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EXCHANGE RATES AND MONETARY POLICY IN OPEN ECONOMIES: THE EXPERIENCE OF CHILE IN THE NINETIES

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Resumen

Este documento caracteriza, de forma empírica, la conducción de la política monetaria en una economía pequeña y abierta. En particular, usando como un caso de estudio la experiencia chilena con metas de inflación durante la década de los noventa, evaluamos el rol que jugaron el tipo de cambio y el producto en la determinación de la tasa de política monetaria. Concluimos que Chile adoptó lo que se denomina un esquema gradual de metas inflación. Lo anterior significa, en la práctica, que el banco central modificó su instrumento de política —la tasa de interés— cuando la inflación esperada se desvió de la meta, pero con algunas consideraciones acerca del producto. En este contexto, encontramos evidencia de que la autoridad monetaria también respondió a desalineamientos del tipo de cambio real. Esta reacción fue comparativamente mayor que la encontrada en economías desarrolladas. Finalmente, la evidencia, a pesar de no ser concluyente, sugiere que existió una respuesta no lineal a desvíos cambiarios: el banco central reaccionó con más fuerza a grandes desvíos que a desvíos pequeños.

Abstract

This paper provides an empirical characterization of the conduct of monetary policy in a small open economy. In particular, using as a case study the Chilean inflation-targeting experience of the nineties, we assess the roles of the exchange rate and output in the determination of the policy interest rate. We conclude that Chile adopted a gradual approach to targeting inflation. This means, in practice, that the central bank modified its policy instrument —the interest rate— whenever expected inflation deviated from its target, but with some concern about output. In this context, we find evidence that the monetary authorities also reacted to real exchange rate misalignments. This reaction was comparatively larger than the one found in developed economies. Finally, the evidence, although not conclusive, suggests that there was a non-linear response to exchange rate misalignments: the central bank reacted more strongly to large deviations than to small ones.

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1 Introduction

Inflation targeting has become the new paradigm in monetary policy. As is noted by Fry *et al* (2000), between 1990 and 1998 the number of countries with explicit inflation targets increased from 5% to 54%. Overall, this monetary policy framework has been adopted by 54 economies throughout the world. These economies include 25 developing countries, like Chile, China, Jamaica, Tanzania and Vietnam; 16 transitional economies like the Czech Republic, Poland, Romania and Russia and 13 developed economies like Australia, Canada, New Zealand, U.K. and Sweden.

In this context, most of the countries that are pursuing inflation targeting are small open economies that use a short term interest rate[1], usually set by the central bank, as the main policy instrument. In general, however, empirical research on the way that central banks target inflation has been limited only to developed economies. In fact, Clarida *et al* (1998) provide structural estimations of the monetary policy reaction functions in some European countries, Japan and the USA. They conclude that an inflation forecast based (IFB) policy rule provides a good characterization of the way in which monetary policy has been conducted in those countries. In addition, they find that exchange rate considerations do not play an important role in the monetary policy design, even though most of the countries that they analyze are small open economies.

For developing countries, Calvo and Reinhart (2002) provide evidence suggesting that central banks react to exchange rate misalignments. In particular, they conclude that, in some emerging economies interest rates are used as the preferred means of smoothing exchange rates fluctuations. This evidence, however, is not based on structural estimations of monetary policy rules, as in Clarida *et al* (1998). In fact, Calvo and Reinhart (2002), derive monetary policy rules from vector autoregressive (VAR) estimations. In these circumstances, those rules do not describe the *systematic* behavior of the central bank. In fact, as is noted by Clarida (2001), in a VAR equation the monetary policy response to the exchange rate does not have a clear interpretation: it can be an explicit response to exchange rate misalignments, a response to expected inflation

[1] Central banks, in general, have abandoned the use of monetary aggregates as a policy instrument. There are two reason for this: i) interest rates are usually easier to interpret by the public and ii) given that money demand is unstable, it is difficult to predict the impact that changes in monetary aggregates will have on output and inflation.

(that is affected by the current level of the exchange rate) or, it can be a combination of the two. Therefore, a monetary policy equation, derived from a VAR, cannot be used to describe the systematic behavior of central banks.

In this context, not knowing how the central bank systematically reacts to different macroeconomic disturbances may become problematic. In particular, it makes it difficult to analyze the welfare implications of alternative policy rules as well as to provide policy recommendations as to how to react in the face of various shocks.

In this paper, we characterize the systematic behavior of the central bank in a small open and emerging economy. In particular, we investigate how the monetary authorities react to exchange rate misalignments and output deviations from trend. We follow Clarida *et al* (1998) and estimate an IFB rule that allows for a response to output and to the exchange rate. In this framework, these responses have a clear interpretation: they reflect the importance that output and the exchange rate have *per se* for the central bank. Hence, it is possible to determine whether the monetary authorities have additional objectives besides controlling inflation.

We use, as a study case, the Chilean inflation targeting experience of the nineties. This is an interesting case because Chile is a small, open and emerging economy and, as is noted by Schmidt-Hebbel and Tapia (2002), it was the second country in the world to adopt inflation targeting, setting its first annual target in September 1990.

The main conclusions of this paper are as follows. First, an IFB monetary policy reaction function provides a good characterization of the way in which the Chilean central bank (CCB) designed its policy in the last decade. In particular, the CCB reacted to expected inflation deviations from target. In this context, the monetary authorities followed a "flexible" approach in targeting inflation; they smoothed output deviations even when inflation was on target. This means that output stability is *per se* a monetary policy objective. Second, exchange rate considerations played a role in the conduct of monetary policy. In fact, besides reacting to expected inflation and output, the CCB moved interest rates whenever the real exchange rate deviated from trend and, compared with other inflation targeting countries, the policy response to exchange rate was larger. Third, there is some evidence that the response to exchange rate misalignments was nonlinear; the CCB seem to react more aggressively to large real exchange rate misalignments than it did to small ones. Finally, as is observed in many other countries, the CCB smoothed interest rates considerably; the degree of interest rate inertia was high.

This paper is organized as follows. Following Clarida (2001), Section 2 presents a simple framework in order to estimate the systematic monetary policy responses to inflation, output and the exchange rate. Section 3 discusses the main characteristics of the inflation targeting regime in place in Chile since 1990. Section 4 specifies the IFB monetary policy rule to be estimated and describes the way in which the relevant variables are constructed. In particular, following Harvey and Jaeger (1993), we use structural times series models to detrend the relevant variables. Section 5 presents the main results, whereas Section 6 performs some robustness exercises. Finally, Section 7 concludes the paper.

2 Identifying the Systematic Components of Monetary Policy

As is noted by Clarida (2001), within a VAR framework it is not easy to identify the systematic responses of the monetary policy instrument to the main macroeconomic variables. In fact, the policy responses that are obtained in a VAR, either in its reduced or its structural form, do not necessarily have a structural interpretation. In this section, we illustrate this point with a simple example. In particular, following Clarida (2001), we analyze how the policy coefficients in a reduced form VAR[2] may be interpreted. The aim of this example is to show why it is difficult, in a VAR framework, to determine whether a central bank in an open economy targets inflation with an independent concern for the exchange rate.

Let's assume that the central bank targets inflation in a flexible way. This means that, besides inflation, the stability in output is also an objective of monetary policy. In this case, the central bank does not target the exchange rate. In particular, suppose that the central bank's policy instrument, the interest rate, can be described by a simple IFB policy reaction function

$$r_t = \rho_\pi E_t\{\pi_{t+n}\} + \rho_y y_{t-1} + \epsilon_{r,t} \tag{1}$$

where r_t is the interest rate controlled by the central bank, $E_t\{\pi_{t+n}\}$ is the expected inflation deviation from a predetermined target, y_{t-1} is the lagged deviation of output from the trend level

[2] A more complete explanaition, that includes a structural VAR, is given in Clarida (2001).

and $\epsilon_{r,t}$ is a random shock to the interest rate. The ρ_π coefficient describes the systematic response to inflation shocks. On the other hand, the ρ_y coefficient represents the systematic response to output deviations. In this case, the central bank does not have any systematic response to exchange rate misalignments.

