

External Shocks and Monetary Policy: Does it Pay to Respond to Exchange Rate Deviations?

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June 18, 2004

Abstract

There is substantial evidence suggesting that central banks in open economies react to exchange rate fluctuations, in addition to expected inflation and output. In some developing countries this reaction is comparatively larger and it is nonlinear. Using an estimated structural macromodel, this paper assesses the advantages and potential costs of adopting such a reaction function. We conclude that, in the face of most of the external shocks, a policy rule that responds to exchange rate misalignments smooths inflation and output variability, while marginally increasing interest rate fluctuations. On the other hand, for some domestic innovations such a rule performs poorly. When all the shocks are considered at the same time, this rule generates important welfare gains. Finally, when the volatility of external shocks rises, increasing the response to exchange rate misalignments brings welfare improvements. In fact, a more aggressive response to the exchange rate offsets the impact that greater external volatility has on output and inflation, at the cost of inducing higher interest rate fluctuations. In this way, one can interpret the nonlinear reaction to the exchange rate as an optimal response to a more volatile external environment.

JEL: E52, E53.

1 Introduction

There is substantial evidence suggesting that central banks in open economies react to exchange rate misalignments, in addition to expected inflation and output. There is, however, some debate as to whether this response improves welfare or not. In general, theoretical and empirical research on this matter have focused on developed economies and, overall, this literature tends to find little role for the exchange rate in monetary policy rules.

On the other hand, in developing economies central banks also react to exchange rate misalignments and, compared to developed countries, this reaction is larger and is nonlinear. In this context, however, there is no formal assessment of the welfare implications of such larger and nonlinear responses. For emerging economies, which face a much more volatile external environment, assessing the advantages and costs of such responses is an important policy question. Hence, the main objective of this paper is to address this issue in a micro founded model estimated for an emerging economy.

For developed economies, Clarida *et al* (1998) show that the monetary authorities in some European countries and Japan respond to exchange rate misalignments. Schmidt-Hebbel and Tapia (2002) and in Caputo (2003) find that the relative size of this response is larger and is also nonlinear in Chile, a small open and emerging economy. Similarly, Calvo and Reinhart (2002) conclude that many emerging economies use the interest rate as the preferred means of smoothing exchange rate fluctuations. In this case, the “fear of floating” induces many central banks to move interest rates aggressively in response to exchange rate fluctuations.

In this context, there is some controversy as to whether this response is optimal or not. In a theoretical model, Clarida *et al* (2001) find no role for the exchange rate in the optimal monetary policy rule. In this model, the representative household welfare criterion depends on the variance of three elements, domestic inflation, the output gap and the real exchange rate. However, because the real exchange rate is proportional to the output gap, such a criterion depends, in the end, only on domestic inflation and the output gap variances. As a consequence, the real exchange rate becomes irrelevant for monetary policy decisions.

More empirically oriented studies also show a small role for the exchange rate. Batini *et al* (2003) conclude that an optimal policy rule for the UK should contain a response to the real exchange rate, but

only marginal gains are derived from responding to it. In calibrated models for small open economies, Leitemo and Sodestrom (2003) and Chapter 3 reach similar conclusions: that responding to the exchange rate brings only marginal gains.

The international evidence concerning the role of the exchange rate seems to support the view that there are only marginal benefits from responding to this variable. This is consistent with the evidence presented for some developed countries showing that when the exchange rate enters the policy reaction function its importance, relative to inflation and output, is considerably smaller.

In this context, it is not surprising to observe that in Chile, a small open economy pursuing inflation targeting, the exchange rate forms part of the monetary policy reaction function, as reported in Schmidt-Hebbel and Tapia (2002) and in Caputo (2003). There are, however, two sets of results that do not fit into the international evidence. First, the magnitude of the response to exchange rate deviations is comparatively 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 is ten times bigger in Chile than in Germany and the UK and eight times bigger than in Japan ¹. Second, the Chilean central bank reacts more strongly to large deviations in the exchange rate than to small ones.

The evidence described above poses a natural question: what are the advantages, if any, for an emerging economy from adopting a policy rule that responds to real exchange rate misalignments? Or, in other words, is there any specific element in emerging economies that explains a comparatively larger, and nonlinear, response to the exchange rate? The objective of this paper is to address this issue in the context of the Chilean economy. In particular, we assess the advantages, and costs, associated with a policy reaction function that contains a response to the exchange rate. This assessment is performed for each individual shock hitting the Chilean economy, as well as for the combination of them.

To address the above issue, we derive and estimate a structural macromodel for Chile. This model, derived implicitly from first principles, is disaggregated enough to identify different sources of volatility. Once the shocks have been identified, it is possible to assess the performance of alternative monetary policy rules according to standard welfare criteria.

We conclude that, in the face of most of the external shocks, a policy rule that responds to exchange rate misalignments, as reported in Caputo (2003), has the advantage of smoothing inflation and output

¹See Chapter 2 and Clarida et al (1998).

fluctuations, while marginally increasing interest rate variability. As a result, responding to exchange rate misalignments is, in this case, welfare improving. On the other hand, for some domestic shocks, such a rule performs poorly. When all shocks are considered at the same time, this rule generates important welfare gains. The reason is that external disturbances are, in Chile, relatively more important than domestic ones.

On the other hand, when the volatility of external shocks rises, increasing the policy response to the exchange rate brings welfare improvements. In fact, a larger response offsets the negative impacts that greater external volatility has on output and inflation. In this way, one can interpret the nonlinear response to the exchange rate, observed in Chile, as an optimal reaction to a more volatile external environment. In this context, it is shown that increasing even further this response does not necessarily generate welfare improvements. In fact, an unusually aggressive response to the exchange rate may exacerbate the volatility of the main macrovariables, increasing the welfare losses.

Finally, given the history of innovations, we derive the optimal policy reaction function. We conclude that the optimal rule entails a positive response to the exchange rate, even though the exchange rate does not enter any of the loss criteria considered in this chapter. Furthermore, as is observed in practice, the response to exchange rate misalignments in this optimal rule is quantitatively less important than the response to output and inflation.

This chapter is organized as follows. In Section 4.2, a structural model for a small open economy is specified and estimated for Chile. This is a rational expectations model, implicitly derived from first principles, containing forward and backward-looking elements. Section 4.3 solves the model and analyzes its dynamic properties. In particular, the dynamic responses of this structural model, when faced with a monetary policy innovation, is compared with the dynamics generated in an unrestricted VAR. Section 4.4 analyzes the dynamics followed by the structural shocks. Section 4.5 assesses the performance of alternative policy reaction functions in the face of the observed structural shocks. Section 4.6 studies the role of the exchange rate in monetary policy when external volatility changes. Section 4.7 analyzes the robustness of the results to normally distributed shocks and finds the optimal policy under a standard welfare criterion. Finally, Section 4.8 concludes the chapter.

2 A Structural Model for a Small Open Economy

As is noted by Dennis (2003), most of the micro founded models used in empirical research are calibrated, not estimated. Moreover, these models are tailored to reflect the characteristics of developed countries, limiting their applicability to small and emerging economies. In this section, we present a micro founded model that is estimated for the Chilean economy. As is noted by Batini *et al* (2003), using a microfounded model enables the researcher to identify the various structural shocks that this emerging economy has faced². In addition, since the model has microfoundations, the structural coefficients that characterize the economy are independent from the monetary policy. Hence, in this framework it is possible to assess the welfare implications of alternative monetary policy rules.

Following Svensson (2000), Gali and Monacelli (2002), and Leitimo and Soderstrom (2003) we lay down a model for a small open economy that is consistent with microfoundations. In particular, the aggregate demand and supply equations could be derived from the optimizing behavior of consumers and firms. We also specify the term structure of interest rates, relating the long-term interest rate to the short-term one, and the uncovered interest rate parity condition (UIP) expressed in real terms. As is common in the literature³, some of the exogenous processes are allowed to follow an autoregressive process of order one. Finally, the model is closed with a monetary policy reaction function which is relevant to Chile and is estimated in Caputo (2003). The model is represented by the following equations⁴

$$y_t = a_1 E_t (y_{t+1}) + a_2 y_{t-1} + a_3 \rho_{t,n} + a_4 q_t + a_5 y_t^* + \epsilon_{y,t} \quad (1)$$

$$\pi_t = b_1 E_t \pi_{t+1} + b_2 \pi_{t-1} + b_3 y_t + b_4 q_t + b_5 \Delta q_t + \epsilon_{\pi,t} \quad (2)$$

$$\rho_{t,n} = c_1 E_t (\rho_{t+1,n}) + c_2 \rho_t + \epsilon_{\rho_n,t} \quad (3)$$

²In a less structural macro-model, the observed shocks may be a combination of structural shocks. Hence, it is difficult to analyze them.

³See Svensson (2000) and Leitimo and Soderstrom(2003).

⁴See Chapter 3 (Section 3.2) for a formal derivation of this microfounded model. Also, Svensson (2000) and Gali and Monacelli (2002) derive a microfounded model.

$$q_t = E_t(q_{t+1}) + d_1(\rho_t^* - \rho_t) + d_2\varphi_t + \xi_{q,t} \quad (4)$$

Equation (1) is an aggregate demand equation in which the output gap, y_t , responds to the n -period long-term real interest rate, $\rho_{t,n}$, but also to open economy variables such as the real exchange rate⁵, q_t , and the foreign level of output, y_t^* . On the other hand, the existence of habit in the consumer's utility function implies that past and expected output enter this specification. In particular, Chapter 3 shows that, from the Euler equation for consumption, it is possible to derive expressions in which a_1 and a_2 are an increasing function of the degree of habit formation in the consumer's utility function. Hence, the coefficient that captures the output gap persistence, a_2 , increases when habits become more important. In the limiting case in which habits are not present, $a_1 = a_2 = 0$. Following Leitimo and Soderstrom (2003), we impose the restriction $a_1 = 1 - a_2$. Finally, the aggregate demand disturbance $\epsilon_{y,t}$ is often interpreted as a preference shock and, in the case of Chile, it is white noise.

In the aggregate demand equation, an increase in $\rho_{t,n}$ induces economic agents to substitute current consumption for saving. Hence, a_3 is expected to be negative. On the other hand, q_t has a direct impact on aggregate demand. A depreciation, for instance, makes domestically produced goods relatively cheaper. As a consequence, economic agents, in the home economy and abroad, replace foreign goods by domestically produced ones. Hence, a depreciation has an expansionary impact on domestic output, and consequently a_4 is expected to be positive. As is shown in Gali and Monacelli (2002), Chapter 3, and Parrado and Velasco (2002), a_4 depends on few structural coefficients: the degree of openness in the small economy and the elasticity of substitution between foreign and domestically produced goods. Finally, an increase in y_t^* has an expansionary impact on aggregate demand because it increases the foreign imports of domestically produced goods. Hence, a_5 is expected to be positive.

Equation (2) represents the hybrid New Keynesian Phillips Curve (NKPC) that describes the behavior of Consumer Price Inflation (CPI), π_t , in an open economy. This specification is hybrid because it reflects the behavior of two types of firms. The first type, forward-looking firms, sets prices optimally, given the constraints on the timing of adjustments and using all the available information in order to forecast future marginal costs. The second type, backward-looking firms, uses a simple rule of thumb that is based on the past history of aggregate price behavior. In this context, Gali and Gertler (1999)

⁵The real exchange rate is defined as the relative price of foreign goods. Therefore, a depreciation is equivalent to an increase in the real exchange rate.

show that lagged and expected inflation will enter the NKPC and, when the discount factor is one $b_1 = 1 - b_2$.⁶ On the other hand, domestic output, y_t , has a positive impact on marginal costs and, consequently, on the general level of prices. As a consequence, it is expected that $b_3 > 0$. Finally, as is noted by Chapter 3, in an open economy the level and the first difference of the real exchange rate, q_t , impact CPI inflation. In fact, an increase in q_t increases the price of some intermediate inputs and shifts foreign and domestic demand towards domestically produced goods. As a consequence, domestic and CPI inflation increase. Therefore, it is expected that $b_4 > 0$. On the other hand, a real depreciation, $\Delta q_t > 0$, increases the domestic price of imported goods. As a result, CPI inflation, π_t , increases as well. Hence, it is expected that $b_5 > 0$.

Equation (3) relates the long-term real interest rate, $\rho_{t,n}$, to the short-term real interest rate, ρ_t . In particular, this specification is derived, as in Fuhrer and Moore (1995a), from the intertemporal arbitrage condition that equalizes the expected real holding-period yields on a long-term bond and the real return on a short-term central bank instrument. As is shown in Fuhrer and Moore (1995a), c_1 and c_2 are positive and it is expected that $c_1 + c_2 = 1$.

In this model, the real exchange rate, q_t , evolves according to equation (4) which is the uncovered interest rate parity condition (UIP) expressed in real terms. The variable $(\rho_t^* - \rho_t)$ represents the real interest rate differential, where ρ_t^* is the real *ex-post* foreign interest rate. On the other hand, ρ_t is the domestic real *ex-post* interest rate, which in the case of Chile is the monetary policy instrument. The φ_t variable is a country risk proxy for Chile defined as the premium on international bonds issued by Chilean corporations. This indicator is based on CCB information and JP Morgan Emerging Markets Bond Index as in Gallego *et al* (2002). The residual of this equation, $\xi_{q,t}$, represents the risk elements not captured by the rest of the variables. If UIP holds, $d_1 = 1$ and $d_2 > 0$.⁷

Now, following Svensson (2000), Batini *et al* (2003) and Leitemo and Sodestrom (2003), we model φ_t as an autoregressive process of order one. In addition, we allow the real exchange rate disturbances, $\xi_{q,t}$, to be autocorrelated⁸. Hence φ_t and $\xi_{q,t}$ can be expressed as

$$\varphi_t = \phi_\varphi^0 + \phi_\varphi \varphi_{t-1} + \epsilon_{\varphi,t} \tag{5}$$

⁶Similar specifications are found in Svensson (2000) and Christiano, Evans and Eichenbaum (2001).

⁷An increase in country risk premium depreciates the real exchange rate.

⁸We do not find persistence in the other structural shocks.

$$\xi_{q,t} = \phi_q \xi_{q,t-1} + \epsilon_{q,t} \quad (6)$$

where $\epsilon_{\varphi,t}$ and $\epsilon_{q,t}$ are risk premium and real exchange rate shocks respectively.

The foreign level of output, y_t^* and the real *ex-post* foreign interest rate, ρ_t^* , are assumed to follow processes that are independent from the small open economy. Furthermore, and following Svensson (2000), we model them as autoregressive processes of order one. We estimate these processes on a monthly basis using US data from 1990.09 to 2000.12. The y_t^* variable corresponds to the US industrial production deviation from trend. On the other hand, the ρ_t^* variable the 180-day LIBO on dollars adjusted for six month ahead US inflation rate⁹. The results are below

$$y_t^* = 0.910y_{t-1}^* + \epsilon_{y^*,t} \quad (7)$$

$$\rho_t^* = 0.934\rho_{t-1}^* + \epsilon_{r^*,t} \quad (8)$$

where $\epsilon_{y^*,t}$ reflects foreign output shocks and $\epsilon_{r^*,t}$ correspond to foreign real interest rate shocks.

