

ESTIMATING GAPS AND TRENDS FOR THE CHILEAN ECONOMY

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Over the past few years, the Chilean economy has experienced a marked deceleration in economic growth. Labor productivity growth averaged more than 6 percent annually from 1994 to 1997, but since 2000 it has registered between 3 and 4 percent. Moreover, the period since the outbreak of the Asian and Russian crises in 1997 and 1998 seems to indicate that more than purely cyclical factors are at play in determining the expansion of productivity and the recent rates of aggregate growth: monetary policy has clearly shifted to a more expansionary stance, and since 1999 long-term interest rates have declined sharply in real terms.

The debate on whether the current and forecast growth rates of the Chilean economy in the short term reflect a shift in the underlying expansion of productivity or are only a symptom of weak aggregate demand reflects the difficulties in separating trends from cycle. The same can be said about the different opinions regarding the size of current slack in capacity utilization. This is unfortunate, though, because these two variables are key inputs in the formulation of monetary and fiscal policy. On the one hand, the current slack in factor and goods markets determines the present underlying inflationary tendencies, through their impact on wages and markups. On the other, the expansion of capacity utilization over the next quarters or years affects the trends in these inflationary pressures.

Since 1999 monetary policy in Chile has been guided by forecast inflation targeting, in which the current stance of monetary policy is

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endogenous to the expected or forecast path of prices. Erring on one side or the other of the output gap or trend growth can affect the achievement of the inflation target. Moreover, whereas supply shocks or relative price shocks (such as oil prices and the exchange rate) are immediately observed, the true extent of underlying price and wage pressures remains uncertain until it is too late to act with monetary policy. The transmission mechanism of monetary policy to inflation through the labor market is likely to have the longest lags of all such mechanisms.

Similar difficulties arise with regard to fiscal policy. The current framework in Chile aims at the achievement of a structural surplus of 1 percent of GDP over the cycle. The yearly discussion of the budget therefore requires an actual quantification of the size of the output gap, to fix the path of real expenditure. Again, using assumptions about the gap or trend growth over the short run can introduce a bias in fiscal policy, inducing too much or too little aggregate demand impulse relative to what is deemed convenient.

Unfortunately, the construction of output gap measures is plagued with difficulties. After briefly reviewing related studies in section 1, we begin our analysis in section 2 with a data-based approach that relies on a two-step procedure. First, we use traditional growth accounting exercises to obtain a measure of total factor productivity (TFP). Second, we define potential output based on the assumption that inputs (labor and capital) are at their normal or trend utilization rates. This procedure is sensitive to assumptions in both steps. An accurate measurement of inputs used in the production process includes issues that should not be accounted for as TFP fluctuations, such as shifting quality and composition of labor and capital, as well as time-varying utilization rates. The second step, in turn, requires assumptions about the trend or normal use of inputs, to work backwards and estimate potential output.

In simple terms, and leaving aside the measurement issues related to quality trends, the data-based approach actually requires identifying a priori the cyclical and trends components in the data. A typical case is the capital utilization rate, which is usually associated with the unemployment rate following Solow's classic exercise. To construct potential output (an exercise that Solow did not pursue), the production function is then evaluated at a "normal" utilization rate (that is, the "natural" unemployment rate, defined in a particular way). It is thus paradoxical that the key identification assumption corresponds closely to the result of the calculation. By going through the two steps mentioned above, we do not pretend to circumvent these difficulties, but rather aim to highlight the type of assumptions needed for this approach.

Section 3 complements the data-based estimates with a simple empirical methodology that estimates the output gap directly from macroeconomic aggregate demand and aggregate supply models. Given that the output gap measures are typically used as inputs in a macroeconomic model such as the one we use, the simultaneous estimation through state-space techniques of the macroeconomic variables and the underlying unobserved level of the output gap provides an interesting alternative to the data-based approach.

This model-consistent estimate still requires some identification assumptions. The first is the actual specification of the macroeconomic model, particularly the functional form and the excluded variables. This is unavoidable, however, given that the output gap measures are used in the context of specific models of the macroeconomy. The second main identification assumption relates to the assumed volatility of output trend.

1. A REVIEW OF RELATED WORK

Interest in potential growth is not novel to Chile. Most of the research refers to the period before 1997, however, and it generally does not acknowledge the importance of the specific identification issues surrounding the estimation.

Roldós (1997) combines two different forms of analysis—namely, growth accounting and regression analysis—to examine economic growth determinants and the relation between economic growth and inflationary pressures. He estimates an aggregate production function using a cointegrating vector, which relates total GDP and production factors (capital and labor) adjusted by quality indexes. These indexes measure changes in the composition of production factors that make aggregate factors more productive. The factor shares obtained from the estimation of the production function allow Roldós to calculate the Solow's residual, or the TFP. He uses a Hodrick-Prescott (HP) filter to remove the cyclical components of the TFP and employment before estimating the potential output. Roldós does not find a positive correlation between output gap and inflation, but rather a small negative one. He interprets these results as a product of the high average inflation throughout the 1990s. However, he does not control for movements in the exchange rate.

Rojas, López, and Jiménez (1997) carry out a similar exercise in a growth accounting model, considering not only capital and labor as production factors, but also the contribution of international trade to growth. They estimate the contribution of Chile's increasing commercial integration in the last decades to effective and potential growth.

Using a cointegration focus, the study estimates a production function that considers capital and labor—corrected by grade of utilization and by quality indexes—and a terms-of-trade variable that controls for fluctuations of international prices faced by the economy. It then calculates the potential output of the Chilean economy during 1960–1996 using a cointegration vector comprising labor, capital, terms of trade, and commercial integration, all filtered by HP.

It is typical for such studies to filter the series to obtain a measure of the gap, although it is questionable how much this differs from directly filtering the GDP data (see figure 1). Studies that do not use filtering methods still imply strong identification assumptions. Marfán and Artiagoitia (1989) use linear programming techniques to obtain a measure of the gap. However, they impose a production function that is linear in capital. García (1995) uses an indirect approach: he estimates a labor demand function to identify the parameters of the production function and then defines potential output as output at full employment. The gap is thus the mirror image of the unemployment rate. Jadresic and Sanhueza (1992) similarly identify the output gap by assuming an increase in the natural rate of unemployment by the late 1970s and early 1980s.

Coeymans (1999) does not estimate a measure of potential output, but rather focuses on an approach based on sources of growth to measure trends in GDP. He estimates a production function in which growth determinants are centered in aggregate supply factors: namely, capital accumulation, hiring of new workers, and TFP.¹ Assuming constant returns to scale, this analysis shows an important cyclical component in productivity. The high correlation between productivity and external shocks reveals their importance as principal determinants of productivity cycles and output.²

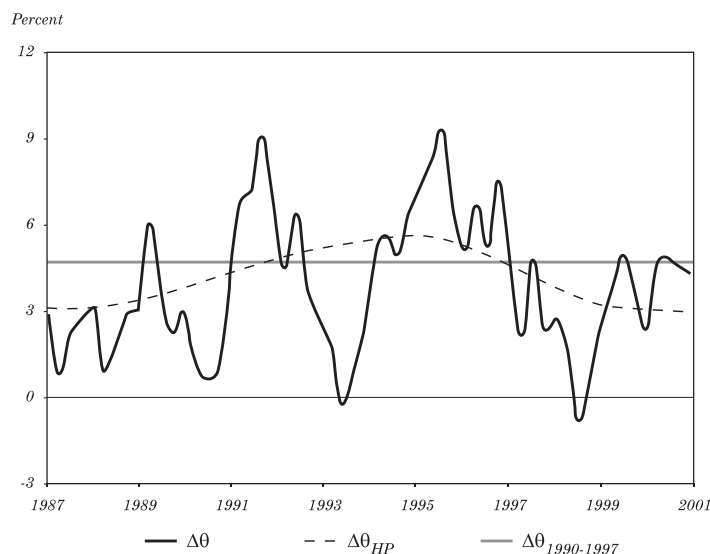
In a related effort, Nadal de Simone (2001) estimates a small macroeconometric model using state-space techniques similar to the ones used here. The main difference between his work and ours is that while he uses an approach based exclusively on unobserved trends in GDP, we incorporate more structure on the main macroeconomic relations, including aggregate demand and price determination.