Now, assume that expected inflation depends on past information about some macroeconomic variables. In particular, expected inflation can be expressed as follows

$$E_t\{\pi_{t+n}\} = \theta_1 y_{t-1} + \theta_2 \pi_{t-1} + \theta_3 r_{t-1} + \theta_4 q_{t-1} \tag{2}$$

where q_{t-1} is the real exchange rate[3], expressed as a percentage deviation from the steady state. On the other hand, the coefficients θ_1, θ_2, θ_3 and θ_4 represent the response of expected inflation to the lagged values of output, inflation, the interest rate and the real exchange rate, respectively. In particular, an increase in the real exchange rate has a positive impact on expected inflation, therefore $\theta_4 > 0$.

Replacing equation (2) into the monetary policy reaction function, equation (1), gives the policy interest rate equation

$$r_t = \rho_\pi \left\{\theta_1 y_{t-1} + \theta_2 \pi_{t-1} + \theta_3 r_{t-1} + \theta_4 q_{t-1}\right\} + \rho_y y_{t-1} + \epsilon_{r,t} \tag{3}$$

the above expression is the interest rate equation implicit in a reduced form VAR that contains the set of variables $z_t = (y_t, \pi_t, r_t, q_t)$. In this case, the innovation in the VAR equation (3) has a structural interpretation; however, the reduced form coefficients do not necessarily reflect the systematic responses of the central bank to the various macroeconomic variables. In particular, in this VAR, the interest rate response to real exchange rate misalignments is different from zero, but it does not have a structural interpretation. This response is given by

$$\frac{\partial r_t}{\partial q_{t-1}} = \rho_\pi \theta_4 > 0 \tag{4}$$

and reflects the fact that the exchange rate influences the interest rate *only* because it is an indicator of future inflation and *not* because the exchange rate is a policy objective *per se*. The

[3] The real exchange rate is defined as $q_t = p_t^* + e_t - p_t$ where p_t^* is the level of foreign prices (in logs), e_t is the nominal exchange rate (in logs) reflecting the domestic price of foreign currency and p_t is the domestic consumer price index (in logs). Hence, an increase in q_t is a depreciation.

response in (4) is the product of the policy reaction to expected inflation, ρ_π, and the response of the inflation forecast to an exchange rate depreciation, θ_4. Hence, the VAR evidence suggests a positive policy response to the exchange rate even if this variable is not an explicit policy objective.

Now, consider the alternative case in which the real exchange rate is *per se* a policy objective. In such a case, the IFB rule in (1) takes the form

$$r_t = \rho_\pi E_t\{\pi_{t+n}\} + \rho_y y_{t-1} + \rho_q q_{t-1} + \epsilon_{r,t} \tag{5}$$

where the ρ_q coefficient captures the systematic policy response to exchange rate misalignments. As before, expected inflation evolves according to equation (2). Now, replacing equation (2) into equation (5) gives the policy interest rate equation

$$r_t = \rho_\pi \{\theta_1 y_{t-1} + \theta_2 \pi_{t-1} + \theta_3 r_{t-1} + \theta_4 q_{t-1}\} + \rho_y y_{t-1} + \rho_q q_{t-1} + \epsilon_{r,t} \tag{6}$$

which, again, represents the interest rate equation derived from a VAR. In this case, the interest rate response to the real exchange rate is given by

$$\frac{\partial r_t}{\partial q_{t-1}} = \rho_\pi \theta_4 + \rho_q > 0 \tag{7}$$

where the above response contains two elements, the systematic policy reaction to the exchange rate, ρ_q, and the policy response to the exchange rate component of the expected inflation, $\rho_\pi\theta_4$. Hence, when the exchange rate is a policy objective *per se*, the VAR response will be positive. However, this response will incorporate both the systematic reaction to the exchange rate and the reaction to expected inflation. In short, from the VAR the ρ_q coefficient cannot be obtained. Also, another drawback of the VAR approach is that, in general, the other monetary policy coefficients, ρ_π and ρ_y cannot be recovered either.

The above exercise has shown that, in a VAR framework, it is difficult to interpret the interest rate response to the exchange rate. More specifically, from the VAR coefficients the systematic policy response to the real exchange rate cannot be identified.

To overcome this identification problem, Clarida *et al* (1998) and Clarida (2001) suggest that one should estimate, directly, the IFB monetary policy rule in equation (5) using the Generalized

Method of Moments (GMM). This approach has the advantage of providing an estimate of ρ_q and enables the researcher to test, using a simple t-ratio test, whether the exchange rate is, *per se*, a policy objective of the central bank. In particular, if $H_0 : \rho_q = 0$ is rejected, then the exchange rate is not a policy target.

In this paper, we follow Clarida *et al* (1998) and identify the systematic components of the Chilean monetary policy by estimating, directly, a policy specification like equation (5).

3 Specifying an IFB Monetary Policy Rule for Chile

In this section we briefly describe the institutional framework in which the CCB operates. Then, we specify an IFB monetary policy reaction function relevant for Chile.

3.1 Monetary and Exchange Rate Policies in Chile

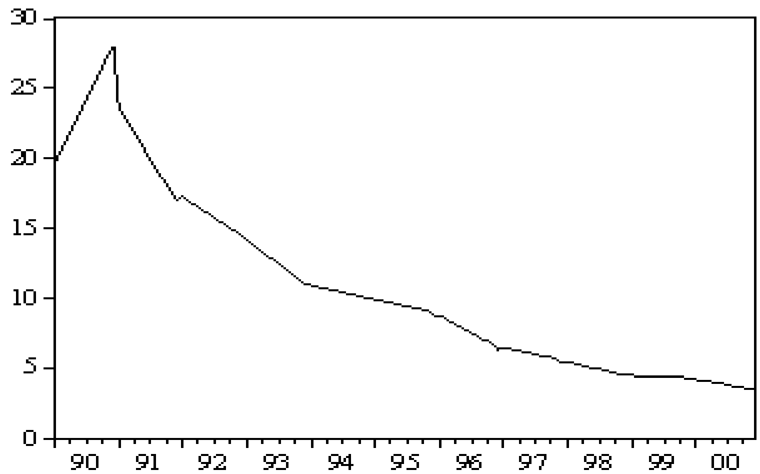
The 1980 Chilean Constitution empowers the CCB to "stabilize the value of the currency and provide normality in the functioning of internal and external payments". This statement has been interpreted as giving three main objectives to the CCB: to control inflation, to provide a sound regulation of the banking system and to avoid situations that may lead to currency crises.

From 1980 to 1990, the CCB did not have any explicit target for inflation. It is only from 1990 that the CCB adopted an explicit inflation targeting regime. The procedure works as follows: each September, in its Report to the Congress, the CCB announces the CPI inflation target for the end of the following year (December year-on-year CPI inflation). This means that the target is announced fifteen months in advance. In practice, the target was gradually adjusted so as to allow for a gradual reduction of inflation. In fact, in 1990, the target for the following year was set at 27%, whereas in 2001 the target was 3% (see Figure 1[4]).

As is noted by Parrado (2001), the inflation targeting regime allows for flexibility; there is no legal mandate to achieve the target each year. This flexibility, along with the gradual adjustment

[4] As in Gallego *et al* (2002), the inflation target series is a linear interpolation of the Chilean central bank December-to-December targets.

Figure 1: Chile: Inflation Target (in %).



of the inflation target, have contributed to maintaining high rates of real GDP growth: on average a 6.7% annual growth rate between 1990 and 2000.

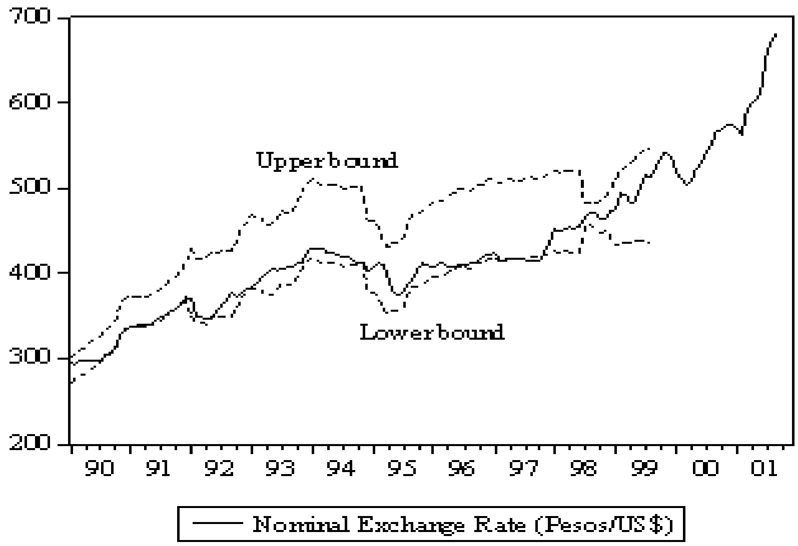
Since 1985, the interest rate has been the main instrument of monetary policy. From 1985 to April 1995, the CCB used a short-term (three months) interest rate indexed to the CPI inflation. In May 1995, the CCB changed its policy instrument to an overnight indexed interest rate which is controlled through open-market operations. Those operations are performed by issuing CCB papers and by conducting repos and anti-repos.

