Commodity Prices and Macroeconomic Policy

Rodrigo Caputo
Roberto Chang
editors

Central Bank of Chile / Banco Central de Chile

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Commodity Prices and Macroeconomic Policy: An Overview

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World commodity prices and their macroeconomic impact, especially on emerging economies, have long been a main concern in economic research. Decades ago, the Prebisch-Singer hypothesis of secularly deteriorating terms of trade (Prebisch, 1950; Singer, 1950) was the subject of intense debate and became a cornerstone of major development theories and, especially in Latin America, of influential policy approaches.[1] In a related fashion, extensive literature has studied the long-run behavior of commodity prices. Although there is some controversy about the main drivers of the relative prices of commodities, there is consensus that, since the nineteenth century, four commodity "super cycles" have taken place. These super cycles have been related to strong demand associated with moments of rapid industrialization and urbanization in major areas of the world. Each of them, lasting on average 20 years, ended once the supply of commodities increased to match the growing demand (Canuto, 2014).

Recent events have brought similar issues back to the top of the economics agenda. During the current commodity super cycle, which began in the late 1990s, the world economy has seen wide swings in the world prices of primary items such as oil, food, and metals. Echoing past debates, commodity prices are again posing urgent

1.Both Structuralism and Dependency Theory relied heavily of the Prebisch-Singer hypothesis. These theories, in turn, underpinned the strategy of Industralization via Import Substitution. For a recent empirical evaluation of the Prebisch-Singer hypothesis, see Aretski and others (2013).

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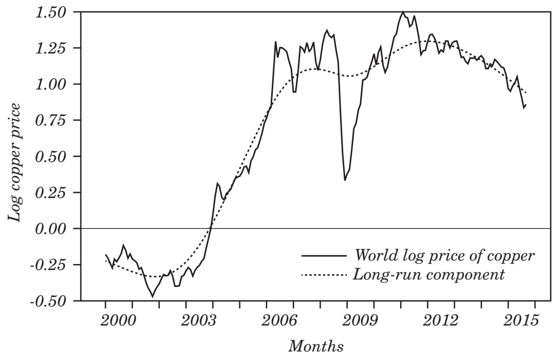
Figure 1. Copper Prices[a]



Source: Central Bank of Chile.
a. Monthly data spanning January 2000 – October 2015.

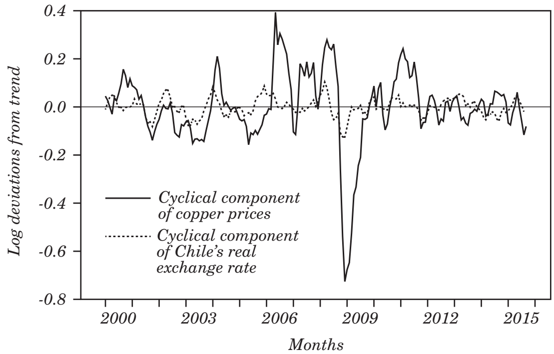
questions to academics and policymakers. The questions are both positive (such as, what is the impact of commodity price shocks on macroeconomic aggregates?) and normative (how should monetary and fiscal policy best react to those shocks?); they pertain to both the short run (are copper funds and other stabilization schemes a good idea?) and the long-run (should developing countries try to change their productive structures to diversify exports away from primary products?). Research on these and related issues is badly needed, particularly for emerging economies that are heavily exposed to commodity price fluctuations.

To contribute to the debate, this volume gathers six studies written for the XVIII Annual Research Conference of the Central Bank of Chile. The unifying theme of the conference was to examine appropriate macroeconomic policies in light of the increased volatility of world commodity prices. The studies in this volume explore different dimensions and aspects of that theme, as well as diverse policy alternatives, instruments, and strategies.

This diversity, to a large extent, reflects the many facets of the problem suggested by the raw behavior of commodity prices. To understand this, it is illustrative to glance at the data. In figure 1, the trajectory of the world price of copper since 2000 is plotted in black.[2]

2.The raw series is the world copper price, US$/lb, taken from the Central Bank of Chile's website. Figure 1 shows the natural log of the price.

Figure 2. Chile: Copper Prices and Real Exchange Rate over the Cycle



Source: Central Bank of Chile.

Copper is, of course, a key export for Chile, Peru, and other emerging economies, but its recent price fluctuations are representative of those of other metals. The raw series exhibits extremely large fluctuations; it is also clear that there is variability in both the short run and the long-run. The identification of low frequency versus high frequency components is in fact a non trivial exercise, but for concreteness the figure shows (dotted line) a "long-run" component, computed via the well known Hodrick-Prescott filter.[3] The short run or cyclical component can then be defined, as usual, by the difference between the raw series and its long-run component; it displays large fluctuations. It is notable from figure 1, however, that fluctuations are also quite large around the trend.

The cyclical component of copper prices is plotted in figure 2 (black line). It shows very large fluctuations: the Lehman crisis saw a crash in which the price fell by more than seventy percent relative to its trend; but the series displays also periods in which the price was above trend by twenty percent or more.

Figure 2 also shows (dotted line) the cyclical component of Chile's real exchange rate (measured so that an increase expresses a real appreciation of the peso). Comparing it against the cyclical component of copper prices, at least two facts become apparent: the

3.The HP filter parameter is set at 14,400, consistent with monthly data.

cyclical variability of copper prices has been an order of magnitude larger than that of the real exchange rate; and there is a positive correlation between the two series (the correlation coefficient is 0.434). The first fact is surprising: it is well known that the real exchange rate is itself much more variable than other macroeconomic aggregates and relative prices; but commodity price fluctuations appear to be much bigger! The second one is also remarkable: in spite of an extensive body of literature discussing the difficulty of relating exchange rates to macroeconomic fundamentals (e.g. the exchange rate disconnect puzzle of Obstfeld and Rogoff, 2001), the relation between commodity prices and exchange rates appears to be quite robust for Chile and other emerging countries, and strongly suggestive of significant economic effects of commodity price shocks on real aggregates.

The fact that commodity price uncertainty has been high both in the short run and the long-run suggests a corresponding need for adjusting multiple policies, intended to work at different horizons. Accordingly, some chapters of this volume are devoted to monetary and fiscal policy and emphasize stabilization at short run, business cycle frequencies; but the volume also includes chapters with a focus on investment, industrial and sectoral policies, and other longer run aspects of policy.

This volume, therefore, is representative of the variety of research approaches to the topic of macroeconomic policy in response to commodity price fluctuations. Recent research has been more active and more technically sophisticated when it regards monetary policy issues and the shorter run. To a large extent, this has been due to the widespread acceptance of a basic theoretical framework for the study of monetary policy, the dynamic New Keynesian model summarized in Woodford (2003) and Galí (2008) for closed economies, and extended by Galí and Monacelli (2005) for small open economies. Also, there is a well-developed arsenal of empirical methods for the analysis of stationary time series. These tools have been applied to the question of commodity prices and macroeconomic fluctuations (although, as noted by Fornero, Kirchner, and Yani in this volume, mostly to the macroeconomic impact of oil prices in developed countries). As the focus shifts to longer horizons, there is less agreement on the usefulness of alternative analytical frameworks and on the appropriate empirical methods; accordingly, the existing literature has more diversity. This state of affairs will become apparent as the reader goes through the different parts of this book.

The rest of this introductory chapter provides a summary and discussion of the chapters in the book. Echoing the comments in the previous paragraphs, we classify them into two groups, the first one emphasizing monetary policy, and the second one addressing other, longer term issues.

1. Contributions: Monetary Policy

The first part of this book deals with aspects of central bank policy in response to commodity price fluctuations. It starts with chapters, by Roberto Chang and by Constantino Hevia and Juan Pablo Nicolini, that are closely related to a recent academic debate on monetary policy. Summarizing that debate helps placing these contributions in perspective.

The basic New Keynesian framework of Woodford (2003) and Galí (2008) lent strong support to a policy of price stability, which has been taken as a theoretical justification for *flexible inflation targeting* regimes: the central bank is assigned the task of stabilizing inflation around a numerical target (close to zero) and an output objective. Indeed, one of the key contributions of Woodford (2003) was the demonstration that, in the canonical New Keynesian model, the welfare of the representative agent can be correctly approximated to second order by a linear-quadratic cost function of inflation and the output gap (the difference between output and its natural or flexible price value). In the absence of cost push shocks, keeping inflation at zero implies a zero output gap as well; therefore zero inflation is first best optimal. When cost push shocks are present, the analysis needs to be modified somewhat, but it is still the case that an optimal policy involves a trade-off between inflation and the output gap and only between those two variables.

Woodford (2003)'s model was one of a closed economy, however. Corsetti and Pesenti (2001) recognized that, in open economy versions of the New Keynesian model, the central bank may have the power and incentive to affect international relative prices in the country's favor. This incentive, sometimes called the *terms of trade externality,* indicates that a country may gain from a monetary policy that targets the real exchange rate or the terms of trade, in addition to inflation and the output gap.

Winds turned again in favor of inflation targeting after Galí and Monacelli (2005) showed that, in a New Keynesian small open economy model, the stabilization of a producer price index (PPI) was optimal under some combinations of behavioral parameters, mostly unit elasticities. While those assumptions were quite restrictive, the suggestion that PPI targeting is indeed an appropriate rule was reinforced by the work of De Paoli (2009). De Paoli extended Galí and Monacelli's analysis in two significant directions. First, she derived a purely quadratic second order approximation to the representative agent's welfare, which turned out to depend only on PPI inflation and the deviations of output and the real exchange rate from exogenous targets. This confirmed Corsetti and Pesenti's insight, in that optimal policy can be written as a rule trading off inflation, the output gap, and the real exchange rate. But De Paoli's second contribution went in favor of Woodford and Galí-Monacelli: after calibrating Galí and Monacelli's model to empirically reasonable parameters, De Paoli found that PPI targeting resulted in a very small welfare loss with respect to the optimum. In other words, De Paoli found that PPI targeting, while suboptimal, was still an excellent monetary framework for small open economies.

De Paoli's results notwithstanding, the robustness of PPI targeting to departures from Galí and Monacelli's assumptions has been the subject of renewed research efforts, especially in view of the increased volatility of commodity prices. A plausible conjecture is that the terms of trade externality may become more of a factor in countries with larger exports or imports of commodities, and in periods in which the commodity prices are more variable. Thus a number of recent papers have explored this conjecture.

In particular, Catão and Chang (2013), Monacelli (2013), and Hevia and Nicolini (2013) extended the Galí-Monacelli model to include an exportable commodity sector as well as imports of a consumption item such as food, whose price relative to world consumption fluctuates in world markets. These papers characterized optimal monetary policy and its dependence on country specific aspects, including elasticities of demand, the volatility of the prices of a country's exports or imports, and the degree of international risk sharing. On the other hand, they all found that, for plausible parameterizations, the finding that PPI targeting is nearly optimal remained remarkably robust.

In his contribution to this volume, Roberto Chang explains the debate just mentioned in the context of a simplified version of his 2013 model with Catão. Many papers in this literature, including those just cited, are difficult to solve by hand, partly because of the dynamics imparted by assumptions about price setting, most often taken to be a version of Calvo (1983)'s staggered price model. Chang observes that, for the comparison of monetary policy options, much of the intuition can be obtained by replacing Calvo's pricing with the alternative assumption of prices set one period in advance. This eliminates some interesting dynamics, but results in a drastic simplification: the resulting model is essentially static, and many results can be derived analytically.

In Chang's model, domestic agents consume an aggregate of a home product and an imported commodity, called "food". All goods are tradable, and the relative price of food is exogenously determined in world markets. Since that price is subject to random fluctuations, the analysis of the model depends on assumptions about international risk sharing. Most of the related literature, starting with Galí and Monacelli (2005), has assumed that risk sharing across countries is perfect. In addition to this case, Chang also examines the polar opposite of portfolio autarky, which implies balanced trade.

Two kinds of allocations are characterized: the optimal *Ramsey* outcome and the flexible price or *natural* allocation. The Ramsey outcome is the social planning solution in the absence of nominal rigidities, and it is of interest because it provides a natural benchmark against which any policy can be compared. The natural allocation, in turn, is crucial because, in this class of models, is often obtained as the result of PPI stabilization.

Chang shows that, indeed, the Ramsey outcome and the natural allocation coincide under the parameterization of Galí and Monacelli (2005); they also coincide under more general parameterizations if one assumes, as in Hevia and Nicolini (2013), that there is a sufficiently rich menu of taxes and transfers. In such cases, therefore, PPI targeting emerges as an optimal monetary strategy. It becomes apparent from Chang's analysis, however, that those cases are quite restrictive, and in general the natural allocation can be quite different from the Ramsey outcome. This depends, as mentioned, on various parameters and assumptions of the model.

A second aspect of Chang's paper is an exploration into the derivation and implications of linear quadratic approximations to welfare. As in De Paoli (2009), the welfare of the representative agent can be written as a purely quadratic function of inflation, and the deviations or gaps of output and the real exchange rate from corresponding targets. But Chang emphasizes that there are other equivalent ways to obtain a linear quadratic social welfare function.

One involves only inflation and an output gap; another one, only inflation and a real exchange gap; yet a third one may be written in terms of inflation and a consumption gap, and so on. (This is possible by redefining the appropriate concepts of gaps and targets in each case.) This point is of some practical significance for countries, such as inflation targeting ones, where there has been debate about whether central banks should (or not) stabilize exchange rates, in addition to inflation and the output gap. According to Chang's analysis, the questions have been ill-defined; the meaningful issue is not whether real exchange rates should be stabilized alongside inflation and the output gap, but how.

Hevia and Nicolini's chapter develops a model of the Galí-Monacelli type, and uses it to explore the role of price rigidities versus nominal wage rigidities. Their model extends Hevia and Nicolini (2013) and includes both an imported good ("food") and an exportable primary good, which we will call "copper"; the prices of food and copper are determined in the world market, and fluctuate randomly. Copper is produced with only labor.

As in typical New Keynesian models, there is a domestic tradable good which is an aggregate of imperfectly substitutable varieties. These varieties are, in turn, produced with labor, food, and copper, under monopolistically competitive conditions. Nominal price rigidities are introduced by assuming Calvo pricing. The main departure with respect to Hevia and Nicolini (2013) is to include wage rigidities, modeled in a similar fashion to price rigidities (this follows Erceg, Henderson, and Levin 2000).

To start the discussion of the implications of the resulting model, Hevia and Nicolini replicate and extend theoretical results of their 2013 paper. In particular, they show that nominal prices and wages can be fully stabilized if the nominal exchange rate and a payroll tax rate adjust appropriately to offset exogenous shocks. This can be seen as a special case of the more general result, already mentioned, that PPI targeting is an optimal policy when sufficiently flexible taxes and transfers are available.

To proceed, Hevia and Nicolini assume that payroll tax rates are constant, which is realistic. Also, they focus on the case in which only the price of copper is variable. They calibrate the model in the standard way, except that the stochastic process for the price of copper is estimated from observed world copper prices. The baseline version of the model assumes isoelastic preferences so that PPI stability is optimal in the absence of wage rigidities.

Under such assumptions, a main exercise involves comparing a trade-off between PPI stability and nominal wage stability. To this effect, they assume a policy rule that implies a fixed PPI on one extreme and a fixed nominal wage on the other, and that can also capture intermediate regimes, depending on the value of a policy parameter. The implications of this rule are then explored under various assumptions on the flexibility of prices versus the flexibility of wages.

The main finding is about the role of wage flexibility. When nominal wages are not that rigid, PPI stability clearly dominates a policy of nominal wage stability and, in this sense, the policy findings of Hevia and Nicolini (2013) remain basically the same. But when nominal wage rigidity is substantial, stabilizing nominal wages is welfare superior to PPI stability.

As Hevia and Nicolini explain, to understand the intuition one needs to refer to the optimal (Ramsey) response to copper price fluctuations. A favorable shock to the copper price should naturally be met with higher copper production and exports. For this to occur, the real wage must fall, so as to induce hiring more labor in the copper sector. But under PPI stabilization, the required fall in the real wage is harder to obtain when nominal wages are more rigid.

Hevia and Nicolini complete their discussion by examining a different policy trade-off: namely, between nominal price stability and exchange rate stability. For their baseline calibration, they show that a combination of PPI stabilization and dirty floating is superior to either strict PPI targeting or a fixed exchange rate. Importantly, they also find that the latter is better than the former if wage rigidities are sufficiently severe.

In sum, Hevia and Nicolini's chapter shows that, for a small open economy facing commodity price volatility, the nature of optimal policy depends on the rigidity of both nominal prices and wages. Their chapter and Chang's, therefore, coincide in stressing that the literature implies that appropriate monetary and exchange rate management should be country specific, and tailored to the particular characteristics of each economy.

In contrast with Chang's and Hevia and Nicolini's chapters, whose focus is on traditional monetary policy, Joshua Aizenman and Daniel Riera-Crichton contribute to this volume a chapter on the so-called *unconventional* monetary policy. In the context of emerging countries, the term "unconventional policy" is best understood by contrasting it against "conventional" inflation targeting. Theoretically at least, inflation targeting involves setting a single policy instrument, often an overnight interest rate, in order to attain a certain level of inflation and, perhaps, an employment or output gap objective. Hence unconventional policy refers to cases in which the central bank has used alternative instruments, including liquidity facilities, discount lending, foreign exchange intervention, or foreign exchange reserves management; or pursued alternative goals, such as exchange rate stability or financial stability.

Interest in unconventional monetary policy has surged following the 2007-2008 global financial crisis and the subsequent policy response of some central banks in advanced countries, including the U.S. Federal Reserve. In response to the crisis, and especially after the September 2008 Lehman debacle, those central banks adjusted their policy rates all the way down to zero, but decided that additional stimulus was needed. As a consequence, they resorted to a number of operations involving the balance sheet of the central bank. In the U.S., the so-called quantitative easing and credit easing policies resulted in more than tripling the asset side of the Federal Reserve. More recently, the European Central Bank has been implementing an aggressive quantitative easing policy as well.

The use of unconventional policies in advanced economies has provided them with some impetus in emerging economies, especially in Latin America. Some differences remain, however, perhaps the most notable of which being that Latin American central banks have often conducted policies in a foreign currency, most often the U.S. dollar. Sterilized foreign exchange intervention has been a prime example, but credit facilities and liquidity mechanisms in foreign currency have also been ubiquitous (Céspedes, Chang, and Velasco, 2014).

As Chang (2007) emphasized, unconventional policies, particularly foreign exchange intervention and reserves accumulation, became more frequent in Latin America after the mid-2000s, partly in response to commodity price fluctuations, and especially with the objective of arresting strong exchange rate appreciation due to increasing export earnings and, concomitantly, capital inflows. This development raises the question of how effective such policies are, especially in the face of exacerbated commodity price volatility. It is this question that provides a focus for Aizenman and Riera-Crichton's chapter.

Using data from the largest twelve Latin American countries for the period spanning from 1980 to the present, Aizenman and Riera-Crichton study the empirical response of real exchange rates and output growth to commodity price shocks, and how that response depends on the accumulation and management of foreign reserves and on sovereign wealth funds. The sample contains enough heterogeneity along the country dimension as well as in terms of subperiods, so that the paper also investigates the impact of different policy regimes—such as the presence of formal inflation targeting or an exchange rate peg—, and of events—such as the Lehman crisis—on the aforementioned links.

The main technical tool for the analysis is a cointegrating equation in which one of the outcome variables (changes in the real exchange rate or output) depends on their long-run equilibrium (or cointegrating relation), as well as a measure of shocks in the commodity terms of trade, called CTOT.[4] The coefficient of CTOT, in turn, is allowed to depend on one of the policy variables of interest: the reserves to GDP ratio, the size in terms of GDP of sovereign wealth funds, or changes in these ratios.

The authors present and discuss several findings; here we highlight a couple of them. In the full sample, an improvement in the commodity terms of trade (an increase in CTOT) implies a real exchange rate appreciation; but the magnitude of the response decreases with the size of foreign exchange reserves (either the stock of reserves or its change), which Aizenman and Riera-Crichton call a "buffer effect". More precisely, as they write: "a stock of reserves of 15 percent of GDP or a change in reserve holdings of 3 percent of GDP can, on average, reduce the REER effects of CTOT shocks on impact by half". Also for the full sample, an increase in CTOT implies an increase in GDP growth. But in this case it is harder to pin down a buffer effect of foreign reserves.

Identifying the influence of sovereign wealth funds on the transmission of CTOT shocks to either the real exchange rate or output is, likewise, elusive. A notable exception, however, is the "Great Recession" period between 2008 and 2009. Aizenman and Riera-Crichton find that, indeed, the impact of CTOT shocks on the real exchange rate and GDP growth was much smaller in countries that had substantial sovereign wealth funds.

The analysis is descriptive and the estimated relationships should be seen as reduced form ones, so they do not necessarily have structural interpretations and, hence, one must be very

4.CTOT differs from the traditional measure of the terms of trade in emphasizing the prices of commodity exports and imports at the expense of the prices of industrial goods.

careful in deriving policy implications. But Aizenman and Riera Crichton's paper is highly suggestive of the fact that foreign reserves management, sovereign wealth funds and, more generally, unconventional policies, can have important real effects, especially at times of financial crises.

2. Contributions: Longer Run Topics

In contrast to the first three chapters, which address monetary policy and the short run, the other three chapters in the book tackle issues pertinent to the medium and long-run. One of them is the impact of commodity prices on investment, and is the central question of the contribution of Jorge Fornero, Markus Kirchner, and Andrés Yany (FKY hereon).

As FKY discuss in the introduction to their chapter, most of the literature on the macroeconomic impact of commodity prices has been concerned with the effect of oil prices on advanced economies (e.g. Blanchard and Galí 2009; Bodenstein, Erceg, and Guerrieri, 2008; Killian, 2009). The focus on oil, usually a main import in advanced economies, is less useful for many emerging economies that are exporters of metals. In those cases, a central concern is how investment in mining reacts to increases in metal prices, how that event is transmitted to the rest of the economy, and how the transmission depends on monetary and fiscal policy.

FKY approach the topic in two complementary ways. One is an empirical analysis based on identified vector autoregressions (VAR). They assemble data from seven metal exporters (Australia, Canada, Chile, New Zealand, Peru, and South Africa), from 1993 to 2013. For each country, they estimate a VAR with an exogenous foreign block that includes world GDP, U.S. inflation, the federal funds rate, and a commodity price index; and an endogenous domestic block which includes real GDP, investment in the mining and non-mining sectors, the inflation rate, the monetary policy rate, the real exchange rate, and the current account balance. In the exogenous block, identification is attained via a recursive (Choleski) decomposition, with the commodity index last; then exogenous disturbances to commodity prices are isolated and their implications can be studied in the usual way.

The VAR analysis yields many notable results. In particular, shocks to commodity prices are found to be fairly persistent, with a half life between two and three years. They are followed by a large and also persistent increase in mining investment, with significant effects on GDP. Non-mining investment increases as well, although naturally not as strongly as mining investment. The investment responses, in turn, are reflected in changes in the current account and the real exchange rate.

A second line of attack on these issues is the analysis of a stochastic dynamic equilibrium model. To this end, FKY extend the model by Medina and Soto (2007) and calibrate it with parameters taken from a related paper by Fornero and Kirchner (2014). Medina and Soto's model is a dynamic New Keynesian one, featuring an export mining sector and also imports of an oil-like commodity, similar to the Hevia-Nicolini model reviewed earlier. FSY add investment and capital accumulation, both in the mining sector and in the non-mining sectors. In addition, the model assumes also a monetary policy rule of the Taylor type, as well as a structural balance fiscal rule resembling the one in Chile. This allows FSY to explore the implications of changing the parameters of fiscal and monetary policy on the transmission mechanism.

FSY find that the predictions of the dynamic model accord well with the VAR analysis. A favorable shock to commodity prices leads to a sizable increase in mining investment. The bonanza spills over to the rest of the economy and, in particular, non-mining investment increases as well. The surge in aggregate demand is reflected in a wider current account deficit and a real appreciation. As for the role of policy, FSY interestingly argue that, while the responses of non-mining output and investment to commodity price shocks are sensitive to fiscal and monetary policy, the corresponding responses in the mining industry are much less so. Hence they suggest that "investment decisions in the commodity sector...are mainly driven by sectoral productivity developments and, particularly, commodity prices."

Next, Radek Stefanski investigates structural transformation, in the form of labor reallocation, in a small open economy, as a consequence of windfall revenues arising from exporting natural resources. He notes three stylized facts in resource-rich countries that warrant explanation: (i) the existence of a small but productive manufacturing sector, (ii) a large yet unproductive non-manufacturing sector, and (iii) a larger proportion of workers in the government sector when compared to resource-poor countries. In a previous contribution, Kuralbayeva and Stefanski (2013) showed that facts (i) and (ii) could be explained by a process of labor self-selection. Here, in the context of Kuralbayeva and Stefanski (2013), the target of this chapter is to explain (iii), the size of public sector employment in resource-rich countries.

Before presenting the theoretical model, Stefanski analyzes a panel of macro cross-country data and documents (i)-(iii). Resource-rich countries employ, proportionally, 27% fewer workers in manufacturing and 6% more workers in non-manufacturing than resource-poor countries. Also, resource-rich countries are 24% more productive in manufacturing and 4% less productive in non-manufacturing (relative to aggregate productivity). Finally, resource-rich countries employ 48% more workers in the public sector and 10% less workers in the non-public sector.

Stefanski then derives a small, open, multi-sector economy model with heterogeneous agents that can account for the observed facts in productivity and employment. The model closely follows Kuralbayeva and Stefanski (2013) but introduces a role for government. There are three final goods in the economy: manufacturing goods, private non-manufacturing goods (services), and a windfall good. It is assumed that manufacturing and the windfall good (endowment) are traded internationally, while services are assumed to be nontraded. It is also assumed that a government sector provides the rest of the economy with inputs such as institutional frameworks, transportation, rule of law, and arbitration, which are productivity enhancing but are external to firms (and workers). Thus, while workers can be employed in the government sector, the sector produces no final goods directly, but rather provides an input to other sectors of the economy which helps them attain a higher level of productivity.

In this model, productivity differences are explained through a process of self-selection. In particular, windfall revenues induce labor to move from the manufacturing sector to the non-manufacturing sector. Self-selection of workers takes place: only those most skilled in manufacturing work remain in the manufacturing sector. Workers that move to the non-manufacturing sector are, however, less skilled in non-manufacturing work than those who were already employed there. Resource-induced structural transformation thus results in higher productivity in manufacturing and lower productivity in non-manufacturing. Now, given that government services are non-traded, higher windfalls increase demand for all goods and services, including government services, but since these cannot be imported, workers shift to the government sector to satiate demand. Furthermore, even with a government sector, the specialization mechanism introduced in Kuralbayeva and Stefanski (2013) is strong enough to explain a large part of the asymmetric differences in sectoral employment shares and productivity between resource-rich and resource-poor countries.

Sir Paul Collier's chapter concludes the book by addressing some of the medium-run and long-run policy challenges faced by commodity exporting countries. Collier points out that economies in which the extraction of a non-renewable natural resource is a significant activity, pose two distinctive challenges for policy. First, revenues are likely to fluctuate because commodity prices have historically been volatile. Second, the revenue from extraction is generated by depleting a finite resource and, therefore, there is a potential case for offsetting depletion with the accumulation of other assets. Collier notes that volatility and depletion work in radically different time scales, hence managing them evidently requires distinct "policy clocks".

In a first section, the chapter explores a policy clock designed to face depletion. Collier points out that a useful starting point for thinking about the depletion of a finite natural asset is the permanent income hypothesis (PIH). The PIH prescribes that the revenue from depletion should be used to give all future generations an equal increase in consumption, which is constant and equal to the interest that would be earned at a fixed world interest rate on the present value of the revenue. The PIH is compared to an alternative prescription, the so-called bird-in-hand rule advocated by the International Monetary Fund, that incorporates extreme caution. In particular, at each moment, savings are optimized subject to the assumption that no further resource revenues will accrue. Clearly, in all circumstances other than this drastic eventuality, the strategy is suboptimal.

The previous rules are designed to smooth consumption, but do not address the fundamental question of how to face depletion. In this section, Collier does not provide a unique prescription to this dilemma. Instead he offers some guidelines that could be applied to different countries. The basic idea, however, is that to face depletion a country should save a proportion of its resource income in an asset that, after the natural resource is exhausted, could be used to produce other non-resource goods.

A second section of Collier's chapter explores a policy clock designed to manage asset accumulation. Collier recognizes that assets held to offset depletion should differ from those used to smooth expenditure in the face of fluctuations in revenue. By their nature, smoothing fluctuations imply that the assets acquired during periods of high prices will be held only temporarily. In contrast, since obsolescence and depletion are permanent states of affairs, the accumulation of assets to offset them will be held permanently.

The difference in the horizon for holding the accumulated assets has important implications for the type of assets to be acquired. Those assets acquired to smooth fluctuations must necessarily be foreign assets, since otherwise they cannot smooth domestic activity. Further, since they are being held in order to be liquidated when needed, they must be readily marketable. Illiquid holdings of private equity would not be appropriate, even though the long-term rate of return on such assets might be higher than that of liquid assets. In addition, since the assets held for smoothing will need to be liquidated in predictable circumstances, namely, a fall in the copper price, they should be chosen so as to have a marketable value that is negatively correlated with the copper price.

In contrast, assets accumulated to offset depletion are held for their long-term return rather than their ability to smooth domestic activity. Consequently, liquidity is not necessary. Instead, a key issue for assets designed to offset depletion is the choice between investment in foreign financial assets and domestic real assets. Collier offers some guidelines in this regard.

A last section of Collier's chapter discusses a third policy clock which describes how expenditures should be smoothed. Collier points out that budgets work with concepts other than depletion, namely, expenditure and revenue. In this case, revenues are the sum of consumption and savings, but expenditures are the sum of consumption and domestic investment. Because it is costly to deviate from planned expenditure, savings should accommodate deviations from planned expenditure and actual revenue. In this case, a key issue is the uncertainty about the future stream of revenues. Collier emphasizes that there is uncertainty at different horizons, and discusses policy issues related to the distinction.

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Commodity Price Fluctuations and Monetary Policy in Small Open Economies

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Increased volatility in the world prices of commodities such as oil and food, which are basic imports for many countries, has rekindled interest on the question of how monetary policy should best adjust to external commodity price movements. Recent studies have analyzed the issue in the New Keynesian framework of Woodford (2003) and Galí (2008) adapted and extended to an open economy. As emphasized by Corsetti, Dedola, and Leduc (2010), optimal monetary policy must then balance at least two considerations. The first one is to counteract domestic distortions related to nominal price rigidities and price setting behavior. This is most critical in closed economies and, as emphasized by Woodford (2003), often results in a prescription that monetary policy should aim at the stabilization of a producer price index (PPI). The second consideration is that it can be beneficial for a small economy to use monetary policy to stabilize an international relative price such as the real exchange rate or the terms of trade. This factor, called the terms of trade externality (Corsetti and Pesenti, 2001) implies that PPI stabilization may not be optimal. Instead, it is at least theoretically possible for other monetary strategies, for example, targeting a headline inflation index such as the CPI, or even fixing the exchange rate, to dominate PPI targeting on welfare grounds.

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The question has not been settled, either in academia or in actual policy practice. In the academic arena, much of the debate has followed an influential paper by Galí and Monacelli (2005) who developed a multi-country version of the New Keynesian model and showed that, under some restrictions on parameter values, it is optimal for a small country to completely stabilize PPI inflation just as in a closed economy. This surprising result was extended by De Paoli (2009), which characterized optimal monetary policy and showed that PPI targeting was not generally optimal but remained dominant over CPI targeting and exchange rate pegging for realistic parameter values.

Both Galí and Monacelli (2005) and De Paoli (2009) abstracted from exogenous commodity price fluctuations and, hence, provide no guidance with respect to episodes of commodity price turbulence. Recent papers have filled this void. In particular, Catão and Chang (2013; 2015) have extended the Galí-Monacelli small economy framework to allow for traded commodities whose prices fluctuate exogenously. They also allow for other significant departures, such as imperfect risk sharing across countries.

In this paper, I develop a simplified version of the Catão-Chang framework with two main objectives in mind. First, I review lessons from the Catão-Chang analysis, especially conditions under which PPI stabilization coincides with or departs from an optimal (Ramsey) outcome. This review underscores that exogenous commodity price fluctuations interact with other aspects of the model including not only elasticities of demand for different goods, but also the degree of international risk sharing.

My second objective is to reexamine the question of what variables (the PPI, the CPI, the exchange rate or the output gap) should be assigned as objectives to a central bank in an open economy subject to exogenous commodity price fluctuations. My discussion is based on an exposition and critique, hopefully novel to many readers, of recent approaches to the general problem of how to compute and implement optimal monetary policy in open economies.

Following the work of Sutherland (2005), Benigno and Woodford (2006), and Benigno and Benigno (2006), the optimal policy problem is attacked by deriving a quadratic approximation to the welfare of the representative agent and expressing it in terms of deviations of endogenous variables, such as output, inflation, or the real exchange rate, from "target" values that are functions of exogenous shocks. In the model of this paper, as well as many related ones, the welfare of the representative agent can be expressed in terms of squared deviations of domestic inflation, output, and the real exchange rate from endogenously derived target values; consequently, optimal monetary policy can be expressed in terms of linear targeting rules for the real exchange rate, inflation, and output. Previous authors have noted this, particularly De Paoli (2009). I point out, however, that the welfare representation in this class of models is, in general, not unique. In fact, both the appropriate welfare criterion and the associated optimal target rules can be rewritten only in terms of inflation and output, inflation and the real exchange rate, or linear combinations of those variables (or even others); one only needs to adjust the definition of the respective targets appropriately. The practical implication is that there is no compelling reason, in terms of this analysis, to make central bank policy react to inflation, output, and the real exchange rate (as De Paoli (2009) suggests) rather than only to inflation and output, or only to inflation and the real exchange rate, as long as the policy reaction functions are designed properly.

Section 1 presents the model that serves as the framework for the analysis. A discussion of optimal monetary policy and its relation to PPI targeting is given in section 2. Section 3 discusses the second-order approximation of welfare, while a second-order approximation of the equilibrium is given in section 4. Section 5 solves for equilibrium first moments in terms of second moments. These results can be used to express the welfare function in terms of only second moments, which can then be paired with a first-order approximation of the equilibrium to find optimal policy as described in section 6. Section 7 explains how the problem can be reformulated in terms of gaps and targets from which an appropriate policy framework and optimal target rules can be applied. Section 8 discusses implications for targets and goals being assigned to the central bank, emphasizing that such reformulations are not typically unique in spite of the uniqueness of the optimal policy found in section 6. Section 9 concludes with some final remarks.

1. A Framework for Analysis

The main ideas are quite general, but it is helpful to express them in the context of a simple, concrete model. The one described in this section simplifies the one in Catão and Chang (2015), primarily in assuming one period nominal rigidities in contrast to the now popular Calvo-Yun approach, which adds realistic dynamics to the setting but obscures the essence of the optimal policy problem.

1.1 Households and Financial Markets

We study a small open economy populated by a representative household that chooses consumption and labor supply in each period to maximize $u(C) - v(N)$, where C denotes consumption, N labor effort,

$$u(C) = \frac{C^{1-\sigma}}{1-\sigma}$$

and

$$v(N) = \varsigma \frac{N^{1+\varphi}}{1+\varphi}.$$

Even if the economy can be thought of as being infinitely lived, our assumptions here allow us to focus on a single period; therefore, we omit time subscripts.

The household takes prices and wages as given. It owns all domestic firms and, as a consequence, receives all of their profits as dividends. Finally, it may have to pay taxes or receive transfers from the government.

In order to characterize the household choice of consumption and savings, we need to describe the menu of assets available. For the most part, we follow Galí and Monacelli (2005) and most of the literature assuming that the household has unfettered access to international financial markets that, in turn, are assumed to be complete. The consequence, as it is well known, is the perfect risk sharing condition

$$C = C^* X^{1/\sigma} \tag{1}$$

where C^* is consumption in the rest of the world (ROW), assumed to be constant for simplicity, and X is the real exchange rate (the relative price of ROW consumption in terms of home consumption).[1] The intuition is that complete financial markets allow perfect sharing of risk across countries, which implies that marginal utilities of

1. To be sure, this condition is usually written as $C = \kappa C^* X^{1/\sigma}$ for some constant κ. But one can redefine world consumption as κC^* so there is no loss of generality in setting $\kappa = 1$.

consumption at home and in the ROW should be proportional up to a correction for their relative cost–the real exchange rate.

Perfect risk sharing is a drastic simplification since it ties domestic consumption to the real exchange rate. It greatly simplifies the analysis, which is the main reason to adopt it here. But most of the analysis will not hinge on that assumption. To illustrate, at the end of section 3 we sketch the consequences of the polar opposite assumption of portfolio autarky, which in this setting is equivalent to balanced trade.

The only other important choice for the household is labor effort. This is given by the equality of the marginal disutility of effort and the utility value of the real wage:

$$\frac{v^{'}(N)}{u^{'}(C)} = \varsigma N^{\varphi} C^{\sigma} = \frac{W}{P} \tag{2}$$

with W and P denoting the wage rate and the price of consumption (the CPI), both in domestic currency units.

1.2 Commodity Structure, Relative Prices, and Demand

The home consumption good is assumed to be a C.E.S. aggregate of two commodities: one of them is an imported commodity (such as food or oil) and the other is a Dixit-Stiglitz composite of differentiated varieties produced at home under monopolistic competition. This commodity structure, taken from Catão and Chang (2015), allows for the study of the role of fluctuations in world commodity prices and their interaction with nominal rigidities and monetary policy.

Cost minimization implies that the CPI is

$$P = \left[(1-\alpha)P_h^{1-\eta} + \alpha P_m^{1-\eta}\right]^{1/(1-\eta)} \tag{3}$$

where P_h is the price of home output and P_m the price of imports, both expressed in domestic currency. η is the elasticity of substitution between home goods and imports and α is a share parameter. It also follows that the demand for home produce is given by

$$C_h = (1-\alpha)\left(\frac{P_h}{P}\right)^{-\eta} C = (1-\alpha)Q^{-\eta}C \tag{4}$$

where we have defined Q as the real price of home output:

$$Q = P_h/P \tag{5}$$

Imports are available from the world market at an exogenous price P_m^* in terms of ROW currency. Assuming full exchange rate pass through, and letting S denote the nominal exchange rate, the domestic currency price of imports is then $P_m = SP_m^*$.

As in Catão and Chang (2015), the world price of imports relative to the world price of ROW consumption is random and exogenous. This captures the recent environment of fluctuating commodity prices and has a key implication for the link between the real exchange rate and the terms of trade defined as the price of imported consumption relative to the price of home produce:

$$T = \frac{P_m}{P_h}$$

The real exchange rate is defined as

$$X = \frac{SP^*}{P}$$

where P^* is the world currency price of ROW consumption. It follows that

$$T = \frac{SP_m^*}{P_h} = \frac{XZ}{Q}$$

where $Z = P_m^*/P^*$ is the world relative price of imports.

Using 3 to substitute for Q in the previous expression and rearranging, one obtains

$$XZ = \frac{T}{\left[(1-\alpha)+\alpha T^{1-\eta}\right]^{1/(1-\eta)}}$$

In the absence of fluctuations in the world relative price of imports, the preceding equation becomes a one to one correspondence between the real exchange rate and the terms of trade. This is a feature of most existing models that is often contradicted by the data. If Z is allowed to fluctuate, the correlation between the real exchange rate and the terms of trade can be less than perfect, which is not only more realistic but also has some consequences for the policy analysis.[2]

In keeping with the literature, we assume that there is a ROW demand for the home composite good which has the same form as (4):

$$\begin{aligned} C_h^* &= \alpha\left(\frac{P_h}{SP^*}\right)^{-\gamma} C^* \\ &= \alpha\left(\frac{Q}{X}\right)^{-\gamma} C^* \end{aligned}$$

where γ is the elasticity of foreign demand.

Two remarks are in order: First, I have not imposed that the elasticities of home demand and foreign demand for the home composite good be the same; almost all of the literature, however, assumes that $\eta = \gamma$.[3] Second, the foreign demand for the home composite depends on the real exchange rate and Q and, hence, the terms of trade–by (3). If monetary policy can affect these relative prices, then it can also affect the foreign demand for domestic output. This will be the source of what is called the terms of trade externality.

1.3 Production

As mentioned, a continuum of varieties of the home composite good are produced in a monopolistically competitive sector. Each variety is produced by a single firm j [0,1] via a technology

$$Y(j) = AL(j)$$

where $Y(j)$ is output of variety j, A an exogenous technology shock, and $L(j)$ labor input.

2. This is emphasized in Catão and Chang (2015).

3. On the other hand, we have chosen the constant of proportionality to be α. This is without loss of generality, as (again) one can redefine the units of world consumption if needed.

Variety producers take wages and import prices as given. For reasons discussed below, we allow for a subsidy υ to the wage in this sector, so that nominal marginal cost is

$$\Psi = \frac{(1-\upsilon)W}{A} \tag{6}$$

As mentioned, variety producers set prices in domestic currency under monopolistic competition. Catão and Chang (2015) assumed that price setting follows the well-known Calvo protocol. While that assumption imparts interesting dynamics to the model, it increases its technical complexity greatly, which obscures the basics of the policy analysis. Hence, I make the much simpler assumption here that prices are set one period in advance of the realization of exogenous shocks. The sacrifice in terms of dynamic realism will hopefully be compensated by increased insight.

With prices set one period in advance, all producers will adopt the same rule, given by

$$\mathcal{E}\left[C^{-\sigma}\frac{Y}{P}(P_h - \frac{\varepsilon}{\varepsilon-1}\Psi)\right] = 0 \tag{7}$$

where $\mathcal{E}$ is the expectation operator and Y is the level of domestic production common to all producers. The intuition is standard: under flexible pricing, each producer j would set its price as a fixed markup (of $\varepsilon/(\varepsilon-1)$) on marginal cost; the condition above can be seen as a generalization of such a condition.

1.4 Equilibrium

Equilibrium requires that the supply of the home composite good equal the sum of home and foreign demand for it:

$$Y = C_h + C_h^* \tag{8}$$

To close the model, I assume that monetary policy determines nominal consumption expenditure:

$$M = PC \tag{9}$$

It will be useful to rewrite the equilibrium equations in a simpler way. The CPI definition (3) can be rewritten as

$$1 = (1 - \alpha)Q^{1-\eta} + \alpha\,(XZ)^{1-\eta} \tag{10}$$

Likewise, the definitions of C_h and C_h^* imply that world demand for home output can be written as

$$Y = (1 - \alpha)Q^{-\eta}C + \alpha X^{\gamma}Q^{-\gamma}C^* \tag{11}$$

Finally, the pricing rule 7 can be written as

$$P_h = \frac{\varsigma\varepsilon(1-\nu)}{\varepsilon - 1}\frac{\mathcal{E}(Y/A)^{1+\varphi}}{\mathcal{E}\left(C^{-\sigma}Y/P\right)} \tag{12}$$

Equations (9)-(12) together with (5), the perfect risk sharing condition (1), and the distribution of M, determine P, C, Y, P_h, X, and Q.

Under portfolio autarky, the balanced trade condition $P_hY = PC$, or equivalently

$$C = QY \tag{13}$$

must hold, replacing (1) in the definition of equilibrium. The other equilibrium conditions remain the same.

2. Optimal Policy, the Natural Outcome, and PPI Targeting

Intuition and a long tradition might suggest that monetary policy should aim at replicating the outcomes under flexible prices (the natural outcome). Indeed, in basic New Keynesian models of closed economies, such a prescription would achieve an optimal or Ramsey allocation. This implies that PPI targeting is an optimal policy rule since zero producer price inflation replicates the natural outcome.

In open economies, however, the Ramsey allocation coincides with the natural outcome only under very stringent circumstances. This section characterizes exactly what those circumstances are and, consequently, identifies conditions under which PPI targeting may potentially be dominated by alternative policy rules. The analysis here is very similar to that in Catão and Chang (2013), to which the reader can refer for a more detailed discussion.

2.1 The Ramsey Outcome

The economy's Ramsey problem can be defined as the maximization of the expected welfare of the representative agent subject to resource constraints and world demand. Since the choice variables can be made contingent on the realization of exogenous uncertainty, the problem is appropriately solved state by state. Hence, we can take any exogenous variables as known.

The resulting problem is to maximize $u(\mathrm{C}) - v(N)$ subject to (10), (11) and, under perfect risk sharing, (1). To simplify, note that (10) defines the real price of home output Q as a function, say $Q(XZ)$ of XZ the real exchange rate multiplied by the world relative price of food. Keeping that in mind, and also (1), world demand can be rewritten as

$$\begin{aligned} AN &= (1-\alpha)Q^{-\eta}C + \alpha X^{\gamma}Q^{-\gamma}C^{*} \\ &= (1-\alpha)Q(XZ)^{-\eta}(C^{*}X^{1/\sigma}) + \alpha X^{\gamma}Q(XZ)^{-\gamma}C^{*} \equiv \Omega(X,Z) \end{aligned}$$

The function $\Omega(X,Z)$ expresses the total demand for home output, in general equilibrium, as a function of the real exchange rate given Z. Importantly, the elasticity of Ω with respect to the real exchange rate summarizes how demand for home output responds to a real depreciation, taking all direct and indirect effects into account. For instance, it becomes apparent that a real depreciation increases demand for home output via an increase in home consumption due to the perfect risk sharing assumption.

The objective function, in turn, can be rewritten as

$$u(C^{*}X^{1/\sigma}) - v(N)$$

under perfect risk sharing. The Ramsey problem, then, is to choose the real exchange rate X and the amount of labor effort N to maximize utility subject to $AN = \Omega(X,Z)$.

The first order condition for maximization is easy to derive and can be written as

$$\frac{1}{\sigma}Cu'(C) = \frac{X\Omega_X}{\Omega}Nv'(N) \tag{14}$$

The intuition is quite simple. A one percent real depreciation increases home consumption by $1/\sigma$ percent because of perfect risk sharing. The level of consumption, then, increases by $1/\sigma$ times C and, hence, utility increases by the LHS of the FOC. On the other side, the term $X\Omega_X/\Omega$ is the total elasticity of demand for home output with respect to X. Hence a one percent real depreciation raises the demand for home output and the level of labor effort by $X\Omega_X/\Omega$ times N. The RHS is, accordingly, the disutility of the real depreciation associated with increased demand for home goods and labor effort. For an optimal plan, the two sides must coincide.

The Ramsey outcome is then pinned down by (14) together with (1), (10), and (11). It is to be noted that these equations depend on the exogenous shocks, including Z. Hence, in general, the Ramsey outcome prescribes a time varying solution.

2.2 The Natural Outcome and Policy Implications

In the absence of nominal rigidities, producers would set prices as a markup on marginal cost:

$$P_h = \frac{\varepsilon}{\varepsilon - 1}\Psi$$

Dividing both sides by P and using (6) and (2), this reduces to

$$Q = \frac{\varepsilon(1-\nu)}{\varepsilon - 1}\frac{v'(N)}{Au'(C)}$$

or rewritten,

$$\frac{\varepsilon - 1}{\varepsilon(1-\nu)}Cu'(C) = \left[\frac{C}{QY}\right]Nv'(N) \qquad (15)$$

The natural outcome is determined by this equation in conjunction with (1), (10), and (11).

It follows that the system of equations that define the Ramsey outcome differ from that underlying the natural outcome only in (14) versus (15).

This has several implications:

— For the natural outcome to be optimal it must be the case that

$$\frac{\varepsilon(1-\nu)}{\varepsilon-1}\frac{C}{QY}=\sigma\frac{X\Omega_X}{\Omega} \tag{16}$$

with Ω and Ω_X evaluated at the natural outcome. This is not the case in general, and the discrepancy will reflect the different elasticities and other aspects of the model.

— There is a discrepancy even if $\varepsilon(1-\nu)/(\varepsilon-1)=1$ that is, even if the production subsidy is adjusted to eliminate the impact of monopoly power in the steady state.

— For the special case in which $\eta=\gamma=1/\sigma=1$ the previous equation reduces to

$$\frac{\varepsilon(1-\nu)}{\varepsilon-1}=\frac{1}{1-\alpha}$$

— This implies that, in that special case, there is a value of the production subsidy under which monopolistic distortions completely offset the terms of trade externality. This is in fact the condition that Galí and Monacelli (2005) gave for PPI stabilization to be fully optimal.

— Most of the literature, focusing on monetary policy takes the subsidy ν to be a given constant. But one may instead suppose that ν can be time varying and chosen optimally. In that case, condition (16) can be taken to define the value of ν under which the natural outcome is equal to the Ramsey outcome. This observation reconciles our analysis with that of Hevia and Nicolini (2013) who argued that PPI targeting must be optimal as long as the government has access to a sufficiently rich menu of taxes and transfers.

One can now analyze how the natural allocation differs from the Ramsey outcome for different parameter values. This provides useful information, especially about how the optimality of PPI targeting depends on elasticities of demand. An extended discussion is found in Catão and Chang (2013).

Before leaving this section, two remarks are warranted. First, we might stress the sense in which the natural outcome can be associated with PPI targeting. Because of our assumptions on pricing here, the producer price P_h is predetermined and, hence, the PPI is always stabilized. However, in general, the markup is variable, being given by P_h/Ψ. Arguably, in models that incorporate Calvo-Yun pricing (and others) the most important implication of PPI targeting is not the stabilization of the price level but rather the stabilization of the markup. It is in this sense that we associate PPI targeting with flexible prices and a policy that results in a constant markup.[4]

The second remark is related to the role of international risk sharing. It is not too hard to amend the analysis in this section for the case of portfolio autarky. Since trade balance implies that $C = QY = QAN$, for example, the world demand function can be written as

$$AN = (1-\alpha)Q^{1-\eta}AN + \alpha X^{\gamma}Q^{-\gamma}C^{*}$$

which, since $Q = Q(XZ)$ clearly defines $Y = AN$ as an implicit function of X and Z. The first-order condition for the Ramsey plan is given by (14), except that the term $X\Omega_X/\Omega$ refers to the elasticity of the function just defined with respect to X. The analysis becomes more complex but the analysis of the determinants of policy can be amended accordingly in an intuitive way. Again, see Catão and Chang (2013) for a full development.

3. Approximating Welfare

To obtain further lessons, one may follow the literature in studying a second-order approximation to welfare. Such an approximation is obtained as follows: one can show that, in second order,

$$u(C) = u(\bar{C}) + \bar{C}u'(\bar{C})[c + \frac{1-\sigma}{2}c^2] + \mathcal{O}^3$$

where $\bar{C}$ is the non-stochastic steady-state value of consumption and $c = \log C - \log \bar{C}$ is the log deviation of consumption from its non-stochastic steady state. Also, $\mathcal{O}^3$ refers to terms that are at least cubic in C and, hence, negligible in a second-order approximation. Such terms will be omitted in the rest of the paper, although, the reader should keep them in mind at certain points.

4. In fact, a policy that ensures that equation (15) holds ex post must result in the flexible price outcome. But such a policy would then stabilize the markup P_h/Ψ.

Likewise, with a similar notation,

$$v(N) = v(\bar{N}) + \bar{N}v'(\bar{N})\left[n + \frac{1+\varphi}{2}n^2\right]$$

Hence, aside from an irrelevant constant, $u(\mathrm{C}) - v(N)$ is proportional to

$$c + \frac{1-\sigma}{2}c^2 - \frac{\bar{N}v'(\bar{N})}{\bar{C}u'(\bar{C})}\left(n + \frac{1+\varphi}{2}n^2\right)$$

In steady state, one can show that

$$\frac{\bar{N}v'(\bar{N})}{\bar{C}u'(\bar{C})} = \frac{\bar{N}}{\bar{C}}\frac{\bar{W}}{\bar{P}} = \frac{\varepsilon - 1}{\varepsilon(1-\nu)}$$

$$\equiv \mu$$

so that the term is a measure of the steady-state distortion associated with monopolistic competition. For notational convenience, we will denote the term by μ. The literature has focused on two cases: when the subsidy v is adjusted to compensate for domestic monopoly power in steady state $\mu = 1$ or the Galí-Monacelli case $\mu = 1 - \alpha$. Regardless, the welfare objective can be then written as

$$\mathcal{W} = \mathcal{E}\left\{c - \mu n + \frac{1}{2}[(1-\sigma)c^2 - \mu(1+\varphi)n^2]\right\} \tag{17}$$

Naturally, social welfare increases with expected consumption and falls with expected labor effort. It also falls with the variance of consumption and labor supply.[5]

The presence of the expected values $\mathcal{E}c$ and $\mathcal{E}n$ is inconvenient because, as Woodford (2003) has stressed, it means that one cannot simply use a first order, log linear approximation to the model's equilibrium in order to evaluate the welfare objective correctly in

5. Notice that $EC = E(\bar{C} + (C - \bar{C})) = \bar{C}E(1 + c + c^2/2)$ in second order. Hence, the term $E(c + c^2/2)$ captures that utility increases with expected consumption. The impact of consumption variability is $-1/2\sigma Ec^2$ and hence always negative.

second order.[6] Notice that, if ν is assumed to correct for monopoly power ($\mu = 1$), this issue disappears in a closed economy since, then, the term $c - n = y - (y - a) = a$ which is independent of welfare and, hence, can be dropped. In an open economy, in contrast, c and y do not generally coincide, and one cannot apply the same argument.

One solution to this issue developed by Sutherland (2005), Benigno and Woodford (2006), Benigno and Benigno (2006), and others, is to express $\mathcal{E}c$ and $\mathcal{E}n$ as functions of only quadratic terms from a second-order approximation of the equilibrium equations. Then one can rewrite the objective as a function of only quadratic terms. We develop this procedure next.

4. A Second-Order Approximation of the Equilibrium

I assume hereon that A and C^* are constant and equal to one, so the only uncertainty concerns the realizations of Z and M. It will be seen that the arguments are straightforward to generalize for the case in which A and C^* are also random.

As mentioned, the equilibrium equations are given by (1), (5), and (9)-(12). Of those, (1), (5), and (9) are linear in logs and, therefore, require no approximation:

$$\sigma c - x = 0, \tag{18}$$

$$q - p_h + p = 0, \tag{19}$$

$$p + c = m. \tag{20}$$

The CPI definition (10) is not log linear, so it must be approximated. One can show that, in second order,

$$(1 - \alpha)q + \alpha x = -\alpha z + \lambda_x \tag{21}$$

6. This is so because a linear approximation to the model would be correct up to a second-order residual. So inserting, say, the resulting expression for c in the welfare objective would insert a second-order residual in the objective, which cannot be ignored (since a quadratic approximation to welfare is intended to be correct up to a residual of third or higher orders).

where I have gathered second-order terms in

$$\lambda_x = -\frac{1}{2}\left[(1-\alpha)(1-\eta)q^2 + \alpha(1-\eta)(x^2+z^2)\right] - \alpha(1-\eta)xz.$$

Some remarks are warranted here. As mentioned, the presence of the commodity price shock z introduces a time varying wedge between the real exchange rate x and other international relative prices such as q. Equation (21) says that the relation between x and q is also affected by their variances, the variance of z, and the covariance between x and z. This would be ignored in a first order approximation, which would treat λ_x just as if it were zero.

The world demand for domestic output (11) can be approximated in second order by

$$y + \theta q - (1-\alpha)c - \gamma\alpha x = \lambda_y \tag{22}$$

where I have collected second-order terms in

$$\lambda_y = -\frac{1}{2}y^2 + \frac{1}{2}\left[(1-\alpha)\eta^2 + \alpha\gamma^2\right]q^2 + \frac{1}{2}(1-\alpha)c^2$$
$$+\frac{1}{2}\gamma^2\alpha x^2 - \eta(1-\alpha)qc - \alpha\gamma^2 qx$$

and defined

$$\theta = (1-\alpha)\eta + \alpha\gamma$$

The parameter θ can be regarded as the elasticity of the total demand for home output with respect to its domestic real price q given the exchange rate. A one percent increase in q reduces home demand for home produce by η percent. In addition, given x, a one percent increase in q is also a one percent increase in the world price of home output, which results in a fall in world demand by γ percent.

Finally, the second-order approximation to the pricing condition (12) is

$$p_h = \mathcal{E}\left[\varphi y + \sigma c + p + \lambda_p\right] \tag{23}$$

with

$$\lambda_p = \frac{1}{2}\left\{(1+\varphi)^2 y^2 - (y - \sigma c - p)^2\right\}.$$

The preceding expression says that p_h increases with expected demand. This is intuitive, as demand determines output and hence, labor effort, wages, and marginal costs. Hence, if expected demand goes up, firms increase prices to maintain the desired markup over marginal costs. Likewise, if expected consumption goes up, the expected wage and marginal costs go up because the marginal utility of the wage falls, resulting in a fall in expected labor supply.

Less obviously, the term λ_p reflects that firms choose nominal prices as a hedge against uncertainty. If, for instance, demand or consumption become more variable (as reflected in an increase in $\mathcal{E}y^2$), the volatility of marginal costs increase for the reasons just mentioned, inducing firms to reduce expected output by increasing prices.

5. Solving for Expected Values

As stressed by Sutherland (2005), it is now straightforward to solve for expected values of all variables as functions of second moments. Let $V = (y\, c\, q\, p\, p_h x)'$ denote the column vector of endogenous variables, and $\Lambda = (0\; 0\; 0\; \lambda_x\; \lambda_y\; \lambda_p)'$ collect second moments. With some loss of generality, we assume that $\mathcal{E}z = \mathcal{E}m = 0$.[7]

Then, taking expectations in the second-order system derived in the previous section, one can collect the six equations (18)-(23) in an expression such as $\Gamma\mathcal{E}V = \mathcal{E}\Lambda$ with the matrix Γ given by the coefficients of the left hand sides of the second-order approximation equations. Expected values are then given by $\mathcal{E}\text{V} = \Gamma^{-1}\mathcal{E}\Lambda$. Therefore, in general, it is relatively straightforward to express first moments as functions of second moments. One can use that result in order to remove $\mathcal{E}c$ and $\mathcal{E}n = \mathcal{E}y$ from the objective function $\mathcal{W}$, thus arriving at the desired purely quadratic objective.

In our case, the simplicity of the model allows us to solve the necessary system by hand. Taking expectations, the perfect risk

7. The first equality is a normalization. The second one entails no loss of generality since money is neutral in this model.

sharing condition becomes $\sigma\mathcal{E}c = \mathcal{E}x$ while $\mathcal{E}q = p_h - \mathcal{E}p$. Inserting these two expressions into the pricing equation yields

$$\mathcal{E}q = \varphi\mathcal{E}y + \mathcal{E}x + \mathcal{E}\lambda_p.$$

Taking expectations in the CPI definition gives

$$(1-\alpha)\mathcal{E}q + \alpha\mathcal{E}x = \mathcal{E}\lambda_x,$$

and the demand for home output in expectations becomes

$$\mathcal{E}y + \theta\mathcal{E}q - \Psi\mathcal{E}x = \mathcal{E}\lambda_y$$

where

$$\Psi = \frac{(1-\alpha)}{\sigma} + \gamma\alpha.$$

The parameter Ψ can be seen as the elasticity of demand for home output with respect to the real exchange rate, other prices given. It reflects that a one percent increase in x leads to a $1/\sigma$ increase in home consumption because of perfect risk sharing, and a one percent fall in the world price of home output, leading to an increase in world demand by γ percent.

These three equations can be solved readily for $\mathcal{E}y, \mathcal{E}q, \mathcal{E}x$, and $\mathcal{E}c$ as functions of the expected λ_x, λ_y and λ_p. The solution has the form

$$\mathcal{E}y = \mathcal{E}\left[\phi_{yy}\lambda_y + \phi_{yp}\lambda_p + \phi_{yx}\lambda_x\right]$$

$$\mathcal{E}c = \frac{1}{\sigma}\mathcal{E}x = \mathcal{E}\left[\phi_{cy}\lambda_y + \phi_{cp}\lambda_p + \phi_{cx}\lambda_x\right]$$

where

$$\phi_{yy} = 1/(1+\varphi\Theta),\ \phi_{yp} = -\Theta\phi_{yy},\ \phi_{yx} = -(\theta - \Psi)\phi_{yy},$$

$$\phi_{cx} = \phi_{yy}(1+\varphi\theta)/\sigma,\ \phi_{cp} = -\phi_{yy}(1-\alpha)/\sigma,\ \phi_{cy} = -\phi_{yy}(1-\alpha)/\varphi\sigma,$$

and we have defined

$$\Theta = \alpha\theta + (1-\alpha)\Psi$$
$$= \Psi + \alpha(\theta - \Psi) = \Psi + \alpha(\eta - \frac{1}{\sigma})$$

The preceding expressions take explicit accounting of uncertainty and show how $\mathcal{E}y$ *and* $\mathcal{E}c$ are related to second moments and uncertainty. Of course, these are not yet solutions to expected values, since λ_x, λ_y and λ_p are functions of endogenous variables. Note that these expressions would be set to zero in a first order approximation.

Expected welfare can then be written as

$$\mathcal{W} = \mathcal{E}\begin{bmatrix} (\phi_{cy} - \mu\phi_{yy})\lambda_y + (\phi_{cp} - \mu\phi_{yp})\lambda_p \\ +(\phi_{cx} - \mu\phi_{yx})\lambda_x + \frac{1}{2}[(1-\sigma)c^2 - \mu(1+\varphi)n^2] \end{bmatrix}, \tag{24}$$

which is purely quadratic, as we had sought.