As is evident from this brief review, we do not stray too far from previous efforts. It is important, however, to acknowledge the

1. TFP includes changes in the level of utilization of capital and labor, reallocation of resources from low to high productivity activities, and technical advance.

2. For example, terms of trade, impact of international interest rate on financial services, and external crisis index.

Figure 1. Aggregate Labor Productivity Growth Rate



$\Delta\theta$ is the change in average labor productivity.
 $\Delta\theta_{HP}$ is the change in the HP filtered average labor productivity.
 $\Delta\theta_{1990-1997}$ is the average annual growth in labor productivity, from 1990 to 1997.

importance of the assumptions behind the estimates of trends and gaps. This is why we use two very different approaches. The results of these two methodologies are different, as expected, and are also quantitatively different from simple filtering techniques such as the Hodrick-Prescott (HP) filter. This reveals that, not unlike many of the other aspects surrounding monetary policy under inflation targeting, considerable judgement must be used to evaluate the underlying inflationary pressures in the economy. The use of a single mechanical procedure to estimate trends and gaps is therefore dangerous, because it is very likely to introduce biases in the conduct of monetary policy.

2. DATA-BASED ESTIMATES OF POTENTIAL OUTPUT AND THE OUTPUT GAP

In this section, we construct estimates of total factor productivity growth and assess its contribution to the slowdown of aggregate growth experienced in Chile over the last few years.

2.1 Dual and Primal Estimates of TFP: Notation

The two possible strategies for estimating TFP are the primal and dual approaches. They differ in the data required, and they are generally viewed as complementary. The primal approach relies on the calculation of Solow's residual, through the use of aggregate GDP data, along with estimates for the capital stock and labor employment. The dual estimate focuses on the path of relative prices: wages and the cost of capital. The relationship between these two approaches is easily demonstrated by assuming a production function for value added and using the income identity of national accounts, both in real terms:

$$Y = F(A, K, N) = C_k K + C_n N. \quad (1)$$

The only assumption underlying equation (1) is that output equals payments before direct taxation to the factors of production—labor ($C_n N$) and capital ($C_k K$). These include depreciation and eventually rents owing to imperfect competition in labor or capital markets. Note that Y is cost-based value added, not including indirect taxes. No assumption is made about the shape of the production function, in particular the way technological change A affects the relative demands for capital and labor.

First order differentiation with respect to time, using the normalization $(\partial F / \partial K) = 1$, leads to

$$\Delta Y = \Delta A + \frac{\partial F}{\partial K} \Delta K + \frac{\partial F}{\partial N} \Delta N = K \Delta C_k + C_k \Delta K + N \Delta C_n + C_n \Delta N. \quad (2)$$

Dividing both sides of the equation by Y yields

$$\Delta y = \Delta a + \frac{\partial F}{\partial K} \frac{K}{Y} \Delta k + \frac{\partial F}{\partial N} \frac{N}{Y} \Delta n = \frac{C_k K}{Y} (\Delta c_k + \Delta k) + \frac{C_n N}{Y} (\Delta c_n + \Delta n). \quad (3)$$

If $\alpha = (C_k K / Y)$ is the share of capital in total costs, then

$$\Delta y = \Delta a + \alpha \Delta k + (1 - \alpha) \Delta n = \alpha (\Delta c_k + \Delta k) + (1 - \alpha) (\Delta c_n + \Delta n). \quad (4)$$

This formulation is correct under both perfect and imperfect competition, as long as markups enter as a wedge between marginal factor productivity and the reservation wage and cost of capital:

and (5)

This means that both approaches should have the same measurement error. The primal (Δa^{primal}) and dual (Δa^{dual}) estimates of TFP growth can now be defined:

(6)

The intuition for this identity is simple: TFP grows if real wages or the real return on capital is growing, too, because these relative prices (not adjusted for quality) should be constant in steady state.

Before moving to the primal and dual estimates of TFP growth, some measurement issues must be highlighted. These revolve around two main aspects: the changing quality of the inputs in production and their varying utilization over the business cycle.

$$\frac{\Delta y - \alpha \Delta k - (1 - \alpha) \Delta n}{C_h} = \frac{\Delta F}{F} = \alpha \Delta c_k + (1 - \alpha) \Delta c_n$$

$\Delta a^{\text{primal}} = \Delta a^{\text{dual}}$

Important quality trends are found in both capital and labor. With regard to capital, the composition of gross fixed investment has shifted dramatically over the last decade and a half. In 1986, machinery and equipment (M&E) composed 43 percent of gross capital formation (in constant 1986 prices), while from 1995 onwards its share stabilized around 60 percent. In nominal terms, the share of M&E first increased from close to 40 percent in the mid-1980s to 50 percent in the early to mid-1990s; it then declined to slightly over 40 percent in recent years.³ Fairly large shifts also occurred within M&E over time. The imported component increased from 80 percent in the mid-1990s to close to 90 percent in 1998, and then experienced a steep decline in 1999 and 2000, reaching 76 percent.⁴

3. Official data on nominal investment are available through 1998, so we used estimates for investment deflators for 1999 and 2000.

4. Again, the later data are estimates based on the path of capital imports quantum, which fell close to 35 percent in 1999. The years 2000 and 2001 have seen a modest recovery: third quarter data are only 11 percent higher than the 2000 average.

Figure 2. Composition of the Capital Stock

Accounting for these large shifts in the composition of investment is important. They have been substantial enough to matter in the composition of the capital stock over the last decade and a half. Recent estimates by Aguilar and Collinao (2001) show that M&E as a share of the capital stock increased from 18 percent in 1985 to 33 percent in 1997, and has remained stable since (see figure 2).