Finally, we closed the model with a policy reaction function that is relevant for Chile. This has been estimated using GMM in Caputo (2003) as an inflation forecast based (IFB) monetary policy rule that allows for a response to exchange rate deviations¹⁰. This IFB rule can be described, on a monthly basis, as

$$\rho_t = 0.878\rho_{t-1} + (1 - 0.878) (0.785E_t(\pi_{t+15}) + 1.122y_{t-1} + 0.633q_t) + \epsilon_{r,t} \quad (9)$$

where ρ_t is the *ex-post* real interest rate which is the monetary policy instrument used by the Chilean central bank. This instrument reacts to expected inflation fifteen months ahead, $E_t(\pi_{t+15})$, to the lagged output gap, y_{t-1} and to the real exchange rate, q_t ¹¹. This policy instrument displays a significant degree of inertia. Finally, the monetary policy shocks are captured by $\epsilon_{r,t}$.

⁹See Appendix E for details.

¹⁰See Table ??.

¹¹The targeting horizon for inflation, fifteen months, is consistent with the way in which the Chilean central bank targets inflation. On the other hand, the response to the lagged output gap reflects the lag in the availability of information (see Chapter 2).

2.1 Estimation

In general, open economy models, like the one described previously, are estimated on a quarterly basis and, in the case of Chile, the equations are estimated individually. One of the innovations of this paper is that such a model is estimated as a system on a monthly frequency. As is noted by Green (1999), estimating equations individually may generate inconsistent estimates. On the other hand, even if single equation estimates are consistent (OLS instrumental variables, for instance), they are not efficient when compared with estimators that make use of all the cross-equation correlations of the disturbances.

To estimate the system of equations (1) to (5), we use two alternative procedures, Full Information Maximum Likelihood (FIML) and the Generalized Method of Moments (GMM). In general, the results support both the hybrid NKPC and an aggregate demand equation containing forward and backward-looking components. The results are, however, more precise with the GMM method. The reason for this is that, in some equations, residuals are not normally distributed and, in that case, GMM generates efficiency gains when compared with FIML. Furthermore, FIML estimates are inconsistent if the distribution of the residuals are misspecified.

On a different issue, inflation and output may react with some lags to innovations in the right-hand side (RHS) variables. This is more likely to happen in the case of models expressed in terms of a monthly frequency. Therefore, when estimating the system, we allow for lagged responses to all the variables. In practice, this means that we include several lags of the RHS variables in each equation and then drop, sequentially, the lags with no significant coefficients. In practice we choose several lags for each variable. Then, we drop the lags that have the highest standard error and then reestimate the equation. In the end, we keep the variables with the lowest standard error¹².

The estimation period is September 1990, which was the formal date on which inflation targeting was adopted, to December 2000¹³. All variables are expressed, as in Smets and Wouters (2002), as cyclical deviations from the trend¹⁴. However, while Smets and Wouters (2002) use linear trends when

¹²Because some variables, like the long-term real interest rate, $\rho_{n,t}$, are persistent the inclusion of several lags may lead to multicollinearity. In these circumstances, some lags may appear to be non significant and may be excluded. To see whether this potential problem affects our results, we also estimate the system considering only the lags that were initially excluded. In general, the excluded lags do not give better information than the lags we choose. In particular, for the $\rho_{n,t}$ variable, the excluded lags show a lower estimated coefficient.

¹³This sample is consistent with the one used in Chapter 2 when estimating the policy reaction function for Chile.

¹⁴The definition of each series is presented in the Appendix E

estimating a macromodel for the Euro Area, we follow Harvey and Jaeger (1993) and fit a structural time series model for each series (the exceptions are the interest rates and country risk variables). This detrending procedure has the advantage of avoiding the creation of spurious cycles and it removes the irregular components that are present in the series. For a more detailed description of the advantages involved in this procedure, see Harvey and Jaeger (1993) and Caputo (2003) of this dissertation.

Finally, y_t , π_t , q_t and y_t^* are expressed on a monthly basis, whereas ρ_t , $\rho_{n,t}$, φ_t and ρ_t^* are all expressed on an annual basis. In this context, in order to interpret properly the output response to the long-term interest rate, a_3 , and the d_1 and d_2 coefficients in the UIP equation, we introduce, in equation (1) and (4), the variables ρ_t , $\rho_{n,t}$, φ_t and ρ_t^* on a monthly basis¹⁵.

2.2 Discussion of Results

As was previously mentioned, the GMM procedure gives more precise estimates. Hence, in what follows, we will discuss these results rather than those obtained by FIML.

The results from estimating the system of equations (1) to (5) are presented, for the FIML and GMM methods, in Table 1. Those results support an aggregate demand equation in which the forward and backward-looking components are present. In particular, the output level presents a significant degree of persistence, $a_2 = 0.548$. On the other hand, the long-term real interest rate has a negative impact on output, in fact, $a_3 = -0.007$. The output responses to the real exchange rate, a_4 , and to foreign output, a_5 , are positive. In particular, $a_4 = 0.016$ and $a_5 = 0.026$. The lag structure of the independent variables in the aggregate demand equation is consistent with the structure found in Garcia *et al* (2002).

When compared with the international evidence on this matter, the estimated coefficients in the aggregate demand equation, a_3 , a_4 and a_5 , are very similar to those in Svensson (2000). In other specifications, like Alexandre *et al* (2002), Batini and Haldane (1999), Leitimo and Sodestrom (2003) and Dennis (2000), these coefficients are larger.

On the other hand, the estimated values for a_3 , and a_4 imply that the aggregate demand equation has a Monetary Conditions Ratio ($-a_3/a_4$) of 0.44. This value is below that found in other small open

¹⁵For instance, the policy interest rate on a monthly basis, ρ_t^m , is expressed as $\rho_t^m = \left\{ (1 + \rho_t)^{(1/12)} - 1 \right\}$

Table 1: Structural Coefficients Estimates for Chile(1990.09-2000.12)

		GMM ^a	FIML ^b
Coefficients	Variable	Estimate	Estimate
a_1	$E_t(y_{t+1})$	0.453 ^c (<i>n.a.</i>)	0.454 ^c (<i>n.a.</i>)
a_2	y_{t-1}	0.547** (0.000)	0.546** (0.005)
a_3	$\rho_{n,t-3}$	-0.007** (0.000)	-0.002 (0.009)
a_4	q_{t-6}	0.016** (0.000)	0.016* (0.009)
a_5	$(\Delta y_{t-8}^*)^d$	0.026** (0.001)	0.025* (0.012)
b_1	$E_t\pi_{t+1}$	0.562 ^c (<i>n.a.</i>)	0.527 ^c (<i>n.a.</i>)
b_2	π_{t-1}	0.438** (0.020)	0.483** (0.041)
b_3	y_{t-3}	0.067** (0.012)	0.046 (0.083)
b_4	q_{t-8}	0.035* (0.018)	0.108 (0.132)
b_5	Δq_{t-5}	0.203** (0.068)	0.344 (0.349)
c_1	$E_t(\rho_{t+1,n})$	0.941** (0.001)	0.931** (0.026)
c_2	ρ_t	0.060** (0.001)	0.070** (0.027)
d_1	$(\rho_t^* - \rho_t)$	1.082** (0.006)	0.935** (0.195)
d_2	φ_t	2.354** (0.020)	2.024** (0.358)
ϕ_φ	φ_{t-1}	0.881** (0.002)	0.858** (0.050)
ϕ_q	$\xi_{q,t-1}$	0.727** (0.004)	0.776** (0.060)

^aGMM Instrumental Variables. The set of instruments contains the following variables: y_{t-1}, \dots

, $y_{t-6}, \pi_{t-1}, \dots, \pi_{t-5}, q_{t-1}, \dots, q_{t-7}, \rho_{n,t-3}, \dots, \rho_{n,t-5}, \rho_{t-1}, \Delta y_{t-8}^*, \rho_{t-1}^*, \varphi_t, \dots, \varphi_{t-3}$.

^bUses the Berndt-Hall-Hausman (BHHH) optimization algorithm. If the Marquard algorithm is used, the results do not change. Residuals failed the normality and heteroscedasticity tests in the following equations: NKPC, the term structure equation and the real UIP.

^crestricted: $a_1 = 1 - a_2$ and $b_1 = 1 - b_2$

^dThe y_t^* series is I(1), hence, we use Δy_t^* .

** Significant at 99% and, * significant at 95%. Standard errors in parenthesis.

economies¹⁶ indicating that, in Chile, real exchange rate fluctuations have a more important effect on output than interest rate movements. This may be due to a high elasticity of substitution between foreign and domestic goods, η . In fact, in that case, a depreciation makes domestically produced goods relatively cheaper. Now, because the elasticity of substitution is high, domestic and foreign agents tend to consume more domestically produced goods. Hence, a higher value of η tends to exacerbate the impact that real exchange rate movements have on output¹⁷. If this elasticity of substitution is zero, the same depreciation will not generate any impact on output.

The hybrid NKPC is supported by the data. In particular, there is a significant degree of inflation persistence, $b_2 = 0.438$. When compared with the evidence for the USA and Europe, presented in Gali and Gertler (1999) and Gali *et al* (2001) respectively, it turns out that in Chile the inflation persistence is twice as much. One possible explanation is the high degree of indexation in the Chilean economy, in particular during the early nineties. On the other hand, domestic output and the level of the real exchange rate impact on inflation with a delay of one and three quarters, respectively. In this case, $b_3 = 0.067$ and $b_4 = 0.035$. The rate of depreciation, Δq_t , has a positive effect on inflation after five months. The coefficient associated with the depreciation, b_5 is 0.203. The value of b_5 is consistent with a degree of openness of nearly 20%¹⁸. This and the fact that $b_3 > b_4$ is consistent with Svensson (2000) and Leitemo and Sodestrom (2003).

The estimated coefficients in the term structure equation are positive, as expected. Furthermore, $c_1 + c_2 = 1.001$, which is in line with the theoretical argument in Fuhrer and Moore (1995a) stating that $c_1 + c_2 = 1$. The c_2 coefficient is equal to 0.06, which implies that the estimated maturity of the long-term bond, n , is equal to $n = 1 - 1/c_2 = 16$ quarters. This estimated maturity is shorter than the nominal one, $n = 32$ quarters (eight-year maturity). The reason for this is that the long-term bond, $\rho_{n,t}$, carries a coupon¹⁹. In these circumstances, as is shown by Campbell *et al* (1999 p.403), the estimated maturity of the bond is shorter than the nominal maturity.

¹⁶According to Dennis (2000 p.10), a typical estimate of the Monetary Condition Ratio for a small open economy is between 1.5 and 3.5.

¹⁷See Chapter 3 for a detailed discussion on the way the elasticity of substitution between foreign and domestic goods, η , is related to a_4 .

¹⁸In fact, in the microfounded model of Chapter 3, the b_5 coefficient can be expressed as $b_5 = \frac{\alpha}{1-\alpha}$ where α is the degree of openness.

¹⁹In the case of this long-term bond, the Chilean central bank pays a coupon every six months.

Estimating the UIP condition, expressed in real terms, gives coefficients with the expected sign. In particular, $d_1 \approx 1$ and $d_2 > 0$. Moreover, our results support the UIP and indicate a significant reaction of the real exchange rate, q_t , to the country risk premium, φ_t .

The risk premium variable, φ_t , and the exchange rate residual, $\xi_{q,t}$, exhibit an important degree of persistence. This feature is also present in the UK economy, as is reported by Batini *et al* (2003).

Finally, we perform a Chow test of structural breaks to see whether the equations in the estimated system are stable or not. This test is performed for two potential break point dates, 1994.12 and 1996.12²⁰. For both dates, there is no evidence of structural breaks in the aggregate demand equation, the NKPC, the UIP condition and the term structure equation.

3 Model Solution and Dynamics

In order to analyze the dynamic properties of the estimated model, we first solve the model and then analyze the impulse response functions (IRFs) to different structural shocks. In particular, we compare the IRF to a monetary policy innovation in both the structural model and in an unrestricted VAR. This innovation has a structural interpretation in both cases and, therefore, the IRFs are comparable.

3.1 Model Solution

The model is a linear perfect foresight one. It can be characterized by a vector of nine variables, $x'_t = (y_t, \pi_t, \rho_{n,t}, q_t, \rho_t, \varphi_t, \xi_{q,t}, y_t^*, \rho_t^*)$ and a vector of eight structural innovations, $\epsilon'_t = (\epsilon_{y,t}, \epsilon_{\pi,t}, \epsilon_{\rho_n,t}, 0, \epsilon_{r,t}, \epsilon_{\varphi,t}, \epsilon_{q,t}, \epsilon_y)$ where the zero value appear because we are explicitly modelling the real exchange rate shock, $\xi_{q,t}$, as an autoregressive process. The state representation of the whole system can be cast in the format

$$\sum_{i=1}^{\vartheta} H_i E_t x_{t+i} + \sum_{i=-k}^0 H_i x_{t+i} = \epsilon_t \quad (10)$$

where H_i are square matrices containing the estimated structural coefficients. The parameters ϑ and k represent, respectively, the maximum number of leads and lags in the system. In this model, the policy reaction function, equation (9), contains the maximum number of leads, $\vartheta = 15$, and the aggregate demand function, equation (1), contains the maximum number of lags $k = 9$.

²⁰Between those dates there is a change in the volatility of supply and country risk shocks. This issue is discussed further in Section 4.6.

The model is solved, as in Fuhrer and Moore (1995b), using the generalized saddlepath procedure of Anderson and Moore (1985), also known as the AIM algorithm. In doing so, it is assumed that $E_t(\epsilon_{t+i}) = 0$ for $i > 0$.

Now, for a given set of initial conditions, if the system has a unique solution that grows no faster than a given upper bound, this procedure generates a representation of the model that is called the *observable structure*

$$S_0 x_t = \sum_{i=1}^9 S_{-i} x_{t-i} + \epsilon_t \quad (11)$$

Equation (11) is a structural representation of the model, because it is driven by the structural disturbance vector, ϵ_t . The coefficient matrix S_0 contains the contemporaneous relationships among the elements of x_t . This is an observable representation of the model because it does not contain unobservable expectations.

Now it is possible to generate the reduced form of the structural model. In fact, premultiplying equation (11) by S_0^{-1} gives the autoregression

$$x_t = \sum_{i=1}^9 S_0^{-1} S_{-i} x_{t-i} + S_0^{-1} \epsilon_t \quad (12)$$

The expression in (12) is a restricted VAR, where the restrictions are those imposed by the estimated structural model. In order to generate impulse-responses functions (IRF) of the estimated model, we use the VAR representation in (12), and the fact that S_0^{-1} and $B_{-i} \equiv S_0^{-1} S_{-i}$ for $i = 1$ to 9 are known, to compute the response of a variable i to structural disturbance j ; $\frac{\partial x_{i,t}}{\partial \epsilon_{j,t}}$.