To illustrate, take the case $\eta = 1/\sigma$ with $\mu = 1$ which has been emphasized in the literature. In that case, $\theta = \Psi = \Theta$ and the expected linear terms in the objective function simplify considerably and become

$$\mathcal{E}c - \mathcal{E}n = \mathcal{E}c - \mathcal{E}y = \frac{\alpha\gamma}{1+\theta\varphi}\mathcal{E}\lambda_p - \frac{\eta(1-\alpha)\varphi + 1}{1+\theta\varphi}\mathcal{E}\lambda_y + \eta\mathcal{E}\lambda_x$$

6. A Linear-Quadratic Approximation to Optimal Policy

As mentioned, a great advantage of having expressed the objective, $\mathcal{W}$, as a purely quadratic term is that it allows the remainder of the analysis to be carried out by looking only at the linear approximation of the model. This is because the residuals associated with the linear approximation, which can be of order two, become terms of third order and higher when taking squares and cross products, so they can be ignored legitimately in second order.

The first order system is obtained from the second-order equations by simply setting λ_x, λ_y and λ_p equal to zero, and becomes

$$\sigma c - x = 0 \tag{25}$$

$$q - p_h + p = 0 \tag{26}$$

$$p + c = m \tag{27}$$

$$(1 - \alpha)q + \alpha x = -\alpha z \tag{28}$$

$$y + \theta q - (1 - \alpha)c - \gamma\alpha x = 0 \tag{29}$$

$$p_h = \mathcal{E}[\varphi y + \sigma c + p] \tag{30}$$

To proceed, take expectations of all equations. It then follows that all variables have an expectation of zero. Hence, $p_h = 0$ in first order, and we can, in practice, forget about (30).

Also, m appears only in (27). This means that we can think of the price level p as the policy variable, letting (27) tell us the associated value of m. This allows us to forget about m altogether in the spirit of the "cashless economy" analysis popularized by Woodford (2003).

Since $p_h = 0$ (26) says that $q = -p$ in first order, therefore, we can equivalently take q as the policy variable.

For concreteness, take p as the control variable. Using $q = -p$ to eliminate q from the system; (28) then gives

$$x = \left(\frac{1}{\alpha} - 1\right)p - z.$$

Consumption is then

$$c = \frac{1}{\sigma}x = \frac{1}{\sigma}\left[\left(\frac{1}{\alpha} - 1\right)p - z\right]$$

$$y = \frac{\Theta}{\alpha}p - \Psi z \tag{31}$$

These expressions can now be used to express λ_x, λ_y and λ_p, as well as c^2 and y^2, in terms of the squares and cross products of p and z.

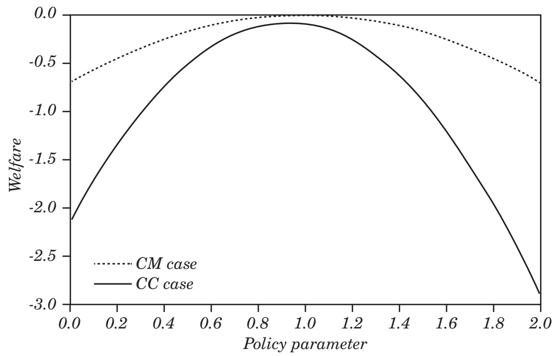
The optimal policy problem can then be seen as one of choosing the distribution of p to minimize the resulting expression for $\mathcal{W}$ as given by (24). Since the problem is now linear-quadratic, the solution will be linear in the shock $z : p = \bar{\kappa} z$, for some constant $\bar{\kappa}$ which is now straightforward to find.

The optimal solution could be compared with any given policy. For example, one could define CPI targeting as a policy that sets $p = 0$. Likewise, a policy that stabilizes the real exchange rate would set $x = 0$; note that this also results in a linear rule in the form $p = \kappa z$ with $\kappa = -\alpha/(1 - \alpha)$. A third option would stabilize domestic markups, which is the hallmark of PPI targeting. From (30), such a policy must set $\varphi y + \sigma c + p = \varphi y + x + p = 0$. With the expressions above, this would require $p = \kappa_{PPI} z$ with

$$\kappa_{PPI} = \frac{\alpha[1 + \varphi\Psi]}{1 + \varphi\Theta} \tag{32}$$

In general, the policies just mentioned will differ from each other and from the optimal policy. One could now explore how the discrepancies depend on the values of different parameters such as elasticities of demand or the coefficient of relative risk aversion σ.

Figure 1. Policy Rules and Welfare



Source: Author's calculations.

To illustrate, figure 1 displays the welfare consequences for alternative policies of the form require $p = \iota\, \kappa_{PPI} z$ where ι varies between zero and two along the horizontal axis. Hence, $\iota = 1$

corresponds to PPI targeting, and $\iota = 0$ to CPI targeting. For each such policy, welfare can be computed to be proportional to the standard deviation of z the proportionality constant is plotted along the vertical axis.

Two parameterizations are examined. Both assume $\alpha = 0.3$ and $\varphi = 1$, which are standard values. Also, μ is set at $1 - \alpha$ so that PPI targeting is theoretically optimal in the unit elasticity case of Galí and Monacelli (2005). So figure 1 plots welfare for that case, $\sigma = \eta = \gamma = 1$, labeled "GM case." As an alternative, the figure also displays a plot for the "CC case" of $\sigma = 3$, $\eta = 0.2$, $\gamma = 5$. This combination of parameters is prominently featured in Catão and Chang (2015), who argue that it is a reasonable approximation of an economy that imports food or oil (so that the elasticity of substitution between domestic goods and imports is low) but exports goods with a relatively elastic world demand.

For the GM case, the figure gives the expected results. Welfare is maximized at $\iota = 1$, confirming that PPI targeting is optimal. But that is a special case. For the CC parameterization, the figure shows that PPI targeting is dominated by other policies. Welfare is maximized at $\iota = 0.92$; this result, in particular, indicates that, as we move away from the GM case, optimal policy places more emphasis on terms of trade externality rather than domestic monopoly distortions.

This suggests that one should explore, in more detail, how optimal policy departs from PPI targeting under more realistic assumptions (e.g. a multi-period setting), and allow for other parameterizations. This topic is developed in Catão and Chang (2013; 2015). Catão and Chang's model is essentially the same as discussed here, except that they assume Calvo pricing, which imparts non trivial dynamics and allows for productivity and monetary policy shocks in addition to commodity price shocks. One of their main findings is that the optimality of PPI targeting, vis a vis other rules (especially the targeting of forecasted CPI), depends crucially on various parameters such as the elasticity of foreign demand for home output (γ) and the structure of financial markets. With complete international risk sharing, PPI targeting delivers lower welfare than expected CPI targeting, except for unrealistically low values of γ. However, PPI is a superior choice under portfolio autarky and, more generally, under even mild degrees of imperfections in international risk sharing. For a complete discussion and details, the reader is referred to Catão and Chang (2013; 2015).

7. Policy Targets, Gaps, and Optimal Rules

Benigno and Benigno (2006), De Paoli (2009), and others have proposed an alternative perspective on the optimal policy problem based on rewriting the social objective function $\mathcal{W}$ in terms of "targets" and "welfare-relevant gaps." An associated implication is that optimal policy can be expressed as a "flexible targeting rule." One of the advantages of such an approach, these authors have argued, is that it identifies targets that should be assigned to a central banker in order to maximize social welfare. It also has the virtue of reconciling recent theory with a venerable tradition of loss functions that are quadratic in inflation and deviations of inflation and perhaps other variables from targets.

In our context, it will be useful to separate a role for ex-post inflation (nominal) variability from the role of real variables. To do this, observe that the price level p does not appear in the Λ terms except for λ_p, which can be rewritten as

$$\begin{aligned}\lambda_p &= \frac{1}{2}\left\{\varphi(2+\varphi)y^2 - (\sigma^2 c^2 + p^2 - 2y\sigma c - 2yp + 2\sigma pc)\right\}\\ &= \frac{1}{2}\left\{\varphi(2+\varphi)y^2 - (\sigma^2 c^2 - 2y\sigma c + 2qy - 2\sigma qc)\right\} - \frac{1}{2}p^2\\ &\equiv \tilde{\lambda}_p - \frac{1}{2}p^2\end{aligned}$$

the next to last replacement using the fact that $q = -p$ in first order.

This implies that the objective function can be rewritten, using (24) as

$$\mathcal{W} = \mathcal{E}\begin{bmatrix}(\phi_{cy} - \mu\phi_{yy})\lambda_y + (\phi_{cp} - \mu\phi_{yp})\tilde{\lambda}_p \\ +(\phi_{cx} - \mu\phi_{yx})\lambda_x + \frac{1}{2}[(1-\sigma)c^2 \\ -\mu(1+\varphi)n^2]\end{bmatrix} - \frac{1}{2}(\phi_{cp} - \mu\phi_{yp})\mathcal{E}p^2$$

plus a term in z^2 and, therefore, independent of welfare. Noting that λ_y, λ_x and λ_p depend only on the vector of real variables $\tilde{V} = (y, c, q, x)'$, the preceding can be written as

$$\mathcal{W} = -\mathcal{E}\left[\left(\frac{1}{2}\tilde{V}'D\tilde{V} + \tilde{V}'Fz\right) + \frac{1}{2}w_p p^2\right]$$

for appropriately chosen matrices D and F and $w_p = (\phi_{cp}\text{-}\mu\phi_{yp})$.

The preceding representation is suggestive as it rewrites the welfare objective as an expected loss function which depends on inflation variability with weight w_p and a component that depends only on the volatility of real variables. Hence, it emphasizes that stable inflation should be an objective of monetary policy but, generally, should not be the only one: the real variables included in the vector $\tilde{V}$ also matter for welfare.

A further simplification is available from the observation that the three first order equations (25), (28), and (29) can, in principle, be solved for any three of the real variables included in the vector $\tilde{V}$ in terms of the fourth one and the shock z. For instance, adding the identity $y = y$ as a fourth equation $\tilde{V}$ one can write

$$\Phi_y \tilde{V} = \psi_y y + \psi_z z, \tag{33}$$

where

$$\Phi_y = \begin{bmatrix} 0 & \sigma & 0 & -1 \\ 0 & 0 & 1-\alpha & \alpha \\ 1 & -(1-\alpha) & \theta & -\gamma\alpha \\ 1 & 0 & 0 & 0 \end{bmatrix}$$

$$\psi_y = \begin{bmatrix} 0 & 0 & 0 & 1 \end{bmatrix}'$$

and

$$\psi_z = \begin{bmatrix} 0 & -\alpha & 0 & 0 \end{bmatrix}'$$

The matrix Φ_y is invertible and, hence, one can write

$$\tilde{V} = N_y y + N_z z$$

where $N_y = \Phi_y^{-1}\psi_y$ and $N_z = \Phi_y^{-1}\psi_z$. Therefore, as mentioned, the vector $\tilde{V}$ can be expressed as a function of only y and z. Note, at this point, that one could have equally expressed $\tilde{V}$ in terms of z and a different variable, say, the real exchange rate x.

Inserting the last equation into the "real" part of $\mathcal{W}$:

$$\begin{aligned}\frac{1}{2}\tilde{V}'D\tilde{V}+\tilde{V}'Fz &= \frac{1}{2}(N_y y+N_z z)' D\left(N_y y+N_z z\right)+\left(N_y y+N_z z\right)' Fz \\ &= \frac{1}{2}(N_y' DN_y)y^2+(N_y' DN_z+N_y' F)yz+t.i.p. \\ &= \frac{1}{2}w_y[y^2-2\varpi yz]+t.i.p.\end{aligned}$$

where w_y and ϖ are scalars defined in the obvious way and, following Woodford (2003), *t.i.p.* stands for terms independent of policy, which are irrelevant for the definition of the welfare objective.

This suggests one further rewriting:

$$y^2-2\varpi yz=(y-y^T)^2+t.i.p.$$

where

$$y^T=\varpi z$$

is the linear function of the shock determined by the parameter ϖ. Replacing it in the objective function, we finally obtain (dropping *t.i.p* terms)

$$\mathcal{W}=\frac{1}{2}\mathcal{E}\left[w_y(y-y^T)^2+w_p p^2\right] \tag{34}$$

This expression for $\mathcal{W}$ emphasizes that monetary policy should seek to minimize a weighted sum of deviations of inflation from a zero mean and deviations of output from $y^T=\varpi z$ (sometimes called the welfare relevant output gap). The random variable y^T is then appropriately seen as a target of policy; in a sense, this provides a justification for flexible inflation targeting.

The main constraint in the maximization is (31), which can be seen as the Phillips Curve in this model and can be rewritten as

$$y-y^T=\frac{\Theta}{\alpha}p-(\Psi+\varpi)z \tag{35}$$

Maximizing (34), subject to this constraint, now gives

$$(y - y^T) + \varkappa p = 0$$

with $\varkappa = \alpha w_p / \Theta w_y$. This can be seen as a flexible targeting rule. It emphasizes that the central bank's optimal policy reflects a trade-off between deviations from a zero inflation target and a nonzero welfare relevant output gap.

The form of the objective function $\mathcal{W}$ and the targeting rule are the same as the ones that Woodford (2003), Galí (2008), and others have proposed as optimal for a closed economy. Hence, our discussion suggests that central banks in small open economies should be given the same objectives and follow the same rules as their counterparts in closed economies.

Such an interpretation, however, would be too simplistic and perhaps misleading for a number of reasons. First, the welfare function just derived is a transformation of the utility function of the representative agent where we have used (second-order) approximations to the equilibrium to replace the original arguments of that function (consumption and labor effort). Naturally, the weights w_y and w_p will depend, in general, on the basic parameters of the economy, including the degree of openness, trade elasticities, technology parameters, preference parameters, and the degree of international risk sharing.

Likewise, the target $y^T = \varpi z$ is a function of the exogenous shocks to world commodity prices. In addition, the parameter ϖ is a function of other basic parameters of the economy as the derivation makes clear. In the closed economy, it is often the case that the appropriate target for output is given by natural output. But this is not the case here. In general, the target y^T found here will be different from the flexible price value of output implied by (32).

To illustrate, table 1 gives the values of w_y, w_p, ϖ, and $\varkappa$ for different parameter values. In the table, parameter values change from the unit elasticity case of Galí and Monacelli given in the first row to the Catão-Chang case in the last row in order to trace the influence of specific parameters.

The Galí-Monacelli case is interesting since the derived coefficients seem counterintuitive at first. Since $w_p = 0$, the implied central bank loss function gives no weight to inflation. Likewise, $\varkappa = 0$ so that inflation does not appear in the optimal "flexible targeting rule," which reduces to $y - y^T = 0$, that is, to stabilize

Table 1. Optimal Policy Objectives, Targets and Rules

	w_y	w_p	ϖ	$\varkappa$
$\sigma = \eta = \gamma = 1$ (GM case)	1.40	0.00	0.00	0.00
$\sigma = 3$, $\eta = \gamma = 1$	1.05	0.16	0.06	0.08
$\sigma = 3$, $\eta = 1$, $\gamma = 5$	0.37	0.38	0.17	0.17
$\sigma = 3$, $\eta = 0.2$, $\gamma = 5$ (CC case)	0.65	0.35	-0.00	0.10

Source: Author's calculations.

output around its target level. In turn, $y^T = 0$. All of this may be puzzling since we know that PPI targeting is optimal in this case. The mystery goes away when one realizes that keeping $y = y^T = 0$ requires $p = [\alpha(\Psi + \varpi)/\Theta]z$ in order to satisfy (35), which is the fixed markup condition associated with PPI stabilization.

The second row is the GM case, except that $\sigma = 3$. An implication is that w_y falls and w_p increases in the loss function. Correspondingly, $\varkappa$ becomes positive so that the flexible targeting rule pays more attention to CPI stabilization relative to output stabilization. This echoes results in Catão and Chang (2015) and reflects that a larger σ increases the importance of the terms of trade externality so that optimal policy tilts towards stabilizing the real exchange rate. Notably, also, the output target becomes $y^T = 0.06z$, expressing that it is socially beneficial for home output and labor effort to expand in response to an increase in the world price of imports. A main point here is that all of the parameters of the linear quadratic social planning problem and, hence, the solution, depend on the economy's more basic elasticities.

The third row assumes $\gamma = 5$. In that case, the linear quadratic loss function places almost the same emphasis on inflation as on the output gap. The output target is now $y^T = 0.17z$, suggesting that the output should react even more strongly than in the previous case to a shock in imports prices. On the other hand, the flexible targeting rule parameter rises to 0.17 indicating that, in the end, CPI stabilization receives more weight. Since $q = -p$ this also means that real exchange rate stabilization receives more emphasis. Overall, the intuition is that a more elastic foreign demand for home output leads to even more emphasis on the terms of trade externality relative to PPI stabilization.

Finally, the last row shows the CC case, which assumes $\eta = 0.2$. A smaller value of η means that imports and domestic goods are less substitutable in domestic consumption. The result is that the welfare function and the flexible targeting rule pay somewhat less attention to the terms of trade externality, and more attention to addressing domestic price distortions.

8. What Variables Should the Central Bank Target?

In small open economies, especially those subject to fluctuations in the world prices of food, oil, and other commodities, a debate often emerges regarding the variables that the central bank should try to stabilize. Some debate participants have sought guidance from the recent academic literature, interpreting it as implying that an optimal flexible inflation targeting should include only inflation, and the output gap.

For example, Svensson (2008) argued the following:

> "But what price index should inflation targeting ideally refer to? Recent work by Kosuke Aoki, Pierpaolo Benigno and others have emphasized that (from a welfare point of view) monetary policy should stabilize sticky prices rather than flexible prices. These results can be interpreted as favoring a core CPI or domestic inflation targeting. How should the central bank respond to oil price changes (or any terms of trade changes)? Good monetary policy is flexible inflation targeting that can be narrowly specified as aiming at both stabilizing inflation around an inflation target and stabilizing the output gap around zero. Importantly, under inflation targeting, the exchange rate is not a target variable and there is no target exchange rate level."

Our analysis in the previous section might be construed as confirming the views of Svensson (2008) and others, but in fact, perhaps surprisingly, it does not adhere to those views completely.

The key observation is that the previous section's representation of $\mathcal{W}$ as a function of an output gap and inflation can be replaced by one with $\mathcal{W}$ being written as a function of, say, a "real exchange rate gap" and inflation, or a consumption gap and inflation, and so on. This is easily seen by retracing the steps leading to (34). Specifically, we noted that the three equations (25), (28), and (29) allowed us to express any three of the four real variables (c, y, q, x)

in terms of the fourth one. In writing (33), we proceeded to express (c, q, x) in terms of y. But we could have equally expressed (c, q, y) in terms of x : adding the identity $x = x$ to (25), (28), and (29), we could have written

$$\Phi_x \tilde{V} = \psi_x x + \psi_z z$$

with $\psi_x = \psi_y$ and Φ_x equal to Φ_y except for its last row–which would be given by (0, 0, 0, 1).

It is now obvious that such a choice would lead to an objective function of the form $\mathcal{W} = -1/2\, \mathcal{E}[w_x(x - x^T)^2 + w_p p^2]$ and a target rule of the form $(x - x^T) + \varkappa p = 0$ where $x^T = \varpi z$ however, the parameters ϖ, w_x, w_p,, and $\varkappa$ would be different in this case.

In other words, there are several equivalent ways to represent the social welfare function and associated constraints and, correspondingly, many seemingly different but equivalent ways to implement an optimal monetary policy. As a consequence, one can assign the central banker an output objective, or an exchange rate objective, or a domestic producer price objective, or all of the above, as long as the meaning of "objective" is defined properly in terms of the underlying shocks that affect the economy. Note that the argument is quite general (in the end, all of the equivalent representations of the social welfare function are ultimately derived from $u(C) - v(N)$ or its second-order approximation (17).

While these observations fall quite easily from our analysis and, indeed, some readers may find them trivial, they are quite important from a practical perspective. As illustrated by the Svensson quote above, it is frequently argued that the central bank should "react to domestic inflation rather than headline inflation," or that monetary policy should "depend on the real exchange rate in addition to inflation and the output gap," or even that the central bank should have "competitiveness and the real exchange rate as one of their objectives." On the basis of the analysis here, which is representative of the recent literature, one must conclude that each and every one of these claims is right and wrong (or, at best, incomplete) at the same time. The analysis establishes that it can be optimal for the central bank to be assigned an output target and zero inflation as objectives, and to follow a rule targeting inflation and an output gap. But such a prescription is incomplete unless it specifies how the output target is defined in terms of the exogenous shocks hitting the economy, and how to compute the relative weights in the central bank's loss function and the target rule. It can be equally optimal to assign an exchange rate target to the central bank instead of, or even in addition to, an output target, as long as the target (or targets) and weights are redefined appropriately as described in this section.

We then conclude that, by itself, our analysis does not provide a rationale for telling central bankers to stabilize the output gap and PPI inflation rather than CPI inflation or the real exchange rate. Any of these variables or others can, in principle, be a suitable target of policy.

One might further ask if there are some other considerations outside the kind of analysis reviewed here that could justify why a central bank should target some variables instead of others. This question is beyond the scope of the present paper, but one may speculate that answers may be based on how the different variables relate to the credibility of the central bank.

More specifically, it may be better to target some variables rather than others from a "transparency" perspective. Arguably, a (nominal) exchange rate target is more transparent than a "domestic inflation" target just because the exchange rate is more easily and more readily observable than a domestic inflation index, especially in economies that are heavily exposed to international relative price fluctuations.

Likewise, an argument in favor of targeting the exchange rate rather than inflation could be based on the different strengths of these variables as commitment devices in the presence of time inconsistency. The announcement of an inflation target is, arguably, not as "hard" as announcing an exchange rate target, partly because sometimes the meaning of "inflation" has not been precisely defined (witnesses debate about whether inflation targets actually referred to core, versus headline, inflation). In contrast, an exchange rate target is often unambiguous.

A third line of argument may be that some variables are observed more frequently and with a shorter lag than others. Output and inflation measures, including the exchange rate and interest rates, are not as readily available as asset prices.

Notably, these arguments tend to favor exchange rates as targets rather than inflation and the output gap. Opposing arguments can indeed be constructed. For instance, one might point out that exchange rates and other asset prices are often affected by bubbles and self-fulfilling expectations and are, therefore, unreliable indicators of the economy's fundamentals. Clearly, much more research remains to be done on these issues.

9. Final Remarks

Our discussion has abstracted from the question of how central banks might implement policy in practice. The current approach to this issue is to derive and characterize the implications of policy rules such as Taylor rules. I prefer not to expand on this question here, partly because there is no satisfactory definition of an interest rate in this paper's model. Also, this issue is explored in detail in Catão and Chang (2015).

This being said, the analysis of policy rules may provide another way to discriminate among the variables that a central bank may target. Theoretical analyses frequently assume rules that make the interest rate react to measures of inflation and the output gap. Both measures are, however, nontrivial to construct and usually obtained after some lags. In contrast, asset prices, including exchange rates, are observed much more easily and quickly. Hence, if one can find a rule that makes the interest rate react to exchange rates and delivers the same allocation as a rule based on the output gap, then one should presumably prefer the former. But this obviously warrants more research.

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Monetary Policy and Dutch Disease: The Case of Price and Wage Rigidity

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From a theoretical point of view, and as we will show, the presence of both price and wage rigidities implies that, to the extent that fiscal policy is unresponsive to shocks, full price stability is not optimal. In this paper, we study optimal monetary and exchange rate policy in a small open economy with both types of rigidity, following a shock to the price of an exportable commodity.

This paper is part of a research project that is motivated by the experiences of many small open economies that in the last two decades became—very effectively!—inflation targeters. Many of these economies are commodity producers, and the size of the commodity sector to GDP is very high. For example, in the decade from 2000 to 2010, exports of copper and marine products for Chile were, on average, around 17% of GDP, while total exports of oil and marine products in Norway accounted for 20% of GDP (Hevia and Nicolini, 2013). During the same decade, the real price of copper and oil experienced changes of around 300%. The size of these shocks is orders of magnitude above any business cycle shock we have ever seen.

These shocks have direct effects on the monetary side of these economies. In effect, the correlation between the HP-filtered price of the exportable commodity and the HP-filtered nominal exchange rate—to concentrate our analysis at the business cycle frequency—ranges from −50% to −70% for both countries, depending on whether

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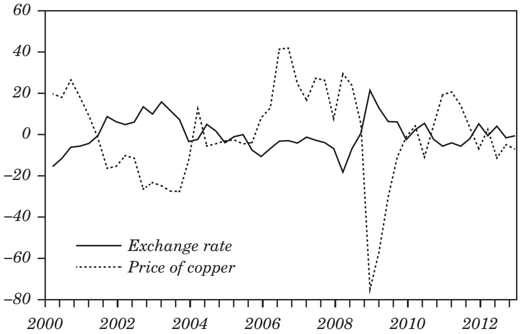
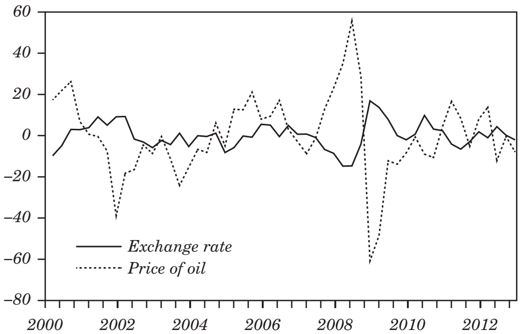
Figure 1. Nominal Exchange Rates and Main Exportable Commodity Price

A. Chile



B. Norway



Source: Elaborated by the authors based on national data sources and the World Bank (Global Economic Monitor).

one includes the last three periods of the decade in the sample. That period of time witnessed very large changes in commodity prices, comoving with the peso in Chile and the krone in Norway.[1] In figure 1, we plot the HP-filtered data for the nominal exchange rate and the relevant commodity price for both countries, where the correlation is strikingly clear.

1. The series are first logged and then HP-filtered with a smoothing parameter of 1600.

Clearly, this correlation cannot be independent of the policy regime. In a currency board or fixed exchange rate regime, that correlation is naturally zero. Thus, one should expect the correlation between the price of copper and the exchange rate in Chile to be much closer to zero during the early nineties, during which time inflation was driven down from close to 30% to below 10% using a managed exchange rate. But in a very successful inflation-targeting regime, like the ones followed by both central banks during the period, the nominal exchange rate floats freely, so the correlation is determined by market forces. According to the model that follows, the negative correlation is a direct implication of the inflation-targeting regime. Indeed, in the model, following a large increase in the price of the exportable, and given price stability, the nominal exchange rate—and the real rate, given price stability—suffers a strong appreciation, generating the traditional Dutch disease effect, which is the optimal response of prices and quantities to a relative price shock.

We are interested in studying conditions under which the strict inflation-targeting regime is optimal. Put differently, we want to find conditions under which these Dutch disease episodes are inefficient from the viewpoint of the allocation of resources. In our view, this is one of the main policy questions in countries like Chile. Indeed, during the successful inflation-targeting period, the Central Bank deviated from the strict rule twice: once in April 2008 and again in January 2011. On both occasions, the justification for the intervention was essentially the same: the terms of trade were too high and the nominal exchange rate too low.

In a previous paper (Hevia and Nicolini, 2013), we studied an economy with only price frictions and showed that even in a second-best environment with distorting taxes, domestic price stability is optimal as long as preferences are of the isoelastic type (which is typically used in the literature), even if fiscal policy cannot respond to shocks. In other words, restrictions on price setting do not necessarily imply that the large and persistent deviations observed in nominal and real exchange rates in countries like Chile are suboptimal, as long as monetary policy is executed so as to stabilize domestic prices. The model in that paper thus fully justifies a pure inflation targeting regime (at a zero rate of domestic price inflation). In other words, the "Dutch disease" is not really a disease; it is just the optimal response of prices and quantities to a relative price shock.

In the conclusion to our previous paper, we pointed out that our results fall apart in the presence of both price and wage frictions.

Quantitatively exploring this question is the purpose of this paper. Exploring this policy problem in the context of both price and wage rigidity seems to us a natural step. Most medium-scale models used for monetary policy evaluation nowadays exhibit both types of rigidities, following the work of Christiano, Eichenbaum, and Evans (2005) and Smets and Wouters (2007). How far from pure price stability is the optimal policy once both types of frictions are present? What implications do they have for the "dirty floating" debate in countries that experience large fluctuations in their terms of trade? Answering these questions is the contribution of this paper.

As mentioned, the theory is clear: the presence of both frictions, coupled with inflexible tax instruments, implies that full price stability is not optimal. For completeness, we first generalize the closed economy results of Correia and others (2013) and the small open economy results of Hevia and Nicolini (2013) with only price frictions to our small open economy model with price and wage frictions and then show that, in general, full price stability is not optimal when taxes cannot be time and state dependent. But the main exploration of this paper is a quantitative one: on the one hand, we explore numerically how far apart from full inflation targeting the optimal policy is; on the other, we compute the welfare difference between the optimal policy and full inflation targeting. For the calibrated version of our model, we find that the key factor is the degree of wage rigidity. When wages are indeed highly rigid (the Calvo parameter is as high as 0.8) and there is enough price rigidity (a Calvo parameter of at least 0.25), the welfare effect of full price stability relative to the optimal policy can be as high as 0.5% of lifetime consumption. However, if the rigidity is mostly concentrated in prices with some wage rigidity, the welfare effect is bounded above by 0.1% of lifetime consumption. We also show that a dirty floating regime approximates the optimal policy remarkably well.

The model we use is the one explored in Hevia and Nicolini (2013), but in this model, we allow for heterogeneous labor with market power and frictions in wage setting. A virtue of the model is that it is fully consistent with the evidence presented in figure 1, as we show in the paper. We present the model in the next section. In section 2 we describe the calibration and numerical solutions and discuss optimal policy. Section 3 concludes.

1. The Model

We study a discrete time model of a small open economy inhabited by households, the government, competitive firms that produce a tradable commodity, competitive firms that produce final goods, and a continuum of firms that produce differentiated intermediate goods. There are two differentiated traded final goods: one produced at home and the other produced in the rest of the world. The small open economy faces a downward-sloping demand for the final good it produces but takes as given the international price of the foreign final good. There are also two commodities—one produced at home, the other imported—used in the production of intermediate goods. These intermediate goods are used to produce the final domestic good.

1.1 Households

A representative household has preferences over contingent sequences of two final-consumption goods, C_t^h and C_t^f, and leisure L_t. The utility function is weakly separable between the final-consumption goods and leisure and is represented by

$$E_0 \sum_{t=0}^{\infty} \beta^t U(C_t, L_t), \tag{1}$$

where $0 < \beta < 1$ is a discount factor, $C_t = H(C_t^h, C_t^f)$ is a function homogeneous of degree one and increasing in each argument, and $U(C,L)$ is concave and increasing in both arguments.

1.1.1 Sticky wages

In order to allow for sticky wages, we assume the single household has a continuum of members indexed by $h \in [0,1]$, each supplying a differentiated labor input n_{ht}. Preferences of the household are described by (1), where leisure is

$$L_t = \bar{L} - \int_0^1 n_{ht} dh, \tag{2}$$

and $\bar{L}$ is the total amount of time available for work or for leisure.

The differentiated labor varieties aggregate up to total labor input N_t, used in production, according to the Dixit-Stiglitz aggregator

$$N_t = \left[\int_0^1 n_{ht}^{\frac{\theta^w - 1}{\theta^w}} dh \right]^{\frac{\theta^w}{\theta^w - 1}}, \theta^w > 1. \tag{3}$$

Each member of the household, which supplies a differentiated labor variety, behaves under monopolistic competition. The workers set wages as in Calvo (1983), with the probability of being able to revise the wage $1 - \alpha^w$. This lottery is *i.i.d.* across workers and over time. The workers that are not able to set wages in period 0 all share the same wage w_{-1}. Other prices are taken as given. There is a complete set of state-contingent assets. We consider an additional tax, a payroll tax on the wage bill paid by firms, τ_t^p.

1.1.2 Market structure

Financial markets are complete. We let $B_{t,t+1}$ and $B^*_{t,t+1}$ denote one-period discount bonds denominated in domestic and foreign currency, respectively. These are bonds issued at period t that pay one unit of the corresponding currency at period $t+1$ on a particular state of the world and zero otherwise.

The household's budget constraint is given by

$$\begin{aligned} & P_t^h C_t^h + P_t^f C_t^f + E_t \left[Q_{t,t+1} B_{t,t+1} + S_t Q^*_{t,t+1} \tilde{B}^*_{t,t+1} \right] \leq \\ & W_t \left(1 - \tau_t^n\right) N_t + B_{t-1,t} + S_t \frac{\tilde{B}^*_{t-1,t}}{1 + \tau_t^*}, \end{aligned} \tag{4}$$

where S_t is the nominal exchange rate between domestic and foreign currency, W_t is the nominal wage rate, τ_t^n is a labor income tax, τ_t^* is a tax on the return of foreign-denominated bonds (a tax on capital flows), and $Q_{t,t+1}$ is the domestic currency price of the one-period contingent domestic bond normalized by the conditional probability of the state of the economy in period $t+1$ conditional on the state in period t. Likewise, $Q^*_{t,t+1}$ is the normalized foreign currency price of the foreign bond.[2] In this constraint, we assume that dividends are fully taxed and that consumption taxes are zero (we explain these choices later).

Using the budget constraint at periods t and $t+1$ and rearranging yields the no-arbitrage condition between domestic and foreign bonds:

$$Q_{t,t+1} = Q^{*}_{t,t+1}\left(1+\tau^{*}_{t+1}\right)\frac{S_t}{S_{t+1}}. \tag{5}$$

Working with the present value budget constraint is convenient. To that end, for any $k > 0$, we let $Q_{t,t+k} = Q_{t,t+1}\, Q_{t+1,\,t+2} \cdots\, Q_{t+k-1,\,t+k}$ be the price of one unit of domestic currency at a particular history of shocks in period $t+k$ in terms of domestic currency in period t; an analogous definition holds for $Q^{*}_{t,t+\mathrm{k}}$. Iterating forward on (4) and imposing the no-Ponzi condition $\lim_{t\to\infty} E_0[Q_{0,t}B_t + S_t Q^{*}_{0,t}\tilde{B}^{*}_t] \geq 0$ gives

$$E_0\sum_{t=0}^{\infty} Q_{0,t}\left(P^h_t C^h_t + P^f_t C^f_t - W_t\left(1-\tau^n_t\right)N_t\right) \leq 0, \tag{6}$$

where we have assumed that initial financial wealth is zero, or $B_{-1,0} = \tilde{B}^{*}_{-1,0} = 0$.

The household maximizes (1) subject to (6). The optimality conditions are given by

$$\frac{H_{C^h}(C^h_t, C^f_t)}{H_{C^f}(C^h_t, C^f_t)} = \frac{P^h_t}{P^f_t} \tag{7}$$

$$\frac{U_C\left(C_t, L_t\right)H_{C^h}(C^h_t, C^f_t)}{P^h_t} = \beta\frac{1}{Q_{t,t+1}}\frac{U_C\left(C_{t+1}, L_{t+1}\right)H_{C^h}(C^h_t, C^f_t)}{P^h_{t+1}}, \tag{8}$$

plus an optimal wage decision that will be discussed later.

2. We use the notation $\tilde{B}^{*}_{t,t+1}$ instead of simply $B^{*}_{t,t+1}$ to distinguish foreign bonds held by the household sector from foreign bonds held by the aggregate economy.

1.2 Government

The government sets monetary and fiscal policy and raises taxes to pay for exogenous consumption of the home final good, G_t^h.[3] Monetary policy consists of rules for either the nominal interest rate R_t or the nominal exchange rate S_t. Fiscal policy consists of labor taxes τ_t^n; payroll taxes τ_t^n, export and import taxes on foreign goods, τ_t^h and τ_t^f, respectively; taxes on returns of foreign assets τ_t^*; and dividend taxes τ_t^d.

The two sources of pure rents in the model are the dividends of intermediate-good firms and the profits of commodity producers—equivalently, one can think of the latter as a tax on the rents associated with a fixed factor of production. Throughout the paper, we assume that all rents are fully taxed so that $\tau_t^d = 1$ for all t. The reason for this assumption is that if pure rents are not fully taxed, the Ramsey government will use other instruments to partially tax those rents. We deliberately abstract from those effects in the optimal policy problem.

Our description of fiscal policy is for completeness. As is well known,[4] when fiscal policy can respond to shocks and there is a complete set of instruments, price stability is optimal. The taxes described in this section do represent a complete set of instruments. The optimal monetary policy becomes nontrivial once fiscal instruments are exogenously restricted to be unresponsive to shocks.

1.3 Final-good Firms

Perfectly competitive firms produce the domestic final good Y_t^h by combining a continuum of nontradable intermediate goods indexed by $i \in (0,1)$ using the technology

$$Y_t^h = \left[\int_0^1 y_{it}^{\frac{\theta-1}{\theta}} di \right]^{\frac{\theta}{\theta-1}}$$

where $\theta > 1$ is the elasticity of substitution between each pair of intermediate goods. Taking as given the final-good price, P_t^h, and

3.It is straightforward to also let the government consume foreign goods.

4.See Adao, Correia, and Teles (2009), Correia, Nicolini, and Teles (2008), Correia and others (2013), Farhi, Gopinath, and Itskhoki (2014) and Hevia and Nicolini (2013).

the prices of each individual variety of intermediate goods, P_t^h for $i \in (0,1)$, the firm's problem implies the cost minimization condition

$$y_{it} = Y_t^h \left(\frac{P_{it}^h}{P_t^h} \right)^{-\theta} \tag{9}$$

for all $i \in (0,1)$. Integrating this condition over all varieties and using the production function gives a price index relating the final-good price and the prices of the individual varieties,

$$P_t^h = \left(\int_0^1 P_{it}^{h\,1-\theta} di \right)^{\frac{1}{1-\theta}}. \tag{10}$$

1.4 Minimization of Labor Costs

Before describing the technologies of the sectors that demand labor, we believe it is useful to describe the labor cost minimization problem. Firms minimize

$$\int_0^1 w_{ht} n_{ht} dh,$$

where w_{ht} is the wage of the h-labor, for a given aggregate N_t, subject to (3). The demand for n_{ht} is

$$n_{ht} = \left(\frac{w_{ht}}{W_t} \right)^{-\theta^w} N_t, \tag{11}$$

where W_t is the aggregate wage level, given by

$$W_t = \left[\int_0^1 w_{ht}^{1-\theta^w} dh \right]^{\frac{1}{1-\theta^w}}. \tag{12}$$

It follows that

$$\int_0^1 w_{ht} n_{ht} dh = W_t N_t.$$

The optimal wage-setting conditions by the monopolistic competitive workers are now

$$w_t = \frac{\theta^w}{\theta^w - 1} E_t \sum_{j=0}^{\infty} \eta_{t,j}^w \frac{U_L(t+j)}{U_C(t+j)} \frac{(1+\tau_{t+j}^c)P_{t+j}}{(1-\tau_{t+j}^n)}, \tag{13}$$

with

$$\eta_{t,j}^w = \frac{(1-\tau_{t+j}^n)\left(\alpha^w\beta\right)^j \dfrac{U_C(t+j)}{\left(1+\tau_{t+j}^c\right)P_{t+j}}\left(W_{t+j}\right)^{\theta^w} N_{t+j}}{E_t\sum_{j=0}^{\infty}(1-\tau_{t+j}^n)\left(\alpha^w\beta\right)^j \dfrac{U_C(t+j)}{\left(1+\tau_{t+j}^c\right)P_{t+j}}\left(W_{t+j}\right)^{\theta^w} N_{t+j}}. \tag{14}$$

The wage level (12) can be written as

$$W_t = \left[\left(1-\alpha^w\right)w_t^{1-\theta^w} + \alpha^w W_{t-1}^{1-\theta^w}\right]^{\frac{1}{1-\theta^w}}. \tag{15}$$

Using (11), we can write (2) as

$$N_t = \left[\int_0^1 \left(\frac{w_{ht}}{W_t}\right)^{-\theta^w} dh\right]^{-1} \left(\bar{L} - L_t\right). \tag{16}$$

From (12), it must be that

$$\int_0^1 \left(\frac{w_{ht}}{W_t}\right)^{-\theta^w} dh \geq 1.$$

This means that for a given total time dedicated to work, $\bar{L} - L_t$, the resources available for production are maximized when there is no wage dispersion.

In equilibrium

$$\bar{L} - L_t = N_t \sum_{j=0}^{t+1} \varpi_j^w \left(\frac{w_{t-j}}{W_t}\right)^{-\theta^w},$$

where ϖ_j^w is the share of household members that have set wages j periods before, $\varpi_j^w = (\alpha^w)^j(1-\alpha^w), j = 0,2,\ldots, t$, and $\varpi_{t+1}^w = (\alpha^w)^{t+1}$, which is the share of workers that have never set wages and charge the exogenous wage w_{-1}.

1.5 Primary-commodity Sector

Two tradable commodities, denoted by x and z, are used as inputs in the production of intermediate goods. The home economy, however, is able to produce only the commodity x; the commodity z must be imported. We denote by P_t^x and P_t^z the local currency prices of the commodities.

Total output of commodity x, denoted as X_t, is produced according to the technology

$$X_t = A_t\left(n_t^x\right)^{\rho}, \tag{17}$$

where n_t^x is labor, A_t is the level of productivity, and $0 < \rho \leq 1$. Implicit in this technology is the assumption of a fixed factor of production (when $\rho < 1$), which we broadly interpret as land.

Profit maximization implies

$$\rho P_t^x A_t\left(n_t^x\right)^{\rho-1} = W_t(1+\tau_t^p). \tag{18}$$

Because the two commodities can be freely traded, the law of one price holds:

$$\begin{aligned} P_t^x &= S_t P_t^{x*} \\ P_t^z &= S_t P_t^{z*} \end{aligned} \tag{19}$$

where P_t^{x*} and P_t^{z*} denote the foreign currency prices of the x and z commodities.[5]

We can use (18) and (19) to obtain

$$\rho S_t P_t^{x*} A_t (n_t^x)^{\rho-1} = W_t(1+\tau_t^p),$$

which, given values for the exogenous shocks and given an allocation, restricts the feasible values for $\{S_t, W_t, \tau_t^p\}$.

5. We could also allow for tariffs on the intermediate inputs. However, these tariffs are redundant instruments in this environment.

1.6 Intermediate-good Firms

Each intermediate good $i \in (0,1)$ is produced by a monopolistic competitive firm that uses labor and the two tradable commodities with the technology

$$y_{it} = \bar{\eta} Z_t x_{it}^{\eta_1} z_{it}^{\eta_2} \left(n_{it}^y\right)^{\eta_3},$$

where x_{it} and z_{it} are the demand for commodities, n_{it}^y is labor, Z_t denotes the level of productivity, $\eta_j \geq 0$ for $j = 1,2,3$, $\sum_{j=1}^{3} \eta_j = 1$, and $\bar{\eta} = \eta_1^{-\eta_1} \eta_2^{-\eta_2} \eta_3^{-\eta_3}$.

The associated nominal marginal cost function is common across intermediate-good firms and given by

$$MC_t = \frac{\left(P_t^x\right)^{\eta_1} \left(P_t^z\right)^{\eta_2} W_t^{\eta_3} (1 + \tau_t^p) \eta^{\eta_3}}{Z_t}.$$

Using (18) and (19), the nominal marginal cost can be written as $MC_t = S_t MC_t^*$, where MC_t^*, the marginal cost measured in foreign currency, is given by

$$MC_t^* = \frac{\left(P_t^{x*}\right)^{1-\eta_2} \left(P_t^{z*}\right)^{\eta_2} \left(\rho A_t \left(n_t^x\right)^{\rho-1} (1 + \tau_t^p)\right)^{\eta_3}}{Z_t}. \tag{20}$$

That is, the marginal cost in foreign currency depends on the international commodity prices, on technological factors, and on the equilibrium allocation of labor in the commodities sector.

In addition, cost minimization implies that final intermediate-good firms choose the same ratio of inputs,

$$\frac{x_{it}}{n_{it}^y} = \frac{\eta_1}{\eta_3} \rho A_t \left(n_t^x\right)^{\rho-1} (1 + \tau_t^p) \tag{21}$$

$$\frac{z_{it}}{n_{it}^y} = \frac{\eta_2}{\eta_3} \frac{P_t^{x*}}{P_t^{z*}} \rho A_t \left(n_t^x\right)^{\rho-1} (1 + \tau_t^p) \quad \text{for all } i \in (0,1),$$

where we have used (18) in the second equation.

Introducing (21) into the production function gives

$$y_{it} = n_{it}^{y} \frac{Z_t}{\eta_3} (\rho A_t \left(n_t^{x}\right)^{\rho-1} (1+\tau_t^{p}))^{1-\eta_3} \left(P_t^{x*}\right)^{\eta_2} \left(P_t^{z*}\right)^{-\eta_2}. \tag{22}$$

Each monopolist $i \in (0,1)$ faces the downward-sloping demand curve (9). We follow the standard tradition in the New Keynesian literature and impose Calvo price rigidity. Namely, in each period, intermediate-good firms are able to re-optimize nominal prices with a constant probability $0 < \alpha^p < 1$. Those that get the chance to set a new price will set it according to

$$p_t^h = \frac{\theta}{\theta - 1} E_t \sum_{j=0}^{\infty} \chi_{t,j} \frac{(P_{t+j}^{x})^{\eta_1} (P_{t+j}^{z})^{\eta_2} \left[W_{t+j}(1+\tau_{t+j}^{p})\right]^{\eta_3}}{Z_{t+j}}, \tag{23}$$

where

$$\chi_{t,j} = \frac{\alpha^{pj} Q_{t,t+j} (P_{t+j}^{h})^{\theta} Y_{t+j}^{h}}{E_t \sum_{j=0}^{\infty} \alpha^{j} Q_{t,t+j} (P_{t+j}^{h})^{\theta} Y_{t+j}^{h}}. \tag{24}$$

The price level in (10) can be written as

$$P_t^h = \left[\left(1-\alpha^p\right)\left(p_t^h\right)^{1-\theta} + \alpha^p \left(P_{t-1}^h\right)^{1-\theta}\right]^{\frac{1}{1-\theta}}. \tag{25}$$

1.7 Foreign Sector and Feasibility

We assume an isoelastic foreign demand for the home final good of the form

$$C_t^{h*} = (K_t^{*})^{\mu} (P_t^{h*})^{-\mu}, \tag{26}$$

where $\gamma > 1$, P_t^{h*} is the foreign currency price of the home final good, and K_t^* is a stochastic process that transforms units of foreign currency into domestic consumption goods.[6]

6. We allow for the final goods to be traded, so a particular case of our model (the one with $A = 0$ and $\eta_1 = \eta_2 = 0$) without commodities is the one typically analyzed in the small open economy New Keynesian literature.

The government imposes a tax $(1+\tau_t^h)$ on final goods exported to the rest of the world and a tariff $(1+\tau_t^f)$ to final-good imports. The law of one price on domestic and foreign final goods then requires

$$\begin{aligned} P_t^h(1+\tau_t^h) &= S_t P_t^{h*} \\ P_t^f &= S_t P_t^{f*}(1+\tau_t^f), \end{aligned} \tag{27}$$

where P_t^{f*} is the foreign currency price of the foreign final good.

Net exports measured in foreign currency are given by

$$m_t^* = P_t^{h*}C_t^{h*} - P_t^{f*}C_t^f + P_t^{x*}\left[X_t - \int_0^1 x_{it}di\right] - P_t^{z*}\int_0^1 z_{it}di. \tag{28}$$

Thus, the net foreign assets of the country, denoted by $B_{t,t+1}^*$, evolve according to

$$B_{t-1,t}^* + m_t^* = E_t B_{t,t+1}^* Q_{t,t+1}^*. \tag{29}$$

Solving this equation from period 0 forward, and assuming zero initial foreign assets, gives the economy foreign sector feasibility constraint measured in foreign currency at time 0:

$$E_0 \sum_{t=0}^{\infty} Q_{0,t}^* m_t^* = 0. \tag{30}$$

In addition, market clearing in domestic final goods requires

$$Y_t^h = C_t^h + C_t^{h*} + G_t^h, \tag{31}$$

and labor market feasibility is given by

$$N_t = \int_0^1 n_{it}^y di + n_t^x. \tag{32}$$

1.8 Fiscal and Monetary Policies

We now show how a flexible exchange rate system, coupled with a flexible payroll tax, can jointly stabilize domestic prices and wages.

First, using the law of one price for the commodities,

$$P_t^x = S_t P_t^{x*}$$
$$P_t^z = S_t P_t^{z*},$$

we can write the cost minimization condition in the commodity sector (19) and the marginal cost for the intermediate-good firm as

$$\rho S_t P_t^{x*} A_t \left(n_t^x\right)^{\rho-1} = W_t (1+\tau_t^p)$$
$$MC_t = S_t \frac{\left(P_t^{x*}\right)^{1-\eta_2} \left(P_t^{z*}\right)^{\eta_2} (\rho A_t \left(n_t^x\right)^{\rho-1})^{\eta_3}}{Z_t}.$$

Because domestic prices are proportional to marginal costs, they will be constant once marginal costs are constant, which implies

$$MC = S_t \frac{\left(P_t^{x*}\right)^{1-\eta_2} \left(P_t^{z*}\right)^{\eta_2} (\rho A_t \left(n_t^x\right)^{\rho-1})^{\eta_3}}{Z_t},$$

so the nominal exchange rate moves to absorb productivity and commodity price shocks. Note that the negative correlation between the nominal exchange rate and the prices of the exportable commodity, presented in figure 1, follows as a direct result of price stability. We can then use this implied equilibrium relationship to solve for the nominal exchange rate and use it on the cost minimization condition of the commodity sector to obtain

$$\rho^{1-\eta_3} MC \left(\frac{P_t^{x*}}{P_t^{z*}}\right)^{\eta_2} Z_t A_t \left(n_t^x\right)^{(\rho-1)(1-\eta_3)} = W_t (1+\tau_t^p).$$

So, to stabilize wages, the payroll tax must move according to

$$(1+\tau_t^p) = \frac{1}{W} \rho^{1-\eta_3} MC \left(\frac{P_t^{x*}}{P_t^{z*}}\right)^{\eta_2} Z_t A_t \left(n_t^x\right)^{(\rho-1)(1-\eta_3)}.$$

Clearly, to the extent that fiscal policy cannot be jointly used with monetary policy, there is a trade-off between eliminating the distortion in prices and eliminating the distortion in wages. The numerical analysis of that question is addressed in the next section.

2. Calibration and Numerical Analysis of Monetary Policy

Before we start, clarifying one issue is important. So far, we have been silent with respect to the implementation of particular equilibria through policy. Since the work of Sargent and Wallace (1975), a vast literature has developed that analyzed the problem of unique implementation using particular policy targets. To briefly summarize that literature, in general, when central banks use money or the interest rate as the policy instrument, typically multiple equilibria are consistent with a single policy rule. On the contrary, if the exchange rate is pegged, uniqueness typically arises. Multiple solutions have been offered. The most popular, in the context of interest rate rules, is to only consider a bounded equilibrium and to assume rules that satisfy the Taylor principle. We fully abstain from the issue of implementation and simply assume that policy can successfully target a nominal variable (or a combination of two of them), such as prices of domestic goods, P_t^h the nominal wage, W_t, or the nominal exchange rate, S_t.

We consider the following utility function:

$$U(C,L)=\frac{C^{1-\gamma}}{1-\gamma}-\varsigma\frac{\left(\bar{L}-L\right)^{1+\psi}}{1+\psi},$$

where γ, ς, and ψ are positive parameters. The subutility function between domestic and foreign final goods is of the constant elasticity of substitution form,

$$C=H\left(C^h,C^f\right)=\left[(1-\varpi)^{1/\phi}\left(C^h\right)^{\frac{\phi-1}{\phi}}+\varpi^{1/\phi}\left(C^f\right)^{\frac{\phi-1}{\phi}}\right],$$

where φ is the elasticity of substitution between home and foreign goods, and ϖ is the share parameter associated with the foreign good. As is common in the literature, ϖ can be interpreted as the degree of openness of the economy.

Each time period in the model represents one quarter. Most of the parameters that we use for calibrating the model are standard and reported in table A1 in the appendix. We choose β so that the discount factor is 0.95 on an annualized basis and set a standard risk aversion parameter of $\gamma = 2$. The parameter ψ is the reciprocal of the Frisch elasticity of labor supply. We set $\psi = 1$, which lies between the micro and macro estimates of this elasticity (Chetty and others, 2011). Furthermore, this number is standard in the literature (see, for example, Catão and Chang, 2013). The parameters ζ and $\bar{L}$ define units of measurement and are not important for the quantitative results of the paper; we set $\zeta = 1$ and choose $\bar{L}$ so that in the steady state, workers allocate one-third of their total available time to market activities.

The parameter ϕ measures the Armington elasticity of substitution between home and foreign final goods. Estimates of the Armington elasticity using microeconomic data tend to be much higher than those based on macroeconomic data. We set $\phi = 1.5$ which is a common number used in the international business cycles literature (Backus, Kehoe, and Kydland, 1994). This value is also consistent with the macro estimates of the Armington elasticity reported in Feenstra and others (2014). We set the share parameter at $\varpi = 0.2$. This value is consistent with the observed home bias in consumption (Obstfeld and Rogoff, 2001) and is similar to that used in Catão and Chang (2013).[7]

The production function of the home intermediates is characterized by the three share parameters, η_1, η_2, and η_3 and by the level of productivity Z_t. We set the share parameters at $\eta_1 = 0.1$, $\eta_2 = 0.4$, and $\eta_3 = 0.5$. A labor share of about 50% is a standard parameterization. We set $\eta_1 = 0.1$ to capture the observation that the home commodity is not used intensively in the production of home goods. The share of imported intermediate inputs $\eta_2 = 0.4$ is not intended to capture the import of a single commodity, such as oil in the case of Chile, but of a large array of intermediate inputs and commodities used in the production of goods in the small open economy. We normalize the long-run level of productivity to $\bar{Z} = 1$.

Regarding the technology to produce the home commodity, we set a small labor share of $\rho = 0.1$, to capture that the production of commodities is either land or capital intensive, and set the steady-

7. Galí and Monacelli (2005) and De Paoli (2009) use $\varpi = 0.4$. Quantitative results are similar if we set ϖ to 0.4 instead of 0.2.

state level of technology, $\bar{A}$, at 0.2. With this calibration, the steady-state share of labor in the commodities sector is about 0.15. This is the target number used in Hevia, Neumeyer, and Nicolini (2013) using a broad definition of the commodity sector and an input-output matrix for Chile (see the discussion in that paper for more details).

For the parameterization of the foreign demand of the home final good in equation (26), we assume an elasticity of $\mu = 1.5$ and set K^* to a constant value of 0.1. The foreign demand does not play an important role in the simulations that we discuss later and, thus, these parameters are almost irrelevant.

The parameters α^p and α^w determine the average number of periods between price and wage adjustments. We follow Christiano, Eichenbaum, and Rebelo (2011) and set $\alpha^w = 0.85$. The parameter α^p is set at 0.5, which implies an expected price duration of two quarters. This is consistent with the evidence in Klenow and Malin (2010).[8] Finally, as is common in the literature, we consider an efficient steady state. This amounts to imposing a constant labor subsidy that eliminates the monopolistic distortions, and a constant tariff that extracts the monopolistic rents in the trade of the home final good. This follows because the small open economy faces a downward-sloping foreign demand for the final good.

We now consider the calibration of the stochastic processes for the different shocks. We assume that both productivity parameters, A_t and Z_t, follow autoregressive processes of the form

$$\log\left(A_t / \bar{A}\right) = \rho_A \log\left(A_{t-1} / \bar{A}\right) + \varepsilon_{At}$$

$$\log\left(Z_t / \bar{Z}\right) = \rho_Z \log\left(Z_{t-1} / \bar{Z}\right) + \varepsilon_{Zt},$$

where ε_{At} and ε_{Zt} are independent mean zero shocks with a standard deviation of σ_A and σ_Z, respectively. We values of these parameters are set at $\rho_A = \rho_Z = 0.95$, and $\sigma_A = \sigma_Z = 0.013$. These are the standard values used in the literature of business cycles in small open economies (Neumeyer and Perri, 2005).

It remains to calibrate the price processes. Commodity prices tend to be correlated among them. One possibility is to calibrate the price processes by running a vector autoregression (VAR) with

8.The value used in Christiano, Eichenbaum, and Rebelo (2011) is $\alpha^p = 0.85$ As we show, the results change very little if we use that value.

the exportable and importable commodity prices. The problem with this approach, however, is that it is not obvious how to identify the importable commodity. Indeed, while exportable commodities are easily identified, importable commodities are not concentrated in a few goods. We thus proceed as follows. We calibrate the price process of the home commodity by running a first-order autoregression using HP-filtered world prices of copper deflated by the U.S. consumer price index over the period 2000-2014:

$$\log\left(P_t^{x*} / \bar{P}^{x*}\right) = \rho_x \log\left(P_{t-1}^{x*} / \bar{P}^{x*}\right) + \varepsilon_{xt},$$

where ε_{xt}:$N(0, \sigma_x{}^2)$. The estimation delivers $\rho_x = 0.72$ and $\sigma_x = 0.016$. We next impose a VAR structure of the form

$$\begin{bmatrix} \log\left(P_t^{x*} / \bar{P}^{x*}\right) \\ \log\left(P_t^{z*} / \bar{P}^{z*}\right) \end{bmatrix} = \begin{bmatrix} \rho_x & \zeta \\ \zeta & \rho_z \end{bmatrix} \begin{bmatrix} \log\left(P_t^{x*} / \bar{P}^{x*}\right) \\ \log\left(P_{t-1}^{z*} / \bar{P}^{z*}\right) \end{bmatrix} + \begin{bmatrix} \varepsilon_{xt} \\ \varepsilon_{zt} \end{bmatrix},$$

where $\rho_z = \rho_x$, so that the importable commodity is as persistent as the home commodity, but $\sigma_z = \sigma_x /2$, reflecting that shocks to a bundle of commodities will be less volatile than shocks to a single commodity. Finally, we set the free parameter ζ so that the model is able to replicate the correlation between the home commodity price and the nominal exchange observed in Chile over the sample period discussed earlier. Setting $\zeta = 0.18$ implies a correlation between the nominal exchange rate and the commodity price of -0.63 under a policy of price stability. As a reference, if we set $\zeta = 0$, the latter correlation drops to -0.20.

In what follows, and given the policy rule we now discuss, we simulate the model by shutting down all shocks except the commodity price P_t^{x*}. To approximate the solution of the model, we use the quadratic perturbation method around the steady state developed by Schmitt-Grohé and Uribe (2004).

2.1 The Policy Rule

In order to capture our interpretation of the recent Chilean experience, one could consider a regime in which price stability is the main stated objective, but with some interventions to reduce the volatility of the nominal exchange rate (similar to the interventions in 2008 and 2011).

Note that from the solution for the marginal cost, we can write

$$MC_t = S_t MC_t^*,$$

where

$$MC_t^* = \frac{\left(P_t^{x*}\right)^{1-\eta_2}\left(P_t^{z*}\right)^{\eta_2}(\rho A_t\left(n_t^x\right)^{\rho-1})^{\eta_3}}{Z_t}.$$

Clearly, MC_t^*—the marginal cost in foreign currency—is a function of the underlying shocks. As we mentioned earlier, full price stability implies constant marginal costs in local currency, so

$$S_t = \frac{MC}{MC_t^*}.$$

We then allow for a general rule in which the deviations of the log of the nominal exchange rate adjust a fraction of the deviations in the log of the marginal costs in foreign currency, or

$$d\ln S_t = -\nu d\ln MC_t^*. \tag{33}$$

Thus, when $\nu = 1$, we have pure inflation targeting, when $\nu = 0$ we have a currency peg, and by letting $\nu \in (0,1)$ we can have all intermediate cases: the lower the value for ν, the lower the volatility of the nominal exchange rate and the larger the volatility of domestic inflation. With the policy rule so specified, the model can be solved numerically.