These shifts have potentially large effects on the dual estimate of TFP growth, as shown by D. W. Jorgenson's definition of the cost of capital. Let $C_{k,i}$ represent the capital cost of brand i of capital, measured relative to the GDP deflator P , while R_i is the net return on capital, D_i the depreciation rate, P_i its own deflator, and τ_i any tax-induced wedge:

$$C_{k,i} = \tau_i (R_i + D_i) \frac{P_i}{P}$$

(7)

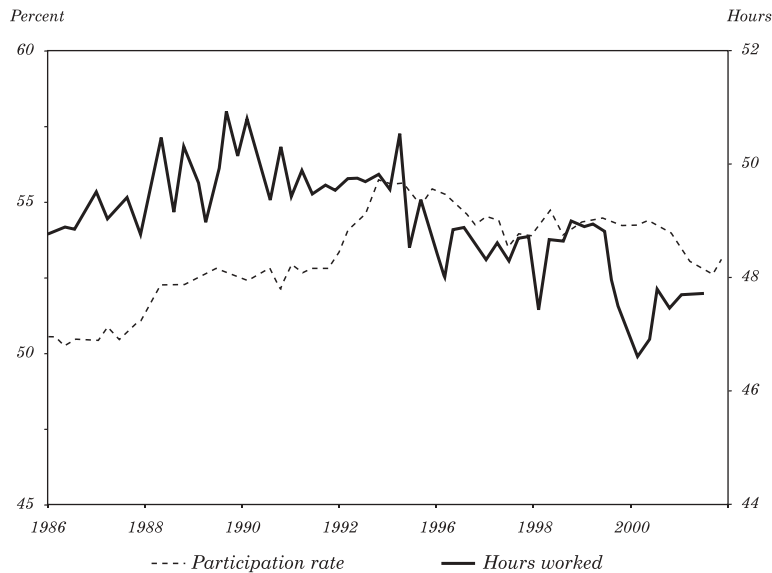
If we abstract from the importance of different tax treatments, τ_i , and if by arbitrage we set R_i equal for all i , different rates of depreciation, as well as different relative prices P_i/P for each brand of capital, will still have an important incidence in the cost of capital. In particular, M&E must be treated differently from construction because it has a high relative rate of depreciation and an important imported component. These

Figure 3. Investment Deflators (Relative to GDP Deflator)

facts affect not only the estimated path of the cost of capital for the dual estimate of TFP, but also the share of M&E in total costs, which is an input for primal growth accounting.

How important quantitatively are these factors in determining the path of the cost of capital? Figure 3 shows quarterly M&E and construction deflators, normalized by the GDP deflator for the period 1986 to 2001. The two deflators display very different evolutionary paths. The increase of the construction deflator has been fairly stable, increasing by a little more than 1 percent over the increase in the GDP deflator. Meanwhile, the appreciation of the real exchange rate had a large impact on the relative price of M&E, which fell around 40 percent between 1990 and 1996. It has remained stable since then: the depreciation of the nominal exchange rate was offset not only by a decrease in the dollar-unit import value of capital goods, which fell 15 percent after peaking in early 1996, but also by a reduction in the average tariff rate of 3 percentage points. The relative price of M&E vis-à-vis construction thus declined 50 percent between the mid-1980s and 1997.

In the area of labor, the quantity and quality of inputs changed considerably over time as a result of increases in educational attainment, the sectoral reallocation of labor, and secular trends in labor

Figure 4. Hours Worked and Average Participation Rate

participation and hours worked. In simple terms, the actual labor input that enters the production function is a combination of the participation rate, p , the employment rate, $(1-u)$, with u being the unemployment rate; hours worked, H ; effort, E ; and educational attainment, S :

$$N = Pp(1 - u) HES$$

(8)

All these factor played a role in Chile over the last decade and a half. Since the mid-1980s, the labor force has increased its average years of schooling by over 10 percent. At the same time, the participation rate also shifted up, especially among women and especially in the early 1990s. Since 1999, though, participation has declined by a couple of percentage points. The number of hours worked shows a downward trend since 1986 (see figure 4).

2.3 Dealing with Utilization over the Cycle

Over and above the changing quality of the inputs, their utilization over the cycle can introduce “false” movements in TFP. Existing frictions prevent the full utilization of the existing stock of capital or the

labor force. This paper does not address why this might be so; we are simply pointing out that this fact must be taken into account to prevent a spurious relationship between TFP and the business cycle.

In the case of labor input, unemployment figures allow at least a partial disentangling of the labor utilization effect. The issue is further complicated, however, because participation rates themselves are not exogenous, and they have a relationship with the business cycle through the combined added-worker and discouraged-worker effects. These two effects actually show interesting empirical dynamics over the cycle, depending on the persistence of the path of unemployment: an increase in unemployment initially increases participation (the added-worker effect), but if this increase persists over time, participation starts to drop below its initial level (the discouraged-worker effect) (see García and Contreras, 2001). Moreover, the intensity of physical labor can vary over the cycle, reflecting changes in hours worked and effort expended. These factors not only affect labor input trends as shown above, but they also have a quantitative impact over the cycle, particularly labor force participation.

The above issues are relevant for a correct interpretation of the primal TFP estimation. They also come into play for the case of the dual estimate. Real wages, controlled for inflation fluctuations, move with unemployment fluctuations in a significant way.⁵ Even more, the real return on long-term bonds, which is the variable used to construct the cost of capital because it is not subject to arbitrage, is sensitive to monetary policy shifts, which themselves react to perceived output deviations from trend and inflationary pressures. Therefore, the dual estimate of TFP growth will be polluted by the cyclical behavior of the cost of capital and wages (see figure 5).

2.4 Identifying Assumptions

Constructing the primal and dual measures of TFP thus requires separately identifying the cyclical and trend components of each of the stock (for the primal) or price (for the dual) estimates. The key identification assumption we make here is the estimation of the natural rate of unemployment, which plays an important role in all the corrections for the TFP estimation.

To obtain the natural rate of unemployment we filter the unemployment rate with the Hodrick-Prescott filter, setting $l = 20,000$ and

5. See García and Restrepo (2001); Coeymans (1999).

Figure 5. Annual Interest Rates

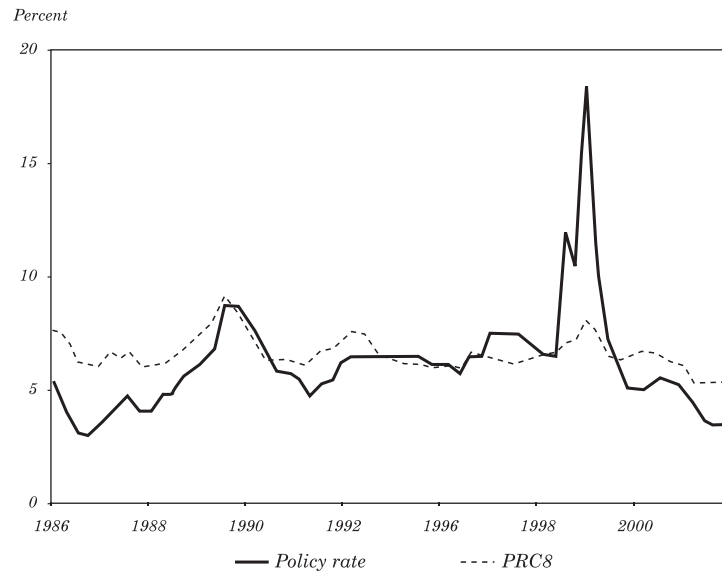
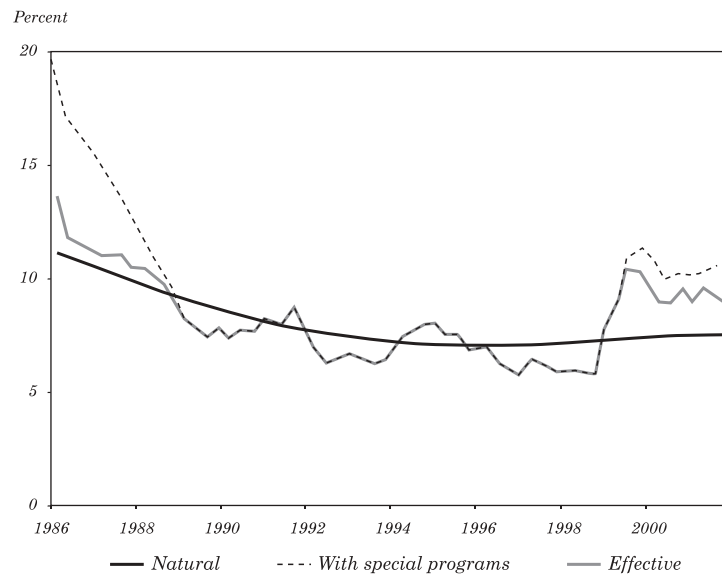