As pointed out by Valdés (1997), the use of indexed interest rates is equivalent to setting $ex-post$ real interest rates. In this context, there were at least three reasons for using a real interest rate as a monetary policy instrument. First, the demand for money had been unstable over the period, therefore the use of interest rate had more predictable effects over output and inflation than monetary aggregates. Second, the high degree of indexation of the Chilean economy (including financial contracts) made it difficult to use nominal interest rates. Finally, in an environment of high and unpredictable inflation, movements in the real interest rates were easy to understand and did not have double interpretations as in the case of nominal rates[5].

The CCB also has the power to set the exchange rate policy. From August 1984 to September

[5] Given a more stable, and low, path for inflation, the CCB abandoned, in August 2001, the use of real interest rates as a policy instrument. Since then, the policy instrument is an overnight nominal interest rate.

Figure 2: Chile: Exchange Rate Band and Observed Exchange Rate



1999, the CCB adopted a crawling exchange rate band. As is noted by Landerretche *et al* (2000 p.461), the main objectives of the band were to maintain international competitiveness and reduce excessive exchange rate volatility. However, since the start of the band, many of its features, including its width, rate of crawl, reference currency basket, degree of symmetry and central parity were modified (see Figure 2). Since September 2, 1999, the country has embraced a fully-flexible exchange rate regime, with the possibility of the monetary authority intervening in the market only if the exchange rate does not reflect the "real" value of the foreign currency (Parrado 2001, p.7).

The basic instruments that the CCB used to stabilize the nominal exchange rate, within the band, were interventions in the foreign exchange market and, in some cases, modifications to the limits of the band. As is noted by Parrado (2001), at the end of 1991, Chile's strong external accounts forced the CCB to lower the referential dollar exchange rate (central parity) by 5 percent and to widen the band to ± 10 percent. Although this decision was taken to increase the market role in determining the exchange rate, in March 1992 it was decided that the CCB should have a "dirty" floating option to intervene within the band. In this context, intra-marginal foreign-exchange rate interventions by the CCB were frequent and, at times, intense (Landerretche *et al*, 2000).

The elimination of the band in September 1999, did not imply the absence of foreign exchange interventions. In fact, "in response to large exchange rate depreciation and volatility, the CCB announced and carried out a temporary policy of sterilized interventions between July 2001 and January 2002[6]. The stated objectives of the interventions were to reduce excessive exchange rate volatility and provide a hedge against future devaluations, without affecting exchange rate trends." Schmidt-Hebbel and Werner (2002. p.72).

In summary, the CCB has specific instrument for each target. In particular, the interest rate is used as the inflation targeting instrument whereas sterilized interventions in the exchange rate market, and sometimes modifications to the limits of the exchange rate band, were used as instruments of the exchange rate policy. In this context, one advantage of the framework used in this paper is that it is possible to test whether the policy interest rate was influenced by exchange rate considerations.

3.2 A Forward-Looking Model of Policy Interest Rate

Following Clarida *et al* (1998 and 2000) and Clarida (2001), we specify a forward-looking model for the monetary policy interest rate. We introduce, however, some modifications in order to obtain the *ex-post* real interest rate that is, in practice, the instrument that has been used by the CCB since 1985.

In a forward-looking environment, the nominal policy interest rate will be determined by current expectations of the central bank's objectives. If we assume that the central bank is concerned about deviations of future inflation, output and the exchange rate, we can express the reaction function as follows

$$i_t^* = \bar{i} + \rho_\pi \left(E_t \left[\pi_{t+n} \right] - \pi_{t+n}^* \right) + \rho_y y_t + \rho_q q_t \tag{8}$$

where i_t^* is the nominal interest rate set by the central bank and $\left(E_t \left[\pi_{t+n} \right] - \pi_{t+n}^* \right)$ is the deviation of expected inflation n periods ahead, $E_t \left[\pi_{t+n} \right]$, from a predetermined target π_{t+n}^*[7]

[6] The bank intervened by selling U.S.$800 millions (less than its preannounced ceiling of U.S.$1.5 billion) and issuing the equivalent of U.S.$3 billion (as announced) in dollar-denominated peso CCB debt (to provide a hedge against future exchange rate devaluation), Schmidt-Hebbel and Werner (2002. p.72)

[7] In general, the inflation target is assumed to be a fixed number. We adopt a more general approach that enables

and $\bar{i}$ is the equilibrium nominal interest rate[8]. The central bank may also be concerned about deviations of output from the equilibrium level[9], y_t, and deviations of the real exchange rate from the steady state, q_t. It is important to notice that the parameters ρ_y and ρ_q capture the non-inflationary components of output and exchange rate deviations. That is, both elements may be objectives of monetary policy even when expected inflation is on target; $\left(E_t\left[\pi_{t+n}\right]-\pi^*_{t+n}\right)=0$. Therefore, the specification in (8) allows us to test whether output and the exchange rate are *per se* objectives of the monetary authorities. In fact, as is noted in Section 2, under the null hypothesis that the central bank is not concerned with output and real exchange rate deviations, the coefficients ρ_y and ρ_q should be equal to zero.

We can re-express the monetary policy interest rate in real terms by subtracting $E_t\left[\pi_{t+n}\right]$ from both sides of (8) and by adding and subtracting π^*_{t+n} from the right hand side of (8). Hence, the *ex-ante, n*-period, real interest rate is expressed as follows

$$r^*_{ea,t}=\bar{r}+\left(\rho_\pi-1\right)\left(E_t\left[\pi_{t+n}\right]-\pi^*_{t+n}\right)+\rho_y y_t+\rho_q q_t \tag{9}$$

where $r^*_{ea,t}=i^*_t-E_t\left[\pi_{t+n}\right]$ is the *ex-ante* real interest rate and $\bar{r}$ is the equilibrium real interest rate. In this specification, if ρ_π is greater than one, the real interest rate increases whenever expected inflation is above the target level. In this case, the central bank tries to stabilize inflation. On the contrary, when ρ_π is less than one, the central bank moves the interest rate in order to partially accommodate any increase in the expected level of inflation. As a result, the monetary authority is not stabilizing inflation.

Now, in order to obtain an expression for the *ex-post* real interest rate, we add and subtract the actual inflation over $t+n$ on the left hand side of (9). Then, the *ex-post* real interest rate is defined as

$$r^*_t=\bar{r}+\left(\rho_\pi-1\right)\left(E_t\left[\pi_{t+n}\right]-\pi^*_{t+n}\right)+\rho_y y_t+\rho_q q_t+\varepsilon_t \tag{10}$$

us to consider the case in which the target is changing over time. This case is of particular importance in economies were inflation is a non-stationary process, and where targets are converging gradually to the long run inflation level.

[8]In fact, when expected inflation, output and the real exchange rate are at their equilibrium, or target level, $\left(E_t\left[\pi_{t+n}\right]-\pi^*_{t+n}\right)=0$, $y_t=0$ and $q_t=0$. It follows that the interest rate is, in equilibrium, $i^*_t=\bar{i}$.

[9]A central bank that targets inflation with a concern for output fluctuations is following what Svensson (1997) calls a gradual approach to inflation targeting.

where $r_t^* = i_t^* - \pi_{t+n}$ is the central's bank target level for the *ex-post* real interest rate. On the other hand, $\varepsilon_t = E_t[\pi_{t+n}] - \pi_{t+n}$ is the inflation prediction error. The specification in equation (10) may be used to see how the CCB sets its policy interest rate; however, it does not capture the tendency that a central bank may have to smooth changes in interest rates. Introducing this tendency may be a difficult task, so it is assumed, as in Clarida *et al* (1998), that the policy interest rate, r_t, partially adjusts to its target level, r_t^*. This assumption can be expressed as

$$r_t = (1-\rho)r_t^* + \rho r_{t-1} + v_t \tag{11}$$

where the parameter $\rho \epsilon [0,1]$ captures the degree of interest rate smoothing and v_t represents a zero mean real interest rate shock. As is noted by Clarida *et al* (1998 p.1039), this shock may reflect a pure random component to the policy or it could arise because the central bank imperfectly forecasts the demand for reserves. Under this scenario, the interest rate jumps in response to an unexpected movement in the demand for reserves that is orthogonal to movements in inflation, output and the exchange rate.