The policy trade-off implied by the previous rule may reflect the one implied by dirty floating regimes, in which some intervention in foreign exchange markets is allowed. According to the theory, dampening the movements in the nominal exchange rate implies increasing the volatility of marginal costs and therefore the volatility of the price level. However, what seems a more natural trade-off, given the nature of the two distortions, is stabilizing prices versus stabilizing nominal wages. In the theory section, we showed how a payroll tax can be used together with the nominal exchange rate to stabilize both prices and wages. Once the payroll tax cannot be used, the nominal exchange rate can be used to stabilize either of them but not both. Thus, let

$$w_t^h \equiv \frac{W_t}{P_t^h}.$$

Then, we can define a policy where

$$d\ln W_t = \nu d\ln w_t^h \tag{34}$$

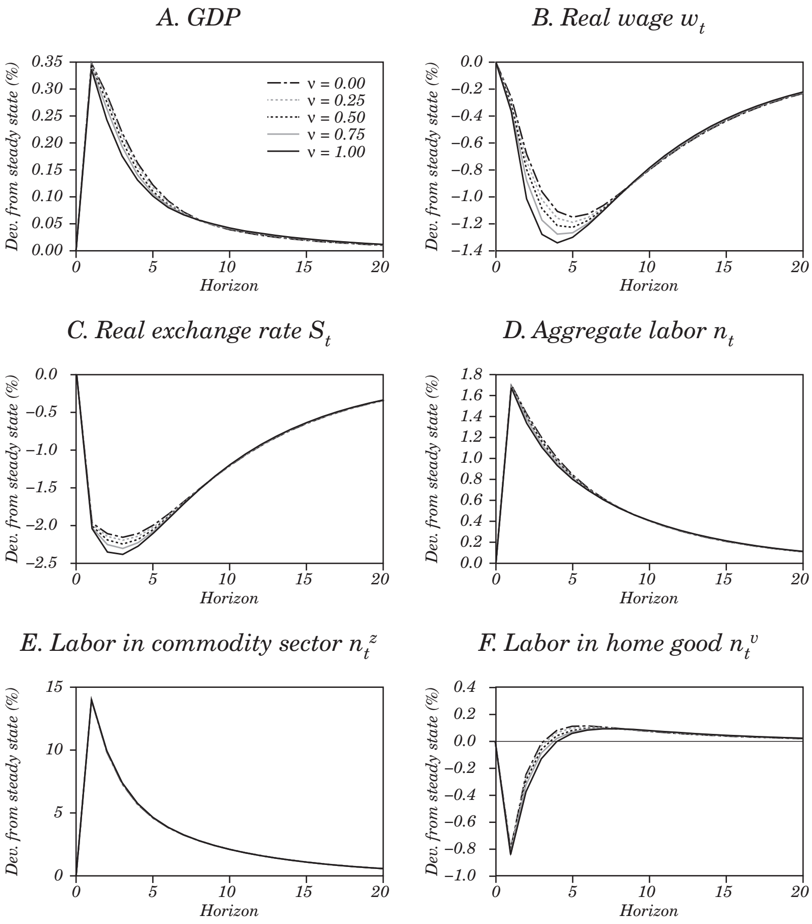
Thus, if $\nu = 0$, nominal wages are fully stabilized, whereas $\nu = 1$ implies full price stability. The optimal policy is given by the value of ν that maximizes welfare, given the process for the exogenous shock—the price of the exportable commodity in this case. The earlier discussion suggests that the optimal policy will indeed have $\nu \in (0,1)$. This conjecture will be verified numerically later. In the appendix we discuss how we perform the welfare comparisons across the different rules.

In view of the preceding discussion, we first consider the case in which the policy trades off price stability with nominal wage stability, which is the trade-off that will deliver the optimal policy. Then, we discuss how the rule that trades off price stability with nominal exchange rate stability behaves, particularly compared with the optimal policy. We believe exploring this a priori suboptimal rule is interesting for two reasons. First, it is the one that best approximates, in our view, the dirty floating policy debate, as our discussion of the recent Chilean experience suggests. Second, while stabilizing wages in this simple model is trivial, it is much less so in a real economy with so many sectors and so many different types of labor. It does seem to us that focusing the policy debate on a single, extremely visible price is much more attractive.

2.2 The Price/Wage Trade-off

We will first discuss the results using the general policy rule (34). To begin, we present simulations for the model with the baseline calibration, except that we set the rigidity in wages to be zero. The advantage of this case is that when prices are fully stabilized ($\nu = 1$), we obtain the optimal allocation, which we use as a benchmark.

Figure 2. Economy with No Wage Rigidities
Wage rule: impulse responses to commodity price shock ($\alpha^p = 0.5$, $\alpha^w = 0$, $\varpi = 0.2$)



Source: Authors' elaboration.

In figure 2 we show the impulse responses for output, the real wage, the real exchange rate, and labor following a one-standard-deviation positive shock to the price of the exportable, for several values of v. Throughout the paper, output (GDP) is computed as the sum of the value added evaluated at the steady-state prices.

As expected, at the efficient allocation ($\nu = 1$), there is a redistribution of labor toward the exportable sector (labor increases by 14% in the commodity sector and drops by 0.8% in the home good sector). Consumption of the home good becomes very expensive, so it goes down, increasing total labor supply. This lowers the real wage and firms hire more labor overall, so GDP goes up by almost 0.35%. Since prices are stable, as the nominal exchange rate goes down, so does the real exchange rate. When nominal wages are stabilized ($\nu = 0$), the same equilibria would obtain by increases in the price level, if prices were fully flexible. But they are not, so the drop in the real wage is lower in this case. Because the price of final goods does not go up as much, demand for the final consumption good is relatively higher, so the drop in labor at the home good sector is smaller and the increase in GDP is higher (although the effect is small). Because the price level does not increase enough, the real exchange rate does not drop very much.

An interesting feature that arises from figure 2 is that the effect of the policy regime (from a fixed exchange rate to a fully floating one in which prices are stabilized) does not have a very big impact on the transmission mechanism of a commodity price shock, even with a relatively high value for the Calvo parameter ($\alpha^p = 0.5$). The larger differences are in the movements of the real wage and the real exchange rate, but not on the real allocation, which is what matters for welfare.

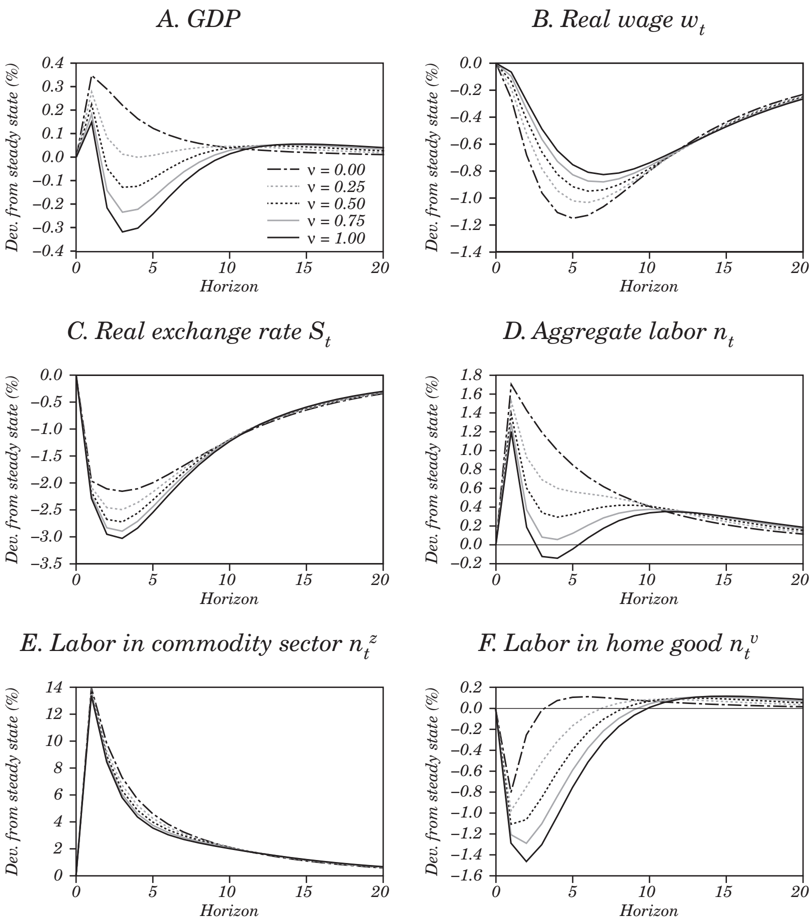
The effect of the policy regime is much more dramatic for the benchmark calibration (with $\alpha^w = 0.85$), in which the optimal allocation cannot be implemented because of the presence of both price and wage rigidity. We show the relevant impulse responses in figure 3. When policy fully stabilizes nominal wages, the behavior of labor and output is relatively similar to the efficient allocation: total output goes up by about 0.35% total labor goes up by about 1.7% and the labor reallocation is very similar. Note, however, that fully stabilizing nominal prices delivers a very different outcome: GDP *falls* by 0.3% and total labor by 0.2%.

We also solved the model by setting the share of foreign goods to 0.01 and 0.4 (the benchmark is 0.2) and the degree of price stickiness to 0.25 and 0.85 (the benchmark is 0.5). The results, presented in the appendix, are roughly similar.

Finally, we switched the degree of rigidity between prices and wages, relative to the benchmark. That is, we increased the degree of price rigidity to $\alpha^p = 0.85$ and reduced the degree of wage rigidity to $\alpha^w = 0.5$. Results are depicted in figure 4. Now, the choice of the policy regime is much less relevant than in the benchmark case.

Figure 3. Baseline Economy

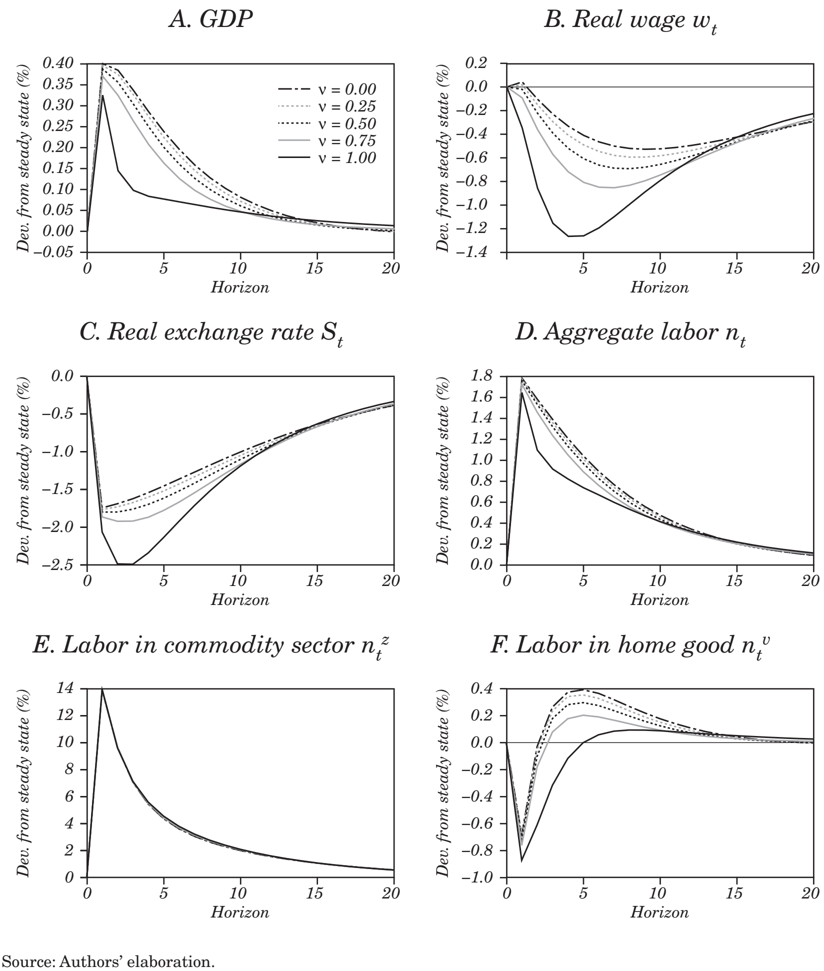
Wage rule: impulse responses to commodity price shock (baseline calibration)



Source: Authors' elaboration.

As can be seen, full price stability delivers outcomes that are very similar to the optimal allocation: an increase in output a bit below 0.35%, an increase in total labor close to 1.6%, and a very similar labor reallocation. This is natural, given that it is in the setting of prices where we have the largest friction. However, notice that

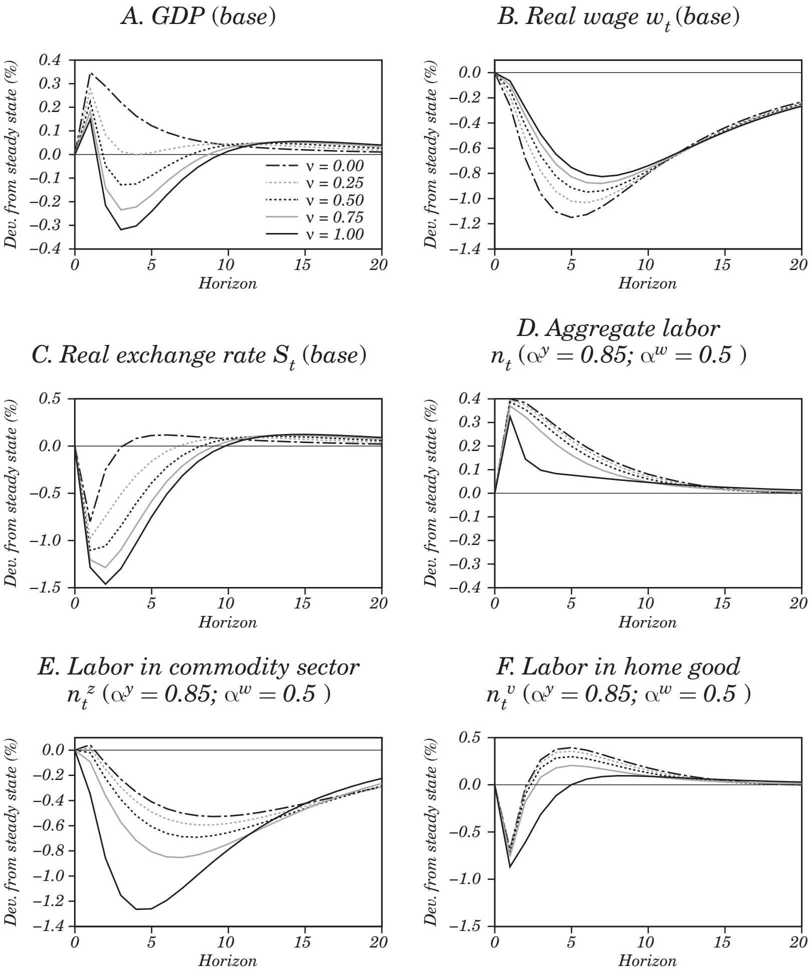
Figure 4. Economy with Higher Price and Lower Wage Rigidity
Wage rule: impulse responses to commodity price shock ($\alpha^p = 0.85$, $\alpha^w = 0.5$, $\varpi = 0.2$)



Source: Authors' elaboration.

the effects of a regime that fully stabilizes nominal wages do not affect the allocation very much: it generates an inefficiently larger expansion, but it is small nonetheless (0.4% instead of 0.35%). For a better visual comparison, in figure 5 we plot the impulse responses of output, the real wage, and labor in the final-good sector for the

Figure 5. Comparison of Different Degrees of Price and Wage Rigidities under the Wage Rule



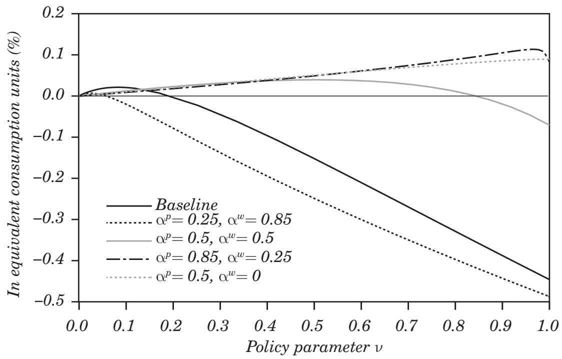
Source: Authors' elaboration.

benchmark case ($\alpha^p = 0.5$ and $\alpha^w = 0.85$) and for this last case analyzed, in which the degrees of rigidity between prices and wages have been switched ($\alpha^p = 0.85$ and $\alpha^w = 0.5$) using the same scales. The difference is remarkable.

The welfare analysis is in line with the previous discussion. We show in figure 6 the welfare gain, in units of lifetime consumption, of alternative values of $\nu \in [0,1]$, relative to the regime $\nu = 0$, which is equivalent to full wage stability. Naturally, for the case in which $\alpha^w = 0$, full price stability is optimal, which is reflected in the fact that the line with circles is always increasing. Note, however, that the opposite policy, the one that fully stabilizes wages ($\nu = 0$), entails a cost of only 0.1% of lifetime consumption. On the other hand, for our baseline parameterization, the optimal policy is slightly below $\nu = 0.1$, which amounts to almost full nominal wage stability. Notice that in this case, which exhibits a high degree of wage rigidity, the welfare cost of full price stability is over 0.45% of lifetime consumption, almost five times more. This is in line with our previous discussion: when there is a high degree of wage rigidity and some degree of price rigidity, the choice of the policy regime becomes more relevant. Notice that lowering the degree of price rigidity to $\alpha^p = 0.25$, makes the optimal policy be even closer to full nominal wage stability. Still, the effect of the policy regime (the value for ν) is very relevant. Finally, when the wage rigidity is lowered to $\alpha^w = 0.5$, the optimal regime becomes close to $\nu = 0.5$, and the effect of full price stability becomes lower than 0.1% of lifetime consumption.

Overall, our results imply that the policy regime is much more relevant when there is a substantial degree of wage rigidity, coupled with some rigidity in the setting of prices. On the other hand, if there

Figure 6. Welfare Comparisons of Different Wage Rules
Wage rule: welfare gain over nominal wage stability ($\nu = 0$)



Source: Authors' elaboration.

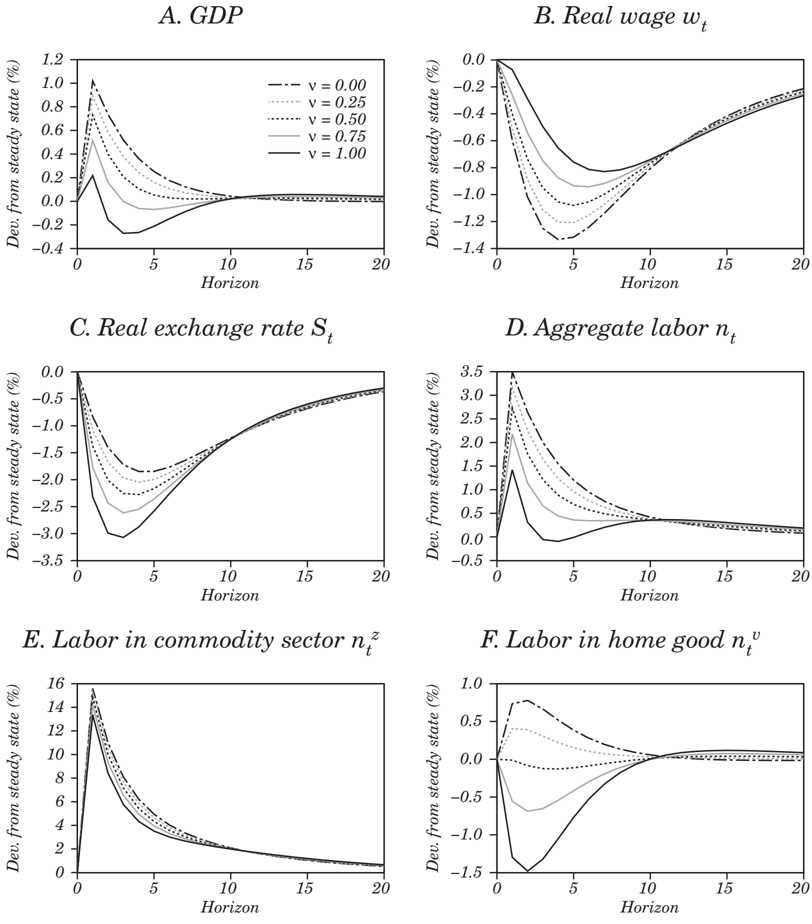
is a high degree of price stickiness, coupled with some degree of wage rigidity, the choice of the policy regime is relatively less important. The reason lies behind the logic of the mechanism at the optimal allocation discussed earlier: the drop in the real wage, which increases total labor and generates an expansion. When prices are stabilized, the nominal wage must fall. If nominal wages are very rigid, real wages do not fall and firms do not hire much labor, which creates the usual recession observed in models with wage rigidity. On the other hand, when prices are very rigid but wages are not, if wages are stabilized, the adjustment must be realized by an increase in prices. As before, if prices are very rigid, they do not increase and the real wage does not fall, creating a recession as before. But contrary to the previous case, since prices do not increase, consumption is relatively cheaper, and demand goes up. This demand effect, also common in models with price rigidity, partially compensates for the lack of adjustment in the real wage. Thus, the more rigid the prices, the lower the adjustment in the real wage, but the larger the demand effect. Therefore, the price rigidity is less relevant than the wage rigidity.

2.3 The Price/Exchange Rate Trade-off

Admittedly, the notion of nominal wage stability is much simpler in the model than in actual economies. Thus, we now consider a restricted optimal policy problem in which we choose the best value for v but use the rule (33) that trades off price versus nominal exchange rate stability. Figure 7 shows impulse responses following a one-standard-deviation increase in the price of the exportable commodity for the baseline calibration. In figure 8, we compare the impulse responses of the benchmark case for output, the real wage, and labor in the final-good sector with the case in which we reverse the degree of rigidity ($\alpha^p = 0.85$ y $\alpha^w = 0.5$). As before, the policy regime matters more when wages are more rigid than prices.

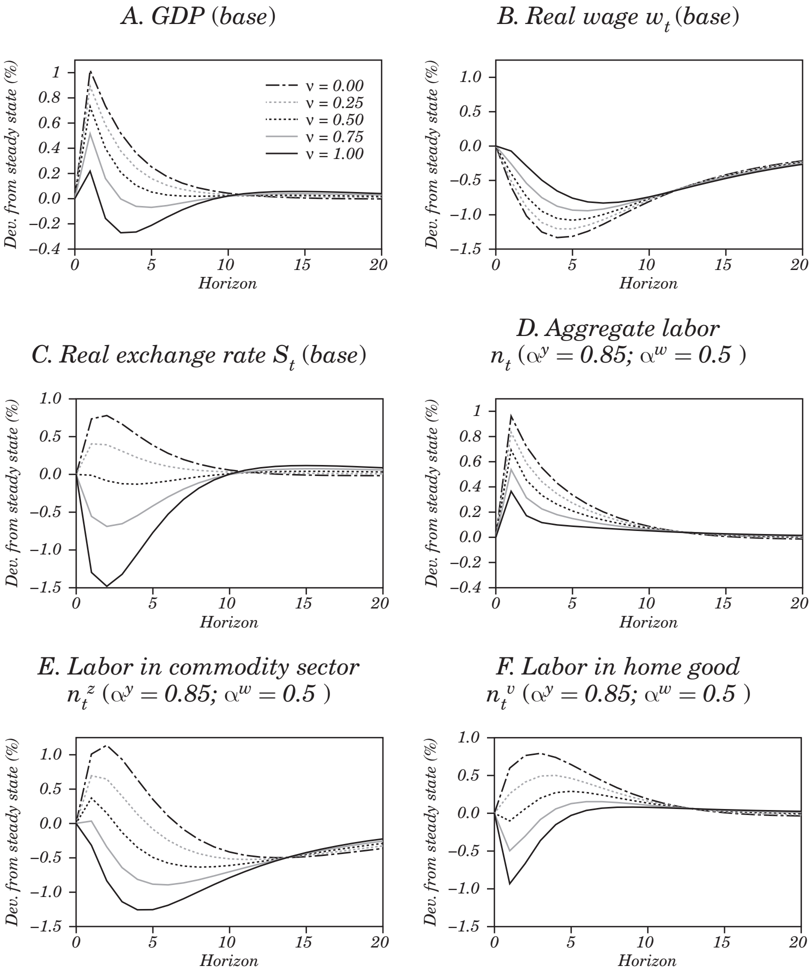
In figure 9, we show the welfare effect, in units of lifetime consumption, of alternative values of $\nu \in (0,1)$, relative to the regime $\nu = 0$, which is equivalent to full exchange rate stability. Notice that for the baseline calibration, the optimal value for ν is close to 0.5 which means a substantial degree of dirty floating. Figure 9 reveals three interesting features. The first is that, as before, the welfare cost of implementing the wrong regime is higher when the friction is concentrated in wages rather than prices (although the difference is not as big as before).

Figure 7. Baseline Economy under the Exchange Rate Rule
Wage rule: impulse responses to commodity price shock (baseline calibration)



Source: Authors' elaboration.

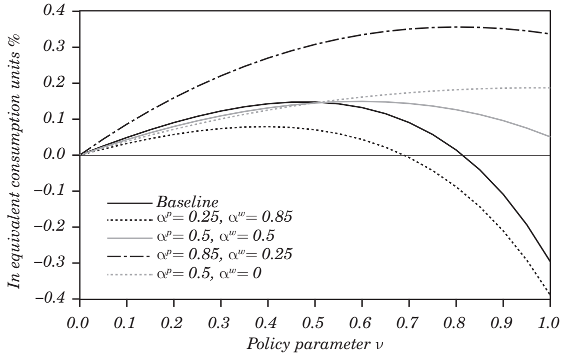
Figure 8. Comparison of Different Degrees of Price and Wage Rigidities under the Exchange Rate Rule



Source: Authors' elaboration.

Figure 9. Welfare Comparisons of Different Exchange Rate Rules

Exchange rate rule: welfare gain over fixed exchange rate ($\nu = 0$)



Source: Authors' elaboration.

The second is that the best policy for the baseline calibration is about 0.45% percent of lifetime consumption, relative to price stability. This is very interesting, since it is very similar to the welfare gain of using the optimal policy, as described in the previous subsection, again relative to full price stability. This means that welfare at the best dirty floating regime is very close to welfare at the optimal policy. To the extent that a policy aimed at stabilizing nominal wages is hard to implement in practice, this result suggests that the best dirty floating regime may be almost as good in terms of implementing good allocations.

The third feature is unrelated to the discussion so far but is still very interesting. A recent paper (Schmitt-Grohé and Uribe, 2012) argues that the cost of a fixed exchange rate regime can be very high relative to a full inflation-targeting one. Our results provide an unintended example in which the result is exactly the opposite: when the wage rigidity is larger than the price rigidity, a policy that fully stabilizes prices is worse than one that fixes the nominal exchange rate. In our case, the difference can be up to 0.4% of lifetime consumption. Exploring the robustness of this result and using the different experiences of Chile (which targets low inflation) and Ecuador (which dollarizes) in the last 15 years is left for further research.

3. Conclusions

From a theoretical viewpoint, the presence of price and wage rigidity implies that full inflation targeting is not the optimal policy. In commodity export countries, which are subject to very large changes in commodity prices that generate very large swings in the real exchange rate, this could be a serious concern. Thus, the question of real exchange rate stabilization has become a central issue in policy debates.

In this paper, we studied a small open economy model that is able to reproduce the large swings in nominal and real exchange rates and which exhibits price and wage frictions. We first showed that if fiscal policy instruments (payroll taxes, for instance) can be made as flexible as monetary policy, then price stability is the optimal policy. But if fiscal instruments cannot, a trade-off between stabilizing domestic prices or nominal wages is involved. We showed that this trade-off is particularly important for policy design when there is a high degree of nominal wages (Calvo parameter higher than 0.8) and some degree of price rigidity (Calvo parameter higher than 0.25). In this case, the wrong regime can cost as much as 0.45% of lifetime consumption, relative to the optimal rule. On the other hand, if the rigidity in prices is the most severe, the wrong regime can cost at most 0.1% of lifetime consumption. In our benchmark calibration, based on models for the United States, wage rigidity is indeed the one that is the most severe. To the extent that this is a reasonable calibration for small open economies, this means that flexible inflation-targeting regimes that let domestic prices move somewhat may be better than pure price stabilization regimes.

Although implementing a rule that trades off price versus wage stability is very simple in the model, given the heterogeneity of wages in actual economies, the discussion in terms of inflation and exchange rate stabilization seems much more useful. Thus, we also considered such a rule and showed that it can approximate the optimal policy remarkably well. Our paper therefore suggests that strong wage rigidity, coupled with some price rigidity, can justify a dirty floating regime, where policy partially stabilizes the nominal (and real) exchange rate.

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Appendix

Welfare comparisons

This appendix elaborates on the welfare comparisons discussed in the text. Suppose that there is a baseline policy, denoted by b, associated with an equilibrium allocation of consumption, aggregate labor, and labor distortions $\left\{C_t^b, N_t^b, \Delta_{t+j}^{w,b}\right\}$. The proposed policy delivers the level welfare V_t^b at time t, given the state of the economy, which we denote by $\mathbf{x}_t$,

$$V_t^b = E_t \sum_{j=0}^{\infty} U\left(C_{t+j}^b, \Delta_{t+j}^{w,b} N_{t+j}^b\right) \equiv V_t^{C,b} - V_t^{N,b},$$

where

$$V_t^{C,b} = E_t\left[\sum_{j=0}^{\infty} \beta^j \frac{\left(C_{t+j}^b\right)^{1-\gamma}}{1-\gamma}\right]$$

$$V_t^{N,b} = E_t\left[\sum_{j=0}^{\infty} \beta^j \varsigma \frac{\left(\Delta_{t+j}^{w,b} N_{t+j}^b\right)^{1+\psi}}{1+\psi}\right].$$

Now consider an alternative policy, a, with associated allocation $\left\{C_t^a, N_t^a, \Delta_{t+j}^{w,a}\right\}$ and utility level

$$V_t^a = V_t^{C,a} - V_t^{N,a}.$$

Our objective is to measure the welfare gain of policy a relative to policy b in terms of consumption units. For this, we ask by what fraction the consumption path associated with policy b should be increased (or decreased) forever to achieve the same level of utility as under the alternative policy a. In particular, we find the value λ_t that satisfies

$$V_t^a = E_t \sum_{j=0}^{\infty} U\left((1+\lambda_t) C_{t+j}^b, \Delta_{t+j}^{w,b} N_{t+j}^b\right) = \left(1+\lambda_t\right)^{1-\gamma} V_t^{C,b} - V_t^{N,b}.$$

Solving for λ_t gives

$$\lambda_t = \left(\frac{V_t^{C,a} - V_t^{N,a} + V_t^{N,b}}{V_t^{C,b}} \right)^{\frac{1}{1-\gamma}} - 1.$$

The recursive structure of the model implies that the values $V_t^{C,j}$ and $V_t^{N,j}$ for $j = a, b$ are time-invariant functions of the state $\mathbf{x}_t$,

$$V_t^{C,j} = V_t^{C,j}(\mathbf{x}_t)$$

$$V_t^{N,j} = V_t^{N,j}(\mathbf{x}_t),$$

which, in turn, implies that the welfare gain is also a time-invariant function of $\mathbf{x}_t$, $\lambda_t = \lambda_t(\mathbf{x}_t)$. We thus can write

$$\lambda(\mathbf{x}_t) = \left(\frac{V^{C,a}(\mathbf{x}_t) - V^{N,a}(\mathbf{x}_t) + V^{N,b}(\mathbf{x}_t)}{V^{C,b}(\mathbf{x}_t)} \right)^{\frac{1}{1-\gamma}} - 1.$$

We report the average value of λ_t $(\mathbf{x}_t)$ under the time-invariant distribution of state $\mathbf{x}_t$. This average value is obtained by computing a simulation of 1,200 periods in the model starting from the steady-state condition, dropping the first 200 simulated values, and then computing the average along the simulated sample path. For the welfare comparisons, it is crucial to perform an approximation of the policy functions of degree higher than one (second order in our case); otherwise, all policies deliver the same level of utility.

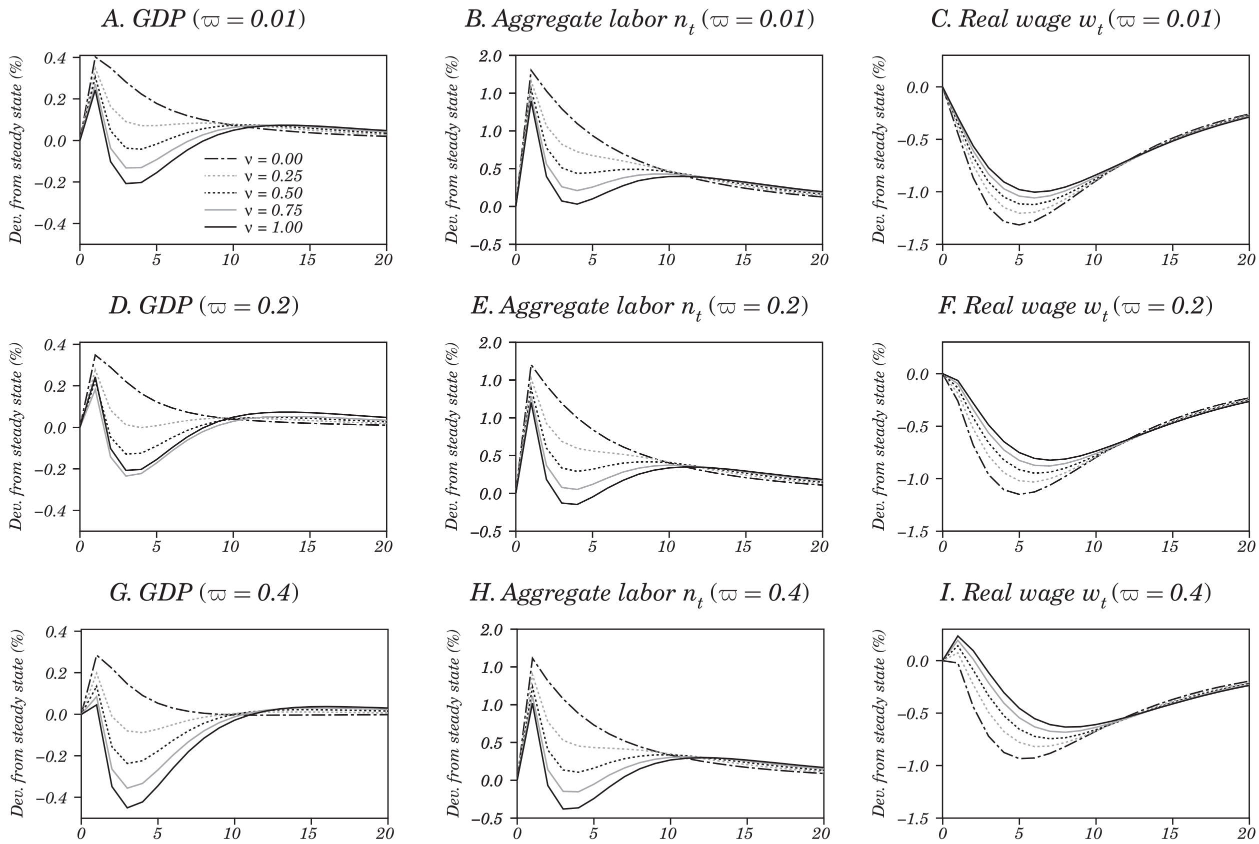
Table A1. Baseline parameters

Parameter	*Description*	*Value*
β	Discount factor (utility, annualized)	0.950
γ	Risk aversion (utility)	2.000
ς	Parameter leisure (utility)	1.000
ψ	Exponent leisure (utility)	1.000
ϕ	Ela. of subst. *h* and *f* (utility)	1.500
ϖ	Share foreign good (utility)	0.200
ρ	Share of labor in commodities technology	0.100
η_1	Share of home commodity in intermediates	0.100
$\bar{A}$	Steady-state productivity in intermediates	0.200
η_2	Share of foreign commodity in intermediates	0.400
η_3	Share of labor in intermediates	0.500
$\bar{Z}$	Steady-state productivity in intermediates	1.000
α^p	Calvo parameter home intermediates	0.500
α^w	Calvo parameter wages	0.850
θ^p	Ela. of subst. intermediate varieties	6.000
θ^w	Ela. of subst. labor varieties	6.000
μ	Elasticity foreign demand home goods	1.500
K^*	Parameter foreign demand home goods	0.100
ρ_x	Coefficient on lagged value home commodity price	0.720
σ_x	Standard deviation shock to home commodity price	0.105
ρ_z	Coefficient on lagged value foreign commodity price	0.720
σ_z	Standard deviation shock to foreign commodity price	0.050
ζ	Cross-relation home and foreign commodity in VAR	0.180
ν	Policy parameter	Varies

Source: Authors' elaboration.

The figure A1 displays the impulse responses of GDP, aggregate labor, and the real wage under different values of the share of foreign goods in the home composite good ϖ. The figures in the first row represent an economy with a very low share of foreign final goods in consumption ($\varpi = 0.01$), the figures in the second row are those of the baseline economy ($\varpi = 0.2$), and the figures in the third row represent an economy with a higher share of foreign final goods in consumption ($\varpi = 0.4$).

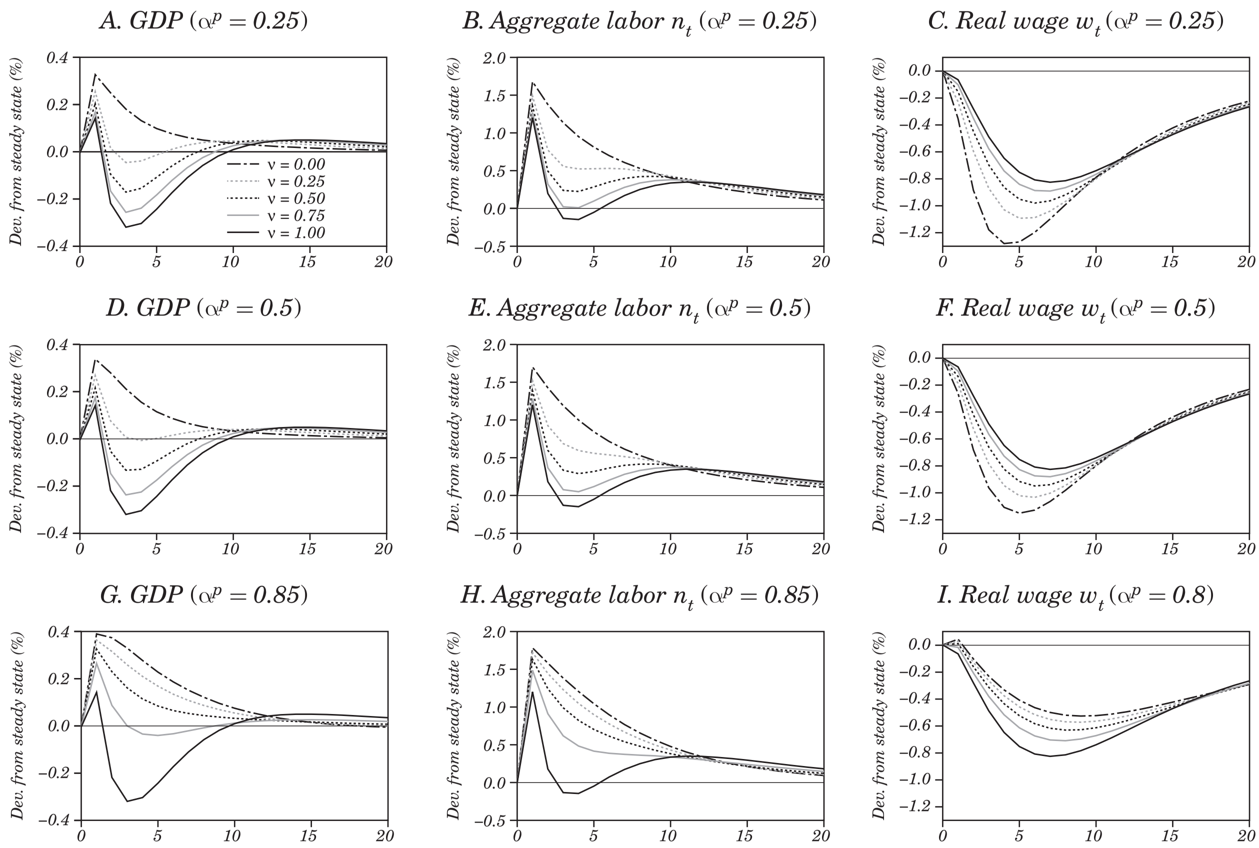
Figure A1. Wage Rule: Impulse Responses to Commodity Price Shock for Different Values of Foreign Good Share ϖ



Source: Authors' elaboration.

Figure A2 displays the impulse responses of GDP, aggregate labor, and the real wage under different values of the share of price stickiness parameter α^p. The figures in the first row represent an economy with a relatively low degree of price stickiness ($\alpha^p = 0.25$), the figures in the second row are those of the baseline economy ($\alpha^p = 0.5$), and the figures in the third row represent an economy with a higher degree of price stickiness ($\alpha^p = 0.85$).

Figure A2. Wage Rule: Impulse Responses to Commodity Price Shock for Different Values of Price Stickiness α^p



Source: Authors' elaboration.

Liquidity and Foreign Asset Management Challenges for Latin American Countries

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The Global Financial Crisis put to the fore the challenges of managing liquidity and foreign assets at times of heightened volatility. Earlier concerns of some observers regarding the costs of precautionary hoarding notwithstanding, the Global Financial Crisis (GFC) validated the buffer value of international reserves and active management of buffer funds. These issues are especially pertinent for commodity exporters, where the high volatility of their commodity terms of trade translates into large shocks impacting the real exchange rate, and the GDP. The history of Latin American countries provides ample examples where adverse terms of trade shocks terminated spells of 'good time,' leading to capital flight and financial crises.

Intriguingly, 'this time has been different' for countries that followed the dictum of "save for a rainy day" during the 2000s, opting for counter-cyclical macro policies, Chile being the prime example of it (Céspedes and Velasco, 2012; 2014). Frankel (2013) found that since 2000, fiscal policy in Chile has been governed by a structural budget rule that has succeeded in implementing countercyclical fiscal policy.[1]

Insightful comments by Martin Bodenstein, Rodrigo Caputo, Roberto Chang, Jose De Gregorio, Pablo Garcia and Governor Rodrigo Vergara are gratefully acknowledged. Any errors are ours.

1. A crucial ingredient accounting for Chile's success is the official estimates of trend output and the 10-year price of copper—which is key to the decomposition of the budget in Chile into structural versus cyclical components—that are made by independent expert panels and thus insulated from the political process.

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Furthermore, Frankel, Vegh and Vuletin (2011) found that, over the last decade, about a third of the developing world has been becoming countercyclical.

In commodity exporting countries, pro-active liquidity, exchange rate and foreign assets management have supported such fiscal policy. Using the pre-GFC data, Aizenman and Riera-Crichton (2008) found that international reserves cushion the impact of terms-of-trade shocks on the real effective exchange rate (REER), and that this effect is especially significant for countries exporting natural resources. Financial depth reduces the buffer role of international reserves in developing countries. In a more detailed analysis, Aizenman, Edwards and Riera-Crichton (2012) found that active reserve management not only lowers the short-run impact of commodity terms of trade (CTOT) shocks significantly, but also affects the long-run adjustment of REER, effectively lowering its volatility. Relatively small increases in the average holdings of reserves by Latin American economies, to levels still well below other emerging regions current averages, provided a policy tool as effective as a fixed exchange rate regime in insulating the economy from CTOT shocks. Reserve management could be an effective alternative to fiscal or currency policies for relatively trade closed countries and economies with relatively poor institutions or high government debt. Céspedes and Velasco (2012), using commodity price boom and bust episodes, provided empirical evidence that commodity price shocks have a significant impact on output and investment dynamics. Economies with more flexible exchange rate regimes exhibit less pronounced responses of output during these episodes. They also found that the impact of those shocks on investment tends to be larger for economies with less developed financial markets. Moreover, international reserve accumulation, more stable political systems, and less open capital accounts tend to reduce the real exchange rate appreciation (depreciation) in episodes of commodity price booms (busts), respectively.

The purpose of this paper is to revisit these issues, extending earlier analysis by looking at the degree to which the more recent data (up to 2013), and the new institutional developments validate the earlier results that relied on pre-GFC data. Specifically, we analyze the degree to which the growing importance of sovereign wealth funds (SWFs), and the diffusion of inflation targeting and augmented Taylor rules have impacted the post crisis adjustment of LATAM to the challenges associated with terms of trade and financial shocks.[2] The paper focuses on the reduced form, positive analysis of observed correlations between key variables, and patterns of observed and conditional volatility. There is no attempt to provide normative analysis; although, the results are consistent with the possibility that volatility triggered by exogenous shocks may be of concern for policy makers. In the discussion section we review some of papers dealing with the normative aspects of these issues; although a fuller treatment of these issues would require a detailed public finance analysis of the conditions and policy tools which may increase welfare by mitigating any adverse effects of heightened terms of trade volatility.[3]

Extending the dataset to 2013, we are able to replicate our previous results: stock of reserves and active management reduce the effects of transitory Commodity Terms of Trade (CTOT) shocks to real exchange rate in LATAM economies. This "buffer effect"[4] seems to work more against risk of real appreciation than against risks of depreciations. Fixed exchange regimes act as a substitute policy to reserve accumulation, and this buffering policy seems to work under relatively high levels of external debt, and in economies that are less open to trade. We confirm the income effects of CTOT–positive correlation of CTOT shocks and the real GDP growth. The positive association between the two seems to be stronger with negative shocks for low debt and more open economies. Accumulation (*de-accumulation*) of reserves helps in buffering the transmission of positive (negative) CTOT shocks to output, respectively.

SWFs add new dimensions to foreign asset managements. In contrast to reserves, SWFs seem important to buffer the real effective exchange rate [REER] from CTOT shocks with fixed exchange rate regimes and in relatively closed economies. SWFs also reinforce the effects of CTOT shocks on real output during negative shocks with

2. See Aizenman and Glick (2014) for an overview of the diffusion of SWFs and possible division of labor between SWFs and central banks. See Mishkin and Schmidt-Hebbel (2007); Aizenman, Hutchison and Noy (2011) and Céspedes, Chang, and Velasco (2014) for analysis on Inflation Targeting in practice.

3. Theory would often imply that the real exchange rate should adjust to reflect real external shocks, including commodity terms of trade shocks. Hence, policies that impede such adjustment, including liquidity management, may have ambiguous or even welfare reducing effects. Thereby, the case for proactive liquidity management may hinge on the structure of the economy, and the quality of institutions.

4. Throughout the paper we refer to "buffering" as the effective reduction of the transmission effects of exogenous real shocks (i.e., CTOT shocks) to key domestic macroeconomic variables such as real output or real exchange rates. This "cushioning" is captured by an opposite-signed non-linear term in our regression specification.

fixed exchange rate regimes, and buffer the effect for relatively high external debt levels. Our buffer story seems to show its strongest version during the 1980s, 1990s and the end of the Great Moderation (2003-2007). Yet, during the great recession (2008-2009) we observe a disconnect between CTOT and REER, and the role of reserves. The REER-CTOT relationship seems to resume during the post-Great Recession period (2010-2013), and reserve buffering returns, but not at the levels observed previous to the crisis. The same story applies for active use of reserves, except that our buffer story returns in a stronger fashion during the post-recession period.

There seems to be a “substitution” between reserves and where SWFs take over the buffering of the REER and the real GDP during the Great Recession and the post-Great Recession period. Inflation targeting policy seems to matter, potentially diverting resources to the preservation of domestic price stability: IT countries seems to give up the use of reserves to buffer against CTOT shocks, relegating this role to the SWFs. In LATAM countries that seem to follow an augmented Taylor rule, their monetary authorities seem to place a large weight on output gaps, while inflation seems to gain importance for IT countries. The nature of the regime matters: non-IT countries seem to switch from a REER stabilization target to an inflation target when committing to a formal IT rule.

The rest of the paper is organized as follows: In section 1, we define the data used in the paper as well as present a set of summary statistics describing the evolution of external liquidity and CTOT shocks over the last three decades. Section 2 presents our econometric strategy to uncover the way CTOT shocks affect macroeconomic performance measures such as the real exchange rates and output growth, both in the short and long runs. We also show the proposed methods to capture the role of international reserves in smoothing temporary TOT shocks under a set of alternative macroeconomic regimes. In section 3, we discuss our econometric results from the analysis of the buffering effect from the *stock of reserves and the stock of sovereign wealth funds*. These results include an investigation of the buffer effect of liquidity management following positive versus negative CTOT shocks under different exchange rate regimes, different stocks of external debt and different degrees of trade openness. Section 4 looks at the changes in the CTOT-REER and CTOT-growth relationship as well as our buffer story over different sample periods. Specifically, we look at the turbulent period from 1980 to 2002, the Great Moderation, the

Great Recession and the period following the global crisis up to the present. Section 5 looks at the relationship between reserves and sovereign wealth funds as competing tools for international liquidity management. Section 6 explores the role of other monetary policies implemented in Latin American economies in the last two decades. This section focuses on the adoption of inflation rules by half the countries in our sample. In section 7, we discuss related literature dealing with positive and normative aspects of buffer and stabilization policies. Section 8 concludes.

1. Macroeconomic Performance, Commodity TOT Shocks and Liquidity Management in Latin America

Looking at the macroeconomic performance of the largest economies (LAC-7) in Latin America over the last two decades, as shown in table 1, we see that "this time was really different." LAC-7 economies did experience a slowdown in growth and increase in volatility during the Great Recession relative to the "good times" of the Great Moderation. Nevertheless, the slowdown did not turn into a crash as in previous occasions and most countries continued to experience real appreciations against the dollar throughout the worst of the crisis. Furthermore, the recovery was "fast and furious" with average rates of annual growth above five percent, rates of real appreciation of almost three and a half percent per year and lower macroeconomic volatility than in the Great Moderation. In this paper we investigate the role of active liquidity management in this success story.

Traditionally, one of the main transmission mechanisms of global real shocks to Latin American economies has been sudden changes in relative international prices. In this paper, we use a "commodity terms of trade" (CTOT) data set to analyze the way in which shocks to commodity prices affect key macroeconomic performance measures such as changes in the real effective exchange rate (REER) or output growth. Our analysis focuses on the twelve largest Latin American economies: Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Ecuador, Mexico, Paraguay, Peru, Uruguay and Venezuela. As shown in previous work, this set of emerging countries has the highest volatility in CTOT. Our current work covers the 1980-2014 period but focuses special attention to the period of relatively low

Table 1. Real Output Growth and Real Exchange Rate in LAC-7

	Pre-GM 1990-2003	*Great moderation 2003-2007*	*Great recession 2008-2009*	*Post-GR 2010-2013*
Real output growth				
Annual averages	3.01	5.71	2.04	5.12
St. dev.	2.43	1.87	4.12	0.91
Real appreciation v. the US$				
Annual averages	-1.21	5.61	1.56	3.40
St. dev.	7.61	3.24	7.83	3.21

Source: Annual data were taken from IADB Macro Watch. LAC-7 includes Argentina, Brazil, Chile, Colombia, Mexico, Peru and Venezuela.

volatility before the Great Recession, dubbed the end of the Great Moderation (2002-2007), the Great Recession (2008-2009) and the post-Great Recession period of 2010-2013. Our key measure, the concept of "commodity terms of trade," follows Ricci and others (2008) and differs from the traditional measure in that it only includes the relative prices of a country's commodity exports and imports, weighted by their country specific GDP shares. By excluding industrial goods, and concentrating on commodity prices, we focus on the most volatile component of import and exports prices. Specifically, this commodity terms-of-trade data set was constructed as follows: $CTOT_i = \prod_j (P_j/MUV)^{X_j^i} / \prod_j (P_j/MUV)^{M_j^i}$, where P_j is the price index for six commodity categories (food, fuels, agricultural raw materials, metals, gold, and beverages), and (X_j^i, M_j^i) are the average shares of commodity *j* in country *i*'s exports and imports over GDP for the 1980-2012 period, respectively. Commodity prices are deflated by the manufacturing unit value (*MUV*) index. Since they are averaged over time, the movements in *CTOT* are invariant to changes in export and import volumes in response to price fluctuations and thus isolate the impact of commodity prices on a country's terms of trade.[5] Another

5. By construction, a percentage increase (decrease) in the commodity terms of trade measure is approximately equal to the aggregate net trade gain (loss) relative to GDP from changes in real individual commodity prices (see Spatafora and Tytell (2009)). See the appendix of NBER working paper # 17692 for further details regarding the derivation of CTOT, data definitions and sources.

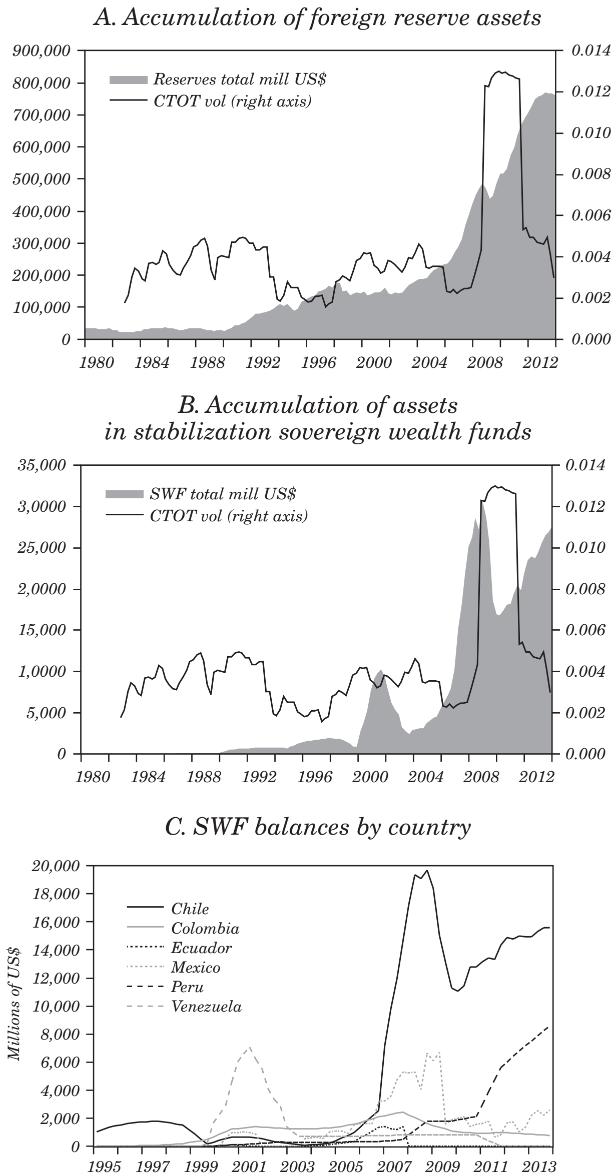
useful property of this CTOT measure arises from the use of export/ import over GDP as our weights. This allows us to reinterpret CTOT shocks as income shocks to the home economy and build a direct link to effects on aggregate income and production.

Figure 1 gives us an overview of the evolution of CTOT shocks volatility over time, as well as the accumulation of international liquidity and composition of this liquidity by Latin American economies over the last three decades. While CTOT shock volatility doubled during the Great Recession, volatility was already persistently high in the previous twenty years. In spite of this high volatility, LATAM economies managed to achieve low output and REER volatility during the last decades, including the Great Recession. Part of this success may have been achieved thanks to a set of countercyclical fiscal policies and, more relevant to our work, a set of monetary policies dedicated to carefully manage international liquidity in order to lower price and output volatility. In this light, figure 1A shows how Latin American economies had started to accumulate large amounts of foreign reserves well before the last crisis. This accumulation drove LATAM economies to move from an average stock of reserves of 7.5 percent of GDP before the Great Moderation, to more than 15% after the Great Recession.

Figure 1B showcases the appearance of stabilizing sovereign wealth funds (SWFs) as an alternative source of international liquidity. Most of these SWFs acted as automatic stabilizers following a fiscal rule dedicated to manage the windfalls from abnormal high prices of the commodities typically exported by each country. Table 2, depicts the SWF used in this analysis.

Figure 1C shows the country composition of the aggregate balance of these stabilization funds in the region. While Chile has been the clear leader of the pack, accumulating close to 20 billion dollars in its copper fund before the crisis, other countries like Mexico, Colombia, and later in the sample, Peru, have been increasing their SWFs thanks to windfalls from their energy (oil and gas) funds. Venezuela was able to accumulate a large amount of funds in the early 2000's but then their fund was liquidated and has not been active since. Another relevant policy change adopted by LATAM countries during the nineties was a set of explicit inflation targets. As shown in table 3, up to half of the countries in our sample became inflation-targeters. Potentially, inflation targeting represents an important part of our buffer story since inflation-targeting (IT) countries may deviate resources from REER stabilization to internal price stabilization.

Figure 1. CTOT Shocks Volatility, Accumulation and Composition of International Liquidity by Latin American



Source: See appendix.

Table 2. Commodity Based Stabilization SWF in LATAM

Country	*Fund*	*Coverage*	*Commodity*	*Source*
Chile	Fondo de Estabilización de los Ingresos del Cobre (Copper Fund)	1987-2006	Copper	Tesorería General de la República
Chile	FEES	2007-2013	Copper	Hacienda Pública de Chile
Colombia	Fondo de Ahorro y Estabilización Petrolera	1996-2013	Oil	Ministerio de Hacienda y Crédito Público
Ecuador	FEP	2000-2007	Oil	Ministry of Economy
Ecuador	FEIREP	2002-2004	Oil	Ministry of Economy
Ecuador	CEREPS	2005-2007	Oil	Ministry of Economy
Ecuador	FAC	2005-2007	Oil	Ministry of Economy
Ecuador	FEISEH	2006-2007	Oil	Ministry of Economy
Mexico	Fondo de estabilizacion de ingresos petroleros (FEP)	2000-2013	Oil	Secretaría de Hacienda y Crédito Público
Peru	Fondo de Estabilización Fiscal	2000-2013	Oil and Gas	Ministerio de Economía y Finanzas del Perú
Venezuela	Fondo de Estabilidad Macroeconómica	1999-2013	Oil	Banco Central de Venezuela

Table 3. Inflation Targets in Latin America

Country	*Converging target period*	*Stationarity-Target period*	*2005 inflation target level (%)*
Brazil	1999:1–2004:4	2004-	4.5 (+/–2.5)
Chile	1991:1–2000:4	2001-	2–4
Colombia	1999:1–2004:4	2004-	5 (+/–0.5)
Mexico	1999:1–2002:4	2004-	3 (+/–1)
Peru	1994:1–2001:4	2002-	2.5 (+/–1)
Uruguay	2002:2–2003:4	2004-	N.A.

Source: See appendix.

2. Macroeconomic Adjustment and Commodity Terms of Trade Shocks

Following previous work, in this paper, we use a fixed effects error correction model to capture the effects of CTOT shocks and the dynamic adjustment of REER and output growth. Our basic framework is represented by equation (1):

$$\Delta Ln(X)_{it} = \alpha_i + \beta_1 \Delta Ln(X)_{it-1} + \beta_2 ECTX_{it-1} + [\theta_1 + \theta_2 Y_{it-1}] TCTOT_{it-1} + \beta_3 Y_{it-1} + \varepsilon_{it} \qquad (1)$$

where X corresponds to one of our two measures of macroeconomic performance: 1) REER, the real effective (trade weighted) exchange rate.[6] 2) Real GDP. $ECTX$ is the error correction term for (the logarithm of) X. As usual, this term is defined as the log deviations of X from its equilibrium value. In order to compute the equilibrium/long-run REER, we use a co-integrating approach.[7] The long-run value of output growth is obtained applying an HP filter to the original series with a smoothing parameter set at 1600. Similarly,

6. For the rest of the empirical section, REER is defined as foreign currency in terms of the domestic currency, e.g., an increase in REER corresponds to a real appreciation of the domestic currency

7. See the Edwards (1989) and Montiel (1999) derivation long-run REER that is detailed in the appendix.

the term *TCTOT* represents transitory CTOT shocks, and is defined as the log deviations of current CTOT from its long-run value. The latter, again, is obtained applying an HP Filter to the original series with a smoothing parameter set at 1600. Finally, Y represents our liquidity measure. In this paper we will use the stock of international reserves to GDP ratio, the stock of SWF to GDP ratio, and the change of these ratios as our proxies for liquidity management policy.

To investigate the potential differences in our buffer story over different sample periods, different macroeconomic/policy structures or asymmetric underlying shocks, we use another layer of non-linearities for our approach:

$$\Delta Ln(X)_{it} = \alpha_i + \beta_1 \Delta Ln(X)_{it-1} + \beta_2 ECTX_{it-1} + [\theta_1(1-Z) + \theta_2(1-Z)Y_{it-1} + \theta_3 Z + \theta_4 ZY_{it-1}]TCTOT_{it-1} + \beta_3 Y_{it-1} + \varepsilon_{it} \quad (2)$$

where Z is defined as a vector of dummy variables that split the regression by sample period or by different economic structures such as degree of trade openness, indebtedness or exchange rate regime.

To provide a more dynamic look at the effects of CTOT shocks to REER and output and the potential for our buffering effect under different macroeconomic conditions, we set up a series of accumulated impulse response functions (IRFs). To build these IRFs, we follow the single-equation approach advocated by Jorda (2005) and Stock and Watson (2007). We use these linear local projections (LP) of real appreciation and output growth on our dynamic error correction model:

$$\Delta Ln(X)_{it+h} = \alpha_{i,h} + \beta_{1,h} \Delta Ln(X)_{it-1} + \beta_{2,h} ECTX_{it-1} + [\theta_{1,h}(1-Z) + \theta_{2,h}(1-Z)Y_{it-1} + \theta_{3,h} Z + \theta_{4,h} ZY_{it-1}] TCTOT_{it-1} + \beta_{3,h} Y_{it-1} + \varepsilon_{it} \quad (3)$$

where $\Delta Ln(X)_{it+h} = Ln(X)_{it+h} - Ln(X)_{it-1}$. It is important to note that, in this approach, each step in the accumulated IRF is obtained from a different individual equation. Thus, we obtain the IRF values directly from the coefficients in each equation "h." Compared to a standard IRF built on a single dynamic panel specification, Jorda's LP methodology gains efficiency using new information for each step of the response function (each step is constructed from the estimates of a unique regression). While our IRF should be very close in the first lags of a traditionally built IRF, as we move further, we would expect the LP to keep providing information on the IRF while the traditional IRF would "die" shortly after it runs out of persistence. Additionally, our methodology does not impose the dynamic restrictions implicitly embedded in traditional simultaneous equation specifications, that is, vector autoregressions (VARs), and can conveniently accommodate non-linearities in the response function. As explained in Jorda (2005), there are multiple advantages in the use of LP. In particular, LPs: (i) can be estimated by single-regression techniques (least-squares dummy variables or LSDVs in our case), (ii) are more robust to potential misspecifications, and (iii) can accommodate highly non-linear, flexible specifications that may be impractical in a multivariate SVAR (structural vector autoregression) context.