Figure 6. Effective and Natural Unemployment Rates



restricting the sample up to the first quarter of 2000. The HP filter has a well-known problem in dealing with end points; we therefore exclude the last six quarters and instead fix the natural rate of unemployment at 7.5 percent for this subperiod (see figure 6). We define the unemployment gap as $u - un$.

We assume that the effective use of capital over the cycle is similar to the gap between the effective unemployment rate and the natural rate.⁶ Utilization is thus over 100 percent during a boom and below 100 percent in a slump. We further assume that the utilization of M&E and the utilization of construction move in tandem. These effective measures of the capital stock are defined as

$$\bar{K}_i = K_i(1 + un - u). \tag{9}$$

Long-term interest rates in Chile were highly volatile in the past, reflecting, in part, the impact of monetary policy decisions. For the dual calculation of TFP, however, we are interested in more persistent factors affecting the demand for long-term bonds, such as, precisely, growth prospects. We therefore need to break down the path of interest rates, disentangling all movements associated with short-term rates. We proceed in two steps. First, we use the Kalman filter to estimate a policy rule for short-term interest rates, including the unemployment gap, the difference between actual inflation and the inflation target, and an autoregressive term.⁷ We interpret the state variable that results as an indicator of the unobserved neutral stance for monetary policy. Second, we input the resulting neutral policy rate into an estimated equation for long-term interest rates, which includes leads and lags of itself. In this manner, we recover a path for long-term interest rates that we hope is unrelated to the cyclical situation of the economy (see figure 7).

$$\ln H = 3.88 + 0.03 \ln trend - 0.008 (\ln trend) - 0.778 (u - un)$$

(0.010)

Finally, a similar exercise needs to be performed on labor to correct for hours worked. We estimate a simple specification, regressing average hours worked on the unemployment gap, and a quadratic trend. The resulting equation is

6. This is the same assumption used in the literature since Solow's classic article (Solow, 1957). It does not imply that the labor-to-capital ratio is constant. Rather, this ratio does not move mechanically with the employment rate.

7. For details, see the Appendix.

Figure 7. Cyclically Adjusted Long-Term Interest Rate (PRC8)

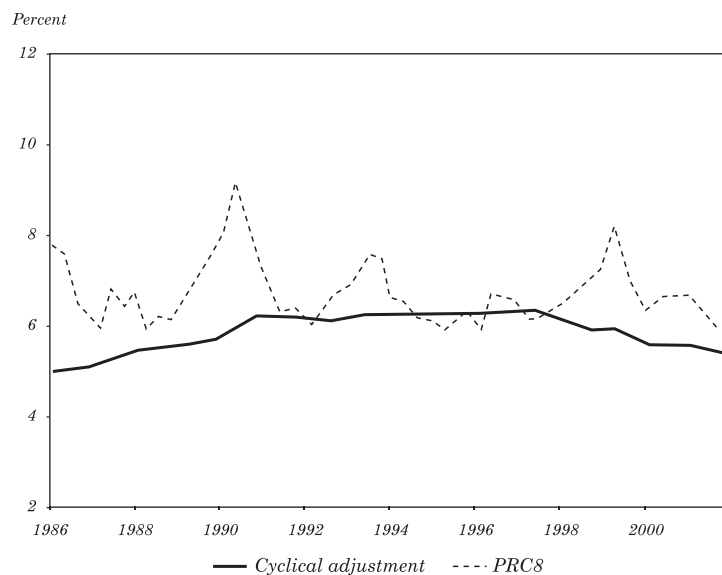


Figure 8. Cyclical Correction of Hours Worked



Figure 9. Cyclical Correction of Participation Rate

with Newey-West standard errors listed in parentheses below the coefficients and with R -squared equal to 0.63, a standard error of 0.01, and a Durbin-Watson statistic of 1.59. The number of hours worked tends to be quite procyclical: a 1.3 percentage point increase in the rate of unemployment leads to a fall of 1 hour worked (see figure 8).

With regard to participation rates, García and Contreras (2001) estimate that the long-run elasticity of the participation rate to unemployment is close to one.⁸ The short-run dynamics play an important role, however, although the cyclical correction, based on their estimates, still shows a large procyclical component in the participation rate (see figure 9).

2.5 Estimation Results

The results of our dual and primal estimates of TFP growth, including forecasts for 2001 and 2002, are not radically different from what other studies obtain (see figure 10).⁹ The period of high average

8. Central Bank of Chile (2001).

9. The forecasts for 2001 and 2002 are not to be taken as official projections by the Central Bank of Chile.

GDP growth (1986–1997) can be decomposed into several subperiods, according to the relative importance of the different growth determinants.

In the mid to late 1980s, high average growth was sustained by a sharp increase in the labor input, after the recession of 1982–1983. This was manifest not only in the increases in employment, but also in the greater hours worked and higher levels of schooling relative to earlier periods. Capital accumulation was less important than labor, although the utilization rate rose sharply. This factor is key in explaining the flat behavior of TFP over the period: not controlling for utilization would result in a larger role for TFP growth over this period. In terms of the dual estimate, slow real wage growth and declining real interest rates confirm this panorama.

The period from 1990 to 1994 displays some of the features of the previous period. In particular, the employment growth rate reached 3 percent a year, on average—well below the rates experienced in the 1980s, but still high. Capital accumulation picked up significantly, and utilization rates reached 100 percent. This period also saw real wage gains that seem to have led to increased female labor participation. TFP growth increased, reaching around 2 percent a year, on average (3 percent in the dual estimate).