Now, we combine equations (10) and (11) to obtain an expression for the policy interest rates that allows for inertial behavior and depends only on observable variables

$$r_t = (1-\rho)\overline{r} + (1-\rho)\left[(\rho_\pi - 1)\left(\pi_{t+n} - \pi_{t+n}^*\right) + \rho_y y_t + \rho_q q_t\right] + \rho r_{t-1} + u_t \tag{12}$$

where the policy interest rate, r_t, is expressed now as a function of realizations of the relevant variables, plus an error term, u_t. This term is a linear combination of the prediction errors and the policy innovation, v_t. In particular, u_t is defined as

$$u_t = \left\{v_t + (1-\rho)\left[\rho_\pi\left(E_t[\pi_{t+n}] - \pi_{t+n}\right) + \rho_y\left(E_t[y_t] - y_t\right) + \rho_q\left(E_t[q_t] - q_t\right)\right]\right\}$$

The specification in (12) is the expression to be estimated empirically. One advantage of this formulation is that all the dependent variables are future and current realizations of observable variables. Therefore, we avoid the problem of modelling, explicitly, the agent's expectations.

4 Estimation

The policy reaction function to be estimated is equation (12) that contains all the parameters of interest[10]. In fact, in that specification, it is straightforward to test whether the real exchange rate and the output misalignments are objectives of the central bank - independently of their impact on future inflation. In this case, a simple t-test on the significance of ρ_y and ρ_q can be performed. If ρ_y and ρ_q are statistically different from zero, then it is not possible to reject the hypothesis that the central bank has additional objectives besides controlling inflation.

Now, it is evident that the correlation between the error term, u_t, and future inflation in (12) is different from zero. In these circumstances, estimating this relationship with Ordinary Least Squares (OLS) will generate biased estimators. To overcome this problem, equation (12) is estimated using the Generalized Method of Moments (GMM), as in Clarida *et al* (1998 and 2000).

To apply GMM, it is necessary to impose an orthogonality condition between the error term in (12) and a set of instrumental variables that reflect the information available at time t. In particular, let Z_t be the set of instruments orthogonal to u_t so that $E\left[Z_t u_t\right] = 0$. This orthogonality condition can be expressed as

$$E_t\left\{\left(r_t - (1-\rho)\overline{r} - (1-\rho)\left[(\rho_\pi - 1)\left(\pi_{t+n} - \pi^*_{t+n}\right) + \rho_y y_t + \rho_q q_t\right] - \rho r_{t-1}\right) Z_t\right\} = 0$$

where the set of instruments is known when the CCB sets the real interest rate, r_t.

The above orthogonality condition can be used to estimate, using GMM, the coefficients that characterize the monetary policy reaction function, ρ, ρ_π, ρ_y and ρ_q. In particular, GMM provides consistent estimates of the policy coefficients. On the other hand, as is noted by Clarida *et al* (1998), by construction, the residual series u_t features and $MA(n-1)$ structure and empirical moments cannot be considered as serially independent. In order to sort out this problem, we follow the estimation procedure suggested by Favero (2001); when implementing GMM estimation we correct for heteroscedasticity and autocorrelation of an unknown form with a lag truncation

[10] Appendix A contains a detailed description of the series we use.

parameter of $n-1$. Furthermore, Barlett weights are chosen to ensure positive definiteness of the estimated variance-covariance matrix (see Favero 2001, p.233).

Finally, in order to assess whether a particular set of instruments, Z_t, is valid, a $J-$ test of overidentifying restrictions is implemented. This test has a χ^2 distribution with $m-k$ degrees of freedom, where m is the number of instruments used and k is the number of variables to be instrumented.

4.1 Identifying the Cyclical Component in the Series

Some of the explanatory variables are expressed as deviations from the steady state or equilibrium level. In order to obtain empirical estimates of the output gap, y_t, and the exchange rate misalignment, q_t, different filtering techniques can be applied. For instance, Parrado (2000), in a similar exercise for Chile, used a quadratic detrending procedure to obtain the long-run level of output. Then the output gap, y_t, is constructed as the percentage difference between the output level and its long-term value. Similarly, Scmidt-Hebbel and Tapia (2002) use the Hodrick-Prescott (HP) filter to obtain y_t and q_t.

In this paper, we use an alternative methodology: in order to determine the output gap, y_t, and the exchange rate misalignment, q_t, a structural times series (STSM) model is fitted to the level of output and to the level of the real exchange rate. The STSM gives the cyclical component of each series and we use this component as a measure of the output gap, y_t, and the exchange rate misalignment, q_t. Using this approach has the advantage of avoiding the creation of spurious cycles, which can be one of the consequences of using a HP ad-hoc filtering procedure (see Harvey and Jaeger 1993). Another advantage of this procedure is that the irregular movements of the series are separated from the cycle. In this way, the series we obtain do not contain noisy information that is sometimes difficult to interpret.

4.1.1 Trend plus Cycle Model

The STSM we use is the trend plus cycle model[11]. Applying this procedure to the Chilean level of output[12] results in an output gap series, y_t , that is less volatile than the series obtained with

[11] Appendix B explains, in more detail, the trend plus cycle model.

[12] The models have been estimated using STAMP 6.0 software.

the HP filter (see Figure 3). On the other hand, the output gap obtained by using linear or quadratic detrending procedures is much noisier. The cyclical component obtained from the HP, linear and quadratic detrending procedures is much more volatile, because it includes the irregular movements in output which appear to be substantial[13]. On the contrary, when a structural times series model is fitted, the irregular component is removed from the cycle. As a result, the output gap series in the lower panel of Figure 3 is less volatile.

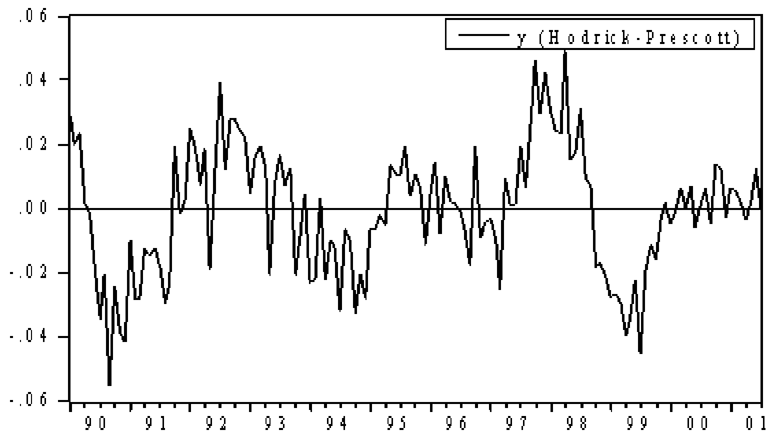
From an economic perspective, the cycle obtained with the STSM has a meaningful interpretation. In fact, it captures many of the stylized facts of the Chilean business cycle. In particular, the slowdown of the Chilean economy at the beginning of the 90s and the subsequent recovery, between 1992 to 1994, are well reflected by this cycle. On the other hand, the rapid expansion of the economy between 1997 and mid-1998 and the subsequent crisis in 1999 are also captured. Finally, the slow recovery of the economy in 2000 and 2001 is reflected at the end of the period.

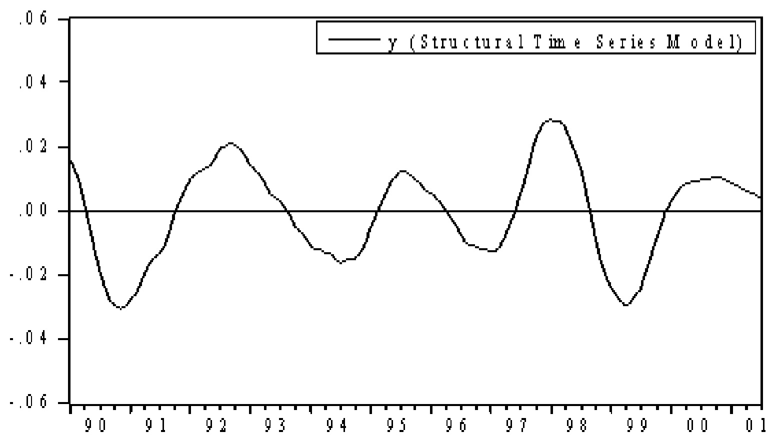
To obtain the cyclical component of the real exchange rate, q_t, the same procedure as before is applied: a trend plus cycle model is fitted to the level of the real exchange rate. As before, the cycle obtained by fitting a STSM is less volatile than the cycle obtained using the HP filter (see Figure 4). On the other hand, the series obtained with the HP filter presents a seasonal pattern with appreciations at the beginning of each year. This may reflect changes in seasonality that are not captured by the HP procedure. In fact, Harvey (2002) argues that changes in seasonality may not be captured by the non-model-based seasonal adjustment procedure, such as the U.S. Census Bureau's X-12 used when filtering by HP. Again, this problem is overcome when using a structural time series model.

