, G. 1996. "End of Three Small Inflations." *Canadian Public Policy* 22: 56-78.

- Duguay, P. 1994. "Empirical Evidence on the Strength of the Monetary Transmission Mechanism in Canada: An Aggregate Approach." *Journal of Monetary Economics* 33: 39-61.
- Duguay, P., and D. Longworth. 1998. "Macroeconomic Models and Policymaking at the Bank of Canada." *Economic Modelling* 15: 357-75.
- Dupasquier, C., and N. Girouard. 1992. "Un Modèle de l'Inflation au Canada." Unpublished paper. Ottawa: Bank of Canada.
- Dupasquier, C., and N. Ricketts. 1998a. "Non-Linearities in the Output-Inflation Relationship." In *Price Stability, Inflation Targets, and Monetary Policy, Proceedings of a Conference held by the Bank of Canada*. Ottawa: Bank of Canada.
- . 1998b. "Non-Linearities in the Output-Inflation Relationship: Some Empirical Results for Canada." Bank of Canada Working Paper 98-14. Ottawa: Bank of Canada.
- Engert, W., and S. Hendry. 1998. "Forecasting Inflation with the M1-VECM: Part Two." Bank of Canada Working Paper 98-6. Ottawa: Bank of Canada.
- Fillion, J. F., and A. Léonard. 1997. "La Courbe de Phillips au Canada: Un Examen de Quelques Hypothèses." Bank of Canada Working Paper 97-3. Ottawa: Bank of Canada.
- Hendry, S. 1992. "Determinants of the Prime Rate." Bank of Canada Working Paper 92-2. Ottawa: Bank of Canada.
- . 1995. "Long-Run Demand for M1." Bank of Canada Working Paper 95-11. Ottawa: Bank of Canada.
- Hendry, S., and G. J. Zhang. 1998. "Liquidity Effects and Market Frictions." Bank of Canada Working Paper 98-11. Ottawa: Bank of Canada.
- Johnson, D. 1997. "Expected Inflation in Canada 1988-1995: An Evaluation of Bank of Canada Credibility and the Effect of Inflation Targets." *Canadian Public Policy* 23: 223-58.
- . 1998. "On the Credibility of Monetary Policy: International Evidence Based on Surveys of Expected Inflation." In *Price Stability, Inflation Targets and Monetary Policy: Proceedings of a Conference held by the Bank of Canada*. Ottawa: Bank of Canada.
- Khemani, R., and J. Murray. 1990. "International Interest Rate Linkages and Monetary Policy: A Canadian Perspective." Bank of Canada Technical Report 52. Ottawa: Bank of Canada.
- Kichian, M. 1999. "Measuring Potential Output within a State-Space Framework." Bank of Canada Working Paper 99-9. Ottawa: Bank of Canada.

- Laflèche, T. 1996-97. "The Impact of Exchange Rate Movements on Consumer Prices." *Bank of Canada Review* (Winter): 21-32.
- Lafrance, R., and Z. Antia. 1998-99. "Technical Note: A New Trade-Weighted Exchange Rate Index for Canada." *Bank of Canada Review* (Winter) 125-26.
- Laxton, D., N. Ricketts, and D. Rose. 1994. "Uncertainty, Learning and Policy Credibility." In *Economic Behaviour and Policy Choice under Price Stability: Proceedings of a Conference held at the Bank of Canada*. Ottawa: Bank of Canada.
- Laxton, D., D. Rose, and R. Tetlow. 1993a. "Is the Canada Phillips Curve Non-linear?" Bank of Canada Working Paper 93-7. Ottawa: Bank of Canada.
- . 1993b. "Monetary Policy, Uncertainty and the Presumption of Linearity." Bank of Canada Technical Report 63. Ottawa: Bank of Canada.
- . 1993c. "Problems in Identifying Non-linear Phillips Curves: Some Further Consequences of Mismeasuring Potential Output." Bank of Canada Working Paper 93-6. Ottawa: Bank of Canada.
- Longworth, D., and C. Freedman. 1995. "The Role of the Staff Economic Projection in Conducting Canadian Monetary Policy." In *Targeting Inflation*, edited by Andrew G. Haldane. London: Bank of England.
- Longworth, D., and J. Murray. 1988. "Canadian Exchange Market Management and Monetary Policy." In *Exchange Market Intervention and Monetary Policy*. Basle: Bank for International Settlements.
- Longworth, D., and S. Poloz. 1986. "A Comparison of Alternative Monetary Policy Regimes in a Small Dynamic Open-Economy Simulation Model." Bank of Canada Technical Report 42. Ottawa: Bank of Canada.
- . 1995. "The Monetary Transmission Mechanism and Policy Formulation in Canada: An Overview." In *Financial Structure and the Monetary Policy Transmission Mechanism*. Basle: Bank for International Settlements.
- Maclean, D. 1998. "Incorporating Credibility in Forward-Looking Models: Some Examples with QPM." In *Topics in Monetary Policy Modelling*. Basle: Bank for International Settlements.
- Millar, J. 1997. "The Effects of Budget Rules on Fiscal Performance and Macroeconomic Stabilization." Bank of Canada Working Paper 97-15. Ottawa: Bank of Canada.

- Montplaisir, M.-C. 1996-97. "The Maturity Structure of Household Financial Assets and Liabilities." *Bank of Canada Review* (Winter): 33-46.
- Muller, P., and M. Zelmer. 1999. "Greater Transparency in Monetary Policy: Impact on Financial Markets." Bank of Canada Technical Report 86. Ottawa: Bank of Canada.
- Perrier, P. 1998. "Un Examen de la Crédibilité de la Politique Monétaire au Canada." Bank of Canada Working Paper 98-12. Ottawa: Bank of Canada.
- Ricketts, N., and D. Rose. 1995. "Inflation, Learning and Monetary Policy Regimes in the G-7 Economies." Bank of Canada Working Paper 95-6. Ottawa: Bank of Canada.
- St-Amant, P., and S. van Norden. 1997. "Measurement of the Output Gap: A Discussion of Recent Research at the Bank of Canada." Bank of Canada Technical Report 79. Ottawa: Bank of Canada.
- Srour, G. 1999. "Inflation Targeting under Uncertainty." Bank of Canada Technical Report 85. Ottawa: Bank of Canada.
- Svensson, L. E. O. 1994. "The Simplest Test of Inflation Target Credibility." CEPR Discussion Paper 940. London: Centre for Economic Policy Research.
- . 1999 "Inflation Targeting as a Monetary Policy Rule." *Journal of Monetary Economics* 43: 607-654.
- . 2001. "Price Stability as a Target for Monetary Policy: Defining and Maintaining Price Stability." In *The Monetary Transmission Process: Recent Developments and Lessons for Europe*, edited by Deutsche Bundesbank. New York: Palgrave.
- Taylor, J. B. 1993. "Discretion versus Policy Rules in Practice." *Carnegie-Rochester Conference Series on Public Policy* 39: 195-214.

MONETARY POLICY RULES AND TRANSMISSION MECHANISMS UNDER INFLATION TARGETING IN ISRAEL

Leonardo Leiderman

Deutsche Bank

Hadas Bar-Or

Tel Aviv University

Disinflation in Israel has been a relatively slow process. It took more than a decade for the annual rate of inflation to fall from about 18 percent in the late 1980s to less than 4 percent in the late 1990s. For 2000 and 2001 the government has set an inflation target range of 3 to 4 percent. Whether low inflation will be a permanent feature of the Israeli economy remains to be seen. Some important aspects of the economy—such as the principles guiding monetary policy and asset market allocations—have adjusted themselves to the new, single-digit-inflation conditions. Yet many key transmission mechanisms that were introduced in the era of double- and triple-digit inflation remain in place. Leading examples are widespread indexation of wages and financial assets to the consumer price index (CPI), as well as a relatively rapid pass-through from changes in nominal exchange rates to changes in prices. Nevertheless, Israel's experience suggests that it has been possible to disinflate and to conduct monetary policy as it is conducted in most inflation targeting countries. Underlying these successes has been a virtuous circle in the interaction between

At the time of this writing, Leiderman and Bar-Or were affiliated with the Bank of Israel.

The views expressed in the paper are the sole responsibility of the authors. We thank O. Bar-Efrat, G. Bufman, N. Liviatan, and F. Morande for detailed comments on an earlier draft. For comments and suggestions we also thank seminar participants at the Research Department of the Bank of Israel, Hebrew University, Tel Aviv University, and the Central Banks of Chile and the Philippines.

Monetary Policy: Rules and Transmission Mechanisms, edited by Norman Loayza and Klaus Schmidt-Hebbel, Santiago, Chile. ©2002 Central Bank of Chile.

disinflation and economic institutions. As disinflation became more credible over the years, an increasing number of transmission mechanisms were adapted to these conditions; the latter, in turn, contributed to making disinflation more credible and to increasing the efficacy of monetary policy.

Under these conditions, however, the conduct of monetary policy has faced numerous difficulties. First, there has not been a wide consensus on the need to bring about a convergence of domestic inflation to rates in the industrial countries. This lack of consensus has created ambiguity about the nature and role of inflation targets, about the conduct of monetary policy, and about the role of fiscal policy in achieving the inflation target. In fact, the mid-1990s saw a considerable overburdening of monetary policy, which had to offset, at least partially, the potential impacts of fiscal expansion on the rate of inflation (Bufman and Leiderman, 1998). Some politicians have disputed the stance adopted by monetary policy, to the point of proposing legislative changes that would effectively reduce central bank autonomy.¹ There is no doubt that lack of full support from fiscal policy and ambiguity about nominal targets have damaged the credibility of the disinflation process and have increased the difficulties encountered by monetary policy. To effectively reduce the rate of inflation, the central bank has had to maintain a more conservative stance than otherwise, and to take on what has become in part an educational role. That is, it has had to explain to other policymakers and to the public at large the importance of having inflation in Israel converge gradually to the level prevailing in the leading countries in a globalized world economy. Second, most of the time inflation targeting has coexisted with targeting of the nominal exchange rate, further raising ambiguity about the guiding principles and priorities for monetary policy. Over the years it has become increasingly clear that the inflation target is the key objective of monetary policy, and the nominal exchange rate is seen more and more as an indicator variable set primarily by the market.

In addition, Israel has had to develop a well-specified forecasting scheme for conducting policy under inflation targeting. It turns out that the econometric relationships that seemed to work well in the high-inflation period (before mid-1985) were subject to structural breaks due to frequent regime changes in the poststabilization period.

1. See Frenkel (1999) on the role of central bank independence in achieving price stability.

In particular, it is likely that the extent of exchange rate pass-through to prices will be reduced over time as inflation targets become more credible and as the flexibility of the exchange rate regime is enhanced. Inflation forecast targeting requires the policymaker to continuously monitor comparisons of inflation forecasts against the inflation target, and discrepancies between these two serve as a trigger for potential monetary policy action. Thus the inflation forecast is a key building block of the policy paradigm under inflation targeting. In the case of Israel, some of the difficulties were overcome by using market-based inflation expectations as one important (yet imperfect) indicator for the market's assessment of the inflation outlook into the future.

These challenges are not unique to Israel. They are shared not only by numerous emerging market countries but also by industrial countries.² For example, when New Zealand adopted inflation targets in 1989, it did so in the context of broad structural and policy reforms, most of which rendered previously estimated models quite obsolete. And when the United Kingdom adopted explicit targets in the fall of 1992, it did so after a period of nominal exchange rate targeting within which the transmission mechanism was quite different from that of inflation targeting coupled with flexible exchange rates. Moreover, in all cases the initial stages of inflation targeting suffered from lack of credibility and from substantial ambiguities, resulting in a time path for inflation expectations well above that of the actual rate of inflation.

In spite of these cross-country similarities, a striking difference between Israel and the industrial countries is that in Israel, a country with a relatively recent history of high inflation, political and public support for inflation targeting and for inflation reduction has been relatively weak. Not long ago, officials from the finance ministry and other official entities publicly criticized inflation targeting. Thus ambiguity and a lack of initial credibility, together with a non-supportive role of fiscal policy for disinflation, created at some point in the past conditions less than favorable for the success of inflation targeting. Even so, substantial disinflation has occurred in recent years under inflation targeting, and monetary policy in Israel continues to be conducted within a framework very similar to that in industrial countries.

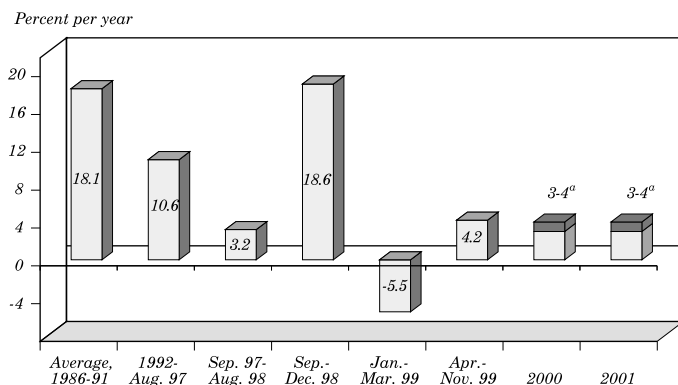
2. See, for example, Leiderman and Svensson (1995) and Morandé and Schmidt-Hebbel (1999).

In this paper we analyze Israel's inflation targeting policies since 1992, with an eye toward those characteristics that may well apply to other countries. Section 1 lays out the main stylized facts about recent disinflation and details about the inflation targeting scheme. Then section 2 discusses the transmission mechanism in the inflation process and reports new estimates of equations for determinants of the rate of inflation. Special attention is given to the changing nature of the pass-through from exchange rates to prices and its dependence on the state of the business cycle and the magnitude of exchange rate fluctuations. Section 3 estimates a representation of the Bank of Israel's policy rule, and section 4 concludes.

1. INFLATION TARGETING AND THE INFLATION PROCESS: THE FACTS

Starting at the beginning of the 1980s, the rate of inflation in Israel rose persistently and at an increasing rate, reaching well into triple-digit territory. This continued until mid-1985, when the Economic Stabilization Program was introduced. Figure 1 depicts the major developments in inflation since then. From 1986 to 1991 average inflation was 18 percent per year, not so much as a result of an explicit policy decision (such as an inflation target) but more as a residual consequence of the targeting of other variables, such as the

Figure 1. Evolution of the Rate of Inflation in Israel



Source: Bank of Israel.

a. Official target 2000-2001.

nominal exchange rate and international reserves. The rate of inflation was then sharply reduced to an average of 10 percent per year in the period from 1992 to 1996. Lately there has been a further reduction in inflation, to 7 percent in 1997, and year-over-year inflation to mid-1998 was a bit below 4 percent. However, the drop in the rate of inflation was interrupted by marked increases in consumer prices in the last third of 1998. These were associated with a sharp depreciation of the shekel in a context of crisis and volatility in world financial markets, mainly related to the financial crisis in Russia and the failure of the hedge fund LTCM in the United States. Nevertheless, thanks to a tightening of monetary policy and the help of other factors, these price increases were reversed in early 1999, and current forecasts are for a rate of inflation in 1999 of less than 1.5 percent, well below the official target of 4 percent (see Bank of Israel, 1999a and b).

An inflation target was first introduced in Israel in the context of the shift to a crawling exchange rate band in late 1991. The inflation target came in through the back door, as it were. It first appeared only as an input in setting the exchange rate's rate of crawl, specified in a forward-looking manner as the difference between the inflation target and a forecast of foreign inflation.³ Both the exchange rate regime and the inflation target are set by the government (mainly following the recommendation of the finance minister) upon consultation with the Bank of Israel, which by law has instrument independence. As a result, there has been considerable ambiguity about the nature and operational meaning of inflation targets as a precommitment device for monetary policy and for fiscal policy as well. This ambiguity was especially strong in the initial years of inflation targeting but has decreased substantially over time, as the central bank has credibly made the inflation target the key objective of monetary policy.

Table 1 summarizes the history of inflation targeting in Israel. In some years targets were set in terms of a range and in others as a point target. In all cases the overall CPI was used in specifying the target, which seems especially appropriate in an economy subject to extensive indexation of wages and financial assets to the overall CPI. In general, targets for a given year have been set only a few months before the end of the preceding year, and rarely have there been explicit multiyear targets. A salient characteristic of the setting of inflation targets in Israel is the generally "adaptive" behavior on the part of the authorities: the target for the next year has typically been set at a

3. See Bufman, Leiderman, and Sokoler (1995).

rate very close to the observed, year-over-year, rate of inflation at the time. In practice, this has meant that progress toward disinflation has typically preceded further reductions in the level of the inflation target. The inflation target for 1999 is 4 percent, and the target for 2000 and 2001 has been set as a range of 3 to 4 percent (see also Sokoler, 1997).

Table 1 indicates that, although there have been deviations of inflation from target in some years, from a multiyear perspective the targets have been achieved on average. From 1992 to 1998 inflation averaged 9.9 percent per year, very close to the average of the yearly targets at 9.7 percent. Figure 2 shows several episodes of marked intrayear deviations from target both of actual inflation in the previous twelve months and of twelve-months-ahead expected inflation. (Market-based expected inflation in figure 2 is derived from the yields on indexed and nonindexed bonds traded in the local capital market.) Major episodes of inflation acceleration well above target occurred in 1994, in the first half of 1996, and in the first half of 1999. In all these cases the credibility of the regime was put to a very serious test: inflation expectations escalated to about 15 percent in the first two episodes and to about 10 percent in the third. On the other hand, the rate of inflation was well below the annual target in the first two-thirds of 1998 and in the last quarter of 1999.

As already discussed, inflation targets in Israel coexist with another nominal policy commitment, namely, the crawling exchange

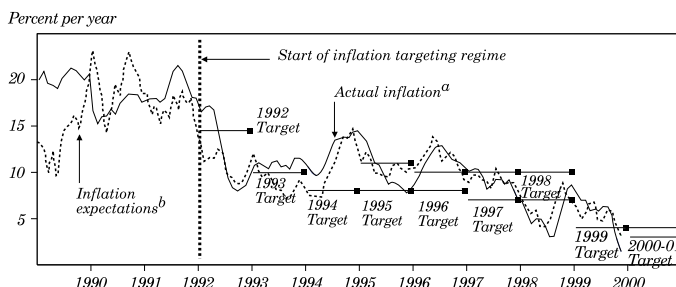
Table 1. Inflation Targets and Inflation Performance in Israel^a
Percent per year

<i>Year</i>	<i>Inflation target</i>	<i>Actual inflation</i>
1992	Up to 14-15	9.4
1993	10	11.2
1994	8	14.5
1995	8-11	8.1
1996	8-10	10.6
1997	7-10	7.0
1998	7-10	8.6
Average, 1992-98	9.7	9.9
1999	4	1.5 ^b
2000-01	3-4	n.a.

Source: Bank of Israel.

a. Inflation is measured by the change in the consumer price index.

b. Forecast.

Figure 2. Actual Inflation, Inflation Targets, and Inflation Expectations in Israel

Source: Authors' calculations.

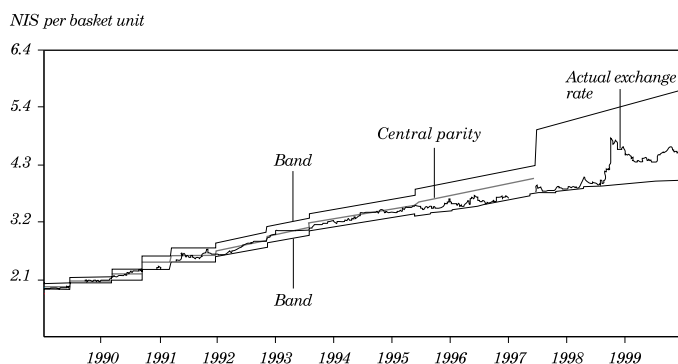
a. Year-over-year change in the consumer price index.

b. Derived from capital market data on indexed and nonindexed bonds.

rate band for the new Israeli shekel (NIS) against a basket of foreign currencies. The NIS exchange rate and its band are depicted in figure 3. Over the years there has been a substantial shift in the direction of liberalization of foreign exchange transactions, including capital flows, together with a gradual move toward increased flexibility of the nominal exchange rate regime. Less than five years ago the exchange rate band was relatively narrow, and the authorities engaged in considerable intramarginal, sterilized intervention in the foreign exchange market. Today, in contrast, daily exchange rates are set primarily by private market forces with no central bank intervention and in the context of a very wide currency band (see Leiderman and Bufman, 1996). In fact, since mid-June 1997 there has been a gradual (daily) widening of the currency band, whose width will be about 40 percent of the central parity by the end of 1999.

Israel's experience in the last five years illustrates that, under conditions of high capital mobility, the coexistence of an exchange rate band and inflation targeting may make the role of monetary policy more difficult than otherwise. Using only one instrument (the monthly setting of the central bank interest rate on repurchase agreements, or repos), the monetary authority is expected to achieve both these targets simultaneously. On several occasions (for example, in the first half of 1997), the level of the repo rate required to achieve the inflation target exceeded that consistent with lack of pressure on the exchange rate band. This situation was associated with considerable capital inflows and sizable sterilized

Figure 3. Path of Exchange Rate against the Currency Basket in Israel



Source: Bank of Israel.

intervention in the foreign exchange market to defend the lower (that is, most appreciated) limit of the band. Over the years the authorities have dealt with these policy dilemmas by increasing the emphasis of monetary policymaking on inflation targeting while increasing the degree of exchange rate flexibility.