3. Has Liquidity and Foreign Asset Management Buffered LATAM Countries from External Real Shocks? Results from a Pooled Regression

We start our results section updating our previous work on the buffer role of foreign reserves with quarterly data until 2013. All regressions include all available data. The pooled regressions include a quarterly sample that ranges in the period from 1980 to 2013. Not all countries have a full sample of data, so our panel regressions are unbalanced. Descriptive statistics of all the variables are summarized in table 4. Additionally, we include a set of stationarity tests for our dependent variables: real output growth and real exchange rate appreciation in table 5. These tests also contain the average optimal lag structure selected through AIC, BIC and HQIC information criterions. All tests show a level of stationarity in our panel that allows proceeding to our main specification without further adjustments. The optimal average lag structure revolts around 1.

Table 4. Descriptive Statistics

All obs.	*No. obs.*	*Mean*	*Std. dev.*	*Min*	*Max*
DREER	1,576	-0.001492	0.088289	-1.936263	0.6924086
ECT REER	1,516	-0.0015106	0.1273096	-0.5987437	1.365942
DRGDP	1,083	0.0088561	0.0203312	-0.1385784	0.1955137
ECT RGDP	1,093	0.0005406	0.0294761	-0.28123	0.1574097
TCTOT	1,632	3.94E-11	0.0144423	-0.1111243	0.1186696
RES OVER GDP	1,632	0.097068	0.0651493	0.0053772	0.4217554
SWF OVER GDP	1,632	0.0028891	0.010467	0	0.1132718
DRES	1,620	0.0007563	0.0116144	-0.086744	0.0801628
DSWF	1,620	0.0000591	0.0017731	-0.0247848	0.0261156
IT DUMMY	1,632	0.2444853	0.4299133	0	1
FLEX REGIME	1,138	0.4841828	0.4999695	0	1
FIXED REGIME	1,138	0.5158172	0.4999695	0	1
HI DEBT	1,632	0.471201	0.4993229	0	1
LOW DEBT	1,632	0.528799	0.4993229	0	1
TRADE OPEN	1,632	0.4920343	0.5000898	0	1
TRADE CLOSE	1,632	0.5079657	0.5000898	0	1

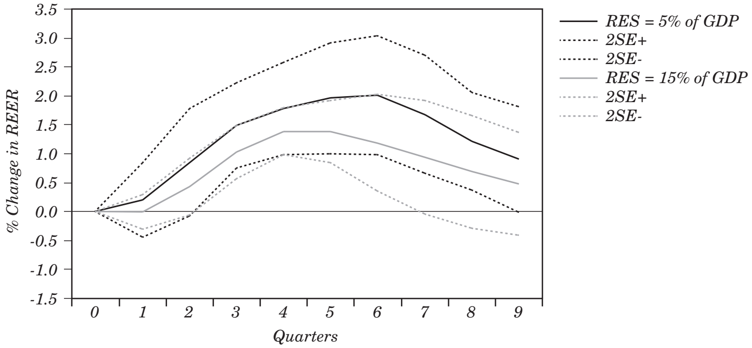
Source: See appendix.

Table 5. Panel Stationarity Test for Dependent Variables and Optimal Lag Structure

Type of test	*Info criterion*	*No. obs.*	*Countries*	*Test statistic*	*P-value*	*Optimal lag structure*
Real output growth						
IPS	AIC	1,164	13	-21.31	0.00	1.54
IPS	BIC	1,178	13	-30.24	0.00	0.46
IPS	HQIC	1,171	13	-27.34	0.00	1.00
Fisher (DF)	-	1,197	13	60.36	0.00	-
Fisher (PP)	-	1,197	13	99.73	0.00	-
Real exchange rate appreciation						
IPS	AIC	1,674	13	-27.91	0.00	1.85
IPS	BIC	1,690	13	-34.39	0.00	0.62
IPS	HQIC	1,684	13	-30.33	0.00	1.08
Fisher (DF)	-	1,711	13	97.61	0.00	-
Fisher (PP)	-	1,711	13	122.98	0.00	-

Source: See appendix.
H0: All panels contain unit roots.
Ha: Some panels are stationary.
Notes: IPS corresponds to Im-Pesaran-Shin (2003), DK to Dickey-Fuller, PP to Phillips-Perron tests. One Lag was used as a default for the Fisher Tests. The test statistics reported correspond to the W-tilda-bar for IPS and the modified version of the inverse chi-squared transformation proposed by Choi (2001) for the Fisher Test.

Figure 2. REER IRF to 1% CTOT Shock under High and Low Stock of Reserves



Source: See appendix.

Tables 6A y 6B corroborate our previous findings in our updated dataset. Table 6A reports the estimation of the basic model using the stock of reserves over GDP as a proxy for "liquidity availability." Meanwhile, table 6B uses the change in reserves as a proxy for "active reserve management." In both tables, the first column confirms a positive correlation between TCOT and REER; column 2 showcases our basic reserve buffer story: a stock of reserve of 15 percent of GDP or a change in reserve holdings of 3 percent of GDP can, on average, decrease the REER effects of CTOT shocks on impact by half. To see the gains of this policy more clearly and in a dynamic environment, we show the dynamic IRF in figure 2. Moving the stock of reserves from 5 percent to 15 percent decreases the REER volatility (measured as the standard deviation of the point estimates on the IRF) by almost 30 percent over the following two years.

Columns 3-6 in tables 5 and 6 use dummy variables to estimate the differences in our buffer story given different policy and macroeconomic structure. Results in both tables are very similar: the buffer effect works against risk of real appreciation more than against risk of depreciation.[8]

8. This asymmetry may reflect a country's concern that losing reserves during a downturn might increase its vulnerability to deleveraging and sudden stops. In addition, deflationary shocks (drops in commodity prices, collapsing export demands, etc.) may mitigate concerns of the inflationary consequences associated with depreciation, increasing the perceived gain of depreciation as a form of demand switching policy, improving the competitiveness of a country.

Table 6A. Buffer Effect on REER
Of stock of reserves

Model	*Basic model*	*Stock of reserves*	*Pos (X) vs Neg (Y) CTOT shock*	*Flex (X) vs Fixed (Y) forex*	*Hi (X) vs Low (Y) debt*	*Open (X) vs Close (Y) trade*
Variables	*DREER*	*DREER*	*DREER*	*DREER*	*DREER*	*DREER*
DREER ($t-1$)	0.0927 [0.060]	0.0930 [0.060]	0.0921 [0.061]	0.3894 [0.044]***	0.0931 [0.060]	0.0938 [0.059]
ECT REER ($t-1$)	-0.2356 [0.066]***	-0.2368 [0.067]***	-0.2390 [0.067]***	-0.1459 [0.017]***	-0.2369 [0.067]***	-0.2435 [0.071]***
TCTOT ($t-1$)	0.4756 [0.141]***	0.7856 [0.228]***				
TCTOT * RES (t-1)		-2.5802 [0.705]***				
TCTOT * X ($t-1$)			1.8765 [0.459]***	1.3254 [0.624]*	0.8367 [0.318]**	0.2177 [0.164]
TCTOT * Y ($t-1$)			-0.0397 [0.511]	0.2526 [0.085]**	0.7031 [0.222]***	2.1394 [0.527]***
TCTOT * RES * X ($t-1$)			-9.7578 [2.804]***	-6.9353 [3.541]*	-2.8613 [0.750]***	-0.1352 [0.917]
TCTOT * RES * Y ($t-1$)			2.2305 [2.695]	0.9470 [0.605]	-1.9789 [1.714]	-8.0886 [3.032]**
RES ($t-1$)	0.1126 [0.043]**	0.1100 [0.042]**	0.1730 [0.065]**	0.0766 [0.022]***	0.1093 [0.041]**	0.1122 [0.045]**
No. observations	1,496	1,496	1,496	1,082	1,496	1,496
R^2	0.113	0.114	0.117	0.153	0.114	0.121
Number of countries	12	12	12	12	12	12

Source: See appendix.
Robust standard errors in brackets. *** p<0.01, ** p<0.05, * p<0.1.
DREER is the real exchange rate appreciation. TCTOT represents transitory commodity terms of trade shocks. RES is the stock of international reserves over GDP. DRES is the change in RES. Quarterly observations from 1980.I to 2013.IV. All observations available were used.

Table 6B. Buffer Effect on REER
Of active change of reserves

Model	*Basic model*	*Change in reserves*	*Pos (X) vs Neg (Y) CTOT shock*	*Flex (X) vs Fixed (Y) forex*	*Hi (X) vs Low (Y) debt*	*Open (X) vs Close (Y) trade*
Variables	*DREER*	*DREER*	*DREER*	*DREER*	*DREER*	*DREER*
DREER ($t-1$)	0.0929 [0.060]	0.0937 [0.060]	0.0933 [0.061]	0.3841 [0.041]***	0.0937 [0.060]	0.0899 [0.055]
ECT REER ($t-1$)	-0.2358 [0.066]***	-0.2362 [0.067]***	-0.2391 [0.067]***	-0.1464 [0.017]***	-0.2371 [0.067]***	-0.2402 [0.072]***
TCTOT ($t-1$)	0.4853 [0.154]***	0.4972 [0.157]***				
TCTOT * DRES ($t-1$)		-6.4029 [1.946]***				
TCTOT * X ($t-1$)			1.0007 [0.342]**	0.5217 [0.200]**	0.5299 [0.246]*	0.2026 [0.078]**
TCTOT * Y ($t-1$)			0.1710 [0.264]	0.3540 [0.053]***	0.5094 [0.084]***	1.1951 [0.600]*
TCTOT * DRES * X ($t-1$)			-21.4704 [10.014]*	-23.7249 [5.466]***	-16.0492 [2.687]***	1.4333 [1.494]
TCTOT * DRES * Y ($t-1$)			-0.0196 [12.498]	10.9922 [5.238]*	15.0122 [3.242]***	-80.6740 [36.803]*
RES ($t-1$)	0.1150 [0.050]**	0.1175 [0.051]**	0.1182 [0.051]**	0.0665 [0.027]**	0.1211 [0.052]**	0.1162 [0.048]**
DRES ($t-1$)	-0.0662 [0.318]	-0.0667 [0.316]	0.0477 [0.361]	0.1187 [0.258]	-0.0468 [0.312]	-0.0526 [0.317]
No. observations	1,496	1,496	1,496	1,082	1,496	1,496
R^2	0.113	0.113	0.116	0.163	0.116	0.125
Number of countries	12	12	12	12	12	12

Source: See appendix.
Robust standard errors in brackets. *** p<0.01, ** p<0.05, * p<0.1.
DREER is the real exchange rate appreciation. TCTOT represents transitory commodity terms of trade shocks. RES is the stock of international reserves over GDP. DRES is the change in RES. Quarterly observations from 1980.I to 2013.IV . All observations available were used.

Fixed exchange regimes seem to act as a substitute policy to reserve accumulation. Reserve management appears to be a more effective policy under relatively high levels of external debt and the buffer policy works in relatively trade-closed economies.

Given the potentially direct relationship between CTOT shocks and income shocks, countries may choose to stabilize output rather than REER. In tables 7A and 7B, we explore the role of reserve accumulation and active reserve management as output stabilizing polices. The first column in both tables confirms the direct income effect of CTOT shocks with a strong positive correlation between both measures. Interestingly, columns 3, 5 and 6 show this income effect being stronger under negative shocks, low debt and relatively open economies. While column three does not provide clear evidence of our buffer effect for either stock of reserves or change in reserves, column 4 in table 7B shows that accumulation and de-accumulation of reserves buffers the transmission of positive and negative CTOT shocks to output. Results from the IRF in this last specification paint a slightly different picture. Figure 3A shows a clear role of active reserve management on stabilizing output volatility under positive shocks. Increasing the rate at which the country accumulates reserves from 1 percent to 3 percent of GDP helps decrease the volatility of real output growth after positive CTOT shocks by 26 percent over the following two years.[9] On the opposite end, figure 3B shows that while de-accumulation of reserves seems to help decrease the effect of negative CTOT shocks into output growth on impact, this policy seems to have an insignificant role buffering the CTOT shock in the following periods.

As mentioned above, an important extension to our previous work with reserves consists in looking at the effects of managing foreign assets in the form of SWF balances. The SWFs included in this study follow a set of fiscal rules that allow countries to manage windfalls from increases in the international prices of the exporting commodities. Tables 8A and 8B report the estimated coefficients for our basic model using the balance of SWFs as our proxy for access to international liquidity. While the most significant effects are obtained in the study of different periods (see table 9 and text below), there are some interesting results captured by tables 8A and 8B. First, in contrast to what we observed with reserves, SWFs seem to act as an important buffer to REERs under fixed exchange rate regimes and relatively close

9. Here we define volatility as the standard deviation of the point estimates for the first 10 periods of each impulse response function.

Table 7A. Buffer Effect on Output Growth
Of stock of reserves

Model	*Basic model*	*Stock of reserves*	*Pos (X) vs Neg (Y) CTOT shock*	*Flex (X) vs Fixed (Y) forex*	*Hi (X) vs Low (Y) debt*	*Open (X) vs Close (Y) trade*
Variables	*DRGDP*	*DRGDP*	*DRGDP*	*DRGDP*	*DRGDP*	*DRGDP*
DRGDP ($t-1$)	0.1672 [0.053]***	0.1664 [0.053]***	0.1637 [0.054]**	0.1692 [0.056]**	0.1700 [0.052]***	0.1670 [0.054]**
ECT RGDP ($t-1$)	-0.2690 [0.044]***	-0.2686 [0.045]***	-0.2653 [0.044]***	-0.3265 [0.023]***	-0.2753 [0.045]***	-0.2698 [0.043]***
TCTOT ($t-1$)	0.2138 [0.061]***	0.2639 [0.075]***				
TCTOT * RES ($t-1$)		-0.4139 [0.376]				
TCTOT * X ($t-1$)			0.1800 [0.075]**	0.2467 [0.313]	0.1076 [0.127]	0.3108 [0.037]***
TCTOT * Y ($t-1$)			0.3596 [0.092]***	0.3126 [0.038]***	0.2782 [0.078]***	0.0235 [0.235]
TCTOT * RES * X ($t-1$)			-0.3937 [0.537]	-0.0284 [2.127]	-0.1399 [0.399]	-0.6093 [0.254]**
TCTOT * RES * Y ($t-1$)			-0.5547 [0.474]	-0.5785 [0.301]*	0.2957 [0.809]	0.1523 [2.075]
RES ($t-1$)	0.0190 [0.009]*	0.0182 [0.009]*	0.0176 [0.011]	0.0112 [0.011]	0.0182 [0.009]*	0.0197 [0.010]*
No. observations	1,073	1,073	1,073	842	1,073	1,073
R^2	0.155	0.155	0.156	0.191	0.160	0.157
Number of countries	12	12	12	12	12	12

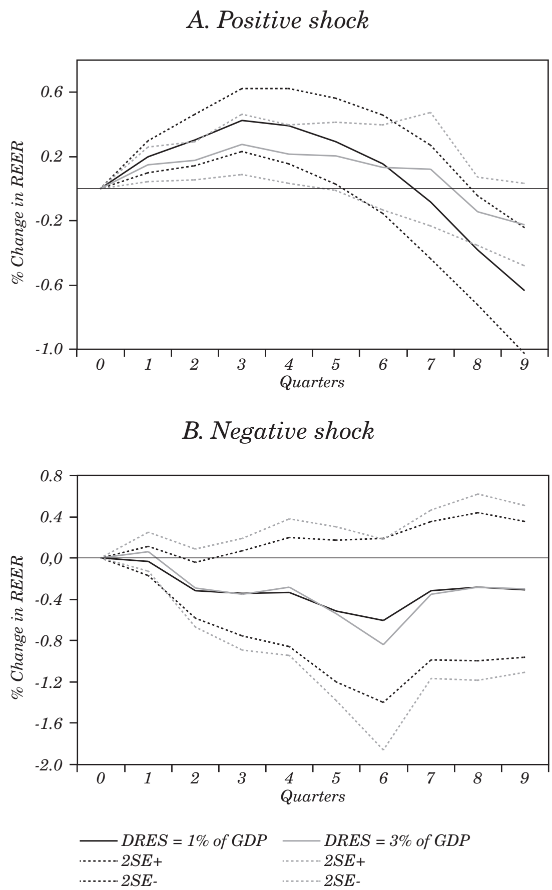
Source: See appendix.
Robust standard errors in brackets. *** p<0.01, ** p<0.05, * p<0.1. DRGDP represents real output growth. TCTOT represents transitory commodity terms of trade shocks. RES is the stock of international reserves over GDP. DRES is the change in RES. Quarterly observations from 1980.I to 2013.IV. Observations under hyperinflation episodes (>100% inflation) are not included.

Table 7B. Buffer Effect on Output Growth
Of active change of reserves

Model	*Basic model*	*Change in reserves*	*Pos (X) vs Neg (Y) CTOT shock*	*Flex (X) vs Fixed (Y) forex*	*Hi (X) vs Low (Y) debt*	*Open (X) vs Close (Y) trade*
Variables	*DRGDP*	*DRGDP*	*DRGDP*	*DRGDP*	*DRGDP*	*DRGDP*
DRGDP ($t-1$)	0.1670 [0.053]***	0.1676 [0.053]***	0.1704 [0.052]***	0.1696 [0.056]**	0.1729 [0.052]***	0.1691 [0.054]***
ECT RGDP ($t-1$)	-0.2685 [0.045]***	-0.2689 [0.045]***	-0.2701 [0.045]***	-0.3266 [0.023]***	-0.2762 [0.046]***	-0.2693 [0.044]***
TCTOT ($t-1$)	0.2070 [0.066]***	0.2072 [0.067]**				
TCTOT * DRES ($t-1$)		0.5048 [1.864]				
TCTOT * X ($t-1$)			0.1842 [0.058]***	0.2400 [0.068]***	0.0745 [0.086]	0.2272 [0.056]***
TCTOT * Y ($t-1$)			0.3133 [0.090]***	0.2383 [0.065]***	0.3080 [0.032]***	0.0448 [0.207]
TCTOT * DRES * X ($t-1$)			-10.3490 [2.267]***	-0.4778 [6.058]	-3.1602 [1.807]	0.9845 [1.680]
TCTOT * DRES * Y ($t-1$)			7.5174 [1.358]***	0.3416 [2.023]	3.7605 [1.136]***	-9.8432 [20.360]
RES ($t-1$)	0.0171 [0.008]*	0.0169 [0.007]**	0.0185 [0.007]**	0.0122 [0.011]	0.0177 [0.008]**	0.0179 [0.009]*
DRES ($t-1$)	0.0480 [0.050]	0.0489 [0.049]	0.1380 [0.042]***	0.0332 [0.065]	0.0581 [0.045]	0.0463 [0.049]
No. observations	1,073	1,073	1,073	842	1,073	1,073
R^2	0.155	0.156	0.163	0.190	0.163	0.158
Number of countries	12	12	12	12	12	12

Source: See appendix.
Robust standard errors in brackets. *** p<0.01, ** p<0.05, * p<0.1. DRGDP represents real output growth. TCTOT represents transitory commodity terms of trade shocks. RES is the stock of international reserves over GDP. DRES is the change in RES. Quarterly observations from 1980.I to 2013.IV. All observations available were used.

Figure 3. Output IRF to 1% CTOT



Source: See appendix.

economies. Additionally, SWFs buffer the effect on output growth for relatively high debt observations. Interestingly, holding large SWF balances seems to increase, instead of decrease, the effects of CTOT shocks on real output during negative shocks and under fixed exchange regimes. As explained in the next section of the paper, this effect may reflect the period of SWF accumulation just before the Great Recession. Once we divide the sample in different periods of interest, we observe that SWFs start buffering the CTOT effects on output during and after the Great Recession, replacing reserves in this role.

Table 8A. Buffer Effect of the Stock of SWF Assets
On REER

Model	*Basic model*	*Stock of SWF*	*Pos (X) vs Neg (Y) CTOT shock*	*Flex (X) vs Fixed (Y) forex*	*Hi (X) vs Low (Y) debt*	*Open (X) vs Close (Y) trade*
Variables	*DREER*	*DREER*	*DREER*	*DREER*	*DREER*	*DREER*
DREER ($t-1$)	0.0935	0.0937	0.0934	0.3960	0.0935	0.0942
	[0.062]	[0.062]	[0.063]	[0.044]***	[0.062]	[0.061]
ECT REER ($t-1$)	-0.2319	-0.2323	-0.2339	-0.1484	-0.2321	-0.2401
	[0.061]***	[0.062]***	[0.061]***	[0.019]***	[0.062]***	[0.066]***
TCTOT ($t-1$)	0.4807	0.4648				
	[0.141]***	[0.190]**				
TCTOT * SWF ($t-1$)		2.6679				
		[11.859]				
TCTOT * X ($t-1$)			0.6626	0.4643	0.4698	0.1395
			[0.288]**	[0.092]***	[0.234]*	[0.142]
TCTOT * Y ($t-1$)			0.2446	0.2355	0.4819	1.4552
			[0.245]	[0.113]*	[0.175]**	[0.389]***
TCTOT * SWF * X ($t-1$)			14.6074	-10.8218	-30.5439	9.2066
			[14.893]	[2.464]***	[38.633]	[13.061]
TCTOT * SWF * Y ($t-1$)			-5.3774	19.6930	2.6773	-285.7981
			[6.258]	[3.229]***	[11.614]	[62.898]***
SWF ($t-1$)	0.2549	0.2674	0.0827	0.0737	0.2685	0.2868
	[0.094]**	[0.101]**	[0.149]	[0.086]	[0.103]**	[0.112]**
No. observations	1,496	1,496	1,496	1,082	1,496	1,496
R^2	0.109	0.109	0.110	0.152	0.109	0.117
Number of countries	12	12	12	12	12	12

Source: See appendix.
Robust standard errors in brackets. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.
DREER is the real exchange rate appreciation. TCTOT represents transitory commodity terms of trade shocks. SWF is the balance of sovereign wealth funds over GDP. DSWF is the change in SWF. Quarterly observations from 1980.I to 2013.IV. All observations available were used.

Table 8B. Buffer Effect of the Stock of SWF Assets
On output growth

Model	*Basic model*	*Stock of SWF*	*Pos (X) vs Neg (Y) CTOT shock*	*Flex (X) vs Fixed (Y) forex*	*Hi (X) vs Low (Y) debt*	*Open (X) vs Close (Y) trade*
Variables	*DRGDP*	*DRGDP*	*DRGDP*	*DRGDP*	*DRGDP*	*DRGDP*
DRGDP ($t-1$)	0.1656 [0.054]**	0.1653 [0.054]**	0.1635 [0.054]**	0.1634 [0.057]**	0.1662 [0.053]***	0.1665 [0.055]**
ECT RGDP ($t-1$)	-0.2668 [0.044]***	-0.2689 [0.044]***	-0.2665 [0.043]***	-0.3265 [0.023]***	-0.2727 [0.044]***	-0.2703 [0.042]***
TCTOT ($t-1$)	0.2163 [0.062]***	0.1864 [0.058]***				
TCTOT * SWF ($t-1$)		3.1976 [2.053]				
TCTOT * X ($t-1$)			0.1309 [0.057]**	0.2161 [0.115]*	0.1131 [0.085]	0.2041 [0.047]***
TCTOT * Y ($t-1$)			0.2413 [0.071]***	0.1905 [0.053]***	0.2756 [0.031]***	0.0131 [0.200]
TCTOT * SWF * X ($t-1$)			2.5032 [3.260]	0.3075 [2.125]	-20.9137 [8.658]**	2.8718 [2.095]
TCTOT * SWF * Y ($t-1$)			3.7074 [2.009]*	8.9772 [1.657]***	1.9230 [2.072]	36.8200 [40.583]
RES ($t-1$)	-0.1157 [0.077]	-0.0981 [0.074]	-0.0827 [0.083]	-0.1462 [0.116]	-0.0887 [0.076]	-0.0983 [0.072]
No. observations	1,073	1,073	1,073	842	1,073	1,073
R^2	0.155	0.157	0.158	0.201	0.161	0.158
Number of countries	12	12	12	12	12	12

Source: See appendix.
Robust standard errors in brackets. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.
DRGDP represents real output growth. TCTOT represents transitory commodity terms of trade shocks. SWF is the balance of sovereign wealth funds over GDP. DSWF is the change in SWF. Quarterly observations from 1980.I to 2013.IV. Observations under hyperinflation episodes (>100% inflation) are not included.

Table 9. Buffer Effects of International Liquidity Management by Periods of Interest

Variables	*X=RES* *Y = DREER*	*X=DRES* *Y = DREER*	*X=SWF* *Y= DREER*	*X=RES* *Y = DRGDP*	*X=DRES* *Y= DRGDP*	*X=SWF* *Y =DRGDP*
Y ($t-1$)	0.0958 [0.057]	0.0961 [0.057]	0.0952 [0.058]	0.1550 [0.049]***	0.1554 [0.047]***	0.1460 [0.050]**
ECT Y ($t-1$)	-0.2469 [0.077]***	-0.2445 [0.075]***	-0.2414 [0.070]***	-0.2831 [0.038]***	-0.2837 [0.038]***	-0.2802 [0.038]***
CTOT ($t-1$)	1.8291 [0.563]***	0.6369 [0.243]**	0.5151 [0.287]	0.2249 [0.148]	0.2696 [0.074]***	0.2048 [0.061]***
CTOT * GM ($t-1$)	-0.4119 [1.003]	-0.4091 [0.311]	-0.6468 [0.514]	-0.1828 [0.355]	-0.1245 [0.061]*	0.0060 [0.101]
CTOT * GR ($t-1$)	-1.9051 [0.664]**	-0.3664 [0.260]	-0.2102 [0.261]	0.0900 [0.206]	-0.0678 [0.059]	-0.0132 [0.054]
CTOT * AGR ($t-1$)	-1.2083 [0.783]	-0.2749 [0.520]	-0.0492 [0.644]	0.0669 [0.166]	-0.0374 [0.085]	0.0437 [0.088]
CTOT * X ($t-1$)	-10.8622 [4.276]**	-15.1314 [3.308]***	20.4624 [7.151]**	0.4305 [0.983]	1.3378 [3.538]	7.5401 [1.099]***
CTOT * X * GM ($t-1$)	1.1372 [7.114]	-5.6076 [17.919]	11.2714 [15.753]	0.5731 [2.664]	3.3774 [9.293]	-10.7666 [7.366]
CTOT * X * GR ($t-1$)	13.1715 [4.352]**	31.6379 [6.339]***	-28.6769 [4.763]***	-1.1617 [1.207]	-0.2277 [2.834]	-6.6374 [1.586]***

Table 9. (continued)

Variables	*X=RES* *Y = DREER*	*X=DRES* *Y = DREER*	*X=SWF* *Y= DREER*	*X=RES* *Y = DRGDP*	*X=DRES* *Y= DRGDP*	*X=SWF* *Y =DRGDP*
CTOT * X * AGR ($t-1$)	8.5414	-15.4449	-31.6551	-1.0388	-19.3620	-9.6771
	[4.292]*	[72.282]	[9.424]***	[1.068]	[14.101]	[3.120]**
RES ($t-1$)	0.0999	0.0937		0.0113	0.0090	
	[0.057]	[0.056]		[0.011]	[0.011]	
DRES ($t-1$)		-0.0302			0.0691	
		[0.318]			[0.066]	
SWF ($t-1$)			0.0137			-0.1472
			[0.094]			[0.113]
No. observations	1,496	1,496	1,496	982	982	982
R^2	0.122	0.120	0.117	0.188	0.189	0.196
Number of countries	12	12	12	12	12	12

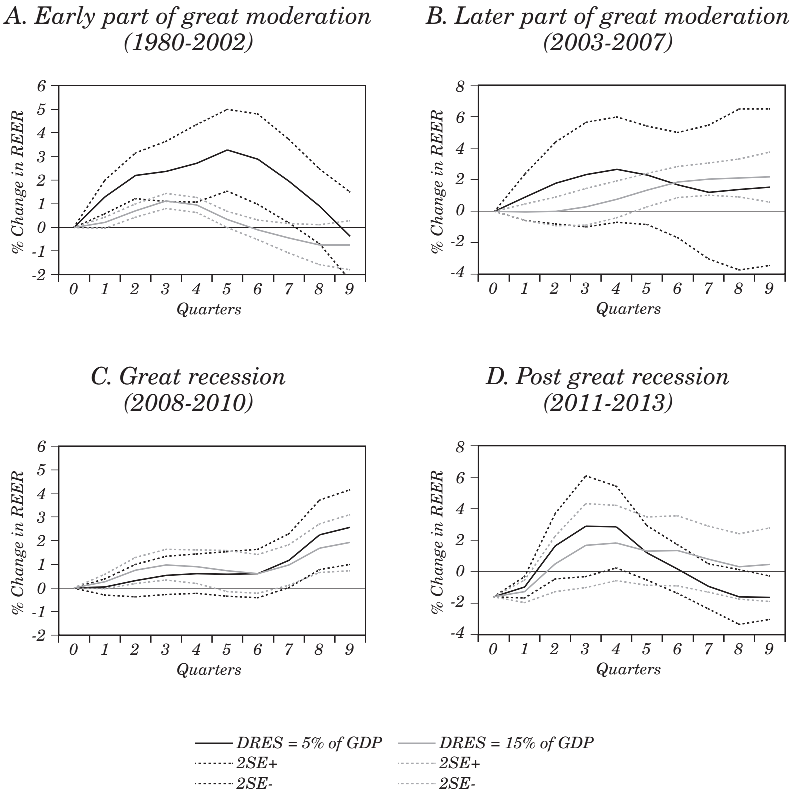
Source: See appendix.
The first three columns are for DREER and the last three for DRGDP
Robust standard errors in brackets. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.
DRGDP represents real output growth. TCTOT represents transitory commodity terms of trade shocks. SWF is the balance of sovereign wealth funds over GDP. Quarterly observations from 1980.I to 2013.IV. GM = Great Moderation, GR = Great Recession, AGR = After Great Recession.

4. What were the Effects of the Great Recession on our Buffer Story?

One of the more important questions in this project is to examine the effects of the Great Recession. In this section, we apply our basic model of liquidity buffer to four distinct periods in time, each with a special economic significance for LATAM region. Our first sample period covers data ranging from the beginning of 1980s to the end of 2002. These are turbulent times in Latin America. Just to cover a few of the major economic crises, we have the debt crisis in 1982 that led to the lost decade, the Tequila crises in 1994-1995 and the Argentinian crises in 2001-2002. Many Latin American economies were plagued by hyperinflation during this period and carried high output and real exchange rate volatility. From table 9, we see how the buffer effect, measured from either the stock of reserves or its active management, is strongest during this period. To explore this point, we compare the IRFs from holding 5% or 15% of GDP in reserves in figure 4A. From this figure we observe a very large decrease in REER volatility; specifically, volatility in the IRF drops by almost 45%. We could argue that in the absence of credible inflation rules or other countercyclical fiscal policies, liquidity management (through international reserves) was one of the strongest tools for emerging LATAM economies to lower inherited macroeconomic volatility. These two decades are the poster child for our international liquidity buffer story.

The second period of interest runs from 2003 to 2007. Due to the relatively low macroeconomic volatility in many emerging regions, this period is commonly dubbed as the end of the Great Moderation (GM). During this time, the relationship between CTOT shocks and real appreciation remains positive but we lose some significance in our regressions. As shown by the IRFs in figure 4B, the buffer effect of reserves remained strong, delaying any reaction of REER to changes in CTOT by more than a year. The Great Recession (GR) brings a change in the previously found empirical regularities. In short, the link between CTOT and REER seems to decrease substantially, and any role for reserves to buffer the shocks disappears. Figure 4C clearly represents this change. Finally, we observe the relationship between CTOT and REER and our buffer story reappear during the years following the GR (2010 to 2013). Nevertheless, neither the link between CTOT and REER, nor the buffer effect of reserves returned to the levels observed before the crises.

Figure 4. REER IRF to 1% CTOT under High and Low Stock of Reserves by Periods

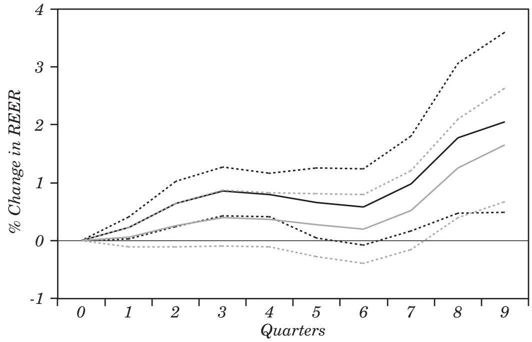


Source: See appendix.

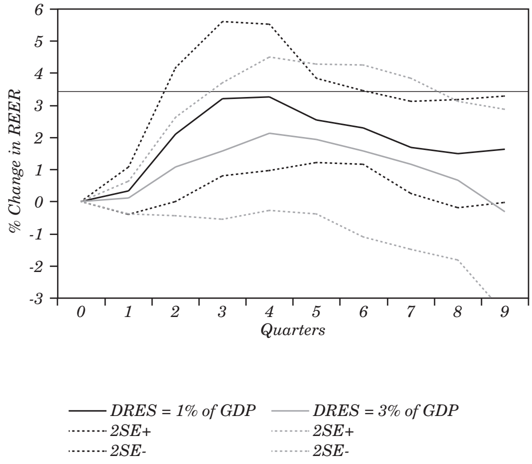
Interestingly, while the stock of reserves fails to smooth the transmission of CTOT shocks to REER during the Great Recession, we observe SWFs stepping up as a potential substitute to traditional reserve assets. Figures 5A and 5B show how moving the stock of SWF assets from 1 to 3 percent of GDP decreased volatility in the GR and the post-GR period by 16 and 32 percent respectively. Column 6 of table 9 shows that SWFs were also effective smoothing the transmission of CTOT shocks to real output growth during the GR and the post-GR periods.

Figure 5. REER IRF to 1% CTOT under High and Low Stock of SWF by Periods

A. Great recession (2008-2010)



B. Post great recession (2008-2010)



Source: See appendix.

5. International Reserves versus Sovereign Wealth Funds: Substitutes or Complements?

Results in the previous section show that during the Great Recession (2007-2009) and the following years, SWFs seemed to inherit the role of buffering LATAM economies against real external shocks previously assigned to international reserves. In this section, we want to look closely at the relationship between the two different tools of liquidity management over last two decades. In order to understand the short-run relationship between movements in the stock of reserves and movements in the balance of SWFs, we build a set of simultaneous equations such as:

$$\Delta RES_t = \sum_{k=1}^{N} \beta_{1k} \Delta SWF_{t-k} + \sum_{k=1}^{N} \theta_{1k} \Delta RES_{t-k} + \varepsilon_t \tag{4}$$

$$\Delta SWF_t = \sum_{k=1}^{N} \beta_{2k} \Delta RES_{t-k} + \sum_{k=1}^{N} \theta_{2k} \Delta SWF_{t-k} + \mu_t \tag{5}$$

where *RES* and *SWF* represent the stock of reserves and the total balance of *SWF* as a ratios of GDP respectively.

In our estimation strategy, we want to account for the potential correlation of the errors terms in these regressions, thus, we collapse equations (4) and (5) into a typical vector autoregression (VAR) specification:

$$\begin{bmatrix} \Delta RES_t \\ \Delta SWF_t \\ \Delta RES_{t-1} \\ \Delta SWF_{t-1} \\ \vdots \end{bmatrix} = \begin{bmatrix} \theta_{11} & \beta_{11} & \dots & \theta_{1n} & \beta_{1n} \\ \theta_{11} & \beta_{11} & \dots & \theta_{1n} & \beta_{1n} \\ 1 & 0 & \cdots & 0 & 0 \\ \vdots & \vdots & & \vdots & \vdots \end{bmatrix} \begin{bmatrix} \Delta RES_{t-1} \\ \Delta SWF_{t-1} \\ \Delta RES_{t-2} \\ \Delta SWF_{t-2} \\ \vdots \end{bmatrix} + \begin{bmatrix} 1 & 0 \\ 0 & 1 \\ \vdots & \vdots \end{bmatrix} \begin{bmatrix} \varepsilon_t \\ \mu_t \end{bmatrix}$$

Or in matrix form,

$$X_t = A(L) X_{t-1} + \in$$

The results of estimating A(L) for a sample of years starting from 2003 (where most SWFs start to arise) and restricting the sample to countries that had stabilizing SWFs (Chile, Colombia, Ecuador, Mexico and Venezuela) are shown in table 10. Since the different information criteria used on both endogenous variables determined a wide array of different optimal lags (from 2 to 8), we show the regressions with three different numbers of lags (2,3 and 4) for robustness. Interestingly, we observe that an increase on assets in SWFs seems to be followed by a significant decrease of international reserves after one quarter in all specifications. These negative correlations range from a 0.6 to 0.9 percent GDP decrease in reserves in the face of a 1 percent GDP increase in SWF balances. To confirm joint significance of the lags we provide the p-values of a simple VAR Granger causality test conducted for both equations in the system. We observe that, while borderline significant at 10 percent, changes in SWFs tend to Granger-cause changes in RES while the opposite can be easily rejected. This evidence seems to reaffirm our substitution story. The emergence of SWFs during the 2000s seemed to provide a valid substitute tool for active liquidity management policies in LATAM countries. While further analysis of these interesting policy interactions seems warranted, we leave a more in-depth analysis for future work.

Table 10. Pool Vector Autoregression Model for the Change of Reserves and Change of SWF

Variables	*1* *DRES*	*2* *DRES*	*3* *DRES*	*1* *DSWF*	*2* *DSWF*	*3* *DSWF*
DRES (t)	0.2325 [0.083]***	0.1880 [0.083]**	0.1482 [0.082]*	0.0182 [0.020]	0.0161 [0.017]	0.0126 [0.018]
DRES ($t-1$)	0.1125 [0.091]	0.0964 [0.088]	0.0784 [0.088]	0.0029 [0.022]	0.0029 [0.019]	0.0071 [0.019]
DRES ($t-2$)		0.2333 [0.093]**	0.2070 [0.093]**		-0.0121 [0.020]	-0.0189 [0.020]
DRES ($t-3$)			0.2370 [0.093]**			0.0100 [0.020]
P-value Granger cause				0.624	0.772	0.778
DSWF ($t-1$)	-0.6036 [0.367]	-0.9471 [0.438]**	-0.9817 [0.473]**	0.1862 [0.088]**	-0.1485 [0.093]	-0.2223 [0.102]**
DSWF ($t-2$)	0.6708 [0.362]*	0.3595 [0.409]	0.1730 [0.421]	0.3719 [0.087]***	0.1009 [0.087]	0.0498 [0.090]
DSWF ($t-3$)		0.7845 [0.523]	0.6970 [0.518]		0.6735 [0.111]***	0.6359 [0.111]***
DSWF ($t-4$)			0.4608 [0.532]			0.2014 [0.114]*
P-value Granger cause	0.13	0.092*	0.175			
Constant	Yes	Yes	Yes	Yes	Yes	Yes
No. observations	113	113	113	113	113	113
R^2	0.109	0.162	0.208	0.278	0.471	0.485

Source: See appendix.
Robust standard errors in brackets. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.
RES STOCK is the total international reserves over GDP. DRES represents 1 period change in RES STOCK. SWF STOCK is the balance of sovereign wealth funds over GDP. DSWF represents 1 period change in SWF STOCK. Sample corresponds to quarterly observations from 2003.I to 2013.IV.

6. Liquidity management and Inflation Targeting

During the last decade and a half, half of our country sample moved to an inflation-targeting regime. This key change in monetary policy regime could, potentially, help explain the resilient macroeconomic performance of Latin American countries during the last decade. Prior to the Great Recession, evidence suggested improved performance for inflation target (IT) adopters, especially among emerging economies (Lin and Ye, 2009; Mishkin and Schimdt-Hebbel, 2007). An important feature among a number of emerging IT economies has been their "flexible" approach to inflation targets. Emerging IT economies are confronted by an additional set of problems to those managed by their advanced economy counterparts. Given their small size and their exposure to external shocks, the exchange rate and the management of capital flows become important targets for these economies (Chinn, 2014). Thus, the emerging economies "flexible" approach to IT is not limited to the use of alternative conventional and unconventional monetary tools, but also to the use of "mixed strategies" where additional targets are imposed by the monetary authority.[10] Aizenman and others (2011) observe that IT emerging markets (especially those exporting basic commodities such as our sample of Latin American economies) appear to use both inflation and real exchange rates as important determinants of policy interest rates. Importantly, for our study, they also observe that the response to real exchange rates is more constrained under IT rather than non-IT regimes. This constrained behavior could translate into less willingness of emerging economies to use liquidity management strategies to smooth real external shocks after the adoption of an IT rule. In this section, we investigate how target rules affected the ability or willingness of LATAM economies to use international liquidity to reduce the macroeconomic volatility inherited from external shocks.

In order to understand the policy goals of LATAM economies we start by setting up an augmented Taylor rule where we 'account' the domestic policy interest rate by a measure of the output gap, CPI inflation and real appreciation. In an alternative specification

10. See Céspedes and others (2014) for a review of the behavior of Latin American targeters under different macroeconomic scenarios. The authors observed a range of behaviors that went from hard targets during normal times to the use of a number of unconventional monetary tools during the Great Recession.

we use a non-linear dummy approach to separate the sample between IT and non-IT countries. Table 11 reports the estimated coefficients. Interpreting these coefficients as the weights across macroeconomic policy goals, we observe that output gaps seem to be the most important component for setting up the policy rate. While inflation gains importance for IT countries, the weight in the Taylor rule seems relatively small. Importantly, for our study, non-IT countries seem to switch from a REER target to an inflation target when committing to an IT rule.[11] This means, potentially, that liquidity management is no longer used towards the stabilization of REER under an IT rule. To investigate this possibility, we adjust our basic specification to account for IT countries and show the results in table 12. Figure 6 builds the IRF for non-IT vs IT countries. As expected, liquidity management seems to be efficient only across non-IT countries, reducing CTOT volatility by 35 percent over two years in the IRF. The relationship between CTOT and REER becomes more chaotic and the buffer story disappears among IT countries. Based on columns 2 and 4 from table 12, SWFs seem to provide IT countries with an alternative form of liquidity management against foreign shocks when traditional reserves are committed to other macroeconomic goals. This is true for both REER and output growth stabilization.

11. This results is consistent with other recent studies using a wider sample of emerging economies, see Chinn (2014).

Table 11. Augmented Taylor Rule

Methodology variables	*LSDV policy rate*	*LSDV policy rate*	*LSDV policy rate*	*HT policy rate*
Policy rate ($t-1$)	0.8406 [0.038]***	0.8529 [0.030]***	0.8572 [0.028]***	0.8042 [0.021]***
Policy rate * IT ($t-1$)			-0.1917 [0.049]***	-0.1682 [0.043]***
ECT RGDP ($t-1$)	38.3912 [6.181]***	35.1963 [5.982]***	32.6971 [8.087]***	28.3668 [7.916]***
ECT RGDP * IT ($t-1$)			-6.0744 [12.187]	-1.8203 [15.827]
INF ($t-1$)	4.4019 [3.042]	2.7090 [3.099]	0.5896 [3.245]	-2.0895 [2.854]
INF * IT ($t-1$)			10.9982 [4.928]**	2.4312 [9.057]
DREER ($t-1$)		12.2343 [6.515]*	19.6533 [9.748]*	17.8656 [4.901]***
DREER * IT ($t-1$)			-21.0437 [10.494]*	-18.6527 [7.736]**
No. observations	1,023	1,023	1,023	1,023
R^2	0.773	0.775	0.782	
Number of countries	13	13	13	13

Source: See appendix.
Robust standard errors in brackets. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.
EC GDP represents real output gap. IT is a dummy with value 1 if the country is targeting inflation, 0 otherwise.
DREER represents real exchange rate appreciation. Quarterly observations from 1980.I to 2013.IV. Observations under hyperinflation episodes (>40% inflation) and with Policy rates above 100 percent are not included.
HT - the Hausman-Taylor regression with all dependent variables considered as potentially endogenous.

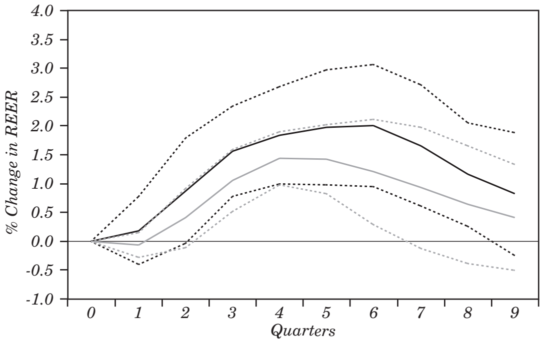
Table 12. The Buffering of International Liquidity Management and Inflation Targeting

Variables	*(1)* *Y= DREER*	*(2)* *Y= DREER*	*(3)* *Y =DRGDP*	*(4)* *Y= DRGDP*
Y ($t-1$)	0.0928	0.0930	0.1632	0.1626
	[0.060]	[0.062]	[0.052]***	[0.053]**
ECT Y ($t-1$)	-0.2370	-0.2323	-0.2672	-0.2681
	[0.068]***	[0.062]***	[0.045]***	[0.044]***
CTOT ($t-1$)	0.8206	0.4369	0.2807	0.1663
	[0.234]***	[0.204]*	[0.069]***	[0.063]**
CTOT * IT ($t-1$)	-1.3213	-0.0374	-0.4233	0.0616
	[0.615]*	[0.336]	[0.171]**	[0.126]
CTOT * RES ($t-1$)	-2.7496		-0.5985	
	[0.642]***		[0.213]**	
CTOT * RES * IT ($t-1$)	7.6299		3.1150	
	[3.202]**		[0.875]***	
CTOT * SWF ($t-1$)		20.9043		8.7804
		[5.864]***		[1.437]***
CTOT * SWF * IT ($t-1$)		-27.1766		-9.0664
		[6.572]***		[2.115]***
IT DUMMY	-0.0046	0.0010	0.0019	0.0032
	[0.009]	[0.007]	[0.001]	[0.002]*
RES ($t-1$)	0.1189		0.0141	
	[0.046]**		[0.009]	
SWF ($t-1$)		0.2097		-0.1283
		[0.112]*		[0.087]
No. observations	1,496	1,496	1,113	1,113
R^2	0.115	0.110	0.184	0.188
Number of countries	12	12	12	12

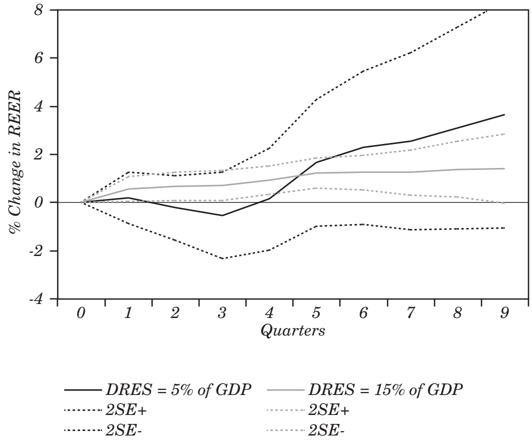
Source: See appendix.
Robust standard errors in brackets. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.
DRGDP represents real output growth. TCTOT represents transitory commodity terms of trade shocks. IT is a dummy with value 1 if the country is targeting inflation, 0 otherwise. RES are the stock of international reserves over GDP. DRES is the change in RES. SWF is the balance of sovereign wealth funds over GDP. Quarterly observations from 1980.I to 2013.IV. For output regressions observations under hyperinflation episodes (>100% inflation) are not included.

Figure 6. REER IRF to 1% CTOT under Inflation Rules

A. Non-IT countries



B. IT countries



Source: See appendix.

7. Discussion

In this paper, we provided evidence consistent with buffer rules using international liquidity to diminish the effects of external shocks. Among these buffer rules we find that SWFs follow fiscal rules that allow countries to manage windfalls and mishaps associated with terms of trade volatility. Similarly, central banks implement buffer rules using 'leaning against the wind' management of international reserves. While we do not evaluate the optimality of these arrangements, this section links our findings with the existing literature. In general, the case for proactive liquidity management may hinge on the structure of the economy, and the quality of its institutions. Chances are that liquidity management, or even welfare reducing, would be redundant with perfect capital markets in the absence of adjustment costs and political and economic frictions. The literature suggests various circumstances and different channels under which buffer policies and liquidity management in the presence of terms of trade shocks may be beneficial for countries with functioning institutions. Velasco (2007) outlines the case of a fiscal rule aiming at curbing the overspending tendencies in a decentralized fiscal system subject to fiscal competition among ministers or provinces. Such a rule aims at reducing the pro-cyclicality bias and excessive fiscal spending in the presence of political competition (see also Velasco, 2000; Frankel, 2011 and Céspedes and Velasco, 2014). In a different context, Devereux and Engel (2007) develop a view of exchange rate policy as a trade-off between the desire to smooth fluctuations in real exchange rates so as to reduce distortions in consumption allocations, and the need to allow flexibility in the nominal exchange rate so as to facilitate terms of trade adjustment. They show that optimal nominal exchange rate volatility will reflect these competing objectives, and find that the optimal exchange rate volatility should be significantly less than would be inferred based solely on terms of trade considerations.[12] Aghion and others (2009) provides a monetary growth model in which real exchange

12. Another perspective on these issues is offered in the presence of sunk fixed costs and uncertainty regarding the permanency of real shocks with entry and exit of heterogonous firms and product variety. In these circumstances, liquidity management aiming at price stability, linked to the perceived permanency of real shocks, may be welfare enhancing (see Bilbiie, Ghironi, and Melitz, 2007).

rate uncertainty exacerbates the negative investment effects of domestic credit market constraints. Testing the relevance of these channels for explaining the possible gains of optimal buffer policy is left for future research.

8. Conclusion

Our paper documents and validates the growing importance of liquidity management for commodity exporting countries. Liquidity management is used to mitigate the transmission from terms of trade shocks to the real exchange rate and output growth, thereby stabilizing the domestic economy. We find evidence that SWFs may provide another margin of stabilization, and this role may be of greater relevance for IT countries, and in periods of heightened volatility. This division of labor is consistent with the Tinbergen rule in policy design: to reach *n* targets, one uses *n* independent instruments. International reserves are useful in dealing with balance sheet exposure, aiming at short and intermediate run stabilization objectives. Yet, hoarding international reserves is not a panacea, as the opportunity cost of reserves imposes a fiscal cost, and hoarding reserves may require sterilization to mitigate their inflationary consequences. Thereby, inflation targeting regimes may relegate the goal of real exchange rate stabilization to its sovereign wealth fund. Such a fund may have greater risk tolerance, and its accumulation directly impacts the fiscal stance and the real exchange rate.[13] Remarkably, the buffering role of reserves and SWFs does not need East Asian levels of hoarding–they are operative in LATAM at relatively modest levels of reserves/GDP and SWF/GDP.

13. This assignment is consistent with the view that IR has a comparative advantage dealing with balance sheet exposure, SWFs with longer term saving and fiscal stabilization.

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Appendix

Data Definition and Sources

CTOT: Commodity terms-of-trade data set was constructed following Ricci et al. (2008):

$$CTOT_i = \prod_j (P_j/MUV)^{X_j^i} / \prod_j (P_j/MUV)^{M_j^i},$$

where P_j is the price index for six commodity categories (food, fuels, agricultural raw materials, metals, gold, and beverages), and (X_{ij} , M_{ij}) are the average shares of commodity *j* in country *i*'s exports and imports over GDP for the period 1980-2012, respectively. Commodity prices are deflated by the manufacturing unit value index (*MUV*). Sources: UN ComTrade, IMF, World Bank.

TCTOT: Transitory CTOT shocks are defined as the log deviations of actual CTOT from long-run values calculated through a HP filter.

REER: Real effective exchange rate is defined a trade based weighted average of nominal bilateral exchange rates deflated by the relative consumer price indices. An increase in REER represents a real appreciation of the domestic currency. **DREER** represents the log change in REER. Sources: DataStream, IMF.

RES: The stock of foreign reserve assets is measured in millions of U.S. dollars and deflated by the five year moving average of the interpolated annual nominal Gross Domestic Product. **DRES** represents the change in the reserves to GDP ratio. Global Financial Data, IMF.

ECT REER: Error correction REER is the log difference between current REER and long-term REER. In order to compute the equilibrium/long-run REER, we use a co-integrating approach. The methodology calls for a series of co-integrating regressors. Following Edwards (1989), Montiel (1999) and others, we estimate the following equation:

$$Ln(REER)_t = \alpha + \mathrm{B}\begin{bmatrix} Ln(CTOT)_t \\ GOV_t \\ TradeOpen_t \\ USINF_t \\ TimeTrend_t \\ IntSpread_t \end{bmatrix} + \varepsilon_t \qquad \text{(A1)}$$

The term *CTOT* is commodity terms of trade, *GOV* represents the share of government expenditures over GDP, TradeOpen is a measure of Trade Openness (exports plus imports over GDP), *USINF* is a measure of inflation in the U.S. based on the U.S. CPI and represents world inflation and IntSpread is the domestic market reference interest rate spread from the 3-month U.S. T-Bill. Once we obtain the coefficients from equation (A1), we use the HP filter to find the long-run values of the fundamentals, we then use these values, jointly with the estimated coefficients, to generate what we refer to as the Long-run REER (LRREER). Sources: World Bank, Penn Tables.

RGDP: Real GDP is taken at a true quarterly frequency from different sources. Table A1 shows the source and data availability. **DRGDP** represents the log change in RGDP.

Table A1. Real GDP Data Sources in Latin America

Country	*Source*	*Data*
Argentina	Inter American Development Bank	1990.I
Bolivia	Inter American Development Bank	1990.I
Brazil	Inter American Development Bank	1990.I
Chile	Global Financial Data	1991.I
Colombia	Global Financial Data	1994.I
Costa Rica	FRED	1991.I
Ecuador	Global Financial Data	1992.I
Mexico	FRED	1981.I
Paraguay	Inter American Development Bank	1994.I
Peru	Global Financial Data	1980.I
Uruguay	Inter American Development Bank	1997.I
Venezuela	Inter American Development Bank	1993.I

FIXED vs FLEX FOREX DUMMIES: Using the de facto exchange rate regime classification of Ilzetzki, Reinhart, and Rogoff (2008), we define, a nominal fixed exchange regime as one where the country either has no legal tender, a hard peg, a crawling peg, and de facto or pre-announced bands or crawling bands with margins of no larger than +/- 2%. All other arrangements are classified as nominal flexible regimes (we exclude episodes of "Free Falling" from the sample of the regression). Sources: Reinhart, C. M., & Rogoff, K. S. 2002. "The Modern History of Exchange Rate Arrangements: a Reinterpretation." (No. w8963). National Bureau of Economic Research.

TRADE OPEN vs CLOSED DUMMIES: Based on the literature we consider a country to be "Open" if our ratio (EX+IM)/GDP is larger than 40% and close if its lower than 40%.

HIGH vs LOW DEBT DUMMIES: We consider High Government Debt any amount over 45 percent of GDP.

IT: Inflation targeting is a dummy with value 1 if the country is officially targeting inflation and zero otherwise. The table 3 shows the IT country/periods. Target bands and transition periods.

SWF: Balance of Sovereign Wealth Fund balances obtained from commodity revenues and dedicated to macroeconomic stabilization. SWF is measured in millions of U.S. dollars and is deflated by the five-year moving average of the interpolated annual nominal GDP. **DSWF** represents the change in SWF balance over GDP ratio. See table 2 for the summary of the funds.

Central Bank Policy Rate: Reference interest rate used by the central bank to conduct monetary policy. Table A2 are the reference rates used and data availability.

Table A2. Data Availability for the Monetary Policy Rate in Latin America

Country	*Policy rate*	*Data availability*
Argentina	Argentina 15-day Loans to Financial Institutions	1980-2013
Bolivia	Bolivia Central Bank Discount Rate	1980-2014
Brazil	Brazil Deposit Rate Over SELIC	1980-2015
Chile	Chile Monetary Policy Rate	1990-2016
Colombia	Colombia Bank of the Republic Discount Rate	1980-2017
Costa Rica	Costa Rica Central Bank Deposit Rate	1991-2018
Ecuador	Ecuador Central Bank Discount Rate	1980-2019
Mexico	Mexico 28 Day Interbank Rate (TIIE)	1980-2020
Paraguay	Paraguay Interbank Rate	1990-2022
Peru	Central Bank of Peru Discount Rate	1980-2023
Uruguay	Uruguay Central Bank Discount Rate	1981-2024
Venezuela	Venezuela Central Bank Discount Rate	1980-2025

Sources: Global Financial Data, DataStream.

Glossary of Terms for Tables in the Appendix

REER:	Real Effective Exchange Rate. An increase implies real appreciation.
DREER	One period log change in REER.
RES:	Stock of Reserves over GDP.
DRES:	One period change in the reserves over GDP.
TCTOT:	Transitory CTOT shocks are defined as the log difference between CTOT and a long-run measure of CTOT obtained from applying the HP filter to the original series.
RGDP:	Real Gross Domestic Product in national currency and seasonally adjusted.
DRGDP:	One period log change of RGDP.
X and Y:	We use "X" and "Y" to proxy for the different variables used in different specifications across the same table. See the top row of each column to see what these variables are in each specification.
ECT:	The Error Correction Term is the distance of the variable to the long-run value. See appendix for the description of the REER long-run value. For output growth, we take log deviations from the smoothed series obtained from applying the HP filter to the original series.
SWF:	Balance of the Macro-Stability Sovereign Wealth Fund as a ratio of GDP.
DSWF:	One period change in the balance of SWF over GDP.
GM:	Great Moderation Dummy: 1 if between 2003.I-2007.IV, 0 otherwise.
GR:	Great Recession Dummy: 1 if between 2008.I-2009.IV, 0 otherwise.
AGR:	After Great Recession Dummy: 1 if between 2010.I-2013.IV, 0 otherwise.
INF:	Inflation measured as the log difference of the consumption price index.
IT:	Inflation Target Dummy: 1 if the country has an Inflation Target, 0 otherwise.

Terms of Trade Shocks and Investment in Commodity-Exporting Economies

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Commodity prices have experienced significant swings over the past two decades. Real commodity prices have, on average, more than doubled in the last decade compared to the previous one, while the prices of some commodities, such as copper and other industrial metals, have more than tripled in real terms. Commodity-exporting economies such as Chile have therefore enjoyed very favorable terms of trade (ToT) by historical standards (figure 1); for Chile, the only main exception is the golden period of saltpeter mineral extraction from 1895 to 1930. Hence, it is not surprising that many policy discussions in commodity-exporting economies have focused on the effects of commodity price fluctuations on output, inflation, real exchange rates, the current account and other macroeconomic variables, as well as on appropriate policy frameworks to deal with commodity price volatility.[1] This issue is also highly relevant in the present context where monetary policy in advanced economies

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1. See, for instance, IMF (2011) chapter 3 and IMF (2012) chapter 4.

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is being normalized and growth in emerging market economies is slowing down with adverse effects on commodity prices and exporters that are vulnerable to a fall in prices.

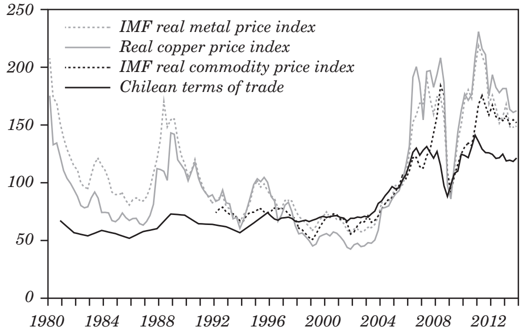
The macroeconomic effects of commodity price fluctuations have been widely studied in the literature, where two major strands can be distinguished.[2] The first one includes studies based on time-series methods such as structural vector autoregressions (SVARs) that attempt to estimate the effects of exogenous commodity price movements on macroeconomic aggregates through short-run or long-run identification and/or sign restrictions.[3] Among those studies are, for instance, Bernanke and others (1997), Blanchard and Galí (2007), Kilian (2008; 2009), Kilian and Lewis (2011), Lombardi and others (2012), Baumeister and Peersman (2013), Gubler and Hertweck (2013), and Filardo and Lombardi (2014). However, most of these studies have focused on the impact of oil price shocks in developed countries such as the United States or Europe (all net commodity importers); whereas, relatively few studies have examined the effects of commodity price shocks in economies that rely heavily on commodity exports (and in particular mineral exports) like many developing and emerging market countries. Only a few recent studies have analyzed this topic, such as Camacho and Pérez-Quirós (2014) who investigate the dynamic interactions between commodity prices and output growth of major Latin American commodity exporters using Markov-switching impulse response functions, or Gruss (2014) who uses Global VAR analysis to examine the impact of commodity price cycles on output growth in Latin America and the Caribbean. In addition, Knop and Vespignani (2014) use SVAR analysis to estimate the effects of commodity price shocks on different industries such as mining, construction and manufacturing in Australia.