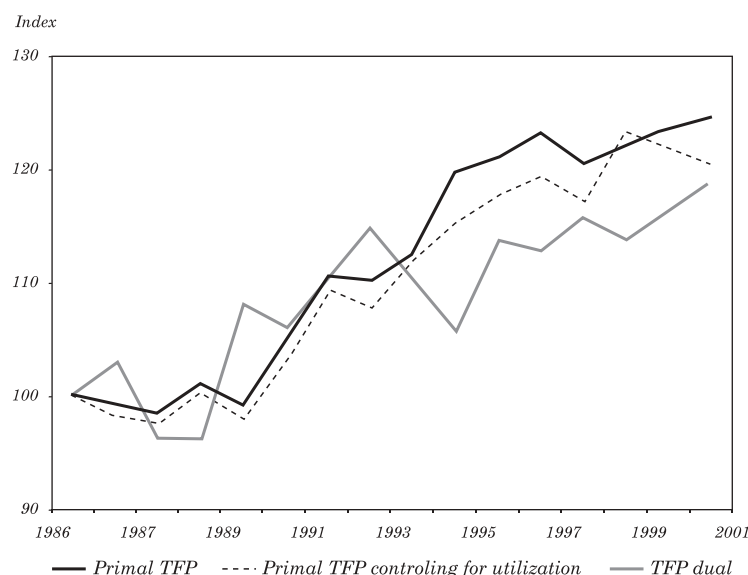
The years between the Mexican and Asian crises (1995–1998) saw an unprecedented acceleration of economic growth. This boom was accompanied by a swift accumulation of capital and a further increase in primal TFP growth measures. The economy was clearly at full employment: employment growth slowed to rates similar to the increase in the working-age population, and real wages grew at close to 6 percent a year. The dual estimates for TFP continue to show high rates of growth, although lower than earlier in the decade.

Growth slowed dramatically following the Asian and Russian crises, with a tightening in monetary policy. However, the reduction in growth was mostly reflected in a sharp stop in the almost continuous expansion of employment over the previous decade, as well as in a sharp reduction in TFP growth and the utilization of the capital stock. Capital accumulation proceeded at a high rate, reflecting relatively important rates of investment even after the sharp fall in 1999.

Finally, the aftermath of the crisis years witnessed a resumption of growth, to rates higher than those seen in 1998 and 1999 but lower than those earlier in the 1990s. This new situation is consistent with increases in the capital output ratio and a flat TFP.

These different periods are reflected in the path of TFP over the last decade and a half (see tables 1 and 2). First, TFP growth was modest in

Figure 10. Primal and Dual TFP



the late 1980s. This is a result of controlling for a varying utilization of capital, which might incorrectly be measured as TFP growth. A second period, featuring high TFP growth, lasts from 1991 to 1995 for the primal estimates and from 1989 to 1994 for the dual estimates. In the final period, TFP growth remained positive, but slowed considerably.

We also constructed an additional measure of the primal TFP estimate, excluding inventory accumulation to reduce the cyclical nature of output. The different types of adjustments matter in the estimates. For example, calculating the primal measure of TFP without making any adjustments results in an additional cumulative growth of 10 percent (see figure 11). This is close to half the growth of adjusted TFP. The cyclical behavior of TFP remains an issue, however, and this affects the estimation of the gap. If one directly uses TFP for the calculation of potential output, the gap in the mid-1980s is close to zero, and the current slack is also small, especially in the unadjusted series (figure 12). Like other authors, we find that the filtering of TFP then seems a reasonable option. Here we applied the HP filter, but with $\lambda = 10,000$. The gap appears more procyclical.¹⁰ The filtering approach

10. The correlations between the three gaps presented and quarterly growth of seasonally adjusted GDP are -0.03, 0.01, and 0.40.

Table 1. Sources of Growth, Primal Estimate of TFP

<i>Period</i>	<i>GDP</i>		<i>Capital</i>				<i>Employment</i>			<i>TFP</i>	
	<i>Total</i>	<i>Without stock</i>	<i>Total</i>	<i>M&E</i>	<i>Construction</i>	<i>Utilization rate</i>	<i>Employed</i>	<i>Hours</i>	<i>Schooling</i>	<i>With stock</i>	<i>Without stock</i>
1987–1989	8.2	8.0	4.5	6.2	3.9	98.8	7.2	0.6	1.2	0.3	0.1
1990–1994	7.3	7.4	6.9	10.9	5.3	100.3	3.0	–0.2	0.9	2.2	2.3
1995–1997	8.5	7.6	9.1	14.8	6.3	100.5	1.6	–0.6	0.6	3.0	2.1
1998–1999	1.5	3.5	7.8	10.8	6.1	98.9	–0.6	–1.4	0.5	–0.4	1.7
2000–2002 ^a	4.3	3.9	5.1	5.5	4.8	97.5	0.5	1.2	0.5	0.8	0.3

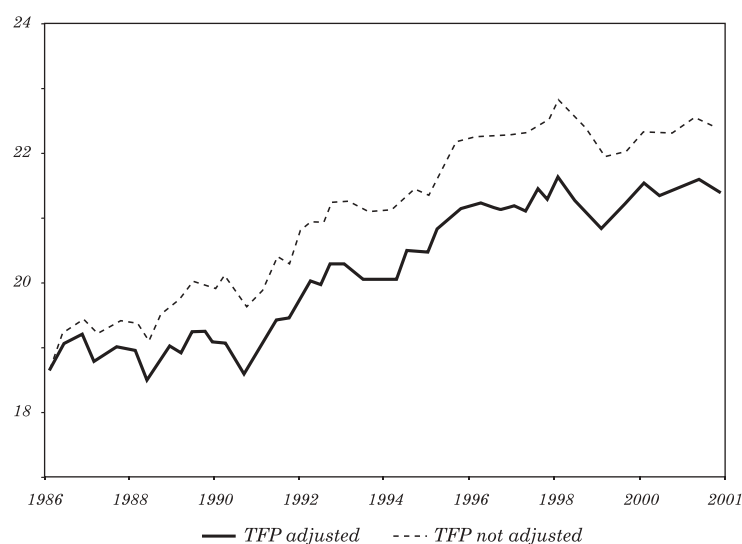
a. Forecast.

Table 2. Sources of Growth, Dual Estimates of TFP

Period	Employment cost	Cost of capital use			TFP
		KC	KM	KT	
1987–1989	0.9	-3.9	-6.3	-5.1	-1.8
1990–1994	5.4	2.6	-3.5	0.6	3.2
1995–1997	5.7	1.9	-4.9	-1.7	2.4
1998–1999	4.9	1.0	-1.8	0.5	2.9
2000–2002 ^a	0.5	3.9	-0.8	0.4	0.1

a. Forecast.

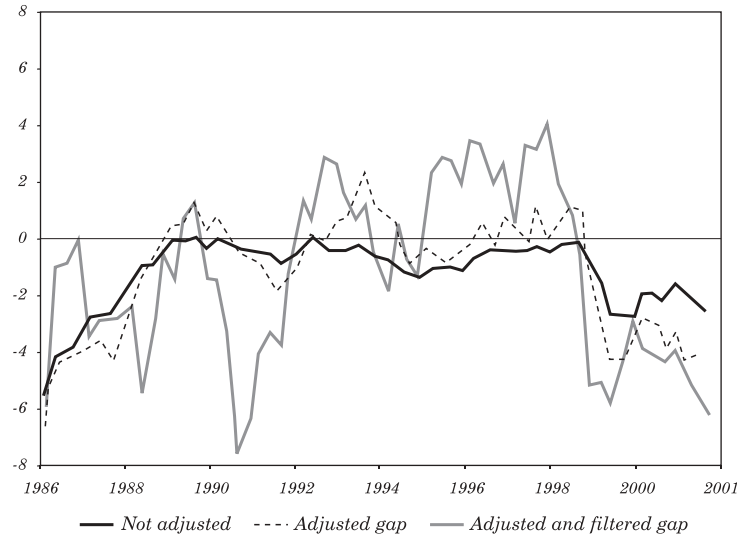
Figure 11. Primal TFP



is required not only for the inputs, but also for the TFP measures that are finally obtained. This difficulty should not be underestimated.