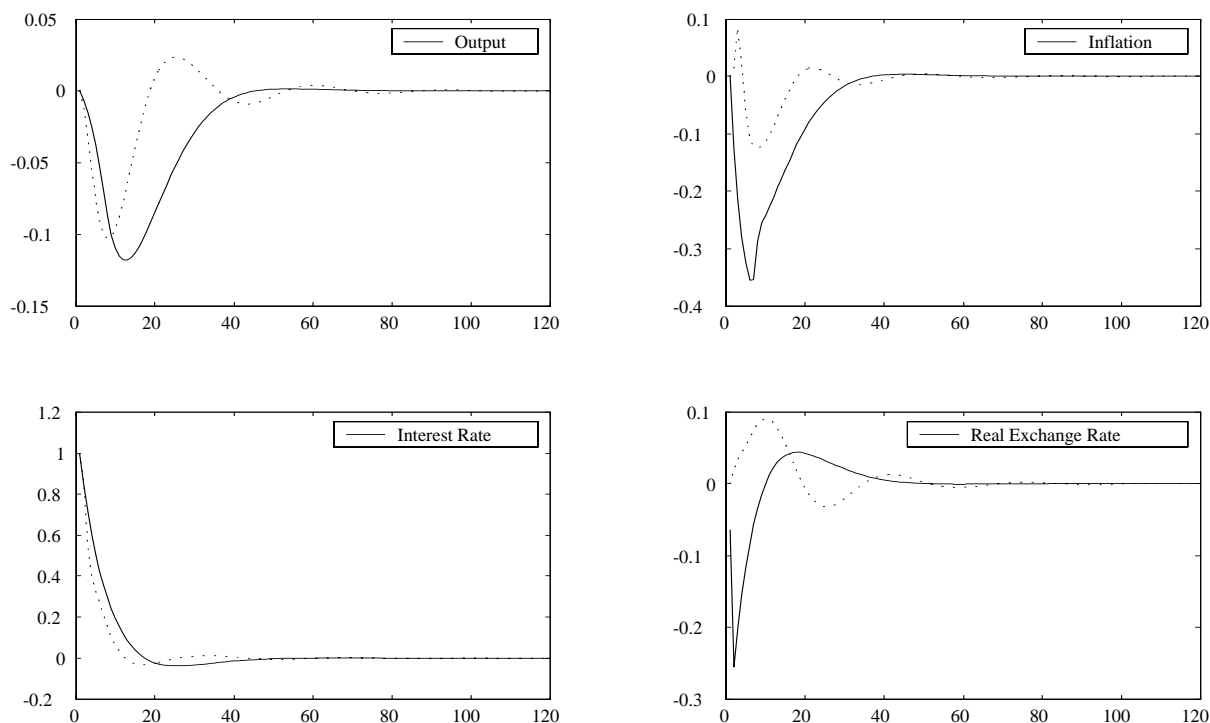
3.2 Model Dynamics

The model is solved using the AIM algorithm and, despite the fact that the model contains fifteen leads and nine lags, there is a unique solution. Hence it is possible to obtain both the *observable structure* of the model, equation (11), and the VAR representation of it, equation (12). It is also possible to derive the IRF to every single structural shock in the ϵ_t vector.

3.2.1 Impulse Response to a Monetary Policy Innovation

We compare the dynamics generated by the structural model and that obtained from a VAR. In particular, we estimate an unrestricted VAR for the x_t vector and compute the IRF to a monetary policy innovation²¹. Then, we compute the IRF to a 1% monetary policy shock in the structural model and compare both IRFs. As is noted by Valdes (1997) and Keating (1992), in an unrestricted VAR the only innovation with a structural interpretation is the monetary policy one. Hence, both innovations have a structural interpretation and their IRFs can be compared. Figure 1 shows the IRFs in each case.

Figure 1: Chile: Responses to a 1% Monetary Policy Shock



In the structural model, the real exchange rate appreciates on impact after a monetary policy shock (an increase in the interest rate). Then the exchange rate depreciates and returns to its equilibrium level after forty months (solid line in Figure 1). In the case of the VAR, the exchange depreciates on impact after this policy shock (dotted line in Figure 1). This depreciation, denominated “exchange rate

²¹The unrestricted VAR contains two lags, chosen with the Akaike criterion, and it uses the lower triangular Cholesky decomposition to identify the shocks.

puzzle”, is also reported for Chile in Parrado (2001) and it is absent from the structural model²².

On the other hand, output contracts when the interest rate rises. The maximum impact of this policy shock is reached after twelve months, in the case of the structural model (solid line), and after ten months in the case of the unrestricted VAR (dotted line). The output contraction is more severe in the structural model and its recovery is also slower. The reason for this is that, in the structural model, there is a real appreciation that brings output down. As is noted before, in the VAR model this appreciation is absent and, as a consequence, output recovery is faster.

In the face of a monetary policy shock, inflation contracts from the beginning in the structural model, reaching its lowest level after eight months. Then it returns to its equilibrium after thirty months²³. In the case of the VAR, inflation increases, initially, and then it goes down. This initial increase, denominated “inflation puzzle”, is also found (for the price level) in Parrado (2001). Again this puzzle is absent from the structural model. The path followed by both IRFs is quite similar, however; inflation contracts more, and for a longer time, in the structural model. The reason for this is that, as we previously discussed, in the structural model, output and the exchange rate contract by more, contributing to an even lower rate of inflation.

Finally, in the structural model and in the VAR, the interest rate returns to its initial level within twenty months of the initial monetary policy shock. In both cases, the interest rate follows almost the same path.

Overall, the structural model tends to replicate quite well the dynamics found in an unrestricted VAR for output, inflation and the interest rate²⁴. Furthermore, the exchange rate and inflation puzzles are absent in this structural model. Hence there is no need to impose restrictions, like those in Parrado (2001), to eliminate those puzzles.

²²To overcome this puzzle, Parrado (2001) estimated a structural VAR that imposes long-term restrictions.

²³In order to match, more closely, the inflation dynamics in the structural model to that in the VAR, we modify the coefficients b_2 and b_3 . In particular, b_2 goes from 0.438 to 0.414 and b_3 goes from 0.067 to 0.031. Those modifications do not change any of the results in the next sections. Furthermore, the modification to b_2 is contained by a 2 S.E. confidence interval and b_3 remains within a 3 S.E. interval.

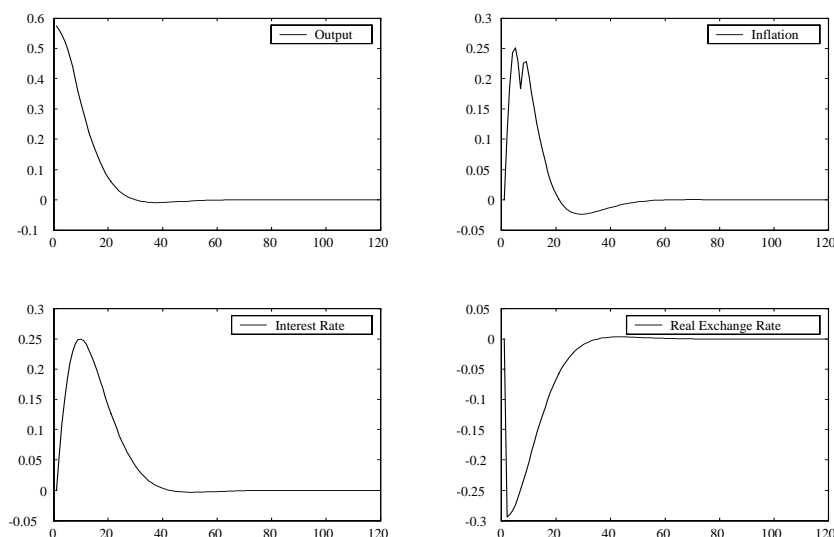
²⁴If we use unrestricted VARs containing more lags (3 to 6 lags), the results hold. For an unrestricted VAR with 9 lags the IRF derived are more volatile and difficult to interpret.

Now, we analyze the dynamic properties of the model when facing the other domestic and foreign innovations. In this case, the IRFs obtained are not directly comparable to those derived from the unrestricted VAR. The reason is that a VAR, that uses a lower triangular Cholesky decomposition to identify innovations, does not necessarily generate IRFs with a structural interpretation. In fact, the IRFs derived from a VAR are likely to reflect a combination of structural innovations and, as a consequence, standard VAR analysis will be difficult to interpret in a structural way (see Keating 1992 p.43). Therefore, we limit our analysis to the IRFs obtained from the structural model.

3.2.2 Impulse Responses to Domestic Shocks

A one standard deviation aggregate demand innovation, $\epsilon_{y,t}$, generates an output expansion during the first twenty months after the innovation (see Figure 2). As a consequence, marginal costs increase and therefore inflation rises. This increase in inflation reaches its maximum level seven months after the shock. The central bank responds to the rise in inflation and output by increasing the policy interest rate. This reaction has its peak nearly ten months after the initial shock and then the interest rate converges to its initial level. As a result of a higher interest rate, the real exchange rate appreciates considerably during the first ten months and then it slowly returns to its equilibrium level.

Figure 2: Chile: Responses to a one S.D. Aggregate Demand Shock



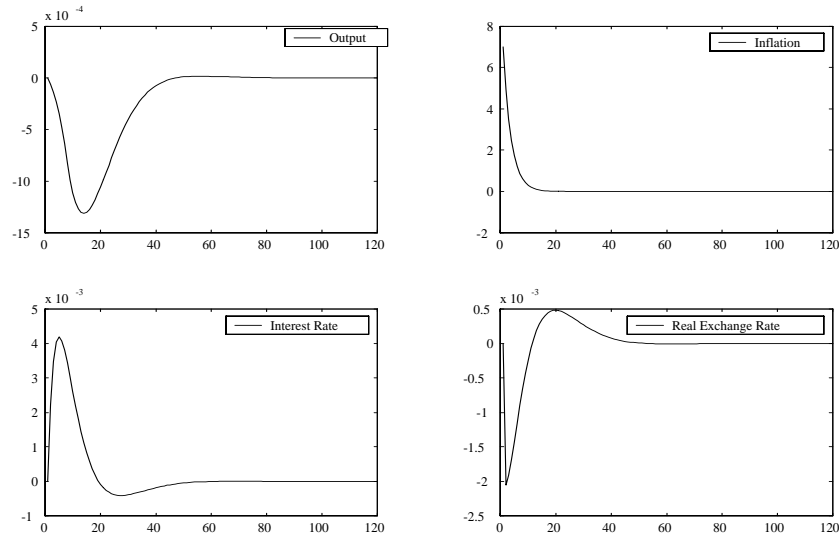
When the economy is subject to an aggregate supply shock, $\epsilon_{\pi,t}$, inflation increases in the first ten

months (Figure 3). The central bank reacts by increasing the interest rate and, as a consequence, output and the real exchange rate contract. Inflation returns to its initial level after twenty months. In this case, it is possible to stabilize the economy with a not very aggressive increase in interest rates. The reason for this is that inflation is determined, in an important way, by expected inflation and, in this model, agents expect inflation to be lower in the future²⁵. This fact generates, by itself, a reduction in inflation without increasing interest rates any further. In other words, the sacrifice ratio goes down with the degree of forward-looking behavior in inflation. In fact, in the limiting case in which inflation is completely forward-looking and there is no inflation persistence, $b_2 = 0$, stabilizing the economy after a supply shock comes at no cost in terms of output and interest rates. Of course, this is an extreme case, and the evidence, in Chile and abroad, indicates that inflation shocks do generate contractions in output.

On the other hand, a positive term premium shock, $\epsilon_{\rho_n,t}$, generates an increase in the long-term real interest rate and, as a result, a contraction in output for almost twenty months (Figure 4). This contraction in output, in turn, generates a reduction in marginal costs which brings inflation down. Now, because the central bank is targeting inflation, with a concern for output as well, the monetary policy response to this reduction in output and inflation is to reduce interest rates for nearly forty months. This lower level of the interest rate generates a real depreciation in the first thirty-five months after the initial shock.

²⁵In this model, the structure of the economy and the policy reaction function are known to all agents and to the central bank as well.

Figure 3: Chile: Responses to a one S.D. Aggregate Supply Shock

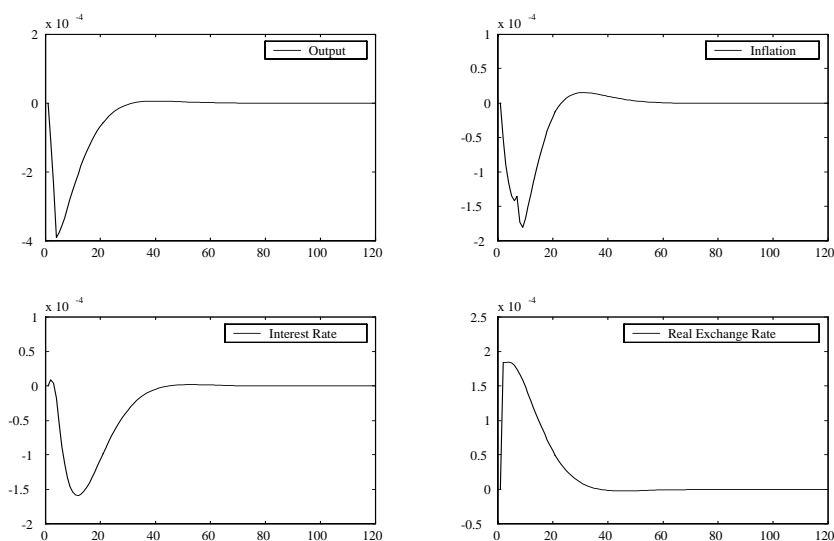


3.2.3 Impulse Responses to Foreign Shocks

A country risk shock, $\epsilon_{\varphi,t}$, generates a real depreciation in the first ten months (Figure 5). As a consequence, output increases - a depreciation has an expansionary impact on output. This output expansion, together with the real depreciation, contributes to an increase in inflation. The central bank reaction is to raise interest rates during the first thirty months after the shock. This pattern of responses has also been found in Parrado (2001), who, using a structural VAR, concludes that a risk premium shock increases output and inflation and generates an increase in interest rates.

Similarly, a real exchange rate shock, $\epsilon_{q,t}$, not related to country risk premium or the interest rate spread, generates a real depreciation that persists for seven months (Figure 6). This depreciation expands output in the first twenty months. Inflation increases as a consequence of higher marginal costs, derived from both a higher level of output and a depreciated real exchange rate. The initial depreciation also increases the price of imported goods which expands inflation further.