The second major strand of the literature is based on dynamic stochastic general equilibrium (DSGE) models that allow us to analyze, in a structural micro-founded framework, the different transmission channels and propagation mechanisms of commodity price shocks and to conduct policy experiments. Among these studies are, for instance,

2. Other related studies are Cashin and others (2004), Raddatz (2007), Izquierdo and others (2008), Adler and Sosa (2011), De Gregorio and Labbé (2011), and Céspedes and Velasco (2012), among others.

3. In the literature, sometimes commodity export price shocks are treated differently than ToT shocks. This distinction may or may not make sense depending on the size of the economy, importance of the commodity sector, co-movement of import and export prices, etc. For our selection of countries and sample periods, both definitions are fairly similar since the ToT for the countries considered are highly correlated with commodity prices.

Figure 1. Commodity Price Indices and Chilean ToT (2005 = 100), 1980.I-2013.IV



Source: See the appendix. Notes: The Chilean ToT series for the period from 1996 onwards is obtained from the Central Bank of Chile. For the period before 1996, we use interpolated annual ToT data from Clio Lab, Pontificia Universidad Católica de Chile. Further details on data sources and definitions are provided in appendix.

Kilian and others (2009), Tober and Zimmermann (2009), Bodenstein and others (2011), and Bodenstein and others (2012). However, most of these studies also focus on the effects of commodity price shocks (and mainly oil shocks) in developed countries, while the literature for developing and emerging commodity-exporting economies is less extensive. Some exceptions include Medina and others (2008) who explore what factors explain current account developments in Chile and New Zealand; Desormeaux and others (2010) who use a DSGE model to examine the transmission mechanism of commodity prices to inflation dynamics; Kumhof and Laxton (2010) who analyze Chile's structural surplus fiscal rule in the face of shocks to the world copper price; and Malakhovskaya and Minabutdinov (2014) who examine the effects of shocks to commodity export revenues in an estimated DSGE model for Russia. However, none of the above studies have analyzed the macro impact of commodity price shocks through their effects on investment in different sectors of the economy. A further examination to fill this gap is therefore interesting in view of recent sectoral investment dynamics in many commodity-exporting economies (also see Knop and Vespignani, 2014).

Hence, the objective of this paper is to analyze the effects of commodity price shocks in commodity exporters from a broad perspective, focusing on metals exporters such as Chile where we highlight the propagation of those shocks through investment in mining and its macroeconomic spillover effects. This focus is motivated by the mining investment boom observed in most major commodity-exporting economies during the last decade, the impact of the latter on external savings balances, and their policy implications.

To conduct our analysis we employ two different methodologies: SVAR analysis and a DSGE model. First, the SVAR approach is aimed at exploring broad cross-country patterns and dynamics in the data. Here we analyze questions such as the following: How do commodity prices interact in the first place with other key variables of the world economy such as output, inflation and interest rates? How do commodity price shocks affect domestic variables? Are the effects similar across countries? Does the persistence of commodity price shocks matter for its impact on macroeconomic variables such as investment? To facilitate this econometric exercise, we analyze a group of small open economies as our identification approach relies on the exogeneity of commodity price fluctuations for commodity exporters.

Second, recognizing the usual difficulties that are involved in the identification of SVAR shocks, we use a DSGE model to add a different dimension to our analysis. This methodology not only allows to investigate the key propagation channels of commodity price shocks in a structural micro-founded way, but it is also useful to further explore several hypotheses that are raised by the SVAR results. For example, even though one may naturally expect a positive response of mining investment to a commodity price shock, it is not clear whether a rise in commodity prices triggers a boom in investment in both mining and non-mining sectors, or whether mining investment crowds out other aggregate demand components.[4] In addition, we may ask whether the persistence of commodity price shocks matters. Finally, the DSGE model is useful to conduct counterfactual policy experiments to answer questions such as the following: How is the response of the economy to commodity price shocks affected by different types of fiscal rules? Should monetary policy try to limit exchange rate fluctuations due to such shocks? For this purpose, we use a New Keynesian small open economy model estimated for Chile. The DSGE model by Medina and Soto (2007a) is extended by including an endogenous commodity production structure. In

4. For instance, at the sectoral level, traditional exporters might suffer a loss of competitiveness if mining sectors compete with other sectors for resources. If this competition implies higher demand and inflation of non-tradable goods, there would be a real appreciation of the currency. The resulting reallocation is challenging for traditional export sectors, a widely studied phenomenon known as the Dutch disease.

addition, we parameterize the block of external variables with the SVAR estimates for Chile. With this model we are able to analyze the main propagation channels of a commodity price shock to decompose historical fluctuations of investment and GDP and to conduct two counterfactual experiments: alternative fiscal rules and response of monetary policy to exchange rate fluctuations.

Our contribution to the literature is thus twofold. First, we provide a study of the impact of commodity price shocks on sectoral investment in commodity-exporting economies based on a SVAR approach. Second, we augment an otherwise standard New Keynesian small open economy model with a commodity sector by an endogenous production structure in order to analyze the transmission channels and policy implications of commodity price shocks.

The main results from the SVAR analysis corroborate that commodity price shocks are an important source of business cycles in commodity-exporting economies. More in particular, we find that those shocks have significant effects on real GDP through their impact on investment where investment in mining shows relatively large, lagged and persistent responses in most analyzed countries. We also find that local currencies appreciate and current account balances deteriorate in some countries as investment rises; inflation shows mixed responses depending on the size and persistence of the exchange rate effect, and interest rates rise in most countries. Furthermore, a stronger persistence of commodity price shocks generates a much larger expansion of mining investment that tends to spill over to non-mining sectors.

Most of these empirical findings are in line with the dynamics predicted by the DSGE model for Chile. In fact, according to the model, mining investment is an important commodity price shock propagation channel where there is a direct link between the duration of the price increases and their macroeconomic impact. Moreover, the model shows that an investment boom in mining can generate a relatively persistent current account deficit. From a policy perspective, our results further suggest that while different monetary and fiscal policy reactions have, in general, important implications for the response of the economy to commodity price shocks, they do not majorly affect investment decisions in the commodity sector that are mainly driven by sectoral productivity developments and, particularly, commodity prices.

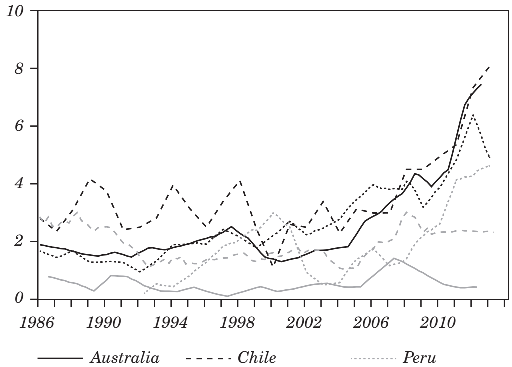
The remainder of the paper is structured as follows. Section 1 discusses a number of stylized facts regarding the recent evolution of investment, real GDP growth and current account balances in selected commodity exporters. Section 2 presents the SVAR analysis conducted for several commodity exporters. Section 3 describes the DSGE model for Chile while section 4 documents the results of the model-based analysis. Finally, section 5 concludes.

1. Recent Evolution of Investment, GDP Growth and Current Account Balances in Commodity-Exporting Economies

In this section we discuss a number of common patterns regarding the recent evolution of investment, GDP growth and current account balances in commodity-exporting economies.

To begin with, mining investment has expanded at a higher rate than GDP (in terms of nominal ratios) in most major commodity-producing countries as figure 2 shows. This increase in investment evolved, to a certain extent, in parallel with the commodity price boom after 2004, but with some lag. For example, in Australia, Canada, Chile and Peru investment in mining as a share of GDP more than doubled in the late 2000s with respect to the average observed in the nineties and early 2000s. The case of South Africa is somehow

Figure 2. Investment in Mining Sectors 1986.IV-2013.IV
Percentage of nominal GDP

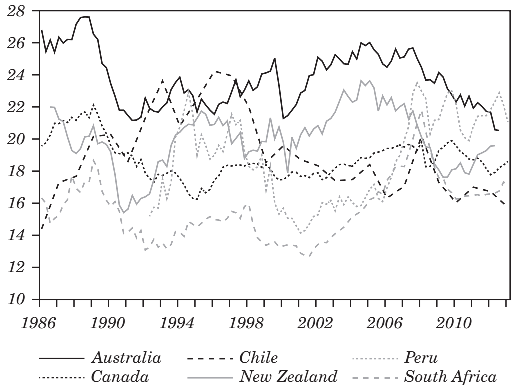


Source: See the appendix.
Note: Investment in mining for Canada includes oil well industries.

different because the increase in the ratio after the mid-2000s recovered figures observed in the eighties. Finally, New Zealand experienced a milder and shorter increase in mining investment.

Furthermore, figure 3 illustrates the evolution of non-mining investment shares for our selection of commodity exporters. In the mid-2000s, non-mining investment increased in several countries compared to its early 2000s volume, but much less than mining investment and relative to historical averages. Hence, most of the increase in total investment in those countries during the recent commodity cycle was due to higher investment in mining.

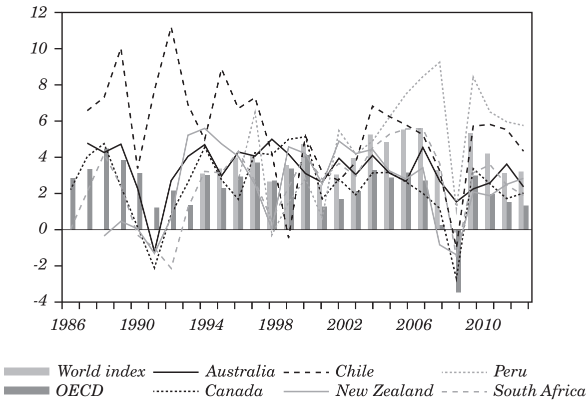
Figure 3. Investment in Non-Mining Sectors, 1986.IV-2013.IV
Percentage of nominal GDP



Source: See the appendix.

Higher investment in those countries has pushed aggregate demand and real GDP growth. Figure 4 compares the growth performance of our selection of countries with the world average and with the average of OECD countries between 1986 and 2013. Notably, the annual real GDP growth rates of most of the selected countries since the mid-2000s were above the OECD average. Economic growth was especially high in Chile and Peru, who grew at a faster pace than the world and OECD average. South Africa was located in the middle as it grew similarly as the world average. Finally, Australia, Canada and New Zealand performed slightly better than the OECD average, but worse than the world average. Differences in these countries' economic growth rates are driven by both structural and cyclical factors. One possible structural explanation hinges on the capital-deepening hypothesis according to which economic growth rates tend to reflect different stages of development (Chile and Peru are less developed than Australia, Canada and New Zealand). In addition, as Gruss (2014) suggests, the commodity price boom may have pushed real GDP growth of Latin American countries above trend.

Figure 4. Real GDP Growth, 1986-2013
Percentage, annual average

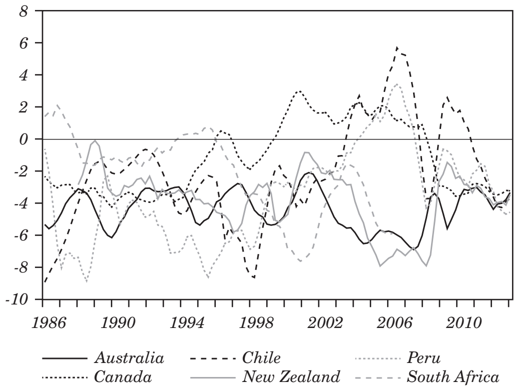


Source: See the appendix.

Finally, figure 5 shows that, despite the high commodity prices, the current account balances of most commodity exporters have been in deficit. Some countries such as Australia, New Zealand and South Africa have been net international borrowers since the late nineties, but it seems surprising that these countries did not save at least part of the unprecedented rise in commodity income since the mid-2000s. The remaining countries, and in particular Chile and Peru, did have positive external savings balances during the mid-2000s, but their current accounts also moved into deficit later on.[5] Are those current

5. There are several hypotheses regarding underlying mechanisms that might explain such current account reversals. For instance, Fornero and Kirchner (2014) show that changes in agents' perceptions on the persistence of the commodity boom can explain the observed behavior of Chile's current account. Their argument is based on evidence of forecast revisions by professional forecasters and the panel of experts that determines the parameters of Chile's fiscal rule.

Figure 5. Current Account Balances, 1986.I-2013.IV
Percentage of nominal GDP



Source: See the appendix. Note: Current account ratios of Australia, Chile, Peru and South Africa are four quarters moving averages.

account deficits due to the investment boom in those countries, and how is the latter related to the surge in commodity prices? What does the macroeconomic adjustment to commodity price shocks look like in commodity exporters such as Canada, Chile, Peru and New Zealand? Are the adjustments different or are they similar? To answer these questions, we now conduct a SVAR analysis of the effects of commodity price shocks in those countries.

2. Structural VAR Analysis

In this section we estimate SVAR models for Australia, Canada, Chile, New Zealand, Peru and South Africa. These countries are commodity exporters that satisfy the small open economy assumption such that foreign variables may be regarded as exogenous. Table 1 reports the recent export shares of this selection of countries. It is noteworthy that Australia, Chile, Peru and South Africa are major exporters of industrial metals. Exports of Canada and New Zealand are also concentrated in commodities, but not as much metals. Hence, these two countries are useful benchmarks to compare our results.

Table 1. Top Five Products Exported in 2013 in Selected Commodity Exporters

Australia	Iron ore & concentrates (26.7%)	Canada	Petroleum (21.4%)
	Coal (15.2%)		Motor vehicles & equipment (12.6%)
	Natural gas (5.6%)		Gold (3.6%)
	Gold (5.3%)		Aircrafts & equipment (2.3%)
	Petroleum (4.5%)		Natural gas (2.2%)
Chile	Copper (29.7%)	N. Zealand	Milk, cream & milk products (20.4%)
	Copper ores & concentrates (22.4%)		Meat (11.4%)
	Fruits (8.0%)		Rough wood (4.9%)
	Fish (5.0%)		Butter (4.6%)
	Pulp & waste paper (3.6%)		Petroleum (3.6%)
Peru	Copper ores & concentrates (17.0%)	S. Africa[a]	Iron ore & concentrates (15.8%)
	Gold (14.2%)		Silver, platinum (7.4%)
	Petroleum (10.0%)		Ores & concentrate of base metals (6.5%)
	Ores & concentrate of base metals (8.7%)		Coal (6.1%)
	Copper (7.6%)		Gold (5.3%)

Source: UNCTAD Statistics, based on UN DESA and UN Comtrade.
a. Estimated values.

2.1 Data

Regarding the data, apart from an external block of variables, we use official quarterly data for each country on GDP, mining and non-mining investment, inflation, interest rates, real exchange rates and current account balances. The sample coverages include explicit or implicit inflation targeting monetary regimes. For Australia, the sample begins in 1993.II and ends in 2013.II due to restrictions of mining investment data. For Canada, the sample covers the period 1991.III-2013.IV. For Chile, the considered period is 1996.I-2014. IV.[6] For New Zealand, the sample period is 1991.I-2013.IV. For Peru, the sample spans the period from 1998.I to 2013.IV. Finally, for South Africa the sample period is 1995.I-2014.I. The foreign block of variables includes a measure of world GDP, foreign inflation and interest rates and a real commodity price index. Details of variable definitions, transformations and sources are provided in appendix. We apply homogeneous transformations to facilitate the comparison of shock sizes and their effects across countries.

2.2 Empirical Model

The empirical model is a standard SVAR with block exogeneity to account for the main characteristics of small open economies. Thereby, it is assumed that foreign variables do not respond to changes in domestic variables. This methodology allows an efficient estimation (compared to an unrestricted VAR) of the joint evolution of domestic and foreign variables. Following Hamilton (1994), the reduced-form VAR can be written as follows:

$$\begin{bmatrix} y_{1,t} \\ y_{2,t} \end{bmatrix} = \begin{bmatrix} c_1 \\ c_2 \end{bmatrix} + \begin{bmatrix} \mathbf{A}_1' & \mathbf{A}_2' \\ \mathbf{B}_1' & \mathbf{B}_2' \end{bmatrix} \times \begin{bmatrix} x_{1,t} \\ x_{2,t} \end{bmatrix} + \mathbf{D} \begin{bmatrix} z_{1,t} \\ z_{2,t} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \end{bmatrix}$$

6. Chilean nominal mining investment in 2014 is estimated using the 2014 annual growth rate of mining investment of Cochilco and FECU *(Ficha Estadística Codificada Uniforme)* reports. Both sources report downward revisions: the former implies a larger fall of -39.7%, while the latter yields -18.2%. Notice that these growth rates result from taking investment denominated in U.S. dollars, so we adjust for annual changes of the nominal exchange rate. In particular, the 2014 annual growth rate estimated from FECU combines effective data for 2014Q1-2014Q3, and the investment for the fourth quarter is assumed to be equal to the average of the first three quarters.

where $y_{1,t}$ and $y_{2,t}$ are vectors of n_1 foreign variables and n_2 domestic variables, respectively. Accordingly, current outcomes are explained by previous developments measured by p lags in the variables $y_{1,t-1}, \ldots, y_{1,t-p}$ and similarly for y_2. This lagged information is gathered in $x_{1,t}$ and $x_{2,t}$, of dimensions $n_1 p \times 1$ and $n_2 p \times 1$, respectively. In addition, the vector z_t includes deterministic terms such as time trends and constants. The unknown coefficients to be estimated are the elements of the vectors c_1 and c_2 and the matrices $\mathbf{A}_1'$, $\mathbf{A}_2'$, $\mathbf{B}_1'$, $\mathbf{B}_2'$, and $\mathbf{D}$. The errors $\varepsilon_{1,t}$ and $\varepsilon_{2,t}$ are of dimension $n_1 \times 1$ and $n_2 \times 1$, respectively. By definition, errors are expected to be zero on average and their variance-covariance matrix is positive definite.

The VAR is further restricted to reflect the small open economy assumption, namely, we impose that $\mathbf{A}_2' = 0$ such that y_1 forms an exogenous block of variables (under the identification scheme that is described below). The resulting system of equations, subject to $\mathbf{A}_2' = 0$, can be estimated by full information maximum likelihood. The implementation is standard and follows the algorithm described in Hamilton (1994).

The exogenous foreign block is composed of the following: (1) an index of real world GDP (in logs), (2) annual U.S. CPI inflation, (3) U.S. federal funds nominal rate and (4) a real commodity price index (in logs).[7] Structural shocks are identified using a Cholesky decomposition of the variance-covariance matrix of the VAR residuals. Therefore, the ordering of the variables implies a recursive identification scheme with the first of the aforementioned variables being the most exogenous. In particular, we assume that U.S. inflation and interest rates respond contemporaneously to exogenous changes in world GDP while world GDP does not respond within a quarter to exogenous changes in inflation and interest rates. The interest rate is assumed to respond to exogenous changes in inflation in the same quarter, but not vice versa. This ordering of variables is fairly standard in monetary SVARs. In addition, we order commodity prices after the remaining external variables to reflect the usage of commodities as financial assets that adjust instantaneously to news on the remaining foreign variables, including foreign interest rates.[8] Hence, under this particular recursive

7. Due to parsimony reasons, the oil price is not included in the external block of the VAR system. In the model of the following section, the oil price is thus assumed to follow an exogenous AR(1) process.

8. We have tried alternative orderings (e.g., ordering commodity prices before interest rates to reflect the fact that these form part of the Fed's information set when monetary policy decisions are taken), overall our main results remain robust to those alternative orderings.

identification scheme, commodity price shocks could also be interpreted to capture signals on future changes in world demand for commodities that are associated with a delayed response of world GDP, inflation and interest rates.[9]

The endogenous domestic block includes seven key variables for each country: (1) real GDP (in logs), (2) nominal non-mining investment as a percentage of nominal GDP, (3) nominal mining investment as a percentage of nominal GDP, (4) the annual CPI inflation rate, (5) the annual nominal monetary policy rate, (6) the real exchange rate (in logs), and (7) the current account balance as a percentage of nominal GDP.

Regarding the lag length of the SVARs, standard information criteria (Schwarz, Akaike and Hannan-Quinn) point towards one or two lags. However, for the sake of parsimony and to facilitate comparisons across countries we choose one lag for all reported estimations. Finally, we add a constant and a quadratic time trend as deterministic terms.

2.3 Cross-Country Comparison of SVAR Results

Table 2 reports the impulse responses of foreign variables to an unexpected commodity price shock of 50%, which roughly corresponds to the observed average increase of real commodity prices in the mid-2000s. In general, the SVAR estimates suggest that the increase in commodity prices is relatively persistent for all countries with a half-life of the commodity price responses ranging between two and three years for most countries (except Peru where the half-life of the shock is less than two years). The estimated shocks are coherent with a delayed expansion of world GDP that is statistically significant at conventional levels and persistent across countries. The peak effect on world GDP materializes after two to three years and ranges between 1.5% and 2.5%. Moreover, all estimations suggest a statistically significant rise in global inflation, which increases up to around one percent after a year. Higher output and inflation explain why interest rates increase consistently with flexible inflation targeting frameworks adopted by the Federal Reserve and other leading central banks around the world.

9. This interpretation is in line with Frankel (2006; 2008a; 2008b) and Calvo (2008).

Table 2. Impulse Responses to Commodity Price Shocks (50%) from SVAR Models, External Variables

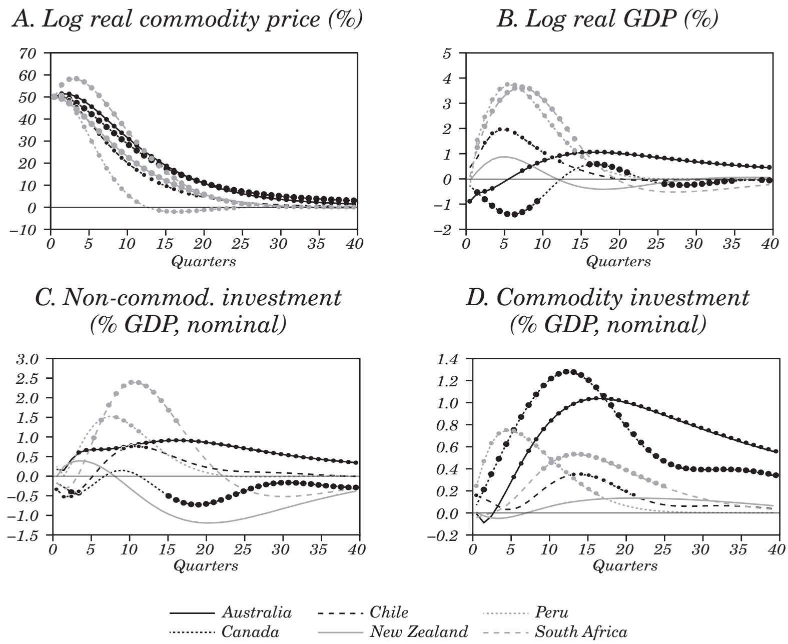
	Log real foreign GDP						*Annual foreign inflation*					
Qrt.	*Aus.*	*Can.*	*Chile*	*NZ*	*Peru*	*SA*	*Aus.*	*Can.*	*Chile*	*NZ*	*Peru*	*SA*
$t = 0$	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$t = 1$	**0.7**	**0.5**	**0.8**	**0.5**	**0.9**	**0.9**	**0.5**	**0.4**	**0.4**	**0.4**	**0.7**	**0.5**
$t = 4$	**1.9**	**1.5**	**1.6**	**1.5**	**1.9**	**2.3**	**1.2**	**0.9**	**0.7**	**1.0**	**1.4**	**1.2**
$t = 8$	**2.2**	**1.9**	**1.3**	**1.8**	**1.3**	**2.4**	**1.2**	**1.0**	**0.5**	**0.9**	**0.8**	**1.1**
$t = 12$	**1.9**	**1.7**	**0.7**	**1.6**	**0.4**	**1.6**	**0.9**	**0.8**	**0.2**	**0.7**	**0.2**	**0.8**
$t = 16$	**1.4**	**1.4**	**0.3**	**1.2**	0.0	**0.9**	**0.6**	**0.6**	0.1	**0.5**	0.0	**0.4**
$t = 20$	**1.0**	**1.0**	0.1	**0.8**	**-0.1**	**0.4**	**0.4**	**0.4**	0.0	**0.3**	**-0.1**	**0.2**

	Foreign interest rate						*Log real commodity price*					
Qrt.	*Aus.*	*Can.*	*Chile*	*NZ*	*Peru*	*SA*	*Aus.*	*Can.*	*Chile*	*NZ*	*Peru*	*SA*
$t = 0$	0.0	0.0	0.0	0.0	0.0	0.0	**50**	**50**	**50**	**50**	**50**	**50**
$t = 1$	**0.4**	**0.5**	**0.5**	**0.5**	**0.6**	**0.5**	**51**	**50**	**51**	**49**	**51**	**55**
$t = 4$	**1.1**	**1.3**	**0.9**	**1.4**	**1.2**	**1.1**	**48**	**45**	**41**	**41**	**36**	**57**
$t = 8$	**1.2**	**1.5**	**0.6**	**1.4**	**0.8**	**1.0**	**37**	**34**	**26**	**28**	**13**	**42**
$t = 12$	**1.0**	**1.1**	0.2	**1.0**	**0.3**	**0.6**	**25**	**23**	**15**	**17**	1	**26**
$t = 16$	**0.6**	**0.6**	0.0	0.5	0.0	**0.2**	**17**	**16**	**8**	**10**	**-2**	**13**
$t = 20$	**0.4**	**0.2**	-0.1	0.1	0.0	0.0	**11**	**11**	5	**6**	**-1**	**6**

Source: Authors' elaboration.
Note: Bold values are statistically significant at the 90% confidence level.

Concerning the domestic effects of the commodity price shocks, figure 6 shows the responses of real GDP and investment in mining and non-mining sectors (as a ratio of nominal GDP). The results show that the estimated commodity price shocks generate an expansion of real GDP in most countries that is partly driven by investment. On one hand, investment in mining tends to react little on impact, but afterwards the responses are positive, relatively large and persistent for the majority of countries, pointing to an expansion of capacity that takes time to materialize. The effects of the commodity price are estimated to be stronger in countries with larger commodity sectors, i.e., Australia, Canada, Chile, Peru and South Africa, whereas, they are not significant for New Zealand. In the case of Chile, the effects are smaller due to the lower persistence of the shock. In Peru, where the shock is also less persistent than in other countries, the effects are stronger initially but less persistent than on average.

Figure 6. Impulse Responses from SVAR Models, Selected Countries

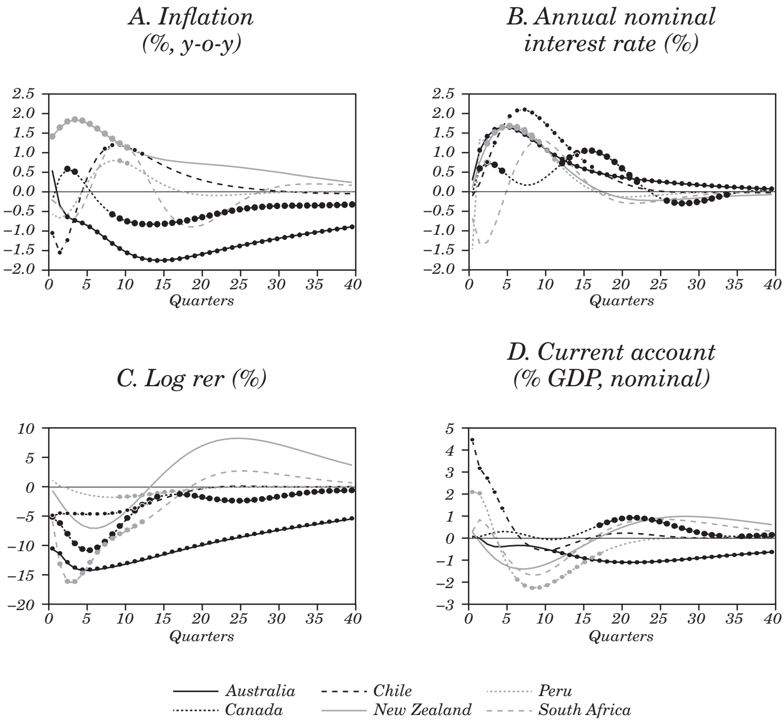


Source: Authors' elaboration.

Notes: Shock is of size 50%. Circles indicate quarters in which the responses are statistically significant at the 90% confidence level.

On the other hand, non-mining investment shows more heterogeneous responses across countries. In the mining-exporting countries (Australia, Chile, Peru and South Africa), the increase in non-mining investment is larger than real GDP. One interpretation of this result is that mining investment induces more investment in construction while it boosts imports of machines and equipment. In contrast, in countries with a more diversified trade structure such as New Zealand and Canada, the reaction of non-mining investment is not significant or negative such that mining investment may crowd out other investment in those countries.

Figure 7. Impulse Responses from SVAR Models, Selected Countries



Source: Authors' elaboration.

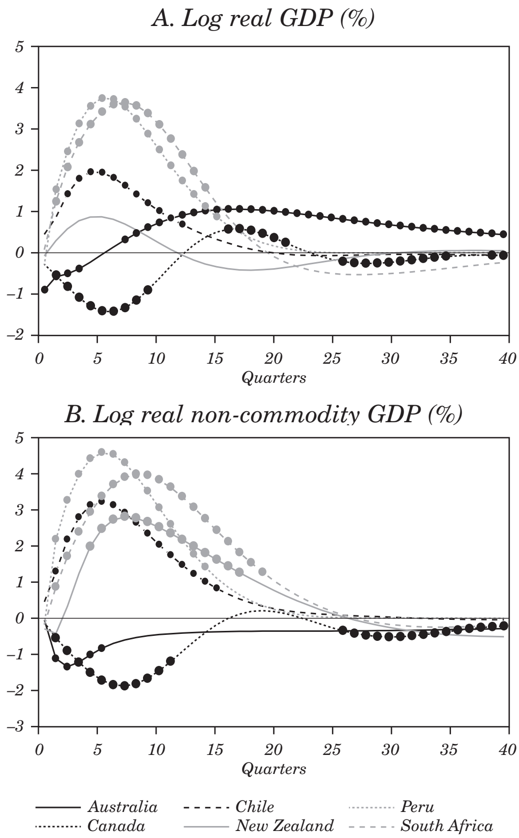
Notes: Shock is of size 50%. Circles indicate quarters in which the responses are statistically significant at the 90% confidence level.

Figure 7 shows the responses of real exchange rates, inflation, interest rates and the current account balances in the different countries. With the exception of Peru and New Zealand, all countries present a significant real appreciation of local currencies in the short-run. These movements in real exchange rates are consistent with an upward adjustment in domestic absorption and demand due to the positive wealth effect associated with the shock. They also explain why inflation falls in some cases despite the increase in demand due to the pass-through effect of the real appreciation on consumer prices. In fact, the negative effects on inflation are stronger in countries with a more persistent real exchange rate appreciation (Australia and Canada). In addition, consistently with higher output and in some cases positive inflation, the estimated responses of monetary policy rates are significantly positive in all countries except South Africa.

Interestingly, current account balances move into deficit in several countries while in some countries (Chile and Peru) we observe a reversal effect after initial surpluses (although this effect is not significant for Chile). The negative and delayed current account responses are evidently related to the hump-shaped dynamics of investment and in particular higher mining FDI.

So far, we have discussed the positive effects of commodity price shocks on investment and total GDP. Here we ask whether these results are robust when considering non-commodity GDP instead of total GDP. Figure 8, panel (B) shows the impulse responses of SVAR models with non-commodity GDP instead of total GDP while panel (A) shows the impulse responses with total GDP (as in figure 6). The evidence reaffirms our previous findings: higher commodity prices generate expansionary effects on the non-commodity sector. For the majority of the countries, except for Australia, the expansion in non-commodity GDP is stronger than in the case with total GDP. This result is consistent with the hypothesis that it is costly to increase the added value of the commodity sector in the short-run. Furthermore, the responses from panel (B) are statistically more significant. The responses for Australia are smaller and less significant in the case with non-commodity GDP, which is consistent with greater flexibility in expanding supply in the commodity sector. However, this evidence also suggests that other sectors in Australia diminish activity because of a crowding out effect. The responses of other variables included in the SVAR models are not reported since they are both quantitatively and qualitatively very similar (the only exception again being Australia).

Figure 8. Responses of Total GDP and Non-Commodity GDP to a Commodity Price Shock from SVAR Models, Selected Countries



Source: Authors' elaboration. Notes: Shock is of size 50%. Circles indicate quarters in which the responses are statistically significant at the 90% confidence level.

In summary, our main findings from the SVAR analysis across countries are as follows:

— The commodity price shocks estimated from the data are relatively persistent. All SVARs associate these shocks with expansionary effects on world GDP, inflation and interest rates.

— We observe delayed responses of domestic investment concentrated in mining sectors and expansion in aggregate output. However, non-mining investment may fall in countries with a more diversified trade structure.

— Commodity price shocks also have important expansionary effects on non-commodity output (in most analyzed countries). In addition, most countries show relatively low short-run supply elasticities in the commodity sector.
— Across countries, as investment rises, local currencies appreciate in the short-run and current account balances deteriorate in the medium term.
— The responses of inflation are positive for some countries while they are negative in others where the exchange rate appreciation is relatively persistent. Interest rates rise in all countries consistently with a tightening response of monetary policy.

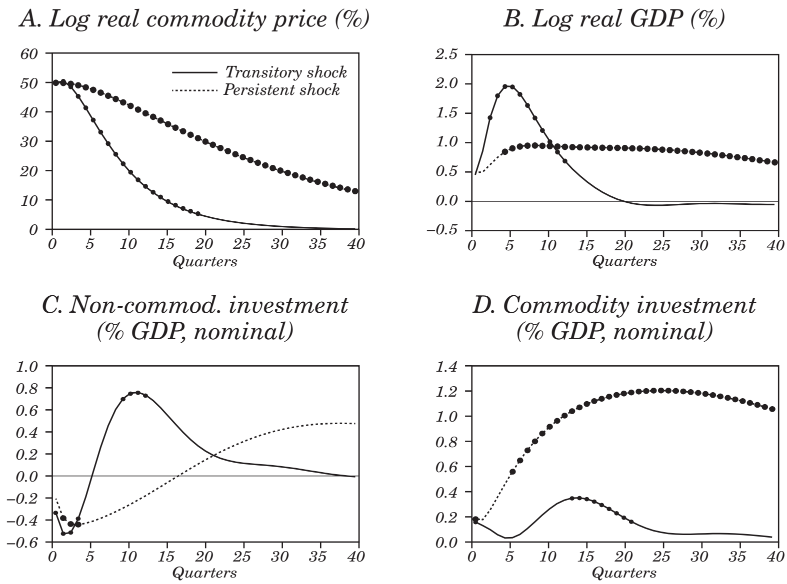
2.4 The Case of Chile with Persistent and Transitory Shocks

In the analysis of the previous section we added time trends as controls to the estimated VARs to match long-run dynamics. In this section, we implement an alternative exercise where we assume that the real price of copper is stationary in the long-run. In other words, we maintain the assumption that the nominal copper price and the U.S. CPI are cointegrated. This assumption is consistent with the finding that, based on longer spans of data, we reject the null hypothesis of a unit root in the real copper price.

Figure 9 shows that the estimated commodity price shock is significantly more persistent in this variant of the SVAR for Chile where the half-life of the shock is more than 6 years. The impulse responses of investment in mining and non-mining sectors are very different from the previous transitory shock case. Under the more persistent shock, mining investment increases by more than 1 percentage point of GDP while under the transitory shock it reaches less than 0.4 percentage points of GDP at maximum. However, while the response of non-mining investment under the transitory shock is positive and significant, under the persistent shock, the response of non-mining investment is not significant and positive after only 4 years.

In summary, the persistence of commodity price shocks seems to matter for the responses of output and commodity investment in commodity-exporting economies to such shocks. While transitory shocks do not seem to activate much investment in commodity sectors, persistent shocks tend to have larger effects. In the following section, we analyze the transmission mechanisms that can explain these dynamics based on a DSGE model in more detail where some of the

Figure 9. Impulse Responses from Alternative SVAR Models for Chile



Source: Authors' elaboration. Notes: Shock is of size 50%. Circles indicate quarters in which the responses are statistically significant at the 90% confidence level.

features of the model (such as time to build frictions) are motivated by the SVAR results.

3. The DSGE Model for Chile

In this section we describe an extended version of the DSGE model developed by Medina and Soto (2007a). The model of Medina and Soto (2007a) is a New Keynesian small open economy model with several standard elements[10] and some specific features of the Chilean economy such as a commodity-exporting sector that is owned

10. The standard ingredients (see, for instance, Adolfson and others, 2008) include a production structure with domestic and foreign tradable goods, sticky prices and wages with partial indexation to past inflation, incomplete exchange rate pass-through into import prices in the short-run, adjustment costs in investment, and habit persistence in consumption. The model also includes a fraction of non-Ricardian households, oil in the consumption basket and as an input for domestic goods production and food consumption.

in part by the government and in part by foreign agents, as well as a structural balance rule to describe fiscal policy in Chile. However, commodity production is assumed to be exogenous in the Medina and Soto (2007a) framework. We drop this assumption and instead assume that commodity production is conducted in an endogenous way through capital with time to build in capital accumulation and investment adjustment costs following Kydland and Prescott (1982) and Uribe and Yue (2006).[11] This extension is described in detail below while the description of the basic framework is relatively brief and we refer to Medina and Soto (2007a) for a more detailed discussion.[12] Finally, we assume that the dynamics of the relevant foreign variables are described by the external block of the SVAR model for Chile from the previous section.

3.1 Households

There is a continuum of households indexed by $j \in [0,1]$. A fraction λ of those households are non-Ricardian ones without access to the capital market. These households receive no profits and do not save and, thus, consume their disposable wage income entirely. The remaining households are Ricardian ones that do have access to the capital market and make intertemporal consumption and savings decisions in a forward-looking manner.

Households of the Ricardian type maximize the present value of expected utility at time t:

$$\max E_t \sum_{i=0}^{\infty} \beta^i \zeta_{C,t+i} \left[\log(C_{t+i}^R(j) - hC_{t+i-1}^R) - \psi \frac{l_{t+i}(j)^{1+\sigma_L}}{1+\sigma_L} \right], \qquad j \in (1-\lambda, 1],$$

subject to the period-by-period budget constraint

$$P_{C,t}C_t^R(j) + E_t\{d_{t,t+1}D_{t+1}(j)\} + \frac{B_t(j)}{r_t} + \frac{\varepsilon_t B_{P,t}^*(j)}{r_t^* \Theta_t} =$$

$$W_t(j)l_t(j) + \Xi_t(j) - TAXN_t(j) + D_t(j) + B_{t-1}(j) + \varepsilon_t B_{P,t-1}^*(j),$$

11. We include time to build and investment adjustment costs, as in Uribe and Yue (2006), to obtain more plausible investment and output dynamics in the commodity sector.

12. A shock to the stock of capital is also added to the basic framework of Medina and Soto (2007a) to resemble the 2010 earthquake in Chile.

where $C_t^R(j)$ is consumption of household j and C_t^R is aggregate consumption of Ricardian households, respectively, while $l_t(j)$ is household j's labor effort (in hours). The variable $\zeta_{C,t}$ is a preference shock to the households' subjective discount factor. Further, $P_{C,t}$ is the aggregate consumer price index (CPI), $W_t(j)$ is the nominal wage set by the household, $\Xi_t(j)$ collects payouts by firms, $TAXN_t(j)$ are lump-sum tax payments to the government, ε_t is the nominal exchange rate (units of domestic currency to buy one unit of foreign currency), and $d_{t,t+1}$ is the period t price of one-period domestic contingent bonds $D_t(j)$ normalized by the probability of the occurrence of the state. The variable r_t denotes the gross interest rate on a non-contingent domestic bond denominated in domestic currency $B_t(j)$, whereas, r_t^* is the (exogenous) interest rate on a non-contingent foreign bond denominated in foreign currency $B_{P,t}^*(j)$. The term $\Theta(\cdot)$ is a premium paid by domestic agents on top of the foreign interest rate.[13]

Following Erceg and others (2000), each household is a monopolistic supplier of a differentiated labor service. These labor services are bundled by a set of perfectly competitive labor packers that hire labor varieties and combine them into an aggregate labor service unit used as an input in production of domestic intermediate varieties. Cost minimization of labor packers yields the demand for each type of labor as a function of relative wages and aggregate labor demand by firms. There are wage rigidities in the spirit of Calvo (1983). In each period, a household faces a probability $(1 - \phi_L)$ of being able to re-optimize its nominal wage. The households that can re-optimize at time t will maximize the expected discounted future stream of labor income net of the disutility from work, subject to the labor demand constraint. All those that cannot re-optimize at time t set their wages according to a weighted average of past CPI inflation and the inflation target set by the central bank. Once a household has set its wage, it must supply any quantity of labor service demanded at that wage.

Households of the non-Ricardian type consume their disposable wage income each period:

$$P_{C,t}C_t^{NR}(j) = W_t l_t(j) - TAXN_t(j), \qquad j \in [0, \lambda].$$

13. The premium is a function of the aggregate (private, $B_{P,t}^*$, plus government, $B_{G,t}^*$) net foreign bond position relative to nominal GDP ($BY_t = \varepsilon_t B_t^*/P_{Y,t}Y_t$), i.e. $\Theta_t = \bar{\Theta}\exp[-\varrho(BY_t - \overline{BY}) + \zeta_{\Theta,t}/\bar{\zeta}_{\Theta} - 1]$ where $\varrho > 0$ to ensure stationarity of net foreign bonds and where $\zeta_{\Theta,t}$ is a shock to the premium (throughout, bars indicate deterministic steady state values).

For simplicity, it is assumed that non-Ricardian households set a wage equal to the average wage set by Ricardian households. As a consequence, the supply of labor by non-Ricardian households coincides with the average labor supply of Ricardian households.

The households' consumption bundle is a constant elasticity of substitution (CES) composite of a core consumption bundle $C_{Z,t}(j)$, food consumption $C_{A,t}(j)$, and oil consumption $C_{O,t}(j)$. Core consumption is a CES composite of final domestic goods $C_{H,t}(j)$, and imported goods $C_{F,t}(j)$. Food consumption is a similar composite of domestic and imported goods but subject to an exogenous shock ($\zeta_{A,t}$) to capture deviations of food price inflation from core inflation. Households minimize the costs of the different bundles, which yields standard Dixit-Stiglitz type demand functions for the individual components as well as expressions for the headline CPI, food prices, and the core CPI excluding oil and food (given oil prices).

3.2 Domestic Goods

In the domestic goods sector, there is a continuum of firms that produce differentiated varieties of intermediate tradable goods using labor, capital and oil as inputs. They have monopoly power over the varieties they produce and adjust prices infrequently. These firms sell their varieties to competitive assemblers that produce final domestic goods that are sold in the domestic and foreign market. Another set of competitive firms produces the capital goods used in intermediate goods production. All firms in this sector are owned by Ricardian households.

A representative capital goods producer rents capital goods to domestic intermediate goods producing firms. It decides how much capital to accumulate each period, assembling investment goods I_t with a CES technology that combines final domestic goods $I_{H,t}$ and imported goods $I_{F,t}$. The optimal composition of investment is determined through cost minimization. The firm may adjust investment to produce new capital goods K_t in each period, but there are convex costs of adjusting investment $\Phi(\cdot)$ following Christiano and others (2005). The firm chooses the level of investment and its stock of capital to maximize the present value of expected profits to households (rental returns on capital net of the cost of investment):

$$\max E_t \sum_{i=0}^{\infty} \Lambda_{t,t+i} [Z_{t+i} \exp(\zeta_{K,t+i}) K_{t+i-1} - P_{I,t+i} I_{t+i}],$$

subject to the law of motion of capital

$$K_t = (1-\delta)\exp(\zeta_{K,t})K_{t-1} + [1-\Phi(I_t / I_{t-1})]\zeta_{I,t}I_t,$$

where $\Lambda_{t,t+i}$ is the stochastic discount factor for nominal payoffs from the Ricardian household's problem and Z_t is the rental price of capital.[14] The variable $\zeta_{I,t}$ is an investment-specific shock that alters the rate at which investment is transformed into productive capital (see Greenwood and others, 2000), while $\zeta_{K,t}$ is an i.i.d. shock to the stock of capital that captures physical destruction of capital due to natural disasters such as an earthquake.

There is a large set of firms that use a CES technology to assemble final domestic goods from domestic intermediate varieties. A quantity $Y_{H,t}$ of those goods is sold domestically, and a quantity $Y^*_{H,t}$ is sold abroad. The assemblers demand intermediate goods of variety z_H for domestic sale $Y_{H,t}(z_H)$ and intermediate goods for foreign sale $Y^*_{H,t}(z_H)$. Input cost minimization yields the typical Dixit-Stiglitz demand functions for each variety.

Intermediate goods producers decide on the most efficient combination of labor, capital and oil (i.e., to minimize input costs given factor prices). The available technology is as follows:

$$\mathbf{Y}_{H,t}(z_H) = a_{H,t}\left[\alpha_H^{1/\omega_H} V_{H,t}(z_H)^{1-1/\omega H} + (1-\alpha_H)^{1/\omega_H} O_{H,t}(z_H)^{1-1/\omega H}\right]^{\frac{\omega_H}{\omega_H - 1}},$$

where $V_{H,t}$ denotes value added produced from labor and capital while $O_{H,t}(z_H)$ is the amount of oil used as intermediate input and $a_{H,t}$ represents a stationary productivity shock common to all firms.[15] Value added is generated through a Cobb-Douglas function:

$$V_{H,t}(z_H) = [T_t l_t(z_H)]^{\eta_H}[\exp(\zeta_{K,t})K_{t-1}(z_H)]^{1-\eta_H},$$

where $l_t(z_H)$ is the amount of labor utilized, T_t is a stochastic trend in labor productivity, and $K_{t-1}(z_H)$ is the amount of capital rented at the beginning of period t.[16]

14. The stochastic discount factor satisfies $\Lambda_{t,t+i} = \beta^i(\zeta_{C,t+i}/\zeta_{C,t})(C^R_t - hC^R_{t-1})/(C^R_{t+i} - hC^R_{t+i-1})(P_{C,t}/P_{C,t+i})$. Further, the function $\Phi(\cdot)$ satisfies $\Phi(1+g_Y) = \Phi'(1+g_Y) = 0$ and $\Phi''(1+g_Y) = \mu_S > 0$ where g_Y is the steady state (balanced) growth rate of the economy.

15. By market clearing, it holds that $Y_{H,t}(z_H) = Y_{H,t}(z_H) + Y^*_{H,t}(z_H)$.

16. The productivity trend evolves according to the process $T_t/T_{t-1} = \zeta_{T,t} = (1+g_Y)^{1-\rho_T}\zeta_{T,t-1}^{\rho_T}\exp(\varepsilon_{T,t})$.

The intermediate producers have monopoly power and set their prices separately in the domestic market $P_{H,t}(z_H)$, and the foreign market $P^*_{H,t}(z_H)$, maximizing profits subject to the corresponding demand constraints. Prices are set in a staggered way following Calvo (1983). In every period, the probability that a firm receives a signal for optimally adjusting its price for the domestic market is $1 - \phi_{H_D}$ and the probability of optimally adjusting its price for the foreign market is $1 - \phi_{H_F}$. If a firm does not receive a signal, it updates its price according to a weighted average of past changes of aggregate producer prices ($P_{H,t}$ or $P^*_{H,t}$) and steady state domestic or foreign CPI inflation. Let $MC_{H,t}$ denote the marginal cost of producing variety z_H. When a firm can re-optimize its price for the domestic market or foreign market, it solves

$$\max E_t \sum_{i=0}^{\infty} \varphi^i_{H_D} \Lambda_{t,t+i} [\Gamma^i_{H_D,t} P_{H,t}(z_H) - MC_{H,t+i}] Y_{H,t+i}(z_H),$$

subject to the final domestic goods producer's demand $Y_{H,t}(z_H) = [P_{H,t}(z_H)/P_{H,t}]^{-\varepsilon_H} Y_{H,t}$. Analogously, when a firm can re-optimize its price for the foreign market, it solves

$$\max E_t \sum_{i=0}^{\infty} \varphi^i_{H_F} \Lambda_{t,t+i} [\Gamma^i_{H_F,t} \varepsilon_{t+i} P^*_{H,t}(z_H) - MC_{H,t+i}] Y^*_{H,t+i}(z_H),$$

subject to the demand constraint $Y^*_{H,t}(z_H) = [P^*_{H,t}(z_H)/P^*_{H,t}]^{-\varepsilon_H} Y^*_{H,t}$.[17]

3.3 Imported Goods

In the imported goods sector, there is a continuum of retail firms that repackage a homogeneous good bought from abroad into differentiated imported varieties through a brand naming technology. Those firms have monopoly power in the domestic retailing of their particular variety and set prices infrequently. They sell their varieties to competitive assemblers that produce final imported goods that are bought by households and firms. As in the case of the domestic

17. For $i > 1$, the passive price updating rules are $\Gamma^i_{H_D,t} = \Gamma^{i-1}_{H_D,t} \pi^{\chi_{H_D}}_{H,t+i-1} \bar{\pi}^{1-\chi_{H_D}}$ for domestically sold goods and $\Gamma^i_{H_F,t} = \Gamma^{i-1}_{H_F,t} \pi^{*\chi_{H_F}}_{H,t+i-1} \bar{\pi}^{*1-\chi_{H_F}}$ for goods sold abroad where $\pi_{H,t} = P_{H,t}/P_{H,t-1}$, $\pi^*_{H,t} = P^*_{H,t} / P^*_{H,t-1}$ and $\bar{\pi}^*$ denotes steady-state foreign CPI inflation. For $i = 0$, we have $\Gamma^0_{H_D,t} = \Gamma^0_{H_F,t} = 1$.

goods sector, all firms in the imported goods sector are owned by Ricardian households.

There is a large set of firms that uses a CES technology to assemble final imported goods $Y_{F,t}$ from imported varieties. Demand for a particular imported variety $Y_{F,t}(z_F)$ is determined through minimization of costs, which yields the Dixit-Stiglitz demand functions for each variety.

Imported goods retailers buy a homogeneous good from abroad at the price $P^*_{F,t}$, which is then differentiated into a particular variety and sold domestically to assemblers of final imported goods. It takes one unit of the homogenous foreign good to produce a unit of retail output. Each importing firm has monopoly power and adjusts the domestic price of its variety in a staggered way following Calvo (1983). Each period, a firm optimally adjusts its price with probability $1 - \phi_F$. If a firm does not receive a signal, it updates its price according to a weighted average of past changes of aggregate producer prices $P_{F,t}$ and steady state CPI inflation. When a firm can re-optimize its price, it solves

$$\max E_t \sum_{i=0}^{\infty} \varphi_F^i \Lambda_{t,t+i} [\Gamma^i_{F,t} P_{F,t}(z_F) - \varepsilon_{t+i} P^*_{F,t+i}] Y_{F,t+i}(z_F),$$

subject to the final imported goods producer's demand $Y_{F,t}(z_F) = [P_{F,t}(z_F)/P_{F,t}]^{-\varepsilon_F} Y_{F,t}$.[18]

3.4 Commodity Goods

We extend the model of Medina and Soto (2007a) by endogenizing commodity production. As in Medina and Soto (2007a), there is a representative firm in the commodity sector S that produces a homogeneous commodity good. The entire production is exported. A fraction χ of the assets of that firm is owned by the government and the remaining fraction is owned by foreign investors. The revenue generated in the commodity sector is shared accordingly, but the government levies taxes on the profits that accrue to foreign investors.

18. The passive price-updating rule is $\Gamma^i_{F,t} = \Gamma^{i-1}_{F,t} \pi^{\chi_F}_{F,t+i-1} \bar{\pi}^{1-\chi_F}$ for $i > 0$ and $\Gamma^0_{F,t} = 1$ for $i = 0$.

3.4.1 Production technology

The firm in sector S uses capital specific to that sector $K_{S,t}$ to produce commodity goods $Y_{S,t}$. Production evolves along the balanced growth path of the economy, but we admit transitory deviations from that growth path due to sectoral technology shocks $a_{S,t}$. Specifically, commodity production satisfies

$$Y_{S,t} = a_{S,t} F^S(T_t, K_{S,t-1}). \tag{1}$$

The function $F^S(\cdot)$ is homogeneous of degree one in its arguments and has diminishing returns to capital additions. While we focus on capital-intensive commodity production and, for simplicity, abstract from other inputs such as labor, the shock $A_{S,t}$ can be interpreted to capture any variations in such additional inputs.[19] We also allow for a fixed transfer to households to capture eventual labor remunerations or other fixed costs (see below).

3.4.2 Profits and cash flow

Let $P^*_{S,t}$ denote the international price of the commodity good, and let $P_{S,t} = \varepsilon_P P^*_{S,t}$ be its domestic price, which the firm takes as given. Gross profits of the firm are given by

$$\Pi_{S,t} = P_{S,t} Y_{S,t} - P_{C,t} T_t \kappa_S$$

where $P_{C,t} T_t \kappa_S$ is a fixed cost of production that grows at the same rate as nominal output. We assume that this fixed cost is a lump-sum transfer to Ricardian households. The cash flow of the firm is $CF_{S,t} = \Pi_{S,t} - P_{I_S,t} I_{S,t}$ where $P_{I_S,t} I_{S,t}$ is the firm's investment. The objective of the firm is to maximize the present real value of its expected cash flow:

19. For instance, we could take the Cobb-Douglas production function $Y_{S,t} = \tilde{F}^S(T_t l_S, T_t F_{S,t}, K_{S,t-1}) = (T_t l_S)^{\eta_{l_S}} (T_t F_{S,t})^{\eta_{F_S}} K_{S,t-1}^{1-\eta_{l_S}-\eta_{F_S}}$ where l_S would be a fixed input of labor and $F_{S,t}$ would capture variations in other factors such as the mineral content of land. Defining $\eta_S = \eta_{l_S} + \eta_{F_S}$, we obtain $Y_{S,t} = a_{S,t} T_t^{\eta_S} K_{S,t-1}^{1-\eta_S}$, which is a representation of (1) with $a_{S,t} = l_S^{\eta_{l_S}} F_{S,t}^{\eta_{F_S}}$ and with $F^S(T_t, K_{S,t-1}) = T_t^{\eta_S} K_{S,t-1}^{1-\eta_S}$. Under those assumptions, total factor productivity $a_{S,t}$ is a function of labor and other factors subsumed in $F_{S,t}$.

$$\max E_t \sum_{i=0}^{\infty} \Lambda_{t,t+i}(S) \frac{CF_{S,t+i}}{P_{C,t+i}},$$

where $\Lambda_{t,t+i}(S)$ denotes the stochastic discount factor relevant to the firm. This discount factor is taken to be identical to the one of the households, i.e., $\Lambda_{t,t+i}(S) = \Lambda_{t,t+i}$.[20]

3.4.3 Law of motion of capital

Notice that the definition of profits does not have any importance for a firm's optimality, however, it is a key determinant of the tax base, which is needed to characterize the Chilean fiscal rule (see next section for details). The stock of capital in sector S is augmented through investment projects $X_{S,t}$. Following Uribe and Yue (2006), there are adjustment costs in investment and time to build in the installation of capital à la Kydland and Prescott (1982). In particular, the firm can start new investment projects in each period, but at a cost that is convex: the larger the change in investment, the larger the implied cost. In addition, new investment projects take $n \geq 1$ periods to mature. Collecting these assumptions results in the following law of motion of capital:

$$K_{S,t} = (1 - \delta_S) K_{S,t-1} + [1 - \Phi_S(X_{S,t-n+1} / X_{S,t-n})] X_{S,t-n+1}. \tag{2}$$

The function $\Phi_S(\cdot)$ is analogous to the Christiano and others (2005) style flow adjustment cost function from the law of motion of capital used in the domestic goods sector, and satisfies $\Phi_S(1 + g_Y) = \Phi_S'(1 + g_Y) = 0$ and $\Phi_S''(1 + g_Y) = \mu_{I_S} > 0$. A similar specification of the law of motion of capital is employed in Uribe and Yue (2006). The effective flow of investment in period t is given by

$$I_{S,t} = \sum_{j=0}^{n-1} \varphi_j X_{S,t-j}, \tag{3}$$

where φ_j denotes the fraction of projects initiated in period $t - j$ that is financed in period t, with $\sum_{j=0}^{n-1} \varphi_j = 1$. We will assume that

20. The relation $\Lambda_{t,t+i}(S) = \Lambda_{t,t+i}$ holds, as we assume, that the government has a stochastic discount factor equivalent to the one of the households and that foreign investors have access to domestic currency bonds.

$\varphi_0 = \varphi_1 = \ldots = \varphi_{n-1}$ as in Kydland and Prescott (1982), i.e., the cost of a project is spread equally over the horizon of its installation. In the extreme, when $n = 1$, we obtain the familiar law of motion $K_{S,t} = (1 - \delta_S)K_{S,t-1} + [1 - \Phi_S(I_{S,t}/I_{S,t-1})]I_{S,t}$.

3.4.4 Capital-investment choice

The firm's first-order optimality conditions are as follows:

$$K_{S,t} : \frac{Q_{S,t}}{P_{C,t}} = E_t\left\{\Lambda_{t,t+1}\left[\frac{Q_{S,t+1}}{P_{C,t+1}}(1-\delta_S) + \frac{P_{S,t+1}A_{S,t+1}F^S_{K_S}(T_{t+1}, K_{S,t})}{P_{C,t+1}}\right]\right\},$$

$$X_{S,t} : \phi_0 \frac{P_{I_S,t}}{P_{C,t}} + \phi_1 E_t\left\{\Lambda_{t,t+1}\frac{P_{I_S,t+1}}{P_{C,t+1}}\right\} + \cdots + \phi_{n-1}E_t\left\{\Lambda_{t,t+n-1}\frac{P_{I_S,t+n-1}}{P_{C,t+n-1}}\right\}$$

$$= E_t\left\{\begin{array}{c} \Lambda_{t,t+n-1}\frac{Q_{S,t+n-1}}{P_{C,t+n-1}}[1-\Phi_S(X_{S,t}/X_{S,t-1}) \\ -\Phi'_S(X_{S,t}/X_{S,t-1})X_{S,t}/X_{S,t-1}] \\ +\Lambda_{t,t+n}\frac{Q_{S,t+n}}{P_{C,t+n}}\Phi'_S(X_{S,t+1}/X_{S,t})(X_{S,t+1}/X_{S,t})^2 \end{array}\right\}$$

where $F^S_{K_S}(\cdot)$ is the derivative of the production function in (1) with respect to capital. These two conditions jointly determine the evolution of investment projects and the mark-to-market value of capital $Q_{S,t}$ in sector S. The law of motion (2) determines the evolution of the stock of capital and (3) determines the effective flow of investment in this sector.

3.4.5 Composition of investment

The investment good that is required to build the stock of capital in sector S is a CES bundle of final domestic goods $I_{H,t}(S)$ and imported goods $I_{F,t}(S)$:

$$I_{S,t} = \left[\gamma_{I_S}^{1/\eta_{I_S}} I_{H,t}(S)^{1-1/\eta_{I_S}} + (1-\gamma_{I_S})^{1/\eta_{I_S}} I_{F,t}(S)^{1-1/\eta_{I_S}}\right]^{\frac{\eta_{I_S}}{\eta_{I_S}-1}}. \quad (4)$$

The optimal composition of investment is determined through cost minimization. In each period, given the effective flow of investment, the firm minimizes $P_{I_S,t}I_{S,t} = P_{H,t}I_{H,t}(S) + P_{F,t}I_{F,t}(S)$ subject to (4), which yields the following demands for investment inputs originating in sector S:

$$I_{H,t}(S) = \gamma_{I_S}(P_{H,t} / P_{I_S,t})^{-\eta_{I_S}} I_{S,t},$$

$$I_{F,t}(S) = (1-\gamma_{I_S})(P_{F,t} / P_{I_S,t})^{-\eta_{I_S}} I_{S,t}.$$

3.5 Fiscal Policy

A share χ of the cash flow that is generated in sector S goes directly to the government, and the government also levies taxes at a fixed rate τ_S on the profits–net of depreciation–that accrue to foreign investors. The budget constraint of the government is therefore as follows:

$$P_{G,t}G_t + \frac{\varepsilon_t B^*_{G,t}}{r^*_t \Theta_t} = \varepsilon_t B^*_{G,t-1} + \tau_t P_{Y,t}Y_t + \chi CF_{S,t}$$
$$+\tau_S(1-\chi)(\Pi_{S,t} - \delta_S Q_{S,t}K_{S,t-1}),$$

where $P_{G,t}G_t$ denotes nominal government consumption expenditure, $B^*_{G,t}$ is the government net foreign asset position, and τ_t are lump-sum taxes from households net of transfers (as a share of nominal GDP, $P_{Y,t}Y_t$). Note that the government net asset position is assumed to be completely denominated in foreign currency, as in Medina and Soto (2007a). In addition, government consumption is characterized by complete home bias, i.e., $G_t = G_{H,t}$ and $P_{G,t} = P_{H,t}$.