3. MODEL-CONSISTENT ESTIMATES

Given the difficulties surrounding the direct estimation of trend GDP starting from the data, in this section we propose the joint estimation of the output gap and the macroeconomic dynamics embedded

Figure 12. Primal Output Gap

in small macroeconomic models for the Chilean economy. This strategy still requires imposing some identification restrictions, which we describe below.

We use two models for the estimation, based on the aggregate demand and price blocks of a more complete model discussed in García, Herrera, and Valdés (2002), who center on empirically based equations that are not explicitly derived from first principles. The two models have a similar structure, with an equation that describes the short-run macroeconomic dynamics, an equation for the unobserved state variable that captures underlying productivity, and a definition of either trend GDP growth or the output gap (or both).

3.1 The Structure of the Models

Our first model (the aggregate demand, or AD, model) consists of an aggregate output growth equation, which relates the first difference of seasonally adjusted log output to its unobserved trend component (γ) and the deviations from steady state of a set of domestic and external variables. Among the former, it includes the stance of monetary policy, given by the slope of the yield curve $r - rl$, and long-term interest rates, rl .

External conditions are here identified with international interest rates, rx , and the log price of copper, $(\ln P_{cu})$. Two lags are included to capture the dynamics. A disturbance term (ε_y) is also added to account for short-term fluctuations. The model can thus be specified as

$$\begin{aligned} \Delta y = & \lambda + \phi_r \left[(r - rl)_{-1} - (\bar{r} - \bar{r}l) \right] + \phi_{rl} (rl_{-2} - \bar{r}l) \\ & + \phi_{rx} (rx_{-2} - \bar{rx}) + \phi_{cu} (\ln P_{cu} - \ln \bar{P}_{cu}) \\ & + \phi_{y1} (\Delta y_{-1} - \gamma_{-1}) + \phi_{y2} (\Delta y_{-2} - \gamma_{-2}) + \varepsilon_y. \end{aligned} \tag{10}$$

We think of the state variable, γ , as capturing underlying trends in output growth. Although the level of productivity should be smooth, we do not have any prior assumptions about the process that drives the growth rate of productivity. We therefore impose an autoregressive functional form:

$$\gamma = \rho \gamma_{-1} + \varepsilon_\gamma. \tag{11}$$

After estimating this small model, we cannot recover trend GDP, but we can infer its rate of change through time. We define trend growth when every variable of the AD model reaches its equilibrium level:¹¹

$$\Delta \bar{y} = \gamma.$$

$$\tag{12}$$

An identification assumption behind this definition is that external conditions do not affect the unobserved underlying productivity component. This view differs from other studies that consider the inclusion of external conditions.¹²

Our second model (the aggregate supply, or AS, model) focuses on prices, determining core consumer price index (CPI) inflation through an accelerationist Phillips curve.¹³ Core inflation is related to its own lags and leads, as well as to imported inflation, given by the sum of

11. For simplicity we imposed the average levels as equilibrium values for each variable.

12. Beechey and others (2000) use this assumption for the estimation of Australian trend growth, as do Rojas, López, and Jiménez (1997) for the Chilean economy, with a focus on terms of trade. Coeymans (1999), however, considers that external conditions play a role in trend growth.

13. Noncore CPI inflation includes products such as fuels, regulates services, and perishables, which follow simple price-setting rules.

nominal exchange rate depreciation and foreign (dollar) inflation. The equation is homogeneous to the first degree in these determinants, reflecting long-term neutrality. Another factor that influences core CPI inflation is the output gap. This is obviously a reduced form, whereas a more general framework would include wage setting and unemployment as determinants. A positive output gap tends to accelerate inflation.

The first (restricted) version of the model imposes dynamic homogeneity on the inflationary process, to guarantee neutrality and a vertical Phillips curve in the long run. This implies adding up restrictions on some of the right-hand-side regressors, as well as the restriction of a zero constant. This model is very simple, whereas inflation in Chile appears to follow more complex dynamics.¹⁴ We therefore also estimate an unrestricted version of the model. However, we cannot reject the null hypothesis of homogeneity and a zero constant.¹⁵

Thus, our AS model is as follows:

$$\begin{aligned} \Delta\pi = & \xi_l \sum_{i=2}^4 \frac{\pi_{-i} - \pi_{-1}}{3} + \xi_f \sum_{i=1}^2 \frac{\pi_{+i} - \pi_{-1}}{2} + \xi_e \sum_{i=1}^2 \frac{\hat{e}_{-i} \pi_{-i}^* - \pi_{-1}}{2} \\ & + \xi_{iva} \Delta \ln IVA + \xi_y \sum_{i=2}^4 \frac{y_{-i} - \bar{y}_{-1}}{3} \end{aligned} \quad (13)$$

The definition of trend GDP in this case is straightforward, as it is directly specified as the unobserved state variable:

$$\bar{y} = \rho \bar{y}_{-1} + \varepsilon_{\bar{y}}. \quad (14)$$

3.2 Estimation Results

The above models are estimated using state-space techniques, imposing identification restrictions with respect to the volatility of the trend components of GDP. We assume throughout that trend output is smoother than actual output. Our choice for the dependent variable is total GDP minus mining, fishing, and energy. These sectors are linked to natural resources, and their expansion over time responds more to exogenous factors.

14. See García and Restrepo (2001).

15. The p value of a chi-squared test of the joint hypothesis of a zero constant and adding-up constraint is 0.756.

Table 3. Estimation Result: AD Models^a

Parameter	OLS		State-space	
	Coefficient	Std. error ^a	Coefficient	Std. error ^a
γ	0.013	0.038	0.016 ^b	
ϕ_r	-0.404	0.067	-0.404	0.087
ϕ_{rl}	-1.501	0.288	-1.461	0.314
ϕ_{rx}	-0.564	0.281	-0.553	0.233
ϕ_{cu}	0.029	0.011	0.028	0.010
ϕ_{y1}	-0.288	0.107	-0.226	0.179
ϕ_{y2}	-0.282	0.068	-0.331	0.252
ρ			-0.494	1.174
$\sigma(\varepsilon_y)$ (in percent)	1.250		1.050	
$\sigma(\varepsilon_\gamma)$ (in percent)			0.470	
Adjusted R^2	0.477			
Log likelihood	175.440		175.520	

a. Newey-West-corrected standard errors.

b. Average for the sample period.

The results of the aggregate demand estimation are broadly consistent with single-equation estimates by ordinary least squares (OLS) (see table 3). As expected, the results show the sensitivity of GDP growth to interest rates, owing to both monetary policy actions and shifts in the cost of external finance.¹⁶ The price of copper also affects GDP growth significantly. The state-space estimates are similar to the OLS estimates, in terms of both their size and statistical significance. However, both models exhibit considerable difference in the estimates of trend output growth (γ), because OLS estimations do not distinguish between the volatility of the trend and cycle components.

The state-space estimation also delivers some interesting results. First, the autocorrelation in the growth rate of the state variable (measured by ρ), although large, is not statistically different from zero. This implies that shocks to the underlying productivity growth show little persistence over time, at least in the context of the AD model. In fact, the state-space estimation of the AD model differs

16. The international interest rate, rx , was constructed using the ten-year U.S. Treasury bond as a benchmark, deflated by U.S. core inflation and adjusted for a measure of the sovereign spread and the incidence of capital controls in the 1990s.