The economic interpretation of real exchange rate deviations is more difficult. In fact, there is no consensus in Chile about the level of the equilibrium real exchange rate in the past decade. Many economists have suggested that an important degree of real appreciation was present in the 90s, but there is no a clear description of this appreciation path on a monthly basis. In any case,

[13] Changing the smoothing parameter in the HP filter does not change the results; for alternative values of this parameter, the HP cycle is noisier than the cycle obtained using a structural time series model. In particular, we compute the cycle with a smoothing parameters of 100, 1600, 10.000, 16.000, 28.800 and 50.000. As a reference, the recommended value of the smoothness parameter is, for monthly data, 14.400.

Figure 3: Chile: Output Gap

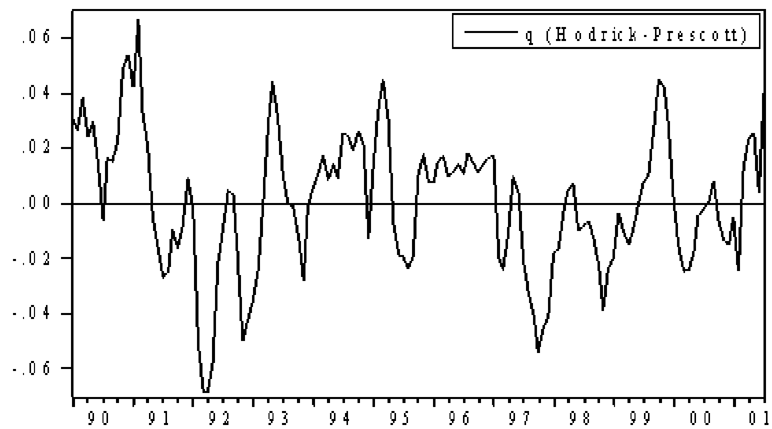


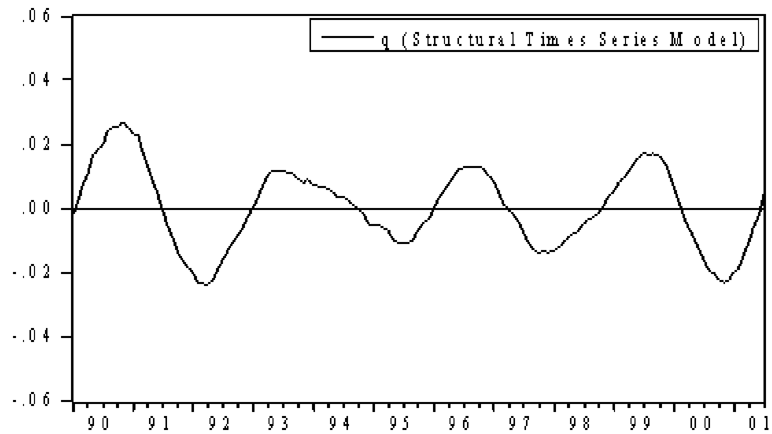


the pressure over the exchange rate market in 1998-1999 is well reflected by the real exchange rate misalignments presented in Figure 4.

Finally, for inflation, we do not need to use any detrending procedure, instead we compute the inflation gap, $\pi_{t+n} - \pi^*_{t+n}$, as the difference between actual inflation and target inflation. The series is presented in Figure 5.

Figure 4: Chile: Real Exchange Rate Deviations





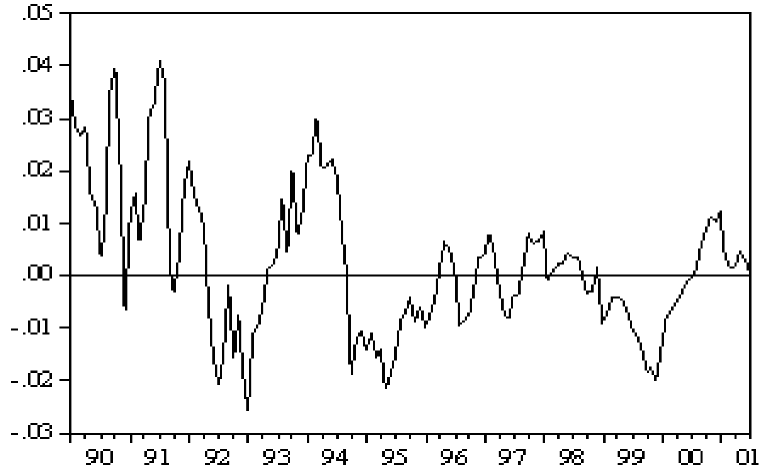
5 Results

In this section, we present the results of estimating the policy reaction function in (12) and three alternative specifications. As is noted by Clarida *et al* (1998), in order to implement GMM the interest rate and the independent variables have to be stationary. We perform a standard Dickey-Fuller test and the null hypothesis that the series are *I(1)* is rejected.

We assume n=15, which is consistent with the way in which the CCB set its inflation targets[14]. On the other hand, due to the lag in the availability of information, the CCB could not observe

[14]Each year, the CCB announces, fifteen months in advance, the inflation target.

Figure 5: Chile: Inflation Deviation from Target



output in t or in *t-1*[15]. As a result, at time t the CCB formed expectations about y_{t-1} based on past information. In a similar way, the CCB could not observe perfectly the contemporaneous level of real exchange rate misalignments; hence, at time t, it formed expectations about q_t.

Now, the set of instruments, Z_t, includes a constant, five lags of the output gap (from *t*-2), three lags in the policy interest rate, lags one to six and lag number nine and twelve of the inflation gap, three lags in the real exchange rate, and three lags in the terms of trade variation. In all cases, the J-test[16] cannot reject the validity of this set of instruments.

5.1 Linear Policy Response to the Exchange Rate

In the second column of Table 1, we present the result of estimating by GMM the monetary policy reaction function in (12). The implicit assumption in this formulation is that the policy response to real exchange rate deviations, ρ_q, is linear. This assumption will be removed later on.

As expected, the results show a positive and significant response to expected inflation, $(\rho_\pi - 1) = 0.786$. This is consistent with the widespread view that, since 1990, the CCB responded aggressively to inflation deviations from target. On the other hand, CCB's responses to output, ρ_y, and to the real exchange rate, ρ_q, were positive and significant. In particular, it is possible

[15] At time t it is only possible to observe output in $t-2$. From 2002 the target was set to a 3%.

[16] This test has a χ^2_{m-k} distribution where m is the number of instruments and k is the number of coefficients to be estimated.

Table 1: Chile: Monetary Policy Rule. Baseline Estimates.

Coefficients	Rule in (12)	Rule in (13) (adding π_{t-1})	Rule in (14) (considers q_t^L and q_t^S)	Rule in (15) (longer horizon for π_{t+n})
$\overline{r}$	0.052** (0.002)	0.068** (0.003)	0.052** (0.002)	0.050** (0.003)
ρ	0.878** (0.024)	0.961** (0.017)	0.893** (0.021)	0.930** (0.014)
$(\rho_\pi - 1)$	0.786** (0.179)	2.486 * (1.120)	0.703** (0.187)	2.263** (0.632)
ρ_y	1.122** (0.314)	4.302 * (1.749)	1.386** (0.319)	2.919** (0.645)
ρ_q	0.633** (0.176)	3.519** (1.295)	–	1.907** (0.403)
$(\rho_\pi - 1)^b$	–	0.631 (0.455)		–
ρ_q^L	–	–	0.860** (0.197)	–
ρ_q^S	–	–	0.557 (0.545)	–
$J - Test$	6.8[0.99]	5.3[0.98]	7.0[0.99]	5.3[0.99]

The J-Test for overidentifying restrictions has a χ^2_{m-k} distribution.