Government expenditure follows a structural balance fiscal rule analogous to the one described in Medina and Soto (2007a):

$$\frac{P_{G,t}G_t}{P_{Y,t}Y_t} = \left[\begin{array}{l} \left(1 - \frac{1}{r^*_{t-1}\Theta_{t-1}}\right)\frac{\varepsilon_t B^*_{G,t-1}}{P_{Y,t}Y_t} + \tau_t \frac{P_{Y,t}\bar{Y}}{P_{Y,t}Y_t} + \chi \frac{CF_{S,t}}{P_{Y,t}Y_t} \\ +\tau_S(1-\chi)\frac{\Pi_{S,t} - \delta_S Q_{S,t}K_{S,t-1}}{P_{Y,t}Y_t} - \frac{VC_t}{P_{Y,t}Y_t} - \bar{s}_B \end{array}\right]\frac{P_{G,t}\zeta_{G,t}T_t}{P_{Y,t}Y_t}$$

where $VC_t = [\chi + \tau_S(1 - \chi)]\varepsilon_t(P_t^* - \tilde{P}_t^*)Y_{S,t}$ is the cyclical adjustment of the rule that depends crucially on the difference between the effective commodity price P_t^* and the long-run reference price $\tilde{P}_t^*$, which is calculated as the forecast of the effective commodity price averaged over a 10-year horizon. In addition, $\bar{Y}$ stands for potential real GDP, which, for simplicity, is taken to be equal to steady state output, and the parameter $\bar{s}_B$ is the structural balance target. The variable $\zeta_{G,t}$ is a shock capturing deviations of government expenditure from the fiscal rule.

3.6 Monetary Policy

Monetary policy is conducted through a simple Taylor-type feedback rule for the nominal interest rate, which is a slightly modified version of the one presented in Medina and Soto (2007a). In particular, while the latter assumes that the central bank responds entirely to deviations of core CPI inflation from target, and output growth from potential growth, we allow for a partial response to headline CPI inflation to capture possible concerns by the central bank on oil and food price inflation. Hence, the monetary policy rule is specified as follows:

$$\frac{r_t}{\bar{r}} = \left(\frac{r_{t-1}}{\bar{r}}\right)^{\psi_r}\left[\left(\frac{\pi_{Z,t}}{\bar{\pi}}\right)^{\psi_\pi\psi_{\pi Z}}\left(\frac{\pi_t}{\bar{\pi}}\right)^{\psi_\pi(1-\psi_{\pi Z})}\left(\frac{Y_t / Y_{t-1}}{T_t / T_{t-1}}\right)^{\psi_Y}\right]^{1-\psi_r}\exp(\zeta_{m,t})$$

where $\pi_{Z,t}$ and π_t are core and headline CPI inflation, respectively, Y_t is real GDP, and $\zeta_{m,t}$ is an i.i.d. shock that captures deviations of the interest rate from the monetary policy rule.

3.7 Rest of the World

Foreign agents demand the commodity good and the final domestic good. They supply oil and the homogeneous good that is bought by importing firms. Foreign demand for the commodity good is assumed to be completely elastic at its international price $P_{S,t}^*$. Likewise, foreign supply of oil is assumed to be completely elastic at any given price $P_{O,t}^*$. The real exchange rate is defined as the domestic currency price of a foreign price index $\varepsilon_t P_t^*$ relative to the domestic CPI. The domestic economy is assumed to be small relative to the rest of the world. As a consequence, the price of the homogeneous foreign good $P^*_{F,t}$ coincides with the foreign price index. Foreign demand for the final domestic good depends on its relative price abroad $P^*_{H,t}/P^*_t$ and foreign aggregate demand Y^*_t according to the demand function $Y^*_{H,t} = \zeta^*(P^*_{H,t}/P^*_t)^{-\eta^*}Y^*_t$.

3.8 Aggregate Equilibrium

The market clearing condition for each variety of domestic goods is

$$Y_{H,t}(z_H) = [P_{H,t}(z_H) / P_{H,t}]^{-\varepsilon_H} Y_{H,t} + [P^*_{H,t}(z_H) / P^*_{H,t}]^{-\varepsilon_H} Y^*_{H,t},$$

where $Y_{H,t} = C_{H,t} + I_{H,t} + I_{H,t}(S) + G_{H,t}$. In the labor market, labor demand by intermediate goods producers equals labor supply: $\int_0^1 l_t(z_H)dz_H = l_t$ where the aggregate labor service unit is given by

$$l_t = \left[\int_0^1 l_t(j)^{1-1/\varepsilon_L} dj\right]^{\frac{\varepsilon_L - 1}{\varepsilon_L}}.$$

Nominal GDP satisfies $P_{Y,t}Y_t = P_{C,t}C_t + P_{I,t}I_t + P_{I_S,t}I_{S,t} + P_{G,t}G_t + P_{X,t}X_t - P_{M,t}M_t$ where $P_{X,t}X_t = \varepsilon_t(P^*_{H,t}Y^*_{H,t} + P^*_{S,t}Y_{S,t})$ and $P_{M,t}M_t = \varepsilon_t[P^*_{F,t}Y_{F,t} + P^*_{O,t}(C_{O,t} + O_{H,t})]$ are nominal exports and imports, respectively, with $Y_{F,t} = C_{F,t}+I_{F,t}+I_{F,t}(S)$. Real GDP is defined as $Y_t = C_t+I_t+I_{S,t}+G_t+X_t-M_t$. Substituting out aggregate profits in the budget constraint of the households, and combining the latter with the budget constraint of the government, yields the following expression for the evolution of aggregate net foreign bonds:

$$\frac{\varepsilon_t B^*_t}{r^*_t \Theta_t} = P_{X,t}X_t - P_{M,t}M_t + \varepsilon_t B^*_{t-1} - (1-\chi)CF_{S,t}$$
$$+\tau_S(1-\chi)(\Pi_{S,t} - \delta_S Q_{S,t}K_{S,t-1}).$$

The terms on the right-hand side are net exports, net interest receipts minus the cash flow from the commodity sector that accrues to foreign investors, and transfers from foreigners due to taxes on profits net of the mark-to-market value of capital depreciation in the commodity sector. Finally, the current account balance is equivalent to the quarter-on-quarter change in the international investment position of the country (relative to nominal GDP):

$$CAY_t = \frac{1}{P_{Y,t}Y_t}\left[\frac{\varepsilon_t B_t^*}{r_t^*\Theta_t} - \frac{\varepsilon_t B_{t-1}^*}{r_{t-1}^*\Theta_{t-1}}\right] - (1-\chi)\frac{Q_{S,t}(K_{S,t} - K_{S,t-1})}{P_{Y,t}Y_t}.$$

3.9 Exogenous Processes and Foreign SVAR

There are fifteen exogenous variables in the model: preferences $\zeta_{C,t}$, neutral technology $a_{H,t}$, productivity growth $\zeta_{T,t}$, investment-specific technology $\zeta_{I,t}$, capital destruction $\zeta_{K,t}$, commodity-specific technology $a_{S,t}$, fiscal policy $\zeta_{G,t}$, monetary policy $\zeta_{m,t}$, stationary foreign demand $y_t^* = Y_t^*/T_t$, foreign inflation $\pi_t^* = P_t^*/P_{t-1}^*$, food prices $\zeta_{A,t}$, real commodity price $p_{S,t}^* = P_{S,t}^*/P_t^*$, real oil price $p_{O,t}^* = P_{O,t}^*/P_t^*$, foreign interest rate r_t^*, and the country premium $\zeta_{\Theta,t}$. The domestic exogenous variables are assumed to follow autoregressive processes of order one in logs AR(1) except the monetary policy shock and the capital destruction shock, which are i.i.d. processes in levels. The foreign variables are assumed to be determined by the external block of the SVAR model from section 2.[21]

4. Analysis with the DSGE Model

We now use the model from the previous section to analyze the impact of commodity price shocks in Chile. In particular, we highlight how the effects of those shocks on the main macroeconomic variables are amplified through the endogenous response of investment in the commodity sector, and discuss the role of the persistence of those shocks. We also compute historical decompositions of investment and real GDP growth in terms of the different structural shocks of the model to examine the importance of commodity price shocks relative to other types of shocks for observed macroeconomic dynamics. Finally, we conduct some counterfactual policy exercises to analyze the effectiveness of alternative macroeconomic policy frameworks in mitigating the impact of commodity price shocks in a commodity-exporting economy such as Chile.

21. As the real oil price does not enter the foreign VAR, it is assumed to follow an AR(1) process.

4.1 Parameterization

The model is parameterized following Fornero and Kirchner (2014), who combine calibration and Bayesian estimation of the structural parameters of the model. In addition, the parameters of the foreign SVAR are assigned using the results from the previous section where we take the persistent case as a benchmark (see section 2.4). Tables 3 and 4 summarize our choice of parameters where we use the posterior mode estimates from Fornero and Kirchner (2014). For reasons of limited space, we only discuss the key parameters related to the commodity sector and refer to Fornero and Kirchner (2014) for a more detailed discussion.

Table 3. Calibrated Parameters

Parameter	*Value*	*Description*
Steady state (SS) values		
g_Y	2.5%	Balanced growth path (net rate, annual basis)
$\bar{\pi}$	3%	SS inflation target (net rate, annual basis)
$\bar{\pi}^*$	3%	SS foreign inflation rate (net rate, annual basis)
$\bar{r}^*$	4.5%	SS foreign interest rate (net rate, annual basis)
$\bar{\Theta}$	1.3%	SS country premium (net rate, annual basis)
$\bar{s}_B$	0%	SS structural fiscal balance target
$\bar{g}$	0.055	SS government consumption (stationary level)
$\bar{a}_S$	0.081	SS productivity in commodity sector
$\bar{y}^*$	1	SS foreign demand (stationary level)
$\bar{p}_O$	1	SS real international price of oil (dom. currency)
$\bar{p}_S$	1	SS real int. commodity price (dom. currency)
Non-Ricardian households		
λ	0.500	Share of non-Ricardian households
Ricardian households		
β	0.999	Subjective discount factor (quarterly basis)
σ_L	1	Inverse Frisch elasticity of labor supply
ψ	15.622	Disutility of labor parameter
α_a	0.19	Share of food consumption in total consumption
α_o	0.03	Share of oil consumption in total consumption

Table 3. (continued)

Parameter	*Value*	*Description*
α_c	0.780	Share of core consumption in total consumption
γ_c	0.740	Share of domestic goods in core and food consumption
Non-commodity sectors		
δ	0.010	Depreciation rate (quarterly basis), sector *H*
α_H	0.990	Share of non-oil inputs in production, sector *H*
η_H	0.660	Share of labor in Cobb-Douglas value added, sector *H*
ε_L	11.000	Elast. of substitution among labor varieties, sector *H*
ε_H	11.000	Elast. of substitution among domestic varieties, sector *H*
ε_F	11.000	Elast. of substitution among imported varieties, sector *F*
γ_I	0.640	Share of domestic goods in investment, sector *H*
Commodity sector		
χ	0.310	Government ownership of assets, sector *S*
τ_S	0.350	Tax rate on foreign profits, sector *S*
κ_S	0.009	Fixed cost of production, sector *S*
$1-\eta_S$	0.314	Capital elasticity of production, sector *S*
δ_S	0.032	Depreciation rate (quarterly basis), sector *S*
γ_{IS}	0.590	Share of domestic goods in investment, sector *S*
n	6.000	Periods of time to build (quarters), sector *S*
ϕ_j	0.167	Financing profile of investment projects, sector *S*
Foreign economy		
ζ^*	0.101	Import share of foreign economy
Exogenous processes		
$\rho_{p_O^*}$	0.893	AR(1) coef., international oil price shock (ML)
$\sigma_{p_O^*}$	0.139	Innov. s.d., international oil price shock (ML)
σ_{z_k}	0.004	Innov. s.d., capital destruction shock

Source: Fornero and Kirchner (2014).

Table 4. Estimated Parameters

Parameter	Description	Prior			Posterior				
		dist.	*mean*	*s.d.*	*mean*	*mode*	*s.d.*	*5%*	*95%*
Households									
h	Habit formation	B	0.70	0.1	0.893	0.862	0.028	0.847	0.939
ω_C	EoS oil and core cons.	IG	1	Inf	0.389	0.385	0.109	0.224	0.551
η_C	EoS H and F core cons.	IG	1	Inf	1.477	1.575	0.706	0.341	2.480
Wages									
ϕ_L	Calvo prob. wages	B	0.75	0.1	0.966	0.975	0.013	0.947	0.987
ξ_L	Indexation wages	B	0.50	0.2	0.785	0.710	0.119	0.610	0.967
Prices									
ϕ_{H_D}	Calvo prob. dom. prices	B	0.75	0.1	0.630	0.626	0.060	0.536	0.727
ϕ_{H_F}	Calvo prob. exp. prices	B	0.75	0.1	0.901	0.890	0.045	0.838	0.969
φ_F	Calvo prob. imp. prices	B	0.75	0.1	0.507	0.504	0.050	0.424	0.588
ξ_{H_D}	Indexation dom. prices	B	0.50	0.2	0.260	0.268	0.141	0.040	0.465
ξ_{H_F}	Indexation exp. prices	B	0.50	0.2	0.430	0.346	0.192	0.112	0.738
ξ_F	Indexation imp. prices	B	0.50	0.2	0.414	0.399	0.148	0.170	0.657

Table 4. (continued)

		Prior			Posterior				
Parameter	*Description*	*dist.*	*mean*	*s.d.*	*mean*	*mode*	*s.d.*	*5%*	*95%*
Production									
ω_H	EoS oil, other inputs	IG	1.000	Inf	0.393	0.460	0.126	0.212	0.565
Investment									
η_I	EoS H and F inv., non-S	IG	1.000	Inf	1.345	0.497	0.942	0.251	2.822
η_{I_S}	EoS H and F inv., S	IG	1.000	Inf	0.868	0.695	0.637	0.234	1.608
μ_S	Inv. adjustm. cost, non-S	G	2.000	0.5	1.844	1.533	0.422	1.154	2.506
μ_{I_S}	Inv. adjustm. cost, S	G	3.000	0.5	2.864	3.078	0.517	2.025	3.708
For.economy									
η_F	Price elast. for. demand	IG	1.000	Inf	0.273	0.239	0.055	0.189	0.356
ρ	Country prem. debt elast.	IG	0.010	Inf	0.008	0.009	0.002	0.005	0.010
Mon.policy									
ψ_r	Interest rate smoothing	B	0.750	0.1	0.818	0.828	0.023	0.780	0.856
Ψ_Y	Int. feedb. GDP growth	N	0.125	0.05	0.101	0.116	0.044	0.030	0.174
ψ_π	Int. feedb. inflation	N	1.500	0.1	1.700	1.733	0.079	1.570	1.831
ψ_{π_Z}	Feedb. weight core infl.	B	0.500	0.2	0.740	0.656	0.128	0.546	0.944

Table 4. (continued)

		Prior			Posterior				
Parameter	*Description*	*dist.*	*mean*	*s.d.*	*mean*	*mode*	*s.d.*	*5%*	*95%*
AR(1)coef.									
ρ_{a_H}	Neutral technology shock	B	0.75	0.1	0.783	0.785	0.087	0.645	0.924
ρ_{ζ_T}	Productivity growth shock	B	0.75	0.1	0.768	0.718	0.060	0.676	0.868
ρ_{ζ_C}	Preference shock	B	0.75	0.1	0.757	0.715	0.073	0.642	0.876
ρ_{ζ_I}	Inv.-specif. techn. shock	B	0.75	0.1	0.619	0.627	0.072	0.503	0.740
ρ_{ζ_G}	Fiscal policy shock	B	0.75	0.1	0.870	0.878	0.039	0.808	0.934
ρ_{ζ_Θ}	Country premium shock	B	0.75	0.1	0.955	0.958	0.020	0.927	0.985
ρ_{ζ_A}	Food price shock	B	0.75	0.1	0.781	0.0825	0.806	0.657	0.918
ρ_{a_S}	Comm.-specif. techn. sh.	B	0.75	0.1	0.959	0.960	0.017	0.932	0.986
Innov.s.d.									
u_{a_H}	Neutral technology shock	IG	0.005	Inf	0.008	0.008	0.002	0.005	0.010
u_{ζ_T}	Productivity growth shock	IG	0.005	Inf	0.011	0.012	0.002	0.007	0.015
u_{ζ_C}	Preference shock	IG	0.005	Inf	0.047	0.036	0.013	0.027	0.067
u_{ζ_I}	Inv.-specif. techn. shock	IG	0.005	Inf	0.047	0.040	0.012	0.029	0.065
u_{ζ_G}	Fiscal policy shock	IG	0.005	Inf	0.038	0.036	0.005	0.030	0.045
u_{ζ_m}	Monetary policy shock	IG	0.005	Inf	0.002	0.002	0.0002	0.001	0.002
u_{ζ_Θ}	Country premium shock	IG	0.005	Inf	0.001	0.001	0.0001	0.0008	0.001
u_{ζ_A}	Food price shock	IG	0.005	Inf	0.014	0.013	0.003	0.008	0.019
u_{a_S}	Comm.-specif. techn. sh.	IG	0.005	Inf	0.034	0.034	0.004	0.029	0.040

Source: Fornero and Kirchner (2014).

Among the calibrated parameters, the share of government ownership in the commodity sector χ is set to 0.31, consistent with the average share of production of the state-owned copper mining company (Codelco) relative to total copper production since 2001. The tax rate on foreign profits τ_S is set to 0.35, which is the flat rate tax on foreign companies in Chile. The fixed costs in production parameter κ_S is chosen to match a labor share in total value added of about 14%, according to recent data. The elasticity of production with respect to capital $1 - \eta_S$ is set to 0.31 in order to obtain a share of physical capital to quarterly output in the commodity sector of 12. This number is in line with available data on the value of financial assets over total sales of Codelco. The quarterly depreciation rate of capital in the commodity sector δ is approximately 3%, chosen to match an average investment-to-output ratio in Chile's mining sector of about 4% from 2001-2012. The home bias in investment in the commodity sector is set to 0.59, consistent with available data on the share of construction in total investment in the mining sector. The horizon of time to build is set to $n = 6$ quarters, consistent with the average duration of investment projects by private mining companies according to data from a regular survey of the Chilean Corporation of Capital Goods (CBC). Following Kydland and Prescott (1982), the financing profile of projects ϕ_j is set to $1/n$.

In addition, the estimated parameters in table 4 reflect a relatively high degree of investment adjustment costs in the commodity sector relative to other sectors in addition to the time to build structure in this sector. Hence, investment in the commodity sector tends to respond relatively sluggishly to commodity price shocks and other types of shocks. The estimates also indicate some degree of complementarity between domestic and foreign inputs for investment in that sector, which tends to enhance the spillover effects from the commodity sector to the rest of the economy. We now proceed to analyze the effects of different types of commodity price shocks on the main macroeconomic variables.

4.2 Effects of Persistent and Transitory Commodity Price Shocks

Figure 10 shows the impulse responses of selected variables to a commodity price shock of 50% in size as in the SVARs from section 3. We distinguish two types of persistence of the shock: a more persistent case where the foreign block is taken from the estimated

VAR model for Chile from section 3.4 (where the real copper price is not de-trended) and a less persistent case where the persistence of the copper price in the foreign VAR is adjusted so that the half-life of the shock matches the half-life of the real copper price in the VAR where all variables including the copper price are de-trended using quadratic trends.

The results show the following in both cases: the shock generates an expansion of real GDP and investment in all sectors, a real exchange rate appreciation, lower inflation in the short-run and higher inflation after some periods, with the associated interest rate response. However, the expansion of investment and GDP is significantly stronger when the shock is persistent. In this case, there is a strong incentive to invest in the commodity sector, as indicated by the persistent rise in the sectoral Tobin's q, such that commodity investment increases by more than 2% above its steady state level with positive spillover effects on investment in other sectors and on real GDP. However, when the shock is transitory, the relatively short-lived increase in the expected Tobin's q is not sufficient to generate a significant response of investment in the commodity sector since it would take too long relative to the duration of the shock (and it would be too costly) to install the additional productive capacity due to the time to build frictions. Another difference between the two cases is that the transitory shock is associated with a current account surplus while the persistent shock is already followed by a relatively sizable current account deficit after just a few quarters. As shown in Fornero and Kirchner (2014), these differences in the response of the current account balance are mainly due to the endogenous response of investment in the commodity sector and its effects on the economy's net international investment position.

Overall, the predictions of the model are therefore in line with the empirical results from section 3. However, an advantage of using a DSGE model is that we can decompose the dynamics of macroeconomic variables such as investment and GDP growth according to the different structural shocks that drive economic dynamics, as we do next.

Figure 10. Impulse Responses to Commodity Price Shocks (50%) with Different Persistences

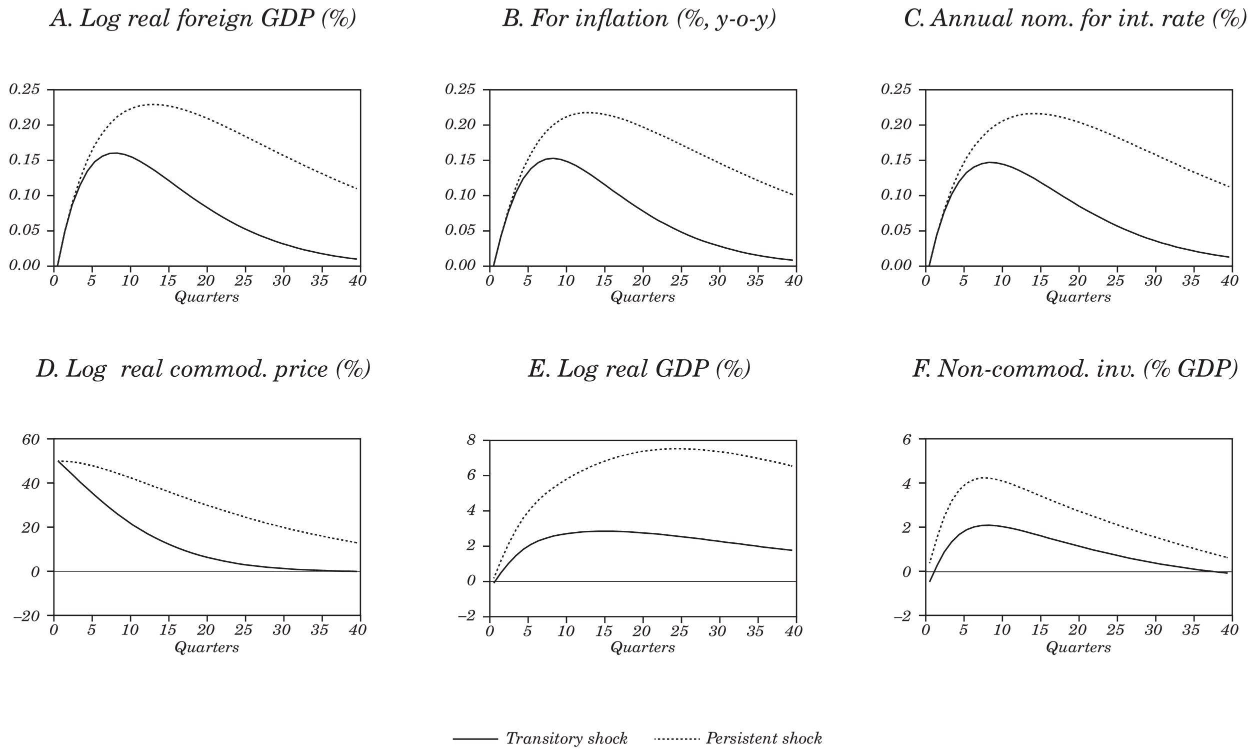
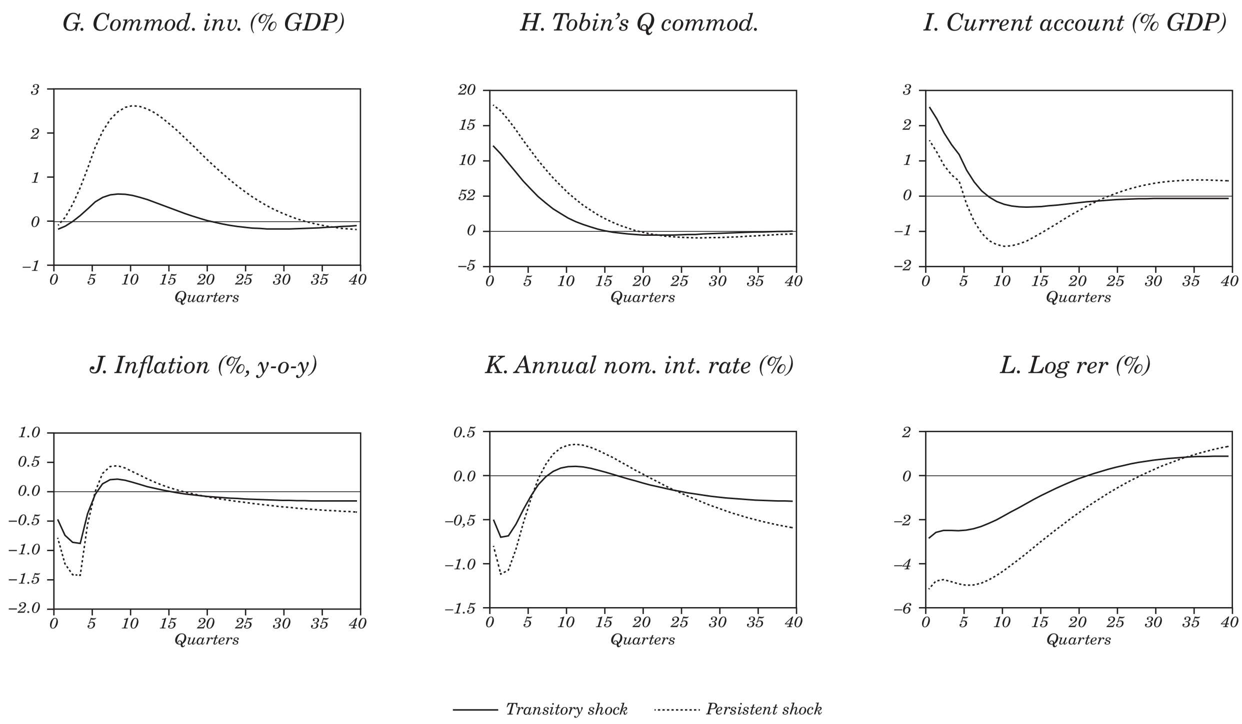


Figure 10. (continued)



Source: Authors' elaboration.
Note: Δ% from Steady State in y-axes.

4.3 Share of Domestic Investment in the Commodity Sector and Trade Balance Adjustments

Do the macroeconomic effects of commodity price shocks depend on the structure of investment in the commodity sector? Changes on commodity investment may be absorbed by trade balance adjustments if the share of foreign inputs in the commodity sector is sufficiently high. To analyze this issue, figure 11 compares the responses to a persistent commodity price shock for the benchmark case having a relatively high share of domestic investment in the commodity sector (59%)[22] to the case with a low share of domestic investment (5%). The results show that expansionary effects on real GDP and investment in the non-commodity sector are significantly smaller in the case with a low share of domestic investment. In this case, the negative trade balance adjustments absorb the positive effects of investment on real GDP, which is more than 2% smaller after 10 quarters in the case with a low share of domestic investment.

4.4 "Pure" Effects of Commodity Price Shocks

According to the results from figure 10, a positive commodity price shock is associated with expansionary external conditions for the domestic economy (increase in foreign demand, decrease in real foreign interest rate), which do not allow to identification of the "true" or "pure" effects of higher commodity prices. To isolate these effects, in figure 12 we compare the responses to a persistent commodity price shock under the benchmark case (i.e., with a foreign SVAR block) with the case where the commodity price follows a first order autoregressive process (the half-life of the shock matches the half-life of the real copper price in the SVAR case). The results show that the expansionary effects on investment are slightly smaller in all sectors when the commodity price is independent from the other foreign variables. In this case, there is a smaller incentive to invest in the domestic economy and this is mainly due to a lower world demand for domestic goods, a neutral foreign monetary policy and a lower Tobin's q. However, the differences in the responses are small and the pure spillover effects in the domestic economy are crucial. In fact, in the AR(1) case, investment in the non-commodity sector still increases by more than 3% of GDP and investment in the commodity sector by more than 2% of GDP.

22. This corresponds to the share of construction investment in total investment during the period 2003-2010.

Figure 11. Impulse Responses to Commodity Price Shocks (50%) with Different Shares of Domestic Investment in the Commodity Sector

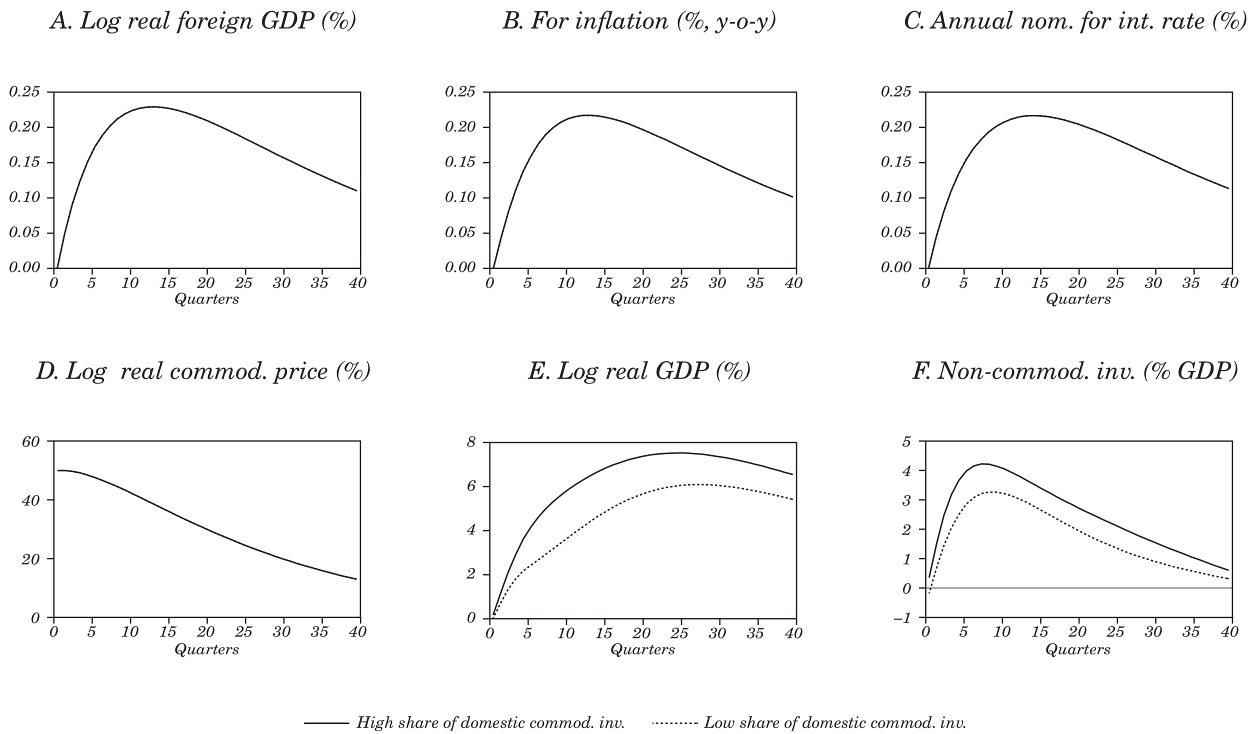
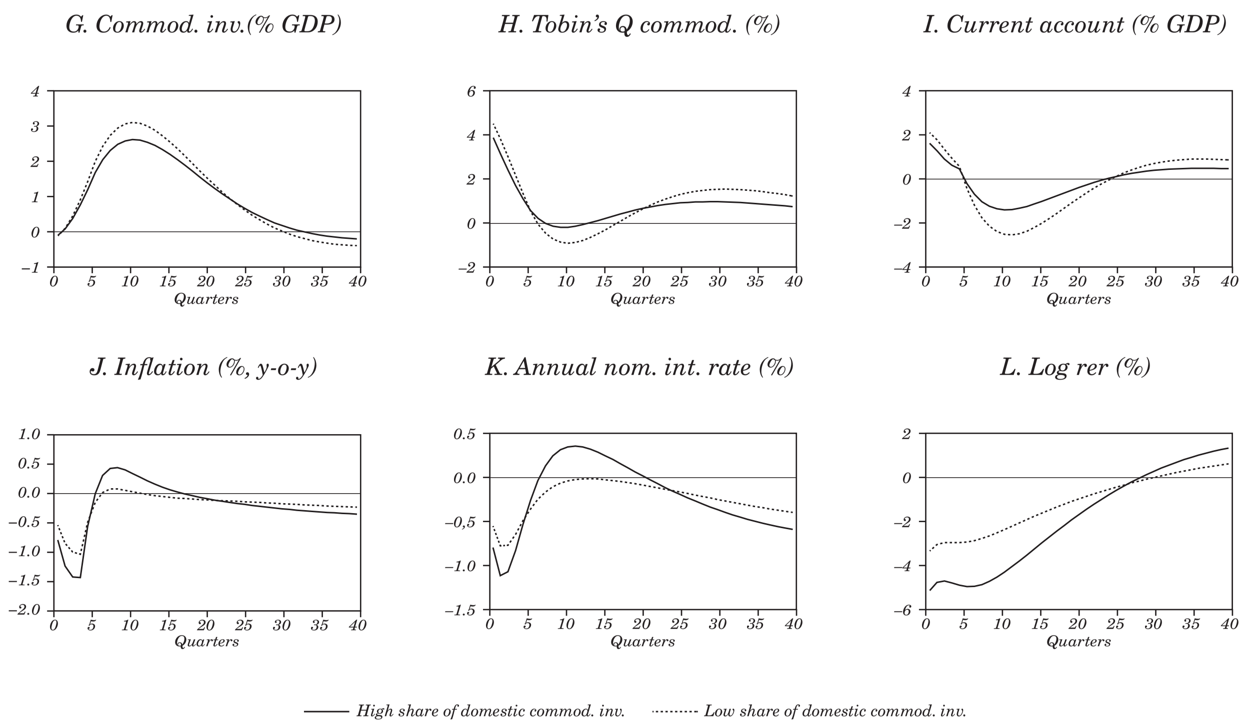


Figure 11. (continued)



Source: Authors' elaboration.
Note: Δ% from Steady State in y-axes.

Figure 12. Impulse Responses to Commodity Price Shocks (50%) with Different Shock Processes

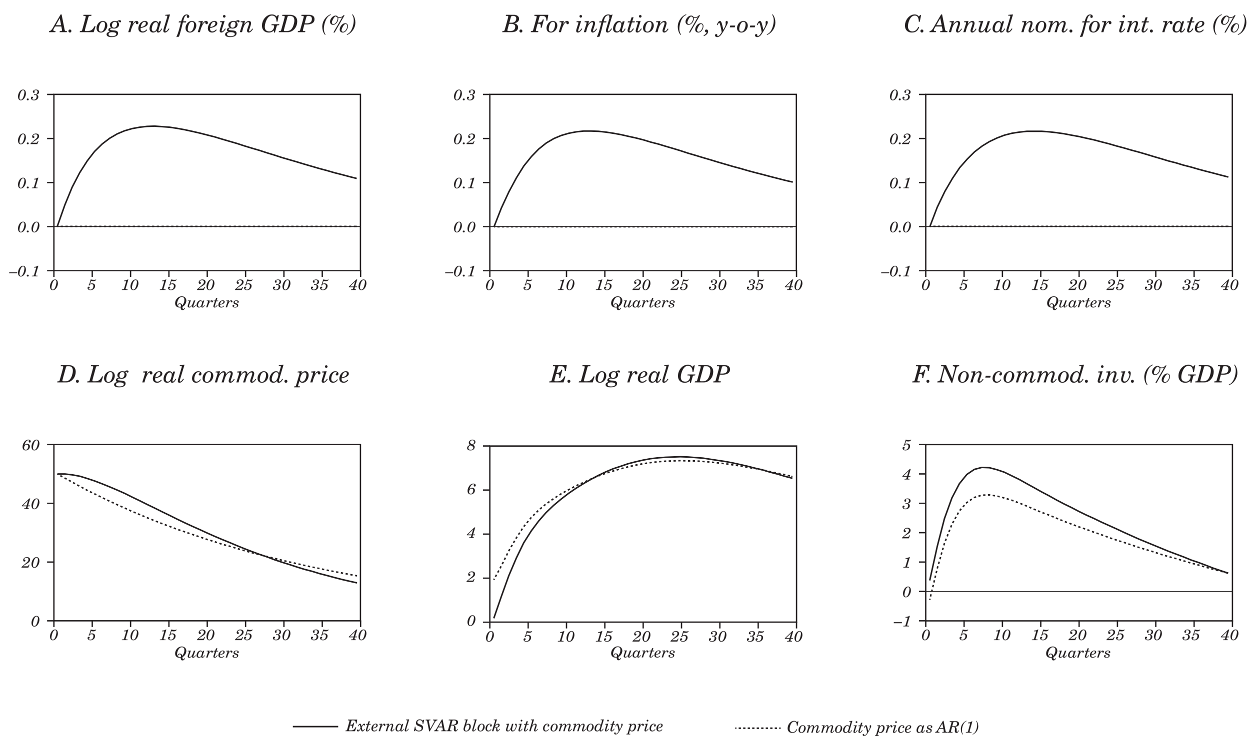
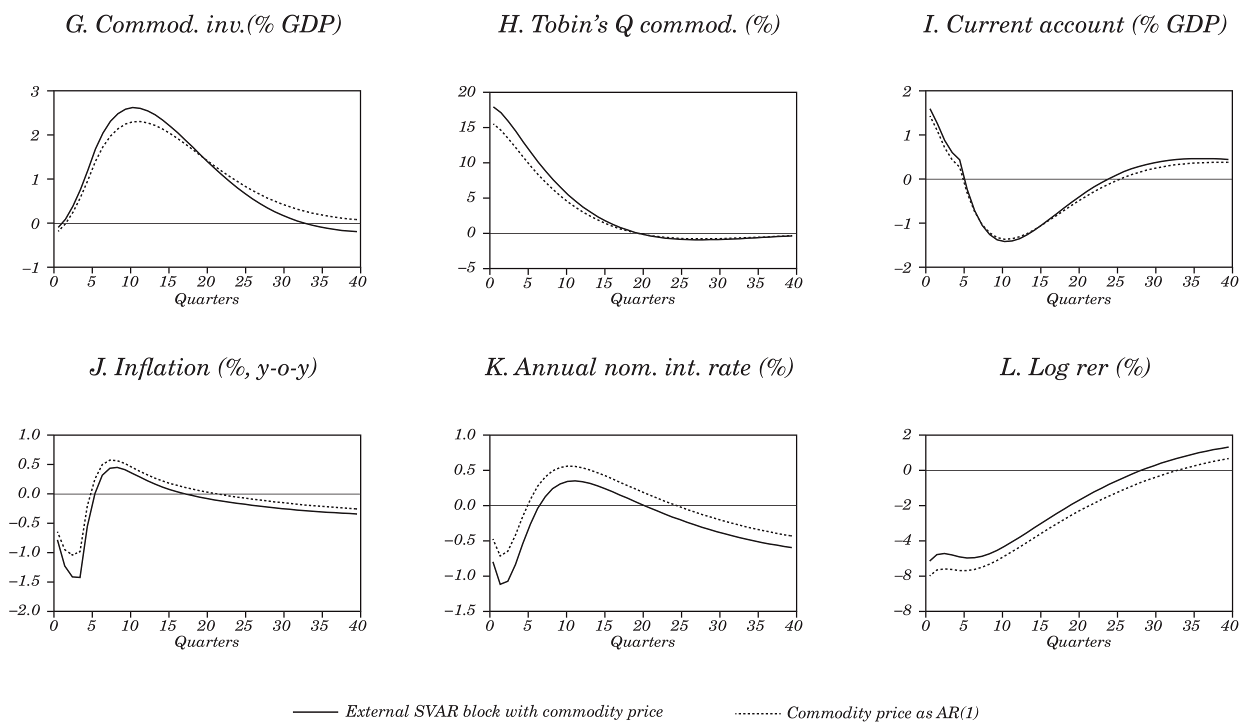


Figure 12. (continued)



Source: Authors' elaboration.
Note: Δ% from Steady State in y-axes.

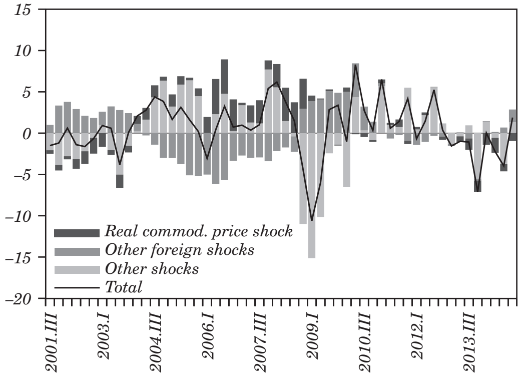
4.5 Historical Decomposition of Investment and GDP Growth

Figure 13 shows the historical decomposition of real investment growth in Chile over the period 2001.III-2014.IV when the contributions of commodity price shocks and other foreign shocks are separated from the contributions of other shocks.[23] According to the results, most of the above-average growth of investment in Chile between 2004 and 2009 is explained by commodity price shocks while other foreign shocks (e.g., relatively high foreign interest rates until 2008) had a negative influence on investment growth until the global financial crisis and a positive influence afterwards (e.g., due to better external financing conditions for emerging economies). However, the investment boom seems to have come to an end after 2012 mainly due to lower commodity prices. Hence, these results suggest that commodity price fluctuations have been a significant driving force of the investment cycle in Chile over the last decade, in line with the empirical findings presented in the previous section and the impulse responses of figure 10.

In terms of real GDP growth, figure 14 shows that commodity price shocks have been an equally important determinant. In fact, the effects of the commodity price surge before the financial crisis and the quick rebound of commodity prices after the crisis have counteracted the impact of the recession and accelerated the recovery of the Chilean economy. However, the effects of the commodity price boom on GDP growth have by now diminished due to the end of the investment cycle. Overall, our model therefore points towards an important role of commodity price fluctuations for business cycles in Chile and similar commodity-exporting economies. Given these findings, we now analyze some policy implications of our model.

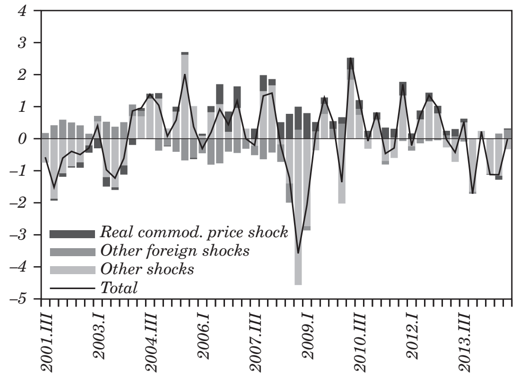
23. To compute the historical decompositions, we used, as observed variables, real GDP Y_t, real copper output as a proxy for commodity production $Y_{S,t}$, private non-durable consumption C_t, total investment $I_t + I_{S,t}$, government consumption G_t, CPI inflation $\pi_{C,t}$, the inflation rate of a price index excluding food and energy prices as a proxy for core inflation $\pi_{Z,t}$, the short-term central bank target rate r_t, the real exchange rate rer_t, the current account balance-to-GDP ratio CAY_t, the foreign variables from the VAR for Chile $Y_{F,t}$, π_t^*, r_t^* and $P_{S,t}^*/P_t^*$, the J.P. Morgan Emerging Market Bond Index (EMBI) spread for Chile as a proxy for the country premium Θ_t, and the real price of West Texas Intermediate crude oil $P_{O,t}^*/P_t^*$. Real GDP, private consumption, investment, and government consumption are measured as quarterly growth rates. The inflation and interest rates are in quarterly terms. Finally, copper output, the real exchange rate, and the real oil price are transformed into natural logarithms. Copper output and foreign output are de-trended using linear trends while the remaining variables are demeaned using their average sample values.

Figure 13. Historical Decomposition of Real Investment Growth in Chile, 2001.III-2014.IV
Percentage, Q-o-Q



Source: Authors' elaboration. Note: The zero line means that the investment growth rate equals the sample average.

Figure 14. Historical Decomposition of Real GDP Growth in Chile, 2001.III-2014.IV
Percentage, Q-o-Q



Source: Authors' elaboration. Note: The zero line means that the GDP growth rate equals the sample average.

4.6 Counterfactual Policy Analysis

What are the implications of alternative types of monetary and fiscal policies for the effects of commodity price shocks? For instance, on the monetary side, it is sometimes argued that a (strong) exchange rate appreciation may be responsible for current account imbalances by reducing the demand for exports and stimulating the demand for imports, which may be a motivation for monetary authorities in commodity-exporting countries to try to limit exchange rate fluctuations. On the fiscal side, a rules-based fiscal framework seems important in order to reduce spending pressures due to higher commodity income for the government, and it is therefore interesting to analyze the consequences of alternative fiscal rules.

Thus, in figure 15, we compare the responses to a persistent commodity price shock under the benchmark set of macroeconomic policies (i.e., a flexible inflation targeting regime with a floating exchange rate, and a structural balance fiscal rule) with the case where the monetary authority adjusts the interest rate in order to stabilize the real exchange rate (i.e., $rer_t = \overline{rer}$ for all t) and the case where the government adheres to a balanced budget rule.[24] The results show that under the real exchange rate target, the central bank needs to generate a reduction in the real interest rate in order to keep the real exchange rate unchanged, but this generates higher inflation that would imply an additional real appreciation and the central bank therefore raises the nominal interest rate initially before cutting it. However, the negative real interest rate response generates a larger expansion of the economy and a larger peak current account deficit than under an inflation targeting policy with a flexible exchange rate.

On the fiscal side, in comparison to a structural balance rule, a balanced budget policy implies a larger expansion of real GDP, higher inflation, a stronger interest rate response, a larger real appreciation and, initially, a somewhat larger expansion of private consumption due to the response of consumption by non-Ricardian households to higher labor income. However, consumption by Ricardian households and investment is crowded out, which explains why the current account response hardly changes even though government savings do not change. Interestingly, while non-commodity GDP and investment

24. We assume that government consumption is the fiscal instrument that adjusts to keep the government balance unchanged.

Figure 15. Impulse Responses to a Persistent Commodity Price Shock under Different Policies

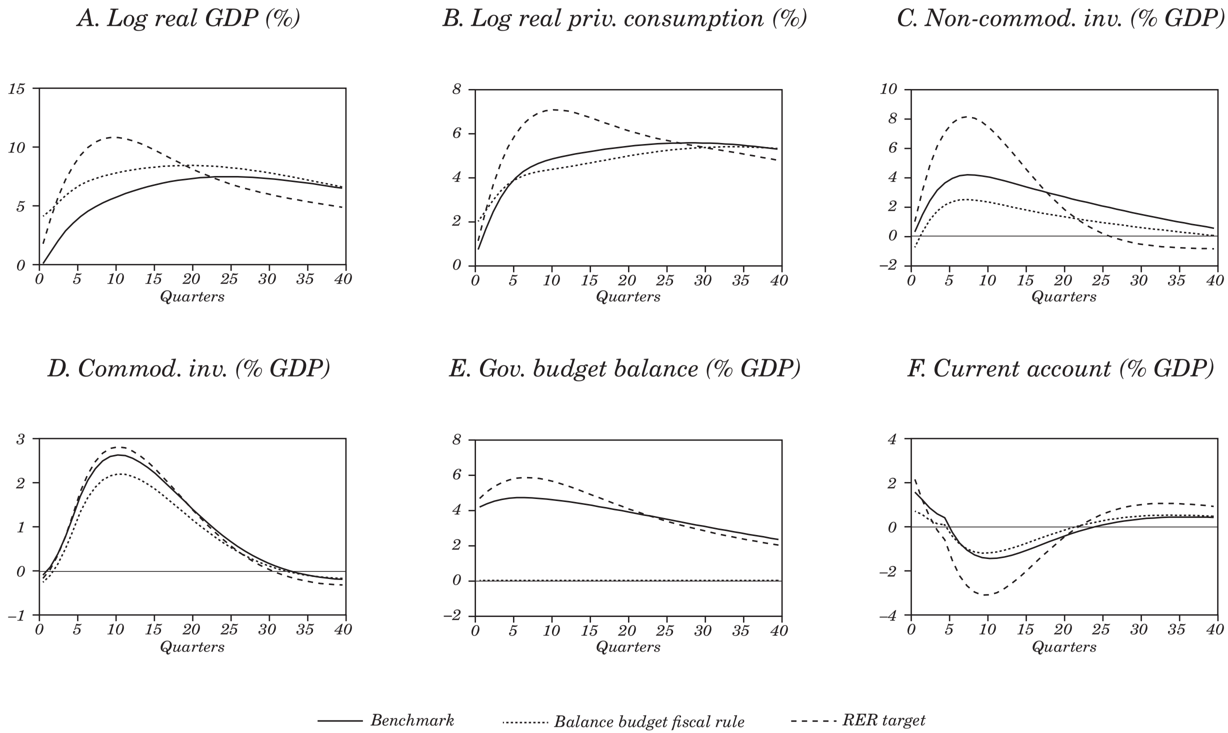
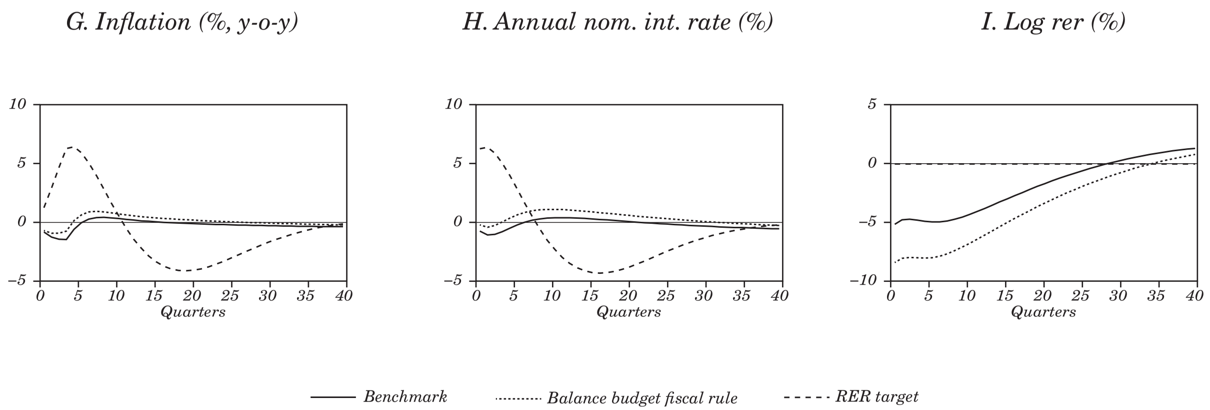


Figure 15. (continued)



Source: Authors' elaboration.
Note: Δ% from Steady State in y-axes.

are quite sensitive to the monetary and fiscal policy responses to the shock, the responses of real GDP and investment in the commodity sector are much less sensitive to the different policy responses. The reason is that commodity investment and production are primarily driven by the international commodity price, while the alternative policies–through different real interest rate and real exchange rate responses–mainly affect the economy-wide stochastic discount factor and the conversion of the international commodity price into domestic currency terms, but those indirect effects are less relevant for investment decisions in this sector. Therefore, these exercises show that while different monetary and fiscal policy reactions have in general important implications for the response of the economy to commodity price shocks, they do not majorly affect investment decisions in the commodity sector according to our model.

5. Conclusions

In this paper we have analyzed the impact of terms of trade shocks (i.e., commodity price shocks) in commodity-exporting economies. In particular, we have examined common patterns of macroeconomic responses in major commodity exporters based on SVAR analysis, and we have complemented this analysis using a DSGE model with a commodity sector for Chile.

The main results follow: first, depending on the share of commodity exports, a commodity price increase generates expansionary effects in the economy in line with previous studies. Part of this expansion is due to positive and delayed effects on investment in commodity sectors that may cause spillovers to non-commodity investment. Second, the persistence of commodity price shocks is crucial to understand those dynamics: when the shock is persistent, the response of investment, real GDP and other quantities are magnified and might lead to a current account deficit. If the share of foreign investment inputs in the commodity sector is sufficiently high, a portion of the expansionary effects on real GDP might be absorbed by balance trade adjustments. Third, according to historical decompositions of fundamental shocks for Chile, the copper price boom after the mid-2000s was a key driver of real investment and real GDP growth. Finally, our structural DSGE model provides additional policy insights. One main finding is that the implications of commodity price fluctuations for monetary policy are not trivial since they depend on the persistence of shocks, their impact on private consumption and investment, the fiscal policy response, real exchange rate pass-through to prices, and so on. Moreover, the policy exercises that we have conducted show that changes in monetary and fiscal policy rules have small impacts on investment decisions in the commodity sector, which are mainly driven by sectoral productivity developments and commodity prices.

Our results thus complement previous studies that have analyzed the macroeconomic impacts of commodity price fluctuations for business cycles and inflation dynamics in commodity exporters (see Medina and others, 2008; Desormeaux and others, 2010), the role of sectoral investment (see Knop and Vespignani, 2014) and the role of macroeconomic policy (see Medina and Soto, 2007b, 2014; Kumhof and Laxton, 2010; Frankel, 2011). From a general perspective, our findings reaffirm the conclusions from previous studies that flexible inflation targeting frameworks, flexible exchange rates and fiscal rules are essential to limit the macroeconomic impact of commodity price volatility in commodity-exporting countries.

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Appendix

The Data

Since we study the particular case of mining investment, for Chile we use the real copper price as a proxy for a commodity price shock. For the remaining countries (Australia, Canada, New Zealand, Peru and South Africa) we use the real IMF metal price index. Alternative estimations were made for every country using different commodity price indices (see table 5) and the results were relatively robust. Commodity investment is measured as nominal gross fixed capital formation in mining as a percentage of nominal GDP. Tables 5 and 6 contain a detailed summary of the different variables and data sources for each country.

Following conventional data adjustments, a number of additional transformations were made. For missing observations of commodity/mining investment, due to a change in the periodicity of the data, we used standard linear interpolations to transform annual data into quarterly data. Real GDP, real exchange rates and commodity price indices were transformed into natural logarithms. We used the U.S. CPI to deflate commodity price indices that were available in nominal U.S. dollar terms from their sources. Real GDP, investment and current account balances were seasonally adjusted using the Census X-12 procedure when they were not available in seasonally adjusted form from the original source.

Table A1. Data Sources and Transformations for Each Country, Foreign Blocks

Series	*Country*	*Proxy*	*Source*
Log real foreign GDP (SA)	All	World real GDP index (SA)	Central Bank of Chile
Foreign inflation (annual % change)	All	Annual % change of US CPI	FRED
Foreign interest rate	All	US federal funds rate	FRED
Log real commodity price index (deflated with U.S. CPI, 2005 = 100)[a]	Australia	**IMF metal price index**	IMF
		RBA commodity price index	RBA
		RBA bulk price index	RBA
	Canada	**IMF metal price index**	IMF
		Local metal price index	Bank of Canada
		Local commodity price index	Bank of Canada
	Chile	**Real copper price**	Cochilco
		IMF metal price index	IMF
	New Zealand	**IMF metal price index**	IMF
		Local commodity price index	ANZ Bank NZ
	Peru	**IMF metal price index**	IMF
		Local commodity price index	CRB of Peru
		Real copper price	Cochilco
	South Africa	**IMF metal price index**	IMF
		Real gold price	IFS

a. Bold letters indicate the indices used in the estimations.

Table A2. Data Sources and Transformations for Each Country, Domestic Blocks

Series	*Country*	*Source*
Log real GDP (SA)[1]	Australia	Australian Bureau of Statistics
	Canada	Statistics Canada
	Chile	Central Bank of Chile
	New Zealand	Reserve Bank of New Zealand
	Peru	Central Reserve Bank of Peru
	South Africa	South African Reserve Bank
Nom. commodity investment (% of nom. GDP) [2]	Australia [3]	Australian Bureau of Statistics
	Canada [3]	UN STATS and Statistics Canada
	Chile [3]	Central Bank of Chile
	New Zealand [3]	Reserve Bank of New Zealand
	Peru [3]	Central Reserve Bank of Peru
	South Africa	South African Reserve Bank
Inflation (annual % change of CPI)	Australia	Reserve Bank of Australia
	Canada	OECD
	Chile	Central Bank of Chile
	New Zealand	Reserve Bank of New Zealand
	Peru	Central Reserve Bank of Peru
	South Africa	OECD

Table A2. (continued)

Series	*Country*	*Source*
Monetary policy rate	Australia	Reserve Bank of Australia
	Canada	IFS
	Chile	Central Bank of Chile
	New Zealand [4]	Reserve Bank of New Zealand
	Peru [5]	Central Reserve Bank of Peru
	South Africa	OECD
Log real exch. rate (increase means depreciation)	Australia [6]	Reserve Bank of Australia
	Canada	IFS
	Chile	Central Bank of Chile
	New Zealand [7]	Reserve Bank of New Zealand
	Peru	Central Reserve Bank of Peru
	South Africa	South African Reserve Bank
Current account (% of nominal GDP)	Australia	Reserve Bank of Australia
	Canada	Statistics Canada
	Chile	Central Bank of Chile
	New Zealand	Reserve Bank of New Zealand
	Peru	Central Reserve Bank of Peru
	South Africa	South African Reserve Bank

Notes: [1] Real non-commodity GDP was computed by subtracting real commodity GDP from real total GDP; [2] Measured as nominal gross fixed capital formation in mining where nominal non-mining investment was computed by subtracting nominal mining investment from nominal total investment; [3] Linear interpolation of annual data; [4] Interbank rate from 1991.I-1999.I; [5] Interbank rate from 1996.I to 2000.IV and overnight rate from 2001.I to 2003.IV; [6] Inverse of trade-weighted index, May 1970 = 100 [7] Inverse of trade-weighted index, long-run average = 100.

Government Size, Misallocation and the Resource Curse

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Structural transformation is a reallocation of labor across sectors. In this paper I investigate the impact of structural transformation in an open economy on sectoral and aggregate productivity with a particular focus on the role of government. While there are potentially many sources of structural transformation,[1] I focus on labor reallocation induced by a windfall of revenue. Furthermore, I only concentrate on windfall revenue arising from the export of natural resources (fuels, ores and metals); although, the entire analysis is applicable to other types of windfalls such as, for example, foreign aid, remittances, EU structural funds or war reparations.

The exact focus here is the size of public sector employment in resource-rich countries. Governments largely provide non-traded services such as law enforcement, defense, infrastructure, arbitration and, thus, we can expect the standard "Dutch-disease" mechanism to hold, pushing workers towards non-traded sectors in resource-rich countries. Higher windfalls of revenue should increase demand for both traded and non-traded goods, but since the supply of non-traded goods can only be provided locally, more workers need to shift to non-traded sectors (including the government sector) in order to satiate the higher demand for non-traded goods in resource-rich countries. As such, I am interested in how the size of public employment should optimally vary between resource-rich and resource-poor countries,

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1. Gollin, Parente, and Rogerson (2002), Duarte and Restuccia (2010), Rogerson (2008), Dekle and Vandenbroucke (2006) and Yi and Zhang (2010), for instance, focus on labor reallocation induced by non-homotheticities in agriculture.

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whether the extent of government employment observed in resource-rich countries is efficient and, if not, what the productivity and welfare costs of this misallocation are.

I do two things in this paper: First, using a panel of macro cross-country data, I demonstrate that the share of public sector employment is greater in resource-rich countries than in resource-poor countries even controlling for the size of other non-traded sectors. Second, I construct and calibrate a small, open economy model with two production sectors and a government sector in which (optimally) higher government employment shares emerge as a consequence of windfall-induced labor reallocation. I then use a model to compare the optimal and observed size of government in order to obtain an estimate of the extent of government misallocation and the impact it has on welfare and productivity.

Importantly, the paper builds on earlier work by Kuralbayeva and Stefanski (2013). In that paper we did two things: First, we showed that resource-rich regions tend to have a) small but relatively productive manufacturing sectors and b) large but relatively unproductive non-manufacturing sectors. While this difference in sectoral size (or Dutch-disease effect) was well known and in line with theoretical predictions,[2] the productivity facts were novel and we showed that standard models were ill-equipped to replicate them. Second, we constructed and calibrated a small, open economy model with two sectors in which observed differences in sectoral productivity emerged endogenously as a consequence of windfall-induced labor reallocation and subsequent worker specialization. Since in the current paper I am interested in studying the impact of windfall-induced changes in government size on sectoral and aggregate productivity, it is crucial to correctly capture the windfall-induced changes in sectoral productivity that are not driven by changes in the size of the government sector. As such, in this paper, I adapt the framework of Kuralbayeva and Stefanski (2013) which does well in reproducing the pertinent facts relating to both sectoral size and sectoral productivity in resource-rich countries in the absence of government.

More specifically, in my model, I assume that manufacturing consumption goods are traded while non-manufacturing consumption goods are non-traded and that agents have heterogeneous skills

2. See for instance, Corden and Neary (1982), Matsuyama (1992) or Michaels (2011) for theoretical and empirical treatments of this so-called Dutch disease.

at performing different tasks in both consumption-good sectors. In addition, I assume the existence of a government sector whose role it is to provide basic public services such as an institutional framework, law-enforcement, judiciary, defense, infrastructure etc. to the two consumption-good sectors. The government sector is modeled as having a positive (external) effect on the productivity of both consumption sectors; however, government employees will have to be paid through a tax levied on all workers. I will also assume that government services cannot be imported from abroad. A region with higher windfall revenues will demand more of both consumption goods and government services than a region without windfalls. While the region's higher demand for manufacturing consumption goods can be satiated by imports from abroad, more workers need to be employed in non-manufacturing sectors (including the government sector) to meet the higher demand for locally produced non-manufacturing consumption goods and government services. This generates a reallocation of labor from manufacturing to the non-manufacturing sectors and results in a process of self-selection. Workers who choose to remain in manufacturing despite a windfall are those who are most skilled at manufacturing sector tasks, which leads to a more specialized and, hence, more productive manufacturing sector. Workers who re-allocate to non-manufacturing do so only in response to the higher demand generated by the windfall and will be less skilled at non-manufacturing sector tasks than workers already employed in that sector. This can lead to a more de-specialized and, hence, less productive non-manufacturing sector.[3] Windfalls thus induce labor reallocation, which, in turn, can generate asymmetric changes in sectoral productivity and an increase in the size of government.