2. THE MONETARY POLICY TRANSMISSION MECHANISM

In principle, the channels for the potential effects of monetary policy on key macroeconomic variables in a small, open economy are well known. A change in the monetary policy stance—as captured, for example, by a change in the central bank's overnight rate—may have a short-run impact on the level and composition of aggregate demand, especially through its impact on short- and long-term real interest rates, on the real exchange rate, and on the liquidity available to consumers and investors. Changes in monetary policy can also influence forward-looking inflation expectations and the nominal exchange rate, which in turn affect the wage- and price-setting mechanism (for example, through changes in domestic pricing of tradable goods and services). Clearly, financial markets and the impact of monetary policy changes on economic agents' balance sheets are key components of the transmission mechanism.

The analysis of these interdependent and simultaneous effects requires the formulation of a model in which each channel of the transmission mechanism and its feedback effects from and to the other channels is properly specified. Accordingly, relatively small-scale macroeconomic models have been formulated and estimated in various central banks in recent years. These typically consist of an aggregate demand equation, a price-setting equation that takes into account (among other things) the impact of the output gap on price pressures, a money demand equation, a wage-setting equation, a real exchange rate equation, a term structure of interest rates (relating short and long rates), an interest rate parity condition, a specification of inflation expectations, and a monetary policy reaction function. Under certain conditions these models can be accurately estimated, and the resulting parameters can be used to assess the quantitative importance of the various transmission channels as well as to simulate the impact of monetary policy shocks.

In Israel, the specification and estimation of such small-scale macroeconomic models faces the methodological difficulties arising from relatively frequent structural breaks due to regime changes. In spite of this, there are current efforts under way at the Bank of Israel to deal with these issues (see, for example, Azoulay and Elkayam, 1997; Djivre and Ribon, 1999; Kahn, Kandel, and Sarig, 1998; and the research papers by various authors in Leiderman, 1999). At the same time, efforts have been devoted to estimating some of the individual components of the overall macroeconomic model, such as money demand and the Phillips curve, with satisfactory results.

We focus here on models for analyzing and forecasting movements in the rate of inflation in Israel, which can play a key role in the inflation targeting scheme. To a large extent, monetary policy consists of what Svensson (1999) has termed "inflation forecast targeting" (see Bufman and Leiderman, 1998). That is, monetary policy decisions mainly depend on an assessment of whether, in the absence of policy changes, it is highly likely that the inflation target will be met. For example, to the extent that the inflation forecast is above the inflation target, a tightening of monetary conditions is called for. Although the existence of market-based data on inflation expectations can be exploited in this forecasting and policy exercise, as implied by the analysis in Bernanke and Woodford (1997), the proper conduct of monetary policy requires reliance on other indicators and forecasts of the inflation outlook as well.

2.1 Estimates of a Quarterly Inflation Equation

Most existing quarterly econometric models of the price-setting equation in Israel relate quarterly movements in the rate of inflation to a set of explanatory variables that includes measures of monetary conditions such as the *ex ante* central bank real interest rate (which, in turn, makes use of market-based inflation expectations) and the nominal exchange rate; indicators of “imported” inflation (such as foreign prices); measures of the level of economic activity such as the output gap or the rate of unemployment; and others (for a review of research by various authors, see Leiderman, 1999). Although estimation of these models has yielded reasonable results, within-sample simulations suggest that, to a large extent, these models are not able to economically account for a sizable part of observed key turning points in the disinflation process, such as from the end of 1991 to mid 1992 and from late 1997 until mid-1998 (see Bar-Or, 1999). Therefore default dummy values are often added to capture the fall in the rate of inflation and to enable a more precise estimation of the parameters. It seems plausible that, to a large extent, these dummies capture the effects of one-time shifts in the stance of fiscal policy with respect to the inflation process. Although quarter-to-quarter impacts of fiscal policy variables on the evolution of the rate of inflation have been difficult to detect, research by Dahan and Strawczynski (1997) has shown that salient changes in the evolution of inflation in the 1970-96 period were preceded by substantial and persistent changes in the same direction in the fiscal policy regime, as reflected in changes in the structural public sector deficit and in the public debt.

Our work relies on a reduced-form representation of the quarterly rate of inflation, which differs from most previous work mainly in the specification of the pass-through mechanism from exchange rates to prices. Specifically, in the proposed model the contemporaneous and lagged pass-through is from the nominal exchange rate to prices of all goods, not just tradables. Because of Israel’s high-inflation history, there exist even today, in spite of lower inflation, various formal and informal indexation mechanisms linking domestic prices and wages to the nominal exchange rate, beyond the impact of the latter on domestic prices of traded goods and services. Hence nominal exchange rates and foreign prices are entered separately in the inflation equation. In addition, the proposed model of the pass-through coefficient allows for this coefficient to vary with time, depending on the state of the economy over the business cycle (see

Bufman and Leiderman, 1998, and Bar-Or, 1999); that is, the extent of pass-through is larger in booms than in downturns. We also examine the extent to which the exchange rate pass-through coefficients depend on the size of the underlying exchange rate change, that is, whether exchange rate movements beyond a given threshold level give rise to a stronger or quicker pass-through than do milder exchange rate changes. Concretely, we estimate an equation of the form

$$\pi_t = \beta_0 + \beta_1 D2 + \beta_2 DPOIL_t + \beta_3 \pi_{t-2}^f + \beta_4 r_t + \beta_5 r_{t-2} + \beta_6 u_t + (\beta_7 + \beta_8 u_t) \varepsilon_t + \beta_9 \varepsilon_{t-1} + \eta_t, \quad (1)$$

where π denotes the quarterly rate of change in the consumer price index excluding fruits and vegetables. The fruits and vegetables price index (whose weight in the CPI is only 3.5 percent) is seasonal and extremely volatile, and was strongly affected in the sample period by the existence or lack thereof of a closure of the borders with the territories, which prevented the entry of Palestinian workers. $D2$ is a dummy variable for the second quarter of each year. $DPOIL$ is the rate of change of fuel prices in Israel. The variable π^f is the rate of change of the price index for imported consumer goods. Variable r denotes the real ex ante interest rate, calculated using the nominal interest rate set by the central bank and market-based inflation expectations. Variable u is the rate of unemployment (seasonally adjusted), and ε is the quarterly rate of change of the NIS-U.S. dollar exchange rate. We allow for the coefficients on exchange rate depreciation—both contemporaneous and lagged—to depend, through dummy variables, on the size of the exchange rate change. We added to equation (1) coefficients β_{10} and β_{11} on these dummies, which correspond to the period 1998Q4-1999Q1. Estimating this equation by the least squares method, correcting for heteroskedasticity, on a sample of data from 1990Q1 to 1999Q3 yields the results in table 2.⁴

For an economy as historically volatile as that of Israel, the results are quite satisfactory in terms of both the estimated individual coefficients (table 2) and the overall within-sample fit of the equation (figure 4). In addition, their broad features conform to those of earlier work. In particular, if we disentangle the nominal interest rate and the ex ante market-based measure of inflation expectations,

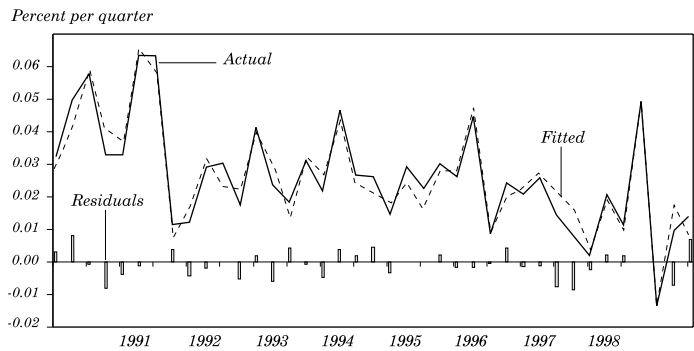
4. Stability tests of equation (1) support the notion that no structural breaks occurred within the sample.

Table 2. Regression Estimates for the Quarterly Inflation Equation

<i>Parameter in equation (1)</i>	<i>Coefficient</i>	<i>Standar error</i>
β_0	0.038	0.005
β_1	0.009	0.002
β_2	0.016	0.006
β_3	0.149	0.039
β_4	-0.263	0.051
β_5	-0.170	0.042
β_6	-0.130	0.041
β_7	0.620	0.151
β_8	-4.325	1.304
β_9	0.205	0.040
β_{10}	0.093	0.045
β_{11}	-0.229	0.045
R^2		0.926
Adjusted R^2		0.896
Standar error of regression		0.005
DW		1.877

Source: Authors' calculations.

Figure 4. Actual and Fitted Inflation and Residuals^a



Source: Authors' calculations.

a. Fitted inflation is that calculated from equation (1).

the coefficients on both these terms, when entered separately, are quite similar, thus providing support for the present specification. An innovative feature of the results is the finding that the pass-through coefficients depend on the state of the business cycle and on the size of the exchange rate change, as discussed further below.

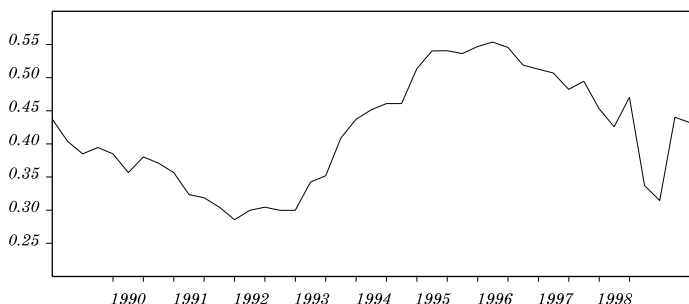
To interpret the estimated parameters for the transmission mechanism in the inflation process, we discuss now some of the implied “partial derivatives” of inflation with respect to various factors, each of which is treated separately from the others. Our estimates imply that, other things equal, a depreciation of 1 percent per quarter of the NIS against the dollar in a given year would result in a 2.1-percentage-point rise in the rate of inflation, mostly in the same year. This calculation assumes that there is no output gap, that is, that the rate of unemployment is about 6.5 percent. However, if the economy were in a slowdown, with a rate of unemployment close to 9 percent, inflation would accelerate by only 1.6 percentage points in response to the same exchange rate shock. In other words, the overall (current and lagged) pass-through from exchange rates to prices is estimated at about 0.5 under full employment and 0.4 in a downturn. Further, the pass-through is spread almost equally over the current and previous quarter in a slowdown, but is faster under full employment (with a coefficient of 0.3 on the contemporaneous term and 0.2 on the one-quarter lag).

To examine whether the size of exchange rate fluctuations matters for the pass-through, we attached, as mentioned above, dummy variables to the direct exchange rate pass-through for the last quarter of 1998 and the first quarter of 1999—a period of sharp exchange rate turbulence. We found that, relative to the earlier sample estimates, in this specification all of the pass-through effects shifted to the contemporaneous term. This indicates that, when exchange rate shifts are sizable, prices respond more quickly.⁵

Figure 5 depicts the implied within-sample, time-varying, overall pass-through coefficient from the NIS-dollar exchange rate to the CPI.

5. We also explored additional specifications of equation (1). First, we checked whether the pass-through associated with the foreign inflation variable varies with the business cycle, as specified for the exchange rate variable. Second, we explored whether the size of the fluctuation in the rate of unemployment has an impact, per se, on the pass-through coefficient. Third, we tested for whether there was a difference between the pass-through effects arising from currency depreciations and those arising from appreciations. Fourth, the effects of the *ex ante* real interest rate on the rate of inflation were allowed to depend on the state of the economy. We found no evidence in support of any of these alternative specifications.

Figure 5. Time-Varying Overall Pass-through Coefficient from the Nis-Dollar Exchange Rate to the CPI



Source: Authors' calculations.

The dependence of the pass-through on the state of economic activity is quite evident. In the early 1990s the overall pass-through plunged from 0.45 to almost 0.25 at the end of 1991 and the beginning of 1992, a period during which unemployment surged. This was mainly the result of an influx of immigrants, which greatly increased labor supply. On the other hand, the marked recovery in economic activity thereafter got translated into a rise in the pass-through coefficient, which reached a peak of almost 0.55 in mid-1996. The slowdown in the most recent period has led to a decline in the degree of pass-through.

As for the direct effects of monetary policy changes, we find that a rise of 1 percentage point in the ex ante real interest rate from the previous year's level is associated with a decrease in the rate of inflation of 1.7 percentage points (about 1.4 in the same year and 0.3 in the subsequent year). A rise in prices abroad of 1 percent per quarter during the year would lead to a rise of 0.6 percentage point in the rate of inflation, which would be spread evenly over two years. Further, a rise in the rate of unemployment by 1 percent from the previous year's level would be associated with a reduction of 0.7 percentage point in the rate of inflation in that year. Of that, 0.52 percentage point would be due to the direct effect on inflation, and the rest due to the moderating effect on the pass-through from exchange rates to prices.⁶

6. No dummy variable was introduced for the interaction term between the rate of unemployment and exchange rate depreciation because of insufficient degrees of freedom.

Before we move on to further applications of the parameter estimates, it is well to discuss some of their potential limitations and ways to overcome these limitations. Although in principle an equation such as (1) may be subject to simultaneity (that is, the regressors may be correlated with the error term), more detailed analysis suggests that this issue may not be very relevant for the present application. First, when Granger causality tests are run for the variables in the sample, in monthly terms for lags of one and two months, we find no evidence for significant causality from the rate of inflation to the rate of depreciation, or to the real interest rate (for detailed results, see Bar-Or, 1999). Yet we do find significant causality from the real interest rate and the rate of depreciation to the rate of inflation.⁷ Second, if equation (1) is estimated using two-stage least squares, the resulting coefficients are very similar to those reported in the table but are less precisely estimated.

Moreover, the following empirical considerations hold. First, the rate of unemployment is typically a lagging indicator for macroeconomic conditions in Israel and is not related to the contemporaneous rate of inflation. Second, for a large part of the sample period there was nominal exchange rate targeting, using foreign exchange market intervention, and thus there was very limited exchange rate adjustment in response to shocks; that is, the path of the nominal exchange rate was predetermined to a large degree. Also, in many macroeconomic models, financial markets clear faster than goods markets. Finally, as far as the real interest rate variable is concerned, the central bank's setting of nominal interest rates probably reacts more to lagged values of inflation expectations and of inflation shocks than to their current values, and market-based inflation expectations are known to be largely adaptive. The combination of these characteristics reduces the scope for simultaneity.⁸

2.2 Quantifying the Role of Various Factors in the 1997-98 Disinflation

As indicated, an important drawback of previous empirical models is that they could not account well for important turning points

7. As is well known, it is not possible to determine the direction of contemporaneous causality by means of Granger tests.

8. As far as the potential for multicollinearity is concerned, contemporaneous cross-correlations among the various explanatory variables are quite small and not statistically significant.

in the process of inflation as measured by quarterly data. Consequently, they had to rely on dummy variables to prevent these turning points from causing imprecise parameter estimates. Here we illustrate how the present inflation equation is able to account well, within the sample, for the marked reduction in the rate of inflation in the period from 1997Q4 to 1998Q3. Inflation in that period fell to about 4.2 percent per year, compared with 8.8 percent per year in the period 1996Q4 to 1997Q3. The relevant data for this task are provided in table 3; see also Bar-Or (1999). The data are organized in the form suggested by taking first differences in equation (1) and measuring by $\Delta\pi$ the drop (of 4.6 percentage points) in the rate of inflation to be accounted for.

Table 3 shows that the estimated equation captures the reduction in the rate of inflation quite well.⁹ A tightening of monetary conditions, as captured both by a higher ex ante real central bank interest rate and by a contemporaneous slower rate of depreciation of the NIS against the dollar, was quantitatively the key factor accounting for the reduction in inflation. In addition, the economic slowdown (as captured by a higher rate of unemployment) and the marked fall in fuel prices abroad helped lower inflation in the period under discussion.

Table 3. Contributors to Inflation Performance in the 1997-98 Disinflation^a
Percent

	<i>1996Q4-1997Q3</i>	<i>1997Q4-1998Q3</i>	<i>Estimated contribution</i>
Inflation rate	8.8	4.2	4.6
"Explained" inflation rate	9.2	4.6	4.6
Foreign inflation	-5.1	-4.7	-0.1
Oil price change	-9.2	-31.4	0.4
Depreciation of NIS against the dollar	11.5	5.9	1.7
Ex ante real interest rate	4.1	5.2	2.0
Unemployment rate	7.6	8.5	0.6

Source: Authors' calculations.

a. Raw data are the source for the first two columns. The third column is derived by applying first differences to equation (1), using the estimated parameter values. "Explained" inflation is the one corresponding to the basic equation underlying this analysis.

9. In addition, as shown in Bar-Or (1999), the estimated equation yields satisfactory results in out-of-sample forecasts. Using actual values of the right-hand-side variables, estimates of equation (1) up to 1997Q3 predict a reduction of 4.5 percentage points in the rate of inflation, compared with an actual reduction of 4.6 percentage points. Also, the contribution of the explanatory variables to the disinflation is very similar to that found within the sample, as shown in table 3.

2.3 Inflation Forecasting

We now turn to the potential use of equation (1) to forecast inflation. Doing so requires formulating forecasts for the right-hand-side variables, such as the rate of currency depreciation, foreign-price inflation, the rate of unemployment, and so on. Although forecasts of the external variables can probably be taken from foreign sources, a proper derivation of forecasts of the internal variables would require working with a fully simultaneous macroeconomic model within which interdependencies among various forecasts could be taken into account. As indicated above, work in developing overall macroeconomic models for the Israeli economy is under way at the Bank of Israel, and further research is needed before a relatively satisfactory small-scale macroeconomic model will be available to derive macro forecasts. Because of this constraint, we focus here on a relatively limited use of equation (1) in forecasting inflation, based on various assumptions about the evolution of the right-hand-side variables.

Consider the forecasting of inflation for the four quarters from 1997Q4 to 1998Q3 based on information and other forecasts that were available as of the third quarter of 1997 and based on the parameter estimates of equation (1) obtained up until 1997Q3. On the basis of forecasts by the International Monetary Fund at that time, we assumed that the rate of change in world fuel prices would be 0.4 percent in the first of the four quarters and -1.6 percent in the remaining three quarters. We further assumed that prices of Israel's imports would fall at a rate of -0.4 percent per quarter. In addition, on the basis of a small-scale macroeconomic model of the real side of the economy developed at the Research Department of the Bank of Israel, we assumed that the rate of unemployment for the relevant four quarters would be 7.9 percent in the first quarter and 8.1 percent in the next three quarters.

The next task is to specify the path of the exchange rate. As is well known, typically there are no satisfactory models for predicting exchange rate fluctuations on a monthly or even a quarterly basis, whether in Israel or in the industrial countries. Much of what appears to move foreign exchange markets is "news," which by definition is hard to predict. What we can do at this stage, however, is derive various forecasts for the rate of inflation based on several alternatives for the rate of currency depreciation in the pertinent future. However, to be specific, consider the forecasts based on what was a relatively plausible assumption at that time about the path of

the exchange rate, namely, appreciations of 0.4 percent and 0.1 percent in the first two quarters of the forecast horizon, and depreciations of 1.6 percent in each of the following two quarters.

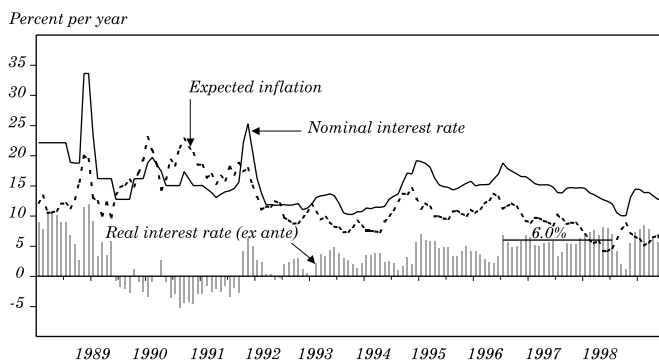
It remains to forecast the *ex ante* real interest rate on central bank funds. In the very short run this can be treated as a policy variable, and as such it should be compatible with achieving the inflation target. Using an *ex ante* real interest rate of 5 percent, in line with rates observed since mid-1996, we derived an inflation forecast of 5 percent for the four-quarter horizon; this was lower than the inflation target range of 7 to 10 percent.

Again, one could derive alternative forecasts based on differing assumptions about the evolution of the exchange rate and of the *ex ante* real interest rate. We believe that more work exploring the forecasting properties of an equation such as (1), and comparing it with the forecasts of other models, is an important avenue for useful research in this area, as is the development of a fully specified, small-scale, simultaneous-equation macroeconometric framework.

3. ASSESSING MONETARY POLICY RULES

Here we attempt to formalize some aspects of monetary policy determination. Clearly, no simple mathematical rule can truly describe a process that involves frequent sharp, unexpected changes in economic circumstances, for example from an LTCM-type default or crisis in another country. With these caveats in mind, it is still instructive to explore the performance of various monetary policy rules, such as those estimated by Taylor (1993) and by Clarida, Galí, and Gertler (1998) for monetary policy of the main industrial economies, using data for Israel.

Figure 6 shows the path of the nominal interest rate as well as of market-based inflation expectations and the implied expected real interest rate for the period from 1988 to the present. It can be seen that, together with the gradual decrease in inflation expectations, especially after 1996, there has been a move toward a more uniform range of *ex ante* real interest rates than in the early 1990s, to levels of about 5 to 7 percent in annual terms. To a large extent, throughout the 1990s monetary policy evolved from a main emphasis on nominal exchange rate targeting in the early 1990s to inflation targeting and enhanced exchange rate flexibility in recent years. It is for these reasons—that is, possible changes in the monetary policy rule within the sample—that we perform our analysis here on monthly data

Figure 6. Effective Nominal and Real Interest Rates and Expected Inflation in Israel^a

Source: Authors' calculations.

a. Nominal interest rates are those on liquid resources of the central bank.

