An Analysis of Devaluations and Output Dynamics in Latin America Using an Estimated DSGE Model

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Abstract

This paper analyses the effects of currency devaluations on output in Chile, Colombia and Mexico using an estimated DSGE model. The model assesses the relative importance of two main transmission channels: the expenditure-switching and the balance sheet effects. Maximum likelihood estimates of the model for these economies indicate that on average during the last two decades explicit devaluationary policy shocks have been expansionary in terms of output. In other words, the expenditure-switching effect has dominated the contractionary balance sheet channel. Results also show that the balance sheets effect has been weaker during the last two decades in Mexico than in Colombia or Chile. Finally, the paper shows that the popular view that devaluations are contractionary fails to take into account the specific source of the shock that triggers an equilibrium response of the exchange rate. Specifically, it is shown that adverse external shocks, such as sudden-stops, rather than the exogenous devaluationary policy shocks account for the output collapses observed in the region

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1. INTRODUCTION

Latin America has a long history of sudden and large currency devaluations. These episodes have frequently been associated with severe output contractions. For this reason, many economists have argued that devaluations are contractionary, in clear contrast with standard macroeconomic theory which predicts that devaluations should be expansionary. Such expansionary outcomes should mainly be the result of the expenditure-switching effect. However, the unfolding of financial crises during the last decade have put into question the importance of this channel. In fact, following the Asian crises, Krugman (1999) argued that contractionary effects could occur due to the impact of devaluations on firms' balance sheets. According to this mechanism, if firms' revenues are denominated in local currency (pesos) while their debts are denominated in foreign currency (dollars), then unexpected devaluations may deteriorate firms' balance sheets. This in turn weakens their capacity to borrow and invest, inducing output to fall.

From an empirical point of view, the relevance of these transmission mechanisms are yet not well understood. Using cross-country analysis, Gupta et al (2003) and Tovar (2004) have shown that nearly half of the large devaluationary episodes in developing countries between 1970 and 2000 where expansionary, while the remaining half were contractionary. However, these studies fail to isolate the specific mechanism that explains when a devaluation is expansionary and when contractionary. Employing a non-parametric reduced-form econometric technique, Magendzo (2002), concludes that the link between devaluations and output vanishes once selection bias is controlled for. Possibly, he argues, because different transmission channels cancel out.[1] The limitations of such studies to identify and isolate the different transmission channels involved in devaluationary episodes justifies the use of a dynamic stochastic general equilibrium model (DSGE) to study how currency devaluations affect output dynamics.

This paper estimates a DSGE model to assess the impact of currency devaluations on output in three Latin American economies, Chile, Colombia and Mexico. Its objective is to disentangle the importance of the various transmission channels through which devaluations affect output. For this purpose, the microfounded model developed by Tovar (2005) is estimated using maximum likelihood econometric methods. Such model is chosen because it embeds both the expansionary effects associated with the expenditure-switching mechanism as well as the contractionary effects arising from the balance sheet effect. The model also allows to identify the effects of an explicit and exogenous devaluationary policy shock. In this manner, it allows on the one hand to isolate the effects of devaluations arising from any other shocks that may hit the economy and, on the other, to assess whether sharp output contractions are more likely to be the result of adverse external shocks, such as sudden stops, rather than the outcome of currency devaluations. This last point is relevant as it reflects an important feature of the paper. More precisely, the framework distinguishes equilibrium exchange rate movements arising from different shocks that hit the economy from explicit devaluationary policy shocks, which are conceptualized in this paper as an explicit policy decision.

The main results of the paper are the following. First, parameter estimates and impulse response analyses indicate that during the last two decades explicit and exogenous devaluationary policy shocks, ceteris paribus, have been on average expansionary in terms of output. This implies that the contractionary balance sheet transmission mechanism has been dominated by the expenditure-switching effect. Across countries it is found that on average the balance sheet effect has been weaker in Mexico than in Chile or Colombia. Second, variance decomposition analysis show that devaluationary policy shocks account up to 29% of the one-quarter-ahead forecast error variance of output in Colombia and up to

1 See Tovar (2004) and Agenor and Montiel (1999) for a detailed review of the empirical literature.

19% in the case of Chile. In the case of Mexico devaluationary policy shocks have significant less importance possible reflecting the longer history of a floating exchange rate regimes. In all three countries the effects of devaluationary policy shocks on output are found to be transitory. In addition, devaluationary policy shocks are found to account for about 67% of the one-quarter-ahead forecast error variance of the nominal exchange rate in Colombia, while in Chile such shocks account for a non-negligible 25% and in Mexico 12%. This estimates also suggest to some extent a "fear of floating" behavior in these economies. Third, the analysis of the model highlights the importance of distinguishing among the effects of different shocks when assessing the effects of devaluations on output. In fact, impulse response analyses show that negative correlations between the nominal exchange rate and output occur when different shocks hit the economy but not when the monetary authority decides to devalue the currency. In fact, it is shown that a negative correlation between exchange rate and output does occur as a result of an adverse external shock, such as a sudden stop. This negative correlation between exchange rate fluctuations and output following an adverse shock possibly explains why it is commonly argued that devaluations are contractionary. The problem with such statement is that it fails to distinguish among fluctuations of exchange rate associated to different shocks and those resulting from an explicit policy decision. Overall, failure to make this distinction may explain why the empirical literature has been unable to provided conclusive answers on the devaluation-output relationship.

The paper makes several methodological contributions. First, it applies a DSGE model in Latin America to the study the impact of devaluations on output and to explicitly evaluate the relevance of the different transmission channels involved. [2] Second, the methods employed in the paper provide estimates on relevant parameter values that can be used for further research in the region, such as the calibration of DSGE models. Third, it illustrates the usefulness of these models for policy purposes. In particular, as a tool to disentangle the effects of different shocks that hit an economy, or to identify the effects of different transmission channels.

The task of constructing and estimating a DSGE model is challenging by its own right. However, it is possibly more so for a Latin American economy. There are at least three reasons for this. First, most of these economies have experienced deep structural transformations during the last two decades, including major shifts in their degree of trade and financial openness, in their monetary policy frameworks, and in their exchange rate regimes. Such changes are not easily captured within a theoretical framework and, therefore, not easy to control for when taking the model to the data. Furthermore, partly as a result of such structural changes some key variables have experienced a trending behavior, which are not easily explained within a theoretical framework.[3] Second, these economies have been exposed to severe external shocks which have triggered sharp business cycles. This creates at least two kinds of problems. On the one hand, the effects of large but low probability events can be difficult to capture in a model or in the empirical estimation. On the other hand, standard tools to solve such models (eg log-linearization) may understate the importance and impact of certain shocks. Finally, quarterly time series data for the economies in the region have a relatively short span, thus limiting the possibility of applying certain tests for parameter stability that could capture changes in the relevance of different transmission channels. A suitable model that is to be taken to the data to fit a Latin American economy must take all these features into account (and probably more). However, for the purpose of this paper the challenge of using a DSGE framework does not end here. The paper also attempts to make a cross-country comparison of the model. This requires the model to be as flexible as possible to fit simultaneously the

[2] DSGE models are only starting to be employed for the analysis of economic problems in the region. For instance, Hamman et al (2005) quantify the cost of disinflation in Colombia. The model is calibrated and validated using spectral analysis. Medina and Soto (2005a) calibrate a DSGE model to analyse and simulate the Chilean economy, while Medina and Soto (2005b) estimate a model to analyze the impact of oil shocks in the chilean economy.

[3] An example of this is that all the economies in the region have seen large and persistent declines in inflation since the 1990s.

different characteristics and dynamics of the three economies studied.

For all these reasons, and in addition to examining the output dynamics of devaluations on output, the paper should be seen as an exploratory exercise that fulfills two main purposes. First, it should be a step forward into showing the usefulness of such models for policy analysis in the region. Second, it highlights the difficulties associated with the modelling of monetary and exchange rate policies in a changing economic environment, such as that seen in Latin America.

The rest of the paper is organized as follows. Section 2. provides an overview of monetary an exchange rate policies in Chile, Colombia and Mexico during the last two decades. Section 3. presents the DSGE model. Section 4. presents the econometric framework to estimate the model and describes the data employed. Section 5. presents the parameter estimates and evaluates the model using impulse response functions and variance decompositions. The robustness of the model's implications are evaluated by analyzing impulse responses of the economies to adverse external shocks. Section 6. checks the robustness of the results by considering the possibility of model misspecification. In particular, the model is estimated once measurement errors are added. Finally, Section 7. concludes.

2. MODELLING LATIN AMERICAN ECONOMIES

Studying the effects of devaluations on output in Latin America using a DSGE model requires a careful consideration of the features of these economies. First, the output dynamics following a devaluation is determined by the monetary and exchange rate regimes currently in place. However, in the region, both the monetary and exchange rate arrangements have been evolving during the last two decades. In fact, as is well known, each economy went through a stabilisation process which brought inflation down from very high inflation levels in the early 1990s to single digit ones nowadays. Such stabilisation was achieved by relying on different monetary and exchange rate regimes not only within countries but also across countries over time.[4] As a result, a model that is to be taken to the data to fit the dynamics of these economies must be flexible enough to capture both the shifts in monetary operating procedures while simultaneously allowing for different exchange rate regimes.

Second, it is necessary to decide which are the most important transmission channels involved during devaluationary episodes. More precisely, both expansionary and contractionary channels need to be included into the model. One transmission mechanism is the expenditure-switching effect, which is considered in the theoretical literature to be one of the main expansionary channels through which currency devaluations operate. According to it a devaluation lowers the relative price of domestically produced goods vis-a-vis foreign produced ones. The resulting shift in domestic demand towards domestically produced goods induces output to expand. Regarding the contractionary channel, the focus will be on the one highlighted by the recent theoretical and empirical literature: the balance sheet effect. According to it, when firms' revenues are denominated in domestic currency while its liabilities are denominated in foreign currency, then unexpected devaluations worsens their balance sheets, and therefore their capacity to borrow an invest, thus forcing output to fall. The emphasis on the balance sheet effect, which highlights the role of wealth effects, contrasts with the older literature (written during the 1970s and 1980s) which stresses the role of income effects (see Agénor and Montiel (1999) and Krugman and

[4] From an institutional perspective grating independence to central banks for the conduct of monetary policy was also essential. The Banco Central the Chile was granted autonomy in 1990. Its new new charter defines the central bank´s objective as that "to ensure the stability of the currency system and the due payment of both domestic and foreign debts". Colombia´s central bank was granted independence by the new Constitution in 1991. The Constitution and the law entrusted the central bank to "defend the purchasing power" of the domestic currency and to preserve the stability of the financial system. Banco de Mexico became independent after the 1993 constitutional reform. The reformed reinforced as the main objective of the central bank the preservation of the purchasing power of the currency.

Taylor (1979)). Of course, other transmission channels could also be introduced into the analysis (eg an export competitiveness channel) however, for the sake of simplicity I only focus on the two mechanisms mentioned earlier.

Finally, an important consideration is whether Latin American economies can be modelled as small open economies. This is not a mute point given that in the past Latin America was characterised by closed current and capital accounts. Given the time span over which the model will be estimated, 1989-2005, the answer is that such economies should be modelled as open. In fact, it was precisely during this period that structural reforms led to the opening of trade and capital accounts in the region. [5]

The evolving nature of monetary and exchange rate arrangements in Chile, Colombia and Mexico during the last two decades deserves a careful discussion, in particular, given the impact that such arrangements have on the transmission of devaluations to output. In what follows, I briefly discuss some of the key changes implemented by these countries since the early 1990s.

2.1 Monetary and Exchange Regimes

2.1.1 Chile

The Central Bank of Chile adopted an inflation target in 1990. This policy objective complemented an exchange rate target that operated from 1984 through 1999 (Schmidt-Hebbel and Werner (2002)).[6] During the 1990s the Central Bank relied on the use of a crawling exchange rate band system. The band and width of the crawling-peg was periodically adjusted to reflect any difference between domestic and foreign inflation, and intra-band interventions by the central bank were frequent during this period. However, managing the Chilean peso became a very difficult task during the 1990s due to the conflict created by the objectives of reducing inflation through an inflation target while maintaining the exchange rate band. This became evident in 1998, when speculative attacks lead to sharp currency depreciations that put under risk the inflation objective. The tight defense of the peso, reflected by an aggressive restriction of liquidity, and the widening of the band avoided an "earth-quake" depreciation.

The conflicts arising from having two objectives led in 1999-2000 to the adoption of a full-fledged inflation targeting (IT) regime. The exchange rate band system was also replaced by a floating regime. Of course, this implied abandoning de facto any sort of exchange rate targeting. Since then the central bank has avoided any interventions in the foreign exchange market. In fact, the central bank has only intervened twice in the foreign exchange market, in 2001 and 2002 (De Gregorio and Tokman, 2005). This has led some analysts to argue that after September 1999 Chile has been immune to the "fear of floating" syndrome.

2.1.2 Colombia

Starting in 1967 Colombia employed a crawling-peg system to manage its exchange rate. In 1991 the system began to operate as an implicit exchange rate band, which became explicit in 1994.[7] During the exchange rate band system the central bank actively intervened in the exchange market. In fact, the limits of the band were tested several times, in particular between 1998 and 1999. The financial

5 It is worth pointing out that both Chile and Colombia relied on the use of controls on capital inflows during the 1990s. This inflows were oriented to reduce short-term speculative capital flows. See De Gregorio et al (2000) and Ocampo and Tovar (2003).

6 The Central Bank of Chile also sought to achieve a sustainable current account. Until 1995 it set a range of 2 to 4% of GDP. Then until 1998 it set a range of 4 to 5%. The goal was assymetrical generating more concern when the CA deficit threatened to exceed the ceiling (Morande, 2003).

7 See Villar and Rincón (2001) for a detailed account of exchange rate policies in the 1990s.

stress at that time together with the eroded credibility of the band system finally led to the adoption of a floating exchange rate regime in November 1999. Despite the adoption of this flexible exchange arrangement, Colombia has been an example of the "fear of floating" syndrome. Indeed, the central bank has continued to actively intervene in the foreign exchange market. This has been done for three main reasons. First, to avoid excessive movements of the nominal exchange rate in a manner consistent with achieving the inflation target. Second, to strengthen the international liquidity position of the country by accumulating foreign reserves. And finally, to moderate excessive and abrupt movements of the exchange rate from its recent trend (See Uribe and Toro (2005)).

In turn, monetary policy was conducted in the early 1990s by setting an inflation target. To meet its target the central bank relied on the use of intermediate monetary targets. In the second half of the 1990s the central bank slowly altered its operational framework of both its exchange and monetary instruments. The shift in the operational framework was evident during the late 1990s, in particular in 1999, when the central bank started to signal its monetary policy stance through the use of the level and structure of its reference interest rates.[8] Notwithstanding, during this period monetary policy was fully tied to the defense of the exchange rate band, which led to pronounced interest rate hikes in 1998 and 1999. The move to a floating exchange regime thus created the conditions necessary to adopt an IT regime in October 2000 which still remains in place today.

2.1.3 Mexico

Mexico adopted a moving band exchange rate system in 1991, which remained in place until early 1994. At that time, a number of shocks pushed the exchange rate to the ceiling of the band and during the rest of that year the exchange rate operated effectively as a pegged exchange rate. The now well-known events that took place in December 1994 (ie Tequila crises) forced the authorities to abandon this system.[9] As a result, in 1995 a floating exchange rate regime was adopted. This meant that the exchange rate would no longer act as a nominal anchor for the economy.

The large devaluation of 1994-1995 and the increasing inflationary pressures undermined the central bank's credibility. Strong criticisms about the lack of transparency in the conduct of monetary policy led the Mexican authorities to adopt a visible anchor: a monetary growth target. Furthermore, concerns about the risks of using interest rates as an instrument of monetary policy motivated the use of borrowed reserves (corto) as its main monetary policy instrument. This meant that the exchange rate and interest rate were determined completely by the market (See Schmidt-Hebbel and Werner (2002) and Martinez at al (2001)). Relying on this instrument the central bank was able to send signals to the market, without determining specific levels for interest rates or exchange rates.[10]

In 1998 the monetary policy framework started a gradual shift towards a full-fledged IT regime. As a result, the monetary base became less relevant while the inflation target gained importance in the conduct of policy. Inflation targeting was officially implemented in 1999. However, the Bank of Mexico

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[8] It is worth mentioning that in 1997 an interbank interest band was introduced to provide some stability for interest rates.

[9] See Sachs et al (1996) for a detailed account of the events that led to the collapse of the Mexican peso in 1994.

[10] Under this framework, the central bank intervenes every day in the money market through auctions, credits, deposits, or transactions with government paper, either directly or through repos. The central bank then sets the amount to auction such that the aggregate level of borrowed reserves in the banking system starts the followoing day at the level predetermined. The signal regarding its monetary policy intention is then determined by the target level of borrowed reserves for the start of the follwoing day. A zero borrowed reserve target would mean that the central bank will satisfy at market interest rates the money demand. A negative target would leave the money market short and would indicate that the bank is not willing to provide liquidity to the banking system at market interest rates, forcing banks to obtain required reserves through overdrafts on their current accounts. This would force an increase in the interest rate and would signal a restrictive monetary policy. See Martinez et al (2001).

has not abandoned its quantitative instrument of monetary policy (corto). Only recently, in August 2005, did the central bank start relying on a policy rate target (the 1 day overnight rate cete or tasa de fondeo) as its main monetary policy instrument.

Foreign exchange policy in Mexico has evolved by moving from discretionary interventions in the foreign exchange market in 1995 to a current policy of automatic mechanisms aimed at managing international reserves while minimizing the impact on the foreign exchange market. Mexico did intervene between 1995 and 1998 in a sporadic manner reflecting concerns of the emergence of speculative bubbles in the foreign exchange market. Such interventions were often complemented with a restrictive monetary policy stance (See Sidaoui (2005)). In addition, between 1996 and 2001 the financial authorities pursued a policy of replenishing the stock of international reserves. This meant that up until the adoption of the inflation targeting regime the exchange rate played a focal role in determining the price level.

2.1.4 Implications

The experience of Chile, Colombia and Mexico illustrate the significant swings in monetary polices and exchange rate regimes. In fact, since 1989 these countries have employed the full range of exchange rate regimes, that is, from virtual pegs to fully flexible regimes, moving through crawling pegs, exchange rate bands and dirty floating regimes. Furthermore, monetary policy has relied on different intermediate operating targets (eg interest rates, exchange rates and monetary targets) to achieve different goals, such as maintaining the purchasing power of the currency or price stability.