Standard Errors in parentheses () and p-values in brackets []

**Significant at 99% and *significant at 90%

to reject the null hypothesis that $\rho_y = 0$ and $\rho_q = 0$. This latter result indicates that the CCB had some concerns about output and real exchange rate deviations, even though they were not explicit monetary policy targets. In comparative terms, the policy response to the real exchange rate, ρ_q was larger in Chile than in developed economies. In fact, relative to the policy response to expected inflation (ρ_q/ρ_π), the reaction to real exchange rate misalignments was ten times bigger in Chile than in Germany and the UK [17] and eight times bigger than in Japan [18]. In a similar way, the relative response to output misalignments, ρ_y/ρ_π, was also bigger in Chile.

On the other hand, the average real interest rate during this period, $\bar{r}$, was 5.2% and the degree of inertia in the policy was high; $\rho = 0.878$. However, the degree of policy inertia was somehow lower that the inertia found in developed economies. In particular, Clarida *et al* (1998)

[17] See Clarida *et al* (1998 p.1045) who presents, in Table 1, the monetary policy coefficients for Germany and in Table 4 (p.1055) the policy coefficients for the UK.

[18] See Clarida *et al* (1998) who presents in Table 2 (p.1047) the policy coefficients for Japan.

find values for ρ between $\rho = 0.91$ and $\rho = 0.95$.

5.2 Testing the Importance of Lagged Inflation

In order to test whether the central bank was, indeed, reacting to expected rather than to past inflation, we estimate an alternative specification for the monetary policy reaction function. In particular, we allow for the possibility that the central bank reacted, also, to lagged inflation. By doing so, it is possible to test whether the IFB monetary policy specification in (12) is more appropriate than a backward-looking Taylor-type monetary policy rule. The extended policy rule that includes lagged inflation is

$$r_t = (1-\rho)\overline{r} + (1-\rho)\left[(\rho_\pi - 1)\left(\pi_{t+n} - \pi^*_{t+n}\right) + \rho_y y_t + \rho_q q_t + (\rho_\pi - 1)^b \pi_{t-1}\right] + \rho r_{t-1} + u_t \quad (13)$$

where the coefficient $(\rho_\pi - 1)^b$ represents the policy response to lagged inflation, π_{t-1}.

We estimate equation (13) using the same set of instruments as before. The results are presented in Table 1 third column. The policy response to lagged inflation, was positive but it was not statistically significant. On the other hand, the policy responses to the rest of the variables increased substantially. In fact, $(\rho_\pi - 1)$ went from 0.786 to 2.486, the response to output misalignments, ρ_y, increased from 1.122 to 4.302 and the policy reaction to the exchange rate, ρ_q, increased from 0.633 to 3.519. Finally, the degree of policy inertia, ρ, increased from 0.878 to 0.961.

From the preceding results, it is clear that the long term policy responses, ρ_π, ρ_y and ρ_q increased substantially. However, because the inertial coefficient increased, too, the short-term policy responses, (1-ρ)ρ_π, (1-ρ)ρ_y and (1-ρ)ρ_q did not change as much. In fact, the short-term response to expected inflation, (1-ρ)ρ_π, went from 0.096 to 0.098, the short-term response to expected output, (1-ρ)ρ_y, went from 0.136 to 0.169 and short-term response to the exchange rate, (1-ρ)ρ_q, went from 0.077 to 0.138. Hence, introducing the lagged value of inflation did not alter, substantially, the short-term policy responses (the exception being the short-term response to the exchange rate).

5.3 Testing Nonlinear Responses to the Real Exchange Rate

It has been argued, by Calvo and Reinhart (2002), that monetary policy can be determined by exchange rate considerations. In particular, developing economies may react to exchange rate misalignment because the abandonment of an exchange rate regime may cause important economic disruptions.

In Chile, the CCB had an explicit band for the nominal exchange rate but, as we discuss in Section 2, it was not supposed to use the interest rate to fulfill this objective.

In practice, however, the CCB may have responded to real exchange rate fluctuations even if those fluctuations were consistent with the nominal exchange rate band. In fact, fluctuations in the exchange rate may signal a probability of devaluation. In this case, the monetary authorities will try to avoid an exchange rate collapse by defending a non-explicit exchange rate target. This reaction corresponds to the "fear of floating" suggested by Calvo and Reinhart (2002).

The above argument is also consistent with Vitale's (2003) theoretical results; a monetary authority that wants to signal a new level for the exchange rate may use both foreign exchange rate interventions and the monetary policy instrument. In fact, Vitale (2003), shows that monetary policy decisions and foreign exchange rate interventions may be correlated. If a central bank is in charge of both interest rates decisions and foreign exchange rate interventions - as was the case in Chile until September 1999 - it can intervene in the exchange market to *signal* the implicit target for the exchange rate. In particular, it buys (sells) the foreign currency to signal a greater (smaller) than expected target for the exchange rate. In this case, a reduction (increase) in the interest rate also generates a greater (smaller) than expected target for the exchange rate. Hence, a reduction (increase) in the interest rate is a policy reaction that is consistent with this *signal*. Therefore, when the central bank perceives a real exchange rate misalignment, it may use both foreign exchange rate interventions and the monetary policy interest rate to correct it.

In some ways, the fact that $\rho_q > 0$ in the Table 1 (second and third column) indicates that the CCB wanted to stabilize the real exchange rate independently of its inflationary impacts. However, it is difficult to distinguish whether the CCB was reacting just to large real exchange rate misalignments. In fact, large misalignments may signal a higher probability of real exchange rate collapse therefore they have to be avoided. On the other hand, relatively small deviations may be transitory events with no further implications for the exchange rate regime. As a consequence, the central bank may not intervene in this case.

In order to test whether CCB's response to the real exchange rate was linear, we re-state equation (12). In particular, we allow for differentiated responses to different levels of real exchange rate misalignment. In doing so, we split real exchange rate deviations into "small" and "large" ones [19]. Then, equation (12) can be expressed as

$$r_t = (1-\rho)\bar{r} + (1-\rho)\left[(\rho_\pi - 1)\left(\pi_{t+n} - \pi^*_{t+n}\right) + \rho_y y_t + \rho^L_q q^L_t + \rho^S_q q^S_t\right] + \rho r_{t-1} + u_t \qquad (14)$$

where ρ^L_q is the policy response to large real exchange rate misalignments, q^L_t, and ρ^S_q is the policy response to small real exchange rate misalignments, q^S_t.

The results of estimating equation (14) are presented in Table 1 fourth column[20]. We conclude that, in the face of larger real exchange rate misalignments, the CCB's reaction was positive and statistically significant[21], whereas the CCB's reaction to small real exchange rate misalignments was also positive but not statistically different from zero[22]. On the other hand, although we cannot reject the null hypothesis that $\rho^L_q = \rho^S_q$, the point estimate results show a stronger policy reaction to large deviations rather than to small ones. In fact, $\rho^L_q = 0.860$ and $\rho^S_q = 0.557$. The evidence presented so far, although not conclusive, seems to suggest a non linear response to exchange rate misalignments.

5.4 Testing the Importance of Longer Expected Inflation Horizons

The formulation in (12) can be modified to allow for responses not only to a specific target in time, $\left(\pi_{t+n} - \pi^*_{t+n}\right)$, but to a path of future inflation gaps. As suggested by Wadhwani (2000), in the short-run, policymakers may react to exchange rate fluctuations to stabilize the future path of inflation and not only of specific inflation targets. In fact, if exchange rate misalignment affects

[19] We assume that large deviations are equal or greater than 1.5% (in absolute value) and small ones are smaller than 1.5%. Under this assumption, roughly half of the observations in the period 1986.01 to 2001.12 correspond to "large deviations".

[20] In this estimation the set of instruments does not change.

[21] The $H_0 : \rho^L_q = 0$ is rejected at 99%.

[22] The $H_0 : \rho^S_q = 0$ cannot be rejected.

the future path of inflation (relative to the horizon that is considered in the design of monetary policy), then it is possible that policymakers will react to exchange rate fluctuations, even if those fluctuations do not have any impact on short-run inflation (or, in this case, inflation in $t+15$). Hence, a positive value of ρ_q in equation (12) may just reflect a concern for inflation beyond $t+15$ and not a concern for the real exchange rate *per se*.