(which is the periodicity of interest rate decisions) for the relatively more uniform period from 1994 onward.¹⁰

3.1 Interest Rate Changes and the Role of Inflation Expectations

The existence of reliable data on market-based inflation expectations is very useful in an inflation targeting context like that of Israel. In fact, substantial changes in these expectations have typically triggered sharp monetary policy responses. For example, the episodes of late 1994 and early 1995, the second half of 1996, and late 1998 (figure 6) illustrate marked increases in central bank rates in the face of sharp increases in inflation expectations. In the first two cases the rise in expected inflation was mainly due to a fiscal expansion together with overheating of the domestic economy, all of which led to a buildup of price pressures. In late 1998 the rise in the interest rate was associated with increased inflation risks due to very rapid depreciation of the NIS during world financial crises.

Tables 4, 5, and 6 report statistical and historical information on interest rate changes by the Israeli central bank, as well as on the main characteristics of fluctuations in the rate of inflation.

10. Interestingly, most of the applied research on monetary policy rules for industrial countries uses quarterly data, in spite of the fact that monetary policy decisions are made much more frequently.

Table 4. Statistical Characteristics of the Bank of Israel's Official Interest Rate

Percent per year except where indicated otherwise

	<i>January 1994 to July 1999</i>	<i>January 1994 to June 1996</i>	<i>July 1996 to July 1999</i>
Simple average	13.41	13.72	13.17
Standard deviation	1.82	1.95	1.68
Normalized standard deviation	0.14	0.14	0.13
Maximum	17.00	17.00	17.00
Minimum	9.50	10.50	9.50
Average increase	0.97	0.78	1.55
Average decrease	0.54	0.72	0.49
Standard deviation of increases	0.65	0.46	0.88 ^a
Standard deviation of decreases	0.29	0.42	0.22
No. of months	67	30	37
Frequency of changes (months)	1.6	1.7	1.5
Frequency of turning points (months)	7.4	7.5	7.4
No. of increases	16	12	4
No. of decreases	26	6	20

Source: Authors' calculations.

a. The figure is 0.4 if November is excluded.

Table 5. Statistical Characteristics of the Inflation Rate in Israel

Percent per year except where indicated otherwise

	<i>January 1994 to July 1999</i>	<i>January 1994 to June 1996</i>	<i>July 1996 to July 1999</i>
Average	9.31	11.18	7.79
Standard deviation	2.89	2.09	2.54
Normalized standard deviation	0.31	0.19	0.33
Maximum	14.45	14.45	12.93
Minimum	3.03	7.75	3.03
No. of months in period	67	30	37

Source: Authors' calculations.

Table 6. Bank of Israel Interest Rate Changes

<i>Date of announcement</i>	<i>Change in interest rate (percentage points)</i>	<i>Level of interest rate after change (percent per year)</i>
December 28, 1993		10.50
May 9, 1994	0.42	10.92
May 23, 1994	0.60	11.52
June 27, 1994	0.54	12.06
July 26, 1994	0.44	12.50
August 29, 1994	1.50	14.00
September 25, 1994	1.50	15.50
November 28, 1994	1.50	17.00
February 21, 1995	-0.70	16.30
March 19, 1995	-1.50	14.80
April 24, 1995	-0.80	14.00
May 29, 1995	-0.50	13.50
July 24, 1995	-0.30	13.20
September 21, 1995	0.50	13.70
October 23, 1995	0.50	14.20
December 25, 1995	-0.50	13.70
January 29, 1996	0.30	14.00
April 21, 1996	0.80	14.80
May 27, 1996	0.70	15.50
June 24, 1996	1.50	17.00
July 29, 1996	-0.70	16.30
August 26, 1996	-0.50	15.80
September 24, 1996	-0.30	15.50
October 28, 1996	-0.30	15.20
December 23, 1996	-0.50	14.70
January 27, 1997	-0.50	14.20
February 24, 1997	-0.30	13.90
June 18, 1997	-1.20	12.70
August 25, 1997	0.70	13.40
January 26, 1998	-0.50	12.90
February 23, 1998	-0.30	12.60
March 23, 1998	-0.40	12.20
April 27, 1998	-0.30	11.90
May 25, 1998	-0.30	11.60
June 22, 1998	-0.30	11.30
July 27, 1998	-0.30	11.00
August 6, 1998	-1.50	9.50
October 26, 1998	2.00	11.50
November 12, 1998	2.00	13.50
February 22, 1999	-0.50	13.00
March 29, 1999	-0.50	12.50
April 26, 1999	-0.50	12.00
July 25, 1999	-0.50	11.50
November 22, 1999	-0.30	11.20
December 27, 1999	-0.50	10.70

Source: Bank of Israel

The highest value of the nominal interest rate on central bank funds in the period since 1994 was 17 percent per year, in the middle of 1996. The lowest was 9.5 percent per year, in August 1998. It can be seen that, out of the sixty-seven months in our sample, the average frequency of interest rate changes was almost two months. Moreover, turning points in the trend of interest rates—from increases to decreases, and vice versa—have been frequent, occurring every 7.4 months on average. From table 5 it can be seen that the inflation environment during the sample period was relatively volatile; thus it is plausible that the volatility in the fundamentals influencing the inflation process prompted frequent interest rate reactions. Another interesting feature of the results is that, in absolute (percentage point) terms, increases in interest rates were typically larger than decreases in rates. This asymmetric pattern would seem quite plausible in an economy in which there are still forces (from the high-inflation periods in the past) toward inflation bias, and where gradual disinflation is a policy objective. In such a context, there is a stronger interest rate response in the face of rises in inflation than in the face of decreases in inflation.

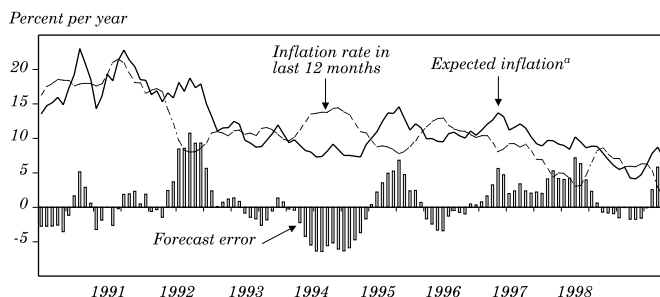
As indicated, market-based inflation expectations are a key variable in the inflation targeting policy regime. That this is the case is quite evident from central bank official statements and reports (see, for example, the Bank of Israel's annual reports and inflation reports) and from typical analysis in the media. In fact, some newspapers report the previous day's market-based measure of inflation expectations. The limitations of this indicator are well known and have been taken into account in the policy process. Moreover, as suggested by the analysis of Bernanke and Woodford (1997), the proper conduct of inflation targeting requires using not only market-based expectations but also the central bank's own forecasts. One key limitation of market-based inflation expectations is the fact that market data on yields on indexed and nonindexed bonds actually measure the sum of expected inflation and the risk premium. Only under the assumption of a constant and zero risk premium is it possible to attribute month-to-month changes in the difference between these yields to changes in expectations of inflation.

A second limitation is that, to a large extent, measured inflation expectations are backward-looking and reflect adaptive behavior by the public; this is evident from figure 2. The level and fluctuations in twelve-months-ahead expected inflation appear to be closely correlated with those of inflation in the last twelve months. Hence a

variable that in principle should contain a strong forward-looking element is largely determined by past performance, although it is well known that for some stochastic processes of the rate of inflation, “adaptive” expectations can be “rational” after all. This means that it would probably be hard to detect expected future turning points in the inflation process solely on the basis of market-based expectations.

A third limitation is that, in a regime where the authorities conduct inflation forecast targeting, with market-based inflation expectations as one of the key indicators, and where there has been gradual learning about the anti-inflation stance of the authorities, it is very difficult to determine the properties of market-based inflation expectations. A sudden rise in expected inflation can trigger a strong interest rate response, which in turn succeeds in stopping the inflationary pressures, so that by, say, the end of the year, inflation is back to the target. Under these conditions, a comparison of expected and actual inflation will lead to a sizable forecast error. Figure 7 depicts twelve-months-ahead expected inflation and actual inflation as recorded twelve months thereafter. It can be seen that there are periods of considerable measured forecast errors and that these errors exhibit relatively strong serial correlation. Again, whether these observations correspond to “irrational” expectations or to rational expectations under frequent changes in fundamentals and gradual learning about the authorities’ inflation forecast targeting cannot be determined on the basis of these data alone. In any case, casual observation suggests that, as the 1990s advanced, there indeed was a learning process under inflation targeting by both the authorities and the public at large.

Figure 7. Expected and Actual Inflation in Israel



Source: Authors' calculations.

a. Expected inflation is derived from capital market data on indexed and nonindexed bonds and is shifted twelve months forward.

3.2 Estimating a Forward-Looking Analogue of a Taylor Rule for Israel

As stressed above, no simple formula can summarize the complexity of the interest rate determination process. With this important caveat in mind, recent influential research by Taylor (1993) has developed a relatively simple empirical rule that describes quite well ex post the behavior of the U.S. federal funds rate under the Federal Reserve's policies as a function of the output gap and the rate of inflation. Svensson (1999) developed the conditions under an inflation targeting regime that will lead to policy rules of the type estimated by Taylor. In both these analyses it was assumed that the central bank makes no use of any available market-based measures of inflation expectations. Here we consider estimates of a relatively plausible interest rate rule for Israel, which exploits the existence of market-based inflation expectations. The rule takes the following form:

$$I_t = \alpha_0 + \alpha_1 \left[\alpha_2 \pi_t^e + (1 - \alpha_2) \pi_{t-1} \right] + \alpha_3 (y_{t-1} - y_{t-2}^*) + \alpha_4 I_{t-1} + \alpha_5 t \text{UHD}_t + \xi_t . \quad (2)$$

In this equation, $y - y^*$ denotes the gap between the last available annual rate of change in the Bank of Israel's economic activity index and a twelve-month annual average calculated from the preceding month backward, and *trend* is a time trend variable that in part will capture the gradual move to increased monetary tightening over time. The presence of the lagged dependent variable represents the well-known case for partial interest rate smoothing, and the variable

$$\alpha_2 \pi_t^e + (1 - \alpha_2) \pi_{t-1} ,$$

stands for the inflation "environment." This reflects a combination of a backward-looking element (the last known value of annual inflation) and a potentially forward-looking one (the last known value of expected inflation as of the time of the interest rate decision). Lagged inflation is of importance mainly because of the widespread indexation in Israel of wages and financial assets to the CPI, which works with a lag, and expected inflation enters as a variable that potentially includes forward-looking elements. In this specification an increase in inflation expectations and/or an increase in last known annual

inflation would trigger a rise in interest rates.¹¹ Although in principle the equation should actually include the gap between the inflation environment and the inflation target, this has no major practical importance here because the latter was relatively unchanged in the sample period (see table 1). As is well known, a linear specification such as equation (2) arises, for example, when the central bank's preference function is quadratic in deviations of the inflation environment from target and in the output gap.

In the econometric implementation, we ensured that the timing of the right-hand-side variables reflected that of the last available information before the policy decision was made. In Israel the CPI for a given month is released on the fifteenth day of the subsequent month. Then, on the last Monday of the month, the central bank announces its decision regarding the interest rate on central bank funds for the subsequent month. For example, the CPI for June 1999 was released on July 15, and the central bank interest rate for August was announced on July 26. Only on rare occasions have there been deviations from this procedure. Thus the lagged inflation term corresponds to two months before the present month. Also, the last known monthly indicator of economic activity is that for a three-month lag, and the last known market-based inflation expectations correspond to the five weeks that precede the interest rate decision. Parameter estimates based on a sample of monthly data from 1994 to the present are given in table 7.

Table 7. Regression Estimates of the Monetary Policy Rule, January 1994 to July 1999

<i>Parameter in Equation (2)</i>	<i>Coefficient</i>	<i>Standard error</i>
α_0	0.0130	0.050
α_1	0.5000	0.000
α_2	0.7470	0.000
α_3	0.0790	0.005
α_4	0.4970	0.000
α_5	0.0003	0.000
R^2	0.946	
Adjusted R^2	0.942	
DW	1.910	

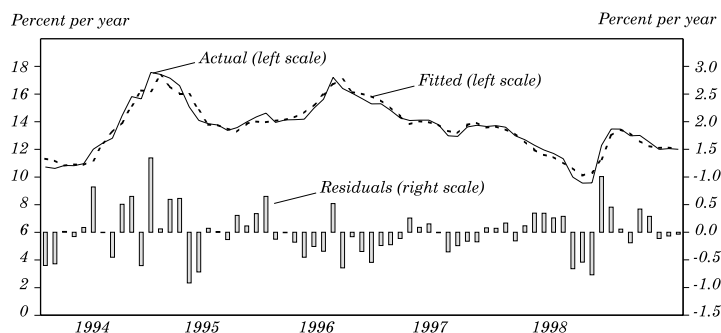
Source: Authors' calculations.

11. Previous work on the Bank of Israel's reaction function appears in Gottlieb and Ribon (1997), Djivve and Ribon (1999), Goldberg (1999), and Levanon (1998).

It can be seen that, on average, a rise in the inflation environment of 1 percentage point in a given month triggers a rise in the central bank rate of 0.5 percentage point. This indicates that in the very short run—say, a month—a rise in expected inflation does trigger a rise in the nominal interest rate, yet the impact coefficient is less than unity, and the implied ex ante real rate partially falls in that month, all else equal. To an important extent, this partial response is consistent with a considerable degree of interest rate smoothing: when conditions require a change in the interest rate, that change appears to be spread over several months. Accordingly, if the same increase in expected inflation does persist over a whole quarter, the overall response of the nominal interest rate will be close to 1.0, which is line with the estimates obtained by Levanon (1998) and Djivre and Ribon (1999).

Within the inflation environment variable, the strongest weight (0.75) is given to market-based inflation expectations. Figure 8 depicts the actual, fitted, and residual values for equation (2). The equation tracks relatively well the evolution of the central bank interest rate within the sample.¹²

Figure 8. Actual and Fitted Interest Rates and Residuals^a



Source: Authors' calculations.

a. Fitted interest rate is that calculated from equation (2).

12. We have also explored the possible inclusion of foreign interest rates and of the rate of domestic-currency depreciation as additional regressors in equation (2). The results, however, did not support their inclusion. It is plausible that market-based inflation expectations, already included as a regressor in the equation, capture well the potential effects of both these variables on the rate of inflation.

If estimation is conducted for the more recent sample period from July 1997 to July 1999, the coefficients change in a clear-cut pattern (table 8). First, there is now a stronger impact of the inflation environment variable on the central bank rate. Second, within the inflation environment variable there is now a stronger effect of forward-looking inflation expectations, and lagged inflation is no longer a significant explanatory variable beyond these expectations (we captured this by setting $\alpha_2 = 0$). Finally, there is a stronger reaction of contemporaneous interest rates to lagged interest rates. All of these considerations imply that a permanent 1-percentage-point rise in expected inflation would lead to a rise in the ex ante central real bank real interest rate, which is consistent with an inflation-stabilizing role of monetary policy (see Clarida, Galí and Gertler, 1998).

3.3 “Strict” or “Flexible” Inflation Targeting?

An important issue in characterizing central bank policy under inflation targeting is to determine—in Svensson’s (1999) terminology—whether targeting is “strict” or “flexible.” Strict targeting does not allow for countercyclical monetary policy, in that the output gap does not enter the interest rate rule beyond its impact on inflation forecasts. Flexible targeting does allow for such a countercyclical response. In official statements Bank of Israel officials have made it clear that their current policy is one of strict inflation targeting.

Table 8. Regression Estimates of the Monetary Policy Rule, July 1997 to July 1999

Parameter Equation (2)	Coefficient	SE
α_0	-0.030	0.052
α_1	0.548	0.000
α_3	0.204	0.001
α_4	0.637	0.000
α_5	0.0007	0.000
R^2		0.932
Adjusted R^2		0.920
DW		2.024

Source: Authors’ calculations.

A common argument has been that, in an economy with such a high-inflation history, strict targeting is needed in the first stages of disinflation, because of the weak credibility of monetary policy and the need to build the reputation needed for a disinflation to be effective. This argument implies that countercyclical policy would be contemplated if and when monetary policy comes to enjoy strong anti-inflation credibility. However, the fact that there is a significant, nonzero coefficient on the economic activity variable in the interest rate equation would suggest that, in practice, there is a partial countercyclical element to monetary policy. Yet whether or not this is the case cannot be determined with the present information alone. To the extent that the inflation environment variable is only an imperfect proxy for true expected future inflation, and to the extent that the latter does depend on the level of economic activity, the latter can appear in the equation with a nonzero coefficient. By itself this need not be interpreted as a deviation from strict inflation targeting. Thus, further work is needed to attempt to empirically discriminate strict from flexible inflation targeting. These and the other features of the results conform quite well with the findings of Clarida, Galí, and Gertler (1998) for monetary policy in the United States and in other industrial countries.

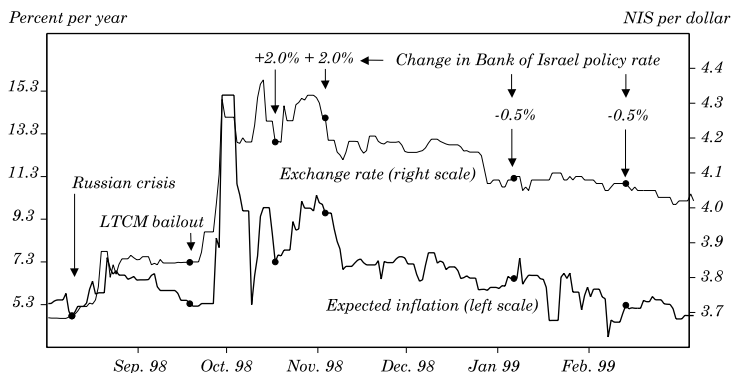
4. CONCLUDING REMARKS

To conclude, it is useful to illustrate the strong interactions between the transmission mechanism in the inflation process and monetary policy rules under inflation targeting; the episode immediately following the Russian crisis and the failure of LTCM in the second half of 1998 provides a convenient example. At that time, growing concern on the part of international investors about their investments in emerging countries led them to reduce their positions in those countries. Israel was among them: some foreign positions in the local stock market were liquidated and the funds transferred abroad. These developments led to a strong depreciation of the NIS within the very wide currency band, both against the currency basket and against the dollar, reaching about 15 percent on average from August to October 1998. In fact, in a space of just three days—October 6 to 8, 1999—the NIS fell against both the basket and the dollar by close to 10 percent, a surprising and unusual event in the contemporary Israeli foreign exchange market (see Bank of Israel, 1999b).

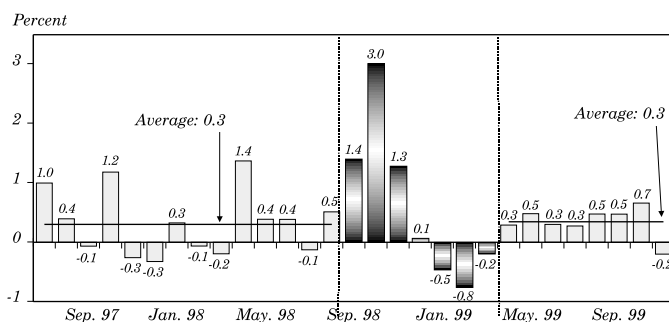
Following these dramatic events, during which the foreign exchange market, although not accustomed to shocks of this magnitude, continued to function in orderly fashion, the next policy concern was about their potential implications for inflation acceleration. In the high-inflation past, currency devaluations were typically one-time events that had a strong and permanent impact on prices and on inflation expectations. In an economy with advanced methods of wage and financial indexation, there was a very quick pass-through from changes in the exchange rate to actual and expected changes in the rate of inflation. However, in this episode one might have expected a relatively weaker pass-through because of the increased flexibility in the exchange rate regime, the weaker state of economic activity, and the stronger credibility of anti-inflation policy by the central bank. In other words, there were good reasons to believe that some degree of exchange rate overshooting had occurred and that eventually some degree of appreciation would offset the previous developments.

Figure 9 depicts the daily behavior of the U.S. dollar-NIS exchange rate and of twelve-months-ahead inflation expectations during this volatile period. The rapid depreciation was accompanied by a sharp upward shift in inflation expectations. There were also very large increases in consumer prices in September, October, and November 1998. In October alone, consumer prices rose by 3 percent (figure 10). Given the substantial risk of an acceleration of inflation

Figure 9. Exchange Rate and Twelve-month Inflation Expectations in Israel



Source: Bank of Israel.

Figure 10. Monthly Rates of Change in the CPI in Israel^a

Source: Authors' calculations.

well beyond the official target, the question for monetary policy was how and when to react to these events. And in doing so the authorities had to allow room for the possibility that these events might represent only a one-time jump in the price level and not necessarily an increase in the rate of inflation, as in the high-inflation past.