For modelling purposes, two lessons are worth considering. First, there is no unique manner to model monetary policy across countries and neither within countries over time. As a result, an ideal model should be able to accommodate for both the monetary and exchange rate regimes shifts over time. Second, the exchange rate has been a central objective of monetary authorities in all three countries at some point in time, although certainly less in recent years, and less so in Mexico and Chile than in Colombia. However, all three countries did experienced at some point certain degree of "fear of floating". In other words, during some episodes central banks intervened in the foreign exchange market despite the announcement that they would allow the currency to float freely. Overall, these considerations are taken into account when modelling monetary policy.

3. THE DSGE MODEL

The model employed is the one developed by Tovar (2005), which expands upon the one used by Céspedes, Chang, and Velasco (2004 and 2003). The model introduces several extensions aimed at making the model more realistic to fit the data. The model consists of four type of agents: firms, households, entrepreneurs, and a monetary authority. A continuum of monopolistically competitive firms rent capital from entrepreneurs and labor from households, and produce in each period a distinct perishable good. Each household has monopoly power over its own type of labor and faces a demand for its labor from firms. As a result of the monopolistic competition assumption, both firms and households operate setting prices and wages, respectively. This introduces the possibility of nominal rigidities, which take the form of price and wage adjustment costs.[11] Entrepreneurs, which introduce the balance sheet effect, rent capital to firms and borrow from abroad to finance new capital. The economy as a whole faces no trade barriers and capital flows are allowed. However, imperfections in international capital markets

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[11] In contrast with Cespedes, Chang, and Velasco (2004 and 2003) these rigidities are endogenously determined.

associated with informational asymmetries give rise to a risk premium that must be paid in addition to the international risk free interest rate to borrow money from abroad.

The economy is subject to eight different shocks. Firms face technology and cost-push or mark-up shocks. Households face a preference shock that enters the Euler equation linking consumption with the real interest rate. International disturbances arise from shocks on export demand or from the international risk free interest rate. Finally, the interest rate rule is subject to three type of shocks: on the inflation, the output, and the nominal exchange rate targets. This last shock is key in the analysis as it is meant to capture a devaluation of the nominal exchange rate.

3.1 Domestic Production: The Firms' Problem

The production of each variety of domestic goods is carried out by a continuum of monopolistically competitive firms indexed by $j \in [0,1]$. Each firm rents capital, K_{jt}, at a rental rate R_t, and hires labor services, L_{it}, from a continuum of heterogeneous workers indexed by $i \in [0,1]$, at a nominal wage rate W_{it} to produce home goods. Each firm chooses the price of the good it produces and its labor and capital demands, given the demand function for its own goods, aggregate demand and the aggregate price level.

It is assumed that it is costly for firms to reset prices due to the presence of quadratic adjustment costs as captured by equation (5) below.[12] The specification adopted shows the percentage cost in terms of output of changing the price level. The cost size is a function of the parameter, ψ_p, and increases with the size of the price change and overall level of economic activity.[13] Intuitively, firms pay an adjustment cost if the increase in the price exceeds the steady-state gross inflation rate of domestic goods, $\bar{f}^p$. For simplicity, these adjustment costs are set to zero at steady state. The problem faced by each firm is summarized by:[14]

$$\underset{L_{jt},K_{jt}}{Max}\, E_o \sum_{t=0}^{\infty} \Delta_t \left(P_{jt}Y_{jt} - \int_0^1 W_{ijt}L_{ijt}di - R_tK_{jt} - P_tAC_t^P \right) \tag{1}$$

s.t.

$$Y_{jt} = A_t K_{jt}^{\alpha} L_{jt}^{1-\alpha}, \quad 0 < \alpha < 1 \tag{2}$$

$$L_{jt} = \left[\int_0^1 L_{ijt}^{\frac{\sigma-1}{\sigma}} di \right]^{\frac{\sigma}{\sigma-1}}, \quad \sigma > 1 \tag{3}$$

$$P_{jt} = \left[\frac{Y_{jt}}{Y_t} \right]^{-\frac{1}{\theta_t}} P_t, \quad \theta_t > 1 \tag{4}$$

$$AC_t^P = \frac{\psi_p}{2} \left[\frac{P_{jt}}{P_{jt-1}} - \bar{f}^p \right]^2 Y_t \tag{5}$$

where Δ_t is the firm's stochastic discount factor. The production function captured by equation (2) is Cobb-Douglas with a multiplicative technology shock captured by the parameter A_t, which is assumed to be common to all firms in the country and subject to shocks. As in the real business cycle literature,

12 An alternative approach to model price rigidities is Calvo's (1983) staggered price setting. Rotemberg (1982) shows that a model with quadratic adjustment costs is equivalent, as far as aggregates are concerned, to a model such as Calvo's (1983). Empirical papers such as Kim (2000), Bergin (2004 and 2003) and Ireland (2004 a,b and 2001) all use this quadratic adjustment approach.

13 Why are prices and not quantities the ones that incur in adjustment costs? The explanation is one of information costs. Price changes must be made known to consumers, but this need not be the case for quantities changes (see Kim, 2000).

14 The present formulation implies a dynamic profit maximization problem associated to the presence of price stickiness rather than the static profit maximization problem in Cespedes, chang and Velasco (2004 and 2003).

A_t follows a first-order autoregressive process:

$$\ln A_t - \ln \overline{A} = \zeta_A \left(\ln A_{t-1} - \ln \overline{A} \right) + \varepsilon_{At} \tag{6}$$

where $0 < \zeta_A < 1$ and $\varepsilon_{At} \sim N\left(0, \sigma_A^2\right)$ is serially uncorrelated. A_t is observed at the beginning of period t.

The labor input captured by equation (3) is a C.E.S. aggregate of heterogenous labor services. Hence, σ is the elasticity of demand for worker i's services. In addition, firms face a demand for their products from domestic consumers, entrepreneurs and foreign consumers captured by (4). P_t stands for the aggregate price index for domestically produced goods. The index is defined in the next subsection.

There is a random shock to the elasticity of substitution between different varieties of goods, θ_t. Known also as a mark-up or cost-push shock, it follows a first-order autoregressive process:

$$\ln \theta_t - \ln \overline{\theta} = \zeta_\theta \left(\ln \theta_{t-1} - \ln \overline{\theta} \right) + \varepsilon_{\theta t} \tag{7}$$

where $0 < \zeta_\theta < 1$ and $\varepsilon_{\theta t} \sim N\left(0, \sigma_\theta^2\right)$ is serially uncorrelated. Its relevance is that it provides an additional source of output and inflation fluctuations different from that of a technology shock alone. Following Galí (2003) it can be rationalized as the consequence of a firm's periodic attempts to correct the misalignment between actual and desired mark-ups.[15]

Observing that P_{jt} is a function of output, which in turn is a function of capital and labor and defining for convenience $r_t \equiv \frac{R_t}{Q_t}$ and $w_t \equiv \frac{W_t}{Q_t}$, where Q_t is the economy's overall price index (defined in the next subsection), yields the first-order conditions with respect to capital and labor, respectively:

$$r_t = \alpha \left[1 - \frac{1}{e_{jt}^Y} \right] \frac{Y_{jt} P_{jt}}{K_{jt} Q_t} \tag{8}$$

$$w_t = (1 - \alpha) \left[1 - \frac{1}{e_{jt}^Y} \right] \frac{Y_{jt} P_{jt}}{L_{jt} Q_t} \tag{9}$$

where the minimum cost of a unit of aggregate labor L_{jt} and aggregate labor cost are given respectively by $W_{jt} = \left[\int_0^1 W_{ijt}^{1-\sigma} di \right]^{\frac{1}{1-\sigma}}$, $W_{jt} L_{jt} = \int_0^1 W_{ijt} L_{ijt} di$, and e_{jt}^Y is the output demand elasticity augmented with adjustment costs. Formally,

$$e_{jt}^Y \equiv \theta_t \begin{bmatrix} 1 - \psi_p \left(\frac{P_{jt}}{P_{jt-1}} - \bar{f}^p \right) \frac{P_t}{P_{jt-1}} \frac{Y_t}{Y_{jt}} \\ + \psi_p E_t \left[\frac{\Delta_{t+1}}{\Delta_t} \left(\frac{P_{jt+1}}{P_{jt}} - \bar{f}^p \right) \frac{P_{jt+1}}{P_{jt}^2} \frac{P_{t+1}}{Y_{jt}} Y_t \right] \end{bmatrix}^{-1} \tag{10}$$

Both equations (8) and (9) are the standard conditions equating the marginal cost of capital and labor to its marginal revenue after considering the mark-up wedge between them, i.e. $\frac{e_{jt}^Y}{e_{jt}^Y - 1}$.[16] They imply an

[15] Clarida, Galí and Gertler (1999) refer to cost-push shocks as anything other than variations in excess demand that might affect expected marginal costs. Ireland (2004b) introduces an additional shock that affects the Phillips curve specification, which is originated as an exogenous disturbance to the firm's desired mark-up of price over marginal cost. This is the interpretation followed here. He has found these shocks to be more relevant than technology ones in explaining output, inflation and interest rates.

[16] In the absence of adjustment costs, the elasticity of output demand equals the elasticity of substitution between different varieties of domestic output. In such a case, a firm's problem FOCs yield the standard condition that in a symmetric monopolistic competition model, equilibrium prices are set so that there is a mark-up over marginal costs.

optimal trade-off between capital and labor inputs that depend on the relative cost of each:

$$w_t L_{jt} = \left(\frac{1-\alpha}{\alpha}\right) r_t K_{jt} \tag{11}$$

3.2 Households' Problem

There is a continuum of heterogenous households indexed by $i \in [0,1]$, who supply labor in a monopolistically competitive manner. Preferences are additively separable over consumption, C_{it} and labor supply, L_{it}, in each period and subject to a shock, a_t. Future utility is discounted at a rate of time preference β. Households derive income by selling labor at a nominal wage rate, W_{it} and hold two types of assets: non-contingent domestic bonds B_{it}, and non-contingent tradable foreign bonds, B^*_{it}. These bonds are denominated in home and foreign currency and yield a nominal return i_t and i^*_t, respectively.

Each household chooses the wage at which to sell its differentiated labor. They take as given the labor demand function for its labor type, as captured by equation (16), as well as the aggregate variables. Therefore, households care about their wage relative to the aggregate wage index. In addition, they face an adjustment cost of changing wages captured by equation (17), which depends on the parameter ψ_w.[17] As specified, the cost is increasing in deviations of actual wage inflation from its steady state and in the overall wage level of the economy, and introduces the possibility of wage rigidities.

The optimization problem faced by each household is expressed as follows:[18]

$$\underset{C_{it},L_{it},B_{it},B^*_{it}}{Max} E_o \sum_{t=0}^{\infty} \beta^t a_t \left(lnC_{it} - \left(\frac{\sigma-1}{\sigma}\right)\frac{1}{\nu} L^{\nu}_{it}\right) \tag{12}$$

s.t.

$$C_{it} = \kappa \left(C^H_{it}\right)^{\gamma} \left(C^F_{it}\right)^{1-\gamma} \tag{13}$$

$$P_t C^H_{it} + S_t C^F_{it} = Q_t C_{it} \tag{14}$$

$$B_{it} - B_{it-1} + S_t\left(B^*_{it} - B^*_{it-1}\right) = i_{t-1}B_{it-1} + S_t i^*_{t-1} B^*_{t-1} + W_{it}L_{it} - AC^w_t - Q_t C_{it} \tag{15}$$

$$W_{it} = \left(\frac{L_{it}}{L_t}\right)^{-\frac{1}{\sigma}} W_t \tag{16}$$

$$AC^w_t = \frac{\psi_w}{2}\left[\frac{W_{it}}{W_{it-1}} - \bar{\Omega}\bar{\pi}\right]^2 W_t \tag{17}$$

where $\beta \in (0,1)$ is the inter-temporal discount factor, $\bar{\Omega}$ and $\bar{\pi}$ are the steady-state real wage inflation and consumer's price inflation respectively and $\kappa = \left[\gamma^{\gamma}(1-\gamma)^{1-\gamma}\right]^{-1}$ is an irrelevant constant. $\gamma \in [0,1]$ is the share of home produced goods in total consumption and can be interpreted as the degree of openness of the economy. This parameter is relevant for our analysis as it determines the strength of the expenditure switching effect.[19] The elasticity of labor supply is captured by $\nu > 1$, and $\frac{\sigma-1}{\sigma}$

[17] The quadratic specification follows Kim (2000). It captures imperfections in the labor market as it contains elements of search process. Similar specifications are found in Ireland (2001) and Bergin (2004 and 2003).

[18] The standard utility function used in the literature is adopted (see Obstfeld and Rogoff, 2000). Money does not appear in the utility function or the budget constraint and monetary policy is specified in terms of an interest rate rule. Following Galí and Monacelli (2002), it is possible to think of money as playing only the role of a unit of account.

[19] Under a more general specification the expenditure-switching effect would also depend upon additional parameters. For instance, under a CES composite index for aggregate consumption its stregth would be determined not only by the degree of openess of the economy but also with the elasticity of substitution between foreign and domestic goods. See for instance Sutherland (2006).

determines the marginal disutility of labor.[20] The preference shock a_t follows an autoregressive process:

$$\ln a_t = \zeta_a \ln a_{t-1} + \varepsilon_{at} \tag{18}$$

where $0 < \zeta_a < 1$ and $\varepsilon_{at} \sim N\left(0, \sigma_a^2\right)$ is serially uncorrelated.

Domestically produced goods, C_{it}^H, are aggregated through a C.E.S. function. This and its associated price index are given by:

$$C_{it}^H = \left[\int_0^1 C_{jt}^{\frac{\theta_t - 1}{\theta_t}} dj\right]^{\frac{\theta_t}{\theta_t - 1}} \quad ; \quad P_t = \left[\int_0^1 p_{jt}^{1-\theta_t} dj\right]^{\frac{1}{1-\theta_t}} \tag{19}$$

where θ_t is the elasticity of substitution between different domestic goods.

Imported goods, C_{it}^F, have a fixed price in terms of foreign currency and the law of one price is assumed to hold.[21] As a result, the price of imports in domestic currency is equal to the nominal exchange rate S_t.

The first-order conditions for the household's intra-temporal problem are:[22]

$$\left(\frac{1-\gamma}{\gamma}\right)\frac{C_t^H}{C_t^F} = \frac{S_t}{P_t} \equiv e_t \tag{20}$$

That is, this condition equates the demand for home versus foreign goods to the real exchange rate. The minimum cost of one unit of aggregate demand is then:

$$Q_t = P_t^{\gamma} S_t^{1-\gamma} \tag{21}$$

Define real wages as $w_{it} = \frac{W_{it}}{Q_t}$, real wage inflation as $\Omega_{it} \equiv \frac{w_{it}}{w_{it-1}}$, overall inflation (CPI) as $\pi_{it} \equiv \frac{Q_t}{Q_{t-1}}$, nominal devaluation as $f_t^s \equiv \frac{S_t}{S_{t-1}}$, and express the nominal wage growth as $\frac{W_{it}}{W_{it-1}} = \Omega_{it}\pi_{it}$. This allows us to write the optimal inter-temporal conditions in a more convenient manner. The households' problem yields the standard inter-temporal Euler equations for consumption smoothing and an optimal wage-setting equation:

$$\frac{1}{C_{it}} = \beta\left(1+i_t\right)E_t\left(\frac{a_{t+1}}{a_t}\frac{1}{\pi_{t+1}C_{it+1}}\right) \tag{22}$$

$$\frac{1}{C_{it}} = \beta\left(1+i_t^*\right)E_t\left(\frac{a_{t+1}}{a_t}\frac{f_{t+1}^s}{\pi_{t+1}C_{it+1}}\right) \tag{23}$$

$$-\left(\frac{1-\sigma}{\sigma}\right)L_{it}^{\nu-1} = \frac{w_{it}}{C_{it}}\left(1-\frac{1}{e_{it}^L}\right) \tag{24}$$

where e_{it}^L is the labor demand elasticity augmented with adjustment costs:

$$e_{it}^L \equiv \sigma\left[\begin{array}{c} 1 - \frac{\psi_w}{L_{it}}\frac{w_t}{w_{it-1}}\pi_t\left(\Omega_{it}\pi_t - \bar{\Omega}\bar{\pi}\right) \\ +\beta\frac{\psi_w}{L_{it}}E_t\left[\frac{a_{t+1}}{a_t}\frac{C_{it}}{C_{it+1}}\frac{w_{it+1}}{w_{it}^2}w_{t+1}\pi_{t+1}\left(\Omega_{it+1}\pi_{t+1} - \bar{\Omega}\bar{\pi}\right)\right]\end{array}\right]^{-1} \tag{25}$$

20 L should be thought of as efficiency labor rather than actual hours worked, H, with $H = \left(\frac{\sigma-1}{\sigma}\right)^{\frac{1}{\nu}} L$. See Obstfeld and Rogoff (1996 and 2000).

21 An important issue in the new open economy macroeconomics literature is departing from the law of one price assumption because evidence seems to reject it on the data. Kollman (2001) assumes pricing to market to avoid the law of one price assumption. For simplicity, this is not pursued in this paper.

22 Formally, this is an equilibrium condition derived after imposing symmetry conditions.

This term can be thought of as a "wage mark-up" that captures frictions in wage-setting. Therefore it distorts the real wage from its competitive equilibrium value $w_{it} = C_{it}L_{it}^{\nu-1}$. Finally, in addition to the above optimal conditions, a non-Ponzi transversality condition for bonds holdings is imposed.

3.3 Entrepreneurs' Problem

Entrepreneurs' behavior is modeled as in Céspedes, Chang and Velasco (2004 and 2003), which in turn is based on Bernanke, Gertler and Gilchrist's (1999) analysis of the role of credit market frictions in business cycle fluctuations in a closed economy.[23] For convenience, it is assumed that entrepreneurs' main activity is to decide how much to invest.[24] The analysis relies on the fact that entrepreneurs borrow from world capital markets to finance investment in excess of net worth. For this purpose they issue dollar-denominated debt contracts, which due to imperfections in international financial markets, require a risk premium over the risk free international interest rate (see Céspedes, Chang, and Velasco, 2004 and 2003, and Tovar, 2005).[25]

More specifically, assume that an entrepreneur is making the decision of how much to invest. This agent will then finance investment employing its own net worth and the remaining porting will be financed through debt. As a result the entrepreneurs' budget constraint is determined by:

$$P_t N_t + S_t D_{t+1} = Q_t K_{t+1} \tag{26}$$

where it is assumed full capital depreciation and that the price index for the cost of investment is the same as that for consumption as captured by equation (21).

Entrepreneurs borrow abroad paying a risk premium, $1 + \eta_t$, above the world risk free interest rate, $1 + \rho_t$. It is assumed that the risk premium is an increasing concave function in the ratio of the value of investment to net worth:

$$1 + \eta_t = \left(\frac{Q_t K_{t+1}}{P_t N_t} \right)^{\mu} \tag{27}$$

where μ is the elasticity of the risk premium to the ratio of investment to net worth.