Figure 4: Chile: Responses to a one S.D. Term Premium Shock



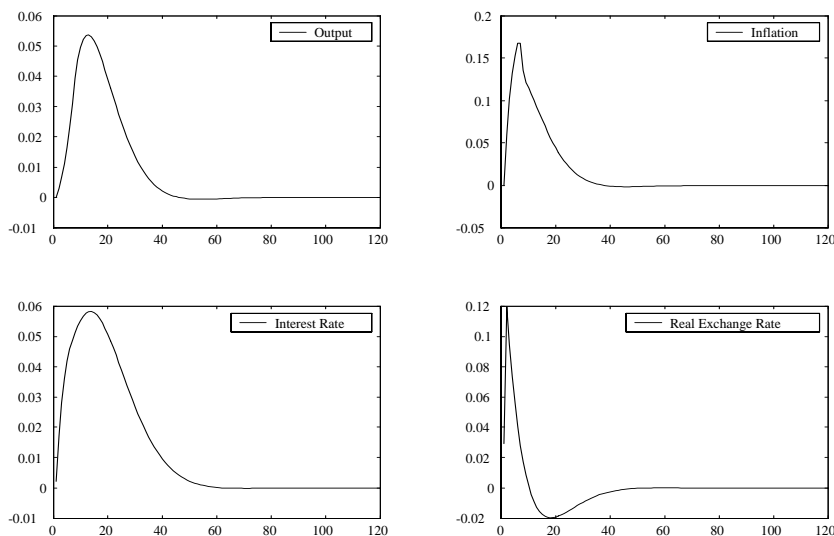
When output in the rest of the world experiences a positive shock, $\epsilon_{y^*,t}$, domestic output expands during the first twenty months (Figure 7). Inflation increases, and, as a consequence of this, the central bank adopts a contractive monetary policy. This increase in the interest rate generates a reduction in the interest rate differential and, consequently, a real appreciation that lasts for twenty months.

Finally, a foreign real interest rate shock, $\epsilon_{r^*,t}$, generates a real depreciation that lasts for nearly ten months (Figure 8). As a result of this, output increases and, in turn, inflation rises in an important and persistent way. The central bank reaction is to increase the interest rate. Again, this pattern is quite consistent with Parrado's (2001) IRF derived from a structural VAR.

To summarize, the structural model estimated for Chile in this paper reflects quite well the dynamics of the economy when faced with different shocks. In particular, in the face of a monetary policy innovation, the model generates a dynamic which is consistent with that found in an unrestricted VAR. On the other hand, in the face of the other domestic shocks, responses are as expected, and coincide with those found for Chile in Valdes (1997). In the case of foreign innovations, in particular country risk and foreign interest rate, the dynamic responses follow a similar pattern to those derived from a structural VAR in Parrado (2001).

The IRF analysis also show the important contribution of aggregate demand shocks to the Chilean business cycle. In fact, as Figure 2 shows, this shock generates a 25 basis point increase in the policy

Figure 5: Chile: Responses to a one S.D. Country Risk Shock



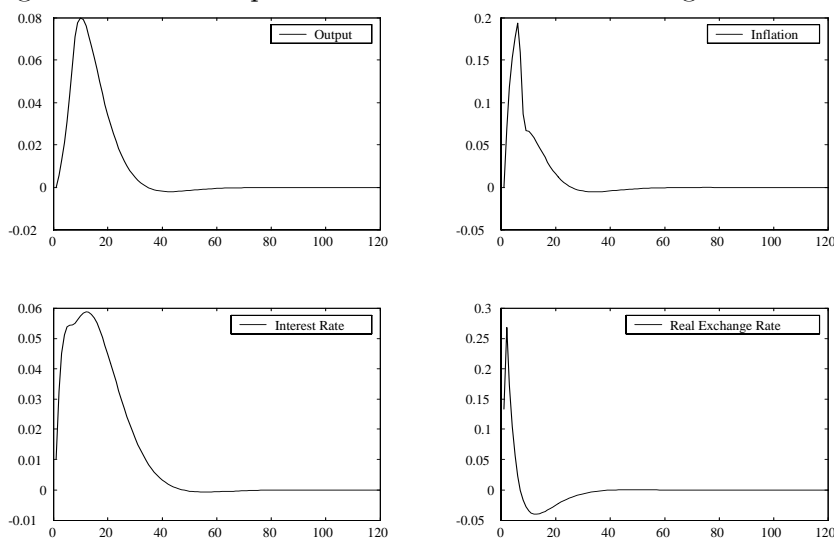
interest rate and a 0.25% increase in the output gap. This shock also generates a real appreciation of 0.30%. In terms of external shocks, real exchange rate and foreign interest rate shocks generate an important effect on output and domestic interest rates.

Now, with this model to hand, it is possible to analyze the welfare implications of alternative monetary policy rules. In particular, given the history of structural shocks, we can analyze what are the advantages, and the costs, of adopting a policy reaction function, like (9), that reacts to exchange rate misalignments. This analysis can be performed for the combination of all shocks and for each shock in particular. Before performing this analysis, the next section describes in more detail the structural shocks that the Chilean economy has faced in the last decade.

4 Structural Shocks

In the nineties, besides facing domestic disturbances, the Chilean economy was subject to several external shocks. In fact, the world economy was hit by several crises in this period: after the Mexican 1995 exchange rate collapse there followed the Asian crisis in July 1997, the Russian crisis in August 1998, and the near-collapse of the U.S. hedge fund Long-Term Capital Management (LTCM) in September 1998. As Keating (1992) and Parrado (2001) make clear, in an unrestricted VAR it is difficult to identify the structural shocks, domestic and external, that an economy may have faced. In a VAR framework, some

Figure 6: Chile: Responses to a one S.D. Real Exchange Rate Shock



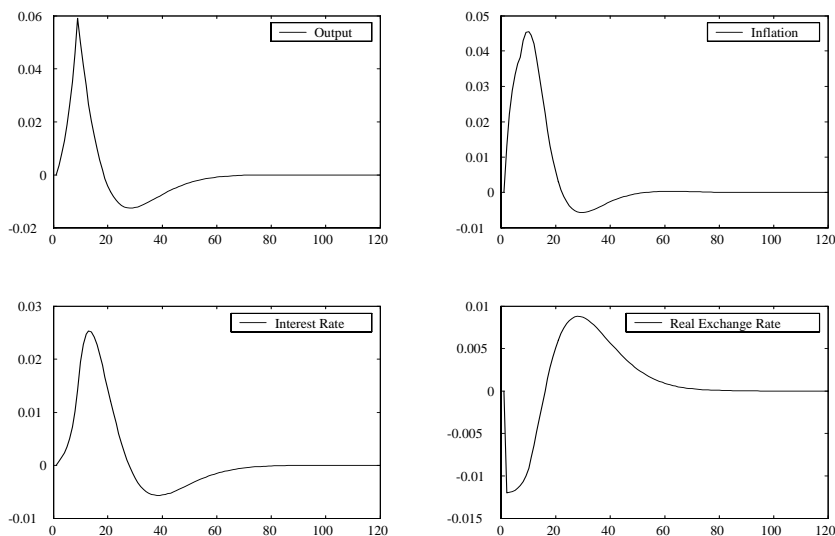
innovations may contain a linear combination of the structural shocks and hence their interpretation may become meaningless. The advantage of the structural model, derived and estimated in this paper, is that domestic and external shocks are fully identified. In fact, the residual series in each equation can be interpreted as a structural shock and therefore it is possible to assess the relative contribution of each shock to the overall volatility in the economy.

4.1 Domestic Shocks

The path followed by the domestic shocks is presented in Figure 9. Aggregate demand innovations reflect the expansionary cycles of the early and mid-nineties. The relative size of those innovations is, however, small. In the case of aggregate supply innovations, they exhibit a high volatility in the first half of the sample, 1990.09-1994.12, that decreased considerably in the late nineties. One interpretation of this fact has to do with the credibility of the inflation target. In fact, before 1994 the target was a two-digit number and when a one-digit target was set and achieved in December 1994, the targeting regime gained confidence. As a result, supply shocks generated less persistent effects on inflation.

The term premium and monetary policy innovations followed a random pattern. However, in September 1998 there is a significant increase in both the long-term and policy interest rate. This increase is particularly important in the case of the monetary policy interest rate and has been interpreted (see Landerretche *et al* (2000)) as a policy response to external shocks.

Figure 7: Chile: Responses to a one S.D. Foreign Output Shock

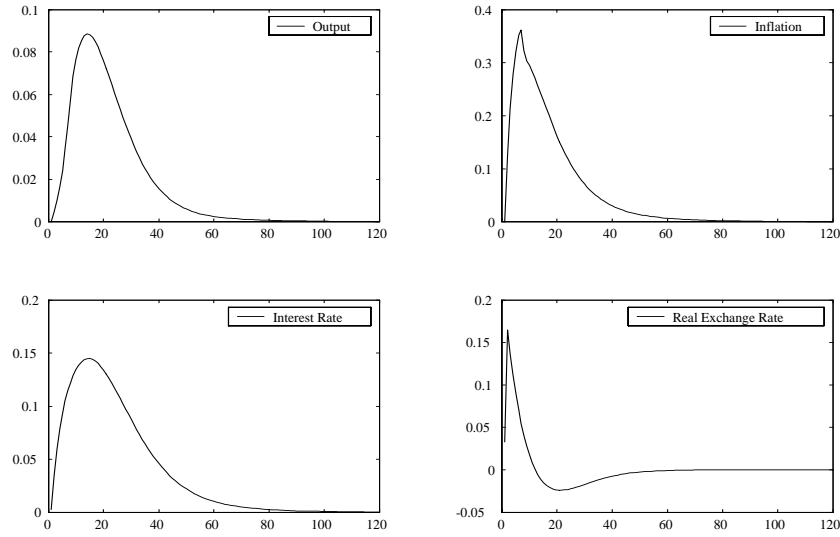


4.2 External Shocks

The external shocks are presented in Figure 10. It is evident that the country risk premium experienced a significant increase in September 1998. According to Dungey *et al* (2002), this increase, observed also in developed countries, is the consequence of higher risk aversion among international market participants as a result of the Russian crisis and LTCM near-collapse in August-September 1998. This increase in risk premium was not present in Chile during other financial crises, like Mexico 1995, and there is evidence that the spillover effects were limited on that occasion. On the other hand, it is worth noting that the country risk shocks did not increase permanently after September 1998. According to Dungey *et al* (2002) the Fed's aggressive easing of monetary policy during that period may have contributed to reducing the duration of the crisis. Consistent with this fact, the foreign interest rate disturbances in Figure 10 show a contraction during the period August to November 1998.

On the other hand, real exchange rate shocks follow a random path. However, they show a period of expansion in 1997 and 1998 and an important contraction at the end of 1999. Finally, foreign output shocks show an increase in September 1998 and also in the period 1999 to 2000, before the US recession that followed.

Figure 8: Chile: Responses to a one S.D. Foreign Interest Rate Shock



5 Performance of Alternative Monetary Policy Rules

In this section, we investigate whether responding to exchange rate fluctuations generates welfare gains when the economy is subject to the structural shocks previously described. Following Leitemo and Sodestrom (2003), Batini *et al* (2003) and Chapter 3 we first specify a welfare loss criterion that penalizes inflation, output and interest rate volatility. This criterion can be described as

$$L = 2\sigma_{\pi}^2 + \sigma_y^2 + 0.5\sigma_r^2 \tag{13}$$

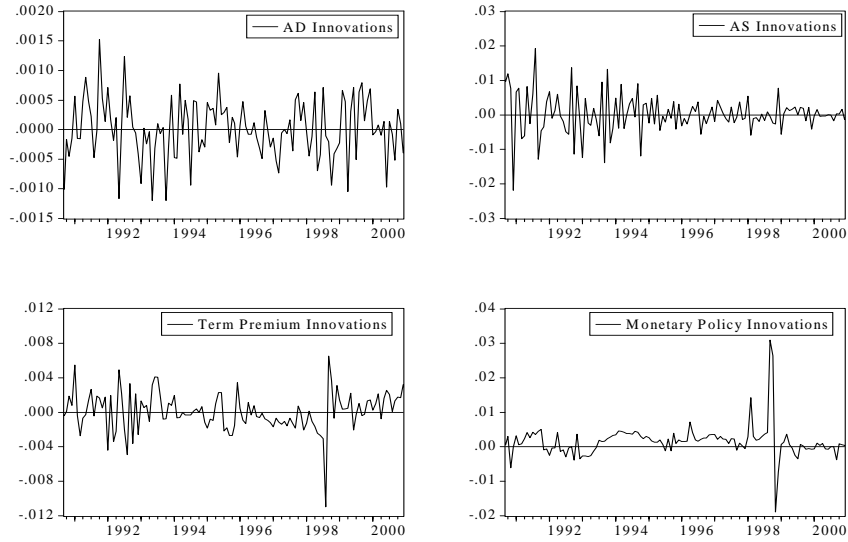
which is an *inflation targeting* loss criterion that mainly penalizes inflation volatility.

In the first exercise, the loss criterion in (13) is computed assuming that the central bank sets interest rates according to equation (9). In this case, the policy response to real exchange rate misalignments, denoted as ρ_q , is $\rho_q = 0.633$. Then we set ρ_q to zero²⁶ and recompute the loss criterion in (13). In this way, it is possible to quantify the advantages (or costs) derived from responding to exchange rate misalignments. This exercise is performed both for individual shocks and for the combination of them. The results are presented in Table 2.

According to the above results, adopting a policy rule like the one in equation (9) reduces welfare losses by 4.6%, well above the gains reported in Leitemo and Sodestrom and in Chapter 3. This order

²⁶The response to output and expected inflation is not modified.

Figure 9: Chile: Domestic Structural Shocks (1990-2000).



of magnitude correspond to what Alexandre *et al* (2002) call substantial gains. This result is robust to the inclusion of an alternative series of monetary policy residuals. In fact, if a zero response to the real exchange rate is imposed, $\rho_q = 0$, the residuals in the monetary policy rule, $\epsilon_{r,t}$, change. This change seems to be marginal (see Figure 11). In addition, if the policy residuals under $\rho_q = 0$ are used in the welfare exercise, the main results do not change. In fact, in this case, adopting a policy rule like the one in equation (9) reduces welfare losses by 4.7% in an all shock scenario. Hence, we conclude that changing the policy response to real exchange rate misalignments from $\rho_q = 0.633$ to $\rho_q = 0$ does not have any significant impact on either the policy residuals or the welfare implications of alternative policy rules.

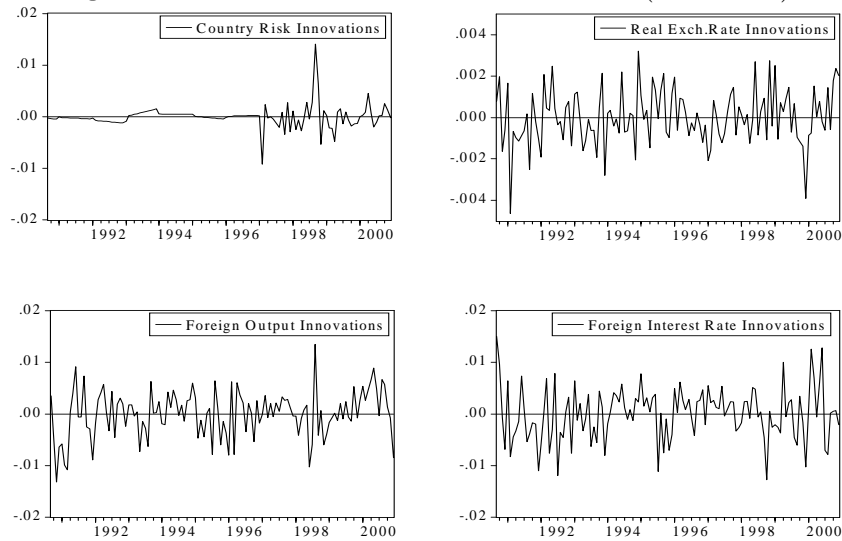
In the following subsections, we analyze the policy performance to individual shocks, domestic and external.