I calibrate the model and show that the exogenous variation in endowments of natural resources does remarkably well in explaining the differences in sectoral employment structure and the large, asymmetric differences in sectoral productivity observed across countries. The model also does well in explaining differences in non-manufacturing prices in the data. However, the optimal increase in government employment in resource-rich countries predicted by the model is significantly smaller than the employment

3. Although the extent of this de-specialization can be tempered by the higher productivity resulting from a bigger government, the exact pattern will depend on the particular calibration.

observed in the data. Resource-rich countries seem to employ far more workers in government than the above model would suggest is optimal. In order to calculate the cost of this apparent misallocation, I feed observed government employment levels into my model, and examine the subsequent changes in labor reallocation across manufacturing and non-manufacturing sectors and the resulting differences in productivity. I find that a ten percentage point increase in resource windfalls is associated with a 1.72% lower aggregate productivity and a 1.11% lower welfare arising from government misallocation. In short, resource-rich countries tend to have governments that are too big, and this can have a relatively large impact on both productivity and welfare.

The above idea of a negative relationship between natural resources and economic outcomes ties into the so-called "resource curse" literature (see for example Neary, 1978; van der Ploeg, 2010; Robinson, Torvik, and Verdier, 2006; Collier and Goderis, 2007; Collier and Hoeffler, 2005, etc.). While the conclusions of that literature are not definitive, there is strong evidence to suggest that resource windfalls can generate various negative economic effects especially in the presence of bad governance and poor institutions. In particular, in that literature, negative economic outcomes are often a consequence of a corrupt political process associated with higher resource wealth. In short, those papers tend to argue that resource-rich countries offer more opportunities for a graft which introduces a drag on the economy. The approach taken in this paper is different and intentionally complementary. In the model, I take the most charitable view of government possible. First, I assume that the government sector is a crucial input in production and that there is no corruption, no directly wasted resources, no electioneering, no graft and no costly power struggles. Second, governance in resource-rich countries is assumed to potentially be just as effective as in resource-poor countries. Finally, I assume that all tax revenues are raised via non-distortive lump-sum taxes. Thus, I do my best to give governments in resource-rich countries the benefit of the doubt and, as such, my model aims to generate the largest possible optimal increase of government employment in response to windfalls. In my setup, the only way that government can be inefficient is if it employs too many or too few workers relative to what is predicted as optimal by the model. Importantly, however, I do not take a stand on why governments are the size that they are and instead, in my baseline experiment, I simply take public sector employment from the data and analyze the implicit misallocation costs of governments that are too big or too small.

Like Kuralbayeva and Stefanski (2013), the self-selection aspect of this work is in the spirit of Lagakos and Waugh (2014), Roy (1951) and Lucas (1978), and is closely linked to a similar discussion in the development literature. Poorer countries tend to have a larger fraction of their labor force employed in agriculture due to subsistence requirements. Caselli (2005) and Restuccia and others (2008) also show that productivity differences in agriculture between rich and poor countries are significantly greater than aggregate productivity differences. Lagakos and Waugh (2014) argue that this fact stems from the specialization that takes place in the smaller agricultural sectors in rich countries. They formalize and test their idea in the framework of a Roy (1951) model of self-selection. The outcomes of the above models, however, are efficient and do not consider the impact of a misallocation stemming from suboptimal government size. Furthermore, Lagakos and Waugh (2014) rely on non-homothetic preferences and an exogenous variation in aggregate productivity to generate a shift of workers across sectors. The current model has homothetic preferences and, instead, emphasizes the role of exogenous resource windfalls and the existence of a non-traded sector as the channel driving labor reallocation. Thus, I avoid what Lagakos and Waugh (2014) call the "key challenge" of their setup, which is the requirement of large, exogenous productivity differences to drive workers across sectors.

Section 1 introduces the data used in this study and establishes the productivity and employment facts. Section 2 introduces a general version of the model while section 3 considers the role of heterogeneity and government in a simple version of the model. Sections 4 and 5 present the solution and calibration of the general model, section 6 presents the results and section 7 delves into the scope of the government misallocation and its impact on productivity and welfare. Section 8 examines the role of weights and section 9 concludes.

1. Data and Facts

In this section, I briefly review the data and facts pertaining to manufacturing and (non-resource) non-manufacturing employment shares and productivity constructed in Kuralbayeva and Stefanski

(2013). I also examine the data and facts pertaining to employment in the government sector. In particular, I show that resource-rich regions have a) small and relatively productive manufacturing sectors, b) large and relatively unproductive non-manufacturing sectors and c) a greater proportion of workers employed in the government sector.

Throughout, I follow aforesaid paper and divide economies into mining and utilities (*MU*), manufacturing (*M*) and non-resource non-manufacturing (*NM*) sectors:[4]

$$\text{Total Economy} = \overbrace{\underbrace{A + C + S + G}_{\text{NonRes.Non-Mfg.}} + \underbrace{M}_{\text{Mfg.}}}^{\text{Non-Resource Economy}} + \underbrace{MU}_{\text{Mining and Utilities}} \tag{1}$$

As in Kuralbayeva and Stefanski (2013), I focus only on the productivity and employment structure of the non-resource economy.[5] Diverging from it, however, I will also consider the proportion of non-manufacturing workers employed in the public sector. Notice, however, that I will not say anything about productivity in the government sector. Constructing sectoral productivity measures is challenging and the assumptions needed to calculate government-specific productivity would be heroic to say the least. In what follows, I give a brief overview of the data.

1.1 Data

In Kuralbayeva and Stefanski (2013), we considered three different measures of productivity for the manufacturing and non-manufacturing sector. We begin with labor productivity, then add sectoral physical capital and finally include sectoral human capital. In principle, each subsequent measure of TFP is better than the last, since it controls for a greater variety of factor inputs. In practice, each measure requires additional data that is often hard to come by and, as such, has to be estimated. Considering all three measures gives a better overall picture of sectoral productivity. However,

4. The lowest level of aggregation available for all data is the one sector ISIC classification. NM here is defined as the sum of agriculture (A), construction (C), (private) services (S) and Government (G).

5. Thus, when we refer to aggregate productivity or sectoral employment share, we always mean aggregate productivity of the *non-resource* economy, or sectoral employment relative to *non-resource* employment.

when we examine the results and compare the changes of sectoral productivity with respect to resource wealth, we find quantitatively and qualitatively very similar results across all three measures. As such, in this paper, to save space, and since that was the baseline measure chosen in the original paper, I will only consider the most comprehensive measure of productivity from that paper, D_s, obtained as a residual from the following production function

$$Y_s = D_s(K_s)^{\alpha_s}(h_sL_s)^{1-\alpha_s} \tag{2}$$

Where Y_s is sector s's value-added, L_s is sectoral employment, K_s is sectoral physical capital, and h_s is average sectoral human capital, so that h_sL_s is the "quality adjusted" workforce.[6] Constant price sectoral value-added data comes from the UN (2009) and is adjusted to control for cross-country sectoral price level differences using the World Bank's 2005 International Comparison Program (ICP) price data. Employment data comes from the ILO (2003) and physical capital is constructed using the perpetual inventory method from the PWT. I follow Caselli (2005) in constructing aggregate human capital from the Barro and Lee (2010) education data set, and in constructing sectoral physical capital. Finally, due to lack of data, I assume the ratio of human capital between any two sectors is constant across countries and time, equal to the corresponding ratio in the U.S., and that labor shares in the last two measures of productivity, $1 - \alpha_s$, are identical across countries, constant over time, and equal to OECD averages. For construction details, see the appendix of Kuralbayeva and Stefanski (2013).

Next, I obtain public sector employment data from the ILO which "covers all employment of [the] general government sector as defined in the System of National Accounts 1993 plus employment of publicly owned enterprises and companies, resident and operating at central, state (or regional) and local levels of government. It covers all persons employed directly by those institutions, without regard for the particular type of employment contract."[7]

6. I also refer to D as the corresponding measure of aggregate (non-resource) productivity.

7. A limited subset of the public employment data is provided at the ISIC one sector level and, in that (very limited) subset, public employment is overwhelmingly in the non-manufacturing sector. As such, in the baseline experiment of this paper, in order to maintain as large a sample of data as possible, I shall assume that all government employment belongs entirely to the non-manufacturing sector.

I follow Sachs and Warner (2001) and Kuralbayeva and Stefanski (2013) in defining natural resource "wealth" as the ratio of exports of natural resources (fuels, ores and metals) to GDP using WDI (2007) data.

In my baseline sample, like in my paper with Kuralbayeva, I consider a panel of the 120 richest countries for the 1980-2007 period.[8] I keep all country-date points for which I have all necessary data and those that do not deviate significantly across different data sources. This leaves me with a total of 33 countries in my sample. On average, there are 10 observations for each country, 22 observations for each year and a total of 340 data points. Notice that, until 1995, the data for public employment is only available once every five years and there are very few observations from 1980 and 1985.

1.2 Summary of Facts

Table 1 shows summary results by comparing the largest 10 percent of natural resource exporters with the smallest 10 percent. The table reproduces the results (pertaining to sectoral size and productivity) found in Kuralbayeva and Stefanski (2013) for the current sample of data and adds the new finding pertaining to the size of government employment in resource-rich countries. The table shows the decomposition of employment according to manufacturing/non-manufacturing and public/non-public sectors. Furthermore it also shows the sectoral productivity (in manufacturing and non-manufacturing) normalized by aggregate productivity of each group. From the table observe that resource-rich countries: a) employ, proportionally, 27% less workers in manufacturing (column 4) and 6% more workers in (non-resource) non-manufacturing (column 3) than resource-poor countries; b) are 24% more productive in manufacturing (column 8) and 4% less productive in non-manufacturing (column 7) relative to aggregate productivity than resource-poor countries and; c) employ 48% more workers in the public sector (column 5) and 10% less workers in the non-public sector (column 6) than resource-poor countries.

8. I focus on richer countries for three reasons: First, I am examining more disaggregate data than is standard so data quality in poorer countries is a serious concern. Second, the mechanism of specialization described later may play a more prominent role in richer countries. Finally, focusing on richer countries may avoid the worst of unobserved cross-country heterogeneity. Since this procedure may in principle result in unobserved selection bias, I have also experimented with a complete sample and the results are independent from this cutoff.

Table 1. Characteristics of Top and Bottom Deciles of Natural Resource Exporters

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	E Res./ GDP	*Output/ worker*	*Emp. NM*	*Share M*	*Emp. G*	*Share NG*	*TFP NM*	(D_s) *M*
10^{th} percentile	0.17	30,716	0.86	0.14	0.25	0.75	0.94	1.37
90^{th} percentile	0.00	17,756	0.81	0.19	0.17	0.83	0.98	1.11
10^{th} /90^{th}			1.06	0.73	1.48	0.90	0.96	1.24

Source: See section 1.1.
(1) Resource Export Share (2) Output per Worker (3-6) Composition of Employment (Manufacturing vs Non-manufacturing and Public vs. Non-public) (7-8) Sectoral Productivity (Relative to Aggregate Productivity). Data for 33 countries from 1980 to 2007.

As in that paper, I stress that the productivity results refer to relative and not absolute productivity. So, for example, looking at the column labeled D_m (column 8) in table 1, the average productivity of manufacturing in the top 10% of resource exporters is 37% higher than the average aggregate productivity of those same countries; whereas, in the bottom 10% of exporters, the average manufacturing productivity is only 11% higher than the average aggregate productivity in that group of countries. Countries that have low aggregate (or sector neutral) levels of productivity will have low absolute levels of productivity in all sectors irrespective of the size of their resource endowments but may still have high productivity in manufacturing relative to their aggregate productivity.

1.3 Earlier Results

In this section, in table 2, I briefly reproduce the baseline regressions of Kuralbayeva and Stefanski (2013) for the current sample of data. For robustness, with respect to these regressions and further discussion, see that paper. Column (1) shows the regression of manufacturing employment share on the log of the windfall measure controlling for changes in output per worker (and output per worker squared) as well as controlling for time-fixed effects.[9] Resource-rich countries employ fewer workers in the manufacturing sector and (implicitly) more workers in the non-manufacturing sector; a doubling of resource windfalls is associated with a 1.4 percentage point decline in the manufacturing employment share. These results are statistically significant at the one percent level.

Columns (2) and (3) of table 2 show how (the log of) manufacturing and non-manufacturing productivity varies with (the log of) resource windfalls and aggregate productivity. Higher aggregate (or sector neutral) productivity is unsurprisingly associated with higher

9. Since employment share in manufacturing is simply one minus the employment share in non-manufacturing, the regressions for non-manufacturing employment are the same with opposite signs on coefficients. As in Kuralbayeva and Stefanski (2013), I take a log transformation of resource windfalls since the data is concentrated near zero. This ensures that the transformed empirical distribution is closer to normal. Importantly this transformation does not drive the results. Finally, I control for output-per-worker and output-per-worker squared since it is a well-established fact that manufacturing follows a hump shape with income. This in no way drives my results. For details and robustness tests, see Kuralbayeva and Stefanski (2013).

Table 2. Baseline Results in Current Sample of Data

	(1)	(2)	(3)	(4)
	M. Emp.	log(D_m)	log(D_s)	log(p_s)
log(NRE)	-0.014*** (0.002)	0.068*** (0.014)	-0.012*** (0.002)	0.048*** (0.011)
logLprod	0.650*** (0.127)			
sqlogLprod	-0.031*** (0.006)			
log(D)		1.458*** (0.078)	0.888*** (0.011)	0.838*** (0.067)
τ_e				-0.355*** (0.132)
Time fixed effects	yes	yes	yes	yes
No. of obs.	340	340	340	340
R^2	0.256	0.567	0.953	0.480

Source: Kuralbayeva and Stefanski (2013).
Standard errors in parentheses.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

sectoral productivity. However, controlling for differences in aggregate productivity, resource-rich countries tend to be more productive in manufacturing and less productive in non-manufacturing than resource-poor countries. These results are significant at the one percent level and are robust to other measures of productivity. A doubling of natural resource windfalls is associated with a 1.2% lower non-manufacturing productivity and a 6.8% higher manufacturing productivity.[10]

The positive impact of windfalls on the non-manufacturing price is an important fact that will be examined later. In Kuralbayeva and Stefanski (2013) we constructed a panel of sectoral price level data by combining ICP cross-country sectoral price levels with sectoral

10. I emphasize that these results refer to *relative* and *not absolute* productivity. Countries that have low aggregate (or sector neutral) levels of productivity will have low *absolute* levels of productivity in all sectors irrespective of the size of their resource endowments but may still have high productivity in manufacturing *relative* to aggregate productivity.

price indices from the UN. Column (4) reproduces the baseline price regression from Kuralbayeva and Stefanski (2013). In particular it shows the regression of the log of relative non-manufacturing price levels (with respect to manufacturing price levels) on the (log) measure of resource windfalls, (log) aggregate productivity, energy subsidies from WEO (2011)[11] and time-fixed effects.[12] I find that a doubling of natural resource windfalls is associated with a 4.8% increase in the price of non-traded goods and these results are significant at the one percent level.

1.4 Public Sector Employment Results

Next, I present the novel empirical results of this paper. Table 3 shows the regressions relating the size of the government sector employment with resource windfalls. In particular, column (1) shows the regression of government employment share on the log of my windfall measure. Resource-rich countries employ more workers in the public sector and (implicitly) less workers in the non-public sector. These results are statistically significant at the one percent level. Column (2), controls for time-fixed effects, while column (3) controls for changes in output per worker that may help reduce unobserved cross-country heterogeneity. Column (4) adds time-fixed effects to the regressions in column (3). In all three cases, the results remain largely unchanged. Finally, column (4) adds employment shares of the non-manufacturing sector. The results of this last regression tell us that, even controlling for the size of other non-manufacturing sectors, resource-rich countries tend to have a larger government sector. Taking column (2) as the baseline result, I find that a doubling of natural resource windfalls is associated with a 1.7% higher public sector employment share and these results are significant at the one percent level.

11. Subsidy data is an average of 2008-2010 data. We assume that these subsidies are country specific and fixed over the 1980-2007 period.

12. Notice that we included aggregate productivity to control for the so-called Penn effect, the observation that richer countries have higher non-traded goods prices than poorer countries. Furthermore, as was discussed in Kuralbayeva and Stefanski (2013), a potential issue with the ICP price data is that they reflect consumer rather than producer prices, which are the focus of the later model. This may be particularly important in resource-rich economies, where consumer subsidies are prevalent. We control for energy subsidies as an indirect attempt at controlling for the overall level of subsidies in a country's economy.

Table 3. Changes in Government Employment Share and Resource Wealth

	(1)	(2)	(3)	(4)	(5)
	G. Emp.	*G. Emp.*	*G. Emp.*	*G. Emp.*	*G. Emp.*
log(NRE)	0.014***	0.017***	0.011***	0.013***	0.021***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
logLprod			0.041***	0.045***	0.045***
			(0.008)	(0.008)	(0.008)
NM. Emp.					-0.595***
					(0.103)
Time fixed effects	no	yes	no	yes	yes
N° of obs.	340	340	340	340	340
R^2	0.045	0.061	0.115	0.139	0.220

Source: See section 1.1.
Standard errors in parentheses
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Finally, notice that while in Kuralbayeva and Stefanski (2013) we controlled for time and country-fixed effects, in the above regressions I include only time-fixed effects. There are two reasons for this. First, I have a far more limited sample of data and therefore not enough variation over time in the sample. Most of the variation over time in windfalls comes from variation in price which tends to be common across countries. Since much of the price variation in natural resources took place in the 1980's and much of our public employment data is missing in that period, there is very little temporal variation in the remaining data.[13] Second, and perhaps more importantly, the focus of this paper will be government employment. This type of work is often characterized by tenure or unionization and is thus often quite unresponsive to shocks over time, at least in the short-run. As such, to examine the persistent effects of resource endowments, it makes more sense to look at cross-country differences that can be interpreted as long-run effects.

13. A rule of thumb here is to regress the independent variable log(NRE) on country-fixed effects. If the value of $1/(1-R^2)$ from the resulting regression is less than ten, the rule of thumb suggests that there is enough variation in the data to include that variable. In our case $1/(1-R^2) = 11$ thus suggesting there is too little variation to include country-fixed effects.

2. The Model

In this section, I introduce a small, open, multi-sector economy with heterogeneous agents that can account for the observed facts in productivity and employment. The model closely follows Kuralbayeva and Stefanski (2013) but introduces a role for government. There are three final goods in the economy: manufacturing goods (m), private non-manufacturing goods, which, for brevity, I will call services (s) and a windfall good which, also for brevity, I will refer to as oil but could equally as well be any other natural resource or alternative source of windfall revenue. I assume that manufacturing and oil are traded internationally, while services are assumed to be non-traded. Oil is assumed to be an endowment good that is not used locally but only exported abroad (and thus serves as a windfall of income) while manufacturing and services can be produced locally using labor but no oil. I also assume the existence of a government sector (the public non-manufacturing sector) which provides the manufacturing, service and oil sectors with inputs such as institutional frameworks, transportation, rule of law, arbitration, etc. that are productivity enhancing, but are external to firms (and workers). Thus, while workers can be employed in the government sector, the sector produces no final goods directly, but rather provides an input that looks like a higher level of productivity to other sectors of the economy. Finally, I assume that the external benefits produced by government cannot be imported from abroad.

2.1 Households

Suppose there is a measure one of agents, indexed by i. Preferences are given by

$$U(c_s^i, c_m^i) \equiv \left((c_s^i)^{\frac{\sigma-1}{\sigma}} + \nu (c_m^i)^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \tag{3}$$

Each agent in the economy is endowed with a unit of time and assumed to have a vector of innate sector specific skills or talents, $\{z_s^i, z_m^i\}$, representing the efficiency of that unit of time in the service sector (s) and the manufacturing sector (m). Endowments of skills $\{z_s^i, z_m^i\}$, are exogenous and are assumed to be randomly drawn from a distribution common to the whole population $N(z_s, z_m)$. Since skills are assumed to be perfectly observable, agents earn a wage income, w^i. The agent is also endowed with a resource tree that provides a stream of O units of oil each period. Oil is not directly used by the agent but is exported and provides windfall revenues. Finally, each agent also potentially faces a lump-sum tax T, paid to government. The budget constraint of the agent is thus given by:

$$p_s c_s^i + c_m^i \leq w^i + G_m(L_g) p_o O - T \tag{4}$$

where p_s is the relative price of service sector goods and p_o is the relative price of oil determined on international markets. Traded manufacturing goods are taken as numeraire. Finally, in the above, $0 \leq G_m(L_g) \leq 1$ is a function capturing the external productivity benefits of government for the export of oil. These are assumed to be positively dependent on the employment size of the government sector L_g. I describe this function in more detail in the following paragraphs.

2.2 Production

I assume a competitive market in all final good sectors so that each worker gets paid its marginal product. The output of worker i in sector $k = s, m$ is given by $Y_k^i = AG_k z_k^i$, where A is aggregate (potentially sector specific) efficiency, z_k^i is the worker's sector specific productivity and $0 \leq G_m(L_g) \leq 1$ is the impact of government on productivity that is external to workers and firms but depends positively on the size of government employment L_g in the manner described in the following paragraph. Aggregate output in sector $k = s, m$ is given by

$$Y_k \equiv \int_{i\in\Omega^k} Y_k^i di = AG_k(L_g)\tilde{L}_k \tag{5}$$

where Ω^k is the set of agents electing to work in sector $k, L_k \equiv \int_{i\in\Omega^k} di$ is the number of workers in private enterprises in sector k and $\tilde{L}_k \equiv \int_{i\in\Omega^k} z_k^i di$ represents the total effective labor units (privately) employed in sector k. Finally, notice that for simplicity, I assume that $G_m(L_g)$ is common to both the oil sector and the manufacturing production sector.

2.3 Trade

It is assumed that manufacturing goods and oil are traded while service sector goods are not traded. In order to close the model, I assume a period-by-period balanced budget constraint given by

$$m - G_m(L_g)p_o O = 0, \tag{6}$$

where m is the value of imported traded goods (recall that traded goods are assumed to be the numeraire) and $G_m(L_g)$ is the impact of government on how effective imports are, capturing the idea of a type of iceberg transport cost. As mentioned above, for simplicity, I have assumed that the government contribution to the productivity of exporting (or producing) oil is the same as the corresponding term in the manufacturing sector. Finally, in the above setup, all oil endowments are exported in exchange for manufacturing imports. A country with no oil (i.e., $p_o O = 0$) is thus assumed to be closed to trade.

2.4 Government

The government employs L_g workers to provide public goods and services such as infrastructure, a justice system, law and order, etc. that enhance sectoral productivity of the consumption sector $G_k(L_g)$ according to the following production function:

$$G_k(L_g) = 1 - \frac{\psi^k}{\psi^k + L_g}, \tag{7}$$

where $\psi^k \geq 0$ is a sector specific constant capturing the importance of government services to production in a particular sector. When $\psi^k > 0$, $G_k'(L_g) > 0$, that is, more government employees contribute more, ceteris paribus, to the output of a sector. Zero employment in the government sector implies $G_k(0) = 0$ and, hence, zero output in sector k. Consequently, with $\psi^k > 0$, a positive employment in government is necessary for production to take place. If $\psi^k = 0$, then $G_k(L_g) = 1$ and the model collapses to the non-government world of Kuralbayeva and Stefanski (2013). I let Ω^G be the set of workers employed in the government sector while the number of workers employed in government is given by $L_g \equiv \int_{i\in\Omega^G} di$. Finally, for simplicity, and to capture the inherent equity of government employment, I assume that government pays each employee the same wage, w^g. Alternatively, we can think of this as a technological constraint either on the ability of government to observe worker specific skills or on the fact that production in the government sector requires a constant level of skill. As such, the government's budget constraint, which is assumed to be balanced period by period, is given by

$$T = w_g L_g. \tag{8}$$

Thus, the government levies a per period lump-sum tax on each worker to pay for the wages of all its employees.

2.5 Market Clearing

Defining $\Omega = \Omega^m U \Omega^s U \Omega^G$, the market clearing conditions for manufacturing, services and employment are given by

$$\int_{i\in\Omega} c_m^i di = Y_m + m \text{ and } \int_{i\in\Omega} c_s^i di = Y_s \text{ and } L_m + L_s + L_g = 1 \tag{9}$$

2.6 Competitive Equilibrium

For each price of oil p_o, every endowment level of oil O, and for a given size of government L_g, equilibrium in the above economy consists of a relative price of service goods p_s, agent-specific wages w^i, and allocations for all agents, firms and government so that labor and output markets clear, and trade, as well as the government budget constraint, remains balanced period by period.

2.7 Solution

Each manufacturing and service sector firm chooses a non-negative quantity of labor to hire. Due to perfect competition, firms offer the following wage schedule to consumer i:

$$w_m^i = AG_m(L_g)z_m^i \text{ and } w_s^i = p_s AG_s(L_g)z_s^i, \tag{10}$$

in manufacturing and service sectors respectively. Consumer i, who decides to work in a non-governmental sector, chooses employment in the sector that provides a higher wage given its particular talent vector. The wage offer for each worker in non-governmental work is thus given by $w^i_{ng} = \max\{w^i_s, w^i_m\} = \max\{p_s A G_s(L_g) z^i_s, A G_m(L_g) z^i_m\}$, which gives rise to the following simple cut-off rule: a worker i employed in non-government work, will choose to work in services if and only if

$$p_s > \frac{G_m(L_g) z^i_m}{G_s(L_g) z^i_s}. \tag{11}$$

Finally, given a worker's wage offer in the private sector, a worker will choose to work in government if he receives a higher wage there. Consequently, the wage of each worker is given by $w^i = \max\{w^i_{ng}, w_g\}$.

Agents take prices, as well as the wage offers arising from the firm and government problems, as given (and, hence, the above decision rules). Having picked their specialization, they then proceed to maximize (3) subject to (4), which results in the following demands of each agent:

$$c^i_s = \frac{(w^i + G_m(L_g) p_o O - T)}{p_s + \nu^\sigma p^\sigma_s} \text{ and } c^i_m = \frac{\nu^\sigma p^\sigma_s (w^i + G_m(L_g) p_o O - T)}{p_s + \nu^\sigma p^\sigma_s}. \tag{12}$$

Using the goods market clearing conditions in equation (9) and the demands of each agent from equations (12), I can show that

$$\nu^\sigma p^\sigma_s Y_s = Y_m + G_m(L_g) p_o O \tag{13}$$

Substituting (5) into (13), provides an implicit expression for p_s as a function of the value of oil endowment $p_o O$ and the level of government employment.[14]

2.8 Observed and Optimal Government

In this paper I consider two ways of determining government employment: First, I will assume the government employment is exogenous and taken directly from the data. Second, I will suppose that government employment emerges from choices of a benevolent

14. Notice that I have assumed that windfall income is distributed evenly across agents. This assumption plays no role in our results since equation (13) and, hence, the equilibrium price and cutoff condition holds regardless of how windfalls are distributed.

social planner who wishes to maximize the utility of workers. In particular, a benevolent government will take the demand functions of agents–derived above in equation (12) as given, and solve a Ramsey-type problem for the optimal size of government employment L_g^{opt} by maximizing the expected utility of workers

$$\max_{0 \leq L_g \leq 1} \mathbb{E}_{\gamma_i}(U(c_s^i(L_g), c_m^i(L_g))), \tag{14}$$

where $\mathbb{E}_{\gamma_i}(U(c_s^i, c_m^i)) = \int_0^1 \gamma_i U(c_s^i(L_g), c_m^i(L_g))di$. In this expression, $\gamma_i : \mathbb{R} \to \mathbb{R}$ is a function that specifies the weight that a government places on individual i. If $\gamma_i = 1$, as it will be in our baseline, then the government cares equally about every individual. In appendix B, I consider the case when different agents have different weights.

3. Heterogenity and Government

3.1 A Simple Example

To illustrate the impact of worker heterogeneity and government on sectoral productivity, I begin with a simple example.[15] Suppose the skill distribution N is degenerate and given by $\{z_s^i, z_m^i\} = \{e_i, e^{1-i}\}$ for each worker $i \in [0,1]$. Furthermore, assume Cobb-Douglas utility ($\sigma = 1$), equal utility weights ($\nu = 1$), normalize A to unity and suppose that $\psi_m = \psi_s > 0$ so that $G \equiv G_s = G_m$. Agent i receives wage offers $w_s^i = p_s G z_s^i$ in services, $w_m^i = G z_m^i$ in manufacturing and w_g in the government sector and will choose to work in the sector that pays most. This gives rise to two cutoff agents, $\bar{i}_m$ and $\bar{i}_g$ who are respectively indifferent between manufacturing and government sectors, so that $w_g = w^{\bar{i}_m}$, as well as between service and government sectors, so that $w_g = w^{\bar{i}_g}$. Suppose that government hires L_g workers. To do so, it will have to offer a wage large enough so that $L_g = \bar{i}_g - \bar{i}_m$. Using these relationships, I can calculate these two cutoffs as a function of price and the size of the government employment so that $\bar{i}_m(p_s, L_g) = (1 - \log p_s - L_g)/2$ and $\bar{i}_g(p_s, L_g) = (1 - \log p_s + L_g)/2$. I illustrate the problem of the worker in figure 1(a) which plots the wage offers in each sector and the cutoffs $\bar{i}_k(p_s, L_g)$ for $k = m, g$. Agents to the left of $\bar{i}_m(p_s, L_g)$ are

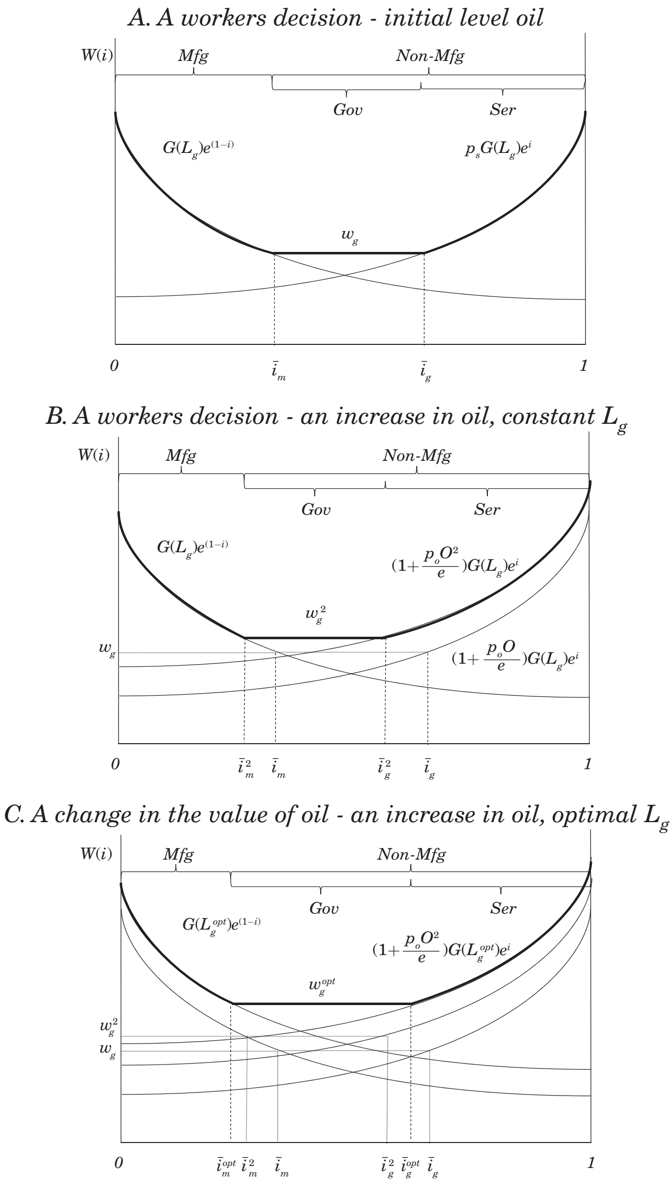
15. While I focus on heterogeneous workers, this setup can easily be related to one with heterogeneous firms without changing the results.

relatively more skilled in manufacturing sector tasks and, hence, have higher wage offers than in services or government and, hence, choose to work in the manufacturing sector. Agents to the right of $\bar{i}_g(p_s, L_g)$ are relatively more skilled in service sector tasks and, hence, have higher wage offers and choose to work in services. Agents in between the cutoffs will have a comparative advantage in government work and will, hence, choose to work in the government sector.

The cutoff values are dependent on the price of service goods and the size of government employment. For the moment, suppose that government adjusts its wage to maintain a constant level of employment and consider the impact of a higher oil windfall. A windfall will influence the price of services and, hence, the distribution of workers across sectors. A windfall of revenue generates a greater demand for both types of consumption goods. To satiate the higher demand for non-traded service sector goods, more workers are needed in the service sector. However, new workers will choose to work in services only if service wages rise, which, in turn, can only happen if the service sector price increases. More formally, I can write output in each sector as a function of the respective cutoff (and, hence, the price): $Y_s\,(p_s; L_g) = G_s(L_g)(e - e^{\bar{i}_g(p_s;\, L_g)})$ and $Y_m(p_s) = G_m(L_g)(e - e^{1-\bar{i}_m(p_s;\, L_g)})$. Using these equations as well as the relationship between the two cutoffs and equation (13), I can determine the equilibrium price of non-manufacturing $p_s = 1 + p_o O/e$. A higher windfall translates into a higher service sector price which results in an increase in service sector wage offers. In order for employment in government to remain unchanged despite the higher price, wages in the government sector must also rise. This results in a shift of workers from manufacturing to government and from government towards services resulting in a leftward shift of both cutoffs to $\bar{i}^2_m(p^2_s; L^s_g)$ and $\bar{i}^2_g(p^2_s; L^s_g)$. As both cutoffs shift left, manufacturing productivity $(Y_m/\bar{i}_m = (e - e^{1-\bar{i}})/\bar{i}_m)$ rises: the workers who remain in the manufacturing sector are most skilled in manufacturing sector work. At the same time, service sector productivity $(Y_s/(1 - \bar{i}_g) = (e - e^{\bar{i}})/(1 - \bar{i}_g))$ falls: new entrants in non-manufacturing pull down productivity since they are, on average, less skilled than those already employed in non-manufacturing. Finally, I can also show that non-manufacturing sector productivity $(Y_s/(1 - \bar{i}_s + L_g) = (e - e^{\bar{i}})/(1 - \bar{i}_g + L_g)$ also falls as long as the government sector is not "too large."[16]

16. In particular $L_g < -2 - log(e + p_o O) + 2\Omega(e(e + p_o O))$ where $\Omega(\cdot)$ is the product logarithm function.

Figure 1. The Mechanics of the Model in a Simple Example



Source: Author's elaboration.

3.2 Government

So far, I have taken the size of government employment as fixed. Suppose, however, that the fiscal authority takes the demand functions of agents derived above in equation (12) as given, cares equally about every agent so that $\gamma_i = 1$, and solves the Ramsey-type problem for the optimal size of government employment L_g^{opt} in equation (14). Taking the first order condition from this maximization problem, and applying the implicit function theorem to the resulting first order condition, it can be shown that the optimal size of government increases with the size of the oil endowment $\partial L_g^{opt} / \partial p_o O > 0$. Intuitively, higher oil endowment means a greater demand for both traded and non-traded goods. Demand for traded, manufacturing goods can be satiated by imports from abroad. Demand for non-traded goods however, which includes government services, is satiated with locally produced goods and, hence, results in a shift of labor towards the non-traded sectors of services and government. This is shown in figure 1(C). The impact on manufacturing productivity is unambiguous: manufacturing productivity will increase both due to the smaller size of the manufacturing sector (and, thus, its more specialized nature) and the larger government sector, which, in turn, increases each workers productivity. The impact on non-manufacturing productivity is mixed and will depend on specific parameters but can potentially be negative.

4. Solving the Model

4.1 Distribution Function

To calibrate and solve the model, I must pick a particular parametric form for the distribution of skills $N(z_s, z_m)$ since the Roy model cannot be identified from cross-sectional wage data alone.[17] In what follows, I assume that skills are drawn independently from a normalized Type II extreme value (or Frechet) distribution with CDF

17. This is because we observe only the outcomes of workers choices (in the form of a worker's observed wages) and not the talent draws (and hence the sectoral wage offers) that underpin these outcomes.

$$N(z_s) = e^{-z_s^{-\theta}} \text{ and } N(z_m) = e^{-z_m^{-\theta}} \tag{15}$$

where $\theta > 1$. The log of a random talent draw $\log Z_i$ has a standard deviation $\pi/(\theta\sqrt{6})$, where π is the constant. The parameter θ thus governs the amount of variation in skills and, hence, the observed productivity dispersion: lower values of θ imply more heterogeneity in ability and higher productivity dispersion. Notice that I assume that θ is common to both manufacturing and service sectors and that talent draws are independent of each other. While both these assumptions may seem restrictive, they allow me to derive simple, analytic solutions which provide insights into the workings of the model. In Kuralbayeva and Stefanski (2013) we extended the "non-government version" of the model to allow correlated talent draws and different dispersions across sectors and we showed that, quantitatively, these channels only played a limited role.

I focus on the Frechet distribution for several reasons. First and foremost, this distribution is one of three extreme value distributions. According to the Fisher-Tippet-Gnedenko theorem from extreme value theory, there are only three types of distributions that are needed to model the maximum or minimum of the collection of random observations from the same distribution. More specifically, the maximum of a sample of i.i.d. random variables converges in distribution to either the Gumbel, the Frechet, or the Weibull distribution.[18] In my case, choosing an extreme value distribution can be thought of as capturing the distribution of agents' "best" talents in each particular sector. Secondly, of these three distributions I choose the Frechet in keeping with the literature. Obviously, Kuralbayeva and Stefanski (2013) chose this distribution. Furthermore, Eaton and Kortum (2001) have used this distribution to parameterize a Ricardian model of international trade, and Lagakos and Waugh (2014) have used it to model talent distribution across sectors. Finally, the Frechet distribution also provides very tractable analytic solutions which allow for easy interpretation of results and does a very good job of fitting the data.

18. Broadly speaking, if one generates *N* data sets from the same distribution, and then creates a new data set that includes only the maximum values of these *N* data sets, the resulting data set can only be described by one of the above distributions. For more details see De Haan and Ferreira (2006).

4.2 Employment

Since z_s and z_m are independently drawn from a Frechet distribution, the joint density function can be expressed as $g(z_s, z_m) = g(z_s)g(z_m)$. Using this, I can relate sectoral labor supply allocation to the parameter that controls the dispersion of skills across sectors.

First, I start with government employment. In order to induce L_g workers to work in the government sector, the government will have to offer a wage w_g such that enough workers are drawn to that sector by earning more than they could in either manufacturing or non-manufacturing. Consequently, the chosen wage will be defined by

$$\begin{aligned} L_g &= P\left(w_g > w_m, w_g > w_s\right) \\ &= P\left(w_g > G_m z_m, w_g > p_s G_s z_s\right) \\ &= \int_0^{\frac{w_g}{G_s p_s}} \int_0^{\frac{w_g}{G_m}} g(z_s) g(z_m) dz_m dz_s \end{aligned} \tag{16}$$

Taking the level of government employment (and, hence, government wage) as given, the expected employment in services and manufacturing are

$$\begin{aligned} L_s &= P\left(w_s > w_m, w_s > w_g\right) \\ &= P\left(p_s G_s z_s > G_m z_m, p_s G_s z_s > w_g\right) \\ &= \int_{\frac{w_g}{G_s p_s}}^{\infty} \int_0^{p_s G_s z_s / G_m} g(z_s) g(z_m) dz_m dz_s \end{aligned} \tag{17}$$

$$\begin{aligned} L_m &= P\left(w_m > w_s, w_m > w_g\right) \\ &= P\left(G_m z_m > p_s G_s z_s, G_m z_m > w_g\right) \\ &= \int_{w_g / G_m}^{\infty} \int_0^{\frac{G_m z_m}{p_s G_s}} g(z_s) g(z_m) dz_s dz_m \end{aligned} \tag{18}$$

Given the Frechet distribution of talent draws, the above equations can be simplified into the following expressions, which only depend on the given level of government employment and the price of non-manufacturing goods:

$$L_s = \frac{G_s^\theta p_s^\theta}{G_m^\theta + G_s^\theta p_s^\theta}\left(1 - L_g\right),$$
$$L_m = \frac{G_m^\theta}{G_m^\theta + G_s^\theta p_s^\theta}\left(1 - L_g\right), \tag{19}$$
$$L_g = e^{-\frac{G_m^\theta + G_s^\theta p_s^\theta}{w_g^\theta}}$$

Solving this for w_g I obtain

$$w_g = \left(-\frac{G_m^\theta + G_s^\theta p_s^\theta}{\log(L_g)}\right)^{\frac{1}{\theta}}. \tag{20}$$

4.3 Output

Normalizing $A = 1$, the output of each sector can be expressed as

$$Y_s = G_s \int_{\frac{w_g}{G_s p_s}}^{\infty} \int_0^{p_s G_s z_s / G_m} z_s g(z_s, z_m) dz_m dz_s,$$
$$Y_m = G_m \int_{w_g / G_m}^{\infty} \int_0^{\frac{G_m z_m}{p_s G_s}} z_m g(z_s, z_m) dz_s dz_m \tag{21}$$

Since z_s and z_m are independently drawn from a Frechet distribution, this simplifies to

$$Y_s = G_s \left(\frac{G_s^\theta p_s^\theta}{G_s^\theta p_s^\theta + G_m^\theta}\right)^{1-\frac{1}{\theta}} \Lambda(\theta, L_g),$$
$$Y_m = G_m \left(\frac{G_m^\theta}{G_s^\theta p_s^\theta + G_m^\theta}\right)^{1-\frac{1}{\theta}} \Lambda(\theta, L_g). \tag{22}$$

where $\Lambda(\theta, L_g) \equiv \Gamma(1-1/\theta) - \Gamma(1-1/\theta, -\log(L_g))$, while $\Gamma(\cdot)$ and $\Gamma(\cdot,\cdot)$ denote the complete and incomplete gamma functions.

For a given level of government employment L_g, using the above equations for sectoral output and (13), it is easy to show that $\partial p_s/\partial p_o O > 0$. It then follows that oil endowments result in a reallocation of labor $\partial L_s/\partial p_o O > 0$ and $\partial L_m/\partial p_o O < 0$. This shift in labor generates specialization (in manufacturing) and de-specialization (in services), $(\partial Y_s/L_s)\ /\partial p_o O < 0$ and $(\partial Y_m/L_m)/\partial p_o O > 0$. If I instead consider productivity in the non-manufacturing sector, I can also show that $(\partial Y_s/(L_s + L_g))/\partial p_o O < 0$ as long as government employment is not "too-large," i.e., if, and only if, $L_g < (1/\theta - 1)(L_s/L_s + L_m)$. Later, in the calibration, it is easy to verify that this condition is satisfied for every country-date in our dataset.

5. Calibrating the Model

5.1 Estimating Skill Dispersion

The parameter θ governs the dispersion of (unobserved) underlying skills. To match this parameter to observed variables, I make use of the properties of the Frechet distribution. The distribution of wage offers in each (non-government) sector is given by

$$\begin{aligned} N_s^w(w_s) &= Pr\{W_s \le w_s\} = Pr\{p_s A G_s Z_s \le w_s\} \\ &= Pr\{Z_s \le \frac{w_s}{p_s A G_s}\} = e^{-(p_s A G_s)^{\theta} w_s^{-\theta}} \end{aligned} \tag{23}$$

$$\begin{aligned} N_m^w(w_m) &= Pr\{W_m \le w_m\} = Pr\{A G_m Z_m \le w_m\} \\ &= Pr\{Z_m \le \frac{w_m}{A G_m}\} = e^{-(A G_m)^{\theta} w_m^{-\theta}} \end{aligned} \tag{24}$$

These are both Frechet density functions with the same dispersion parameter (θ) as the talent distributions.[19] Thus, the wage offers in the non-governmental sector are the maximum an agent could earn

19. Notice that these are not distributions of observed wages in a given sector, but the distribution of (unobserved) wages that agents could earn if they chose to work in a particular sector.

in either sector $w_{ng} = \max\{w_s, w_m\}$. The distribution of this wage $N^{ng}(w)$ is then the maximum order statistic of wage offers in non-governmental sectors and is given by

$$N^{ng}(w) = N_s^w(w)N_m^w(w) = e^{-A^\theta(G_m^\theta + G_s^\theta p_s^\theta)w^{-\theta}}. \tag{25}$$

The above distribution is also a Frechet with the same dispersion parameter (but with a different mean) as the skill distribution. This is a consequence of the assumption that the original talents were drawn from an extreme value distribution. Finally, agents with a non-governmental wage offer drawn from this distribution will choose to work in government if, and only if, the wage offered by government w^g is higher than their non-governmental wage offer. Consequently, the distribution of observed wages will be given by

$$N(w) = N^{ng}(w)\mathbf{1}_{w \geq w_g}(w). \tag{26}$$

In order to match the parameter θ, I use a method of moments. In particular, I calculate the standard deviation of a sample of log wages in a "resource-poor" country and match it to the implied standard deviation of log wages in the model. As in Kuralbayeva and Stefanski (2013), I obtain cross-sectional wage data from the 2009 U.S. Current Population Survey (CPS) and find that the standard deviation of log wages in this sample is 0.58.[20] Then, I calculate the corresponding theoretical standard deviation of the log-wage and choose $\theta = 2.10$ so that the two match.[21]

5.2 Government Parameters

To calibrate the government parameters, I first impose the restriction that $\psi \equiv \psi^s = \psi^m$ so that the impact of government on

20. Following Kuralbayeva and Stefanski (2013), Lagakos and Waugh (2014) and Heathcote and others (2009), I include individuals aged 25 to 60 who have non-missing data on income and hours worked. Wages are before tax and are taken to be the sum of wage, business and farm income. The sample is further restricted to include workers who average more than 35 hours per week of work and earn at least the Federal minimum wage.

21. To do this, notice that for any integrable function f, I can write $\mathbb{E}(f(w)) = f(w_g)\int_0^{w_g} dG^{ng}(w) + \int_{w_g}^{\infty} f(w)dG^{ng}(w)$. Noting that the standard deviation of log-wages in the model σ is given by $\sigma = \sqrt{Var(\log(W))} = \sqrt{\mathbb{E}(W^2) - (\mathbb{E}(W))^2}$, I use the above formula and the CDF of $N^{ng}(w)$ to calculate θ.

productivity is the same in both manufacturing and service sectors. The reason for this assumption is twofold: first, it simplifies the analysis and, second, there is no *a priori* reason to believe that the impact of government spending should affect productivity more in one sector than in another. I choose $\psi = 0.015$ so that the predicted optimal government employment in resource-poor countries in the model exactly matches government employment in the lowest decile of resource exporting countries in the data of approximately 17 percent.

This is a logical benchmark. I wish to reproduce the observed economic structure of resource-poor countries and examine the impact of adding natural resources to those countries. Notice, however, that if observed public sector employment in resource-poor countries were larger than optimal, then the above assumption will underestimate the extent of misallocation and government inefficiency in resource-rich countries. In other words, if resource-poor countries have inefficiently large government, then the scale of misallocation in resource-rich countries will be even larger than the model suggests. Of course, if resource-poor countries have governments that are "too-small" relative to the optimum, because higher levels of public-sector employment in resource-rich countries could be seen as getting closer to the efficient levels of public sector employment, my measure of government inefficiency will overestimate the extent of misallocation.

Of the two cases, it seems eminently more plausible that we are in the first and that we are underestimating the extent of misallocation in resource-rich countries. After all, resource-rich countries exhibit worse (rather than better) economic outcomes than resource-poor countries, so it would be surprising if it were resource-poor countries that were further away from the optimum. Furthermore, notice that the public sector employment of 17% is a very reasonable choice. For example, in the U.S., government sector employment is approximately 13% of the labor force, while in the OECD it is approximately 19%. Our assumption that, in resource-poor countries, optimal government employment share is 17% is, thus, a half way point between these two extremes. Nonetheless, I demonstrate the robustness of this assumption on ψ in appendix B. Finally, I also impose that $\gamma_i = 1$ so that the government cares equally about all agents. I also examine this assumption in further detail in appendix B.

5.3 Preference Parameters

Finally, I follow Kuralbayeva and Stefanski (2013) in estimating preference parameters σ and ν. From the household's problem, I can derive an equation relating relative consumer expenditure on the relative price $c_m/c_s = (\nu p_s)^\sigma$. Taking logs of this equation, I estimate elasticity of substitution between manufacturing and non-manufacturing goods using ICP data and find that $\sigma = 0.94$. Finally, I choose the preference parameter to be $\nu = 0.29$ to match the employment share in the manufacturing sector in resource-poor countries in the model to the employment share in manufacturing in the lowest decile of exporters in our sample (approximately 19%).

6. Results

To examine the implications of the calibration, I consider three different versions of the model: 1) a model without government, 2) a model where government employment is taken directly from the data, and 3) a model where government employment is chosen optimally.

Table 4 compares the empirical windfall elasticities from the data (shown in tables 2 and 3) with the corresponding windfall elasticities implied by the different versions of the model for

Table 4. Changes in Sectoral Employment and Sectoral Productivity Associated with Resource Wealth in the Data and Model

	Data	*Model*			*Model/Data*		
		(1)	*(2)*	*(3)*	*(1')*	*(2')*	*(3')*
		No Gov.	*Obs. Gov.*	*Opt. Gov.*	*No Gov.*	*Obs. Gov.*	*Opt. Gov.*
M. Emp., L_m	-0.014	-0.009	-0.015	-0.008	0.65	1.09	0.53
M. Prod, D_m	0.068	0.025	0.062	0.025	0.37	0.90	0.36
NM. Prod, D_s	-0.012	-0.007	-0.003	-0.004	0.53	0.21	0.36
NM. Price, p_s	0.048	0.031	0.073	0.030	0.65	1.53	0.63
G. Emp., L_g	0.017	-	0.017	0.002	-	1.00	0.12

Source: see section 1.1.

sectoral employment, productivity and prices.[22] First, in column (1) and (1') of table 4, I consider a version of the model without a government.[23] A doubling of natural resource windfalls in the optimal model results in a 0.9 percentage point decline in manufacturing employment, a 2.5% increase in manufacturing productivity, a 0.7% decline in non-manufacturing productivity and a 3.1% increase in the price of non-manufacturing goods. With respect to these measures the model does well to explain between 37% and 65% of the observed changes. This is in line with the results of Kuralbayeva and Stefanski (2013).

In column (2) and (2') of table 4, I now consider a case with government, where the observed government employment shares are fed directly into the model. Notice that the findings of Kuralbayeva and Stefanski (2013) continue to hold. The model captures all—and even slightly over-predicts—the elasticity of manufacturing employment. It also explains 90% of the elasticity in manufacturing productivity and 21% of the productivity in non-manufacturing productivity. Finally the model over-predicts the increase in non-manufacturing prices and—by construction—it accounts for all of the government employment elasticity.

Finally, in columns (3) and (3') of table 4, I examine how the elasticities in the data compare to the model where government employment shares are chosen optimally. The model once more does relatively well and accounts for between 36% and 63% of the non-governmental employment and productivity. Where the optimal model does very poorly is in explaining the elasticity of government employment. Here a doubling of windfalls in the model is associated with only 0.2 percentage point increase in government employment; whereas, in the data, a doubling of windfalls is associated with a 1.7 percentage point increase. Thus, the model explains only 12% of the observed elasticity. This suggests that resource-rich countries

22. In the data, we measure resource wealth as the ratio of current price exports of natural resources to current price GDP measured in international dollars. International dollars are constructed to have the same purchasing power over GDP as the U.S. dollar has in the United States. Since the U.S. is a resource-poor country (according to this measure), we can view GDP in international dollars as the GDP of a country measured using a resource-poor country's prices. As such, in the model, we construct our resource wealth measure as the value of exports of natural resources divided by GDP, measured with the prices of a resource-poor country (i.e., one that has $p_0 O = 0$).

23. Thus, the model is re-calibrated here in that ψ is set to zero, and all other parameters are chosen to match the relevant moments described in the paper. In particular, I choose $\nu = 0.22$, $\theta = 2.23$, and $\sigma = 0.94$.

have a much higher government employment share than the model predicts they "should."

The message from this exercise is that the specialization mechanism introduced in Kuralbayeva and Stefanski (2013) is strong enough to explain a big part of the large differences in sectoral employment shares and asymmetric productivity differences between resource-rich and resource-poor countries. Furthermore, the differences in the size of government employment between resource-rich and resource-poor countries act to magnify the differences in sectoral productivity and employment produced by the specialization effect. Thus, the large size of government in resource-rich countries effectively amplifies the "Dutch-disease" effects of a smaller manufacturing sector and higher non-manufacturing prices. Finally, and most importantly, the observed government employment shares in resource-rich countries tend to be significantly "too-large." I explore the impact of this latter effect on welfare and productivity in the following section.

7. The Resource Curse

The resource-curse: a well-known, stylized fact relating negative economic outcomes to resource windfalls. In the context of this paper, the mechanism for a resource curse is clear. If there is a misallocation of public sector employment in resource-rich countries so that government employment is either too large or too small relative to the optimum, we will observe a lower productivity and welfare in the model. Table 5 shows the regressions of the ratio of observed-to-optimal aggregate productivity and welfare respectively emerging from the model versus the size of natural resource windfalls (and the log of natural resource windfalls). Observe in the data from columns (1) and (2) that a doubling of the natural resource windfall is associated with productivity that is 0.6% lower and a welfare that is 0.4% lower than it otherwise could be if government employment were not misallocated. Equivalently, from columns (3) and (4), a one percentage point increase in resource export shares in GDP is associated with a productivity that is 0.17% lower than it otherwise could be and a welfare that is 0.11% lower than it otherwise could be. Notice, that these are big effects. Countries that have natural resource exports accounting for 10 percent of GDP, will have a productivity that is, on average, 1.7% lower and a welfare that is 1.1% lower than it otherwise could be. Countries with 40%

resource export share will have an aggregate productivity that is, on average, a massive 6.8% lower and a welfare that is 4.4% lower than it otherwise could be.

Table 5. Regressions of the Ratios of Productivity and Welfare in the Observed and Optimal Models with Respect to Resource Wealth

	(1)	*(2)*	*(3)*	*(4)*
	Rel. Prod. (D^{obs}/D^{opt})	*Rel. Welf.* (U^{obs}/U^{opt})	*Rel. Prod.* (D^{obs}/D^{opt})	*Rel. Welf.* (U^{obs}/U^{opt})
log(NRE)	-0.006*** (0.001)	-0.004*** (0.001)		
NRE			-0.172*** (0.022)	-0.111*** (0.021)
Time FE	yes	yes	yes	yes
Obs.	340	340	340	340
R^2	0.114	0.086	0.181	0.108

Source: See section 1.1.
Standard errors in parentheses
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

As I showed before, the misallocation occurs due to a government sector that tends to be too large in resource-rich countries. Importantly, I make absolutely no claims as to why the size of government employment tends to be what it is and, in particular, why government employment tends to be higher in resource-rich countries. Government employment in resource-rich countries can be non-optimal for a range of reasons (some associated with natural resources, and others not), but this paper takes no stand on the issue and simply takes the observed size of government in resource-rich countries as given. As such, the observation that resource-rich countries have larger than optimal government is a characteristic of the given sample of data, and will not necessarily hold in every single resource-rich country. The findings here thus reflect the fact that, in this particular sample of data, resource-rich countries tended to have public employment that was "too-large." It is, of course, entirely possible to find examples of resource-rich countries in the sample that the model predicts had "too-small" or "just-right" government. As two such specific examples, consider the cases of Chile and Canada in 2007. Chile's windfall measure was approximately 20 percent of GDP. This was associated with a productivity that was approximately 2% lower and a welfare that was approximately 3% lower than they otherwise could have been. This lower productivity and welfare was a consequence of a government sector employment share that was, according to the above model, approximately 8.4 percentage points too small relative to the predicted optimum. In the case of Canada, its windfall measure was approximately 11% of GDP in 2007. This was associated with a productivity that was only 0.2% lower and a welfare that was approximately 0.1% lower than they otherwise could have been. This was a consequence of the fact that Canada almost had "the right" levels of government employment given its resource windfall.

The above fits in well with the institutional view of the resource curse. In particular, by emphasizing the role of government misallocation, my theory lends support to arguments by Robinson and others (2006), van der Ploeg (2010) and others where explanations of the resource curse should be sought outside economic structure perhaps, as they suggest, in areas such as political economy, weak institutions or property rights.

8. The Role of Weights

In the baseline model I focused on governments that weigh individuals equally within and across countries so that $\gamma_i = 1$ in equation (29). Now I consider a government that can potentially weigh workers unequally and I allow these weights to vary across countries. In particular, I assume that governments value public sector workers differently from private sector workers according to this function:

$$\gamma_i = \begin{cases} m_g, & \text{if } i \in \Omega^g \\ 1, & i \notin \Omega^g \end{cases} \tag{27}$$

In the above, m_g is the mass placed on public-sector relative to private-sector workers. I allow these weights to potentially vary across countries. In particular, I choose m_g to reconcile the discrepancies between optimal and observed government employment in resource-rich countries. Since the baseline model is chosen to match public sector employment in the lowest decile, for that particular decile, m_g will be one and all other parameters will remain exactly as in the baseline. To match the observed public sector employment share of approximately 25% in the highest decile of resource-rich countries, I must set $m_g = 1.38$. Thus, in order for the model to optimally reproduce the higher observed public sector employment in the top decile of resource-rich countries, the governments in those countries must implicitly value public sector workers 38% more than private sector workers. Thus, in principle, the model can optimally reproduce observed differences in public sector employment between resource-rich and resource-poor countries, but only if we assume a larger weight is placed by the social planner on government sector employees in resource-rich countries. While there may be some justification to such a weighing scheme,[24] it nonetheless seems to be difficult to justify why governments in resource-rich countries should place more weight on the public sector than governments in resource-poor countries. This is an interesting and suggestive result that can be seen as a complement to the discussion of the resource curse in the previous section. The higher weights on public sector workers can be interpreted as a measure of how much government workers in resource-rich countries manage to bias government policy in their favor. Thus, this is further indication that there may be institutional failures in resource-rich countries that lead governments to effectively care more about their own employees than the employees of other sectors. Finally, since the model now exactly matches employment shares in the government sector, the sectoral and aggregate employment and productivity results are once more given by columns (2) and (2') of table 4, although now, given the particular choice of weights, the observed government employment is optimal and there is no misallocation in the model.

9. Conclusion

Kuralbayeva and Stefanski (2013) show that, in the data, resource-rich regions have small and productive manufacturing

24. For example, in the model, government sector employees will be the lowest wageworkers and, hence, placing greater weight on them can be seen as a form of progressive taxation.

sectors and large and unproductive non-manufacturing sectors and propose a mechanism that explains these productivity differences through a process of self-selection. Windfall revenues induce labor to move from the (traded) manufacturing sector to the (non-traded) non-manufacturing sector. A self-selection of workers takes place. Only those most skilled in manufacturing sector work remain in manufacturing. Workers that move to the non-manufacturing sector are, however, less skilled at non-manufacturing sector work than those who were already employed there. Resource-induced structural transformation thus results in higher productivity in manufacturing and lower productivity in non-manufacturing.

In this paper, I show that, in addition to the above facts, in the data, resource-rich countries also tend to employ a larger proportion of workers in the government sector than resource-poor countries. I then adapt the model of specialization of Kuralbayeva and Stefanski (2013) to include a productive government sector and proceed to examine optimal government employment in resource-rich countries. In particular, I show that the model can generate higher employment in the government sector when windfalls are higher. In a nutshell, government services are non-traded. Higher windfalls will increase demand for all goods and services, including government services, but since these cannot be imported, workers will shift to the government sector to satiate demand. Furthermore, even with a government sector, the specialization mechanism introduced in Kuralbayeva and Stefanski (2013) is strong enough to explain a large part of the asymmetric differences in sectoral employment shares and productivity between resource-rich and resource-poor countries. In addition, the differences in the size of government between resource-rich and resource-poor countries act to magnify the differences in sectoral productivity and employment shares produced by this specialization mechanism. Finally, the observed government employment shares in resource-rich countries tend to be "too-large" relative to optimum. In the calibrated, best-case-scenario model, government employment is nearly 10 times smaller than in the data. This implicit misallocation of resources has a large, negative impact on welfare and aggregate productivity. Using the calibrated model, I find that a ten percentage point increase in resource windfalls is associated with a 1.72% lower aggregate productivity and a 1.11% lower welfare arising from government misallocation in resource-rich countries.

As such, the above theory and empirical evidence suggest that institutions may play a key role in driving the resource curse. In particular, this paper lends support to arguments by Robinson and others (2006), van der Ploeg (2010) and others that explanations of the resource curse should be sought outside economic structure, perhaps, as they suggest, in areas such as political economy, weak institutions or property rights which induce governments to be particularly large in resource-rich countries.