Therefore, in equilibrium, the expected yield of capital in foreign currency must equal the cost of borrowing in international capital markets to finance capital investment:

$$\frac{E_t \left(R_{t+1} K_{t+1} / S_{t+1} \right)}{Q_t K_{t+1} / S_t} = (1 + \rho_t)(1 + \eta_t) \tag{28}$$

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[23] Bernanke, Gertler, and Gilchrist's (1999) analysis is an optimal debt contract problem between a single entrepreneur and foreign lenders. These agents face a joint problem of choosing investment, a dollar loan, and a repayment schedule so as to maximize profits. This problem can be transformed into one where the optimal contract maximizes the entrepreneur's utility by choosing the investment to net worth ratio and the optimal cutoff of a random variable required to make the project profitable enough to allow the repayment of the loan. See also Calstrom and Fuerst (1997).

[24] This assumption differs from Bernanke, Gertler, and Gilchrist (1999), who rely on a more general setting that considers the possibility of consumption by these agents. This simplifies matters as we need not care about their labor supply or the impact of their consumption on the economy.

[25] IT would be more realistic to consider an optimal portfolio problem in which entrepreneurs could both in foreign and domestic currency. For simplicity this is not pursued here. However, intuitively, one could possibly think of the implications of borrowing in local currency for our analysis. Posssibly, the main impact , if any, would be observed in the medium to long run. The reason is because with a devaluation, local currency debt has no immediate impact on the firm´s balance sheet. Therefore, the impact on the economy would only manifest itself depending on the effect of a devaluation the nominal and real interest rates.

In addition, it is assumed that the world interest rate follows a first-order autoregressive process:

$$\ln \rho_t - \ln \overline{\rho} = \zeta_\rho \left(\ln \rho_{t-1} - \ln \overline{\rho} \right) + \varepsilon_{\rho t} \tag{29}$$

where $0 < \zeta_\rho < 1$ and $\varepsilon_{\rho t} \sim N\left(0, \sigma_\rho^2\right)$ is serially uncorrelated.

In Bernanke, Gertler and Gilchrist (1999), net worth is defined as the entrepreneurial equity of the firms that remain in business, that is, the wealth accumulated from operating firms. Firms that fail in t consume the residual equity, which in this case is only imported goods. Entrepreneurs are assumed here to own domestic firms, so entrepreneurial equity equals gross earnings on holdings of equity from $t-1$ to t less repayment of borrowings. Therefore, net worth is defined as:

$$P_t N_t = R_t K_t + \Pi_t - S_t D_t = \left[1 - \frac{\psi_p}{2} \left(\frac{P_t}{P_{t-1}} - \bar{f}^p \right)^2 \right] P_t Y_t - W_t L_t - S_t D_t \tag{30}$$

3.4 Monetary Policy

In what follows I present the manner in which monetary policy is modelled. However, in addition to this and given that the objective of the paper is to study the effects of devaluations on output, I also provide a precise definition of currency devaluations.

Following the discussion of section (2.1), monetary policy must be modelled in a flexible manner as to capture the shifts in monetary and exchange rate regimes observed in the three Latin American economies considered. For these reasons, an interest rate rule that targets different macroeconomic variables is employed.[26] The specification adopted is one in which monetary policy responds to deviations of expected CPI inflation, output, and the nominal exchange rate from their long-run levels (i.e., steady-state levels). Formally, the interest rate target is captured by:

$$\frac{1 + \tilde{\imath}_t}{1 + \bar{\imath}} = \left(\frac{E_t \pi_{t+1}}{\bar{\pi}_t} \right)^{\omega_\pi} \left(\frac{Y_t}{\bar{Y}_t} \right)^{\omega_y} \left(\frac{S_t}{\bar{S}_t} \right)^{\frac{\omega_s}{1-\omega_s}} \tag{31}$$

where $\bar{\pi}_t = \frac{\bar{\pi} \cdot \kappa}{\kappa_t}$, $\bar{y}_t = \frac{\bar{y} \cdot \vartheta}{\vartheta_t}$, and $\bar{S}_t = \frac{\bar{S} \cdot \bar{\chi}}{\chi_t}$.[27] $\omega_s \in [0, 1)$, ω_π, and ω_y are the weights on each of the target variables.[28] κ_t, ϑ_t are shocks on the inflation and output targets, thus allowing the targets to depart from their long-run or steady-state levels, which are denote by a hat $(\bar{\cdot})$. χ_t has a similar interpretation, however, its role is more important for the purpose of this paper, as it will capture a devaluationary policy shock, as discussed below.[29] Since central banks tend to smooth changes in interest rates the actual

[26] In open economies, setting the specification of such rules is more controversial than in closed economies, where most of the theoretical contributions have been made. The reason for this is the wider set of variables to which monetary policy can react. See Woodford (2003) and Clarida, Galí, and Gertler (1999) for a discussion of interest rate rules in a closed economy setting. For an open economy overview, see Clarida, Galí, and Gertler (2001, 1998), Beningno (2004) and Benigno and Benigno (2000) among others.

[27] Currently the specification implies that in the absence of shocks the target reverts to it steady-state level. For Latin American economies it would be more desirable to define targets that do not revert to its steady-state or long-run level. The modification of this specification is left for future research.

[28] The weights of each target is assumed to be exogenous. However, this might not be the best assumption for Latin American economies. In particular, because such weights are likely to depend on structural characteristics of the economy such as the initial value of inflation and the credibility of the central bank. Morande (2003) discusses some of these issues in the context of Chile. In addition, such weights may also be a function of the shocks affecting the economy. For instance, under a sudden stop it is likely that the weight on output would reflect the concerns of a deep recession.

[29] The coefficient ω_s is restricted to be less than 1, following the general perception, shared by the IMF, that an increasing exchange rate should induce the central bank to raise interest rates. This has been subject of controversy following the Asian crises. See Cho and West (2003) on the issue.

interest rate is allowed to partially adjust to the target as follows:[30]

$$\frac{1+i_t}{1+\bar{\imath}} = \left(\frac{1+i_{t-1}}{1+\bar{\imath}}\right)^{\omega_i}\left(\frac{1+\tilde{\imath}_t}{1+\bar{\imath}}\right)^{1-\omega_i} \tag{32}$$

where the parameter $\omega_i \in [0,1]$ is the interest rate smoothing parameter.

The inclusion of an inflation and output target in the monetary policy rule specification is standard in closed economy models. However, it is less standard to allow the targets to change over time (few exceptions are Ireland (2006) or Erceg and Levin (2003)). Such shocks on the targets are introduced to capture the changes in monetary policy frameworks experienced by Chile, Colombia, and Mexico during the period of analysis. Furthermore, it is also a desirable feature to improve the fit to the data. $\kappa_{t,}$ and ϑ_t are both assumed to follow a first order autoregressive process as described by:

$$\ln \kappa_t - \ln \bar{\kappa} = \zeta_\kappa \left(\ln \kappa_{t-1} - \ln \bar{\kappa}\right) + \varepsilon_{\kappa t} \tag{33}$$

$$\ln \vartheta_t - \ln \bar{\vartheta} = \zeta_\vartheta \left(\ln \vartheta_{t-1} - \ln \bar{\vartheta}\right) + \varepsilon_{\vartheta t} \tag{34}$$

where $0 < \zeta_{\kappa t} \leq 1$, $0 < \zeta_{\vartheta t} \leq 1$, and $\varepsilon_{\kappa t} \sim N\left(0, \sigma_\kappa^2\right)$ and $\varepsilon_{\vartheta t} \sim N\left(0, \sigma_\vartheta^2\right)$ are serially uncorrelated.

A more controversial and unresolved matter is whether central banks should target the nominal exchange rate. Taylor (2001) has argued that if monetary policy is determined by expected inflation, the central bank should not react to exchange rate fluctuations. However, in emerging market economies, the exchange rate could be used to stabilize exchange rate disequilibriums (Calvo and Reinhart, 2002) or as a credibility device in economies with poor history of inflation.[31] Furthermore, targeting the nominal exchange rate can be also justified within the model because firms borrow in foreign currency (dollars) and external shocks may cause significant volatility of the exchange rate. Such theoretical considerations imply that it makes sense for some emerging market economies to have a nominal exchange rate target. In the present paper, the exchange rate is also introduced in the interest rate rule for two additional reasons which are directly related with fitting the model to the data. First, because Chile, Colombia and Mexico were all countries that had at some point in time a target for the exchange rate (see section 2.1). Second, to capture the shifts of exchange rate policies. On this regard, notice that the specification of the interest rate rule in equation (31) has the important property that it allows to approximate the systematic behavior of monetary policy for a continuum of exchange rate regimes depending on the weight ω_s (See Monacelli, 2003 and Parrado and Velasco, 2002). Specifically, for $\omega_s = 0$ the rule captures a pure floating exchange rate regime, as reflected by the fact that $\frac{\omega_s}{1-\omega_s} = 0$. In contrast, for larger values of ω_s the rule would capture a managed float regime. In the extreme case in which $\omega_s \to 1$ then $\frac{\omega_s}{1-\omega_s} \to \infty$ and therefore the rule would describe a fixed exchange rate regime.[32]

In addition, the interest rate rule specification allows to introduce a precise definition for currency devaluations. In particular, a devaluation is defined as an increase in the nominal exchange rate target, $\bar{S}_t$.

30 Clarida, Galí, and Gertler (1998 and 2000) adopt this partial adjustment mechanism in their empirical analysis. Benigno (2004) shows that interest rate smoothing together with price rigidities can introduce additional inertia into the economy as this makes the real exchange rate more persistent.

31 For instance, Caputo (2004) analyses the performance of simple monetary policy rules, not necessarilly optimal, under different degrees of inflation persistence and habit formation. He finds that a policy rule reacting to expected inflation, output and exchange rate disalignments is capable of marginally reducing the volatility of output and inflation.

32 Of course, one could argue that the real exchange rate should be included in the interest rate rule. This is not done here as it would not allow to interprete the parameter of the weight in the exchange rate as that capturing the exchange rate regime. On this regard, the volatility of the exchange rate would not be appropriate either. It is also worth indicating that if real exchange target is set to equal the difference between home and external inflation, then the relevant term to be included in the Taylor rule is the nominal exchange rate. See Engel and West (2006).

Therefore a policy of devaluing the currency would decrease the interest rate.[33] Intuitively the reader can think that if a central bank is defending an exchange rate target then it will have to rise interest rates or keep them in high levels. Therefore, when the central banks stops defending the exchange rate target, i.e. a devaluation takes place, then there is no need for the monetary authority to sustain the high interest rates, thus allowing a decrease in the interest rate. To capture the possibility of currency devaluations a shock χ_t on the exchange rate target is introduced (See Cho and West, 2003 for a similar approach). Formally, χ_t follows a first-order autoregressive process:[34]

$$\ln \chi_t - \ln \bar{\chi} = \zeta_\chi \left(\ln \chi_{t-1} - \ln \bar{\chi} \right) + \varepsilon_{\chi t} \tag{35}$$

where $0 < \zeta_{\chi t} \leq 1$ and $\varepsilon_{\chi t} \sim N\left(0, \sigma_\chi^2\right)$ is serially uncorrelated.

It is well known that interest rate rules are a commitment device. However, the shock on the exchange rate target introduces a discretionary behavior on the part of the monetary authority. It is possible to sustain within Calvo and Reinhart's (2002) "fear of floating" argument that central banks should maintain in practice a fixed exchange rate regime without losing their discretion to allow exchange rate fluctuations. The credibility mechanism here would be the announcement of a flexible exchange rate regime. This possibility would then be captured by the interest rate rule and a shock on the nominal exchange rate target as proposed here. The discretionary behavior is also justified from an empirical perspective. In fact, as discussed in section (2.) Chile, Colombia and Mexico have all intervened in the foreign exchange market in a discretionary manner.

3.5 Market-Clearing Condition

Provided that a proportion γ of output is spent on consumption and investment of domestic goods, that a fraction of output is used to cover price adjustment costs, and another fraction of domestic output is exported, then the market-clearing condition may be written as:

$$P_t Y_t = \gamma Q_t \left(K_{t+1} + C_t \right) + \frac{\psi_p}{2} \left(f_t^p - \bar{f}^p \right)^2 P_t Y_t + S_t X_t \tag{36}$$

where the last term stands for the home good value of exports to the rest of the world. For simplicity's sake, export demand is assumed to follow an autoregressive process:

$$\ln X_t - \ln \overline{X} = \zeta_x \left(\ln X_{t-1} - \ln \overline{X} \right) + \varepsilon_{xt} \tag{37}$$

where $0 < \zeta_x < 1$ and $\varepsilon_{xt} \sim N\left(0, \sigma_x^2\right)$ is serially uncorrelated.

To close the model, firms' stochastic discount factor must be specified. In standard models, where firms are owned by households and every agent has access to a complete competitive market for contingent claims, it is assumed that firms maximize their market value. Hence, there is a unique discount factor equivalent to the marginal utility to the representative household of an additional unit of profits received each period. However, in the present framework, firms are owned by entrepreneurs. Therefore, for purposes of simplicity, it is assumed that entrepreneurs discount profits at a rate equivalent to that of the marginal utility of consumption, i.e. $\frac{\Delta_{t+1}}{\Delta_t} = \beta \left(\frac{a_{t+1}}{a_t} \frac{C_t}{C_{t+1}} \right)$.

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[33] Notice that monetary policy is tightened by increasing the nominal interest rate if the nominal exchange rate, S_t, exceeds its long-run level, $\bar{S}_t$.

[34] For operational purposes, the shock enters in a multiplicative form in the interest rule. Therefore, a devaluation will be captured by a negative shock on $\varepsilon_{\chi t}$.

4. TAKING THE MODEL TO THE DATA

4.1 Econometric Methodology

Recently, there have been a number of studies estimating DSGE models. However, most of them have been applied to closed economies (Ireland, 2004a, 2004b; Dib, 2003; Smets and Wouters, 2003; Ruge-Murcia, 2003; or Kim, 2000). Very few have been applied to small open economies (Tovar, 2006; Medina and Soto, 2005a; Ambler, Dib and Rebei, 2003; Bergin, 2003; and Lubik and Schorfheide, 2003) and its main focus has been on relatively developed economies (Australia, New Zealand and South Korea) or industrialized countries (Canada, US or UK). Overall, the literature has paid less attention to the estimation of DSGE models for "less" developed economies. In this sense this paper intends to help fill in a gap.

In the literature, only Lubik and Shorfheide (2003) and Tovar (2006) have estimated models for small open economies in which the monetary authority reacts not only to output, and inflation, but also to exchange rate movements. Lubik and Shorfheide (2003) find that in the case of Canada the central bank responds to exchange rate movements, while Tovar (2006) finds that the nominal exchange rate is a statistically significant component of the interest rate rule for South Korea. These studies also show that the importance of incorporating output measures in small open economies may not be that relevant. For instance, Tovar (2006) finds output to be statistically irrelevant in the monetary policy rule for South Korea. Medina and Soto (2005a) estimate for the Chilean economy an interest rate rule that responds to the deviations of CPI inflation from its target and to the deviation of output growth from trend. Their Bayesian estimates suggest that monetary policy put very low weights on output, with a mean weight of 0.12 and a standard deviation of 0.26.

The literature has proposed several econometric methods to estimate DSGE models such as maximum likelihood, generalized method of moments, simulated method of moments or more recently Bayesian methods. All have their own strengths and weaknesses (See Ruge-Murcia, 2003 and Fernández-Villaverde and Rubio, 2004). In this paper the maximum likelihood method is employed.

A key issue that arises in the estimation of DSGE models is the stochastic singularity problem. According to it DSGE models predict certain combinations of endogenous variables to be deterministic. Therefore, if exact linear definitions established by the model do not hold in the data, then any attempt to estimate such model will fail. Two approaches have been proposed in the literature to address this problem. The first is to incorporate additional structural disturbances until the number of shocks equal the number of series employed in estimation. In the present framework this would be captured by the eight shocks built into the model (ie technology, mark-up, preferences, exports, risk free international interest rate, nominal exchange rate target, inflation target and output target). The second is to add measurement errors as suggested by Ireland (2004a). Measurement errors are motivated as a way to capture the movements and co-movements in the data that the model, because of its simplified structure cannot explain. An advantage of relying on them is that they allow to take advantage of the information contained in a larger set of variables to estimate the parameters of the model.[35] In this paper, an eclectic view is taken as both structural shocks and measurement errors are considered to deal with the stochastic singularity problem. In particular, the estimation is done first without measurement errors and then, by introducing measurement errors. Performing these two estimations provide a robustness check of the model's degree of misspecification.[36]

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[35] Ruge-Murcia (2003) analyzes alternative methods to estimate a particular DSGE and finds that parameter estimates are more efficient when measurement errors are incorporated.

[36] There are alternative ways of fitting DSGE models. An alternative to adding structural shocks or measurement errors is the

The estimation process consists of four steps. First, the linear rational expectations model is solved for the reduced form state equation in its predetermined variables (see Tovar (2005)). Second, the model is written in state-space form, and measurement errors are incorporated in the observation equation if they are to be employed in the estimation. Third, the Kalman filter is used to construct the likelihood function. Finally, the parameters are estimated by maximizing the likelihood function.

Formally, the solution of the log-linearised system can be written as:

$$\tilde{x}_t = \Gamma_P \tilde{x}_{t-1} + \Gamma_Q \tilde{z}_t \tag{38}$$

$$\tilde{y}_t = \Gamma_X \tilde{x}_t = \Gamma_R \tilde{x}_{t-1} + \Gamma_S \tilde{z}_t \tag{39}$$

$$\tilde{z}_{t+1} = \Gamma_N \tilde{z}_t + \tilde{\varepsilon}_{t+1} \tag{40}$$

$$E_t \left[\tilde{\varepsilon}_{t+1}\right] = 0 \tag{41}$$

for all $t = 0, 1, 2, ..$, where $\tilde{x}$ and $\tilde{y}$ keep track of the percentage deviations of each de-trended variable from its steady state level, with $\tilde{x} = \left[\hat{k}\ \hat{e}\ \hat{w}\ \hat{d}\ dB^*\ \hat{\imath}\ \hat{s}\right]'$ being the endogenous state vector, $\tilde{y} = \left[\hat{\pi}\ \hat{y}\ \hat{l}\ \hat{r}\ \hat{c}\ \hat{f}^s\ \hat{\imath}\ \hat{\varrho}\right]'$ the vector of endogenous variables, and $\tilde{z} = \left[\hat{\rho}\ \hat{x}\ \hat{A}\ \hat{\theta}\ \hat{\chi}\ \hat{a}\ \hat{\kappa}\ \hat{\vartheta}\right]'$ the vector of exogenous stochastic processes. The goal is to estimate the matrices Γ_P, Γ_Q, Γ_R, Γ_S, and Γ_N which are nonlinear functions of the model's structural parameter so that the equilibrium is stable. The specific details of the implementation of the econometric methodology, including the manner in which the system can be augmented with measurement errors, are discussed in appendix A.