5.1 Policy Performance in Response to Domestic Shocks

For most domestic innovations (the exception being monetary policy shocks), responding to real exchange rate misalignments increases welfare losses (see Table 4.2 third column). In fact, the welfare loss increases in the case of aggregate demand and term premium shocks²⁷ and it remains unchanged for aggregate supply innovations.

²⁷Term premium shocks generate a negligible welfare loss level. Hence the 48.8% increase in welfare loss does not impact the total welfare level.

Figure 10: Chile: External Structural Shocks (1990-2000).



To understand why the policy performance to aggregate demand shocks is poor, Figure 12 shows the dynamic response of the main variables under the two monetary policy rules considered in the previous exercise.

In the baseline scenario, $\rho_q = 0.633$, an aggregate demand shock generates an increase in the interest rate (solid line Figure 12). This increase is, however, smaller than the one in the alternative scenario ($\rho_q = 0$). The reason for this is that, when $\rho_q = 0.633$, the central bank reduces the initial exchange rate appreciation by reducing the interest rate. As a result, the real exchange rate appreciation is also smaller. Now, this lower appreciation keeps output and inflation at higher levels. As a consequence, when $\rho_q = 0.633$, output and inflation become more volatile whereas interest rates and the exchange rate become more stable. Overall, the losses associated with higher volatility in output and inflation dominate the benefits of a more stable interest rate.

On the other hand, in the face of monetary policy shocks, reacting to the exchange rate brings welfare gains. The reason for this can be understood by analyzing the dynamic responses to a monetary policy shock in Figure 13. In this case, an interest rate shock generates a real appreciation and a contraction in output. Now, when $\rho_q = 0.633$, the central bank reduces its interest rate more aggressively in order to stabilize the exchange rate (solid line in Figure 13). As a consequence, the appreciation is reduced and the contraction in output is attenuated. In the end, output and interest become more stable and,

Table 2: Chile: Welfare Loss under Alternative Monetary Policy Rules
(Full Sample: 1990.09-2000.12)

Shock	Loss for $\rho_q = 0$	Loss for $\rho_q = 0.633$	Difference (%)
Aggregate demand ($\epsilon_{y,t}$)	0.020	0.024	18.1%
Aggregate supply ($\epsilon_{\pi,t}$)	0.607	0.607	0.0%
Term premium ($\epsilon_{\rho_n,t}$)	0.000	0.000	40.8%
Monetary policy ($\epsilon_{r,t}$)	1.483	1.390	-6.2%
Country risk premium ($\epsilon_{\varphi,t}$)	0.483	0.438	-9.3%
Real exchange rate ($\epsilon_{q,t}$)	0.443	0.415	-6.3%
Foreign output ($\epsilon_{y^*,t}$)	0.065	0.076	17.7%
Foreign interest rate ($\epsilon_{r^*,t}$)	2.873	2.723	-5.2%
Total Loss (all shocks)	4.718	4.503	-4.6%

eventually, the total welfare loss is reduced²⁸.

5.2 Policy Performance in Response to External Shocks

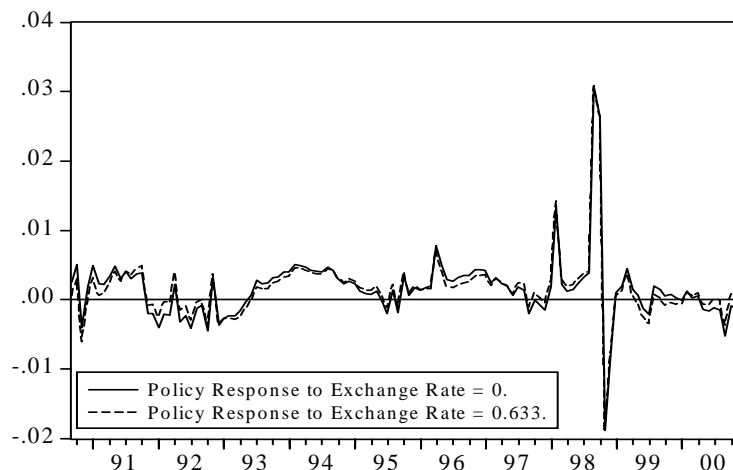
For most of the external shocks, a monetary policy rule like (9) brings welfare gains (see third column in Table 2). In fact, in the face of real exchange rate, country risk, and foreign interest rate shocks responding to exchange rate misalignments generates a more stable path for the real exchange rate, which in turn reduces the volatility of output and inflation. These welfare gains come at the cost of inducing a higher interest rate volatility that is, however, not strongly penalized by the loss criterion in equation (13).

To understand the dynamics behind the previous results, it is useful to analyze the impulse response functions to a country risk shock in Figure 14²⁹. An increase in country risk depreciates the real exchange rate, increasing both output and inflation. In the case in which the central bank reacts to real exchange rate misalignments, the solid line in Figure 14, the policy interest rate increases by more, attenuating the real depreciation and the subsequent expansion of output and inflation. Hence, a policy reaction

²⁸In this case there is a marginal increase in inflation volatility.

²⁹The dynamic response to the other external shocks, foreign interest rate and real exchange rate, is similar to that presented in Figure 14. Hence, for brevity, we do not include a graphical analysis of those shocks.

Figure 11: Chile: Monetary Policy Residuals in Alternative Scenarios



function like (9) attenuates output and inflation volatility³⁰, reducing the welfare loss associated with a country risk shock. The same result holds for exchange rate and foreign interest rate innovations.

Overall, responding to real exchange rate misalignments reduces the impact that external shocks have on output and inflation. In particular, such a response generates a more stable path for the real exchange rate that induces a lower volatility in both output and inflation. In consequence, the welfare losses are reduced.

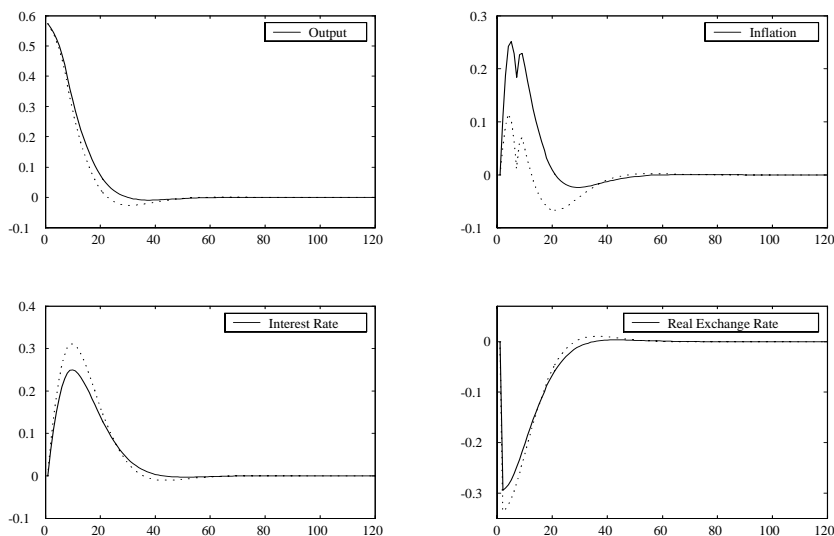
Finally, a more general result in this section is that responding to exchange rate misalignments brings welfare benefits, even though exchange rate volatility does not enter *per se* into the welfare loss criterion (13).

6 External Volatility and the Role of the Exchange Rate

The results presented so far suggest that there are welfare gains from responding to real exchange rate misalignments. These gains are particularly important when the economy is subject to external shocks: country risk premium, foreign interest rate and exchange rate innovations. Given the recent episodes of high volatility in the country risk premium in 1998 (see Figure 10), it is interesting to analyze whether the advantages from responding to exchange rate misalignments are somehow determined by

³⁰Interest rate volatility increases. This, does not offset the gains from a lower deviation in inflation and output.

Figure 12: Chile: Alternative Responses to a one S.D Aggregate Demand Shock



the volatility of the external (and perhaps domestic) innovations. In this section, we investigate this issue in three stages. First, we assess the performance of policy rules in sub-samples with different volatility of innovations. Second, we illustrate how the policy reaction to the exchange rate, ρ_q , may change in the presence of more volatile innovations. Finally, we test whether, in fact, the central bank reacted differently to different external innovations and the consequences of this on welfare.

6.1 Sub-sample Analysis

A visual inspection of Figures 9 and 10, reveals an apparent shift in the volatility of some structural shocks. In particular, it seems that inflation shocks are more stable in the late nineties whereas, in the same period, country risk and domestic interest rate shocks appear to be more volatile. In this subsection, we analyze whether this apparent shift in volatility is significant and the implications that it may have on the performance of alternative monetary policy rules.

To provide a more formal analysis of the apparent shift in volatility, we proceed as in McConnell and Quiros (2000) and test whether the volatility of each shock has experienced a structural break. In particular, for each of the i elements in the vector of estimated innovations, $\epsilon'_{i,t}$, we estimate the following equation

$$\sqrt{\frac{\pi}{2}} |\epsilon_{i,t}| = \alpha_1 D_{1,t} + \alpha_2 D_{2,t} + \mu_t \quad (14)$$

Figure 13: Chile: Alternative Responses to a one S.D. Monetary Policy Shock

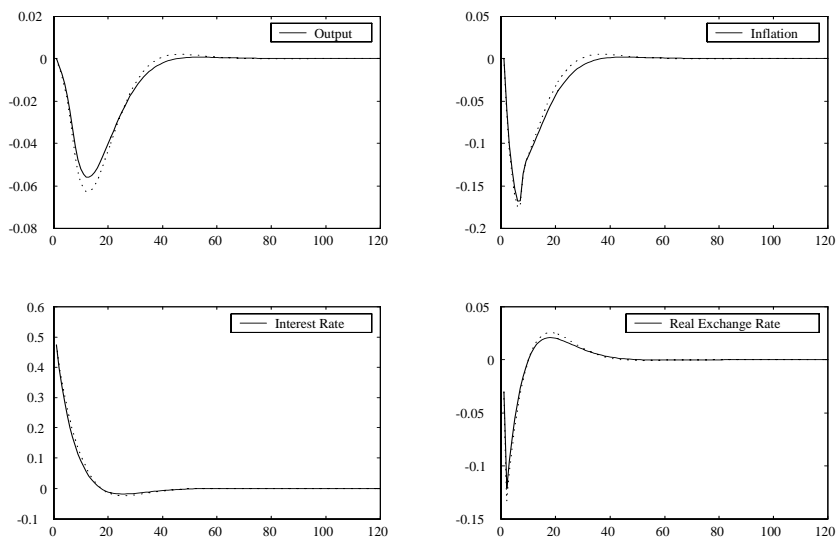
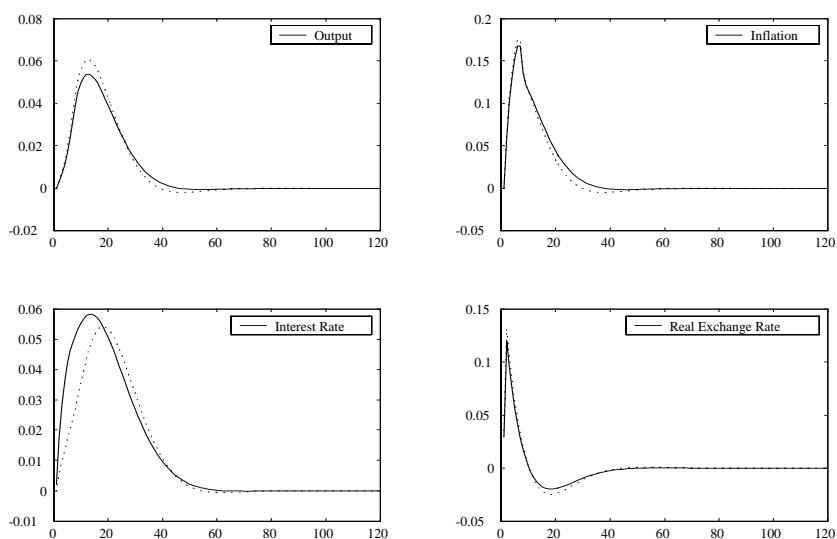


Figure 14: Chile: Alternative Responses to a one S.D. Country Risk Shock



where, as is noted by McConnell and Quiros (2000), $\sqrt{\frac{\pi}{2}} |\epsilon_{i,t}|$ is an unbiased estimator of the standard deviation of $\epsilon_{i,t}$. On the other hand, the dummy variables $D_{1,t}$ and $D_{2,t}$ are defined as

$$D_{1,t} = \begin{cases} 1 & \text{if } t \leq T \\ 0 & \text{if } t > T \end{cases} \quad \text{and} \quad D_{2,t} = \begin{cases} 0 & \text{if } t \leq T \\ 1 & \text{if } t > T \end{cases}$$

and T is the break point date. In this context, if $\alpha_1 = \alpha_2$ we reject the hypothesis that shocks have experienced a volatility shift.

We estimate equation (14) for two break point dates, $T = 1994.12$ that reflects the moment at which the volatility of inflation shocks begins to decline and $T = 1996.12$ that marks the beginning of more volatile country risk disturbances. For both dates the results are similar. However, for $T = 1996.12$ the change in risk premium and domestic interest rate shocks is more important. Hence, since we are interested in analyzing the role of ρ_q in a more volatile external environment, we only present the results for $T = 1996.12$ ³¹. Table 3 shows the standard deviation of each innovation in different samples. It also presents, for each series of innovations, the t -test for the null hypothesis that volatility is the same across samples, $H_0 : \alpha_1 = \alpha_2$.

The results in Table 3 confirm, for standard confidence levels, a shift in the volatility of inflation and country risk shocks. In particular, in the sub-sample 1996.12 to 2000.12, inflation shocks become less volatile while country risk shocks increase their variance substantially. For less conventional confidence levels (80%), monetary policy innovations also become more volatile in this sub-sample.

In terms of the general performance of alternative monetary policy rules, a volatility shift does not change the main conclusion derived in the previous section: that reacting to exchange rate misalignments generates welfare gains. In fact, in the early and late nineties responding to exchange rate misalignments reduces welfare losses by -4.6% and -3.5% respectively (see Table 4 and 5).

The volatility shift affects, however, the total loss associated with particular shocks and the relative advantage of responding to exchange rate misalignments. In fact, when country risk shocks are more volatile the welfare loss associated with this shock increases from 0.341 in the early nineties (Table 4) to 0.594 in the late nineties (Table 5). For this same shock, the relative advantage³² of reacting to exchange

³¹The results, in terms of the performance of alternative monetary policy rules in different samples, do not depend on T .