A first element in the policy dilemma was whether to intervene in the foreign exchange market to smooth out exchange rate fluctuations. Despite many calls for intervention in policy and public discussions, the central bank opted not to intervene, especially given that such intervention might well create additional incentives for capital outflows and for speculation against the central bank's actions. The central bank saw the situation as an opportunity to allow private market forces to fully determine the exchange rate, while internalizing the true extent of exchange rate risk in the new, more flexible regime. Nor did the central bank increase interest rates in September and October, as it believed the episode likely represented more of a one-time price-level jump than a permanent increase in the rate of inflation. Only toward late October, when substantial turbulence in domestic financial markets arose, did the Bank of Israel raise its interest rate by 2 percentage points. However, since this change was not followed by stabilizing trends in the foreign exchange market and in inflation expectations, a "surprise" additional interest rate rise of 2 percentage points followed in early November.

This policy move contributed to a reversal in the previous trend of the nominal exchange rate and in inflation expectations. As figure 10 shows, the rate of inflation soon moved back to its earlier level; this was accompanied by a sizable appreciation of the NIS (about 5 percent from December 1998 to March 1999), and inflation expectations adjusted downward. This opened some room for interest rate reductions in 1999. Our estimates indicate that although the overall pass-through to inflation may have remained unchanged in this episode, there has been an increase in the contemporaneous exchange rate coefficient, and a decrease in the lagged coefficient. One possible explanation is that the exchange rate shifts were so large that they prompted quicker price responses than before.

In sum, we believe these developments provide support for the policy strategy of focusing on the inflation target and allowing for market determination of the nominal exchange rate, with no intervention in the foreign exchange market (unless the market is not operating in an orderly fashion). Four months after the dramatic, 4-percentage-point rise in the central bank rate, the central bank was able to begin reducing interest rates without jeopardizing the inflation target. By mid-1999 there was a common assessment that inflation had returned to about 4 percent per year (although the rate of inflation for 1999 itself was forecast to be well below that figure). This was internalized by the government's decision to set the inflation target for the years 2000 and 2001 in the range of 3 to 4 percent.

It would be desirable in future work to explore analytically and empirically various aspects of inflation targeting that have emerged from Israel's experience. One of these is possible asymmetries in monetary policy actions in the course of a disinflation process, whereby the policy response to deviations of inflation above the target is stronger than those when inflation is below the target. Another is the evolution of the exchange rate pass-through mechanism as it relates to the process of disinflation, to the increased flexibility of the exchange rate regime, to the changing credibility of monetary policy and of the inflation target, and to the effective degree of external openness of the economy. Finally, a third topic for future study is the role of credibility of the inflation target, and of monetary policy, in choosing the degree of fixed versus flexible inflation targeting.

REFERENCES

- Azoulay, E., and D. Elkayam. 1997. "A Model of the Effect of Monetary Policy on Economic Activity and Inflation in Israel, 1988-1996." Occasional Paper 1. Jerusalem: Monetary Department, Bank of Israel, 1997 (in Hebrew).
- Bank of Israel. 1999a. *Annual Report 1998*. Jerusalem: Bank of Israel.
- . 1999b. *Inflation Report, First Half of 1999*. Jerusalem: Bank of Israel.
- Bar-Or, H. 1999. "The Inflation Process and the Passthrough from Exchange Rates to Prices in Israel in the 1990's." Internal working paper. Jerusalem: Research Department, Bank of Israel (June).
- Bernanke, B. S., and M. Woodford. 1997. "Inflation Forecasts and Monetary Policy." *Journal of Money, Credit and Banking* 29: 653-84.
- Bufman, G., L. Leiderman, and M. Sokoler. 1995. "Israel's Experience with Explicit Inflation Targets: A First Assessment." In *Inflation Targets*, edited by L. Leiderman and L. E. O. Svensson. London: Centre for Economic Policy Research.
- Bufman, G., and L. Leiderman. 1998. "Monetary Policy and Inflation in Israel." Discussion Paper 98.04. Jerusalem: Research Department, Bank of Israel.
- Clarida, R., J. Galí, and M. Gertler. 1998. "Monetary Policy Rules and Macroeconomic Stability: Evidence and Some Theory." Discussion Paper 1908. London: Centre for Economic Policy Research (June).
- Dahan, M., and M. Strawczynski. 1997. "Fiscal Policy and Inflation in Israel." Unpublished manuscript. Jerusalem: Research Department, Bank of Israel.
- Djivre, J., and S. Ribon. 1999. "Monetary Policy, the Output Gap and Inflation—The Case of Israel." Unpublished manuscript. Jerusalem: Research Department, Bank of Israel (April).
- Frenkel, J. A. 1999. "Central Bank Independence and Monetary Policy for Price Stability." In *Inflation and Disinflation in Israel*, edited by L. Leiderman. Jerusalem: Bank of Israel.
- Goldberg, D. 1999. "Interest Rate Smoothing in Inflation Targeting Models." M.A. thesis. Tel Aviv: Tel Aviv University (June).
- Gottlieb, D., and S. Ribon. 1997. "Private International Capital Movements and Monetary Policy in Israel-October 1988 to March 1997." Discussion Paper 97.09. Jerusalem: Research Department, Bank of Israel (December).

- Kahn, M., S. Kandel, and O. Sarig. 1998. "Real and Nominal Effects of Central Bank Monetary Policy." Unpublished manuscript. Jerusalem: Monetary Department, Bank of Israel (May).
- Leiderman, L., ed. 1999. *Inflation and Disinflation in Israel*. Jerusalem: Bank of Israel.
- Leiderman, L., and L. E. O. Svensson, eds. 1995. *Inflation Targets*. London: Centre for Economic Policy Research.
- Leiderman, L., and G. Bufman. 1996. "Searching for Nominal Anchors in Shock-Prone Economies in the 1990s: Inflation Targets and Exchange Rate Bands." In *Securing Stability and Growth in Latin America: Policy Issues and Prospects for Shock-Prone Economies*, edited by R. Hausmann and H. Reisen. Paris: Organisation for Economic Co-operation and Development.
- Levanon, G. 1998. "On the Bank of Israel's Reaction Function." M.A. thesis. Tel Aviv: Tel Aviv University.
- Morandé, F., and K. Schmidt-Hebbel. 1999. "The Scope for Inflation Targeting in Emerging Market Economies." Unpublished manuscript. Santiago: Central Bank of Chile.
- Sokoler, Meir. 1997. "Credibility Half-Won in an Ongoing Battle: An Analysis of Inflation Targets and Monetary Policy in Israel." Working paper. Jerusalem: Monetary Department, Bank of Israel.
- Svensson, L. E. O. 1999. "Inflation Targeting as a Monetary Policy Rule." *Journal of Monetary Economics* 43: 607-54.
- Taylor, J. B. 1993. "Discretion versus Policy Rules in Practice." *Carnegie-Rochester Series on Public Policy* 39: 195-214.

ESTIMATING MONETARY POLICY RULES FOR SOUTH AFRICA

Janine Aron

University of Oxford

John Muellbauer

University of Oxford

Monetary policy in South Africa's emerging market economy, given capital account liberalization and severe constraints on fiscal policy, has the major responsibility for curbing inflation and currency instability while trying to ensure sufficient growth for longer-term political stability and the reduction of poverty. South Africa's monetary policy is going through a rapid transition away from an old-fashioned, partly monetarist view that assumed a simple connection between the money supply and inflation. Accumulated international evidence does not support this view, and in South Africa itself the force of circumstance has recently compelled a move away from these ideas. The shift to a regime with an explicit, publicly announced inflation goal in late 1999 demands good forecasting models of inflation, using all available information to guide policy rather than a single intermediate target such as a monetary aggregate.¹ Important, too, is a shared understanding with the private sector of the effectiveness of monetary policy for inflation, as well as greater policy transparency and more open public discussion of the underlying issues (see, among others, Leiderman and Svensson, 1995; Bernanke and Mishkin, 1997; Bernanke and others, 1999).

The authors acknowledge funding from the Central Bank of Chile and the U.K. Department for International Development for the project New Monetary Policy Challenges for Sustainable Growth in South Africa, grant number R7291. John Muellbauer acknowledges additional research support from the Economic and Social Research Council under grant number R000237500. The authors are grateful for comments from Luis Herrera, Christopher Adam, and seminar participants at Oxford and Nottingham Universities, the School of Oriental and African Studies, and Chatham House.

1. The feasibility of moving to a formal inflation targeting system was first discussed by the South African Reserve Bank in Casteleijn (1999) and by Kahn (1998).

Monetary Policy: Rules and Transmission Mechanisms, edited by Norman Loayza and Klaus Schmidt-Hebbel, Santiago, Chile. ©2002 Central Bank of Chile.

The quarterly macroeconometric model used by the South African Reserve Bank (SARB) has not wholly been opened to outside scrutiny;² by contrast, in the United Kingdom models developed by the Treasury and the Bank of England are published and discussed at conferences and academic panel meetings. Discussions suggest that the SARB's large macro model³ appeared to omit two of the most important interest rate transmission channels: that via wealth effects, and hence domestic asset prices; and that via expectations.⁴ Consequently, it is difficult to arrive at a well-informed view of the size and dynamics of the effects of monetary policy. Further, these models gave insufficient attention to the consequences of regime shifts, such as financial liberalization, and more generally to the highly influential Lucas critique of the use of policy modeling (Lucas, 1976). Such defects in earlier U.K. models played a major role in the costly macroeconomic policy failures of the late 1980s and early 1990s. This paper analyzes the conduct of monetary policy by the SARB, both through a description of the historical record and through formal modeling of various extended Taylor rules for interest rate policy formation.

Table 1 shows the different monetary policy regimes in place in South Africa since the 1960s. The first regime, in effect until the early 1980s, was one based on liquid asset ratios, with quantitative controls on interest rates and credit. This regime was reformed gradually toward a cash reserves-based system by about 1985. Preannounced, flexible monetary target ranges were used from 1986 onward, and the central bank's discount rate was used to influence the cost of overnight collateralized lending and hence market interest rates. Financial liberalization beginning in the early 1980s, and a more open capital account in the 1990s, much diminished any usefulness of such targets. In later years they were therefore formally supplemented by a broader set of indicators (see *South African Reserve Bank Quarterly Bulletin*, October 1997). It is likely that such indicators played a role in previous years as well.

2. An exception is a technical workshop in September 1998, attended by private sector and academic participants, at which certain sectoral equations of the pre-2000 models were discussed, some of which have been published piecemeal in the *South African Reserve Bank Quarterly Bulletin*.

3. A model comprising 400 equations was in use until 2000. This has been replaced by a far smaller model, which is now responsible for the main forecasts of the SARB (also not published).

4. The inflation sector of the model (see Pretorius and Smal, 1994) does, however, include one asset price (the exchange rate) and a simple expectations proxy in the inflation equation, based on lagged inflation and the change in the money supply.

Table 1. Sequence of Monetary Policy Regimes in South Africa

<i>Years</i>	<i>Monetary Policy Regime</i>
1960-81	Liquid asset ratio-based system with quantitative controls on interest rates and credit
1981-85	Mixed system during transition (see appendix for details)
1986-98	Cost of cash reserves-based system with preannounced monetary targets (M3)
1998-99	Daily tenders of liquidity through repurchase transactions (repo system), plus pre-announced M3 targets and targets for core inflation
2000-	Repo system with inflation targeting (CPI-X)

Source: Authors' calculations. For more details see section 1.

Starting in early 1998, a new system of monetary accommodation was introduced, with daily tenders of liquidity through repurchase transactions. Monetary growth guidelines continued to be announced, on a three-year rather than an annual basis. Target ranges for core inflation were informally announced beginning in 1998, and an inflation targeting regime was instituted in 2000 (see table 2).

Table 2. Money Growth and Inflation Targets in South Africa

<i>Percent</i>						
<i>Year</i>	<i>Money growth</i>		<i>Inflation</i>			
	<i>Guidelines</i>	<i>Actual</i>	<i>Core target^a</i>	<i>Actual total</i>	<i>Actual core</i>	<i>CPIX</i>
1986	16-20	9.3		18.6		
1987	14-18	17.6		16.1		
1988	12-16	27.3		12.9		
1989	14-18	22.3		14.7		
1990	11-15	12.0		14.4		
1991	8-12	12.3		15.3	18.9	
1992	7-10	8.0		13.9	16.8	
1993	6-9	7.0		9.7	12.6	
1994	6-9	15.7		9.0	8.9	
1995	6-10	15.2		8.7	7.9	
1996	6-10	13.6		7.4	7.2	
1997	6-10	17.2		8.6	8.8	
1998	6-10	14.6	1-5	6.9	7.5	7.1
1999	6-10	10.2	1-5	5.2	7.9	6.9

Source: *South African Reserve Bank Quarterly Bulletin*, various issues.

a. Core targets were informally announced. The core inflation rate is the overall consumer price index (CPI) for the metropolitan and other urban areas, excluding certain food prices, interest costs, value-added tax, and municipal rates. In February 2000 a CPIX target of 3-6 percent was announced for 2002, in the context of a new inflation targeting regime. The CPIX inflation rate is the overall CPI for metropolitan and other urban areas, excluding interest rates on mortgages.

Our principal interest in this paper is in the second of these regimes (the one immediately preceding inflation targeting), when the short-term interest rate first became the main monetary policy instrument of the SARB. Setting of monetary policy was particularly opaque in this regime and has never been studied in the context of rigorous empirical models. It is not clear which indicators influenced interest rate policy in practice, or what weights attached to them. Our aim is to clarify the historical record.

Further, despite the major changes in policy now in process and in prospect, continuities with past policies are inevitable. The new interest policy rules under inflation targeting can be seen as variants, using different weights, of the interest rate feedback rules we have found to describe past behavior. Our analysis is intended to contribute toward an understanding of the likely continuities as well as changes in policy. Moreover, many structural economic features persist across different regimes.

Section 1 of the paper describes the institutions of South African monetary policy: the central bank, monetary policy regimes and operating procedures, exchange rate regimes and the capital account, and targeting policies. Section 2 gives narrative evidence across particular episodes of how policy has operated in practice. Periodically, major shocks in the form of significant gold price changes and political crisis or change have resulted in large changes in capital flows, which have complicated monetary management.

Section 3 analyzes quarterly extended Taylor rules as quantitative descriptions of monetary policy in the 1986-97 period (using our own forecasting models up to 1998 for output and inflation, to derive efficient instruments). The basic Taylor rule with partial adjustment and incorporating a foreign interest rate gives a poor description of policy. Indeed, at face value, such a rule suggests an apparently perverse policy with respect to inflation. However, this ignores the reactions of interest rates to excess money growth, which is found to be significant in a further extension of the model, reducing the apparent perversity. We show that a satisfactory policy description needs to control for financial liberalization, which, with the removal of quantitative controls on interest rates and credit and restrictions on competition, was associated with a substantial rise in real interest rates in South Africa after 1980. Weak evidence was found for structural breaks reflecting balance of payments considerations. Even with the more satisfactory model, it is plain that forecast inflation received a lower weight in the reaction function in the 1986-97 period than in most of the economies studied by Clarida, Galí, and Gertler (1998a). Section 4 summarizes the findings and concludes.

1. INSTITUTIONS OF SOUTH AFRICAN MONETARY POLICY

1.1 The South African Reserve Bank

The legal independence of the SARB is guaranteed by the South African constitution (approved by the Constitutional Court in December 1996), which states: "The primary object of the SARB is to protect the value of the currency in the interest of balanced and sustainable economic growth in the Republic. The SARB, in pursuit of its primary object, must perform its functions independently and without fear, favour or prejudice, but there must be regular consultation between the Bank and the Cabinet member responsible for national financial matters." The constitution can only be altered by a two-thirds parliamentary majority; any other attempt to dilute the independence or alter the objectives of the SARB would be contested in the Constitutional Court. In practice, before 1996 the central bank operated largely with autonomy, although it was not always immune from political interference. Arguably, the constitution formalized the stated ultimate goal of monetary policy between 1989 and 1995, that of low inflation (see, for example, Stals, 1995a).

The constitution further clarifies that the SARB shall be regulated in terms of an act of Parliament, which determines the exact powers and functions of the SARB and the conditions governing their exercise or performance. Both the transparency and the accountability of monetary policy, as regulated by the Reserve Bank Act (1989, with subsequent amendments), have improved with the move to inflation targeting in 1999 and 2000. The act requires the publication of monthly statements of assets and liabilities and submission of an annual report to Parliament, and periodically the governor of the SARB appears before the Standing Committee on Finance. However, during the policy regime with loose monetary guidelines, the law was not explicit about what level of inflation offered sufficient price stability, the time horizon within which it should be achieved, and with whom the ultimate responsibility for price stability rested. Thus there were no explicit benchmarks against which the performance of the SARB could be judged, and this diminished accountability. By contrast, under the new, inflation targeting regime, the target range of 3 to 6 percent specified by the Ministry of Finance is for a particular price index and is to be reached on average for 2002.

This is the clear responsibility of the Monetary Policy Committee of the SARB.⁵

Since its establishment in 1921, the SARB has been privately owned. Its shares are listed on the Johannesburg Stock Exchange, and there is a ceiling on the number of shares that one person or institution may hold. After transfers to reserves, dividend payments, and other provisions, the surplus of earnings is paid to the government. The Reserve Bank Act states that the SARB's management and functions are ultimately the responsibility of the SARB's full fourteen-member Board of Directors,⁶ which meets four times a year at present. The minutes of board meetings are not published.

In practice and by law, the operation of the main monetary policy tool, the so-called bank rate, between 1986 and 1999 was at the behest of the governor, after consultation with the deputy governors (see section 1.3).⁷ Minutes of these meetings were not published. The minister of finance could also be consulted, but policy could be altered without the minister's approval, and minutes of the minister's meetings with the SARB were not published. The president of South Africa appoints the governor and three deputy governors for terms of five years.⁸ Typically, however, the tenure of governors and deputies has been longer than this,⁹ which may have enhanced the independence of the SARB but may also have concentrated power in the hands of too few.

5. There are, however, currently some weaknesses in the institutional design of the SARB's inflation targeting regime, which may compromise transparency and accountability. Notably, there are no explicit rules governing what happens when targets are breached, as there are for the Bank of England; rather, there is a vague provision to make allowance for exogenous supply shocks (SARB, 2000, point 3.4).

6. The board consists of the governor, three deputies, three additional officials appointed by the government, and seven persons elected by the SARB's private shareholders (four representing finance or commerce, two representing industry, and one representing agriculture). Note that an exclusion clause was first publicly announced in October, 2001.

7. This arrangement continues, *de jure*, under the inflation targeting regime, where the governor and deputy governors are the sole voting members of the fifteen-member Monetary Policy Committee and thus hold final decisionmaking power on monetary policy. In practice, however, decisions on interest rate policy are reached by consensus after extensive discussions by the committee, and the committee's Monetary Policy Statement is drafted by the entire committee. Unlike at the Bank of England, the minutes of these meetings are not published.

8. The finance minister may dismiss governors but, under current law, only for malfeasance or incapacity.

9. Governors T. W. De Jongh (1967-80), Gerhard de Kock (1981-89), and Chris Stals (1989-99) and Deputy Governor Chris De Swardt (1990-), all served longer than five years. The new governor, Tito Mboweni, began his term in August 1999.

Apart from the fact that monetary policy rested in the hands of a few people or, ultimately, one person, the process by which decisions were arrived at between 1986 and 1999 is unclear. As will be seen below, a wide range of intermediate variables, such as private credit growth and the level of and change in reserves, have in recent years supplemented the money growth “guidelines” in influencing interest rate decisions aimed at lowering inflation. However, it is not known what weights applied to these indicators in the interest rate rule, or how these weights changed after exogenous shocks or policy regime changes. This rendered policy quite opaque.

1.2 Exchange Rate Regimes

South Africa’s exchange rate policy during the 1970s mirrored volatile developments on the international front, and throughout the period a number of significant regime shifts occurred (see appendix table A6).¹⁰ Until 1979 the exchange rate was fixed, with the rand pegged to either the U.S. dollar or the pound sterling. Alterations in the rate were determined by policymakers and took the form of discrete step changes. Exchange controls restricted residents’ capital flows, and proceeds from the sale of assets by nonresidents were placed in blocked rand accounts, which made the repatriation of capital difficult. In 1976 the system was modified to allow for the transfer of assets between nonresidents.

Greater flexibility was introduced in 1979 with a dual-currency exchange rate system, following the recommendations of the interim De Kock Commission (De Kock and others, 1978). An official (“commercial”) exchange rate was announced on a daily basis in line with market forces. The second, “financial” exchange rate applied to most nonresident portfolio and direct investment transactions, with all other transactions channeled through the commercial rand market. The intended impact of the dual system was to break the direct link between domestic and foreign interest rates, as well as to insulate the capital account from certain categories of capital flows.

In 1983 the commercial rate was set free to be determined in the market, subject to direct intervention by the SARB, and the dual rates were unified as recommended by the De Kock Commission (De Kock and others, 1978, 1984). Controls on nonresident capital movements

10. This section draws on Aron, Elbadawi, and Kahn (2000).

were removed, and although those on residents remained, a more lenient attitude was taken to applications by residents to make direct investments abroad.

The unified currency remained stable for a few months but then, following the gold price decline in 1983, began a sharp descent. In 1985, following a prolonged period of political upheaval, U.S. banks recalled their loans, precipitating a debt crisis, followed by a debt standstill, and subsequently a series of four debt rescheduling agreements. The unified rand fell even further, and eventually the financial rand was reintroduced and capital controls on residents were tightened. The dual-currency system remained in existence until its unification a decade later, in March 1995, under a managed float. The nature of the SARB's varying implicit exchange rate targets are discussed in section 1.4.