4.2 The Data

During the last two decades, Chile, Colombia and Mexico have been exposed to devaluationary episodes of different magnitude, making them ideal case studies to answer the main question of the paper: are currency devaluations expansionary or contractionary in terms of output?

The eight series employed for estimation are inflation, output, labor, private consumption, changes of the nominal exchange rate, interest rate and the level of the nominal exchange rate. The last two variables were introduced as definitional variables in the observation equation to exploit the information contained in them. The data is seasonally adjusted quarterly series for the period 1989:1 to 2005:4 and was obtained directly from national sources and some series such as the nominal exchange rate were taken from the IMF's International Financial Statistics (See appendix B). Output and consumption are measured in per capita terms. All data, with the exception of interest rates, was logged and then Hodrick-Prescott filtered. When necessary data was also seasonally adjusted. Figures 1, 2, and 3 display the filtered data used for estimation.

Certainly, for some readers it would be better to incorporate the trend into the model by adding, for instance, a labor-augmenting technology shock. Although, this may make sense for a developed economy it seems to be a less realistic solution for the estimation of the models in Latin America. The reason is that such economies may have cycles in the trend (see Aguiar and Gopinath, 2004), and this would make the modelling and estimation substantially more complex than those for advanced economies. Thus, for the sake of simplicity, Hodrick-Prescott filtered data is employed to take the model to the data.

DSGE-VAR approach proposed by Del Negro et al (2005) which consists in finding optimal weights to combine a DSGE model with an atheoretical model such as a VAR or a VECM. Another alternative is to specify a DSGE model and add additional structure as done in the BEQM model of the Bank of England. See Alvarez-Lois et al. (2005) for an excellent discussion comparing different aproaches.

5. EMPIRICAL RESULTS

5.1 Parameter Estimates

Successful estimation requires the calibration of some parameters whose values are summarized in Table 1. For simplicity and to allow a better comparison of results, such values are assumed to be common to all three economies. Parameter values for preferences and technology are standard in the literature so no major comments are necessary.[37] An exception is the elasticity of substitution between different varieties of goods, $\theta = 6$, which was chosen following Galí and Monacelli (2002) so that the steady-state mark-up equals 20%.

Table 2 shows the maximum likelihood estimates and the corresponding standard errors for eight key structural parameters of the model estimated without measurement error.[38] These parameters capture the balance sheet effect (μ), the expenditure switching effect (γ), the degree of nominal rigidities (ψ_p, ψ_w), and the parameters associated to the interest rate rule (ω_i, $\omega_p, \omega_y, \omega_s$).

The point estimates for the balance sheet effect, i.e. the elasticity of the risk premium to the investment-net worth ratio, which captures the degree of international capital market imperfections varies significantly among the three countries. Chile is found to have the strongest balance sheet effect, while in Mexico this mechanism appears to be weak. To make sense of the values, it is important to consider that the literature considers the normal values of this parameter to fall within a range of 0.2 to 0.4 (Carlstrom and Fuerst,1997). Tovar (2006) estimates this parameter for South Korea and finds it to be equal to 0.4. Elekdag, Justiniano and Tchakarov (2006) employ a prior for this parameter ranging between 0.03 and 0.47, with a mean of 0.2.In their estimates they find the median value of the parameter to equal 0.05 for South Korea (quite low given the 0.09 estimate by Christensen and Dib (2004) for the US). Using cross-section reduced form regressions, Berganza, Chang and Herrero (2003) estimate the elasticity of the risk premium to a devaluation to range between 0.5 and 0.6. The estimated parameter values for μ reported in Table 2 fall within a range of 0.14 and 0.31, that is well within the range of what is expected in the theoretical and empirical literature. The estimated parameter values for Chile Colombia and Mexico imply, ceteris paribus, a risk premium of 716, 526, and 317 basis points, respectively for each economy (given an investment-to-networth ratio of 1.25).[39]

The estimates for the expenditure switching effect, captured by the share of domestically produced goods (γ), as reported in Table 2. As shown it exceeds in all cases 0.6 (ie the share of domestically produced goods in all three economies exceeds 60%). Such a high estimate is thus indicative of a significant expansionary effect associated with this mechanism following a devaluation.

Parameter estimates for the interest rate rule shows that in all three countries there is little interest rate smoothing. In fact, the parameter estimates for ω_i are below 0.55 in all the three countries, and in the case of Chile it is very close to zero.

The estimated weight for expected inflation satisfies the *Taylor principle* in all cases. According to this rule the optimal policy response to a rise in inflation is to increase interest rates sufficiently as to induce an increase of real interest rates. Therefore, ω_p should exceed unity. The estimated parameter value

37 Medina and Soto (2005a) report estimated values for the inverse of the elasticity of labor supply that are consistent with the value of $\nu = 2$ employed for estimation. As for the discount factor they also employ the same value of $\beta = 0.99$.

38 Standard errors correspond to the square roots of the diagonal elements of minus one times the inverted matrix of second derivatives of the maximized log-likelihood function. Estimating them requires numerically evaluating the matrix of second derivatives of the log-likelihood and then inverting that very large matrix having elements of varying magnitudes. This can introduce significant approximation errors into the statistics and therefore they should be interpreted with caution (see Appendix A for details and Ireland, 2004a).

39 Notice that a lower level of indebteness, as reflected by the investment-to-net worth ratio would imply a lower risk premium.

indicates that, ceteris paribus, a one percentage increase in quarterly expected inflation induces about a 90 basis point increase in the quarterly real interest rate in Chile and Colombia and a 150 basis points increase in Mexico. Chile and Colombia are also found to put little weight on output as reflected by the low values for the parameter ω_y. However, in Mexico the point estimate for the weight on output, ω_y, implies that holding everything else constant, an increase in output is compensated by the monetary authority with a 115 basis point increase in the quarterly nominal interest rate. Finally, recall that ω_s captures the exchange rate regime, that is a value $\omega_s = 0$ would imply a flexible exchange rate regime, while $\omega_s = 1$ would indicate a fixed exchange rate regime. The estimated value of 0.92 for Colombia is a clear indication of a high degree of intervention by the central bank during the period of analysis. In Chile and Mexico the exchange regime is found to be less rigid. However, the parameter estimates are still relatively high and thus indicative of a "fear of floating" behavior during the period of analysis. Overall, these results confirm the discussion of monetary and exchange rate regimes of section (2.).

Point estimates also show that nominal rigidities are significant in Chile and Colombia, and less so in Mexico. The coefficient for price rigidities, ψ_p, suggests that a 2% increase on the inflation rate above its steady state level implies a 0.14% price adjustment cost in terms of domestic output for firms in Chile and of 0.09% in Mexico. In turn, the coefficients for wage rigidities, ψ_w, imply that a 2% increase in nominal wage inflation above the steady state has a cost of 0.03% of workers' wage in Colombia.

The persistence and standard deviation for the model's structural shocks are reported in Table 3. The estimated coefficients show a high degree of persistence in all cases. Standard deviations of this shocks are found to be quite high in general, probably indicating that the model does not impose enough dynamics to explain the data.

5.2 Impulse Responses

This subsection employs impulse response analyses to answer the main questions of the paper: i) whether currency devaluations are expansionary or contractionary in terms of output, and ii) what is the relative importance of the two main transmission channels in the model. For this purpose, the dynamics of key variables in the model are evaluated following an exogenous devaluationary policy shock (a negative shock on χ_t). Results are reported in Figures 10, 11, and 12. The north-west panels of these figures show the dynamics for the nominal and real exchange rates, as well as for output. In all three countries, there is an overshooting of the nominal and real exchange rates, which in turn results in an output expansion. Such dynamics imply that a currency devaluation, defined as an exogenous and explicit policy decision, is expansionary. However, the effect is slightly weaker in Mexico, were the exchange rate regime is found to be more flexible on average during the period of analysis (see the estimated value for ω_s). This confirms the simulation results reported by Tovar (2005) indicating that the ability of a central bank to take advantage of the expansionary expenditure-switching effect by devaluing the currency depends on the degree of flexibility of the exchange rate regime.

Notice that for devaluations to be expansionary in the model it must be true that the expenditure-switching effect dominates the balance sheet effect. To verify this it is only necessary to assess the strength of both the balance sheet and expenditure switching transmission channels. The relevance of the balance sheet effect is visually analyzed by looking at the impulse response functions in the north-east panels in Figures 10, 11, and 12. As illustrated, following the devaluationary policy shock, firms' net worth experience a significant decline in all three countries. This worsening of firms' balance sheets triggers an increase in the cost of debt as reflected by the increase of the risk premium thus forcing capital investment to fall. Overall, these dynamics confirm the contractionary nature of the balance sheet effect operating via aggregate demand.

Impulse responses also provide evidence on the expenditure switching effect as reflected in the aggregate capital investment and consumption decline. Such behaviour is incompatible with an output expansion unless there is a strong expenditure-switching effect (which must also be able to compensate for the contractionary balance sheet effect). In other words, for output to expand when aggregate consumption and investment are declining it is necessary to have a recomposition of output that shifts the consumption and investment of imported goods towards domestically produced goods.

The expansionary effect of devaluation on output, is no free-lunch as devaluations are also found to have side effects. Besides an important inflationary effect, there are also important income distribution side effects. As shown in the south-east panel of Figures 10, 11, and 12, a devaluation forces real wages to fall. The resulting loss in workers' income is then compensated by increasing the amount of labor supplied.

At this point we have reached two important conclusions. First, that a devaluation, in isolation from any other shock to the economy, is expansionary in terms of output. Second, that the expansionary expenditure-switching dominates the contractionary balance sheet effect. This result also surprising may be less so once it is taken into account, as indicated by Sutherland (2006), that the empirical evidence suggests that the expenditure switching effect can be potentially very strong. In fact stronger than in much of the recent open economy literature, including this paper, where the elasticity of substitution between home and foreign goods is restricted to unity. It also becomes less surprising once the empirical literature on balance sheet effect. The results are also in line with recent firm-level studies such as those of Bleakey and Cowan (2005), which find inconclusive evidence regarding the contractionary effect of exchange rate depreciations on investment.

5.3 Variance Decompositions

To assess the explanatory power of the model variance decompositions of k-step-ahead forecast errors are employed. This allows to determine the percentage of the variation in each of the endogenous variables explained by each of the eight structural shocks in the model. Results for the forecast error variance decompositions are reported in Tables 4 through 9. This exercise offers three interesting things. First, it allows to determine how much output variation is explained by a devaluationary policy shock. Second, it also allows to determine how much of the variation in the nominal exchange rate is explained by a devaluationary policy shock. And finally, it allows an evaluation of the overall performance of the model. Finally, notice that the robustness of the results can be assessed in the context of the model by attaching standard errors to the forecast-error variance estimates as calculated in Runkle (1987).

Variance decompositions show that devaluationary policy shocks account for up to 29% of the one-quarter-ahead forecast error variance of output in Colombia and up to 19% in the case of Chile. In the case of Mexico devaluationary policy shocks have significant less importance possible reflecting the longer history of a floating exchange regime. It is important to observe that the effects of devaluationary policy shocks are transitory as reflected by the fact that the relevance of the devaluationary policy shock explaining output dissipates for longer forecast horizons. Estimates indicate that the effects dissipate much faster in Colombia than in Chile.

It is worth pointing out at this point that in all countries output variance is largely explained by the shock on export demand. The evidence is mixed regarding other shocks. In particular, while technology shocks account for an important part in the forecast-error variance of output in Colombia and Mexico they have a non-negligible effect in Chile, where the preference shocks has a significant role. Also, in Chile and Mexico shocks on the inflation target have a more relevant role explaining the one-quarter-ahead forecast error variance of output, while in Colombia such shock appears to be less relevant. Certainly, this pattern might reflect a historically more stable and lower inflation rate in Colombia than in Chile or Mexico. Estimates in general confirm results found in the literature indicating that technology shocks are not the only and main source of output fluctuations (eg Smets and Wouters, 2003 or Galí, 1999 and 2003) .

Another important aspect to look at is to determine the extent to which devaluationary policy shocks contribute to the variance of the nominal exchange rate. On this regard, we find that devaluationary policy shocks account for about 67% of the one-quarter-ahead forecast error variance in the nominal exchange rate in Colombia. This is indicative of a significant fear of floating. In Chile, such shocks account for a non-negligible 25% of the one-quarter-ahead forecast error variance of the nominal exchange rate, while in Mexico they only account for 12%. In Chile and Mexico, the inflation target appears to account for a larger share of the variance of the changes in the nominal exchange rate, reflecting again the impact of inflation stabilisation in these countries.

Variance decompositions also allow to assess the performance of the model in other dimensions. Although, it is not the main purpose of the paper, some results seem allow to observe a comparison of the factors driving inflation dynamics. In particular, it is possible to observe that supply shocks seem to be more relevant in Mexico (as reflected by the fact that cost-push shocks are found to account for much of the forecast error variance of inflation over longer horizons) or in Colombia where technology shocks account for a fourth of the total forecast error variance . In contrast, in Chile, preference shocks account for a larger share of inflation dynamics, suggesting an important role for demand shocks in explaining inflation in the long-run.

5.4 Robustness Analysis

5.4.1 Adverse External Shocks

The results presented so far support the notion that devaluations are expansionary in terms of output, despite the contractionary balance sheet effect. Readers might then be trying to reconcile these results with the fact that the Chilean, Colombian and Mexican economies all have seen their output fall during episodes in which their currency declined in value relative to the US dollar. In this subsection, I argue that a negative correlation between devaluations and output is not enough for concluding that devaluations are contractionary. The reason is that it depends on the nature of the shock or shocks that hit the economy. To make the point, this section analyses impulse responses to an adverse external shock, as captured by an increase in the international interest rate. The objective of this exercise is to show the behaviour of the economy when affected by a sudden stop. In addition, in the following policy exercise, I ask what would be the dynamic behaviour of these economies if the monetary authority decided to devalue the currency in response to a sudden stop.

Sudden Stops Reversals of capital flows or sudden stops have often been blamed for large output losses in emerging markets. To capture the possibility of sudden stops the behavior of the economy is analysed following a rise in international interest rate. Impulse responses to a one percentage increase in the international risk free interest rates is shown in Figure 13. The shock induces upon impact an increase in the nominal exchange rate due to its the effect on the interest parity condition. Higher interest rates abroad also result in an increase of domestic interest rates, and therefore a decline in aggregate demand which forces output to fall. In Mexico, the collapse in output takes place with a lag, mainly because the exchange rate is flexible enough to adjust to the shock (recall that estimates suggest on average a more flexible exchange rate regime in Mexico) and this triggers the expenditure-switching effect.

The key point of this exercise is two fold. First, it illustrates that currencies can decline in value when the economy is hit by an adverse external shock. Depending on the nature of the shock output may fall, thus generating a negative correlation between the nominal exchange rate and output. However, this negative correlation is not due to a devaluation per se, but rather to the adverse shock or sudden stop as is here analysed. The second point, is that the model is able to capture important features of the dynamics of these economies following a sudden stop.[40] In particular, the decline in aggregate demand and its component, as well as in output. Overall, these results confirm that currency devaluations are not be blamed for the contractionary effects on output. On the contrary, it shows that the focus should be on the type of shock that hits the economy. It also shows that any reduced form analysis that attempts to estimate the effects of devaluations on output must distinguish upon movements in the exchange rate that are an equilibrium response to different shocks that hit the economy and those movements in the exchange rate that result from explicit policy decisions.

Devaluations and Sudden Stops A policy exercise that can be performed using the current framework is to consider what happens to these economies if the monetary authority decides to devalue the currency in response to a sudden stop. The dynamics for each economy under such scenario are shown in Figure 14. In particular, the figure shows the impulse response to a one percentage increase in the international interest rate jointly with a one percentage point devaluation. Notice that a noticeable feature is that in all three countries the exchange rate overshoots significantly. However, in this policy experiment the expenditure-switching effect is unable to compensate in a sustained manner for both the contractionary balance sheet effect and the adverse effect of the shock on the cost of capital (and therefore on aggregate demand). Therefore, the key result to highlight is that a devaluationary policy response to an adverse external shock will only have a minor effect in delaying output losses.

6. Model Misspecification: Adding Measurement Errors

Until now it has been assumed that the model is well specified. However, it is possible that due to its simplified structure the model is unable to capture some movements and co-movements in the data. As a result some parameter estimates may be biased. In order to control for possible model misspecification, measurement errors are incorporated into the estimation of the model (See details in Appendix A).[41] The maximum likelihood parameter estimates once white noise measurement errors are incorporated are reported in Tables 15, 16, and 17. The estimates of the main structural parameter of the model show little variation in terms of the qualitative results reported in Section 5..

The new estimates confirm Mexico as the country having the weakest balance sheet transmission mechanism. However, Chile is now found to have a weaker balance sheet effect than in the previous estimates as capture by the lower value for μ. The the expenditure switching effect as measure by γ is robust to the inclusion of measurement errors in all three countries.

The new estimates for the interest rate rule show few minor changes. First, Chile is found to have an important degree of interest rate smoothing .This clearly contrasts with the lack of interest rate smoothing

[40] The model resembles very closely the qualitative response found in empirical analyses that link shocks on international interest rates, credit spreads and the business cycle. The model however fails to replicate an empirical feature identified by Uribe and Yue (2006) according to which there is a delayed overshooting of the risk premium following a shock on international interest rates.

[41] The limited sample size contrains the number of parameters estimated in the model. Although different specifications for the measurement error dynamics were tried, only those with uncorrelated measurements errors i.e. $D = 0$, are reported. This was found to be the most stable specification. More than those in which different parameters had to be restricted to zero e.g. uncorrelated persistence among measurement errors or constant variance covariance matrix.

reported before. The relevance of this is that results now appear to be more in line with the literature for Chile (See Medina and Soto, 2006). Second, the interest rate response to changes in expected inflation is a bit weaker now in Chile and Mexico but higher in Colombia. Third, the interest rate response to output is now statistically insignificant in Colombia. Fourth, the weight on the nominal exchange rate is now found to be a bit higher in Mexico and in line with that of Chile. Estimates also confirm that Colombia is the country that weights the exchange rate the most, which is in line with the discussion in section 2.1.

Results also confirm the importance of including price and wage rigidities in all three countries. Furthermore, wage rigidities are now shown to play a more important role. Finally, parameter estimates reported in Table 16 show that measurement errors shocks have a variance that exceed those of the structural shocks.