Figure 13. Actual and Trend Output Growth in AD Model

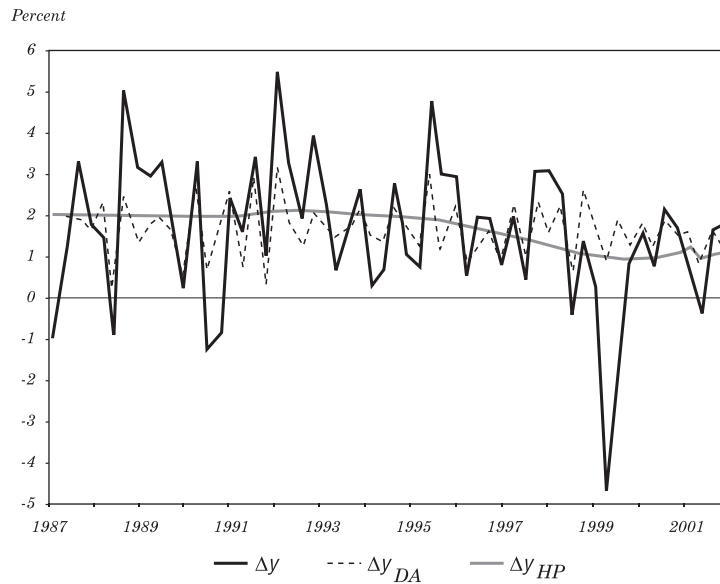
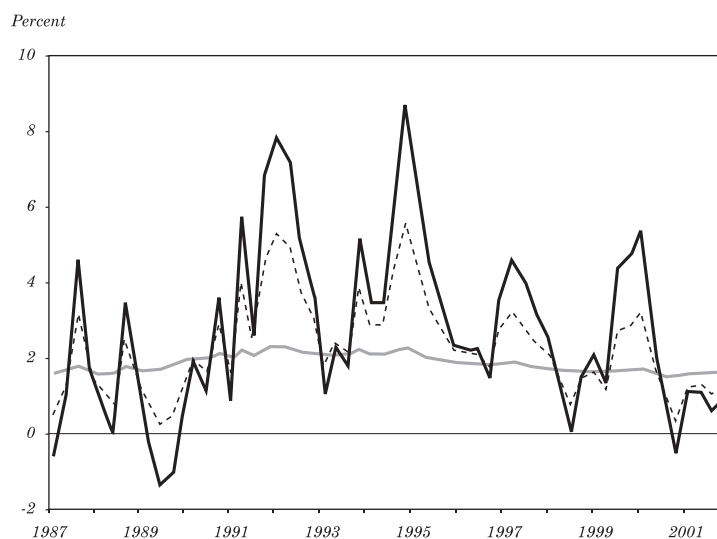


Table 4. Estimation Results: AS Models^a

$\sigma(\varepsilon_y)$

Parameter	IV	State-space		
		$\sigma(\varepsilon_y) = 1.0\%$	$= 3.95\%$	Unrestricted
ξ_i	0.462 (0.122)	0.410 (0.127)	0.322 (0.116)	0.305 (0.124)
ξ_f	0.332 (0.113)	0.195 (0.117)	0.406 (0.106)	0.442 (0.141)
ξ_e	0.085 (0.037)	0.094 (0.050)	0.055 (0.051)	0.048 (0.054)
ξ_{iva}	0.700 (0.206)	0.663 (0.264)	0.650 (0.258)	0.641 (0.260)
ξ_y	0.048 (0.036)	0.054 (0.037)	0.038 (0.036)	0.025 (0.045)
ρ		0.982 (0.062)	0.974 (0.066)	0.972 (0.065)
$\sigma(\pi)$ (in percent)	0.730	0.660	0.560	0.580
$\sigma(\pi)$ (in percent)		1.000	3.950	6.900
Adjusted R^2	0.477			
Log likelihood		208.52	211.62	211.73

a. Estimated with instrumental variables. Instruments used for p_i include inflation, interest rate, and unemployment lags. An HP trend is used as a proxy for the gap. Standard errors are in parentheses.

Figure 14. Trend Output Growth in AS Model, $\sigma(\epsilon_y) \in [0.1\% - 1\%]$ 

very little from the OLS estimation, in that only a small fraction of the variation in the data can be attributed to the state variable. Figure 13 shows the path of actual output growth (the thick line), the trend growth rate that result from the state-space model, and the results from an HP filter.

These results show that little information about trends is gained from direct observation of the path of output. With the AS model, however, the inference about the size of the output gap and the growth rate of trend GDP depends on how much information can be taken from the path of inflation.

As before, some identification assumptions must be made, this time related to the magnitude of the volatility of trend GDP. We estimate the AS model with a variety of assumptions about this volatility. Table 4 shows the resulting estimates.

The growth rates of trend output differ, but they tend to be stable over time (see figure 14). However, some of the estimations show evidence of a slowdown in trend growth. The measures of the gap differ, as well, generally showing a positive gap throughout most of the 1990s and a negative one since 1999 (figure 15). The magnitudes are important: over 10 percent in recent quarters. This is probably related to the low pass-through from exchange rate depreciation until now, which the state-space estimation interprets as a large, negative output gap.