A way in which we can test the above hypothesis is by re-expressing equation (12) as

$$r_t = (1-\rho)\overline{r} + (1-\rho)\left[(\rho_\pi - 1)\sum_{n=15}^{24}\frac{\left(\pi_{t+n} - \pi^*_{t+n}\right)}{10} + \rho_y y_t + \rho_q q_t\right] + \rho r_{t-1} + u_t \qquad (15)$$

Now, if the monetary authority wants to stabilize the future path of inflation gaps (from n=15 to 24 for instance), then $(\rho_\pi - 1) > 0$ and ρ_y and ρ_q will capture the degree to which CCB is concerned about output and exchange rate deviations that do not affect this path.

The results of estimating the specification in (15) are presented in Table 1 fifth column. In this case, the central bank reacted to the future path of inflation. In fact, $(\rho_\pi - 1) = 2.263$. On the other hand, the responses to output deviations and real exchange misalignments were still positive and significant. In particular, $\rho_y = 2.919$ and $\rho_q = 1.907$.

The preceding results indicate that, even in the case where longer horizons for the inflation deviations are considered, the CCB was still concerned about output and exchange rate deviations.

6 Robustness Exercises

The results presented so far show that the CCB policy reaction function could be modelled with an IFB policy rule. In particular, the CCB moved interest rates whenever expected inflation deviates from target. In this context, the CCB was also concerned about output and real exchange rate misalignments. Furthermore, the response to exchange rate misalignments was nonlinear: in the face of large real exchange rate misalignments the policy response was more aggressive.

In this section, we test whether the preceding results are robust to alternative definitions of the explanatory variables. In particular, we consider the case in which output deviations and exchange rate misalignments are generated with the non-model based Hodrick-Prescott filter. We also test whether the CCB reacted to exchange rate deviations from the central parity. Finally, we determine how long it takes the exchange rate to affect inflation. If the pass-through is almost immediate, then the coefficient ρ_q may reflect a response to very short-term inflation rather than a genuine concern about exchange rate fluctuations.

6.1 Results with the Hodrick-Prescott Filter

In the following exercises, the variables y_t and q_t are computed using the HP filter. The set of instruments is the same as before. However, the y_t and the q_t series that are included in this set are the series generated with the HP filter.

In the first exercise, the IFB monetary policy rule in (12) is reestimated. The results, presented in the second column of Table 2, are very similar, in quantitative and qualitative terms, to the results in the baseline estimation. In particular, the CCB reacted to expected inflation deviations from target with a concern for output and real exchange rate fluctuations.

In the second exercise, we reestimate the IFB rule in equation (13) that allows for a policy response to lagged inflation. Again, the HP filter is used to compute y_t and q_t. The results, presented in the third column of Table 2, show that the CCB reacted to both expected and lagged inflation. As before, the CCB was concerned about output deviations and real exchange rate misalignments. In fact, the policy responses, ρ_y and ρ_q were both positive and statistically significant[23].

The third exercise reestimates the IFB monetary policy rule that allows for a nonlinear response to exchange rate misalignments[24], equation (14). In this case, the CCB is reacting to deviations of expected inflation from target as well as to deviations of output from trend. The coefficients $(\rho_\pi - 1)$ and ρ_y were positive and significant and their value is similar to the baseline estimates presented in Table 1. In this case, however, the policy response to the real exchange rate did not change with the size of the real exchange rate misalignments. In particular, $\rho_q^L = 0.564$ and $\rho_q^S = 1.017$.

[23] In both cases, the estimated value is below the baseilne estimates.

[24] In this case we split the q_t series generated with the HP filter into large and small deviations. Each group contains the same number of observations.

Table 2: Chile: Monetary Policy Rule. Alternative Estimates

Coefficients	Rule in (12)	Rule in (13)	Rule in (14)	Rule in (13)[a]
$\bar{r}$	0.062** (0.002)	0.057** (0.001)	0.063** (0.001)	0.056** (0.001)
ρ	0.922** (0.012)	0.847** (0.019)	0.912** (0.015)	0.698** (0.015)
$(\rho_\pi - 1)$	0.769** (0.306)	0.420** (0.114)	0.570 * (0.280)	0.429 (0.304)
ρ_y	1.833** (0.299)	0.523** (0.104)	1.622** (0.311)	1.257** (0.331)
ρ_q	0.667** (0.115)	0.185** (0.037)	–	−0.148** (0.049)
$(\rho_\pi - 1)^b$	–	0.477** (0.093)	–	0.687** (0.190)
ρ_q^L	–	–	0.564** (0.129)	–
ρ_q^S	–	–	1.017** (0.333)	–
$J - Test$	7.6[0.99]	7.3[0.98]	7.5[0.98]	7.0[0.99]

The J-Test for overidentifying restrictions has a χ^2_{m-k} distribution

Standard Errors in parentheses () and p-values in brackets []

**Significant at 99% and *significant at 90%

[a]The variable q_t is defined as the percentage deviation of the observed.

nominal exchange rate from the central parity of the band.

On the other hand, the hypothesis that $\rho_q^L = \rho_q^S$ cannot be rejected[25]. This result sharply contrasts with the nonlinear response to the real exchange rate found in the baseline case (Table 1 second column). The reason for this result is that the Hodrick-Prescott filter does not separate the irregular component from the cycle. As a result, the q_t series obtained with the Hodrick-Prescott filter is much noisier (see top panel in Figure 4). This fact implies that, for a given level of real exchange rate misalignment, the q_t series obtained with the Hodrick-Prescott filter contains an element, the irregular, that makes it difficult to distinguish whether the level of misalignment is "large" or "small". In fact, suppose that an observation has an underlying cyclical component of zero but it also contains a large irregular element. In theory, this observation should be classified

[25]The wald test for the $H_0 : \rho_q^L = \rho_q^S$ is 1.305. Hence the H_0 cannot be rejected at any conventional confidence level.

as a small real exchange rate misalignment (the cyclical deviation is zero). However, the large irregular element will determine that, in practice, the *observed* real exchange rate misalignment is far from zero and therefore this observation will be classified (wrongly) as a large misalignment. The preceding problem is absent from the q_t series obtained with a structural times series model and we believe that this is the reason why we find significant differences between ρ_q^L and ρ_q^S in the baseline exercise. Also, this is another reason why it is preferable to use the q_t series obtained with a structural times series model.

The last exercise in this subsection consists of testing whether the CCB reacted to an alternative definition of the exchange rate misalignment. In particular, given the exchange rate band present in Chile in the nineties, we test whether nominal exchange rate deviations from the central parity of this band generated a monetary policy response. In the last column of Table 2 we present the results of estimating an IFB policy rule with this alternative definition for the exchange rate. The results show that the CCB reacted to inflation deviations from target (past and expected values) as well as to output deviations from trend. However, the reaction to exchange rate deviations from the central parity had the opposite sign, $\rho_q = -0.148$. Hence, we do not find evidence that monetary policy had been used to avoid deviations of the nominal exchange rate from the central parity of the band.

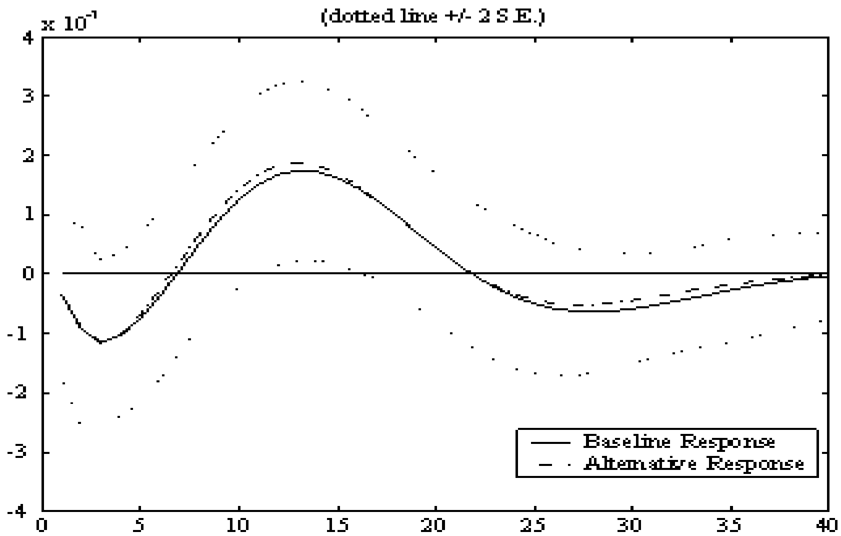
6.2 Exchange Rate Pass-through to Inflation

As mentioned previously, the ρ_q coefficient may reflect a response to very short-term inflation rather than a genuine concern about exchange rate fluctuations. This can be the case if, for instance, exchange rate misalignments impact on inflation almost immediately. To see whether this was the case, we estimate the number of periods that an exchange rate shock takes to impact on inflation. In doing so, we estimate an unrestricted VAR that contains the following variables: $(\pi_t - \pi_t^*)$, y_t, r_t and q_t[26]. Then we compute the response of inflation deviation, $(\pi_t - \pi_t^*)$, to a real exchange rate shock. The results, presented in Figure 6, indicates that the maximum impact of a real exchange rate shock is reached between eleven and sixteen months after the shock (see solid line in Figure 6).