Overall, we do not find significant changes in our parameter estimates that would overturn the qualitative results regarding the transmission mechanism of devaluations to output reported earlier.

7. CONCLUSIONS

An old question in macroeconomics is whether currency devaluations induce output to expand or collapse. Theory has identified specific mechanisms through which devaluations may affect output. However, the empirical literature has failed to provide conclusive answers on the direction of the effect as well as on the reasons why such effects might go in one direction or another. This paper estimated a structural DSGE model for three Latin American economies (Chile, Colombia and Mexico) to answer such questions. The estimates and impulse response analysis indicate that during the last two decades explicit and exogenous devaluationary policy shocks, ceteris paribus, have been on average expansionary in terms of output. Also that the contractionary balance sheet transmission mechanism has been dominated by the expenditure-switching effect. Finally, it is found that on average the balance sheet transmission mechanism has been weaker in Mexico than in Chile or Colombia.

The estimates highlight the importance of distinguishing among the effects of different shocks. In particular, it is shown that negative correlations between exchange rate changes and output in Latin America do not support the popular claim that devaluations are contractionary. In fact, impulse response analyses show that such negative correlations do not arise if the monetary authority decides to devalue the currency. However, they can be generated as a result of an adverse external shock, such as a sudden stop. Therefore, the nature of a shock is all important. The results also shed some light as to why the empirical literature has failed to provided conclusive answers on the devaluation-output relationship: changes in the nominal exchange rate are associated with different shocks which may operate in opposite directions, and isolating them might prove extremely difficult unless one is willing to rely on a well-specified structural framework that distinguishes among them.

As mentioned in the introduction, this paper should be taken as an exploratory exercise. In particular, because the evolving nature of Latin American economies impose major challenges on how to model these economies as well as on how to pusue parameter estimation. Future research will necessarily have to focus not only in capturing the most relevant features and transmission mechanisms for these economies, but also on how to capture evolving features of them such as structural changes, shifts in monetary and exchange rate regimes, or even more, on how to deal with the trend of key macroeconomic variables which are subject to major cycles.

References

Agénor, P., Montiel,P. (1999). *Development macroeconomics*. 2nd edition. Princeton University Press. Princeton, New Jersey.

Aguiar, M. and Gopinath, G. (2004). Emerging market business cycle: the cycle is the trend. NBER Working Paper No. 10734.

Alvarez-Lois, P., Harrrison, R., Piscitelli L. and Scott A. (2005). Taking DSGE models to the policy environment. Mimeo Bank of England.

Ambler, S., Dib A., Rebei N. (2003). Nominal rigidities and exchange rate pass-through in a structural model of a small open economy. Working Paper 2003-29. Bank of Canada.

Benigno, G. (2004). Real exchange rate persistence and monetary policy rules. Journal of Monetary Economics. Vol. 51. pp. 473-502.

Benigno, G., Benigno P. (2000). Monetary Policy Rules and the exchange rate. CEPR Discussion Papers No. 208.

Berganza, J., Chang R., Herrero A. (2003). Balance sheet effects and the country risk premium: an empirical investigation. DT 0316. Banco de Espana.

Bergin, P. (2004). How well can the New Open Economy Macroeconomics explain the exchange rate and current account?. NBER Working Paper No. 10356.

Bergin, P. (2003). Putting the “New Open Economy Macroeconomics” to a test. Journal of International Economics. Vol. 60. Issue 1. May.

Bernanke, B, Gertler M., Gilchrist S. (1999). The financial accelerator in a quantitative business cycle framework, in Taylor J.E. and Woodford M. (Eds.), Handbook of Macroeconomics. Vol. 1C. North-Holland. Amsterdam.

Blanchard, O. and Charles K. (1980). The solution to linear difference models under rational expectations. Econometrica. Vol. 48. Issue 5, July. pp1305-1312.

Bleakley, H. and Cowan, K. (2005). Corporate dollar debt and depreciations: much ado about nothing?. Mimeo.

Calvo, G. (1999). Capital flows and capital market crises: the simple economics of sudden stops. Journal of Applied Economics. Vol. 1, No.1. pp. 35-54.

Calvo, G. (1983). Staggered prices in a utility-maximizing framework", Journal of Monetary Economics, Vol. 12. No. 3. pp 983-998.

Calvo, G., Reinhart, C. (2002). Fear of floating. Quarterly Journal of Economics. Volume 177 Issue 2. pp.379-408.

Caputo, R. (2004). Persitence and the role of the exchange rate and interest rate inertia in monetary policy. Central Bank of Chile Working Papers No. 300. December.

Carlstrom, C., Fuerst, T. (1997). Agency costs, Net Worth, and Business Fluctuations: A Computable General Equilibrium Analysis. The American Economic Review, Vol. 87, Issue 5. December. pp. 893-910.

Céspedes, L., Chang R., Velasco A. (2004). Balance Sheets and exchange rate policy. American Economic Review. Vol. 94 No. 4. pp. 1183-1193.

Céspedes, L., Chang R., Velasco A. (2003). IS-LM-BP in the Pampas. IMF Staff Papers, Vol. 50. pp. 143-156.

Cho, D., West, K.D., 2003. Interest rates and exchange rates in the Korean, Philippine and Thai exchange rate crises. In Dooley M. and Frankel J. (Eds.) *Managing currency crises in emerging markets*. NBER. Chicago University Press.

Choi, W., Cook, D. (2004). Liability dollarization and the bank balance sheet channel. Forthcoming Journal of International Economics.

Christensen, I., Dib, A. (2004). Monetary policy in an estimated DSGE model with financial accelerator. Mimeo Bank of Canada. September.

Clarida, R., Galí J., Gertler M. (2001). Optimal monetary policy in open versus closed economies: an integrated approach. The American Economic Review, Papers and Proceedings Vol. 91 No. 2. May. pp. 248-252.

Clarida, R., Galí J., Gertler M. (2000). Monetary policy rules and macroeconomic stability: evidence and some theory. Quarterly Journal of Economics. Vol. 105. February. pp. 147 -180.

Clarida, R., Galí J., Gertler M. (1999). The science of monetary policy: A new Keynesian perspective. Journal of Economic Literature. Vol. XXXVII. December. pp. 1661-1707.

Clarida, R., Galí J., Gertler M. (1998). Monetary policy rule in practice: some international evidence. European Economic Review. Vol. 42. pp. 1033 -1067.

Cook, D. (2004). Monetary policy in emerging markets: can liability dollarization explain contractionary devaluations?. Journal of Monetary Economics. Vol. 51. pp. 1155-1181.

Dib, A. (2003). An estimated Canadian DSGE model with nominal and real rigidities. Canadian Journal of Economics, Vol. 36. No. 4. pp. 949-972. November.

De Gregorio, J., Tokman, A. (2005). Flexible exchange rate regime and forex intervention, in *BIS Papers No. 24 Foreign exchange market intervention in emerging markets: motives, techniques and implications*. May.

De Gregorio, J., Edwards, S., Valdes, R. (2000). Controls on capital inflows: do they work?. Journal of Development Economics, Vol. 63, No. 1. October.

Del Negro, M., Schorfheide, F., Smets, F., Wouters, R. (2005). On the fit and forecasting performance of New-Keynesian models. Working Paper 2004-37, Federal Reserve Bank of Atlanta.

Engel, C., West, K. (2006). Taylor rules and the Deutschmark-Dollar real exchange rate. Journal of Money Credit and Banking Vol. 38, No. 5. pp. 1175-1194. August.

Erceg, C., Levin, A. (2003). Imperfect credibility and inflation persistence. Journal of Monetary Economics Vol. 50, pp 915-944.

Elekdag, S., Justiniano, A., Tchakarov, I. (2005). An estimated small open economy model of the financial accelerator. IMF Staff Papers, Vol. 53, No. 2.

Fernández-Villaverde, J., Rubio-Ramírez, J. (2004). "Comparing dynamic equilibrium models to data: a bayesian approach". Journal of Econometrics, Vol. 123, pp. 153-187.

Galí, J. (2003). New perspectives on Monetary policy, Inflation and the Business Cycle, in: Dewatripont, M., Hansen,L., Turnovsky S. (Eds.) Advances in Economic Theory, vol. III, 151-197, Cambridge University Press.

Galí, J. (1999). Technology, employment and the business cycle: do technology shocks explain aggregate fluctuations. The American Economic Review. Vol. 89. No.1. March. pp 249-271.

Galí, J., Monacelli T. (2002). Monetary policy and exchange rate volatility in a small open economy. NBER Working Paper No. 8905.

Hamman, F., Julio, J., Restrepo, P., Riascos, A. (2005). "Disinflation costs under inflation targeting in a small open economy: the colombian case". Paper presented at the Central bank workshop on macroeconomic modelling: recent developments in macroeconomic modelling. 7-9 September, South African Reserve Bank. Pretoria - South Africa.

Hamilton, J. (1994a). *Time series analysis*. Princeton University Press. Princeton.

Hamilton, J. (1994b). State Space Models, in Engle R.F., McFadden D.L. (Eds.) *Handbook of Econometrics*. Volume IV. Elsevier Science.

Ireland, P. (2006). Changes in the Federal Reserve's inflation target: causes and consequences. Mimeo Boston College, January.

Ireland, P. (2004a). A method for taking models to the data. Journal of Economic Dynamics and Control. Vol. 28, Issue 6, March. pp. 1205 - 1226.

Ireland, P. (2004b). Technology shocks in the new keynesian model. The Review of Economics and Statistics. Vol. 86. No.4. November.pp 923-936.

Ireland, P. (2001). Sticky-price models of the business cycle: specification and stability. Journal of Monetary Economics. Vol. 47 No. 1. pp 3-18.

Kim, J. (2000). Constructing and estimating a realistic optimizing model of monetary policy. Journal of Monetary Economics. Vol 45. pp 329-359.

Kollman, R. (2001). The exchange rate in a dynamic-optimizing business cycle model with nominal rigidities: a quantitative investigation, Journal of International Economics, Vol. 55, pp. 243-262.

Krugman, P. (1999). Balance sheets, the transfer problem, and financial crises, in Isard P., Razin A., Rose A. (Eds.) International Finance and Financial Crises: Essays in Honor of Robert Flood. Kluwer Academic Publishers-IMF.

Lubik, T., Schorfheide F. (2003). Do central banks respond to exchange rate movements? A structural investigation. Forthcoming Journal of Monetary Economics. Available at: http://www.econ.upenn.edu/~schorf/papers/soe.pdf

Luengnaruemitchai, P. (2003). The Asian crises and the mystery of the missing balance sheet effect. Job Market Paper. University of California - Berkeley.

Martinez, L. Sánchez, O., Werner, A. (2001). Monetary policy and the transmission mechanism in Mexico, in *BIS Papers No. 8 Modelling aspects of the inflation process and the monetary transmission mechanism in emerging market countries*, November.

McCallum, B. (2001). Should monetary policy respond strongly with output gaps?. The American Economic Review. Papers and Proceedings. May. pp. 258-262.

Medina, J., Soto, C (2006). "Model for analysis and simulations: a small open economy DSGE for the Chilean economy". Mimeo Central Bank of Chile.

Medina, J., Soto, C (2005a). "Oil shocks and monetary policy in an estimated DSGE model for a small open economy". Central Bank of Chile Working Papers No. 353. December.

Medina, J., Soto, C. (2005b). "Model for the analysis ans simulations (MAS): a new DSGE for the Chilean Economy". Paper presented at the Central Bank Workshop on Macroeconomic Modelling: recent developments in macroeconomic modelling. 7-9 September, South African Reserve Bank. Pretoria - South Africa.

Monacelli, T. (2004). Into the Mussa Puzzle: Monetary policy regimes and the real exchange rate in a small open economy. Journal of International Economics. Vol. 62 Issue 1, pp. 191-217. January.

Morandé, F. (2002). A decade of inflation targeting in Chile: developments, lessons and challenges. In Loayza and Soto (Eds.) *Inflation targeting: design, performance, challenges*. Series on central Banking, Analysis and Economic Policies No. 5. Central Bank of Chile.

Obstefeld, M., Rogoff, K. (2000). New directions in stochastic open economy models, Journal of International Economics, Vol. 48, pp. 117-153. February.

Obstefeld, M., Rogoff, K. (1996). Foundations of international macroeconomics. Cambridge, Ma. MIT press.

Ocampo, J., Tovar, C. (2003). Managing the capital account: Colombia's experience witrh price-based controls on capital inflows. Cepal Review No. 81. Santiago-Chile.

Parrado E., Velasco, A. (2002). Alternative monetary rules in the open-economy: a welfare based approach. In Loayza and Soto (Eds.) *Inflation targeting: design, performance, challenges*. Series on central Banking, Analysis and Economic Policies No. 5. Central Bank of Chile.

Rotemberg, J. (1982). Sticky prices in the United States. Journal of Political Economy. Vol. 90. pp. 1187-1211.

Ruge-Murcia, F. (2003). Methods to estimate dynamic stochastic general equilibrium models. Département de sciences économiques and C.I.R.E.Q., Université de Montréal. September. Available at: http://www.cirequation umontreal.ca/online/frm-Methods2-03-09-24.pdf

Runkle, D. (1987). Vector autoregressions and reality. Journal of Business and Economic Statistics 5. pp. 437-442.

Sachs, J., Tornell A., Velasco A. (1996). The collapse of the Mexican peso: what have we learned, Economic Policy, 22. pp. 15-56.

Schmidt-Hebbel K., Werner A. (2002). Inflation targeting in Brazil, Chile and mexico: performance, credibility, and the exchange rate, Central Bank of Chile Working papers No. 171.

Sidaoui, J. (2005). Central banking intervention under a floating exchange regime: ten years of Mexican experience, in *BIS papers No. 24 Foreign exchange market intervention in emerging markets: motives, techniques and implications*, May.

Sims, C. (2001). Solving linear rational expectations models. Computational Economics. Vol. 20. pp. 1-20.

Smets, F., Wouters, R. (2003). An estimated dynamic stochastic general equilibrium model of the Euro area. Journal of the European Economic Association. Vol. 1, No. 5, pp. 1123-1175. September.

Sutherland, A. (2006). The expenditure switching effect, welfare and monetary policy in a small open economy. Journal of Economic Dynamics and Control. Vol. 30. pp. 1159-1182.

Taylor, J. (2001). The role of the exchange rate in monetary-policy rules. The American economic review. Papers and proceedings. May. pp. 263-267.

Tovar, C (2006). Devaluations, output and the balance sheet effect: a structural econometric analysis. BIS Working Paper No. 215. Bank for International Settlements. September.

Tovar, C. (2005). The mechanics of devaluations and the output response in a DSGE model: how relevant is the balance sheet effect. BIS Working Papers No. 192. Bank for International Settlements. November.

Tovar, C. (2004). Three essays in international finance: devaluations and output behavior. Department of Economics. University of Wisconsin - Madison.

Villar, L., Rincón H. (2001). Flujos de capital y regimenes cambiarios en la década de los 90", in Ensayos sobre política económica, No. 39, pp 5-71. Bogotá.

Uribe, J., Toro, J. (2005). Foreign exchange market intervention in Colombia, in *BIS papers No. 24 Foreign exchange market intervention in emerging markets: motives, techniques and implications*, May.

Uribe M. and Yue (2006). Country spreads and emerging countries: who drives whom?. Journal of International Economics Vol. 69. pp. 6-36.

Uhlig, H. (1997). A toolkit for analyzing nonlinear dynamic stochastic models easily. Available at: http://www.wiwi.hu-berlin.de/wpol/html/toolkit/toolkit.pdf

Woodford, M. (2003). *Interest and prices: foundations of a theory of monetary policy*. Princeton University Press.

A Appendix: Solving The Model

The system of equations describing this economy cannot be solved for analytically. As a result, the system is log-linearized around the non-stochastic symmetric steady state.[42] The estimation of the model starts by representing the model in state-space form. For this purpose, the system is log-linearized around the non-stochastic symmetric steady state and solved with the method of undetermined coefficients described by Uhlig (1997). For estimation purposes, two definitional equations were added: $\hat{\imath}_t = \hat{\imath}_t$ and $\hat{s}_t = \hat{\varrho}_t$.[43] With this in mind, let $\tilde{x} = \left[\hat{k}\ \hat{e}\ \hat{w}\ \hat{d}\ dB^*\ \hat{\imath}\ \hat{s}\right]'$ be the endogenous state vector, $\tilde{y} = \left[\hat{\pi}\ \hat{y}\ \hat{l}\ \hat{r}\ \hat{c}\ \hat{f}^s\ \hat{\imath}\ \hat{\varrho}\right]'$ the vector of endogenous variables, and $\tilde{z} = \left[\hat{\rho}\ \hat{x}\ \hat{A}\ \hat{\theta}\ \hat{\chi}\ \hat{a}\ \hat{\kappa}\ \hat{\vartheta}\right]'$ the vector of exogenous stochastic processes, so that the system is written as:

$$0 = \Gamma_A \tilde{x}_t + \Gamma_B \tilde{x}_{t-1} + \Gamma_C \tilde{y}_t + \Gamma_D \tilde{z}_t \tag{42}$$

$$0 = E_t[\Gamma_F \tilde{x}_{t+1} + \Gamma_G \tilde{x}_t + \Gamma_H \tilde{x}_{t-1} + \Gamma_J \tilde{y}_{t+1} + \Gamma_K \tilde{y}_t + \Gamma_L \tilde{z}_{t+1} + \Gamma_M \tilde{z}_t] \tag{43}$$

[42] The symmetric equilibrium, existence of the steady state, and the log-linearized system are discussed in Tovar (2005).

[43] This allows us to extract information about the nominal exchange rate and the interest rate in the estimation process.

$$\tilde{z}_{t+1} = \Gamma_N \tilde{z}_t + \tilde{\varepsilon}_{t+1} \tag{44}$$

$$E_t\left[\tilde{\varepsilon}_{t+1}\right] = 0 \tag{45}$$

where Γ_C is of size (8×8), and of rank 8, Γ_F is of size (7×8), and Γ_N has only stable eigenvalues. The solution expresses all variables as linear functions of a vector of endogenous variables $\tilde{x}_{t-1}$ and exogenous variables $\tilde{z}_t$ given at date t, which are usually state or predetermined variables, so that the recursive equilibrium law of motion becomes:

$$\tilde{x}_t = \Gamma_P \tilde{x}_{t-1} + \Gamma_Q \tilde{z}_t \tag{46}$$

$$\tilde{y}_t = \Gamma_X \tilde{x}_t = \Gamma_R \tilde{x}_{t-1} + \Gamma_S \tilde{z}_t \tag{47}$$

where equation (46) is the endogenoues state equation and equation (47) is the observation equation. Formally, the idea is to obtain matrices $\Gamma_P, \Gamma_Q, \Gamma_R$ and Γ_S so that the equilibrium is stable.[44] Also notice that these matrices are nonlinear functions of the model's structural parameters. The system can easily now be re-written in state-space form by defining the (15×1) vector $S_t = [\tilde{x}_t' \, \tilde{z}_t]'$.