³²This advantage is measured as the reduction in welfare losses.

Table 3: Chile: Volatility of Structural Shocks
(standard deviation in %)

Shock	Full Sample (1990.09–2000.12)	Early Nineties (1990.09–1996.12)	Late Nineties (1997.01–2000.12)	t-test ($H_0:\alpha_1=\alpha_2$)
Aggregate Demand ($\epsilon_{y,t}$)	0.574	0.575	0.576	0.08
Aggregate Supply ($\epsilon_{\pi,t}$)	6.981	8.633	3.142	25.43**
Term Premium ($\epsilon_{\rho_n,t}$)	0.222	0.205	0.248	0.17
Monetary Policy ($\epsilon_{r,t}$)	0.470	0.251	0.698	1.48*
Country Risk Premium ($\epsilon_{\varphi,t}$)	0.210	0.060	0.328	29.33**
Real Exchange Rate ($\epsilon_{q,t}$)	1.624	1.626	1.632	0.05
Foreign Output ($\epsilon_{y^*,t}$)	5.547	5.707	5.189	1.23
Foreign Interest Rate ($\epsilon_{r^*,t}$)	0.510	0.516	0.503	0.43

** $H_0:\alpha_1=\alpha_2$ rejected at 99%.

* $H_0:\alpha_1=\alpha_2$ rejected at 80%.

rate increases from -5.2% (Table 4) to -12.9% (Table 5). On the other hand, an increase in the volatility of monetary policy shocks also increases the welfare losses associated with this disturbance, from 0.963 to 1.716, and the relative advantage of responding to the exchange rate, from -8.5% to -10.9%. Finally, a lower degree of volatility in inflation innovations reduces the welfare losses from 0.866 to 0.196 without changing the relative advantage of reacting to exchange rate (which is zero).

Table 4: Early Nineties Welfare Loss for Alternative Policy Rules in Chile
(Early Nineties: 1990.09-1996.12)

Shock	Loss for $\rho_q = 0$	Loss for $\rho_q = 0.633$	Difference (%)
Aggregate demand ($\epsilon_{y,t}$)	0.020	0.023	18.3%
Aggregate supply ($\epsilon_{\pi,t}$)	0.866	0.866	0.0%
Term premium ($\epsilon_{\rho_n,t}$)	0.000	0.000	35.0%
Monetary policy ($\epsilon_{r,t}$)	1.052	0.963	-8.5%
Country risk premium ($\epsilon_{\varphi,t}$)	0.360	0.341	-5.2%
Real exchange rate ($\epsilon_{q,t}$)	0.432	0.438	1.2%
Foreign output ($\epsilon_{y^*,t}$)	0.060	0.072	20.1%
Foreign interest rate ($\epsilon_{r^*,t}$)	2.942	2.728	-7.3%
Total Loss (all shocks)	5.893	5.624	-4.6%

6.2 Risk Premium and Nonlinear Response to Real Exchange Rate

One feature of the Chilean monetary policy, reported in Caputo (2003), is that there is a nonlinear policy response to exchange rate misalignments: the central bank reacts more strongly to large real exchange rate misalignments. In this context, a natural question emerges: is it desirable to react more strongly to the exchange rate when external shocks become more volatile? The previous results, in Table 4 and 5, seem to support this view. In fact, we conclude that the *relative advantages* of a positive response to exchange rate, $\rho_q = 0.633$, increase with the volatility of country risk shocks. However, in the previous exercise the ρ_q coefficient is kept constant across samples. Hence, it is not possible to conclude that it is optimal to increase ρ_q when external volatility rises.

In order to determine whether it is optimal to increase ρ_q when innovations become more volatile, we perform a counter-factual exercise. Given the history of shocks, we induce more volatility in some

Table 5: Late Nineties Welfare Loss for Alternative Policy Rules in Chile
(Late Nineties: 1997.01-2000.12)

Shock	Loss for $\rho_q = 0$	Loss for $\rho_q = 0.633$	Difference (%)
Aggregate demand ($\epsilon_{y,t}$)	0.020	0.024	17.1%
Aggregate supply ($\epsilon_{\pi,t}$)	0.196	0.196	0.0%
Term premium ($\epsilon_{\rho_n,t}$)	0.000	0.000	41.3%
Monetary policy ($\epsilon_{r,t}$)	1.927	1.716	-10.9%
Country risk premium ($\epsilon_{\varphi,t}$)	0.682	0.594	-12.9%
Real exchange rate ($\epsilon_{q,t}$)	0.457	0.383	-16.1%
Foreign output ($\epsilon_{y^*,t}$)	0.061	0.073	19.8%
Foreign interest rate ($\epsilon_{r^*,t}$)	1.427	1.261	-11.6%
Total Loss (all shocks)	2.442	2.356	-3.5%

specific innovations³³. Then we compute the value of ρ_q that generates the same welfare loss as in the baseline scenario (no increase in volatility). This exercise considers shocks that have experienced a significant shift in volatility: country risk premium, $\epsilon_{\varphi,t}$, and monetary policy innovations, $\epsilon_{r,t}$. It also considers innovations with no volatility shifts, but with a direct impact on the exchange rate: real exchange rate shocks, $\epsilon_{q,t}$, and foreign interest rate innovations, $\epsilon_{r^*,t}$. Table 6 reports the counter-factual values of ρ_q in each scenario. For the purpose of comparison, it is useful to remember that, originally, $\rho_q = 0.633$.

The above results show a significant departure of ρ_q from its original level. In particular, when country risk and monetary policy innovations (domestic and foreign) become more volatile it is desirable to react more strongly to exchange rate misalignments. On the other hand, a more modest increase in ρ_q is observed in the case of more volatile exchange rate innovations.

The evidence presented so far provides some understanding of why a nonlinear response to the exchange rate, like the one observed in Chile, may emerge. In fact, reacting more strongly to large exchange rate misalignments, induced by larger and more volatile shocks to the interest rate and country risk premiums, is optimal: such a nonlinear response contributes to the stabilization of output and

³³The volatility is increased by 20%. In each case, just one series of shocks is modified. The remaining series of shocks are set to their historical levels.

Table 6: Chile: Counter-Factual Exchange Rate Reaction Coefficients

(Full Sample: 1990.09-2000.12)

Increased Volatility in	Counter-factual value of ρ_q
Country Risk Shocks, $\epsilon_{\varphi,t}$	2.305
Monetary Policy Shocks, $\epsilon_{r,t}$	4.865
Real Exchange Rate Shocks, $\epsilon_{q,t}$	1.140
Foreign Interest Rate Shocks, $\epsilon_{r^*,t}$	2.891

inflation while increasing interest rate volatility.

To illustrate the above argument, Table 4.7 presents the relative performance of two monetary policy rules when country risk innovations are more volatile³⁴ and the rest of the shocks are set to the historical levels. In the first policy rule ρ_q is set to its original level, $\rho_q = 0.633$. In the second one, ρ_q is the counter-factual value of $\rho_q = 2.305$. It is clear that the benefits, in terms of the reduction in output and inflation variance, dominate the costs associated with a more volatile interest rate. Overall when country risk shocks are more volatile, a more aggressive response to exchange rate misalignments reduces welfare losses by 10.1%.

Table 7: Chile: Total Losses for an All Shock Scenario
(standard deviation of country risk shocks, $\epsilon_{\varphi,t}$, is increased by 20%)

	$\rho_q = 2.305$	$\rho_q = 0.633$	Difference
Inflation Variance, σ_{π}^2	1.569	1.875	-37.3%
Output Variance, σ_y^2	0.100	0.160	-16.3%
Interest Rate Variance, σ_r^2	2.531	2.197	15.2%
Total Loss (all shocks)	4.503	5.008	-10.1%

³⁴The conclusions hold for the rest of the innovations in Table 6, hence for brevity we do not present those results.

6.3 Testing Nonlinear Responses to the Components of the Real Exchange Rate

The previous two exercises illustrate how monetary policy may have reacted in a more volatile environment. It is concluded that, when the volatility of some domestic and external shocks increases, a stronger policy response to the exchange rate, ρ_q , is desirable.

In this sub-section we test how the Chilean central bank did react, in practice, to different shocks. To perform this analysis, we substitute the exchange rate equation (4) into the policy reaction function, equation (9). We then estimate explicit policy responses to the various observable shocks to the exchange rate equation. The modified policy reaction function to be estimated is

$$\rho_t = 0.878\rho_{t-1} + (1 - 0.878) [0.785E_t(\pi_{t+15}) + 1.122y_{t-1} + 0.633(g_0E_t(q_{t+1}) + g_1(\rho_t^* - \rho_t) + g_2\varphi_t)] \quad (15)$$

where g_0 , g_1 and g_2 capture the response of the central bank to the observable shocks to the exchange rate equation. If those responses are consistent with a uniform response to the exchange rate, then $g_0 = 1$, $g_1 = d_1 = 1.082$ and $g_2 = d_2 = 2.354$ ³⁵. As in Caputo (2003), we use GMM instrumental variables to estimate equation (15). The results are presented in the second column of Table 8.

Table 8: Chile: Monetary Policy Response to RER Components^a

Coefficients	Baseline Estimates	Estimate with Dummy 98.09-98.10
g_0	1.042** (0.065)	1.039** (0.065)
g_1	7.394** (0.843)	7.305** (0.815)
g_2	16.896** (1.677)	16.770** (1.626)
g_2^1	—	115.833** (6.520)

^aGMM Instrumental Variables: Uses the same instruments as in Chapter 2.

**Significant at 99%.

The response to the expected real exchange rate, g_0 , is not statistically different from one³⁶. However, g_1 and g_2 are considerably larger than d_1 and d_2 respectively. This suggests that, in the face of interest

³⁵See Table 1 for the estimated values of d_1 and d_2 .

³⁶The $H_0 : g_0 = 1$ cannot be rejected at 95% confidence interval.

rate spread and country risk shocks, the response of the central bank was more aggressive than the uniform response to the exchange rate.

To see whether the above result may have been determined only by large external shocks, such as the increase in the country risk premium associated with the LTCM collapse and the Russian financial crisis, we reestimate equation (15) including a multiplicative dummy³⁷ for the country risk variable. The results, presented in the third column of Table 8, suggest that during the period September-October 1998 the policy response to the country risk premium, g_2^1 , was much more aggressive than the response in the rest of the sample, g_2 . On the other hand, the coefficients g_0 , g_1 and g_2 do not change significantly from the baseline estimates.

The preceding result indicates that a more aggressive response to country risk was not determined by a single episode of higher external volatility³⁸ but was a more permanent feature of Chilean monetary policy. This result also indicates that, in response to the 1998 increase in the risk premium, the Chilean central bank deviated substantially from its historical reaction to this type of shock.

In this context, some authors, like Taylor (2001), have suggested that policy rules with an aggressive response to the exchange rate may induce additional volatility in the economy. In consequence, those rules may generate a worse performance. To see whether this is the case in Chile, we analyze the welfare implications of responding more aggressively to country risk and interest rate spread shocks. In particular, we compare the performance of a policy rule with a uniform response to the exchange rate, equation (9), with a policy rule that allows for differentiated responses to each component of the exchange rate, equation (15). The results of such a comparison are presented in Table 9.

The results in Table 9 show that there are significant gains from adopting a more aggressive response to both interest rate spreads and country risk shocks. In fact, this type of response reduces, in an important way, the volatility of inflation and output. Moreover, this more aggressive policy rule changes only marginally the volatility of interest rates. The behavior of the Chilean central bank is fully consistent with the results presented in Table 6. In that case, it was concluded that a more aggressive

³⁷The dummy variable, $dum=1$ in 1998.09 and 1998.10 and it is zero in all other dates. Then, the response to country risk can be expressed as $(1-dum)g_2+dumg_2^1$. In this case, the total response to country risk in 1998.09 and 1998.10 is captured by g_2^1 .

³⁸This result is robust to a more extended sample for the dummy variable. In fact, if the dummy is extended for an additional five months, the estimated value of g_2 does not change significantly.

Table 9: Chile: Total Losses for an All Shock Scenario

	Equation(15)	Equation (4.9)	Difference
Inflation Variance, σ_{π}^2	1.448	1.661	-13.7%
Output Variance, σ_y^2	0.108	0.125	-12.8%
Interest Rate Variance, σ_r^2	2.098	2.112	-0.7%
Total Welfare Loss (all shocks)	4.053	4.503	-10.0%

Equation (4.9): $g_0=1, g_1=d_1=1.082$ and $g_2=d_2=2.354$.

Equation(15): $g_0=1.402, g_1=7.394$ and $g_2=16.896$.

policy response to country risk premium and domestic and external interest rates shocks was desirable if the volatility of such variables increases (which is the case for Chile in the late nineties, see Table 2).

Now, there is evidence that in some particular episodes, the LTCM collapse and the Russian financial crisis in 1998, the response to country risk shocks was even more aggressive. In fact, as shown in Table 8, in that particular episode, the central bank's reaction to country risk increased from $g_2 = 16.896$ to $g_2^1 = 115.833$. Many analysts have criticized this type of reaction on the grounds that it can exacerbate the volatility of the macroeconomic variables without generating any welfare benefit. In particular, Jonas and Mishkin (2003 p.38) call this focus on the exchange rate a serious "policy mistake". In order to see whether this episodic response was indeed destabilizing, we assess the performance of two policy rules. The first one does not contain an episodic response to country risk shocks and hence, $g_2 = 16.896$ in the whole sample (see Table 8, second column). The second policy rule contains an episodic response, $g_2^1 = 115.833$ in the period September-October 1998, and also allows for a more moderate reaction in the rest of the sample, $g_2 = 16.770$ (see Table 8, third column). The results are presented in Table 10.

According to the results in Table 10, a much more aggressive policy reaction in the period September-October 1998 increases welfare losses by 4.1%. In fact, such a reaction induces much more volatility in interest rates, an increase of 14.8%, without reducing the variance of inflation that increases by 0.5%. In this case, there is only a small gain in terms of output stability³⁹.

³⁹Output is more stable because, in the aggregate demand equation, the effects of a more stable exchange rate dominate the negative impacts of a more volatile interest rate. However, if output has a nonlinear reaction to the interest rate, this result may be reversed. In such a case, output will also be more volatile.

Table 10: Chile: Total Losses for an All Shock Scenario

	Equation (15) with dummy	Equation (15)	Difference
Inflation Variance, σ_π^2	1.455	1.448	0.5%
Output Variance, σ_y^2	0.105	0.108	-2.5%
Interest Rate Variance, σ_r^2	2.408	2.098	14.8%
Total Welfare Loss (all shocks)	4.219	4.053	4.1%

Equation(15): $g_0=1.042$, $g_1=7.394$ and $g_2=16.896$.

Equation(15)with dummy: $g_0=1.039$, $g_1=7.305$, $g_2=16.770$ and $g_2^1=115.833$.