An alternative response can be generated if we assume that the central bank did not react to

[26] The VAR has two lags according to the Akaike Information Criterion (AIC).

Figure 6: Inflation Response to a Real Exchange Rate Shock



real exchange rate misalignments. This exercise is equivalent to setting to zero the coefficient in the VAR that captures the interest rate response to the real exchange rate. In this alternative scenario, the response of inflation did not change significantly (see Alternative Response line in Figure 6).

The preceding exercises have shown that real exchange rate shocks take between eleven and sixteen months to impact on inflation. This means that the expected inflation variable in the policy rule (12), $\left(\pi_{t+n} - \pi^{*}_{t+n}\right)$, already contains information about the current level of the real exchange rate, q_t. As a consequence, the policy response to the real exchange rate, ρ_q, could be interpreted as a genuine concern about real exchange rate misalignments.

7 Conclusions

This paper provides empirical evidence on the way in which a small open economy targeted inflation. In particular, using as a case study the Chilean inflation targeting experience of the nineties, we estimate the CCB monetary policy reaction function.

We conclude that the CCB had been forward-looking: it responded mainly to anticipated inflation as opposed to lagged inflation. Furthermore, we find evidence that the CCB had some implicit objectives; avoiding output and exchange rate deviations from equilibrium. Therefore, even when inflation was under control, the CCB showed some concern about real activity and the evolution of the real exchange rate. In this respect, the CCB monetary policy in the nineties can be characterized as a gradual approach to inflation targeting, as described in Svensson (1997).

On the other hand, the policy response to the exchange rate, and to output as well, was much more important in Chile than in developed economies. In addition, the CCB's reaction to real exchange rate misalignments seem to be nonlinear: apparently the CCB reacted more strongly to large deviations than to small ones. This provides evidence that the CCB either tried to avoid excessive exchange rate depreciations (fear of floating), or tried to avoid important appreciations.

The main results are robust to alternative specifications of the monetary policy reaction function, to different definitions of the variables and to longer targeting horizons.

A novel feature of this paper is the use of structural time series models to derive long run deviations in the relevant variables. We believe this is a better alternative to *ad-hoc* detrending procedures, like the HP filter.

Finally, this is a descriptive study that characterize the CCB reaction function in the last decade. The normative question of whether this policy was optimal cannot be answered in this framework. In this sense, future research should assess the properties of this type of reaction functions in an estimated (or calibrated) model of the Chilean economy.

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Appendix A. Data

We use monthly time series from 1985.01 to 2002.04. The data are[27];

y_t: log IMACEC[28] (Source: Central Bank of Chile).

π_t: Year on year CPI variation (Source: Central Bank of Chile).

π_t^*: Inflation target. (Source: Gallego *et al*(2002)).

e_t: log of the real exchange rate (Source: Central Bank of Chile).

r_t: CCB's domestic real interest rate. This is a hybrid definition: from 1987 to 1995 it is the indexed interest rate on the three months CCB instruments (PRBC 90); from 1995 to 2001 it is the CCB's overnight indexed interest rate (Source: Central Bank of Chile).

tot: Terms of trade. This variable is used as one of the instruments. (Source: Valdés and Bennett (2001)).

Appendix B. Univariate time series model

A structural time series model is set up in terms of components that have a direct interpretation. Following Harvey and Jaeger (1993), we specify a univariate time series model as

$$y_t = \mu_t + \psi_t + \epsilon_t, \qquad \epsilon_t \sim NID(0, \sigma_\epsilon^2) \tag{16}$$

where y_t is the observed series, μ_t is the trend, ψ_t is the cycle, and ϵ_t is the irregular component. The stochastic trend component is specified as

$$\mu_t = \mu_{t-1} + \theta_t + \eta_t, \qquad \eta_t \sim NID(0, \sigma_\eta^2) \tag{17}$$

$$\theta_t = \theta_{t-1} + \zeta_t, \qquad \zeta_t \sim NID(0, \sigma_\zeta^2) \tag{18}$$

where θ_t is the slope or gradient of the trend μ_t. The irregular ϵ_t, the level disturbance η_t and the slope disturbance ζ_t are mutually uncorrelated.

The statistical specification for the cycle, ψ_t, is given by

[27] Most data are available from the CCB's webpage; www.bcentral.cl . Alternatively, the data are available, on request, from the author.

[28] The IMACEC is a monthly indicator of economic activity, which covers over 90% of Chilean GDP.

$$\begin{bmatrix} \psi_t \\ \psi_t^* \end{bmatrix} = \rho \begin{bmatrix} \cos\lambda_c & \sin\lambda_c \\ -\sin\lambda_c & \cos\lambda_c \end{bmatrix} \begin{bmatrix} \psi_{t-1} \\ \psi_{t-1}^* \end{bmatrix} + \begin{bmatrix} \kappa_t \\ \kappa_t^* \end{bmatrix} \tag{19}$$

where ρ is a damping factor such that $0 \leq \rho_\psi \leq 1$, λ_c is the frequency of the cycle in radians and κ_t and κ_t^* are two mutually independent white noise disturbances with zero means and common variance σ_κ^2.

Estimation of the hyperparameters, $\left(\sigma_\epsilon^2, \sigma_\eta^2, \sigma_\zeta^2, \rho, \sigma_\kappa^2\right)$, can be carried out by maximum likelihood. Once this has been done, estimates of the trend, cyclical and irregular components, are obtained from a smoothing algorithm[29].

Smooth trend plus cycle model

The model in (16) to (19) can be restricted in order to get a smoother trend. As noted by Harvey (2002), allowing σ_ζ^2 to be positive, but setting σ_η^2 to zero gives an integrated random walk trend, which when estimated tends to be relatively smooth, this is often referred to as the "smooth trend" model. The above restrictions can be imposed *a priori*, depending on the nature of the series.

In this context, the HP filter can be understood as a particular case of the smooth trend model. In fact, this filter may be rationalized as the estimator of the trend component in a structural time-series model of the form

$$y_t = \mu_t + \epsilon_t, \qquad \epsilon_t \sim NID(0, \sigma_\epsilon^2) \tag{20}$$

where μ_t is defined by equation (17) to (18) and σ_η^2 and ψ_t are set to zero. The optimal filter of (20) which gives the detrended observations, y_t^d, is shown to be

$$y_t^d = \left[\frac{(1-L)^2 \left(1-L^{-1}\right)^2}{q_\zeta + (1-L)^2 \left(1-L^{-1}\right)^2} \right] y_t \tag{21}$$

where $q_\zeta = \frac{\sigma_\zeta^2}{\sigma_\epsilon^2}$ is the signal-noise ratio and L is the lag operator. As noted by Harvey and Jaeger (1993), if (20) is believed to be the true model, q_ζ could be estimated by maximum likelihood. Now, the HP filtering procedure, assumes that the true model is (20), that is, it is assumed that $\sigma_\eta^2 = 0$ and $\psi_t = 0$. Furthermore, a value for q_ζ is imposed, rather than estimated.

[29] See Harvey and Jaeger (1993) and Harvey (2002) for empirical applications using the STAMP software.

This value, denoted by $\overline{q}_{\zeta}$, is 1/14400 for monthly data. Then, the HP detrended series on a monthly basis, y_t^{HP}, can be represented as

$$y_t^{HP} = \left[\frac{(1-L)^2 \left(1-L^{-1}\right)^2}{1/14400 + (1-L)^2 \left(1-L^{-1}\right)^2} \right] y_t \tag{22}$$

Therefore, the HP filter is a restricted smooth trend model in which the cycle component is assumed to be zero and the signal-noise ratio, $\overline{q}_{\zeta}$, is set to a constant number.

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