A1 Adding Measurement Errors

The state-space model can be augmented with error terms by adding serially correlated residuals to the observation equation. Although this is usually done to deal with the stochastic singularity problem, its motivation here is to improve the model's fit to the data. Formally, the state-space model is transformed so that the observation equation equation (47) is now replaced by:

$$\tilde{y}_t = \Gamma_X \tilde{x}_t + u_t \tag{48}$$

where $u_t = Du_{t-1} + \xi_t$ is an (8×1) vector of shocks of measurement errors that are allowed to follow a first-order vector autoregression, with a serially uncorrelated innovation $\xi_t \sim N(0, V)$ and $V = E\left(\xi_t \xi_t^{'}\right)$. It is further assumed that the measurement error contains no information about current or future shocks to the economy, that is $E\left(\tilde{z}_t \xi_t\right) = 0$. Notice that since the observation equation (48) contains some identities, the variables $\hat{f}^s$, $\hat{\imath}$, and $\hat{\varrho}$ have no measurement errors attached to them. More precisely, define $u_t = [u_{\pi t}\ u_{yt}\ u_{lt}\ u_{rt}\ u_{ct}\ 0\ 0\ 0]'$ and $\xi_t = \left[\xi_{\pi t}\ \xi_{yt}\ \xi_{lt}\ \xi_{rt}\ \xi_{ct}\ 0\ 0\ 0\right]' = \left[\xi_t^{*\prime}\ 0_{1\times 3}\right]'$with matrices D and V as follows:

$$D = \begin{bmatrix} d & 0_{5\times 3} \\ 0_{3\times 5} & 0_{3\times 3} \end{bmatrix} \text{ where } d = \begin{bmatrix} d_{\pi\pi} & d_{\pi y} & d_{\pi l} & d_{\pi r} & d_{\pi c} \\ d_{y\pi} & d_{yy} & d_{yl} & d_{yr} & d_{yc} \\ d_{l\pi} & d_{ly} & d_{ll} & d_{lr} & d_{lc} \\ d_{r\pi} & d_{ry} & d_{rl} & d_{rr} & d_{rc} \\ d_{c\pi} & d_{cy} & d_{cl} & d_{cr} & d_{cc} \end{bmatrix} \tag{49}$$

[44] Details for the conditions under which this can be achieved are discussed in Uhlig (1997). The method is equivalent to Blanchard and Kahn (1980) and employs Sims' (2001) QZ decomposition, which is numerically more stable.

$$V = \begin{bmatrix} V^* & 0_{5\times3} \\ 0_{3\times5} & 0_{3\times3} \end{bmatrix} \text{ where } V^* = E\left(\xi_t^* \xi_t^{*\prime}\right) = \begin{bmatrix} v_\pi^2 & v_{\pi y} & v_{\pi l} & v_{\pi r} & v_{\pi c} \\ v_{\pi y} & v_y^2 & v_{yl} & v_{yr} & v_{yc} \\ v_{\pi l} & v_{yl} & v_l^2 & v_{lr} & v_{lc} \\ v_{\pi r} & v_{yr} & v_{lr} & v_r^2 & v_{rc} \\ v_{\pi c} & v_{yc} & v_{lc} & v_{rc} & v_c^2 \end{bmatrix} \tag{50}$$

The structural parameters are constrained to satisfy the theoretical restrictions discussed in Section 3. In addition, the eigenvalues of matrix D are constrained to lie inside the unit circle. As a result, the residuals in u_t must be stationary. Finally, the covariance matrix V is constrained to be positive definite. This is done calculating a Choleski decomposition $V = \tilde{V}\tilde{V}'$ where $\tilde{V}$ is a lower triangular matrix.

Let $\tilde{S}_t = [\tilde{x}_t' \; \tilde{z}_t']'$ so that equations (46) and (44) are summarized by a single equation $\tilde{S}_t = \Gamma_\Pi \tilde{S}_{t-1} + \tilde{e}_t$ where $\tilde{e}_t = \begin{bmatrix} 0_{7\times1} \\ \tilde{\varepsilon}_t \end{bmatrix}$ and $\Gamma_\Pi = \begin{bmatrix} \Gamma_P & \Gamma_Q \\ 0_{8\times7} & \Gamma_N \end{bmatrix}$.

Now define $\tilde{h}_t = \left[\tilde{S}_t' \; u_t'\right]'$ a (23×1) vector to track the model's unobserved state variables. This allows us to re-write the model in compact state-space form as:

$$\tilde{h}_t = \Gamma_V \tilde{h}_{t-1} + v_t \tag{51}$$

$$\tilde{y}_t = \Gamma_Z \tilde{h}_t \tag{52}$$

where $\Gamma_V = \begin{bmatrix} \Gamma_\Pi & 0_{15\times8} \\ 0_{8\times15} & D \end{bmatrix}$, $v_t = \begin{bmatrix} \tilde{e}_t \\ \xi_t \end{bmatrix}$ and $\Gamma_Z = [\Gamma_X \; 0_{8\times8} \; I_{8\times8}]$. The serially uncorrelated innovation vector, v_t, has variance-covariance matrix equal to:

$$E\left(v_t v_t'\right) = Q = \begin{bmatrix} \Omega & 0_{13\times8} \\ 0_{8\times13} & V \end{bmatrix} \tag{53}$$

where $\Omega = E\left(\tilde{e}_t \tilde{e}_t'\right) = \begin{bmatrix} 0_{7\times7} & 0_{7\times8} \\ 0_{8\times7} & \Lambda \end{bmatrix}$ and $\Lambda = E\left[\varepsilon_t \varepsilon_t'\right]$ is the (8×8) diagonal variance-covariance matrix for the shock's innovations.

A2 Kalman Filter and Maximum Likelihood Function

With the model in state-space form as captured by equations (51) and (52) it is possible to construct the likelihood function using the Kalman filter. For this purpose, first collect the structural parameters in the (31×1) vector:

$$\Theta = \begin{bmatrix} \alpha \; \gamma \; \beta \; \psi_p \; \psi_w \; \sigma \; \mu \; \nu \; \eta \; \omega_i \; \omega_\pi \; \omega_y \; \omega_s \; A \; \theta \; a \; \chi \; \rho \; x \\ \zeta_A \; \zeta_\theta \; \zeta_a \; \zeta_\chi \; \zeta_\rho \; \zeta_x \; \sigma_A \; \sigma_\theta \; \sigma_a \; \sigma_\chi \; \sigma_\rho \; \sigma_x \end{bmatrix}' \tag{54}$$

Observe that in addition to the structural parameters, the maximum likelihood function incorporates 25 elements of the matrix D that governs the persistence of the measurement errors and 15 elements of the variance-covariance matrix V associated to the measurement error residuals. Furthermore assume as in Ireland (2004a) and Ruge-Murcia (2003) that the state vector is unobserved, and let the observed data obtained through date $t-1$ be summarized by the vector $\aleph_{t-1} \equiv \left(\tilde{y}'_{t-1},\ \tilde{y}'_{t-2}, ..., \tilde{y}'_{1}\right)'$.

Now define $\hat{h}_{t|t-1} = E\left(\tilde{h}_t|\aleph_{t-1}\right)$ as the best estimate of the unobservable state vector $\tilde{h}_t$ for period t based on past observations of $\tilde{y}_t$, and let $\Sigma_{t|t-1} = E\left\{\left(\tilde{h}_t - \hat{h}_{t|t-1}\right)\left(\tilde{h}_t - \hat{h}_{t|t-1}\right)'\right\}$be the associated forecast error covariance matrix. Finally, let the best forecast of $\tilde{y}_t$ based on past observations be $\hat{y}_{t|t-1} = E\left(\tilde{y}_t|\aleph_{t-1}\right)$. Therefore, observe that these results and equation (52) imply that $\hat{y}_{t|t-1} = \Gamma_Z \hat{h}_{t|t-1}$.

The Kalman filter is an algorithm for calculating the sequence $\left\{\hat{h}_{t|t-1}\right\}_{t=1}^{T}$ and $\left\{\Sigma_{t|t-1}\right\}_{t=1}^{T}$, where T is the sample size. Following Hamilton (1994a and 1994b), these sequences are calculated as : $\hat{h}_{t+1|t} = \Gamma_V \hat{h}_{t|t-1} + \tilde{K}_t\left(\tilde{y}_t - \Gamma_Z \hat{h}_t\right)$ and $\Sigma_{t+1|t} = \Gamma_V \Sigma_{t|t-1}\Gamma'_V - \tilde{K}_t \Gamma_Z \Sigma_{t|t-1}\Gamma'_V + Q$ where $\tilde{K}_t \equiv \Gamma_V \Sigma'_{t|t-1}\Gamma'_Z\left(\Gamma_Z \Sigma_{t|t-1}\Gamma'_Z\right)$ is the "Kalman gain" or "gain matrix". To start the recursion, the values are initialized with the unconditional mean and variance of $\tilde{h}_1$, i.e.$\hat{h}_{1|0} = 0$ and $\Sigma_{1|0} = E\left\{\left(\tilde{h}_1 - \hat{h}_{1|0}\right)\left(\tilde{h}_1 - \hat{h}_{1|0}\right)'\right\}$ where $\Sigma_{1|0}$ is calculated using $vec\left(\Sigma_{1|0}\right) = \left[I_{23^2 \times 23^2} - \Gamma_V \otimes \Gamma_V\right]^{-1} \cdot vecQ$ assuming that the expression in brackets is non-singular.

Now, let the innovations of the model be normally distributed. It follows then that the density of $\tilde{y}_t$ conditional on $\aleph_{t-1}$ is $f\left(\tilde{y}_t|\aleph_{t-1}, \Theta\right) = N\left(\Gamma_Z \hat{h}_{t|t-1}, \Gamma_Z \Sigma_{t|t-1}\Gamma'_Z\right)$. Therefore, the Maximum Likelihood estimator of Θ is $\hat{\Theta}_{ml} = \underset{\{\Theta\}}{\text{Max}}\ L\left(\Theta\right)$ where $L\left(\Theta\right)$ denotes the log likelihood function:

$$L\left(\Theta\right) = -\frac{Tn}{2}\ln\left(2\pi\right) - \frac{1}{2}\sum_{t=1}^{T}\ln\left|\Gamma_Z \Sigma_{t|t-1}\Gamma'_Z\right| - \frac{1}{2}\sum_{t=1}^{T}\left(\tilde{y}_t - \Gamma_Z \hat{h}_t\right)'\left(\Gamma_Z \Sigma_{t|t-1}\Gamma'_Z\right)^{-1}\left(\tilde{y}_t - \Gamma_Z \hat{h}_t\right) \quad (55)$$

and $n = 8$ i.e. the number of observed variables in $\tilde{y}_t$.

Now it is possible to evaluate the likelihood function for any given set of parameters. Therefore, a search algorithm can be used to find the parameter values that maximizes it. In particular, the medium-scale Quasi-Newton line search algorithm is employed.

To implement the procedure, the model's structural parameters are transformed so that they can take any value on the real line. To ensure the numerical search always satisfies the theoretical restrictions imposed on the parameters, the likelihood function is re-parameterized. As suggested by Hamilton (1994, Ch. 5), a vector λ for which $\Theta =$ g(λ), where the function g:$R^a \rightarrow R^a$ incorporates the desired restrictions. Therefore, given the data and initial value for the transformed vector of parameters λ, it is possible to set $\Theta =$ g(λ) and calculate $L\left(\Theta\right)$. Once the value of $\hat{\lambda}$ that maximizes the likelihood function is found, it is possible to obtain $\hat{\Theta} =$ g$\left(\hat{\lambda}\right)$. For estimation purposes, the following transformations are used. For parameter values λ_i, the original parameters are recovered as follows.[45] For $\theta_i \in (0,1)$ then $\theta_i = \frac{\lambda_i^2}{1+\lambda_i^2}$; For parameter values such that $\theta_i \geq 0$ then $\theta_i = |\lambda_i|$ and for $\theta_i > 1$ then $\theta_i = 1 + |\lambda_i|$.

To calculate the standard errors, rely on the fact that for a large sample size, the distribution of the maximum likelihood estimate $\hat{\Theta}$ can be well approximated by $\hat{\Theta} \approx N\left(\Theta_o, T^{-1}\vartheta^{-1}\right)$ where Θ_o denotes the true parameter vector and ϑ is the information matrix. The information matrix is estimated using the second-derivative of the information matrix $\hat{\vartheta} = -T^{-1}\left.\frac{\partial^2 L(\Theta)}{\partial\Theta\partial\Theta'}\right|_{\Theta=\hat{\Theta}}$. With these results it is possible to approximate the variance-covariance matrix of $\hat{\Theta}$ by $E\left(\hat{\Theta} - \Theta_o\right)\left(\hat{\Theta} - \Theta_o\right) \cong \left[-\left.\frac{\partial^2 L(\Theta)}{\partial\Theta\partial\Theta'}\right|_{\Theta=\hat{\Theta}}\right]^{-1}$where

45 With some abuse of notation, in this appendix θ_i represents an element of Θ. Therefore, θ should not be confused with the model's mark-up parameter.

the term inside the brackets is calculated numerically as $\hat{D}_T = \left(\frac{1}{T}\right)\sum_{t=1}^{T} \left.\frac{\partial^2 \log f(\tilde{y}_t|\aleph_{t-1},\Theta)}{\partial\Theta\partial\Theta'}\right|_{\Theta=\hat{\Theta}}$. See Hamilton (1994, Ch. 14).

Standard errors for $\hat{\Theta}$ cannot be calculated directly using the re-parameterization discussed above. To obtain them, the likelihood function is first parameterized in terms of λ to find the MLE, and then the MLE is re-parameterized in terms of Θ to calculate the matrix of second derivatives evaluated at $\hat{\Theta}$. Finally, to calculate the standard errors, it is necessary to evaluate numerically the matrix of second derivatives of the log-likelihood function and then invert that full matrix. These two steps can introduce significant approximation errors into the statistics, so it is important to interpret these statistics with caution.

B Data sources

Chile

- Output: Real GDP. Million of pesos of 1996. Source National Accounts.
- Consumption: Real private consumption. Million of pesos of 1996. Source: National Accounts.
- Interest rate: Reference monetary policy rate. Source: Banco de Chile.
- Nominal exchange rate: Pesos per dollar. RF Series. Source: International Financial Statistics. International Monetary Fund.
- Prices: Consumer price index. Source: International Financial Statistics. International Monetary Fund.
- Labor: Wage earners. Source: INE.
- Population: Working age population. Source: Ministerio del Trabajo.

Colombia

- Output: Real GDP. Million of pesos of 1994. Source: DANE National Accounts.
- Consumption: Real Household consumption. Million of pesos of 1994. Source: DANE National Accounts.
- Interest rate: Interbank interest rate. Source: Banco de la República.
- Nominal exchange rate: Pesos per dollar. RF Series. Source: International Financial Statistics. International Monetary Fund.
- Prices: Consumer price index. Source: DANE.
- Labor: Wage earners. Source: DANE.
- Population: Working Age Population. Source: DANE.

Mexico

- Output: Real GDP at constant prices of 1993. Billions of pesos. Source: INEGI

- Consumption: Real private consumption at constant prices of 1993. Billions of pesos. Source INEGI.

- Interest rate: Cetes 91 days. Period average. Source: Banco de Mexico.

- Nominal exchange rate: Pesos per dollar. RF Series. Source: International Financial Statistics. International Monetary Fund.

- Prices: Consumer price index. Source: International Financial Statistics. International Monetary Fund.

- Labor: Workers insured with the Mexican social security system. Period average. Source: INEGI.

- Population: Total population. Source: CONAPO.