1.3 Monetary Policy Regimes and Operating Procedures

Broadly speaking, there have been three monetary policy regimes since the 1960s (table 1 and appendix). Our quantitative interest rate models focus on the second of these. As noted in the introduction, the first regime, operated until the early 1980s, was a liquid asset ratio-based system with quantitative controls on interest rates and credit. Little importance was attached to the interest rate as a corrective tool, the main form of monetary control being the use of liquid asset requirements. Commercial banks were obliged to hold certain assets defined as "liquid" as a specified minimum proportion of their deposits (appendix table A3). The limited supply and low yields of these assets were expected to curtail bank lending and money supply growth. Beginning in 1978 the SARB fixed its accommodation rates at a margin above the market rates of the previous week (this practice ceased in December 1983). The result was an upward ratcheting of interest rates during money market shortages (when banks needed accommodation): market rates followed the accommodation rates, which, in turn, followed the market rates (De Kock and others, 1978, 1984). Since the main instrument of credit control was direct limits on the banking system, considerable disintermediation occurred, particularly between 1976 and 1980, distorting the credit supply figures.

Increasing dissatisfaction with the liquid asset ratio-based system led to enactment of a range of reforms beginning in the early 1980s (appendix table A3), moving toward a cash reserves-based system following the recommendations of the De Kock Commission (De Kock and others, 1978, 1984). The removal of some direct controls

(such as those on deposit rates) in March 1980, and bank credit ceilings later that year, resulted in reintermediation and a decline in the velocity of circulation. There were also technical changes to asset requirements over a few years, and the role of the discount rate was redefined. This second regime was in full operation by mid-1985.

Under the cash reserves system, preannounced monetary targets were used for the first time beginning in 1986 (see section 1.4), to be achieved indirectly through adjusting interest rates.¹¹ The main policy emphasis was on using the central bank's discount rate to influence the cost of overnight collateralized lending and hence market interest rates.

In practice, to reduce the demand for bank credit, the SARB increased the bank interest rate at which it provided discount-window accommodation to banking institutions against collateral in the form of various government bills. The supply of credit (a major component of money supply changes in South Africa) could be influenced by open market operations and various other policies acting on overall liquidity. By creating a persistent "money market shortage" and setting the bank rate at a relatively high level, the SARB was able to link commercial bank interest rates fairly closely to the bank rate. According to the SARB, monetary control thus operated indirectly by slowing the demand for money, with an estimated lag for its ultimate effect on inflation of over twelve months (see, for example, Stals, 1995a).

Under the third system of monetary accommodation, introduced in 1998 and based on daily tenders of liquidity through repurchase transactions, monetary growth guidelines continued to be announced, as well as an inflation target. Domestic and international financial liberalization further reduced any usefulness of the monetary targets. The government also wished to avoid the political sensitivity of direct interest rate setting in a context of volatile capital flows. The repurchase interest rate is determined at auction. In theory, rather than controlling the price of liquidity by setting the discount rate, monetary policy effectively rations the quantity of liquidity. The SARB signals its policy intentions on short-term interest rates to the market through the amount offered at the daily tender for repurchase transactions (see *South African Reserve Bank Quarterly Bulletin*, June 1999). A full provision of the estimated daily liquidity requirement of banks indicates a neutral position, whereas marginal over- or underprovision of the estimated liquidity requirement signals that the SARB would prefer the

11. In 1990 the term "money supply targets" was replaced by "money supply guidelines."

repurchase rate to stabilize at prevailing levels. Significant over- or underprovision of liquidity signals a preference for movement in the repurchase rate, the degree of which depends on the extent of rationing. Auctions with a predetermined fixed interest rate, much used in the early days of the new system, now only operate under exceptional circumstances, when the SARB seeks an immediate and substantial change in money market interest rates (for example, in the face of a large external shock). However, in practice there has been little difference in interest rate behavior between the current and the previous regime: even under price auctioning, the commercial banks collectively have remained heavily influenced by SARB-directed preferences for the level of the interest rate.

1.4 Explicit Monetary and Implicit Exchange Rate Targets

Monetary Targets. Explicit monetary growth targets for M3 were announced annually from 1986 to 1998, following the recommendations of the De Kock Commission (De Kock and others, 1984).¹² The choice of M3 centered on its supposedly relatively stable relationship over time to current GDP, on the view that it was less sensitive than other money aggregates to disintermediation and reintermediation, and on the assumption that, being so broad, it reflected changes in the budget deficit, private credit extension, and the balance of payments. Target ranges were set annually using a three-month moving average of the aggregate and were announced in the March budget to cover the period from the fourth quarter of the previous year to the fourth quarter of the current year.

The setting of the target aimed both to accommodate projected real GDP growth and to contain inflation, although the procedure used to choose the target was not transparent. As at the German Bundesbank (Clarida and Gertler, 1997), these targets were intended as guidelines rather than strict rules. The SARB had discretion to breach the targets, for instance in the face of external trade and financial shocks. There was no penalty for doing so, nor was a public explanation required (as it is for the Bundesbank).

The target growth zones and money growth outcomes for 1986-98 are given in figure 1. Large deviations are apparent during the 1980s,

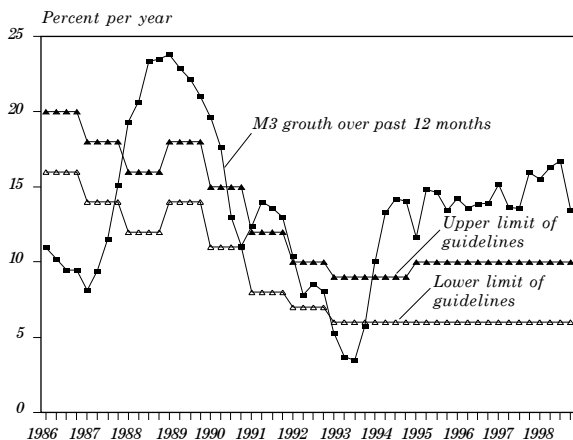
12. M3, newly defined for targeting purposes, is a broad definition of money that includes notes and coins held by the public as well as all types of deposits—short-, medium-, and long-term—of the domestic private sector with South African banking institutions. Since March 1998, M3 growth guidelines have operated over a three-year rather than an annual basis.

and persistent overshooting from 1994 onward, after the resurgence of capital inflows to South Africa. Starting in the 1990s the guidelines were supplemented by an eclectic set of indicators, including the exchange rate, asset prices, the output gap, the balance of payments, wage settlements, total credit extension, and the fiscal stance (*South African Reserve Bank Quarterly Bulletin*, October 1997).

Exchange Rate Targets. Starting in 1979 the SARB engaged in active intervention in both spot and forward foreign exchange markets, although low levels of reserves at certain times limited its extent. There is some evidence that, during 1979-88, exchange rate intervention was directed at maintaining profitability and stability in the gold mining industry by smoothing the real rand price of gold faced by producers despite large fluctuations in the dollar price of gold (Kahn, 1992).¹³

After August 1989, under a new governor, Chris Stals, the SARB appeared to be actively seeking to stabilize the real effective exchange rate, partly out of concern for the international competitiveness of South Africa's manufacturing exports. The apparent aim was to prevent excessive real appreciation of the rand when the currency was tending to appreciate in nominal terms. There was, however, no explicit official policy to stabilize the real exchange rate.

Figure 1. South Africa: Actual and Target Percent per year Money Growth



Source: *South African Reserve Bank Quarterly Bulletin*, various issues.

13. It was only after December 1988 and for a limited period between September 1983 and January 1985 that the SARB paid the gold mines in dollars (50 percent of gold production was paid in dollars during 1983-85) and reduced its role in the foreign exchange market.

Intervention was less successful at stabilizing the exchange rate in the uncertain atmosphere before the elections of April 1994, when huge capital outflows occurred. However, during the first twenty-one months after the elections, the nominal rand-dollar exchange rate moved by no more than 2 percent from 3.65 rand to the dollar. From April 1995 to January 1996 the range was even narrower, with the currency moving in an "implicit" band of R3.65 plus or minus 1 percent. Many investors viewed the stylized fact of a steady bilateral rate in the face of the large capital inflows as a "one-sided" implicit nominal target (see, for example, Union Bank of Switzerland, 1996). Officially, the SARB claimed that the rand was floating and that the interventions were intended only to smooth temporary and reversible short-term fluctuations (Stals, 1995b). After a classic exchange rate crisis in early 1996, with a massive loss of reserves (Aron and Elbadawi, 1999), a pattern of periodic temporary targeting of the nominal exchange rate was apparently resumed. Under inflation targeting such exchange rate management is expected to have a fairly low priority.

2. MONETARY POLICY AND OUTCOMES, 1980-98

The following brief and selective review of monetary policy and outcomes over two decades is organized around four episodes: 1980-85, 1986-89, 1989-93, and 1994-98. In the first episode, under Governor De Kock from 1981 on,¹⁴ credit controls were rapidly removed and liquid asset ratios more gradually reduced from levels close to 60 percent in the early 1980s to around 25 percent by early 1985. The definition and use of the "bank rate" (the discount rate) underwent important changes. During the second episode, a cash reserves-based monetary policy system operated under De Kock, and flexible money supply targets were announced annually starting in 1986. A new governor, Governor Stals, presided over the third and fourth episodes, which are distinguished from the earlier two by less variable and consistently positive real interest rates. The capital account was opened to nonresidents after democratic elections in 1994. A period of considerable currency volatility ensued, which helped catalyze the change to a repurchase system of monetary policy beginning in March 1998.

14. A useful source on this period is Gidlow (1995).

2.1 From 1980 Q1 to 1985 Q3

The period of the early 1980s was a complicated one for monetary policy, combining major shifts in monetary and exchange rate regimes and a huge gold price shock. Further, the limited political liberalization initiated in the period led to social unrest, which received international publicity. Opprobrium for the apartheid regime and a deteriorating sovereign risk rating were reflected in capital outflows and disinvestment, culminating in an external debt crisis in 1985 and international trade and financial sanctions.

During the 1970s annual inflation had averaged 9.0 percent,¹⁵ with the principal shocks to prices coming from the 1973 and 1979 oil shocks and the sharp gold price rise from 1979 on.¹⁶ The use of import surcharges over and above the tariff regime represented a considerable tightening of trade policy. The surcharges were first used in April 1977, following the cessation of capital inflows in the wake of the 1976 Soweto riots. They remained in force until March 1980, when high gold prices took the pressure off the current account. High import surcharges were reintroduced from February 1982 to November 1983.

The SARB's quarterly discount rate averaged 6.6 percent during the 1970s, declining after each of the oil shocks (figure 2). However, the main downward pressure on interest rates in 1979-80 came from an (unsterilized) accumulation of reserves by the SARB in response to the rising gold price, in an attempt to prevent excessive appreciation of the newly floating rand. By the first quarter of 1980 the discount rate had reached a trough of 4.7 percent, despite inflation at almost 15 percent. The low interest rates helped fuel an investment boom, and later a consumption boom, which partly dissipated the windfall gains. The ensuing current account deficits were financed by a substantial buildup of foreign debt.

This inflationary trend was later reversed after a very sharp rise in interest rates starting in 1981 (figure 2).¹⁷ This occurred in two stages. First, under a new monetary policy regime, interest rates were liberalized (appendix tables A1 and A2), but the discount rate was

15. Inflation figures are reported for the four-quarter log change in the quarterly consumer price deflator, which is the variable used in our inflation forecasting equations. This slightly understates the conventional percentage change measurement, particularly when inflation rates are high.

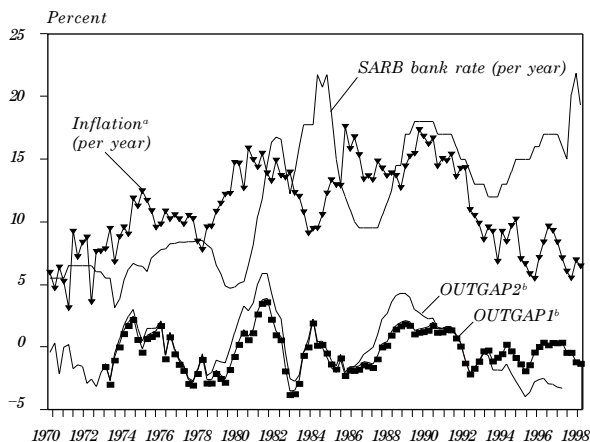
16. The gold price reached a peak of \$850 per fine ounce in January 1980.

17. The average quarterly discount rate during 1980 Q1 to 1985 Q2 was 14.1 percent, while annual inflation averaged 13 percent. The quarterly real prime interest rate averaged 4.1 percent.

automatically tied to the market rates in the manner described in section 1. In the aftermath of the gold shock, in 1981-82, the ensuing money market shortage produced a ratcheting up of interest rates.

In the second stage beginning in 1983, the commercial and financial exchange rates were unified, as already noted. This removed the shield to domestic inflation and interest rates provided by the dual exchange rate regime. Large capital outflows induced a sharp fall in the currency. These outflows were not sterilized. In the event, the exchange rate unification was temporary: it was abandoned at the onset of the debt crisis in late August 1985. The effect was to prevent further outflows of capital by foreign investors, except where there was matching inward investment. The nominal effective exchange rate fell from 278 to 145 (1990 = 100) during the unification period. The feed-through to inflation became evident by late 1984, and coupled with continuing strong consumer demand, this induced a sharp rise in interest rates, which reached almost 22 percent in early 1985. Quarterly real prime interest rates averaged almost 10 percent during the unification period. The contractionary effect on the money supply, however, was partly offset by a domestic credit expansion, fueled by the SARB's monetary accommodation policies and financial liberalization (including the removal of interest rate controls and a reduction in bank reserve requirements).

Figure 2. South Africa: Output Gap, Inflation and SARB Bank Rate Percent



Source: Authors' calculations and *South African Reserve Bank Quarterly Bulletin*, various issues.

a. Change in log (consumer deflator).

b. Log (output) deviation from trend. For more details see section 3.2.

2.2 From 1985 Q3 to 1989 Q2

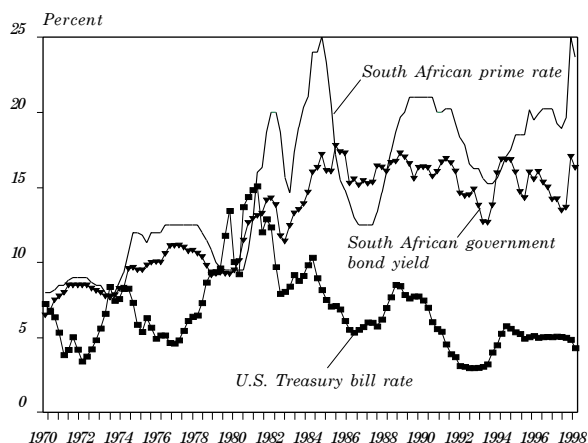
Following the debt standstill in 1985, no new foreign bank loans were forthcoming, apart from trade credits. Coupled with the requirement to repay capital and interest on the existing debt, this implied that the capital account remained in deficit until 1994.¹⁸ Continuing pressure on the capital account required the economy to adjust in order to maintain current account surpluses of over 3 percent of GDP (Leape, 1991). This adjustment was partly achieved by the sharp currency depreciation, and partly by trade policy, with large increases in tariffs and the reimposition of large import surcharges in September 1985. There was a collapse of domestic investment by both private firms and state enterprises.

With investor confidence declining, the SARB tried to stimulate demand domestically. Within a year of the crisis, nominal interest rates had more than halved, to trough at 9.5 percent. Inflation continued to rise, averaging 16.4 percent in 1986, and the real interest rate entered negative territory in 1986 for the first time in four years.

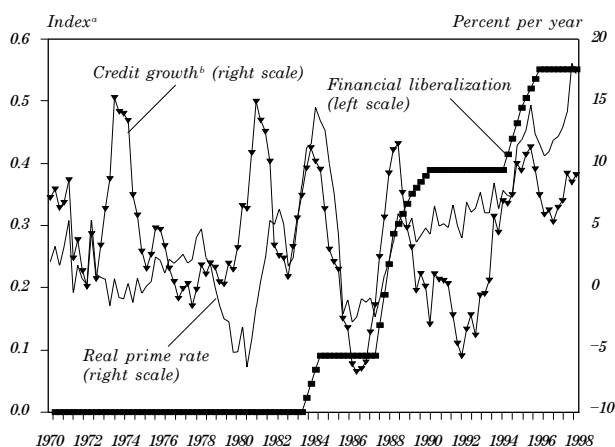
However, with gold prices rising from late 1986 through 1988, domestic investment and growth began to increase (figure 2), inducing a current account deficit in the second quarter of 1988. Trade policy was tightened considerably: import surcharges were increased in 1988, at times generating more revenue than the already high tariffs. Interest rates were raised substantially: between the first quarter of 1988 and the second quarter of 1989, the bank rate increased from 10.5 percent to 17 percent, in part influenced by substantial rises in world interest rates over the same period (figure 3). Positive growth trends were reversed. Thus monetary policy may have been influenced by balance of payments considerations.

Significant domestic financial liberalization was under way by the mid-1980s (see section 3.3 and appendix tables A4 and A5), which rapidly increased credit growth (figure 4). Money targets were announced from 1986 onward (table 2). By the end of 1986, M3 growth had turned sharply upward, and within a year it had exceeded its target ceiling (see figure 1). M3 growth remained outside the target for the remainder of this episode, beginning to decline only in the second quarter of 1989, when interest rates reached 17 percent.

18. At the time of the debt crisis, approximately 70 percent of South Africa's debt, which amounted to 42 percent of GDP, had a maturity of less than one year. The final 1994 debt arrangements provided for the full amortization of the affected debt by August 2001.

Figure 3. Percent U.S. and South African Interest Rates

Source: South African Reserve Bank Quarterly Bulletin, various issues.

Figure 4. South Africa: Index Financial Liberalization

Source: Authors' calculations and South African Reserve Bank Quarterly Bulletin, various issues.

a. Index constructed using the methodology described in Aron and Muellbauer (2000c).

b. Real growth in credit to the private sector.

2.3 From 1989 Q3 to 1994 Q1

After the accession of Governor Stals in the third quarter of 1989, real interest rates were less variable and consistently

positive.¹⁹ High rates were maintained with the twin objectives of curbing inflation and maintaining a current account surplus. Nominal interest rates rose to 18 percent by the end of 1989 and remained there for a year before falling to 17 percent in 1991. Inflation remained persistent until 1992, usually exceeding 15 percent in these years.

Balance of payments pressures moderated in the early 1990s, partly because of prospects for political reform under a new leadership. The high import surcharges were sustained until the elections but were phased out by the end of 1995. In the uncertain atmosphere before the 1994 elections there were again huge capital outflows. Despite borrowing from the International Monetary Fund and a significant increase in other short-term foreign borrowing, the SARB was unable to prevent a nominal effective depreciation of close to 19 percent between January 1993 and the end of July 1994. (The corresponding real depreciation was about 10 percent.)

During 1992-93 the bank rate gradually declined to 12 percent, at which level it was sustained until the elections. (U.S. interest rates had fallen sharply during 1991 and 1992.) Starting in 1992, a trend decline in inflation began, with inflation reaching single figures in early 1993. The reversal was strongly connected with trade liberalization (see Aron and Muellbauer, 2000a). Under Governor Stals, money targets declined until the mid-1990s. Money growth fell sharply, to within or close to the official targets from mid-1990 until the election (figure 1). Annual real GDP growth fell from 2.4 percent in 1989 into negative territory the next year, recovering somewhat only in 1993, when real growth measured 1.2 percent.

2.4 From 1994 Q2 to 1998 Q1

Following democratic elections in April 1994, the new government committed itself to a long-term development strategy for generating rapid and widely shared growth through two highly publicized programs.²⁰ It also promised to achieve macroeconomic stability in

19. From 1980 to 1992, inflation displayed strong inertia, fluctuating about the 14 percent level and with a quarterly maximum of close to 18 percent. However, with the discount rate varying from 4.7 percent in 1980, to 22 percent in 1984, to 9.5 percent by end of 1986, and then 18 percent by the end of the decade, there was substantial variability in real interest rates.

20. The broad goals of the earlier Reconstruction and Development Programme (RDP) were reinforced by the Government's Growth, Employment and Redistribution strategy (GEAR), announced in June 1996.

the short to the medium run. The initial assessment by international capital markets was that the country would achieve a sustained growth path, in a situation where strong and sophisticated financial markets, a robust civil society, and transparent and democratic governance were seen as comparative advantages.

However, after an initial upturn, growth performance after the elections was disappointing. Real GDP growth was 0.5 percent in 1998 and 2.4 percent in 1997, compared with 4.2 percent and 3.1 percent in 1996 and 1995, respectively. Apart from labor market inflexibility, trade competition, and a declining gold price from late 1996 onward, probably the most important factor affecting growth performance was high real interest rates.²¹ These were a direct consequence of rapid liberalization of the capital account and the need to manage the ensuing large, volatile capital inflows.

Capital flows to the country increased markedly after the elections, although from a very low base following more than a decade of financial sanctions. Flows accelerated with the effective removal of exchange controls on nonresidents in March 1995, after the dual exchange rate system was again unified (appendix table A7). A large proportion of the inflows consisted of short-term flows, making the economy vulnerable to flow reversals.