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Appendix A
Data

A.1 Resource wealth

I follow Sachs and Warner (2001) and Kuralbayeva and Stefanski (2013) in defining natural resource "wealth" as the ratio of exports of natural resources (fuels, ores and metals) to GDP using WDI (2007) data. Following Kuralbayeva and Stefanski (2013), I use PPP GDP (in current prices) in the denominator of our measure since higher endowments of resources can potentially impact prices of non-resource goods (and, hence, measured GDP) influencing both the numerator and the denominator of our measure. Using PPP GDP keeps prices fixed across countries and, hence, the measure only captures changing resource wealth. I have experimented with both measures and resource wealth, as well as other measures such as the ratio of net exports of natural resources to gross domestic product (both observed price and PPP). The results, however, are unaffected. For more detail of data construction, see the appendix of Kuralbayeva and Stefanski (2013).

A.2 Labor shares

To calculate the measure of productivity, I need to find expressions for labor shares $1 - \alpha s$ for each sector s. Although these shares can potentially vary across countries, due to a lack of comprehensive cross-country sectoral data, I make use of OECD data to calculate the average annual share of employee compensation for each sector in OECD countries for the longest period of time that data is available. I calculate the labor share as the ratio of total compensation of employees (wages and salaries before taxes, as well as employer's social contributions) over sectoral value-added.[25] I find labor share in manufacturing is 0.57 while in non-manufacturing it is 0.53.[26]

A.3 Sectoral employment

I obtain sectoral employment data for 1980-2006 from the ILO KILM online database. To obtain the largest set of employment data, I combine ISIC revision 2 and ISIC revision 3 employment data.

25. Tables 7 and 8 in the OECD Annual National Accounts, volume 2, 1970-2008 (2009 prov.) Detailed aggregates, in millions of national currency.

26. For more detail of data construction see the appendix of Kuralbayeva and Stefanski (2013).

A.4 Prices

Since I want to compare sectoral productivity across countries, it is crucial to control for any price differences that may exist between sectors, across countries, and over time. To do this, I use the methodology and data from Kuralbayeva and Stefanski (2013). In particular, in that paper, we constructed country and sector-specific price levels for each sector by combining the sectoral price levels from the World Bank's 2005 International Comparison Program (ICP) database and sectoral price indices from the UN (2009). The resulting series gives the price level of a particular sector in each country relative to the price of the same sector in the U.S. in 2005.

Importantly, as is mentioned in Kuralbayeva and Stefanski (2013), although the ICP study is especially built to provide accurate cross-country measures of price differences, it does have some well-known limitations. The main objection is that expenditures are valued at the actual transaction prices paid by purchasers and, hence, may include delivery charges and any taxes payable (or subsidies received) on purchased products. This may be an issue if taxes/subsidies vary systematically with resource wealth. We recognize this fact, but our hands are tied for lack of better data. In the main body of the paper, we use a simple version of our model to show that, to account for observed productivity differences, unrealistically large subsidies would be necessary. Notice also that this re-basing is not driving our results and we see similar productivity differences when value-added is left in constant U.S. dollars.

A.5 Aggregate capital

I follow Caselli (2005) and Kuralbayeva and Stefanski (2013) and use the Penn World Tables (version 6.3) to construct estimates of aggregate capital stock. This is done using the perpetual inventory method with the depreciation rate set to 0.06.

A.6 Sectoral capital

I follow Caselli (2005) and Kuralbayeva and Stefanski (2013) in estimating sectoral capital. First, assume that economies consist of five sectors: agriculture (A), mining and utilities (MU), manufacturing (M), construction (C) and services (S). Then, assume that the production function of each sector s is of the form given in equation 2. If I also assume that the rates of return on capital are equalized across sectors (an arbitrage condition), then it is easy to show that the above functional form implies that for any two sectors *s* and *s'*, the following holds:

$$\alpha_s \frac{P_s^D Y_s}{K_s} = \alpha_{s'} \frac{P_{s'}^D Y_{s'}}{K_{s'}} \tag{A1}$$

Where $P_s D$ is the domestic producer price of sector *s* goods. For more detail of data construction see the appendix of Kuralbayeva and Stefanski (2013).

A.7 Aggregate human capital

I follow Kuralbayeva and Stefanski (2013), Caselli (2005) and Hall and Jones (1999) in constructing a measure of aggregate human capital from the Barro and Lee (2010) average years of schooling data set.

A.8 Sectoral human capital

To calculate sectoral human capital, I follow Kuralbayeva and Stefanski (2013) and Caselli (2005) when estimating sectoral human capital. I assume that the ratio of human capital between any two sectors is constant across countries and time and equal to the corresponding ratio in the U.S. and that labor shares in the last two measures of productivity, $1 - \alpha_s$, are identical across countries, constant over time and equal to OECD averages.

A.7 Public sector employment

Public sector employment data is from the ILO which covers all employment of the general government sector as defined in System of National Accounts of 1993 plus employment of publicly owned enterprises and companies residing and operating at central, state (or regional) and local levels of government. It covers all persons directly employed by those institutions without regard for the particular type of employment contract. A limited subset of the public employment data is provided at the ISIC one sector level and, in that (very limited) subset, public employment is overwhelmingly in the non-manufacturing sector. As such, in the baseline experiment of this paper, in order to maintain as large a sample of data as possible, I shall assume that all government employment belongs entirely to the non-manufacturing sector.

A.8 Summary statistics

Table A1 presents summary statistics for the main economic variables: sectoral employment shares (ISIC), public or government sector employment share, sectoral TFP (physical and human capital), value-added per worker (this is the sum of all sectoral value-added data divided by the total labor force), GDP/capita in international 2005 dollars from the WDI, and the natural resource export share.

Table A1. Summary Statistics for Data

Variable	*Sector*	*N*	*mean*	*sd*	*min*	*max*	*p10*	*p90*
Emp. share	A	340	0.10	0.10	0.01	0.67	0.02	0.21
	C	340	0.08	0.02	0.03	0.14	0.06	0.10
	S	340	0.18	0.04	0.07	0.30	0.12	0.24
	M	340	0.65	0.10	0.22	0.82	0.51	0.76
Emp. share	G	340	0.21	0.08	0.06	0.54	0.11	0.34
TFP	A	340	2.80	0.81	0.99	5.23	1.70	3.84
	C	340	216.95	54.41	98.75	417.48	143.08	280.86
	S	340	128.14	21.09	72.99	234.69	106.34	147.25
	M	340	139.17	54.24	26.84	382.27	74.90	193.26
	ACS	340	106.96	19.51	49.37	204.96	90.29	126.21
	ACSM	340	111.75	22.29	50.10	223.95	86.90	134.65
VA/worker	-	340	50,553	21,644	6,038	170,198	18,150	71,069
gdp/capita	-	340	23,279	11,281	2,489	72,783	8,586	35,164
NR	-	340	0.04	0.06	0.00	0.39	0.01	0.08

Source: See section 1.1.

Appendix B
Robustness and Extensions

B.1 Optimality in resource-poor countries

Table B1. Changes in Sectoral Employment and Sectoral Productivity Associated with Resource Wealth in the Data and Model under Different Assumptions on ψ

	(1)	*(2)*	*(3)*	*(4)*	*(5)*
			Model/data		
ψ =	*Opt. Gov. 0.015*	*Opt. Gov. 0.008*	*Opt. Gov. 0.020*	*Opt. Gov. 0.038*	*Opt. Gov. 0.079*
M. emp.	0.53	0.55	0.52	0.50	0.46
M. prod.	0.36	0.35	0.37	0.39	0.43
NM. prod.	0.36	0.40	0.34	0.29	0.22
NM. price	0.63	0.61	0.63	0.66	0.71
G. emp.	0.12	0.09	0.13	0.17	0.22
Imp. opt. govt. emp.:	0.17	0.13	0.19	0.25	0.33

Source: See section 1.1.

In this section, I carry out a robustness exercise on the parameter ψ that influences the optimal size of government. Column (1) of table B1 reproduces column (3') of table 4 and shows the percentage of sectoral productivity and employment explained by the baseline version of the model under the assumption of optimal government size. The top row of the table presents the value of ψ in the current calibration while the bottom row shows the observed 17% government employment share in the lowest decile of resource-poor countries that the parameter was chosen to reproduce. Notice that, in the baseline version of the model, only 12% of the increase in government employment share between resource-rich and resource-poor countries is captured by the model. As mentioned above, it is however eminently likely that most countries, including resource-poor countries, have some form of inefficiencies that translate into government sectors that are too large. In column (2), I set $\psi = 0.008$ so that the true optimal share of government employment is a lower 13% like that in the U.S. In this case the model only explains 9% of the increase in government employment share. Notice, however, from columns (3)-(5) of table B1, that choosing a larger ψ to match government employment shares in the OECD (19%), the EU (25%) or Sweden (33%), does indeed result in the model predicting slightly larger increases in government employment in resource-rich countries. Notice, however, that these increases are still significantly smaller than observed in the data and that the different choice of ψ implies the model completely misses the level of government employment found in resource-poor countries.

B.2 Uncertainty

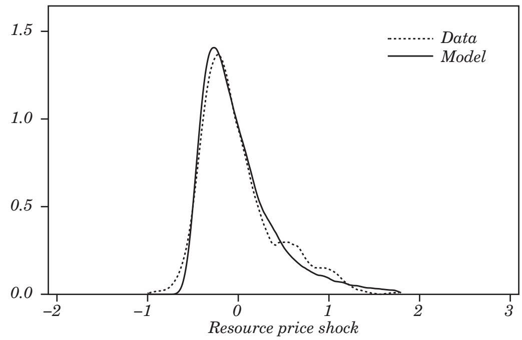
An interesting extension of the baseline model is to consider the impact that uncertainty stemming from the volatility of natural resource prices (and, in particular, the inability of government to quickly and optimally adjust employment levels in response to these shocks) plays in influencing employment, welfare and productivity in resource-rich countries. This government stickiness may be another reason why resource-rich countries tend to employ too many people in the public sector. To examine this idea, I continue to assume that the value of a country's endowment is given by $p_o O$ in each period; however, I now suppose that $p_o \equiv (1+\varepsilon)\,\bar{p}_o$. In this expression, $\bar{p}_o$ is the long-term mean of the oil price while ε is a random variable with CDF G_ε on domain Ω_ε. Thus, I assume that the price of oil fluctuates around a long-term mean and I examine the implications of this on the extent of government misallocation.

I assume that households and firms continue to take the realization of $p_o O$ and L_g as given and proceed to solve their (static) problems just as in the baseline. However, I now assume that governments are slow to respond to price shocks and no longer maximize the weighted welfare of consumers in any given period as in equation (14), but rather maximize the expected weighted welfare of consumers

$$\max_{0 \le L_g \le 1} \int_{\varepsilon \in \Omega_\varepsilon} \mathsf{E}_{\gamma_i}(U(c_s^i(L_g, p_o(\varepsilon)O), c_m^i(L_g, p_o(\varepsilon)O)))dG_\varepsilon(\varepsilon), \tag{29}$$

with expectations taken over price shocks. In this way, governments of countries with different endowments levels will choose different levels of public sector employment, $\bar{L}_g(O)$ but will find it difficult to re-optimize after a price shock realization. Consequently, for every realization of $\varepsilon \neq 0$, the size of government will be non-optimal which will imply a misallocation of workers and hence welfare and productivity distortions.

Figure B1. Distribution of Resource Price Shocks in the Model and the Data



Source: See section 1.1.

The baseline model was calibrated to match a country with zero natural resource endowments. Since shocks to ε do not affect such a country, the previously calibrated parameters stay exactly as in the baseline. Now however, I need to choose the distribution of the price shocks, ε. In this experiment I will suppose that ε is an iid, zero-mean random variable that follows a truncated Frechet cumulative distribution G_ε on domain $[\underline{\varepsilon}, \overline{\varepsilon}]$:

$$G_\varepsilon(\varepsilon) = \frac{e^{-(\varepsilon-m)^{-\zeta}} - e^{-(\underline{\varepsilon}-m)^{-\zeta}}}{e^{-(\overline{\varepsilon}-m)^{-\zeta}} - e^{-(\underline{\varepsilon}-m)^{-\zeta}}} \qquad \text{(B1)}$$

In the above m is the location parameter and $\zeta > 1$ is the parameter governing the dispersion of price shocks. The choice of the Frechet distribution will allow me to match the thick tails that are associated with fluctuations of natural resource prices while the truncation will help with the numerical solution of the problem. To estimate this distribution, for each country I calculate $(p_o O_t/\bar{p}_o) - 1$, which I take to be the realization of ε. I then set $m = -1.21$ to match the zero-mean of the shocks and $\zeta = 3.71$ to match the standard deviation 0.41 of the realizations of ε calculated above. Finally, I set the bounds on the distribution so that $[\underline{\varepsilon}, \bar{\varepsilon}] = [-1, 1.8]$. The lower bound is set so that the value of the natural resource can potentially hit zero while the upper bound is chosen to match the largest observed realization of ε in the data. The kernel density of the realizations and the simulated distribution is presented in figure 2. As we can see the fit is good and the chosen distribution does well in capturing the thick, right tail of price shocks.

Table B2. The Impact of Uncertainty on Public Sector Employment, Welfare and Productivity in the Top Decile of Resource Exporters

Top decile (NR exp. sh. = 0.17)	*(1)* L_g^{opt}	*(2)* L_g^{set}	*(3)* L_g *diff. (set/opt)*	*(4) Welfare diff. (set/opt)*	*(5) Prod. diff. (set/opt)*
$\varepsilon = \bar{\varepsilon}$	0.1881	0.1816	0.9656	0.9998	1.0007
$\varepsilon = \underline{\varepsilon}$	0.1716	0.1816	1.0583	0.9997	0.9997

Source: See appendix, section B.2.

Given the above setup, a country with an endowment of resources O will choose a level of government $\bar{L}_g(O)$ based on equation (29). Since governments are assumed to be unable to re-optimize after the initial choice of public sector employment, a price shock which changes the value of natural resource endowments will generate a misallocation of resources whenever the realization of the shock $\varepsilon \neq 0$. To give the mechanism the greatest chance of working, I consider (in the top decile of natural resource exporters) the impact of both the maximum and minimum possible shock on the extent of public sector employment misallocation and the effect this has on welfare and aggregate productivity. The results are shown in table B2.

It turns out that, while the idea of this additional channel of misallocation is intriguing, the quantitative impact is tiny. In particular, from column (3) of the above figure, notice that government misallocation arising from this friction will result in public sector employment that is 3.4% lower from the "optimal" when the maximum shock hits, and 5.8% higher when the minimum shock hits. This is very small given that the differences in government employment in the data between the decile composed of the resource-richest countries and the decile composed of the resource-poorest countries are closer to 50%. Furthermore, this small misallocation translates to even smaller changes in productivity, as seen in column (5), and welfare losses of between 0.01% and 0.03% relative to the optimum, as seen in column (4). The reason we do not observe a large impact from the inability of government to re-adjust is exactly the reason why the model does not predict the large observed increase in government between resource-rich and resource-poor countries in the first place. Since predicted optimal changes in government employment between resource-rich and resource-poor countries are small, a price shock hitting a country that acts to increase the value of the resource endowment of a country would also imply only a small re-adjustment. The model thus predicts higher government employment in the resource-rich country, but only marginally so. Thus, the cost of misallocation from not adjusting in response to a shock is very small indeed.

Resource Revenue Management: Three Policy Clocks

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Economies in which the extraction of a non-renewable natural resource is a significant activity pose two distinctive challenges for economic policy: Revenues are likely to fluctuate because commodity prices have historically been volatile. Furthermore, the revenue from extraction is generated by depleting a finite resource and, therefore, a potential case for offsetting depletion with the accumulation of other assets. Volatility and depletion work in radically different timescales. Managing them evidently requires distinct 'policy clocks.' Chile has led the world in its approach to managing volatility, but it has yet to think through the issues posed by depletion with equivalent rigor. Hence, my initial focus will be on whether Chile should be at all concerned about depletion and, if so, what an appropriate policy response might be.

1. Policy Clock 1: Offsetting Depletion

The conventional framework for thinking about the depletion of a finite natural asset is permanent income hypothesis (PIH). While this framework is inadequate, it is a useful starting point.

The revenue from depletion is used to give all future generations an equal increase in consumption. This has a superficial attraction of appearing equitable as the resource is perceived as an increment to wealth with consumption from the wealth being smoothed in perpetuity. This hypothesis is familiar from the tax smoothing

I would like to thank Rodrigo Caputo for extensive comments on a previous draft, including the graph in figure 2.

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literature (Barro, 1979) and underlies the Sovereign Wealth Funds theory. The dashed line in figure 1 illustrates the PIH strategy taken from Collier and others (2010). The increment of consumption is constant and equal to the interest that would be earned at a fixed world interest rate on the present value of the revenue evaluated at initial date t = 0. Notice that this strategy involves smoothing consumption from the date at which the resource windfall is 'discovered.' It therefore involves borrowing (i.e., dissaving) during the period in which permanent income exceeds actual income, and saving and accumulating assets when actual income exceeds permanent income. Thus, in figure 1(b), the country borrows for the first ten years and then pays back this debt before accumulating a savings fund. The size of the savings fund and level of consumption increment on all dates are such that interest payments on the fund (once resource revenue has come to an end) exactly finance the consumption increment. Since the level of consumption is determined in this way, the shares of revenue that are saved and consumed at any date fluctuate with the magnitude of the current revenue flow. In the figure, the PIH prescription is compared to the Bird-in-Hand Rule, advocated by the International Monetary Fund until recently, and an 'optimal' path that will be discussed below. The Bird-in-Hand Rule incorporates extreme caution in that, at each moment, savings are optimized subject to the assumption that no further resource revenues will accrue. Clearly, in all circumstances other than this drastic eventuality, the strategy is sub-optimal.

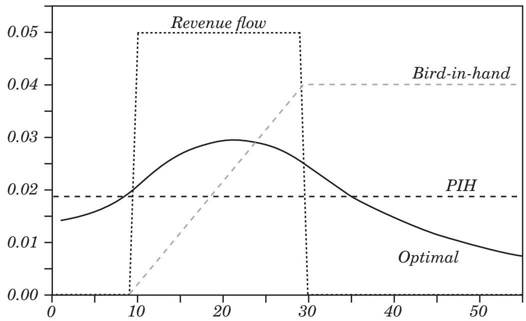
The revenue flow is assumed to be a step function that lasts for 20 years. The discovery predates the flow by ten years.

A proposition that follows immediately within the PIH framework is that the longer the duration of the resource is, the lower the savings rate should be. If the resource lasts for only one year, the optimal savings rate will approach 100 percent; whereas, if it is expected to last for a century, it can be far lower. Hence, the issue is how long will Chile's copper last.

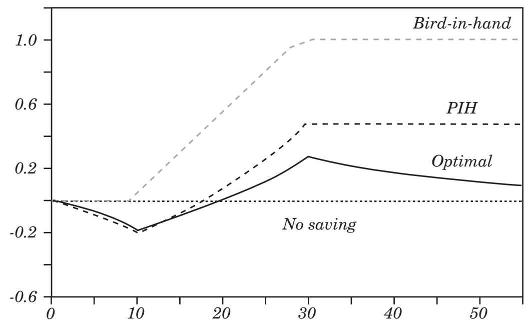
Posed as a question of physical supply, the evident answer is 'a very long time.' However, while the physical limits of availability are pertinent in some contexts, such as the discovery of a small oil field, for Chile, a more pertinent issue is long-term price risk. In predicting the long-term price path of a natural resource, there is a seductive temptation to invoke the Hotelling Rule. The Hotelling Rule predicts that the path of prices for depleting natural assets will rise at the same rate as the world interest rate. The rationale is

Figure 1. What to do with Windfall Revenue under Alternative Rules

A. Profiles of incremental consumption



B. Profiles of incremental asset holdings



Source: Taken from Collier and others (2010).

to imagine that natural assets are precisely equivalent to financial assets and will therefore only be held in portfolios if their expected return is equal to that of financial assets. By invoking the rational expectations hypothesis, expected returns must be unbiased estimates of actual returns. Hence, the actual return on holding a portfolio of natural assets will, on average, be the same as that of financial assets, namely, the world interest rate. Since the price of natural assets must be ultimately determined by non-speculative demand and supply, for expectations to be rational, the current price of the natural asset must adjust so as to be consistent with them. If the current price is too high to increase at the world interest rate, portfolio holders will switch to other assets, driving it down (and conversely so if it is too low).

The implications of the Hotelling Rule for savings are dramatic. An influential paper by Hartwick (1977) combined the Hotelling Rule and the PIH framework to derive the optimal savings rule for the world as a whole. Unfortunately, its implications have often been misinterpreted as directly applying to an individual, resource-rich country. While such a rule can be readily derived, it happens to be precisely the opposite of the rule for the world as a whole. Hartwick characterized global production by a Cobb-Douglass production function with three inputs: labor, physical capital, and a natural resource. Physical capital could be accumulated, but the natural resource was non-renewable. The globally optimal strategy was for the natural resource to be depleted at a diminishing rate, being asymptotic towards exhaustion. To keep global output constant in the face of the diminishing use of the natural resource, physical capital would have to be accumulated. Given the unit elasticities of substitution assumed in the Cobb-Douglass specification, this would require that the annual accumulation of physical capital be equal to the annual value of the natural resource that had been used up.

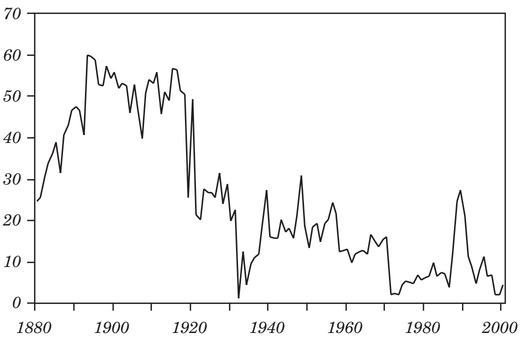
This answer is sometimes associated with the savings rule for a resource-exporting country. In fact, once the Hartwick model is decomposed into a resource exporter (Chile) and a resource importer (China), its assumption of unit-elasticity of demand has the consequence of the gradual reduction in export quantities being precisely offset by the rise in relative price. As a result, for the resource exporter, revenue is permanently constant. Each year, the unit price of copper would rise by the world interest rate, and this would precisely offset the reduced volume of copper that Chile would sell. Within the PIH framework, it immediately follows that since the stream of resource revenue is constant and permanent, the entire revenue should be used for consumption. Chile should save nothing from its copper revenues. Resource rents are permanent because an ever-smaller quantity is sold at an ever-increasing price. All the global saving effort required by the Hartwick Rule is done by the resource importing country, China, because it is paying a constant total amount for a diminishing physical flow.

I would not advise Chile to rely on either the Hotelling Rule or the Hartwick Rule that incorporates it. The theoretical "Achilles' heel" of the model is that technology is assumed to be constant. Yet, faced with an ever-rising price for using an ever-smaller quantity of the natural resource, both the incentive to innovate, and the scope for it, are also increasing. It is also not empirically supported; the actual path of resource prices over the past century has not conformed to it. Major distant technological advances cannot be forecast. They are, in effect, 'unknown unknowns.' Almost certainly their prospect does not strongly influence current extraction decisions. Extraction usually requires major irreversible investments that have to be planned years in advance so that the rate of extraction is unlikely to be varied until 'unknowns' become 'knowns.' Yet, such variation is an essential assumption for the validity of the Hotelling Rule. In consequence, when future technologies are discovered, they are liable to generate structural breaks in the path of future prices.

There are two such risks, one concerning demand, and one supply. Much of the demand for copper is due to its properties of conductivity. It seems to me quite likely that, by 2114, electricity will no longer be transmitted through copper wires. On the supply side, the world has virtually infinite amounts of copper. Chile's dominance of the global copper industry is entirely due to its present extraction technology endowment, which makes it considerably cheaper to mine there than elsewhere. As extraction technologies change, this advantage may persist, but then again, it may not. Currently, Chile has an extraordinary 27 percent share of global copper production. The probabilities of these types of technological advances cannot be reasonably assessed. The typical horizon of likely technological advance seems to be around two to three decades (for example, revolutionary change in nuclear technology has been forecast as being four decades away for the past half century). These distant technological uncertainties are no different for resource extraction than for any other industry as any national industry could become unviable due to technological change. The reason why such change is uniquely important for the resource extraction sector is that, because of the consequences, far more is at stake. Resource extraction generates substantial rents, whereas, industrial sectors do not. Technological change in manufacturing and services (creative destruction) merely shifts the activities where capital can earn a normal return; whereas, countries that are fortunate to have major deposits of high-value natural assets enjoy substantial rents over and above the normal return on capital and it is these rents which are at risk from sector-destroying technology. Initially, Chile's post-socialist policy on copper was based on the assumption that there were no significant rents in the activity. The large, prolonged increase in global prices of natural resources has required that assumption be revised. Currently, and prospectively, the copper sector generates substantial rents, much of which accrue in Chile–some to the government, some to the national copper company, and some to workers in the sector and local companies supplying it.

Indeed, Chile already provides the archetypical example of a sudden and catastrophic loss of resource rents as a result of unanticipated technological discovery. Through the late 19th century, Chile earned massive rents from nitrates. As shown in figure 2, for three decades they accounted for around half of all government revenue. Then, in 1920, a German scientist discovered how to make them synthetically. The price collapsed and the rents evaporated, inflicting a severe shock on government revenues. Having lived through this experience, Chile is better suited than any other country to recognize the vulnerability of resource rents and to plan accordingly.

Figure 2. Chile's Fiscal Revenues from Nitrates as a Percentage of Total Revenue



Source: Calculations of Rodrigo Caputo, based on Díaz and others (2010)

What happened to nitrates is by no means unique. It seems likely that the oil market will experience a similar shock. Four decades ago, global warming was not part of serious policy discussion; however, we now know that we have already discovered more oil than can be safely burned. At some stage in the next half-century, rules are likely to emerge that will result in 'stranded assets,' potentially destroying all the rents on oil. The first indications of this risk are already apparent: major portfolio investors are beginning to divest from oil companies. As expectations adjust to this scenario, oil prices will decline. Indeed, they will become subject to the 'green paradox'–if some oil must be left permanently unexploited, the maximizing response of individual oil-owners is to accelerate extraction, generating a global race to extract.

I have no expertise in forecasting the price of copper fifty years hence; however, you may conclude that the rents that Chile currently gets from its copper sector can be relied upon so far into the future that depletion can be ignored, or you may decide that, faced with substantial long-term downside uncertainty, it is better to be prudent. I will proceed on the assumption of prudence, since this seems the more appropriate stance for a central bank. In effect, were you to regard the rents from copper as secure only for the next three decades, what would be the implications?

Because unknown unknowns are so speculative, it is better to incorporate the implied risks through savings policies than through more targeted sectoral strategies. With the benefit of hindsight, prior to 1920, it would have been better for Chile to accelerate the extraction of its nitrates while trying to diversify the economy into other activities. But a policy that had implemented such strategies would not have been warranted on the information available at the time. Sectoral policies cannot be set on the basis of unknown unknowns. In contrast, savings policies should recognize both known risks and unknowable uncertainties. Indeed, the challenges to savings policy posed by the structural price risk arising from the technological uncertainties discussed above are not fundamentally different in kind from the cyclical price risk that Chile is already managing. Hence, the obvious high-level implication is that some of the resource rents should be used for the accumulation of long-term assets. While the nature of the information challenge is not fundamentally different, the practical arrangements of a savings fund designed to offset permanent obsolescence are, indeed, quite distinct from those appropriate for smoothing short-term fluctuations in rents.

The country that has best recognized the risks of obsolescence and depletion in recent decades is Norway. By using a substantial proportion of oil revenues to accumulate assets, Norway is protecting itself against both physical exhaustion and technological or regulatory obsolescence. The halving of oil prices in late 2014 and, consequently, the even larger decline in oil rents, is probably a belated response to the technological innovation in supply associated with fracking, itself a typical unknown–until recently. Thanks to its prudent policy of asset accumulation, Norway is far better placed than other oil-dependent economies to withstand the fiscal shock.

Beyond this general case for asset accumulation, even the simple PIH model with which I started can offer more specific guidance. Within the PIH model, the consumption attributable to resource extraction must be constant at its permanently sustainable rate. But what is seldom appreciated is that this implies that the savings rate from resource revenues should rise over time. The reason for this is that, as the stock of assets resulting from the savings accumulates, the income generated by this stock, which is permanent and can therefore be devoted entirely to consumption, increases. Indeed, the point at which the resource is exhausted, by definition, the sustainable income stream must equal the consumption target. Hence, with sustainable consumption almost fully financed by the income from accumulated assets, the savings rate from the revenues generated by the last resources extracted should be virtually 100 percent. In contrast, the savings rate from the first resources extracted should only be revenue less target consumption. While this is analytically straightforward, it has not been widely noticed, and the practice of committing to a rising long-term savings rate out of resource rents has not yet been incorporated into public policy in any resource-rich country.

While the assumptions of the above simple case were stringent, the rising savings rule turns out to be almost general. Only if the path of extraction were to generate an extremely rapid decline in revenues (which is very unlikely) would the optimal savings rate not rise. In the more normal case, in which the extraction path is hump-shaped, a first phase generates rising resource revenues followed by a second phase in which they are declining. During the first phase, the rule of the rising savings rate is reinforced: savings can increase because a smaller proportion of revenue is needed to maintain the PIH level of consumption. During the second phase, this effect goes into reverse. However, because the point of exhaustion is now closer, the annual effect of its approach is powerful. Hence, as noted above, only a very rapid decline in revenues (more than exponential) will overpower the need for a continued gradual increase in the savings rate.

While the PIH framework is a useful starting point, it is not adequate for an economy such as that of Chile, which is still only about halfway to converging on the level of income found in fully developed economies (van der Ploeg and Venables, 2011). It is only applicable for an economy that is able to borrow and lend at the world interest rate and has, thereby, already fully aligned the rates of return on different activities. Specifically, the social discount rate is already equated with the return on domestic investment, which in turn is already equated with the return on foreign assets. The optimal response to a windfall is therefore not to push consumption forwards or backwards in time, but simply have a one-off increase in its level. Furthermore, the incremental assets should be held in foreign assets because any further investment in the domestic economy would increase the capital-labor ratio, pushing the return in the domestic economy below that of world markets. The resource discovery, therefore, has no impact on domestic non-resource income, implying unchanged growth of consumption.

While these conditions may be applicable to some high-income countries, they are not applicable to an economy that is still converging on the OECD frontier. Hence, it would not be optimal for converging economies to follow this rule. Essentially, in Chile, people are considerably poorer now than they will be in the future. Somewhat offsetting this, during the convergence phase, the rate of return on capital should be atypically high. The net effect of these opposing forces within a Utilitarian framework is to increase the optimal initial consumption level relative to that under PIH assumptions, but to gradually taper the consumption increment. This is illustrated in figure 1 by the 'optimal' paths for incremental consumption and savings. These qualifications to the conclusions derived from the PIH analysis reinforce the rationale for the savings rate to rise during extraction.

The practical import of the above discussion is that a prudent policy would perhaps regard copper rents as secure for only the next three or four decades, while trusting that, by the end of the century, Chile will have fully converged on the OECD levels of income. By the time, in mid-century, that the rents might be seriously dwindling, the appropriate savings rate from them would therefore be high, likely above 50 percent. Currently, long-term savings from resource rents are essentially no different from any other source of income, and this makes no allowance for their distinctively uncertain sustainability. Hence, an initial extra savings rate might be set at a few percentage points over the average for all other income while the rising savings rate rule would gradually raise this during the ensuing three or four decades. Note that this would apply to the rents on copper extraction over and above the normal return on the capital deployed in the sector.

2. Policy Clock 2: Managing Asset Accumulation

The assets held to offset depletion should differ from those used to smooth expenditure in the face of fluctuations in revenue. By their nature, smoothing fluctuations imply that the assets acquired during periods of high prices will only be held temporarily. In contrast, since obsolescence and depletion are permanent states of affairs, the accumulation of assets to offset them should be held for a long time (as implied by the 'Optimal' path in figure 1b) and would indeed need to be held permanently within the PIH framework.

In turn, this major difference in the horizon for holding the accumulated assets has important implications for the type of assets to be acquired. Those assets acquired to smooth fluctuations must necessarily be foreign assets, otherwise they cannot smooth domestic activity. Further, since they are being held in order to be liquidated when needed, they must be readily marketable. Illiquid holdings of private equity would not be appropriate, even though the long-term rate of return on such assets might be higher than that of liquid assets. Finally, since the assets held for smoothing will need to be liquidated in predictable circumstances, namely, a fall in the copper price, they should be chosen so as to have a marketable value that is negatively correlated with the copper price.

In contrast, the assets accumulated to offset depletion are held for their long-term return rather than their ability to smooth domestic activity. Consequently, liquidity is not necessary. The key issue for assets designed to offset depletion is the choice between investment in foreign financial assets and domestic real assets.

Analogous to the PIH framework, the simplest starting point is an economy fully integrated into global financial markets. If there is diminishing marginal productivity, then incremental wealth should be held entirely in foreign assets. Increasing the capital stock would reduce the return on domestic capital and would thus be inefficient. This is sometimes referred to as a 'separation' result since it implies that the domestic capital stock and, consequently, wages and non-resource national income are completely unaffected by the accumulation of assets from resource rents.

Although this is the benchmark, there are good reasons for departing from it: Firstly, a period of high resource rents, such as Chile has experienced over the past decade, may bring its own financing needs. For example, infrastructure projects may need to be brought forward, with a demand on public funds. Structural change into non-tradable goods and away from non-resource tradables will create demand for investment and new capital spending. Some part of savings will, and should, be directed to the domestic economy. Specifically, a likely consequence of a resource boom is that the return on investment temporarily rises above the rate of time preference. High resource rents signal private investors that the domestic market will become larger and thus induces an increase in private investment. For example, following the upsurge in resource discoveries in Africa over the past decade, there has been an upsurge in private investment. This correspondingly raises the return on public investment. In summary, a high income economy, with perfect access to international capital markets before and after a resource windfall, should only invest in foreign assets after any domestic capital requirements associated with the discovery and associated structural change have been met.

Secondly, the PIH benchmark assumes that the social rate of return on domestic capital is equal to the private return on foreign assets. If this is not the case, then investment should be directed at assets that yield the higher social return. There are several reasons for thinking that, in a developing economy, these are likely to be domestic assets. There may be capital market imperfections. For the country as a whole, this might apply at the level of international capital markets; for domestic firms it might arise because of poorly developed domestic financial systems. For example, the interest rate which the government needs to pay to attract foreign financing of infrastructure may include a substantial premium for the risk that the government will renege on agreed terms; however, this is not a risk that the government faces if it finances the investment itself. In either case, it creates a case for directing investment to the domestic economy rather than using it to accumulate foreign assets.

Thirdly, many economies face critical shortages of economic and social infrastructure. This is because of constraints on the availability of public funds that are often due to weakly developed tax systems. Even those public investments with high social rates of return may pose insuperable problems of private financing because only a modest proportion of returns are appropriated through the tax system. Debt accumulated to finance such assets would become unserviceable. In these circumstances, it could be sensible for the government to use the long term savings from resource rents to finance such assets because in its asset choice, as opposed to its debt strategy, it can afford to be guided by the social rate of return irrespective of whether it is able to appropriate that return.

Fourthly, it is quite generally the case that the government should be looking at the social rate of return on domestic investments, i.e., the internal rate of return derived from a full cost-benefit analysis of its spending. Domestic investment may yield wider benefits due to the wedge between private and social returns created by taxes, once again suggesting the possibility of high returns.[1]

These arguments all suggest that domestic investment may be a better use of funds. If the rate of return on these assets is high, but likely to fall as the capital stock is built up, resource revenues should be used to bring forward the development of the domestic economy. Norway is often taken as an example of the foreign asset strategy, but foreign accumulation only began once Norway already had more invested capital per member of the labor force than any other country. Chile is not yet in that position. A model that may be more pertinent for Chile than modern Norway is that of Malaysia. Until the 1970s, Malaysia was a resource-dependent economy. However, during the following decades the government adopted a policy of high domestic investment, both public and private, and successfully diversified the economy (Yusof, 2011). For example, the impoverished fishing region of Penang was targeted for development. Public investment in social and physical infrastructure was the first stage in building what became a world-class center for the manufacture of light electronics. Cumulatively, such developments transformed Malaysia, as its resource rents are now a minor component of GDP.

For a country at Chile's level of development there is a reasonable presumption that, as in Malaysia, the potential rate of return on domestic investments is higher than the modest global returns on financial assets. However, implementing efficient investment may be difficult. Countries seeking to scale up domestic spending, particularly investment, are frequently constrained by a variety of bottlenecks. A pipeline of good investment projects might be

1. This point is emphasized by Nobel Laureate, Michael Spence.

absent, and there may be a lack of capacity to design and develop projects. Project selection and cost-benefit processes may be weak, and so too the ability to procure, implement, and monitor projects. Even if projects are undertaken, there may be supply bottlenecks so that spending raises prices and buys little capital investment. This is likely to be particularly true for 'home-grown' capital: while equipment can usually be imported, structures and human capital requires domestic capacity (e.g., in the construction and training professions), all of which take time to develop.

These absorptive capacity constraints bear on the balance between investment in the domestic economy and foreign asset accumulation. If the capacity to invest well is initially limited relative to the savings generated from offsetting depletion, then capacity needs to be built. The process of building the capacity to invest can be thought of as 'investing-in-investing.' It has three potential components. The most evident is the capacity of government to make public investments. The IMF has a useful new measure of this capacity, the Public Investment Management Index, but, unfortunately, Chile is not yet included in it. Further, since public and private investment are complements, policies that facilitate private investment become more valuable. Finally, the efficiency of investment depends upon the unit cost of capital. There is a remarkably wide international variation in the cost of capital goods, both equipment and structures, and these are partly the result of policy differences. For example, in a small economy, competition in the supply of equipment can be increased by integration with larger economies.

A conscious strategy of 'investing-in-investing' can gradually increase the capacity of the economy to absorb savings domestically. However, the level of the rents to be saved will periodically exceed the capacity to absorb them. For example, a quantum expansion in extraction due to a new mine may create a step increase in rents. In this case there is a strong case for parking savings abroad until absorptive capacity has increased or the flow of savings diminished. Such savings are conceptually distinct from a smoothing fund: they are intended to permanently augment the domestic capital stock, but are temporarily held as foreign assets until the capacity to absorb investment exceeds the flow of savings.

In effect, the policy of 'investing-in-investing' endogenizes absorptive capacity. Directly, it endogenizes the capacity to absorb investment, but ultimately, once this capacity is deployed to increase investment, it endogenizes the capacity to absorb aggregate demand. Once the capacity to invest has been enhanced, the domestic rate of investment can be increased without reducing the return upon it, and the extra supply that this new capital produces enables aggregate demand to be increased without significant pressure on relative prices. It thereby provides a solution to 'Dutch disease,' exemplified by Malaysia, which is superior to that of the Norwegian model of saving revenues in foreign assets. The Norwegian approach is only appropriate once the domestic capital stock has accumulated to the point at which, at globally efficient standards of production, the social rate of return on domestic capital has fallen to the private return on international assets. Norway satisfies this condition, as do the petro-economies of the Gulf, but most other economies do not. For a review of eight countries' experiences with the challenge of transforming resource revenues into development, which demonstrates that, while technically feasible, the decisions are politically difficult, see Collier and Venables (2011).

3. Policy Clock 3: Smoothing Expenditures

The above analysis has focused on offsetting depletion. Its key distinction was between consumption and savings. Budgets, however, work with different concepts, namely, expenditure and revenue. Revenues are the sum of consumption and savings, but expenditures are the sum of consumption and domestic investment. Because it is costly to deviate from planned expenditure, savings should accommodate deviations between itself and actual revenue.

That the path of future revenues is not known with certainty raises three distinct issues. One of these, being uncertainty about the average rate of change of revenues, can be incorporated by an increase in the discount rate, and this in turn raises the appropriate savings rate. In effect, this is what I have already discussed in terms of the prudent response to the risk of future rent loss. The expected path of revenues will need to be revised periodically in the light of new geological and market information and this will adjust the optimal path of savings and consumption.

Here I focus on two other types of uncertainty: One is the intra-year uncertainty about prices, which is of particular importance because of annual budgeting. An annual budget incorporates, explicitly or implicitly, an assumption about the average price of the resource over the coming year and this assumption will inevitably prove incorrect. The other is the volatility of the annual average of prices because even if, at the start of each year, the average for the year were to be correctly forecast, there would be a need to react to the changes in the average between years. If annual expenditures are to be non-volatile, recourse must be made to savings or borrowing.

3.1 Short-Term Uncertainty and Annual Budgeting

Over a horizon of twelve months, the path of physical extraction is largely known. Hence, the main uncertainty concerns prices. However, for all significant commodities it is now possible to hedge prices over this horizon. The whole point of annual budgeting is to enhance the coherence of spending, and so there is value in reducing uncertainty over intra-year revenues.

Among hedging strategies, the first choice is in the form of payment. Either the payment can be explicit, a known expenditure to purchase a floor price, or the floor price purchased in exchange for a ceiling price, between these, the former being more likely preferable; where it is important to avoid receiving a price below the floor price, there is no equivalent need to avoid particularly high prices since, above any ceiling, all revenues should be saved and marginal additions to such savings should incur no cost. Hence, there is no point in paying an implicit risk premium to eliminate this range of uncertainty. Further, while the use of a ceiling may appear to have political advantages, disguising what would otherwise be an explicit budgeted payment, the circumstances in which it is triggered may be particularly damaging politically. Namely, sacrificing a high price that has materialized has paid for an insurance against a very low price, which has, a fortiori, turned out to be unnecessary. A routine annual insurance premium for the purchase of a floor price securing the budget may be politically less exposed.

Having determined the form of payment, the remaining hedging choice is the precise floor price to be chosen. In the neighborhood of the mean of market expectations, an additional dollar on the floor price will increase the cost of the hedge by around 50 cents. Hence, in this range, the hedge eats half of the marginal revenue generated. Manifestly this is far too large a proportion to be warranted politically. An implication is that a floor price hedge should pitch the floor price conservatively, well below the mean of market expectations. Indeed, the floor price does not normally need to be close to the mean of market expectations. The floor price is not itself a forecast, but rather a way of protecting expenditure. Planned expenditure will, on average, be below expected revenue partly because not all planned savings will be invested domestically, and partly because expected revenues will be conservatively estimated due to a risk discount. Further, to a modest degree, it should be possible to scale back intra-year spending relative to budgeted plans at little cost. What matters is the price at which costly budget cuts would become necessary.

Hence, where the market expectation for the coming year is equal to the long-run expected price, the hedged floor price needed to protect expenditure can be below this level.

3.2 Medium-Term Uncertainty and Inter-Year Smoothing of Expenditure

The revenues prevailing in any one year may be above or below the long-term, risk-discounted, expected path. As long as actual (post-hedged) revenues are above planned expenditure for that year, then it is of no consequence for spending if they are below their expected level. All the difference between actual and expected revenues can be borne by a deviation of actual financial savings from planned financial savings. If, however, actual revenues are below planned expenditure, then either actual spending falls short of plans, or the shortfall is financed.

In principle, finance can be through either borrowing or drawing down savings. However, in practice, the two are often not alternatives. The ability to borrow depends upon a record of prudent savings and the prior accumulation of liquid assets. For example, during the global economic crisis of 2008/2009, the government of Botswana was able to borrow $1bn in order to protect public spending, but this was only possible because it had accumulated a much larger stock of wealth that it preferred not to draw down at such a time. For countries without such a record, the only reliable source of finance is the prior accumulation of liquid assets.

However, liquid savings have an opportunity cost in terms of more productive assets foregone. Hence, not all possible scenarios of needs for liquid savings should be accommodated. There will be times at which actual expenditure will indeed need to fall below planned expenditure. As liquid assets are drawn down, actual expenditures should be preemptively reduced to avoid the risk that finance will be exhausted, forcing a large, abrupt reduction in expenditure. In effect, this override is a second line of defense against an overly optimistic assessment of the path of future revenues, protecting accumulated assets intended to offset depletion from being used to finance an unsustainable level of consumption.

If revenues exceed planned expenditure, then the surplus should evidently be saved. However, there are two distinct functions for such savings: the accumulation of liquid savings to buffer expenditure and the accumulation of longer-term financial assets as part of the strategy of offsetting the depletion of natural assets. Although, in the long-run, a large majority of the assets that offset depletion should usually be domestic, reflecting the initial lack of domestic capital, the decision as to the composition between foreign and domestic investments should be taken year-by-year and reflect the limits on current capacities to invest well within the economy. Hence, in the years of high resource revenues, there is likely to be a substantial investment flow into foreign assets. There is therefore a need for a decision rule as to how much of the excess of revenues over planned expenditure should be used for future smoothing, and how much should be used for long-term portfolio investment. One approach is to decide the allocation according to whether the smoothing fund is at or below its target level. Until the fund reaches this level, all savings into foreign financial assets would be allocated to it and, beyond that, all would be allocated to offsetting depletion. This approach has the advantage of avoiding the anomalous situation of the government being required to add to its stock of foreign financial assets at a time when it would be justified in running them down. Such anomalies would not only be symptoms of misallocation, but they might also jeopardize an entire rule-based system of managing resource revenues.

To summarize, planned expenditure is derived from the path of expected revenues. Having determined planned expenditure for the coming year, these plans should be implemented even in the face of revenue shortfalls subject to an override reflecting concerns over liquid savings. Because expenditure is to be protected from revenue fluctuations, it is important that there is a responsible process of regularly updating expected revenues so that plans are based on realism tempered by risk. The override requires annual spending to be reduced below its planned level if the country encounters a run of unexpectedly low revenues that drains liquid savings to a dangerous level, the danger being an enforced and abrupt reduction in spending.

The key operational concepts are the optimal level of expenditure, the average level of liquid savings to be held for maintaining expenditure at this level, and the rules for overriding the drawdown in savings. In turn, setting these parameters should rest on an analysis of the likely volatility of revenues, which is commodity-specific, and the likely costs of volatility in expenditure, which, in turn, will reflect specific features of the system of public spending.

3.3 International Lessons for Chile

Chile leads the world in its approach to smoothing expenditures in the face of revenue shocks (Fuentes, 2011). Evidently, the challenge for policy is to maintain the policy rule in the face of periods when it would be politically convenient to break it. For example, in 2011, at the onset of its oil income, Ghana established a smoothing fund. By 2014, there was already political pressure to draw it down. There had been an explosion in public recurrent expenditure, consequent to a 50 percent increase in public sector wages, and faced with a 10 percent budget deficit and a rapid depreciation in the currency; drawdown was politically attractive relative to the alternatives. Clearly, however, the fund was not established in order to prolong periods of excessive exuberance in public spending, but rather to cushion periods of revenue shortfall due to a decline in oil prices.

The best defenses against the subversion of a stabilization fund are policy inertia and a critical mass of citizens who understand the rationale for the fund. Policy inertia builds with the time that a policy has been in place. Hence, changes in the stabilization rule, even when well justified as a genuine improvement, are likely to incur a hidden cost. In contrast, a critical mass of citizen understanding is something that has to be built and renewed. It requires an active and astute policy. The stabilization fund in Ghana is fragile not only because it is new, but also because it is not understood.

The crash in world copper prices in 2009 was a valuable lesson for Chilean citizens in the benefits of stabilization. This knowledge is, however, a wasted asset unless a running public narrative of prudence regularly replenishes it. The contrast between the persistent aversion of German citizens to inflation, and the repeated macroeconomic mismanagement licensed by the electorate of Argentina, demonstrates that societies cannot rely upon automatic processes of learning such as Bayesian updating from objective experience. Most people understand causal structures, not from direct experience or from analytics, but from well-presented narratives. One task of a central bank, however distasteful, is to master the art of such mass communication.

3.4 Implementing Policy Clocks: from Principles to Budget Rules

Budgets are decision processes for allocating revenues to a variety of expenditures. Over recent decades, two principles of good budgeting have been widely accepted, one macro the other micro. The macro principle is that aggregate expenditures should be kept broadly in line with aggregate revenues. Commonly, this principle has been encapsulated in the balanced budget rule that sets ceilings both for the fiscal deficit and the ratio of debt to GDP. The micro principle is that the marginal benefit of expenditures should be equated across categories. Since it is reasonably assumed that priorities will change over time, this principle has been encapsulated in the integrated budget rule that discourages pre-commitments of revenues and earmarking of particular revenue streams to particular items of expenditure.

Resource-rich developing countries face distinctive fiscal problems, the solutions to which involve distinctive principles. They therefore need distinctive rules that encapsulate these principles. At the core of the distinctive problem is that, unlike other countries, a significant component of revenue is from rents that are unsustainable. We should not expect this distinctive feature to be adequately dealt with by minor tweaks to the budget process. It is particularly problematic because inter-temporal resource allocation is an issue that standard budget procedures barely address–budgets are essentially devices for annual commitment. At the most, governments announce medium-term fiscal frameworks, but these are essentially informal statements of intention over a three-year horizon. Not only do these statements of intent have limited credibility, but also there is no intention that they will bind a successor government beyond an election.

The distinctive principle for a resource-rich country is that a certain proportion of revenues should be saved, whether in financial assets or domestic investment. Conventional budgeting processes are inadequate to deal with this problem in two important respects: First, they lack any mechanism for inter-temporal commitment, both for managing volatility, and for the longer horizon required for offsetting resource depletion. Commitment technologies are valuable to governments to reduce the risk of temporary lapses resulting from random short-term political pressures, which is indeed why they adopt the balanced budget rule and the integrated budget rule. But in the case of savings from resource revenues a commitment technology is even more important. It is not just that without it there is a risk of a random lapse, but rather, without it, the incentive to save is reduced even for a good government. Without a commitment mechanism, the savings of one government may merely transfer spending power to a bad successor. Indeed, the rationale for augmenting permanent income depends upon the current government believing that all future governments will behave prudently. In the absence of a rule, a good government may reasonably decide that it is better to spend all the revenue now on items that it regards as desirable, rather than risk its savings being spent by a successor government on items that the current government regards as less valuable. Worse, without a commitment technology, as wealth accumulates, with the incentive to be a rogue government that favors only expenditure, consumption actually increases. Hence, a long-term savings rule is not a mere nice-to-have addition to the standard budget rules, but it is paramount.

Second, because the balanced budget rule is defined in terms of expenditure relative to revenues, it misses the key required distinction between expenditure on consumption and the acquisition of assets. Domestic investment, which is aggregated under the balanced budget rule with consumption as expenditure, is the activity that, for a resource-rich country, is most important to distinguish. Hence, the recent IMF practice of modifying the balanced budget rule so as to exclude resource revenues–through concepts such as 'the non-oil fiscal balance'–has little analytic basis. Indeed, the government of a resource-rich developing country that actually constrained total expenditure to be equal to non-resource revenue would be massively misallocating its resource revenues, both under-consuming and under-investing. Conventional budget rules cannot be restored to relevance simply by setting resource revenues to one side. Rather, the principles underlying the optimal management of resource revenues must be woven into the foundation of a distinctive set of budget rules.

The PIH dictates that the (constant) increment to consumption should be sustainable in perpetuity, funded from a fraction of current resource revenues and from income on the accumulated asset. This is sometimes interpreted as sustainability of the non-resource balance (NRB), but consumption and the non-resource balance are the same only if it is optimal not to use any of the revenue for domestic investment.[2] In general, as discussed, this will not be the case. In all but very special cases, it will be optimal to have a period in which there is a relatively high level of domestic investment. This will create an NRB that appears unsustainable, implying that the NRB is an inappropriately restrictive anchor.

3.5 A Rule for Rising Savings from Resource Rents

Not only should a proportion of resource rents be devoted to long-term asset accumulation, but also that proportion should rise over time. How might the principle of a rising savings rate best be incorporated into rules? Formulating a rule involves a trade-off between accuracy and simplicity. The less accurate the rule is, the more sub-optimal the allocation it will generate and the more subject it is to challenge and change. However, it is more difficult to build a critical mass of citizen support for a complex rule than for a simple rule. While ignoring the first derivative of the savings schedule (the fact that it is upward sloping) would impose major costs of misallocation, ignoring the second derivate (the fact that it is unlikely to be linear) is probably warranted. Hence, a sensible compromise between accuracy and simplicity may be to have a rule in which the savings rate starts at some modest rate, rising annually through the lifetime of extraction. Would such a savings rule be practical politics? Arguably, it might be more practical than a rule for a constant savings rate that cumulated to the same asset value. Evidently, it is easier for politicians to commit to the formula 'God make me good, but not yet.' This is, indeed, the explanation for the infamous 'weeping willow' pattern of medium-term budget projections–the government acknowledges that spending will rise this year, but reassures markets that this will be reconciled by future fiscal tightening. Yet in respect of savings from natural resource revenues, such a behavior profile is actually optimal, the appropriate decision being what is politically easy.

Governments sometimes create specific funds into which resources for future generations are placed. When designed as

2. Baunsgaard and others (2012).

Sovereign Wealth Funds composed entirely of foreign assets, they breach the principle that much of the asset accumulation to offset depletion should be domestic. But even when redesigned to include domestic assets, they may add to citizen confusion rather than reduce it. For example, Ghana created a Future Generations Fund into which the government paid a few hundred million dollars. However, at the same time it borrowed $2bn through issuing sovereign bonds and reduced public investment relative to GDP. The existence of the fund created the illusion that oil revenues were being saved and thereby disguised the reality that the government response to the onset of oil was to reduce saving, using the oil as implicit collateral to borrow for consumption. It is important that citizens know the size of resource rents, and how they are used between assets and consumption. But the use of resource rents can only be ascertained by assessing the fiscal stance relative to a reasonable counterfactual estimating what the fiscal stance would be in the absence of resource rents. This is no more difficult than other fiscal counterfactuals, many of which are common in policy discourse.

3.6 Rules for Managing Volatility

Above, I set out the principles for smoothing expenditures in the face of revenue volatility. I proposed four such principles. One straightforward principle was the hedging rule that proposed governments should lock into budget assumptions by hedging resource revenues for the forthcoming year. A more complex but fundamental principle was that governments should make an assessment of optimal expenditure–that level above which revenues should be parked, and below which expenditures should be sustained by drawing on liquid assets. I emphasized that it was important to ground this estimate in realism. One approach is the Chilean panel of independent experts. Another is to adopt a mechanical rule such as a long-term moving average of commodity prices. The further principle was the need for a second line of defense, namely, that if liquid assets become dangerously depleted due to a run of misfortune, expenditure needs to be reduced preemptively below its optimal level rather than risk an abrupt collapse in expenditure upon the exhaustion of liquid assets.

A simple and effective formulation for the rule is that in no year may more than a certain proportion (such as a quarter) of the remaining liquid assets be withdrawn. In the event of persistent over-optimism in revenue projections, this imposes a gradual adjustment to reality. Evidently, the final rule specifies the target level of liquid assets. This is analogous to the conventional target for foreign exchange reserves commonly specified as a certain number of months of imports. In the case of resource revenues, the numeraire should evidently be the revenues themselves rather than imports; hence, the rule would be that liquid assets for purposes of smoothing revenue volatility should be built up to a certain multiple of resource revenues. The actual multiple can only be determined by studying the expected volatility of revenues and the damage that expenditure volatility would inflict.

In equilibrium, the government will thus be holding foreign financial assets for two different purposes: expenditure smoothing and parked money awaiting domestic investment to offset depletion. There is a good case for holding these assets in separate funds with distinct rules because a parking fund needs a rule contrary to that of a smoothing fund, namely, that assets cannot be liquidated to finance consumption.

It might be useful to place the implementation of the hedging rule within the smoothing fund. Analytically, it is a means of achieving expenditure smoothing, and it politically enables the Finance Minister to be distanced from the decision to spend money on any particular hedge that may or may not turn out to have been vindicated by events. The purpose of the fund is thus to make expenditure resilient to revenue shocks, whether by hedging or by the accumulation of liquidity.

3.7 Comparing the Rules with Conventional Budget Rules

How do these rules align with the conventional budget rules, namely, the balanced budget rule and the integrated budget rule?

First, consider the balanced budget rule as applied to a resource-rich country. In its unmodified form it would preclude the accumulation of assets other than domestic investment and, thus, seriously distort the process of asset accumulation. In its modified variant of the 'non-oil budget balance' it has the opposite distorting effect of squeezing out domestic investment. More trivially, the balanced budget rule collides with the need to smooth expenditure; self-evidently, resource-rich countries need rules for enabling and, indeed, requiring expenditure to deviate from revenues. Hence, the balanced budget rule is irretrievably inappropriate for a resource-rich developing country. It is not up to the central task of inter-temporal resource allocation.

Now consider the integrated budget rule, the principle that all expenditures should be left uncommitted so as to be freely allocated each year. As will now be apparent, this is also fundamentally at odds with the need to pre-commit some revenues to asset acquisition. Without such pre-commitment there is little chance that the marginal equivalences between expenditures, which are normally the ultimate justification for an integrated budget, can be maintained.

Were the government to have full information about all future needs and revenues, the optimal budget process for a resource-rich developing country would not be a series of annual budgets, but rather a single intertemporal budget over the horizon of resource depletion. Such a budget would incorporate the optimal path of asset accumulation, thereby achieving the marginal equivalence between the value of current and future consumption. Obviously, no government has full information and, as such, a comprehensive budgeting process is inappropriate. The solution is to leave open as many expenditure decisions as possible, locking in only to the minimum necessary to ensure the intertemporal equivalence of consumption expenditures. This is what is achieved by the rule of the rising savings rate. Having predetermined savings, the composition of those, such as between domestic investment and financial assets, can be left open to the annual budget, as well as the allocation of consumption spending between items. If we conceptualize all present and future uses of revenue as a matrix, with the rows being the years and the columns the various uses, the annual budget pre-commits the current row, while the rule of the rising savings rate pre-commits the assets column. All other items are left for future decision. This structure mirrors the pattern of markets with the markets for goods largely confined to the present period while transactions concerning future periods are accommodated in an aggregated form through the capital market. Hence, the rule of the rising savings rate replaces the balanced budget rule and introduces a constraint into the integrated annual budget rule.

4. Conclusion

Due to high commodity prices, resource rents have become important for many countries. The management of these rents poses distinctive policy challenges that have not been faced by the major OECD countries (Collier and Venables, 2011). As a result, the standard rules of economic management have not been designed with resource rents in mind. There are no suitable practical models to follow. The handful of resource-rich, high-income countries, such as the Gulf States, Norway and Australia, are so structurally different from each other and have such radically different approaches that none can be taken as models. Hence, the governments of resource-rich countries must think these issues through themselves.

I have focused on one distinctive and central policy issue: how much of the revenues from natural resources should be saved? I have combined the two core features that make resource revenues distinctive: they are depleting and they are volatile. An important implication of the paper is that the fiscal rules that have become conventional for countries that are not resource-rich are seriously inappropriate. The issue cannot be addressed by minor tweaking of conventional fiscal rules. The challenges that resource-rich, converging countries face are sufficiently distinctive and, for that purpose, designed fiscal rules are necessary.

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Commodity Prices and Macroeconomic Policy

Terms-of-trade fluctuations caused by long commodity price cycles are an important driving force of macroeconomic dynamics in many emerging and advanced economies, and hence have been the focus of economic research since the Merchantilists. "Commodity Prices and Macroeconomic Policy" contains six articles that define the new research frontier on this subject. The articles produce new and interesting findings on the implications of commodity price fluctuations for the conduct of macroeconomic policy. Both short-run business cycle issues and long-run structural topics are examined using state-of-the-art empirical tools and quantitative dynamic stochastic general equilibrium models. The ongoing collapse of commodity prices makes this book a must-read for anyone interested in understanding the macroeconomic implications of commodity price fluctuations and in learning about the way in which policy should respond.

Enrique Mendoza, University of Pennsylvania

The effects of commodity price shocks and their policy implications for importing countries have long been a central theme in macroeconomists' research agenda. The perspective of commodity producing countries, however, has generally been ignored. The present volume goes a long way in overcoming that neglect and, as a result, it is likely to become a key reference on the subject.

Jordi Galí, Universitat Pompeu Fabra

Referring to a Latin America country two hundred years ago, the German explorer and scientist Alexander von Humboldt said that it was like "a beggar sitting on a bench of gold." He might have meant this almost literally: the fabulous wealth in gold, minerals, and commodities found in these countries was wholly inconsistent with the poverty of their people. Managing and properly using natural resources has been a challenge and, at times, a curse for developing countries around the world. This timely book revisits the connection between commodity prices and macroeconomic variables and policies. It starts by recognizing that the issue extends to both the short and long runs, implying then that macroeconomic policy should consider different time horizons and objectives in its design. In spite of its breath and ambition, the book manages to be lucid and concise, becoming a useful and insightful tool for specialists and practitioners especially in the developing world.

Norman V. Loayza, World Bank

How important are disturbances in the terms of trade for macroeconomic stability? How do trends in commodity prices affect growth? What should fiscal and monetary authorities do, if anything, in response to changes in the relative prices of export and import goods? These questions are of central importance to a large number of emerging and developed countries whose economies depend heavily on exports or imports of commodities. This book addresses this topic with state-of-the art econometric and theoretical tools. It is an excellent source for academic economists and policymakers alike.

Martín Uribe, Columbia University

BANCO CENTRAL DE CHILE