Figure 1: **Chile 1989:1 to 2005:4. Main economic variables in logs and HP filtered.**

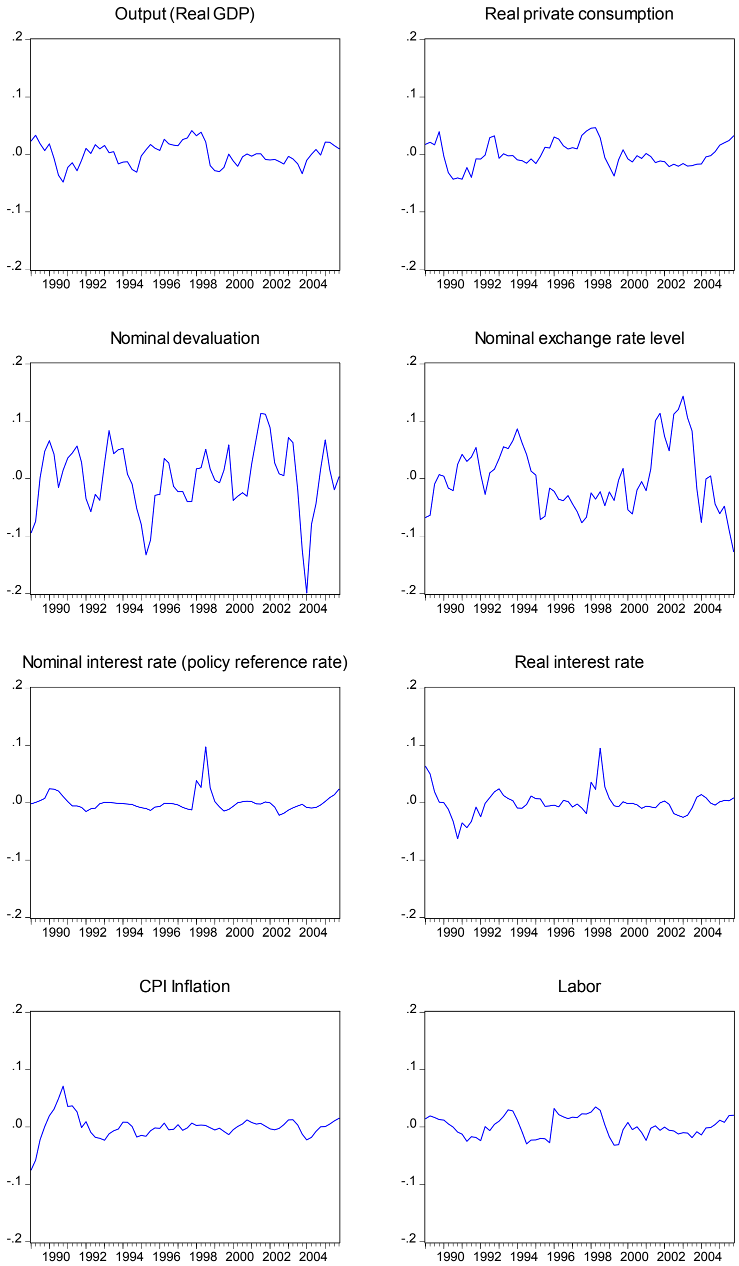

Figure 2: **Colombia 1989:1 to 2005:4. Main economic variables in logs and HP filtered.**

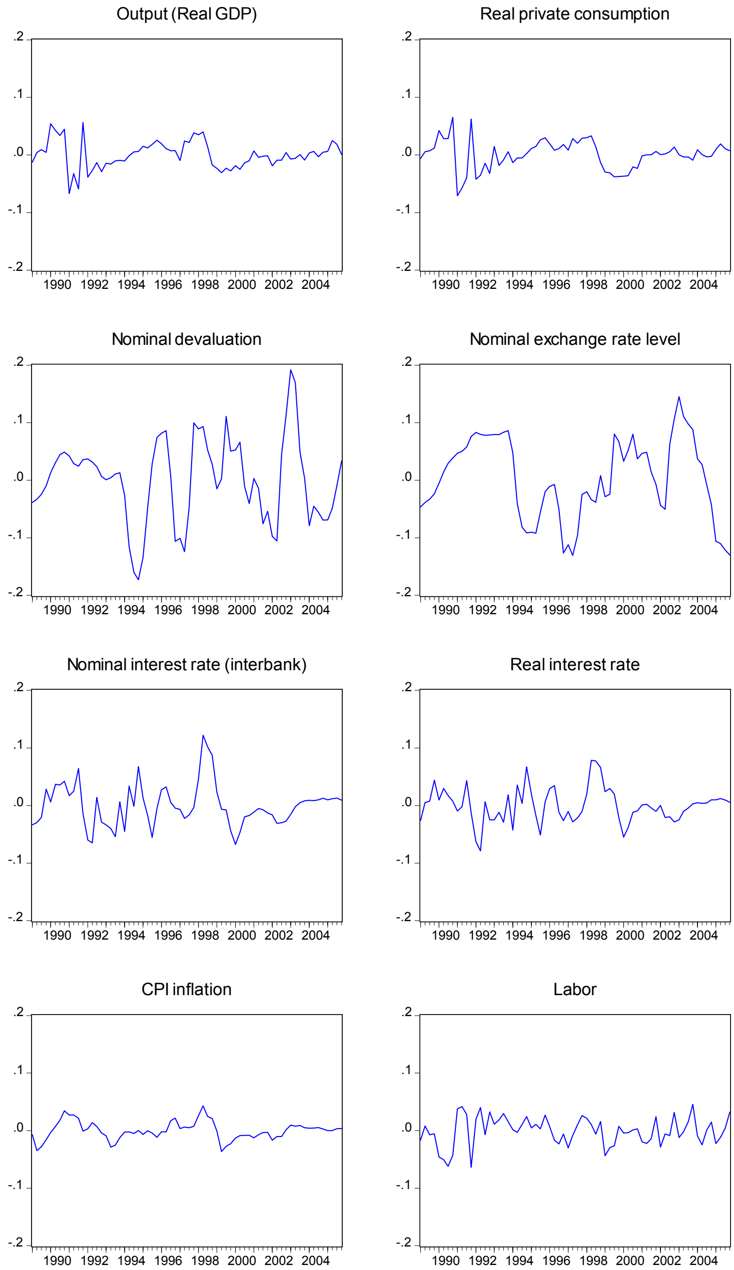

Figure 3: **Mexico 1989:1 to 2005:4. Main economic variables in logs and HP filtered.**

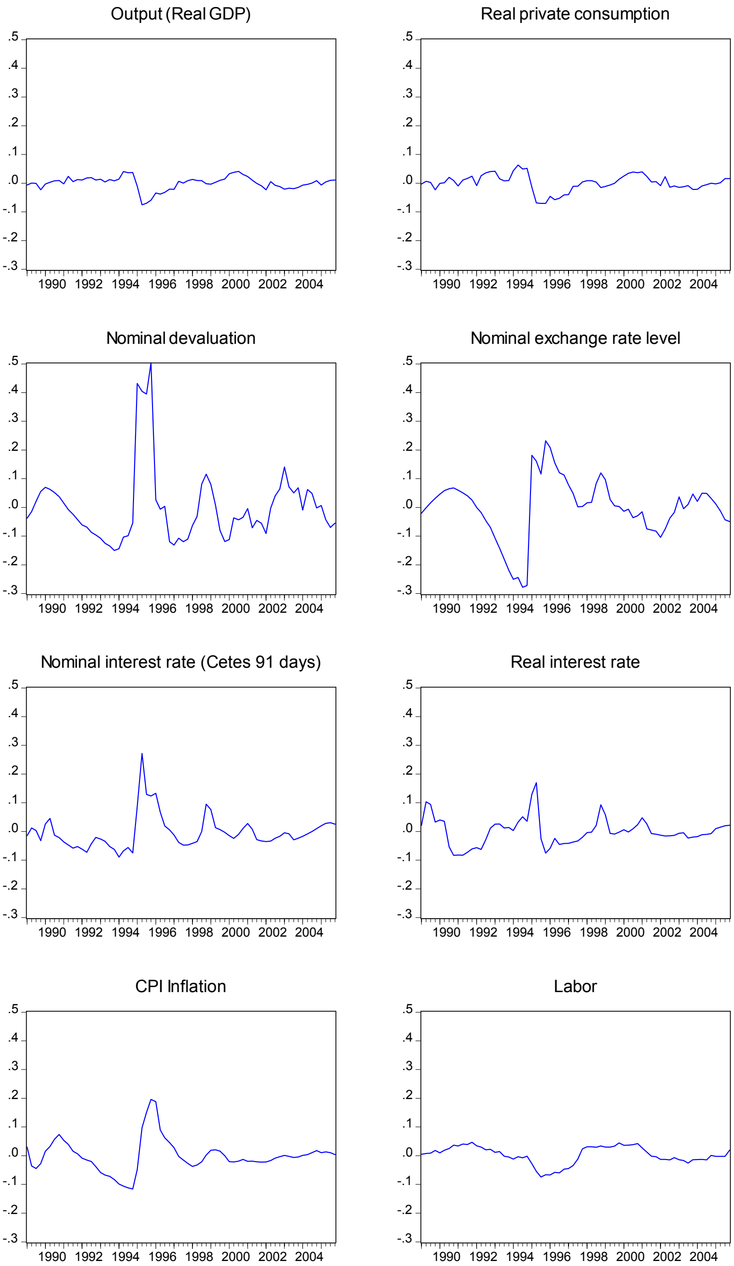

Table 1: **Benchmark parameter values for estimation**

Preferences		Technology	
-Discount factor	$\beta = 0.99$	-Capital share	$\alpha = 0.4$
-Elasticity of labor supply	$\nu = 2$	-Elasticity of labor demand	$\sigma = 2$
-Elasticity of substitution b/w different varieties	$\theta = 6$		

Table 2: **Maximum likelihood estimates: main parameter values**

	Chile		Colombia		Mexico	
	Estimate	Std Error	Estimate	Std. Error	Estimate	Std. Error
Transmission channels of devaluations						
- Balance sheet, μ	0.31	0.0019	0.23	0.0021	0.14	0.0030
- Expenditure switching, γ	0.62	0.0012	0.68	0.0046	0.63	0.0034
Interest rate response to:						
- Lagged interest rate, ω_i	0.03	0.0014	0.53	0.0024	0.55	0.0029
- Expected inflation, ω_p	1.93	0.0013	1.98	0.0012	2.50	0.0024
- Output, ω_y	0.04	0.0011	0.16	0.0033	1.14	0.0049
- Nominal exchange rate, ω_s	0.66	0.0007	0.92	0.0028	0.58	0.0029
Nominal rigidities						
- Price rigidities, ψ_p	7.13	0.0050	6.38	0.0024	4.60	0.0024
- Wage rigidities, ψ_w	0.86	0.0010	1.53	0.0030	0.24	0.0043

Table 3: **Maximum likelihood estimates: shocks' persistence and standard deviation estimates**

	Chile		Colombia		Mexico	
	Estimate	Std Error	Estimate	Std. Error	Estimate	Std. Error
Persistence parameters						
- Technology, ζ_A	0.68	0.0006	0.86	0.0030	0.96	0.0043
- Mark-up, ζ_θ	0.96	0.0018	0.93	0.0049	0.97	0.0043
- Preferences, ζ_a	0.98	0.0011	0.92	0.0050	0.90	0.0024
- Devaluationary policy, ζ_χ	0.86	0.0015	0.93	0.0014	0.87	0.0028
- International interest rate, ζ_β	0.79	0.0015	0.78	0.0021	0.90	0.0014
- Exports, ζ_x	0.98	0.0013	0.78	0.0023	0.87	0.0034
- Inflation target, $\zeta_\varkappa$	0.74	0.0009	0.85	0.0032	0.50	0.0042
- Output Target, ζ_ϑ	0.87	0.0011	0.86	0.0031	0.77	0.0046
Standard deviations						
- Technology, σ_A	0.01	0.0013	0.06	0.0052	0.10	0.0046
- Mark-up, σ_θ	0.01	0.0019	0.02	0.0023	0.02	0.0032
- Preferences, σ_a	0.23	0.0021	0.08	0.0021	0.02	0.0035
- Devaluationary policy, σ_χ	0.11	0.0016	0.13	0.0021	0.10	0.0023
- International interest rate, σ_ρ	0.03	0.0014	0.02	0.0026	0.13	0.0032
- Exports, σ_x	0.23	0.0015	0.35	0.0020	0.21	0.0028
- Inflation target, $\sigma_\varkappa$	0.15	0.0008	0.21	0.0023	0.11	0.0049
- Output Target, σ_ϑ	0.16	0.0016	0.12	0.0018	0.10	0.0015

Table 4: **Chile: Forecast-error variance decomposition**

	Technology		Mark-up		Preference		Devaluation		Intl. Interest		Export		Inflation target		Output target	
Q	coef.	s.e.	coef.	s.e	coef.	s.e	coef.	s.e.	coef.	s.e.	coef.	s.e	coef.	s.e	coef.	s.e
								Inflation								
1	0.03	0.003	5.78	0.804	19.50	0.809	18.90	0.328	0.03	0.001	20.20	0.481	35.55	0.464	0.02	0.000
4	0.08	0.008	10.97	1.562	36.47	1.688	14.41	0.353	0.04	0.001	16.17	0.579	21.86	0.349	0.01	0.000
8	0.04	0.004	16.08	2.321	53.49	2.552	6.66	0.250	0.61	0.015	15.05	0.690	8.06	0.209	0.01	0.000
20	0.00	0.001	18.32	2.628	66.05	2.837	0.99	0.044	0.77	0.023	12.86	0.628	1.00	0.031	0.00	0.00
								Output								
1	1.01	0.082	5.62	0.796	19.50	0.845	19.05	0.325	0.23	0.002	17.40	0.276	37.17	0.497	0.02	0.000
4	1.16	0.114	10.47	1.562	37.73	1.623	9.09	0.234	0.62	0.011	24.91	0.524	16.02	0.129	0.01	0.000
8	0.65	0.070	12.42	1.908	47.41	1.840	3.85	0.120	0.47	0.008	28.12	0.704	7.07	0.080	0.00	0.000
20	0.29	0.031	11.59	1.809	50.84	1.468	1.69	0.051	0.22	0.003	32.27	0.780	3.11	0.050	0.00	0.000
								Labor								
1	0.11	0.011	11.20	1.648	40.25	1.872	16.79	0.430	0.01	0.001	0.43	0.073	31.20	0.425	0.01	0.001
4	0.15	0.016	14.73	2.183	51.46	2.397	12.73	0.448	0.03	0.001	1.96	0.172	18.94	0.429	0.01	0.000
8	0.06	0.007	18.00	2.652	61.93	2.875	6.29	0.271	0.56	0.016	5.66	0.383	7.49	0.224	0.01	0.000
20	0.01	0.001	18.93	2.726	69.41	2.933	1.00	0.046	0.74	0.023	8.93	0.508	0.99	0.032	0.00	0.000
								Real Interest rate								
1	1.35	0.106	5.66	0.806	20.87	0.773	3.82	0.074	0.00	0.000	60.93	1.063	7.37	0.136	0.00	0.000
4	0.61	0.053	9.05	1.278	30.90	1.369	12.11	0.267	0.09	0.002	28.17	0.751	19.05	0.304	0.01	0.000
8	0.16	0.016	14.31	2.053	47.72	2.243	7.18	0.243	0.47	0.010	21.19	0.805	8.96	0.205	0.01	0.000
20	0.01	0.002	17.85	2.559	64.10	2.757	1.08	0.047	0.77	0.023	15.10	0.687	1.09	0.033	0.00	0.000

Table 5: **Chile: Forecast-error variance decomposition (continued)**

	Technology		Mark-up		Preference		Devaluation		Intl. Interest		Export		Inflation target		Output target	
Q	coef.	s.e.	coef.	s.e	coef.	s.e	coef.	s.e.	coef.	s.e.	coef.	s.e	coef.	s.e	coef.	s.e
								Consumption								
1	1.39	0.092	0.01	0.002	0.61	0.045	35.98	0.697	2.64	0.085	7.03	0.171	52.31	0.780	0.03	0.001
4	1.55	0.111	0.20	0.040	4.35	0.193	34.38	0.369	5.79	0.146	0.14	0.248	47.58	0.766	0.03	0.001
8	1.24	0.105	0.18	0.037	7.29	0.294	27.22	0.528	19.59	0.476	6.77	0.347	37.68	0.685	0.02	0.000
20	0.89	0.079	0.49	0.094	15.45	0.521	22.00	0.359	18.15	0.467	13.81	0.645	29.19	0.614	0.02	0.000
								Nominal exchange rate change								
1	0.02	0.001	5.90	0.833	20.41	0.870	25.49	0.453	0.03	0.001	0.21	0.027	47.92	0.489	0.02	0.000
4	0.06	0.006	11.31	1.644	38.52	1.739	19.66	0.533	0.18	0.002	0.35	0.038	29.90	0.437	0.02	0.001
8	0.03	0.004	17.21	2.527	58.47	2.702	9.29	0.381	0.81	0.021	3.04	0.244	11.14	0.312	0.01	0.000
20	0.00	0.001	19.11	2.751	69.98	2.952	1.39	0.063	0.78	0.025	7.33	0.451	1.40	0.045	0.00	0.000
								Nominal interest rate								
1	1.24	0.063	0.19	0.034	1.41	0.058	22.31	0.590	6.81	0.191	5.59	0.125	62.45	0.728	0.02	0.001
4	0.96	0.051	0.21	0.042	2.50	0.092	30.98	0.663	3.38	0.077	4.55	0.158	57.39	0.775	0.03	0.001
8	0.54	0.031	0.17	0.026	1.84	0.076	40.82	0.647	4.59	0.087	4.02	0.154	47.98	0.741	0.04	0.001
20	0.41	0.023	0.66	0.076	1.43	0.059	45.90	0.460	4.73	0.107	6.55	0.179	40.27	0.691	0.04	0.001
								Nominal exchange rate level								
1	0.00	0.000	0.01	0.002	0.02	0.001	32.46	0.789	0.54	0.018	0.16	0.006	66.78	0.788	0.03	0.001
4	0.02	0.002	0.02	0.003	0.13	0.006	37.12	0.795	0.67	0.020	0.40	0.010	61.61	0.799	0.03	0.001
8	0.02	0.002	0.08	0.012	0.51	0.019	42.42	0.763	0.81	0.024	1.00	0.028	55.12	0.783	0.04	0.001
20	0.02	0.002	0.16	0.025	1.26	0.039	44.44	0.696	0.82	0.024	2.54	0.081	50.71	0.754	0.04	0.001

Table 6: **Colombia: Forecast-error variance decomposition**

	Technology		Mark-up		Preference		Devaluation		Intl. Interest		Export		Inflation target		Output target	
Q	coef.	s.e.	coef.	s.e	coef.	s.e	coef.	s.e.	coef.	s.e.	coef.	s.e	coef.	s.e	coef.	s.e
								Inflation								
1	0.83	0.134	3.23	0.641	3.55	0.228	15.01	1.037	0.02	0.003	76.35	1.036	1.02	0.098	0.00	0.00
4	2.11	0.310	9.19	1.784	9.27	0.596	17.39	1.157	0.02	0.004	60.98	1.103	1.04	0.115	0.00	0.00
8	2.04	0.247	20.03	3.686	18.18	1.613	15.39	1.272	0.62	0.104	42.94	0.895	0.80	0.106	0.00	0.00
20	0.64	0.042	39.66	6.881	31.61	4.736	6.92	0.844	1.88	0.311	19.00	1.030	0.29	0.050	0.00	0.00
								Output								
1	27.07	3.120	5.58	0.932	6.57	0.554	29.38	2.327	0.04	0.008	29.37	1.509	1.99	0.264	0.00	0.000
4	38.84	3.117	9.14	1.195	10.79	1.266	13.36	1.497	0.14	0.027	26.91	2.233	0.82	0.131	0.00	0.000
8	41.58	2.682	12.77	1.728	14.67	2.071	7.81	0.989	0.14	0.028	22.57	2.166	0.45	0.077	0.00	0.000
20	39.93	2.316	16.56	2.865	18.10	3.064	6.14	0.823	0.12	0.024	18.80	1.893	0.35	0.061	0.00	0.000
								Labor								
1	8.55	1.046	13.84	2.517	17.18	1.165	34.64	2.893	0.01	0.002	23.52	1.430	2.26	0.274	0.00	0.001
4	8.13	0.927	16.98	3.015	18.69	1.518	25.51	2.219	0.02	0.003	29.20	1.210	1.47	0.192	0.00	0.000
8	4.75	0.469	24.35	4.296	23.20	2.328	18.26	1.730	0.61	0.104	27.92	0.882	0.91	0.131	0.00	0.000
20	1.18	0.045	40.59	7.037	32.86	5.050	7.60	0.951	1.80	0.303	15.66	0.823	0.31	0.053	0.00	0.000
								Real Interest rate								
1	15.75	2.130	1.64	0.273	2.11	0.165	2.45	0.191	0.00	0.001	77.89	2.232	0.16	0.018	0.00	0.000
4	15.32	1.980	5.31	0.902	5.58	0.436	11.30	0.825	0.02	0.003	61.78	2.005	0.68	0.082	0.00	0.000
8	9.43	1.085	15.22	2.673	13.88	1.292	14.28	1.167	0.43	0.078	46.02	1.568	0.75	0.100	0.00	0.000
20	2.31	0.134	37.63	6.522	30.00	4.451	7.36	0.882	1.82	0.302	20.57	1.113	0.31	0.052	0.00	0.000