Aron and Elbadawi (1999) argue that the SARB had dual objectives during the period of large net capital inflows from April 1994 until the first currency crisis in February 1996.²² These were to contain inflation through an interest rate policy based on explicit monetary targets, and to stabilize the nominal exchange rate, *de facto*, through an implicit one-sided target. As is well known from the literature on currency crises, under persistent capital inflows a policy trade-off arises where sustaining an exchange rate "target" may come at the expense of higher inflation, higher interest rates, and eventually reduced output.

The SARB intervened heavily in the market to prevent the currency from appreciating, at the expense of the monetary targets (Stals, 1995b). Note that the money target floor did not alter in this episode, but the ceiling was raised in 1995, widening the band and reflecting the diminished status of the monetary targets under a capital account

21. See, for example, the output forecasting model in Aron and Muellbauer (2000a).

22. Subsidiary goals were to withdraw from the forward foreign exchange market and to accumulate foreign reserves (Stals, 1994).

liberalized to inflows (as described in section 1.4). Sterilization of the effects of the reserve accumulation began only late in 1994. Consequently, large increases in the liquidity of the banking sector induced an “endogenous” financial liberalization, compounding the recent explicit liberalization, for instance through the mortgage market (see section 3.3). Private sector credit grew strongly, partly because of demand-led pressures from new borrowers under the new political dispensation. Adding to balance of payments pressures was a progressive liberalization of trade policy, while trade volumes responded strongly to the ending of trade sanctions.

The excess money growth is evident in figure 1. As a consequence, monetary policy was tightened considerably. The bank rate rose sharply from 12 percent at the time of the elections to 15 percent by mid-1995, minimum cash reserve requirements for banks were increased, and open market operations were initiated. The trend decline in inflation, which had begun around 1992, persisted after the elections, although with some volatility (figure 2). Annual inflation averaged 8 percent during 1994 Q2 to 1997 Q4, compared with 13.6 percent during the previous episode (1989 Q3 to 1994 Q1). However, it then increased after the elections, reaching double digits again in mid-1995.

Interviews conducted by the authors suggest that, toward the end of 1995, foreign investors had become concerned about the widening current account deficit, apparently rising inflation, the size of the domestic public debt, and the real effective appreciation of the rand (modest though it was). Further, it was anticipated that domestic exchange controls would be significantly relaxed in the Budget (early March 1996). In the event, the intended decontrol package was put on hold until July 1997, given the currency crisis that had begun in mid-February. By late April the rand had depreciated by 20 percent from its mid-February level. The SARB intervened massively to try to prevent this depreciation, with a net cumulative intervention of \$5.3 billion from mid-February to the end of April (Centre for Research into Economics and Finance in Southern Africa, 1996).

Crises recurred in October 1996, November 1997, and April 1998, triggered largely by contagion effects from the Asian crisis, but also by declines in the prices of gold and other metals. After the April 1998 crisis, in which there was also substantial intervention, the rand was some 40 percent below its average value between the elections and the first crisis.

The bank rate rose to 17 percent after the first crisis and remained at that level until the end of 1997; it then fell to 15 percent just before the April 1998 crisis, when it was raised to over 20 percent (figure 2). Given that inflation averaged just over 6 percent in 1998, this implied very high real interest rates. Unsurprisingly, output was seriously reduced. Investors had generally revised their expectations about emerging markets in the aftermath of the Asian crises, but nevertheless domestic factors such as the widening current account deficit and poor growth prospects further damaged investor confidence in South Africa.

3. INTEREST RATE RULES: SPECIFICATION AND ESTIMATION

3.1 Simple Interest Rate Rules

A substantial literature has accumulated on the Taylor rule (Taylor, 1993),²³ which describes interest rate-setting behavior by central banks with some autonomy over monetary policy (Taylor, 1999). The simple Taylor rule characterizes an interest rate feedback policy that is a linear function of both the deviation of actual from target inflation and the output gap (that is, a measure of the deviation of output from capacity or trend output):

$$i_t^* = \alpha + \beta(\pi_t - \pi^*) + \gamma(y_t - y_t^*) \quad (1)$$

where $\alpha \equiv \bar{r} + \pi^*$, $\beta > 1$, and $\gamma > 0$. The target interest rate defined by the rule is i_t^* , $\bar{r}$ is the long-run equilibrium real interest rate, π^* is the target inflation rate, y_t is real output, and y_t^* is trend output.²⁴ Inflation adjusts gradually to its target through the adjustment of real interest rates, and with $\beta > 1$, the nominal rate adjusts more than one for one with inflation. The role of the output gap is to adjust countercyclically with demand shocks but to accommodate supply shocks reflected in i_t^* .

23. Related early work is that by McCallum (1988), and Henderson and McKibbin (1993) examined a rule similar to equation (1) below.

24. In practice, Taylor (1993) used a backward-looking measure of inflation: the deviation between inflation in the past year and target inflation. He did not estimate the rule for the United States but used judgment to suggest that parameter values of $\beta = 1.5$ and $\gamma = 0.5$ for $\bar{r} = 2$ and $\pi^* = 2$ well described U.S. interest rate policy during 1987-92.

There is a large literature, going back to Phillips (1954), on optimal control in dynamic, stochastic macroeconomic equation systems. Optimal control policies for any but the simplest systems tend to be sensitive to model misspecification and are complex and nontransparent. Since an important aim of stabilization policy is to influence private sector expectations, recent research has instead emphasized simple, robust rules that are more easily understood by the private sector. Thus part of this research effort has been devoted to finding “good” parameter values for particular classes of relatively simple linear feedback rules. Policy simulations with macroeconometric models for a range of countries suggest that variants of the Taylor rule have desirable stabilization properties (see, for example, Taylor, 1999, and Levin, Wieland, and Williams, 1999).

We present a generalized and forward-looking version of the Taylor rule based on work by Clarida, Galí, and Gertler (1998a), which encompasses the simple Taylor rule and other variants as special cases. Batini and Haldane (1999) have recently emphasized the importance of forward-lookingness in monetary policy, and in practice it is highly relevant in inflation-targeting countries.²⁵ The target for the nominal short-term interest rate, i_t^* , is given by

$$i_t^* = \bar{i} + \beta [E(\pi_{t+n}/\Omega_t) - \pi^*] + \gamma [E(y_t/\Omega_t) - y_t^*] + \xi E(z_t/\Omega_t), \quad (2)$$

where E is the expectation operator and Ω_t is a vector representing the central bank's information when setting interest rates at time t , $\bar{i}$ is the long-run equilibrium nominal interest rate, π_{t+n} is the forecast rate of inflation between time t and $t + n$, y_t is real output, y_t^* and π^* are desired output and target inflation, and z_t is a vector of additional variables that may influence on policy.

Much of the literature on the Taylor rule has focused on the United States, a large, relatively closed economy. Inclusion of the z_t variables can be motivated by modeling considerations from small, open economies, or by the use of money targets by the country in question. Candidates for the z_t variables thus include foreign interest rates,

25. Rotemberg and Woodford (1999) argue that there are circumstances where backward-looking rules can work well. In their example, private agents are forward-looking and believe that the central bank will adhere to its rule and that economic activity depends on expected future interest rates or long-term rates, and not just on current short-term rates.

the money supply (or its deviation from an announced target), and the real exchange rate (or the deviation of the nominal rate from an announced target).²⁶

The case for including foreign interest rates is the following. For small, open economies subject to some degree of international capital mobility, domestic interest rates will necessarily tend to follow foreign rates if the domestic monetary authority wishes to stabilize the nominal exchange rate. In the extreme case of perfect capital mobility, under the uncovered interest parity condition, international interest rate differentials reflect expected changes in the nominal exchange rate and risk premiums. Analogously, for a monetary authority wishing to stabilize the real exchange rate, domestic real interest rates will tend to follow foreign real rates (see Taylor, 1995, p. 16). Recent literature emphasizes the importance of exchange rate targets, implicit or otherwise, in small, open economies. Indeed, the role of the exchange rate increases in importance in policy formulation, the shorter the inflation target horizon (see Ball, 1999).

Clarida, Galí, and Gertler (1998a) emphasize the importance of the parameter β in evaluating policy rules. The implicit real interest rate target corresponding to equation (2) is

$$\begin{aligned} \bar{U}_t^* = U + (\beta - 1) \left[(\pi_{t+n}/\Omega_t) - \pi^* \right] + \gamma \left[(y_t/\Omega_t) - y_t^* \right] \\ + \xi (z_t/\Omega_t), \end{aligned} \quad (3)$$

where r_t^* is the target for the real short-term interest rate and $\bar{r}$ is the long-run equilibrium real interest rate. The target rate adjusts relative to the equilibrium interest rate when inflation or output deviates from the target. If β exceeds 1, as in the simple Taylor specification in equation (1), the target rate adjusts to stabilize inflation and output; if β is less than 1, the target rate accommodates changes in inflation (real interest rates fall).

One widely adopted modification of the Taylor rule is to permit the central bank to smooth changes in the interest rate. Central banks typically try to avoid interest rate volatility, in order to promote financial market stability and avoid loss of credibility from interest rate reversals (see, for example, Mishkin, 1999, p. 247). Clarida, Galí,

26. Clarida, Galí, and Gertler (1998a) also examine lagged inflation, to test the simple Taylor rule against their forward-looking specification.

and Gertler (1998a) assume a partial adjustment of the central bank's rate to the target rate as follows:

$$i_t = (1 - \rho) i_t^* + \rho i_{t-1} + v_t, \quad (4)$$

where v_t is a random shock. Equation (2) can be simplified by setting $\alpha \equiv \bar{i} - \beta\pi^*$ and

$$x_t \equiv y_t - y_t^*, \text{ or}$$

$$i_t^* = \alpha + \beta E(\pi_{t+n}/\Omega_t) + \gamma E(x_t/\Omega_t) + \xi E(z_t/\Omega_t), \quad (5)$$

where z_t includes the foreign interest rate (the U.S. rate, i^{USA} , in our case). Formalizing a comment in Clarida, Galí, and Gertler (1998a), an alternative interpretation of the interest rate target as the weighted average of an extended Taylor rule and the foreign interest rate is

$$i_t^* = (1 - \lambda) \left[\alpha + \beta (\pi_{t+n}/\Omega_t) + \gamma (x_t/\Omega_t) + \xi (z_t'/\Omega_t) \right] + \lambda (i_t^{USA}/\Omega_t). \quad (6)$$

Note that z_t' now refers to other variables excluding the foreign interest rate. When $\alpha > 0$ and $\beta > 0$, this has the effect of raising the implied reaction to inflation in the Taylor rule, compared with equation (5).

The combination of partial adjustment with the model in equation (5) gives

$$i_t = (1 - \rho)(1 - \lambda) \left[\alpha + \beta (\pi_{t+n}/\Omega_t) + \gamma (x_t/\Omega_t) + \xi (z_t'/\Omega_t) \right] + (1 - \rho)\lambda (i_t^{USA}/\Omega_t) + \rho i_{t-1} + v_t. \quad (7)$$

Note that the special case of inflation targeting is nested within this specification, where the weight on the output gap and z_t terms is zero, and the policy rate responds only to expected inflation (see Batini and Haldane, 1999).

3.2 Estimating an Extended Taylor Rule for South Africa

Estimating extended Taylor rules can lend insight into past policy rules when the size of the weights applied to different indicators in

interest policy formation is unknown, or where policy may deviate in practice from stated policy.²⁷

Rewriting equation (7) in terms of realizable variables gives the following estimable function:

$$i_t = \delta_0 + \delta_1 i_{t-1} + \delta_2 \Delta_4 \ln P_{t+k}^F + \delta_3 x_{t+m}^F + \delta_4 z_t^F + \delta_5 i_{t-1}^{USA} + \varepsilon_t, \quad (8)$$

where $\delta_0 = (1-\rho)(1-\lambda)\alpha$, $\delta_1 = \rho$, $\delta_2 = (1-\rho)(1-\lambda)\beta$, $\delta_3 = (1-\rho)(1-\lambda)\gamma$, $\delta_4 = (1-\rho)(1-\lambda)\xi$, $\delta_5 = (1-\rho)\lambda$, and ε_t is the error term. The central bank's short-term discount rate is i_t , $\Delta_4 \ln P_{t+k}$ is the annual rate of change of the consumer price deflator over the horizon of k quarters, and x_{t+m} is the output gap at $t + m$ quarters. F denotes the forecast value of these two variables using information available at $t - 1$. The horizon of k and m is at the discretion of the central bank but will be constrained by its forecasting ability. Finally, i_{t-1}^{USA} is the foreign short-term interest rate (we use the U.S. three-month Treasury bill rate).

We later extend the set of z_t terms in this model to include deviations of money growth from announced targets, as well as exchange rate and balance of payments effects, and we control for an important regime shift, namely, the financial liberalization of the early 1980s.

The SARB's end-of-quarter bank discount rate was modeled using equation (8) for the period 1986 Q2 to 1997 Q4, using an instrumental variables (IV) technique to instrument forward-looking expectations.²⁸ The discount rate, scaled by 100, is shown in figure 2. Four alternative horizons were selected.²⁹ The first gives a backward-looking model where $k = m = 1$. This can be estimated by the ordinary least-squares method. The second uses contemporary inflation and output gaps, $k = m = 0$. The IV estimation is used on the conservative assumption that the SARB's information set is

27. For instance, Clarida and Gertler (1997) argue that, despite the Bundesbank's claims to base interest rate policy largely on ensuring that monetary growth falls within specified target ranges, a modified Taylor rule provides a better description of its actual behavior.

28. Clarida and Gertler (1997) use the generalized method of moments to estimate the parameter vector for a Taylor rule similar to equation (8).

29. Note that in estimating equation (8) we assume that, over a short horizon, short-term interest rates and inflation are stationary, that is, $I(0)$. The evidence is given in table 3. Note that the augmented Dickey-Fuller test (Dickey and Fuller, 1979) has low power against the alternative of stationarity over the short sample.

dated $t - 1$.³⁰ The third model uses forward-looking inflation and the current output gap. Thus $k = 3$, implying the four-quarter-ahead inflation rate seen at $t - 1$, and $m = 0$. The final specification takes forward-looking versions of both, $k = m = 3$.

Our models of the discount rate are estimated only from 1986 onward, for two reasons. First, the transition in the early to mid-1980s from a liquid assets-based system to a cash reserve-based system of monetary control was not accomplished immediately, and liquid asset requirements were reduced only gradually during 1980-85 from the abnormally high levels prevailing in 1980 (see section 1). The formal monetary growth target ranges were introduced for the first time in 1986. Second, during the debt crisis of 1985, interest rates were raised to extraordinary levels in a vain attempt to attract foreign capital inflows and prevent default on the external debt. Clearly a Taylor rule will fail to describe this shock.

The output gap is constructed using an extended version of stochastic trend models of the type recommended by Harvey (1993; see also Harvey and Jaeger, 1993). This can be estimated using the STAMP program of Koopman and others (1995). We used several different measures of the output gap. For the first measure, the model has the following form:

$$\log y_t = \alpha_0 + STOCH_t + \alpha_1 \log y_{t-1} + \sum_j \beta_j X_{jt} + \varepsilon_t, \quad (9)$$

where y_t is real GDP and $STOCH_t$ is a smooth, stochastic trend reflecting the underlying capacity of the economy to produce. The X_{jt} capture cyclical factors: we use distributed lags of changes in log capacity utilization and changes in the log real gold price for an estimation period of 1973 Q1 to 1998 Q4. The stochastic trend is defined as a moving average of random shocks. More precisely, $STOCH$ is an $I(2)$ variable, which requires twice-differencing to give a stationary series:

$$\Delta^2 STOCH_t = \eta_t, \quad (10)$$

where η_t is a random shock. The technique gives good results and is to be preferred to the widely used Hodrick-Prescott filter, because it does not rely on any arbitrary calibration of the variance

30. This is approximately correct for information available in the South African national accounts, although this is subject to revision. Information on prices and money and credit aggregates tends to be available with lags of a few weeks or less, and information on interest rates is almost instantaneous.

of the underlying shocks η_t (see Harvey and Jaeger, 1993, for a discussion). Instead, all the parameters of the model are estimated from the data.³¹

The resultant output gap, defined as $(\log y_t - \alpha_0 - \text{STOCH}_t)/(1 - \alpha_1)$, was used to construct the first output gap measure, OUTGAP1 (figure 2). This trend was compared in estimations with the alternatives of a cubic function of time and with split time trends. For almost all specifications reported below, the output gap derived from the stochastic trend model gives a better fit than these two alternatives. The second measure of the output gap, OUTGAP2, also shown in figure 2, employs a stochastic trend from a richer model of output taken from Aron and Muellbauer (2000a).³² The principal differences between the two measures occur in the aftermath of the 1980-81 gold price shock and the smaller price shock in 1987, when OUTGAP2 indicates lower excess capacity in the economy, and after 1994, when OUTGAP2 indicates greater excess capacity.³³

We also used two models for forecast inflation to derive instruments for the interest rate rule. A simple inflation forecasting model, similar in conception to the SARB models used at the time, was derived from a model linking consumer inflation, respectively, one

31. Standard augmented Dickey-Fuller tests suggest that, over 1973-98, $\log(y_t)$ is $I(1)$, implying that $\Delta \log(y_t)$ is a stationary variable. The combination of equation (8), where the X_{jt} are clearly $I(0)$, and equation (9), appears to contradict this, since STOCH_t is $I(2)$. However, the hypothesis that a variable such as $\log(y_t)$ is $I(1)$ is hard to distinguish from alternatives, for example that $\log(y_t)$ has a large autoregressive component and is stationary about a deterministic trend, or a deterministic trend with a change in trend at some point in the sample. A low-variance $I(2)$ stochastic trend resembles the latter. In other words, the hypothesis that $\log(y_t)$ is $I(1)$ is quite hard to distinguish from the alternative of $I(0)$, on the one hand, and $I(2)$ on the other, when the $I(2)$ component is a smooth, low-variance series.

32. This is a four-quarter-ahead forecasting model for the log of real GDP. The model uses a stochastic trend to measure long-run changes in the capacity to produce. On the demand side there are important negative interest rate effects, although these have been altered by changes in the monetary policy regime. The ratios of the trade surplus and the government surplus to GDP, which also respond to interest rate changes, and improvements in the terms of trade, all have a positive effect on future output. The deviation of output from the four-quarter lag of the stochastic trend defines the output gap.

33. The main economic reason is the inclusion of the real interest rate among the economic variables. This variable is $I(1)$, and in the 1990s it rose strongly, depressing output, in part by contracting capital accumulation. Conceptually, therefore, OUTGAP2 differs from OUTGAP1. In recent years a demand boost from lower interest rates would generate more inflation using the OUTGAP1 measure. The OUTGAP2 measure effectively implies that capacity would respond to lower real interest rates, thus reducing the inflationary pressure.

quarter and four quarters ahead, with lags in consumer price and wholesale price inflation, wage changes, money growth, interest rate changes, and the output gap. This model does not have an equilibrium correction form, so that relative price levels play no role. A more sophisticated model is described in detail in Aron and Muellbauer (2000a).³⁴

The results of estimating the extended Taylor rule in equation (8) for the four horizons are shown in table 4 (variables are defined in table 3, and the set of instruments is shown in the footnotes to table 4). The South African discount rate and the annual log change in the consumer expenditure deflator, our measure of annual inflation, are shown in figure 2. The foreign interest rate, again taken as the three-month Treasury bill rate for the United States, and two South African interest rates are shown in figure 3.

The results are striking. In all specifications the interest rate has a strongly significant *negative* response to domestic inflation, whether lagged or forward-looking. At the least this suggests that some important omitted factors influence short-term interest rates in South Africa. The U.S. Treasury bill rate is always significant, and the hypothesis can be accepted that, *ceteris paribus*, a 1-percentage-point rise in the U.S. rate is eventually followed by a more than 1-percentage-point rise in the South African rate.³⁵ The output gap is always significant. If the U.S. nominal interest rate is excluded, the fit of the model deteriorates markedly. There was little difference between using the more sophisticated and simpler forecasting inflation models as instruments, and we report results for the former. We tested robustness over both

34. The four-quarter-ahead inflation model has an equilibrium correction form, which clarifies medium- or longer-run influences on inflation, including opening the economy to foreign imports. This model implies that if consumer prices deviate from the trend of wholesale prices, an adjustment process tends to bring them closer together again. Further, when the real exchange rate is high (that is, the currency is strong in real terms), domestic price setters find it harder to push through price rises. The nominal exchange rate affects inflation through both these channels since wholesale prices are strongly linked to import prices. The model confirms the importance of the output gap and the influence from recent changes in the ratio of the current account surplus to GDP, both of which are sensitive to short-term interest rates. However, a rise in interest rates can also raise inflation in the short run, through a rise in the real prime rate and in mortgage interest payments (a component of the consumer price index). The one-quarter-ahead inflation forecast derives from the four-quarter-ahead forecast made three quarters earlier, updated using the intervening information on consumer prices, wholesale prices, and foreign inflation.

35. In all specifications the addition of the real U.S. Treasury bill rate, defined as the nominal rate less annual U.S. consumer price inflation, produces an insignificant, negative coefficient. Also note that the U.S. interest rate is defined as a period average, whereas the quarterly South African discount rate is measured at the end of each quarter. The implication is that the U.S. interest rate dated t is potentially part of the relevant information set of the SARB. We tested for this possibility but found it insignificant.