Figure 15. Output Gap in AS Model, $\sigma(\epsilon_y) = 0.5\%$ and HP Filter



Figure 16. Output Gap: AD-AS Model and HP Filter

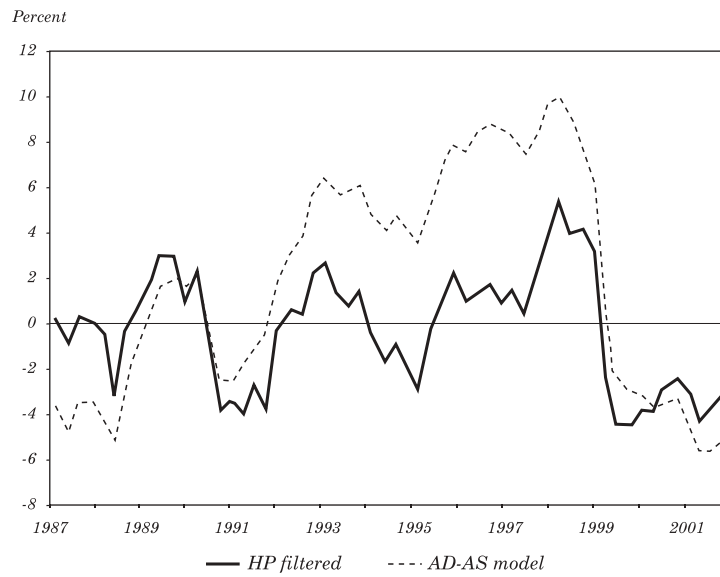


Table 5. Correlation between Gaps

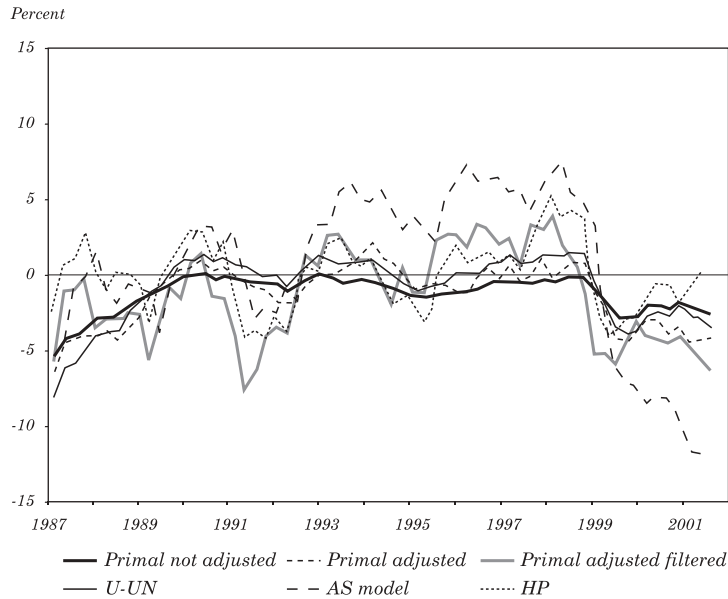
<i>Gap estimates</i>	<i>HP filter</i> ($\lambda = 1600$)	<i>AS model</i>	<i>Primal estimate</i>			<i>Unemployment gap</i>
			<i>Adjusted</i>	<i>Not adjusted</i>	<i>Filtered</i>	
HP filter	1.00	0.53	0.41	0.29	0.76	0.36
AS model		1.00	0.77	0.59	0.75	0.66
Primal adjusted			1.00	0.90	0.57	0.92
Primal not adjusted				1.00	0.40	0.99
Primal filtered					1.00	0.49
Unemployment gap						1.00

The disadvantage of estimating AD and AS model separately is that one obtains two unrelated measures of trend growth. To resolve this problem, we estimated the two models together in an equation system, using the state-space method. This generates a consistent measure of the output trend (shown in figure 16). For this purpose, however, we imposed the coefficients on the right-hand-side variables obtained from single equation estimates, given the difficulties of obtaining convergence.

4. CONCLUDING REMARKS

The estimates presented in this work give rise to four important lessons. First, both the magnitude and the trends of the different estimates of the output gap are widely dispersed (see table 5). Figure 17 displays several measures of the output gap that have been presented in the course of this work. One relies on growth accounting exercises, another results from assuming a particular natural rate of unemployment, and a third is the product of a state-space estimation of a simple Phillips curve. As a benchmark, the thick gray line results from a simple HP filter. While some seem very procyclical, others are smoother. Some show a stable gap over the last quarters, whereas others indicate an increasing slack. Some are not very correlated with each other, and others are extremely so. This is particularly the case with the filtered primal TFP estimate and the unemployment gap, which shows the importance of particular identification assumptions.

Second, all the measures indicate that current slack lies between 2 and 11 percent and, more importantly, that it has been mostly stable since 1999. The notable exception is the simple, $\lambda = 1600$ HP filter,

Figure 17. Output Gaps

which actually indicates a positive output gap for the second quarter of 2002. The well-known sensitivity of this filter to end-points is the culprit for this somewhat counterintuitive result.¹⁷

Third, growth accounting must be treated carefully, for two reasons. It is the first step for the estimation of potential output, although the dual approach is not useful for estimating the gap since it leads to the growth rate—not the level—of TFP. Moreover, no matter what alternative statistical method is used for in-sample estimation, for forecasting purposes there is no easy substitute for a sources-of-growth approach.

Finally, our findings stand as a warning to the mechanical application of statistical methods, loosely related to economic theory, for the measurement of trends and gaps. Some structure is necessary to infer economically sensible conclusions about the measurement, through a particular method, of the output gap. A judgmental approach seems best: using a variety of methods provides a wider perspective on an issue that is key to the efficient conduct of monetary policy. Potential

17. See Chumacero and Gallego (2001) for evidence on the sensitivity of this filter to new information.

output and the output gap are conditional statistics, and they are thus sensitive to the particular identifying assumptions chosen.

Most of the output gap measures derived in the paper are either stable or increasingly negative over the last few years. This, coupled with the results from the aggregate demand models and TFP estimates, implies that trend GDP growth has probably stayed above actual growth but below the levels of the 1990s. We therefore discard the alternative that the recent slowdown in growth is due mainly to supply side factors, although the prospects for longer term growth depend critically on them.

APPENDIX

Policy Rule and the Yield Curve

To obtain the dual estimation of TFP, we consider only those factors that affect the long-run demand for long-term bonds, such as growth prospects. We thus correct for the volatility of long-term interest rates caused by the impact of movements of monetary policy decisions (associated with short-term interest rates).

We start by estimating the neutral stance for monetary policy using a Kalman filter in a policy rule for short-term interest rates. This regression includes the unemployment gap, the difference between inflation and the target, an autoregressive term, and an unobserved state variable. This variable, which we interpret as the neutral policy rate, is used as an input into an estimated equation for long-term interest rates, which includes leads and lags of itself. Hence, we recover the cyclically adjusted long-term interest rates.

First, we model the policy rule:

(A1)

The construction of the natural rate of unemployment, u_n , is explained in the text. We use a dummy variable (D_{98}) for the year 1998, when interest rates were allowed to float and the de facto exchange rate arrangement was closer to a fixed than a floating exchange rate.

We impose an autoregressive functional form for the neutral policy rate, restricting the disturbance term ε_{rn} to take a standard deviation of 0.22:

(A2)

The last two equations form the state-space model, which is resolved with the Kalman filter; results are in table A1. The initial condition needed for rn is taken from the OLS estimates. With the neutral policy rate one can obtain the equilibrium short-run interest rate, when inflation reached target inflation and employment gap is null:

(A3)

Finally the cyclically adjusted long-term interest rate is obtained,

$$\frac{r_t = \alpha_r r_{t-1} + (1 - \alpha_r) \pi_{meta,t}}{1 - \alpha_r}$$

Table A1. Estimation Results: Policy Rule Model

Parameter	OLS ^a		State-space ^b	
	Coefficient	Std error ^a	Coefficient	Std error ^a
α_π	0.063	0.026	0.085	0.095
α_u	0.430	0.053	0.192	0.364
α_r	0.502	0.042	0.396	0.091
α_{gg}	7.574	0.507	5.902	0.587
ρ			0.994	0.015
$\sigma(\varepsilon_r)$ (in percent)	0.690		0.920	
Adjusted R^2	0.920			
Log likelihood	-59.970		-86.621	

a. Newey-West-corrected standard errors.

b. Standard errors in italics. Ordinary least square estimates were used as initial conditions.

replacing r of equation 17 in the already-estimated equation for rl .¹⁸ This construction needs values for the initial and final conditions of the long-term interest rate, which are assumed as 5.5 (1986:1) and 5.2 (2002:1). The result is

$$rl = 0.31 + 0.36 rl_{-1} + 0.54 rl_{+1} + 0.05 r, \tag{A4}$$

(0.387)
(0.053)
(0.035)
(0.008)

with R -squared equal to 0.83, a standard error of 0.29, and a Durbin-Watson statistic of 2.34.

18. This model uses instrumental variables for the lead of the long-term interest rate, including the exchange rate, lags of interest rates, the difference between actual inflation and the inflation target, and the exchange rate band.

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