The previous subsections show that it is desirable to adopt an aggressive response to some of the components of the exchange rate. In this way, it is possible to reduce the volatility of output, inflation and interest rate. This result does not imply, however, that welfare will increase indefinitely if the central bank becomes even more aggressive. In fact, very large responses to external shocks can exacerbate the volatility of the main macro variables increasing welfare losses. Hence, a monetary policy overreaction to external shocks may be destabilizing.

7 Robustness Exercises

The Chilean monetary policy rule, as described by equation (9), has a good performance in the face of the structural shocks that Chile faced in the nineties. This result is independent of the sample and, for an all shocks scenario, the gains from reacting to the exchange rate are important.

In this section, we test the robustness of our general results. In doing so, we perform three exercises. In the first one, we analyze the performance of the monetary policy rule, equation (9), to random disturbances rather than to the observed shocks. In the second exercise, we derive a policy reaction function that minimizes a criterion like (13) and see whether the exchange rate plays a role in such an optimal policy. Finally, we analyze the robustness of the results according to an alternative welfare loss criterion.

7.1 Policy Performance in Response to Random Shocks

Some of the shocks faced by the Chilean economy were not normally distributed and reflect, in some cases, specific events in which some variables, like interest rates and risk premium, deviated significantly from their average levels⁴⁰. Given the history of such shocks, the monetary policy rule in equation (9) performs well. In this context, a natural question is whether such a policy is still an efficient rule for a different configuration of shocks. In order to address this question, we assess the performance of alternative monetary policy rules in the face of random structural shocks. We perform three alternative exercises.

In the first exercise, we investigate whether the previous result is robust to different assumptions about the way in which shocks are generated. In particular, we generate, for each element in the ϵ_t vector, a series of normally distributed random shocks⁴¹. We set the variance of the shocks according to their historical level. On the other hand, we assume there is no covariance among shocks: in this exercise this covariance is set at zero. Then we compute the welfare criterion, equation (13), under the two alternative policy rules analyzed so far: one that contains the original exchange rate response, $\rho_q = 0.633$, and another in which $\rho_q = 0$. This sequence is repeated 100 times. The motivation for this exercise is that the observed comovement among structural shocks may be a transitory phenomenon and may not reflect a permanent feature of the Chilean economy. For instance, the high correlation between monetary policy and country risk shocks, observed in late 1998, reflects an unusually aggressive policy response to a very volatile external environment. The results, in terms of the welfare losses associated with each random shock, are presented in Table 4.11.

In this exercise, a policy rule that reacts to the exchange rate performs well. In particular, as in the main results of Section 4.5, such a rule generates substantial gains in the face of most of the external shocks. In fact, for country risk, real exchange rate and foreign interest rate shocks that rule has a good performance. For monetary policy shocks, the performance is also good. On the other hand, as before, the performance is poor for the other domestic shocks.

In the second exercise, we assume that the variances and covariances of the random shocks are

⁴⁰See notes in Table 1 indicating which of the shocks failed the normality test.

⁴¹Each random series contains 124 observations. This is consistent with the number of observations in the original estimation sample, 1990.09 to 2000.12. For larger random samples of 1240, 12400 or more observations the results do not change.

Table 11: Chile: Welfare Loss for Random Shocks (No Shock Covariance).
(historical variance of shocks and zero covariance)

Shock	Loss for $\rho_q = 0$	Loss for $\rho_q = 0.633$	Difference (%)
Aggregate demand ($\epsilon_{y,t}$)	0.013	0.011	18.0%
Aggregate supply ($\epsilon_{\pi,t}$)	1.342	1.342	0.0%
Term premium ($\epsilon_{\rho_n,t}$)	0.000	0.000	29.7%
Monetary policy ($\epsilon_{r,t}$)	0.727	0.779	-6.7%
Country risk premium ($\epsilon_{\varphi,t}$)	0.300	0.323	-7.0%
Real exchange rate ($\epsilon_{q,t}$)	0.280	0.289	-3.1%
Foreign output ($\epsilon_{y^*,t}$)	0.073	0.060	21.6%
Foreign interest rate ($\epsilon_{r^*,t}$)	1.958	2.032	-3.7%
Total Loss (all shocks)	2.261	2.325	-2.8%

set according to their historical level. In this way, the random shocks have similar properties to the estimated shocks. In this setup, we can assess whether the covariance among shocks explains the relative performance of a policy rule that reacts to the exchange rate. As before, we generate, for each element in the ϵ_t vector, a series of normally distributed random shocks. The results, in terms of the welfare losses associated with each random shock, are presented in Table 12.

In this scenario, a policy rule that reacts to the exchange rate performs well. The simulations presented here show that, if the relative size and comovements of shocks are kept at their historical levels, a policy reaction function like (9) will perform well. Furthermore, when the comovements are considered, the performance of such a rule improves (compare results in Table 4.11 and Table 12). This indicates that, besides the size of the shocks, their covariance is also an important element determining the advantages of responding to the exchange rate.

The last exercise considers a situation in which the shocks' covariance is set at zero and where all shocks have the same variance of 1%. This means that some of the shocks for which the policy reaction function (9) has bad performance, like aggregate demand shocks, will increase their relative contribution to the total loss. On the other hand, some shocks for which the policy performance is good,

Table 12: Chile: Welfare Loss for Random Shocks (Historical Shock Covariance).
(historical shocks' variance and covariance)

Shock	Loss for $\rho_q = 0$	Loss for $\rho_q = 0.633$	Difference (%)
Aggregate demand ($\epsilon_{y,t}$)	0.012	0.010	18.4%
Aggregate supply ($\epsilon_{\pi,t}$)	1.309	1.309	0.0%
Term premium ($\epsilon_{\rho_n,t}$)	0.000	0.000	29.5%
Monetary policy ($\epsilon_{r,t}$)	0.793	0.848	-6.5%
Country risk premium ($\epsilon_{\varphi,t}$)	0.398	0.418	-4.7%
Real exchange rate ($\epsilon_{q,t}$)	0.246	0.262	-6.1%
Foreign output ($\epsilon_{y^*,t}$)	0.069	0.056	22.3%
Foreign interest rate ($\epsilon_{r^*,t}$)	1.534	1.618	-5.2%
Total Loss (all shocks)	2.266	2.356	-3.8%

like exchange rate shocks, will diminish their relative contribution. Finally, some shocks for which the policy performance is good, like country risk and monetary policy shocks, will increase their relative contribution to the total loss. In this exercise, increasing the policy response to the exchange rate from $\rho_q = 0$ to $\rho_q = 0.633$ reduces the total welfare loss from 12.792 to 12.291 (a percentage reduction in welfare losses of 3.9%). On the other hand, the relative performance in response to individual shocks is the same as the one presented in Table 12 (last column).

As in all previous exercises, a monetary policy rule that reacts to exchange rate misalignments has a good performance. Overall, independently of the size and comovement of the structural shocks, adopting a monetary policy rule that allows for a response to the exchange rate improves welfare if shocks are generated randomly.

7.2 Optimal Policy Reaction Function

The policy rule that has been assessed so far is the estimated reaction function for Chile in equation (9). This policy rule generates welfare gains and, therefore, is more *efficient* than a rule that sets $\rho_q = 0$ and keeps the rest of the coefficients unchanged. The previous result does not necessarily imply, however, that such a rule is the *optimal* one given the welfare criterion in (13) and the history of shocks. In other words, it is possible that another rule, with different coefficients, does perform better. Furthermore, we

have not ruled out the possibility that an *optimal* policy rule is one in which $\rho_q = 0$. To address this issue, we perform a grid search to determine the optimal coefficients in the following IFB rule

$$r_t = \rho r_{t-1} + (1 - \rho) (\rho_\pi E_t(\pi_{t+15}) + \rho_y y_{t-1} + \rho_q q_t) \quad (16)$$

we perform the grid search taking as given the historical series of structural shocks for Chile. The search procedure is same as the one described in Chapter 3 (Appendix C). The optimal coefficients and the relative performance of two alternative policy rules are presented in Table 13.

Table 13: Chile: Optimal Policy Rule Coefficients

Policy Rule	ρ	ρ_π	ρ_y	ρ_q	Loss Function
<i>R1</i> : Rule with $\rho_q = 0$	0.80	3.4	6.2	0.0	2.175
<i>R2</i> : Rule with unrestricted ρ_q	0.78	3.4	5.9	0.8	2.139

According to the above results, the optimal monetary policy reaction function contains a more aggressive response to output and expected inflation than the one observed in practice. In fact, the response to expected inflation increases from $\rho_\pi = 0.79$ to $\rho_\pi = 3.4$ whereas the response to output increases from $\rho_y = 1.12$ to $\rho_y = 5.9$.

On the other hand, the optimal rule shows a high degree of interest rate persistence consistent with the observed monetary policy inertia in Chile. Finally, the optimal policy rule considers a response to exchange rate deviations and, as in equation (9), this response is comparatively less important than the policy reaction to expected inflation and output. The performance of the optimal rule is presented in Table 14.

The optimal policy rule, *R2*, has a good performance in the face of almost every single shock. The exception is the foreign interest rate shock for which the performance is marginally worst.

Although *R2* is superior to the policy rule in equation (9), there are several reasons why the central bank did not adopt *R1* as its policy. The first, and most obvious, reason is that the welfare criterion in (13) does not necessarily reflect the preferences of the Chilean central bank. Second, in this model it is assumed that the monetary authorities know the structure of the economy and can observe and identify

Table 14: Chile: Welfare Loss for the Optimal Policy Rule

Innovation	Loss for R1 ($\rho_q = 0$)	Loss for R2 ($\rho_q = 0.8$)	Difference (%)
Aggregate demand ($\epsilon_{y,t}$)	0.143	0.100	-30.0%
Aggregate supply ($\epsilon_{\pi,t}$)	0.607	0.607	0.0%
Term premium ($\epsilon_{\rho_n,t}$)	0.000	0.000	-27.2%
Monetary policy ($\epsilon_{r,t}$)	0.469	0.389	-17.1%
Country risk premium ($\epsilon_{Risk,t}$)	0.119	0.103	-13.4%
Real exchange rate ($\epsilon_{q,t}$)	0.287	0.231	-19.4%
Foreign output ($\epsilon_{y^*,t}$)	0.315	0.219	-30.5%
Foreign interest rate ($\epsilon_{r^*,t}$)	0.464	0.470	1.2%
Total Loss (all shocks)	2.175	2.139	-1.7%

each shock. As a result, in this model, the central bank can predict, perfectly, the macroeconomic consequences of any given shock. In practice, however, the central bank has only limited information about the structure of the economy and the sources of macroeconomic volatility. In this respect, a less aggressive policy reaction function may be the consequence of uncertainties not captured in this model. In particular, as suggested by Sack (2000), uncertainty about the structural parameters governing the economy may generate a more gradual policy response to macroeconomic shocks. In fact, in this scenario (parameter uncertainty) current policymakers are inhibited by past policy choices, since altering the policy response results in a higher expected variance of the target variables (Sack, 2000 p.246).

7.3 Performance under an Alternative Welfare Criterion

The welfare criterion used so far is an *inflation targeting* criterion that heavily penalizes inflation volatility. This criterion is not derived, explicitly, from the behavior of consumers and firms. Now, we analyze the performance of the monetary policy rule in (9) when an alternative loss criterion is used. In particular, as is shown in Chapter 3, a utility-based welfare criterion penalizes, almost equally, consumption and domestic inflation volatility. This criterion also contains a negative weight on consumption autocovariance (i.e. higher consumption autocovariance reduces welfare losses). This criterion can be expressed as

$$L_1 = \sigma_\pi^2 + \sigma_y^2 - \sigma_{y,y} \quad (17)$$

where the variances of domestic inflation and consumption are approximated by the variance of CPI inflation, σ_π^2 , and output, σ_y^2 , respectively. On the other hand, the consumption autocovariance is approximated by the autocovariance in output, $\sigma_{y,y}$.

The intuition behind the preceding result is that inflation volatility, σ_π^2 , increases the expected disutility from labor, whereas the output variance, σ_y^2 , reduces the expected utility of consumption. In consequence, σ_π^2 and σ_y^2 have a negative impact on welfare. On the other hand, an increase in the autocovariance in output, $\sigma_{y,y}$, tends to smooth the utility of consumption. In fact, when habits are present, the consumer's utility function is less volatile if current consumption and past consumption are highly correlated. Hence, a high value of $\sigma_{y,y}$ increases expected consumer's utility⁴².

Computing L_1 for alternative values of ρ_q in the policy rule equation (9) shows that responding to the exchange rate is welfare improving, for the full sample and two sub-samples (Table 15).

Table 15: Chile: Welfare Loss for an Alternative Welfare Criterion

Sample	$\rho_q = 0$	$\rho_q = 0.633$	Difference (%)
Full Sample	1.771	1.633	-6.1%
Early Nineties	2.415	2.275	-5.8%
Late Nineties	0.657	0.619	-5.8%

Finally, when the optimal coefficients in Table 13 are considered, the results are the same: responding to the exchange rate, $\rho_q = 0.8$, generates a reduction in the welfare loss criterion, L_1 , of -1.4%.

8 Conclusions

In the context of the Chilean economy, a small open economy that pursues inflation targeting, this paper assesses the advantages of introducing exchange rate considerations into the monetary policy design. This question is relevant because, as reported by Schmidt-Hebbel and Tapia (2002) and Caputo (2003),

⁴²For a formal derivation of this result, see Chapter 3 and Appendix D.2.

the Chilean central bank does, indeed, react to exchange rate misalignments. Therefore, assessing the welfare implications of such responses is useful from a policymaking perspective.

In order to perform a welfare analysis, this paper derives and estimates a small-scale macromodel and then it identifies the main sources of macroeconomic volatility. It is concluded that, external shocks were an important source of macroeconomic volatility in the nineties. In this context, a monetary policy rule that considers a response to the exchange rate brings important welfare gains. In fact, responding to exchange rate misalignments reduces the negative impacts that some external shocks have on output and inflation volatility. This reaction increases the variance of the policy instrument, but this effect does not dominate the welfare gains derived from a more stable path for inflation and output. In the face of some domestic shocks, reacting to exchange rate misalignments does not generate welfare gains. In particular, in the face of aggregate demand shocks, responding to the exchange rate exacerbates the volatility of output and inflation.

On the other hand, when the volatility of external shocks increases, it is optimal to respond more strongly to exchange rate misalignments. In fact, a more aggressive response to exchange rate misalignments offsets the negative implications, for output and inflation, of a more volatile external environment. In particular, the volatility of output and inflation is reduced with this more aggressive response to external disturbances that affect the real exchange rate. This latter result may explain why, in practice, it has been observed that the Chilean central bank reacts more strongly to larger exchange rate misalignments than to smaller ones. This result does not imply, however, that welfare will increase indefinitely if the central bank becomes even more aggressive. In fact, even larger responses to external shocks can exacerbate the volatility of the main macro variables, increasing welfare losses. Hence, a policy overreaction to external shocks, like the one observed in 1998, may be destabilizing.