Table 3. Variable Definitions and Statistics

<i>Variable</i>	<i>Definition</i>	<i>Mean, 1986Q2- 1997Q4</i>	<i>Standard deviation, 1986Q2- 1997Q4</i>	<i>I(1),^a 1980Q1- 1997Q4</i>	<i>I(2),^a 1980Q1- 1997Q4</i>
Discount rate	SARB bank rate divided by 100	0.144	2.76E-2	-3.43*	-5.45**
U.S. Treasury	Three-month U.S. Treasury bill rate divided by 100	5.46E-2	1.52E-2	-3.41*	-5.19**
Inflation	Annual inflation rate of the consumer expenditure deflator	0.120	3.48E-2	-1.60	-3.79**
Output gap measure	Deviation of real GDP from a stochastic trend	1.69E-3	1.36E-2	-3.77**	
Excess M3 growth	Annual growth rate of M3 less the annual growth target rate	3.12E-2	4.96E-2	-4.97**	
FLIB	Financial liberalization measure (see text for full definition)	0.411	0.163		
DumANC	Equals 1 for 1994Q2-1997Q4 and 0 otherwise				
DumANC*excess M3 growth	DumANC interacted with excess M3 growth ($t-1$)				
ZBOP	Negative values only for the ratio of the (lagged) current account surplus to GDP (in percent) minus 2				

Source: Authors' calculations.

a. For a given variable X , the augmented Dickey-Fuller (1979) statistic is the t statistic on π from the following regression: $\Delta X_t = \pi X_{t-1} + \sum_{i=1}^k \theta_i \Delta X_{t-i} + \Psi_0 + \Psi_1 t + \varepsilon_t$, where k is the number of lags on the dependent variable, Ψ_0 is a constant term, and t is a trend. The k th-order augmented Dickey-Fuller statistic is reported, where k is the last significant lag of the five lags employed. The trend is included only if significant. For null order $I(2)$, ΔX replaces X in the equation above. Critical values are obtained from MacKinnon (1991). Asterisks * and ** denote rejection at the 5 percent and 1 percent critical values, respectively. The stationarity tests are performed for the variables in levels before time transformation, that is, before taking moving averages and changes. For the variable excess M3 growth, the sample period for the stationarity tests is 1986Q2-1997Q4. The output gap measure is OUTGAP1 (see text).

Table 4. Results of Regressions Testing Taylor Rules with Partial Adjustment and Foreign Rates ^a

Explanatory variable	Regression equation			
	(1)	(2) ^b	(3) ^c	(4) ^d
Intercept	0.032 (4.0)	0.028 (4.1)	0.032 (3.5)	0.017 (3.3)
Discount rate ($t-1$)	0.830 (22.6)	0.852 (27.0)	0.809 (22.0)	0.889 (25.7)
U.S. Treasury bill rate ($t-1$)	0.287 (4.2)	0.281 (3.7)	0.387 (4.9)	0.353 (2.8)
Lagged inflation	0.194 (5.8)			
Current inflation		0.188 (5.6)		
Future inflation			0.225 (4.9)	0.180 (5.3)
Lagged output gap	0.365 (3.7)			
Current output gap		0.373 (3.1)	0.424 (2.8)	
Future output gap				0.281 (2.1)
SER	0.00552	0.00614	0.00682	0.00721
R^2	0.964	0.955	0.944	0.938
Adjusted R^2	0.960	0.950	0.939	0.932
DW	2.40	2.42	1.84	1.72
F statistic ^e		3.00 p = 0.010	2.27 p = 0.041	2.50 p = 0.020

Source: Authors' calculations.

a. The dependent variable is the SARB discount rate. The sample period is 1986Q2 to 1997Q4. Absolute values of asymptotic t statistics are in parentheses. The output gap measure is OUTGAP1, the inflation forecasting equations are the more sophisticated models, and the broad set of instruments is used. The instruments used for regression equations (2) to (4) are the lagged financial liberalization indicator, the lagged deviation of annual M3 growth from target, one lag each of quarterly and annual inflation rates, two lags in the rate of change in capacity utilization, two lags in the rate of change of the nominal exchange rate, and the lagged annual growth rate of real private sector credit.

b. Fitted values from our equations for annual inflation and the output gap are added, using $t-1$ information.

c. Forecast value of the three-quarters-ahead annual inflation rate is added, using $t-1$ information.

d. Forecast value of the three-quarters-ahead annual rate of growth of output is added, using $t-1$ information.

e. The F test is a test for overidentifying restrictions on the instruments.

measures of the output gap, and for a narrower set of instruments, and found very similar results in each case.

It would appear therefore that, in the 1986-97 period, the SARB was concerned with stabilizing output: that is, it raised interest rates when output or prospective output was above trend. However, it apparently

moved interest rates perversely with inflation or prospective inflation. This seems not to be the most obvious way of controlling inflation, although to the extent that the output gap is a cause of subsequent inflation, the focus on the output gap is likely to have been beneficial. However, a specification test of overidentifying restrictions for regression equations (2) to (4) in table 4 rejects all the specifications.³⁶

3.3 Further Extensions of the Taylor Rule

Since, on the evidence just presented, the extended Taylor rule represented by equation (8) clearly makes little sense for South Africa, further extensions of the set of z_t terms in equation (6) were considered.

Extensions of the Taylor Rule for Excess Money Growth. Since in 1986 the SARB declared its official policy to be one of following monetary growth targets, one can include in the equation the deviation of actual monetary growth from the announced target (taking the latter to be the average of the upper and lower ranges set for the guidelines; figure 1). Experimentation suggested that the deviation of annual monetary growth perceived at $t - 1$ was a better measure than the current growth measure (instrumented appropriately). The results are shown in table 5. The excess money growth term has a significantly positive effect in all four specifications. The fit of all the equations improves compared with table 4. The counterintuitive result of a negative inflation effect remains but is much weaker, and indeed is insignificant in the current and forward-looking inflation specifications. Again there was little difference between regressions using the more sophisticated and those using the simpler forecasting inflation models, and between different measures of the output gap, and for a narrower set of instruments than reported.

Although the results in table 5 are less implausible than those of table 4, the combination of results from the two tables suggests that excess money growth is negatively related to recent, current, and future inflation, given the other variables in the hypothesized interest rule relationship. Clearly the excess money growth variable in table 5 eliminates about half the negative inflation effect in table 4.

36. The test compares the fit of the unrestricted reduced-form regression of the dependent variable on all the instruments with the fit obtained when the endogenous explanatory variables in equation (8) are replaced by their fitted values from ancillary regressions of these variables on the instruments.

Table 5. Results of Regressions Testing an Extended Taylor Rule with Excess Money Growth^a

Explanatory variable	Regression equation			
	(1)	(2) ^b	(3) ^c	(4) ^d
Intercept	0.030 (4.0)	0.023 (5.0)	0.025 (3.6)	0.020 (4.9)
Discount rate ($t-1$)	0.801 (22.7)	0.815 (30.0)	0.798 (23.9)	0.822 (28.0)
U.S. Treasury bill rate ($t-1$)	0.182 (2.5)	0.146 (1.2)	0.175 (1.6)	0.152 (1.3)
Lagged inflation	-0.105 (-2.4)			
Current inflation		-0.055 (0.8)		
Future inflation			-0.066 (1.3)	-0.050 (1.3)
Lagged output gap	0.231 (2.3)			
Current output gap		0.141 (1.0)	0.150 (1.4)	
Future output gap				0.110 (1.3)
Excess M3 growth ($t-1$)	0.075 (2.9)	0.096 (4.1)	0.102 (4.7)	0.108 (5.6)
SER	0.00508	0.00537	0.00547	0.00553
R^2	0.970	0.966	0.965	0.964
Adjusted R^2	0.966	0.962	0.961	0.960
DW	2.74	2.74	2.55	2.56
F statistic ^e		2.08 p = 0.066	1.22 p = 0.320	1.18 p = 0.343

Source: Authors' calculations.

a. The dependent variable is the SARB discount rate. The sample period is 1986Q2 to 1997Q4. Absolute values of asymptotic t statistics are in parentheses. The output gap measure is OUTGAP1, the inflation forecasting equations are the more sophisticated models, and the broad set of instruments is used. The instruments used for equations (2) to (4) are the lagged financial liberalization indicator, the lagged deviation of annual M3 growth from its target, one lag each of quarterly and annual inflation rates, two lags in the rate of change in capacity utilization, two lags in the rate of change of the nominal exchange rate, and the lagged annual growth rate of real private sector credit.

b. Fitted values from our equations for annual inflation and the output gap are added, using $t-1$ information.

c. Forecast value of the three-quarters-ahead annual inflation rate is added, using $t-1$ information.

d. Forecast value of the three-quarters-ahead annual rate of growth of output is added, using $t-1$ information.

e. The F test is a test for overidentifying restrictions on the instruments.

The test of overidentifying restrictions for regression equations (2) to (4) now marginally accepts the specifications.

Controlling for Financial liberalization in the Taylor Rule. The major changes in the financial system in South Africa in the 1980s and

1990s were discussed in section 1. The government initiated financial liberalization following the De Kock Commission reports (De Kock and others, 1978, 1984), which advocated a more market-oriented monetary policy. Some interest and credit controls were removed in 1980, and banks' liquidity ratios were reduced substantially between 1983 and 1985. Competition rose in the mortgage market following the 1986 Building Societies Act and amendments to the act in 1987-88. Demutualization and takeovers in 1989-90 consolidated the stronger competition in the credit market. In the 1990s pensions were increasingly used to provide additional collateral for housing loans, and from 1993 on, special mortgage accounts ("access bond accounts") allowed households to borrow and repay flexibly from these accounts up to an agreed limit set by the value of their housing collateral. After the 1994 elections more black South Africans obtained formal employment, particularly in the public sector, gaining access to credit that they may previously have been denied (total formal employment, however, continued to decline). Exchange controls on nonresidents were eliminated in early 1995: large nonresident capital inflows beginning in mid-1994 induced a temporary, endogenous financial liberalization. Finally, exchange controls on domestic residents, in existence since before the 1960s, were partially relaxed after 1997.

With the removal of interest rate controls, credit restrictions, and barriers to competition, supply and demand for credit have become increasingly market-determined. This has the implication, other things being equal, that higher rates of interest are required to equilibrate the market for credit. In Aron and Muellbauer (2000b and c) we develop a univariate indicator of the degree of liberalization of credit markets, which we denote as $Fi\ IB$. We include this indicator in the Taylor rule as a measure of the regime change, since the bank rate set by the SARB cannot be immune from the effects of financial liberalization.

An innovation in Aron and Muellbauer (2000b and c) is to treat financial liberalization as an unobservable indicator entering both quarterly household debt and consumption equations. The indicator, $Fi\ IB$, is proxied by a linear spline function, whose parameters are estimated jointly with the consumption and debt equations (subject to cross-equation restrictions on the coefficients in the spline function). The debt and consumption equations also incorporate a rich set of economic variables including income and income expectations, important wealth effects, and interest rate effects. The estimated parameters for $Fi\ IB$ in the model reflect the key institutional changes in credit

markets. Our estimated indicator shows strong rises in 1984, 1988, and 1995, with more moderate increases in 1989, 1990, and 1996 (figure 4). It is noteworthy that both the consumption function and the debt equation are subject to major structural breaks (failing Chow tests) when allowance is not made for financial liberalization.

The estimation results for the extended Taylor rule, equation (8), including both the money target variable and *Fi IB*, are shown in table 6. The results improve dramatically. *Fi IB* has a significant positive effect in all four specifications, and the inflation effect becomes positive throughout. The specification with current-dated inflation and the current-dated output gap gives the strongest inflation effect, as well as the best fit, although the effect of the output gap is weak.³⁷ The fit is substantially worse for the specifications with future inflation. However, all the variables now have the expected direction of effect, with excess money growth and the U.S. interest rate remaining significant in all specifications.³⁸ The current output gap tends to be insignificant when current inflation is included, and the future output gap is insignificant when future inflation is included. Table 6 includes a selective sample of results to indicate sensitivities to an alternate specification of the output gap, alternative inflation forecasts, and different sets of instruments. All four specifications easily pass the test of overidentifying restrictions.

We also investigated the hypothesis that low domestic saving-to-GDP ratios, which might have been expected to affect real interest rates, influenced the bank rate. However, these effects are insignificant when included in the table 6 specifications.

We now interpret these results in the light of equation (7), using as representative the results from equation (2a) in table 6. The coefficient on the lagged interest rate, ρ , is estimated at 0.320. This implies that the long-run coefficient on the U.S. interest rate, λ , is 0.587, whereas β , which measures the response to domestic inflation, is 0.83. In this equation the output gap is insignificant. When the corresponding structural equation (7), which is nonlinear in parameters, was

37. We compare the results both for the sophisticated inflation forecasting model, regression equation (2a), and a simpler model, regression equation (2b), in each case using the broad set of instruments. The relevance of inflation relative to the output gap is decreased for equation (2b). We found similar results for the same comparison using regression equation (3). Comparing regression equations (4a) and (4c), table 6, which incorporate the inflation forecast at $t - 1$, four quarters ahead, it is noteworthy that the simpler model gives the stronger inflation coefficient.

38. As before, including the lagged U.S. real interest rate gives positive but insignificant coefficients.

Table 6. Results of Regressions Testing an Extended Taylor Rule with Excess Money Growth and Financial Liberalization^a

<i>Explanatory variable</i>	<i>Regression equation</i>							
	<i>(1)</i>	<i>(2a)</i>	<i>(2b)^b</i>	<i>(2c)^c</i>	<i>(3)</i>	<i>(4a)</i>	<i>(4b)^b</i>	<i>(4c)^d</i>
Intercept	0.018 (2.1)	0.001 (0.16)	0.008 (0.9)	0.003 (0.6)	0.016 (2.4)	0.010 (1.6)	0.008 (1.3)	0.003 (0.4)
Discount rate ($t - 1$)	0.457 (3.2)	0.320 (4.0)	0.421 (4.3)	0.326 (4.8)	0.595 (8.0)	0.645 (10.8)	0.633 (11.2)	0.583 (10.6)
U.S.Treasury bill rate ($t - 1$)	0.395 (3.6)	0.399 (5.5)	0.367 (4.6)	0.417 (6.1)	0.297 (3.6)	0.249 (2.8)	0.248 (2.8)	0.243 (2.9)
Lagged inflation	0.059 (0.8)							
Current inflation		0.234 (3.7)	0.151 (2.2)	0.192 (3.5)				
Future inflation					0.029 (0.6)	0.068 (1.4)	0.084 (1.8)	0.148 (2.8)
Lagged output gap	0.251 (2.6)							
Current output gap		0.072 (0.6)	0.123 (1.2)	0.114 (1.8)	0.188 (2.1)			
Future output gap						0.052 (0.7)	0.040 (0.5)	-0.022 (0.3)

Table 6. (continued)

<i>Explanatory variable</i>	<i>Regression equation</i>							
	<i>(1)</i>	<i>(2a)</i>	<i>(2b)^b</i>	<i>(2c)^c</i>	<i>(3)</i>	<i>(4a)</i>	<i>(4b)^b</i>	<i>(4c)^d</i>
Excess M3 growth ($t - 1$)	0.053 (2.1)	0.069 (3.3)	0.066 (3.3)	0.046 (2.2)	0.060 (2.6)	0.078 (3.8)	0.078 (3.8)	0.076 (3.6)
FLIB ($t - 1$)	0.075 (2.5)	0.112 (5.7)	0.089 (3.8)	0.117 (6.5)	0.052 (2.9)	0.047 (2.9)	0.049 (3.2)	0.062 (4.0)
SER	0.00478	0.00432	0.00436	0.00414	0.00478	0.00494	0.00492	0.00496
R^2	0.974	0.979	0.978	0.980	0.974	0.972	0.972	0.972
Adjusted R^2	0.970	0.976	0.975	0.978	0.970	0.968	0.968	0.968
DW	2.36	2.28	2.44	2.47	2.64	2.62	2.61	2.51
F statistic ^e		2.30 p = 0.947			0.56 p = 0.781	0.84 p = 0.560		

Source: Authors' calculations.

a. The dependent variable is the SARB discount rate. The sample period is 1986Q2 to 1997Q4. Absolute values of asymptotic t statistics are in parentheses. The output gap measure is OUTGAP1, the inflation forecasting equation is the more sophisticated model, and a broad set of instruments is used, unless otherwise indicated. The instruments used for equations (2) to (4b) are the same as in the preceding two tables.

b. The simpler inflation forecasting equation is used.

c. The output gap measure is OUTGAP2.

d. The simpler inflation forecasting equation and a narrower set of instruments are used: the exogenous or lagged variables in the equation, forecast inflation, and the forecast output gap, using $t - 1$ information.

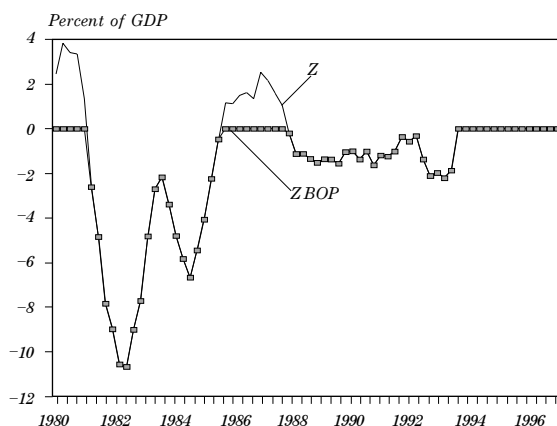
e. The $\bar{F}$ test is a test for overidentifying restrictions on the instruments.

estimated by the IV method, and the output gap omitted, the estimated value of β was 0.87, with a standard error of 0.19, suggesting that the hypothesis that $\beta = 1$ is acceptable.

Extension of the Taylor Rule for Balance of Payments Constraints. As discussed in section 2, South Africa has periodically experienced major shocks to the balance of payments from external trade shocks and political shocks: first under a closed capital account, and after March 1995 under a capital account fully open to foreign flows and international contagion. These shocks may have resulted in monetary policy being subordinated for long periods to balance of payments considerations. We have attempted to test for such effects.

First, we examine the period after the debt crisis of September 1985, in which a debt standstill was followed by rescheduling arrangements, which remained in force until the debt was fully paid off in 1994. We test whether interest rates were higher in this period than could be justified simply by the fundamentals, because of massive capital outflows (including debt repayments) and insignificant new inflows. We define a variable Z as the lagged ratio of the current account surplus to GDP less a value of 3 percent, which has been suggested as the basic surplus required for debt repayments (Leape, 1991). In figure 5 we show both Z and $ZBOP$, which is defined to be all the negative values of Z and is the variable we include in our interest rule regression in table 7. However, given that South Africa made extensive use

Figure 5: South Africa: Percent of GDP Balance of Payments Constraints



Source: Author's elaboration.

made of an alternative, flexible trade policy instrument to suppress import demand (high import surcharges exceeded tariff rates in many years; see section 2), one may not expect to see much of an effect from *ZBOP*. The result is shown in regression equation (2) in table 7: although the coefficient is negative, it is not significant.

We also tested for an implicit bilateral exchange rate target from the second quarter of 1994 until the first currency crisis of February 1996 (see section 1.4) but were unable to find an effect over this short

Table 7. Regression Results Testing an Extended Taylor Rule for Balance of Payments Effects^a

<i>Explanatory variable</i>	<i>Regression equation</i>		
	<i>(1)</i>	<i>(2)</i>	<i>(3)</i>
Intercept	-0.002 (-0.47)	-0.002 (0.0)	0.002 (0.4)
Discount rate ($t-1$)	0.306 (2.5)	0.315 (2.7)	0.276 (2.6)
U.S. Treasury bill rate ($t-1$)	0.405 (4.9)	0.426 (5.9)	0.488 (6.4)
Current inflation	0.266 (3.7)	0.234 (2.9)	0.207 (2.4)
Excess M3 growth ($t-1$)	0.078 (4.3)	0.076 (4.2)	0.078 (4.3)
FLIB ($t-1$)	0.116 (4.3)	0.111 (4.1)	0.124 (5.3)
ZBOP		-0.162 (-1.3)	
DumANC*excess M3 growth			-0.094 (1.8)
SER	0.00436	0.00426	0.00416
R^2	0.978	0.979	0.980
Adjusted R^2	0.975	0.976	0.977
DW	2.20	2.37	2.38

Source: Authors' calculations.

a. The dependent variable is the SARB discount rate. The sample period is 1986Q2 to 1997Q4. Absolute values of asymptotic t statistics are in parentheses. The estimations employ the narrow set of instruments (see table 6) and the more sophisticated inflation model.

period of six quarters. However, there was some evidence (a *t*-statistic of 1.8) for a reduced weight on excess M3 in the policy rule from the second quarter of 1994, implying that excess money growth was effectively abandoned as a guide to intermediate policy; see regression equation (3) in table 7. The impact of capital inflows from July 1994 onward, with accumulated reserves unsterilized until the following year (when monetary policy tightened sharply), is clear from the sharp rise in excess M3, afterward sustained at the new high level (figure 1). As shown in Aron and Elbadawi (1999), there was a trade-off between monetary policy and exchange rate objectives in the period, leading to a currency crisis early in 1996.

4. SUMMARY AND POLICY ISSUES

Monetary policy in South Africa has gone through major evolutionary changes, particularly in the 1980s, when there was extensive financial liberalization, with monetary targeting initiated in 1986, and since 1998, with the move to inflation targeting. In this paper we have modeled extended Taylor rules for interest policy over the period 1986-97, using our forecasts of inflation and the output gap to 1998 in the instrument set.