The main conclusions are robust to the sample period and the configuration of shocks. In particular, a monetary policy rule that responds to the exchange rate misalignments performs well in the face of normally distributed random shocks. In addition, the results are also robust to the use of an alternative welfare criterion. In fact, if an approximation to a utility-based welfare criterion is used, responding to exchange rate misalignments improves welfare.

Finally, the optimal policy reaction function is derived. It considers a response to output and inflation but also to the exchange rate. Furthermore, and consistent with empirical findings in Chile

and elsewhere, the optimal policy response to the exchange rate is comparatively smaller than the response to output and inflation.

(Chapter head:)Conclusions and Directions for Future Research

This thesis is a contribution to the literature studying the design of monetary policy in small open economies. In particular, it investigates the role of the exchange rate in the design of monetary policy in emerging economies. In addition, this thesis explores the links between endogenous persistence in the economy and interest rate inertia.

We conclude that, in practice, it is optimal to respond to exchange rate misalignments. In fact, results from calibrated and estimated models for small open economies support this view. In addition, the policy response to exchange rate misalignment is comparatively larger in an emerging economy, like Chile, than in developed countries that also pursue inflation targeting. Furthermore, this response is nonlinear: the Chilean central bank reacts more aggressively to larger exchange rate misalignments. One potential reason for this behavior is that in the face of increasing external volatility, it is optimal to respond more aggressively to exchange rate misalignments. Hence, a nonlinear response is an optimal policy reaction to a more volatile external environment.

A second set of results links the endogenous persistence in the economy to the observed inertia in the monetary policy reaction function. In particular, the advantages of adopting a more inertial policy rule depend on the degree of inflation inertia. In fact, if inflation is more persistent, supply shocks will take longer to die out. As a consequence, inflation deviates from target for more periods and this induces more persistent interest rate responses to supply shocks. Therefore, when inflation is more persistent, it is optimal to increase the inertia in the policy interest rate.

Finally, future research should address some of the issues not covered in this dissertation. In particular, the microfounded models used in this thesis and elsewhere assume that the structural coefficients that characterize the economy are “policy invariant”. That is, those coefficients do not change when alternative monetary policies are adopted. This feature of the microfounded models is very convenient in order to analyze the performance of alternative monetary policy rules within a macroeconomic model. However, it would be interesting to analyze whether some of the structural coefficients change with monetary policy. In particular, it is possible that the proportion of firms that set prices according to a rule of thumb that considers past inflation depends on the way in which monetary policy is conducted. In

fact, if monetary policy is not credible, then economic agents may expect inflation to be more persistent and, therefore, setting prices according to a rule of thumb that considers past information may be an optimal policy. In this respect, the evidence presented in Chapter 4 shows that inflation persistence is more important in Chile than in the European countries analyzed in Gali *et al* (2001). This may provide a motivation to investigate how the structural coefficients in the economy are altered by the monetary policy.

References

- [1] Alexandre, F; Driffill, J; and Fabio Spagnolo “Inflation Targeting, Exchange Rate Volatility, and International Policy Co-ordination” *The Manchester School*, vol. 70, no 4, Special Issue, pp 546-569.
- [2] Agenor and Montiel (1999) *Development Macroeconomics*. Princeton University Press.
- [3] Anderson, G. and Moore, G (1985) “A Linear Algebraic Procedure for Solving Linear Perfect Foresight Models” *Economic Letters*, XVII, pp.247-52.
- [4] Amato, J. and Laubach, T. (2001). “Implications of Habit Formation for Optimal Monetary Policy”. Federal Reserve, Working Paper.
- [5] Ball, L. (1999)“Policy Rules for Open Economies” in Taylor, J. *Monetary Policy Rules*. The University of Chicago Press.
- [6] Batini, N and Haldane, A.(1999) “Forward-Looking Rules for Monetary Policy” in Taylor, J. *Monetary Policy Rules*. The University of Chicago Press.
- [7] Batini, N., Harrison, R., and Millard, S. (2003). “Monetary Policy Rules for Open Economies”.*Journal of Economics Dynamics and Control*. Forthcoming.
- [8] Bernanke, B., Laubach, T., Mishkin, F. and Posen, A. (1999) *Inflation Targeting. Lessons from the International Experience*. Princeton University Press.
- [9] Campbell, J.; Lo, A.and MacKinlay, A. (1999) *The Econometrics of Financial Markets*. Princeton University Press.
- [10] Calvo, G. (1983). “Staggered Prices in a Utility Maximizing Framework”. *Journal of Monetary Economics*, 12, pp.383-98.

- [11] Calvo, G., Reinhart, C. (2002). “Fear of Floating”. *Quarterly Journal of Economics*. vol.177, pp.379-408.
- [12] Caputo, R. (2003) *Three Essays on Monetary Policy and the Exchange Rate*. PhD Dissertation. Cambridge University.
- [13] Chari, W., Kehoe, J. and McGrattan, E. (2000) “Can Sticky Prices Explains Exchange Rate Persistence?” Federal Reserve Bank of Minneapolis Working Papers.
- [14] Christiano, L.; Martin, E.; and Evans, C. (2001) “Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy” *NBER Working Papers* 8403.
- [15] Clarida, R. (2001). “The Empirics of Monetary Policy Rules in Open Economies”. *International Journal of Finance and Economics*. vol. 6, issue 4, pp.315-23.
- [16] Clarida, R.; Gali, J.; Gertler, M.(1998) “Monetary Policy Rules in Practice: Some International Evidence”. *European Economic Review*, June. pp.1033-67.
- [17] Clarida, R., Gali, J., Gertler,M. (2001).“Open versus Closed Economies an Integrated Approach” *American Economic Review*. May. pp 263-67.
- [18] Clarida, R., Gali, J., Gertler,M. (2003).“A Simple Model for International Monetary Policy Analysis” *Journal of Monetary Economics* 49, pp 879-904.
- [19] Dennis, R. (2000). “Optimal Simple Targeting Rules for Small Open Economies” . Federal Reserve Bank of San Francisco *Working Paper*. No 2000-20, December.
- [20] Dennis, R. (2003). “Exploring the Role of the Real Exchange Rate in Australian Monetary Policy” . *The Economic Record*. Vol. 79. No 244, March pp.20-38.
- [21] Dungey, M. ; Fry, R. ; Gonzalez-Hermosillo, B. ; Martin, V. “International Contagion Effects from the Russian Crisis and the LTCM Near-Collapse” *IMF Working Paper*. N.02/74.
- [22] English, W., Nelson, W. and Sack, B. (2002) “Interpreting the Significance of the Lagged Interest Rate in Estimated Monetary Policy Rules”. Federal Reserve Working Paper N.224.
- [23] Favero, C. (2001). *Applied Macroeconometrics*. Oxford University Press.

- [24] Fry, M, Deanne Julius, Lavan Mahadeva, Sandra Roger and Gabriel Sterne (2000). “Key Issues in the Choice of Monetary Policy Framework” in *Monetary Policy Frameworks in a Global Context* Mahadeva, L and Gabriel Sterne (2000). Routledge
- [25] Fuhrer, J. (1997) “The (Un)Importance of Forward-Looking Behavior in Price Specifications” *Journal of Money, Credit and Banking*, Vol.29, N.3, pp.339-50.
- [26] Fuhrer, J. (2000). “Habit Formation in Consumption and Its Implications for Monetary-Policy Models”. *American Economic Review*, June, Vol. 90. n3.
- [27] Fuhrer, J. and G. R. Moore. (1995a) “Monetary Policy Trade-offs and the Correlation between Nominal Interest Rates and Real Output”, *American Economic Review*, 1995, 85 No 1.
- [28] Fuhrer, J. and Moore, G. (1995b) “Inflation Persistence” *Quarterly Journal of Economics*. February pp.128-159.
- [29] Fujii, E. and Chinn, M. (2000) “Fin de Siecle Real Interest Parity”. NBER Working Paper No. W7880.
- [30] Gali and Gertler (1999). “Inflation Dynamics: A Structural Econometrics Analysis”. *Journal of Monetary Economics.*, vol.44, pp.195-222.
- [31] Gali, J.; Gertler, M. and Lopez-Salido J.D. (2001). “European Inflation Dynamics” *European Economic Review*, Vol.45, pp.1237-1270.
- [32] Gali, J. and Monacelli, T. (2002), “Optimal Monetary Policy and Exchange Rate Volatility in a Small Open Economy”. *NBER Working Paper*.
- [33] Gallego, F; Hernandez, L; Schmidt-Hebbel, K. (2002). “Capital Controls in Chile: Where they Effective?” in *Banking, Financial Integration, and International Crisis*. Schmidt-Hebbel and Hernandez (editors).
- [34] Garcia, P; Herrera L.O.; Valdes, R. (2002) “New frontiers for Monetary Policy in Chile”. in *Inflation Targeting: Design, Performance, Challenges*. Loayza, N. and Soto, R. (editors).
- [35] Green, W. (1999) *Econometric Analysis* Third Edition Prentice-Hall.

- [36] Harvey, A. and Jaeger, A.(1993) “Detrending, Stylized Facts and the Business Cycle” *Journal of Applied Econometrics*, 8, pp.231-47.
- [37] Harvey, A.(2002) “Trends Cycles and Convergence” .in *Economic Growth: Sources, Trends and Cycles*. Loayza, N. and R. Soto (editors).
- [38] Jonas, J., and F.S. Mishkin (2003). “Inflation Targeting in Transition Economies: Experience and Prospects”. In M. Woodford (ed.), *Inflation Targeting*. NBER Conference Series. University of Chicago Press.
- [39] Keating, J. (1992) “Structural Approaches to Vector Autorregresions”. Federal Reserve Bank of St. Louise Review, September/October pp.35-57.
- [40] Kozicki, S. and Tinsley, P. (2002) “Dynamic Specifications in Optimizing Trend-Deviation Macro Model”. *Journal of Economic Dynamics & Control*. Vol.26 Issue 9-10, pp.1585-1611.
- [41] Koopman, S.J; Harvey, A.; Doornik and N. Shephard (2000). *STAMP 6.0 (Structural Time Series Analyser and Predictor)*. London: Timberlake Consultants, 2000.
- [42] Landerretche, O., Morande, F., Schmidt-Hebbel, K. (2000) “Inflation Targets and Stabilization in Chile” in *Monetary Policy Frameworks in a Global Context* by Lavan Mahadeva (Editor), Gabriel Sterne (Editor). Routledge.
- [43] Leitemo, K. (2003) “Optimal Perception of Inflation Persistence at an Inflation-Targeting Central Bank”. *mimeo*. Norwegian School of Management.
- [44] Leitemo, K. and Soderstrom, U. “Simple Monetary Policy Rules and Exchange Rate Uncertainty” *Journal of International Money and Finance*. Forthcoming.
- [45] McCallum, B. (2001). “Should Monetary Policy Respond Strongly to Output Gaps?” *American Economic Review*. May. pp.258-62.
- [46] McConnell, M. and Perez-Quiros, G. (2000). “Output Fluctuations in the United States: What Has Changed Since the Early 1980’s?” . *American Economic Review*, Vol. 90, No.5, pp.1464-1476.
- [47] Parrado, E. (2000) “Inflation Targeting and Exchange Rate Rules in an Open Economy”. New York University. Mimeographed.

- [48] Parrado, E. (2001) “External Shock and the Transmission of the Monetary Policy”. *Economia Chilena*. December (In Spanish).
- [49] Parrado, E. and Velasco, A. (2002). “Alternative Monetary Rules in the Open Economy: A welfare Based Approach”. in *Inflation Targeting: Design, Performance, Challenges*. Loayza, N. and Soto, R. (editors).
- [50] Rotemberg, J. and Woodford, M. (1997) “An Optimization-Based Econometric Framework for the Evaluation of Monetary Policy: Expanded Version”. *NBER Technical Working Paper Series*.
- [51] Rudebusch, G. (2002). “Term Structure Evidence on Interest Rate Smoothing and Monetary Policy Inertia”. *Journal of Monetary Economics*, 49. pp.1161-1187.
- [52] Sack, B. (2000). “Does the Fed Act Gradually? A VAR Analysis”. *Journal of Monetary Economics*. Vol.46 pp.229-256.
- [53] Sack, B. and Wieland, V. (2000) “Interest-Rate Smoothing and Optimal Policy: A Review of Recent Empirical Evidence”. *Journal of Economics and Business*, N.52 pp.205-228.
- [54] Schmidt-Hebbel, K. and Werner, A. (2002). “Inflation Targeting in Brazil, Chile and Mexico: Performance, Credibility, and the Exchange Rate”. *Journal of the Latin American and Caribbean Economic Association*. Vol. 2 N.2 pp.31-79.
- [55] Schmidt-Hebbel, K. and Tapia, M. “Inflation Targeting in Chile”. *North American Journal of Economics and Finance*. vol 13. pp.125-146.
- [56] Svensson, L. (1997) “Inflation Forecast Targeting: Implementing and Monitoring Inflation Targets”. *European Economic Review*. (41) pp.1111-1146.
- [57] Svensson, L. (1998). “Open-Economy Inflation Targeting”. *Working Paper IISE*.
- [58] Svensson, L. (2000). “Open-Economy Inflation Targeting”. *Journal of International Economics*, February.
- [59] Smets, F. and Wouters, R. (2002). “An Estimated Stochastic Dynamic General Equilibrium Model of the Euro Area”. *ECB Working Paper Series*. No. 171.

- [60] Taylor, J. (1999) “The Robustness and Efficiency of Monetary Policy Rules as a Guidelines for Interest Rate Setting by the European Central Bank.” *Journal of Monetary Economics*, June. pp.655-79.
- [61] Taylor, J. (2001). “Using Monetary Policy in Emerging Market Economies”. Mimeo Stanford University.
- [62] Taylor, J. (2001). “The Role of the Exchange Rate in Monetary-Policy Rules” *American Economic Review*. May. pp 263-67.
- [63] Valdes, R. (1997). “The Transmission of Monetary Policy in Chile”. Central Bank of Chile. *Working Paper*.
- [64] Valdes, R. and Bennett, H. (2001) “Terms of Trade for Chile a Monthly Series” Central Bank of Chile. Working Paper.
- [65] Vitale, P. (2003). “Foreign Exchange Rate Intervention: How to Signal Policy Objectives and Stabilize the Economy”. *Journal of Monetary Economics*. Vol.50. Issue 4. pp.841-870.
- [66] Wadhvani (2000) “The Exchange Rate and the MPC: What can we do?” Bank of England, May 2000.
- [67] Woodford, M. (1999). “Optimal Monetary Policy Inertia”. *NBER Working Paper* 7261.
- [68] Woodford, M. (2002) “Inflation Stabilization and Welfare” *mimeo* Princeton University.

A Data

We use monthly time series from 1985.01 to 2002.04. The data are⁴³;

y_t : log IMACEC⁴⁴ (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)).

⁴³Most data are available from the CCB’s webpage; www.bcentral.cl . Alternatively, the data are available, on request, from the author.

⁴⁴The IMACEC is a monthly indicator of economic activity, which covers over 90% of Chilean GDP.

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: Valdes and Bennett (2001)).