There are four key results. First, attempts to fit a Taylor rule, extended for the lagged dependent variable and the U.S. short-term interest rate, do not give sensible results. Astonishingly, it appears that the SARB changed the interest rate perversely with lagged, current, or future inflation: the estimated coefficients are strongly significant. Only when excess money growth and an indicator of financial liberalization are introduced—both factors that raised real interest rates and happen to be negatively correlated with inflation over the sample—does the SARB's policy rule look more sensible.

Second, in the context of a liberalization of credit and other financial markets, and given the international interest rate environment, the SARB followed a rule that included current inflation in its interest rate policy formulation, despite claiming to focus largely on money growth targeting. The rule appears to target inflation and to deemphasize the output gap. Future inflation has no weight placed on it; this result is robust for both simple and sophisticated models of inflation forecasts and may have been influenced by the limited development of inflation forecasting models in the SARB. Moreover, given the large structural changes in money and credit markets, the attempt

to target money probably led to worse output and inflation outcomes than if a more sensible version of the Taylor rule been followed.³⁹

The force of this last point is weakened, however, by the fact that policy had competing preoccupations starting in late 1985, the principal one being the need to maintain surpluses on the current account, given the virtual cessation of capital inflows. Our third finding is on the relevance of structural breaks related to the difficulty of managing large capital outflows during 1986-94 after the debt crisis, and later, the large inflows following democratic elections in 1994 and the freeing of capital controls on foreign investors. We find evidence that excess money growth is less important after 1994, and weak evidence that balance of payments concerns had some influence on monetary policy during 1986-94.

Finally, even with the interpretation of the long-run coefficient on the inflation term given in equation (8), the weight attached to inflation is below that found for policy rules in other countries, or indeed, with pure inflation targeting. For the United States, Clarida, Gali, and Gertler (1998b) find that, when inflation rose, the pre-1979 Federal Reserve raised interest rates by less than the rise in inflation, so that real interest rates fell (β is less than 1). After 1979, in contrast, when inflation rose, real interest rates also rose, so that policy reaction was more anti-inflationary (β is greater than 1; this policy strategy is termed "leaning against the wind"). For a range of countries, Clarida, Gali, and Gertler (1998a) found values for β of 1 or higher in the post-1979 period (for example, β is estimated at 1.8 for the Federal Reserve, 2 for the Bank of Japan, and 1.3 for the Bundesbank). We find weights in the region of 0.8 to 1.1 for β in South Africa, using nonlinear IV estimation for equation (7), as described in section 3.1. One can accept the hypothesis of a weight of 1 on the basis of standard errors. This suggests that, after controlling for excess money, financial liberalization, and the foreign interest rate, there was little "leaning against the wind" by the central bank, but that the real interest rate was almost invariant with inflation. This does not suggest a highly anti-inflationary stance after 1986, as has been claimed, although clearly there were competing considerations concerning the balance of payments.

39. The United Kingdom had effectively abandoned monetary targeting by 1986, in large part because of the lack of stability in the relationship between money growth and output, inflation, and interest rates. By then, it had been demonstrated in a number of econometric studies (for example, Hendry, 1985) that inverting a money demand equation does not give a sensible model of inflation, except perhaps in countries with hyperinflation or budgetary problems so severe that the authorities are tempted to resort to the inflation tax as a major source of revenue.

APPENDIX

Financial Liberalization in South Africa, 1960-97

Table A1. Liberalization of Interest Rates^a

<i>Date</i>	<i>Measure</i>
<i>Deposit rate controls</i>	
March 1965 to July 1966	Upper limits first imposed on rate of interest payable on bank and building society deposits
December 1969	Reintroduced at 7 percent per year
August 1970	Dropped. Government decides to subsidize certain interest rates
March 1972	Reintroduced
March 1980	Dropped
<i>Lending rate controls</i>	
Before 1967	Clearing bank prime rates for overdrafts: Minimum and prime overdraft lending rates set by agreement with the SARB at 1.5 and 2 percent above the bank rate
1967 to mid-1975	Minimum and prime overdraft lending rates set at 2 percent and 2.5 percent above the bank rate
July 1975	A newly defined prime rate ("the lowest rate at which a clearing bank will lend on overdraft") is set by individual banks within the margins of 2.5 to 3.5 percent above the bank rate (changes to be discussed first with the SARB)
February 16, 1982	Banks released from the obligation to keep the prime rate within specific limits (but still have to inform the SARB of intended prime rate changes)
	Loan and credit transactions: Maxima have been in force since before the 1960s in terms of various Usury and Finance Acts. Maximum finance charge rates are now linked to clearing banks' prime rates by formula, for various categories of money loan and credit and leasing transactions.
	Mortgage rates: Informal constraints removed only in the early 1980s

Source: Bandiera and others (2000); De Kock and others (1984); *SARB Quarterly Bulletin*, various issues; *Money and Banking Statistics of South Africa: 1970-92*.

a. Adjustments to deposit and lending rates were made at various times to the maximum rates and various classes of intermediaries and liabilities subject to these controls, and the coverage and level of credit ceilings was adjusted on several occasions.

Table A2. Directed Credit

<i>Date</i>	<i>Measure</i>
November 1965	Total of discounts and advances by monetary banking institutions to the private sector restricted to the level of such credit on March 31, 1965
December 1966	Ceiling reduced to 92.5 percent of the March 1965 level
August 1967	"Voluntary" controls made mandatory by proclamation
May 1968	Extended ceilings to cover bank investment in private sector securities
August 1970	Extended to nonmonetary banks to curb competition
September 1972	Intention announced to phase out ceilings, but ceilings are raised by 7.5 percent
November 1972	Credit ceilings abolished
February 1976	Credit ceilings reimposed for bank credit to the private sector
1977-80	Ceilings further tightened at various points
August 1980	Credit ceilings finally withdrawn

Source: Bandiera and others (2000); De Kock and others (1984); *SARB Quarterly Bulletin*, various issues; *Money and Banking Statistics of South Africa*: 1970-92.

Table A3. Cash Reserve and Liquid Asset Requirements

<i>Date</i>	<i>Measure</i>
<i>Liquid asset requirements^a</i>	
August 1980	Two categories of banks with differing requirements; for example, category A: 58 percent (short-term), 35 percent (medium-term), 5 percent (long-term)
September 27, 1982	Two categories of banks: for example, category A: 54 percent (short-term), 34 percent (medium-term), 5 percent (long-term)
July 19, 1983	All banks have the same percentage requirements: 48 percent (short-term), 28 percent (medium-term), 5 percent (long-term)
September 20, 1983	All banks have the same percentage requirements: 40 percent (short-term), 20 percent (medium-term), 5 percent (long-term)
December 8, 1983	All banks have the same percentage requirements: 30 percent (short-term), 20 percent (medium-term), 5 percent (long-term)
March 14, 1984	All banks have the same percentage requirements: 25 percent (short-term), 18 percent (medium-term), 5 percent (long-term)
March 29, 1985	All banks have the same percentage requirements: 22 percent (short-term), 16 percent (medium-term), 5 percent (long-term)

Table A3. (continued)

<i>Date</i>	<i>Measure</i>
August 31, 1985	New method to calculate short-term liabilities results in a larger calculated amount of such liabilities. Requirements for all banks: 20 percent (short-term), 15 percent (medium-term), 5 percent (long-term)
February 1991	Definition of short-term liabilities extended to include repurchase agreements and other liabilities not previously included. Requirement for all banks: 20 percent of short-term liabilities
April 1993	Certain types of assets (such as banker's acceptances) lose liquid asset status. Requirement for all banks: 5 percent of total liabilities
<i>Cash reserve requirements</i>	
April 11, 1980	Two classes of banks: 8 percent (short-term, non-interest-bearing); additional: 7 percent (short-term, non-interest-bearing), 5 percent (medium-term, interest-bearing with the National Finance Corporation, NFC)
September 12, 1980	Two classes of banks: for example, class A: basic: 8 percent (short-term, non-interest-bearing); additional: 10 percent (short-term, non-interest-bearing), 3 percent (medium-term, non-interest-bearing), 2 percent (medium-term, interest-bearing with NFC)
March 31, 1982	Two classes of banks: for example, class A: basic: 8 percent (short-term, non-interest-bearing); additional: 4 percent (short-term, non-interest-bearing), 3 percent (medium-term, non-interest-bearing), 2 percent (medium-term, interest-bearing)
September 27, 1982	All banks: basic: 8 percent (short-term, non-interest-bearing); additional: 2 percent (short-term, non-interest-bearing), 2 percent (medium-term, interest-bearing with NFC)
September 30, 1983	All banks have only basic requirements: 8 percent (short-term, non-interest-bearing), 2 percent (medium-term, non-interest-bearing), 2 percent (medium-term, interest-bearing with NFC)
March 15, 1984	All banks: 8 percent (short-term, non-interest-bearing), 2 percent (medium-term, non-interest-bearing)
July 31, 1985	Bank's vault cash included in cash reserves
April 1, 1986	All banks: 5 percent (short-term, non-interest-bearing), 2 percent (medium-term, non-interest-bearing)
February 1, 1991	All banks: 4 percent (short-term, non-interest-bearing)
July 21, 1992	All banks: 4 percent (short-term, non-interest-bearing); additional 1 percent (short-term, interest-bearing)
April 26, 1993	All banks: 3 percent (short-term, non-interest-bearing); additional 1 percent (short-term, interest-bearing)
August 1993	All banks: 1.5 percent (short-term, non-interest-bearing), 1 percent all other liabilities; additional 1 percent (short-term, interest-bearing)

Source: Bandiera and others (2000); De Kock and others (1984); *SARB Quarterly Bulletin*, various issues; *Money and Banking Statistics of South Africa: 1970-92*

a. Liquid asset requirements were the principal monetary policy instrument from 1960 through mid-1982.

Table A4. Competition in Financial Markets

<i>Date</i>	<i>Measure</i>
February 28, 1983	Register of Co-operation (an agreement among commercial banks limiting competition) ended
1983	A substantial number of new banks are allowed to start operations (few new banking institutions had been established prior to 1980)
<i>Takeovers and mergers</i>	
1989	Nedbank and SA Permanent Society merge to form Nedperm Bank
1991	United, Volskas, and Allied Societies form ABSA
1992	ABSA takes over Bankorp (leaves four major banking groups)
1994 onward	Foreign banks enter South Africa
<i>Financial innovation</i>	
1990s	Credit cards; "access bonds" where households can borrow against housing collateral; pension assets can be used as collateral for mortgage lending

Source: Bandiera and others (2000); *SARB Quarterly Bulletin*, various issues; interviews conducted by the authors.

Table A5. Supervisory and Prudential Regulatory Changes

<i>Date</i>	<i>Measure</i>
1986	Building Society Act: tax benefits and other advantages giving building societies a monopoly of the mortgage market are phased out
1988	Amendments to banking and building society legislation make cash reserve and liquid asset requirements the same for each. Previously building societies required no cash reserve requirements against liabilities to the public, substantially lower liquid asset requirements, and no supplementary liquid asset requirements
1990	Deposit-taking Institutions Act of 1990: banks and building societies brought under the same legislation, except for small mutual building society sector (covered by separate act)

Source: Bandiera and others (2000); *SARB Quarterly Bulletin*, various issues; *Money and Banking Statistics of South Africa: 1970-92*.

Table A6. Exchange Rate Liberalization

<i>Date</i>	<i>Measure</i>
1961-75	Fixed exchange rate regimes of various types
September 22, 1975	Rand is devalued 17.85 percent; new rate is R1.00 = \$1.15
January 24, 1979	Two-tier exchange rate system established: official rate renamed the commercial rate and put on a controlled float, applicable to foreign trade, authorized capital transfers, and current payments including remittance of dividend and interest payments. Free-floating financial rand applicable to nonresidents' financial transactions, including foreign direct investment, repatriation of capital and profits, and outward capital transfers by residents and emigrants
February 7, 1983	Dual exchange rates unified to a controlled float of an effective rand
September 2, 1985	Two-tier system reestablished, with commercial and financial rands
March 1995	Dual rates finally unified in a "managed" float

Source: Aron, Elbadawi, and Kahn (2000); Bandiera and others (2000); De Kock and others (1984); *SARB Quarterly Bulletin*, various issues.

Table A7. Capital Account Liberalization

<i>Date</i>	<i>Measure</i>
<i>Nonresidents</i>	
March 1995	Dual exchange rates unified (abolition of all controls on the transactions of nonresidents)
June 1996	Local borrowing limit for 100 percent foreign investors doubled to 100 percent of effective capital
<i>Residents</i>	
July 13, 1995	Institutional investors allowed to swap up to 5 percent of their total assets with foreign investors (insurance companies, pension funds, and unit trusts)
June 1996	The limit on institutional investors for asset swaps is raised to 10 percent. Financial institutions can place up to 3 percent of 1995 cash flows abroad in 1996 by end-1996, and foreign exchange access is made easier for corporations wishing to invest in neighboring states. Exports still have to be repatriated within 7 days but can offset foreign exchange needs for imports within 30 days
October 1996	Authorized foreign exchange dealers' foreign exchange cash limits doubled to \$1.5 billion (since April 1996 they had been allowed to exceed these limits)

Table A7. (continued)

<i>Date</i>	<i>Measure</i>
March 12, 1997	Reforms announced in budget speech, effective from July 1997, include the following: • Corporates can transfer up to R30 million per new investment to countries outside the Common Monetary Area, and up to R50 million per new investment in Southern Africa Development Community member countries • Firms can raise offshore financing based on balance sheet strength of their parent company • Long-term insurers, pension funds, and unit trusts authorized—in addition to swap facilities previously sanctioned—to transfer capital abroad in 1997 equal to 3 percent of net inflow of funds to these institutions during 1996, with overall limit of 10 percent of total assets to be held in foreign currency-denominated securities • Qualifying institutional investors allowed to invest 2 percent of net domestic income surpluses during 1996 in securities listed on stock exchanges in SADC member countries, subject to the overall limit of 10 percent of total assets

Source: Bandiera and others (2000); *SARB Quarterly Bulletin*, various issues; *Money and Banking Statistics of South Africa*: 1970-92.

REFERENCES

- Aron, J., and I. Elbadawi. 1999. "Reflections on the South African Rand Crisis of 1996 and Its Consequences." Working Paper Series 13. Oxford, England: Centre for the Study of African Economies, Oxford University.
- Aron, J., I. Elbadawi, and B. Kahn. 2000. "Real and Monetary Determinants of the Real Exchange Rate in South Africa." In *Development Issues in South Africa*, edited by I. Elbadawi and T. Hartzenberg. London: MacMillan.
- Aron, J., and J. Muellbauer. 2000a. "Inflation and Output Forecasting for South Africa: Monetary Transmission Implications." Working Paper Series 23. Oxford, England: Centre for the Study of African Economies, Oxford University.
- . 2000b. "Financial Liberalisation, Consumption and Debt in South Africa." Working Paper Series 22. Oxford, England: Centre for the Study of African Economies, Oxford University.
- . 2000c. "Personal and Corporate Saving in South Africa." *World Bank Economic Review* 14(3): 509-44.
- Ball, L. 1999. "Policy Rules for Open Economies." In *Monetary Policy Rules*, edited by J. B. Taylor. Chicago: University of Chicago Press.
- Bandiera, O., G. Caprio, P. Honohan, and F. Schianterelli. 2000. "Does Financial Reform Raise or Reduce Private Savings?" *Review of Economics and Statistics* 82(2): 239-63.
- Batini, N., and A. G. Haldane. 1999. "Forward-looking Rules for Monetary Policy." In *Monetary Policy Rules*, edited by J. B. Taylor. Chicago: University of Chicago Press.
- Bernanke, B. S., and F. S. Mishkin. 1997. "Inflation Targeting: A New Framework for Monetary Policy?" *Journal of Economic Perspectives* 11: 97-116.
- Bernanke, B. S., T. Laubach, F. S. Mishkin, and A. S. Posen. 1999. *Inflation Targeting: lessons from the International Experience*. Princeton, N.J.: Princeton University Press.
- Casteleijn, A. J. H. 1999. "The Viability of Implementing an Inflation Targeting Monetary Policy Framework in South Africa." *South African Reserve Bank Quarterly Bulletin* (June): 37-47.
- Clarida, R., and M. Gertler. 1997. "How the Bundesbank Conducts Monetary Policy." In *Reducing Inflation: Motivation and Strategy*, edited by C. Romer and D. Romer. Chicago: University of Chicago Press.

- Clarida, R., J. Galí, and M. Gertler. 1998a. "Monetary Policy Rules in Practice: Some International Evidence." *European Economic Review* 42: 1033-67.
- . 1998b. "Monetary Policy Rules and Macroeconomic Stability: Evidence and Some Theory." NBER Working Paper 6442. Cambridge, Mass.: National Bureau of Economic Research.
- Centre for Research into Economics and Finance in Southern Africa. 1996. "Managing the Rand's Depreciation: The Role of Intervention." , London School of Economics *Quarterly Review* (April): 2-13.
- De Kock, G., and others. 1978. "Exchange Rates in South Africa." In *Commission of Inquiry into the Monetary System and Monetary Policy in South Africa: Interim Report*. Pretoria: Government Printer.
- . 1984. "The Monetary System and Monetary Policy in South Africa." In *Commission of Inquiry into the Monetary System and Monetary Policy in South Africa: Final Report*. Pretoria: Government Printer.
- Dickey, D. A., and Fuller, W. A. 1979. "Distribution of the Estimators for Autoregressive Time Series with a Unit Root." *Journal of the American Statistical Association* 74 (366): 427-31.
- Gidlow, R. M. 1995. *South African Reserve Bank Monetary Policies under Dr. Gerhard De Kock, 1981-89*. Pretoria: South African Reserve Bank.
- Harvey, A. C. 1993. *Time Series Models*, 2nd ed. London: Harvester Wheatsheaf.
- Harvey, A., and A. Jaeger. 1993. "Detrending, Stylized Facts and the Business Cycle." *Journal of Applied Econometrics* 8: 231-47.
- Henderson, D. W., and W. J. McKibbin. 1993. "A Comparison of Some Basic Monetary Policy Regimes for Open Economies: Implications of Different Degrees of Instrument Adjustment and Wage Persistence." *Carnegie-Rochester Conference Series on Public Policy* 39: 221-317.
- Hendry, D. 1985. "Monetary Economic Myth and Econometric Reality." *Oxford Review of Economics and Policy* 1(1): 72-84.
- Kahn, B. 1992. "South African Exchange Rate Policy, 1979-91." Research Paper 7. London: Centre for the Study of the South African Economy and International Finance, London School of Economics.
- . 1998. "Inflation Targeting." Centre for Research into Economics and Finance in South Africa, London School of Economics, *Quarterly Review* 2: 17-25.
- Koopman, S. J., A. C. Harvey, J. A. Doornik, and N. Shephard. 1995. *STAMP 5.0*. London: Chapman and Hall.

- Leape, J. 1991. "South Africa's Foreign Debt and the Standstill, 1985-1990." Research Paper 1. London: Centre for the Study of the South African Economy and International Finance, London School of Economics.
- Leiderman, L., and L. E. O. Svensson. 1995. *Inflation Targets*. London: Centre for Economic Policy Research.
- Levin, A., V. Wieland, and J. C. Williams. 1999. "Robustness of Simple Monetary Policy Rules under Model Uncertainty." In *Monetary Policy Rules*, edited by J. B. Taylor. Chicago: University of Chicago Press.
- Lucas, R. E. 1976. "Econometric Policy Evaluation: A Critique." *Carnegie-Rochester Conference Series on Public Policy* 1: 19-46.
- MacKinnon, J. 1991. "Critical Values for Cointegration Tests." In *Long-Run Economic Relationships: Readings in Cointegration*, edited by R. Engle and C. Granger. Oxford, England: Oxford University Press.
- McCallum, B. T. 1988. "Robustness Properties of a Rule for Monetary Policy." *Carnegie-Rochester Conference Series on Public Policy* 29: 107-204.
- Mishkin, Frederic S. 1999. "Comment." In *Monetary Policy Rules*, edited by J. B. Taylor. Chicago: University of Chicago Press.
- Phillips, A. W. 1954. "Stabilisation Policies in a Closed Economy." *Economic Journal* 64: 290-323.
- Pretorius, C. J., and M. M. Smal. 1994. "A Macro-economic Examination of the Price-formation Process in the South African Economy." *South African Reserve Bank Quarterly Bulletin* (March): 25-36.
- Rotemberg, J. J., and M. Woodford. 1999. "Interest Rate Rules in an Estimated Sticky Price Model." In *Monetary Policy Rules*, edited by J. B. Taylor. Chicago: University of Chicago Press.
- South African Reserve Bank. 2000. *A New Monetary Policy Framework: Appendix, Statement of the Monetary Policy Committee* (April 6).
- Stals, C. 1994. "Governor's Address." Pretoria: South African Reserve Bank (August 23).
- . 1995a. "Monetary Policy and Its Implications." Address to the *International Herald Tribune* conference, September 11.
- . 1995b. "Monetary Policy in South Africa." Address to the Second South African Economy, Investment and Trade Conference, London, October 17.
- Taylor, J. 1993. "Discretion versus Policy Rules in Practice." *Carnegie-Rochester Conference on Public Policy* 39: 195-214.

- . 1995. "The Monetary Transmission Mechanism: An Empirical Framework." *Journal of Economic Perspectives* 9(4): 11-26.
- . 1999. *Monetary Policy Rules*. Chicago: University of Chicago Press.
- Union Bank of Switzerland. 1996. "Economic Research Note." (February 13).

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