Table 7: **Colombia: Forecast-error variance decomposition (continued)**

	Technology		Mark-up		Preference		Devaluation		Intl. Interest		Export		Inflation target		Output target	
Q	coef.	s.e.	coef.	s.e	coef.	s.e	coef.	s.e.	coef.	s.e.	coef.	s.e	coef.	s.e	coef.	s.e
								Consumption								
1	48.64	4.907	0.51	0.115	2.52	0.198	33.04	3.797	0.15	0.040	13.12	0.972	2.02	0.311	0.00	0.001
4	48.85	4.677	0.85	0.282	5.40	0.555	21.75	2.657	5.97	1.204	15.76	1.404	1.42	0.220	0.00	0.000
8	37.00	4.374	0.58	0.230	6.45	0.656	14.08	1.598	16.07	2.747	24.92	1.745	0.90	0.124	0.00	0.000
20	26.85	3.777	0.60	0.228	7.67	0.843	21.04	1.853	15.78	2.531	27.17	1.260	0.89	0.113	0.00	0.000
								Change in nominal exchange rate								
1	1.12	0.162	9.62	2.096	11.17	0.426	66.65	2.440	0.08	0.013	6.85	0.739	4.51	0.464	0.01	0.001
4	2.06	0.260	16.53	3.298	17.40	1.080	44.82	2.776	0.23	0.041	16.28	0.893	2.67	0.318	0.01	0.001
8	1.68	0.174	25.32	4.695	23.60	2.183	26.50	2.275	0.96	0.159	20.61	0.778	1.33	0.185	0.00	0.000
20	0.52	0.028	40.90	7.183	32.89	5.011	9.62	1.195	1.90	0.315	13.79	0.688	0.38	0.066	0.00	0.000
								Nominal interest rate								
1	9.51	1.552	0.16	0.047	0.02	0.011	62.59	1.925	3.50	0.621	19.26	0.856	4.94	0.444	0.01	0.001
4	9.89	1.628	0.21	0.046	0.02	0.001	66.11	1.866	1.48	0.276	18.01	0.768	4.27	0.405	0.01	0.001
8	6.03	1.068	0.61	0.126	0.03	0.004	74.09	1.599	1.43	0.261	14.30	0.719	3.51	0.342	0.01	0.001
20	3.55	0.670	1.27	0.317	0.14	0.013	81.56	1.454	1.24	0.225	9.64	0.607	2.60	0.270	0.01	0.000
								Nominal exchange rate level								
1	0.02	0.005	0.11	0.039	0.17	0.018	87.03	1.094	2.12	0.350	4.09	0.311	6.45	0.540	0.01	0.002
4	0.01	0.003	0.15	0.053	0.22	0.023	88.30	1.045	2.10	0.361	3.47	0.270	5.73	0.494	0.01	0.001
8	0.01	0.002	0.18	0.066	0.25	0.027	90.72	0.863	1.56	0.270	2.54	0.212	4.73	0.429	0.01	0.001
20	0.00	0.001	0.20	0.082	0.27	0.029	92.94	0.706	1.11	0.197	1.81	0.168	3.65	0.357	0.01	0.001

Table 8: **Mexico: Forecast-error variance decomposition**

	Technology		Mark-up		Preference		Devaluation		Intl. Interest		Export		Inflation target		Output target	
Q	coef.	s.e.	coef.	s.e	coef.	s.e	coef.	s.e.	coef.	s.e.	coef.	s.e	coef.	s.e	coef.	s.e
								Inflation								
1	1.35	0.206	0.29	0.115	0.03	0.008	6.63	0.269	1.01	0.185	55.02	1.369	30.51	0.992	5.17	0.269
4	2.15	0.587	11.57	1.310	0.25	0.139	8.94	0.250	0.84	0.168	44.03	1.620	26.09	1.449	6.14	0.214
8	5.30	1.009	33.63	1.623	0.62	0.306	5.31	0.231	24.16	1.040	17.90	0.956	9.95	0.643	3.13	0.155
20	1.23	0.257	32.31	2.082	0.37	0.181	0.80	0.039	60.97	1.779	2.67	0.187	1.22	0.042	0.42	0.031
								Output								
1	38.73	2.737	14.61	1.321	0.42	0.194	3.81	0.209	0.76	0.177	23.40	0.779	15.46	1.652	2.81	0.135
4	56.96	2.764	13.97	1.375	0.37	0.161	1.17	0.070	10.93	1.109	11.66	0.437	4.12	0.505	0.82	0.043
8	63.26	2.630	13.43	1.536	0.28	0.125	0.46	0.026	14.12	1.223	6.41	0.186	1.71	0.210	0.33	0.018
20	69.25	2.739	13.75	2.215	0.19	0.089	0.24	0.012	11.86	0.771	3.67	0.148	0.87	0.092	0.17	0.008
								Labor								
1	8.86	1.790	11.92	1.223	0.30	0.175	12.27	0.682	8.33	1.217	4.13	0.692	45.34	3.406	8.85	0.166
4	15.77	2.400	28.90	1.571	0.65	0.327	10.61	0.574	2.54	0.168	6.65	0.644	27.88	2.432	7.00	0.198
8	11.60	1.756	39.27	1.823	0.71	0.344	4.99	0.252	26.54	1.129	5.11	0.326	8.91	0.638	2.87	0.151
20	2.12	0.372	33.37	2.144	0.37	0.183	0.79	0.039	60.13	1.814	1.64	0.120	1.18	0.040	0.40	0.030
								Real Interest rate								
1	22.57	3.740	2.81	0.520	0.11	0.036	1.72	0.036	0.05	0.304	64.07	3.117	7.35	0.640	1.31	0.056
4	38.82	3.418	3.04	0.317	0.07	0.035	4.51	0.225	3.82	0.351	33.94	2.324	12.77	1.398	3.04	0.140
8	34.78	2.691	20.07	1.510	0.37	0.175	4.55	0.244	11.85	0.782	17.30	1.023	8.42	0.863	2.66	0.109
20	5.95	0.724	30.10	2.066	0.35	0.170	0.87	0.043	58.08	1.579	2.94	0.183	1.28	0.058	0.44	0.030

Table 9: **Mexico: Forecast-error variance decomposition (continued)**

	Technology		Mark-up		Preference		Devaluation		Intl. Interest		Export		Inflation target		Output target	
Q	coef.	s.e.	coef.	s.e	coef.	s.e	coef.	s.e.	coef.	s.e.	coef.	s.e	coef.	s.e	coef.	s.e
								Consumption								
1	28.33	2.383	6.74	0.887	0.28	0.131	1.97	0.287	45.90	1.168	7.36	0.424	7.84	1.274	1.57	0.170
4	13.87	1.766	2.84	0.520	0.12	0.059	0.70	0.072	77.08	1.221	1.52	0.141	3.26	0.337	0.61	0.033
8	4.71	0.733	1.12	0.352	0.05	0.024	0.18	0.016	92.56	0.449	0.36	0.045	0.86	0.068	0.16	0.006
20	2.18	0.337	0.86	0.519	0.03	0.014	0.13	0.009	96.16	0.312	0.17	0.020	0.40	0.034	0.08	0.003
								Change in nominal exchange rate								
1	6.14	0.986	12.64	0.806	0.34	0.182	12.17	0.580	15.01	0.598	0.01	0.037	44.97	2.443	8.72	0.240
4	13.88	1.841	27.89	1.723	0.65	0.321	12.28	0.598	4.75	0.201	1.59	0.097	31.03	2.225	7.95	0.262
8	14.01	1.784	41.95	2.020	0.77	0.364	6.85	0.359	18.34	0.862	3.13	0.176	11.18	0.832	3.78	0.195
20	2.80	0.426	35.23	2.206	0.39	0.192	1.02	0.053	57.22	1.803	1.47	0.110	1.37	0.054	0.49	0.037
								Nominal interest rate								
1	0.82	0.034	2.06	0.232	0.06	0.031	13.03	0.434	15.30	0.716	5.00	0.259	54.13	0.562	9.60	0.519
4	0.73	0.027	2.15	0.299	0.06	0.031	16.48	0.518	22.16	0.817	4.81	0.301	43.08	1.332	10.53	0.586
8	2.28	0.255	1.08	0.244	0.03	0.015	13.45	0.385	53.13	1.190	2.97	0.244	20.38	0.899	6.68	0.339
20	7.00	0.593	0.53	0.112	0.01	0.007	8.23	0.350	70.05	0.993	1.52	0.139	9.36	0.575	3.30	0.131
								Nominal exchange rate level								
1	4.48	0.745	0.14	0.020	0.01	0.005	15.82	0.505	1.79	0.190	0.01	0.001	65.95	1.576	11.81	0.639
4	13.35	1.885	0.70	0.090	0.03	0.016	19.03	0.659	1.32	0.046	0.05	0.005	52.89	2.328	12.63	0.512
8	31.25	2.987	1.90	0.264	0.06	0.029	20.20	0.670	1.03	0.058	0.11	0.012	34.62	2.671	10.83	0.293
20	51.02	2.799	3.17	0.674	0.06	0.029	15.97	0.741	0.68	0.044	0.10	0.010	21.78	2.60	7.23	0.208

Table 10: **Chile: impulse response to a devaluationary policy shock**

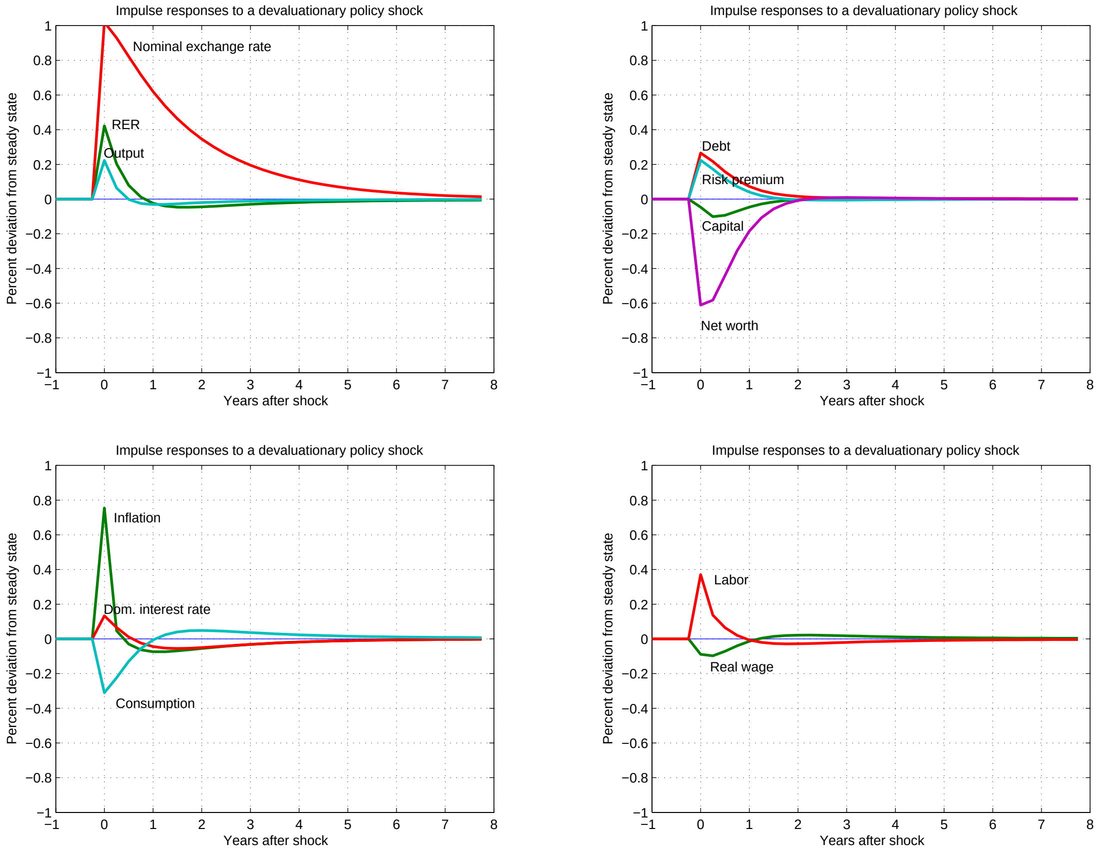

Table 11: **Colombia: impulse response to a devaluationary policy shock**

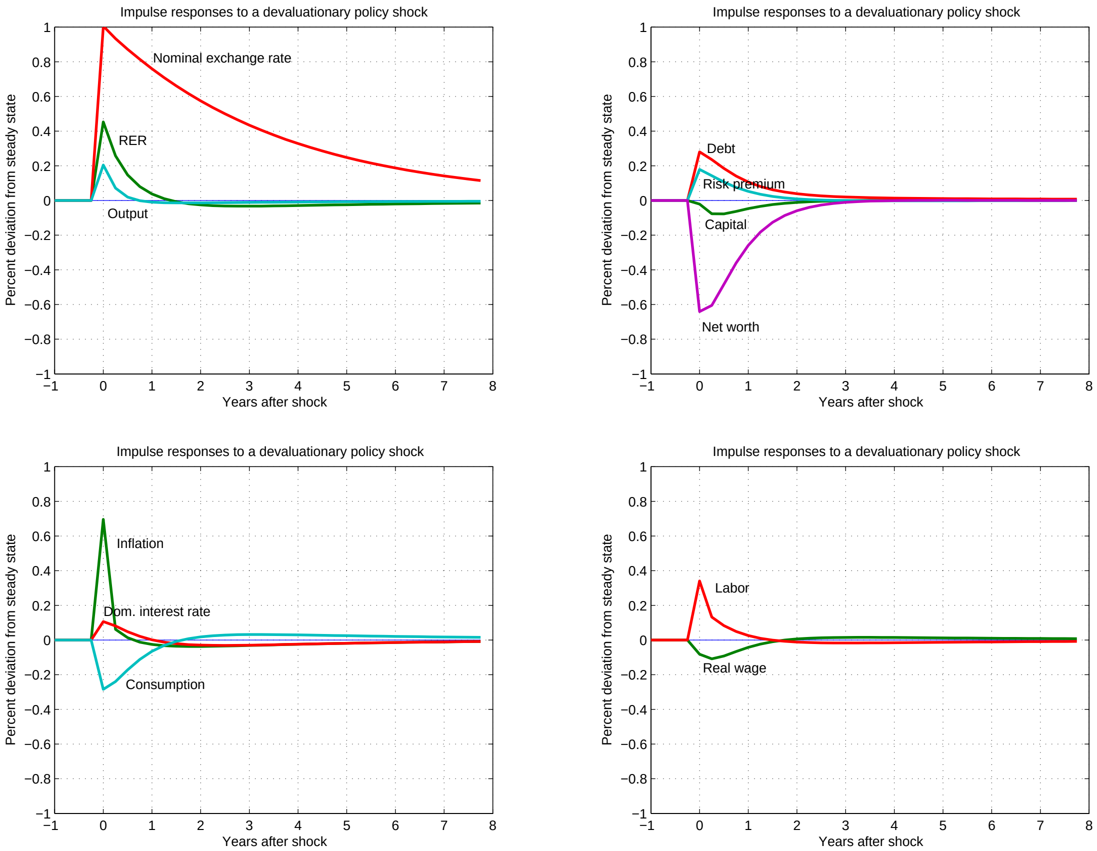

Table 12: **Mexico: impulse response to a devaluationary policy shock**

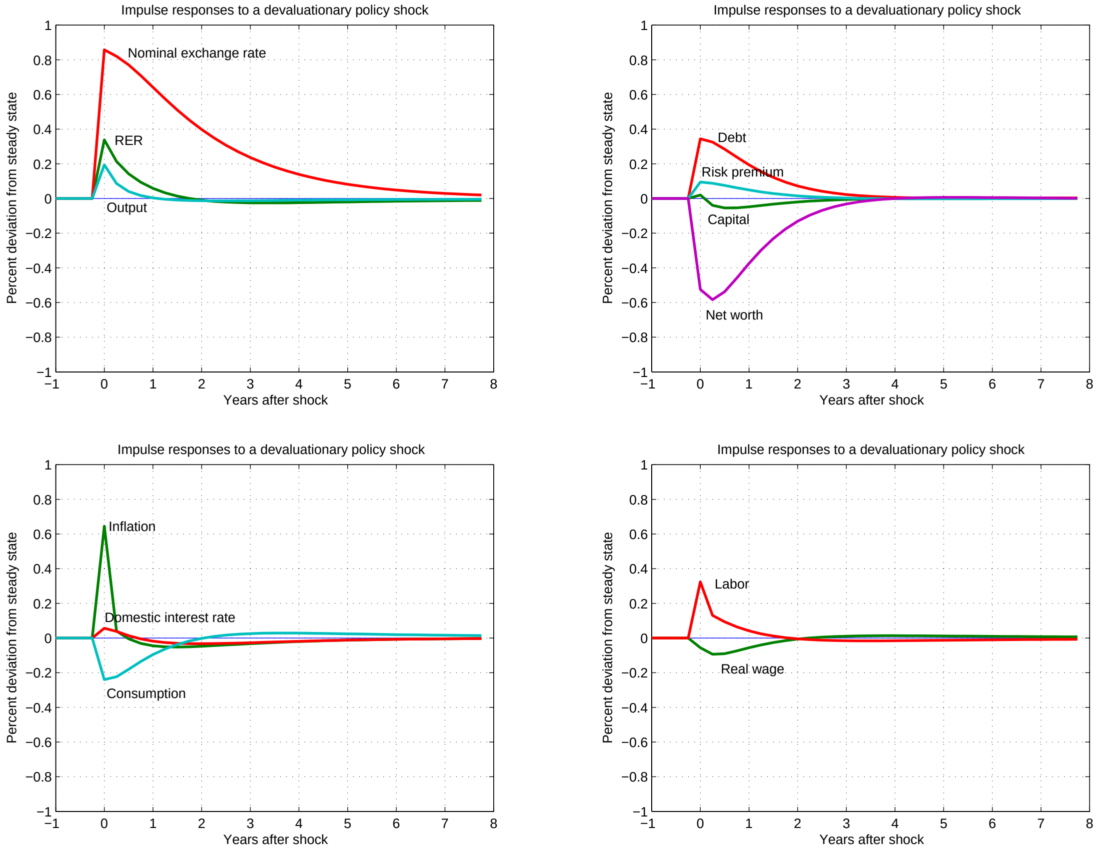

Table 13: **Latin America: impulse response to an adverse external shock**

International interest rate

Chile | Colombia | Mexico

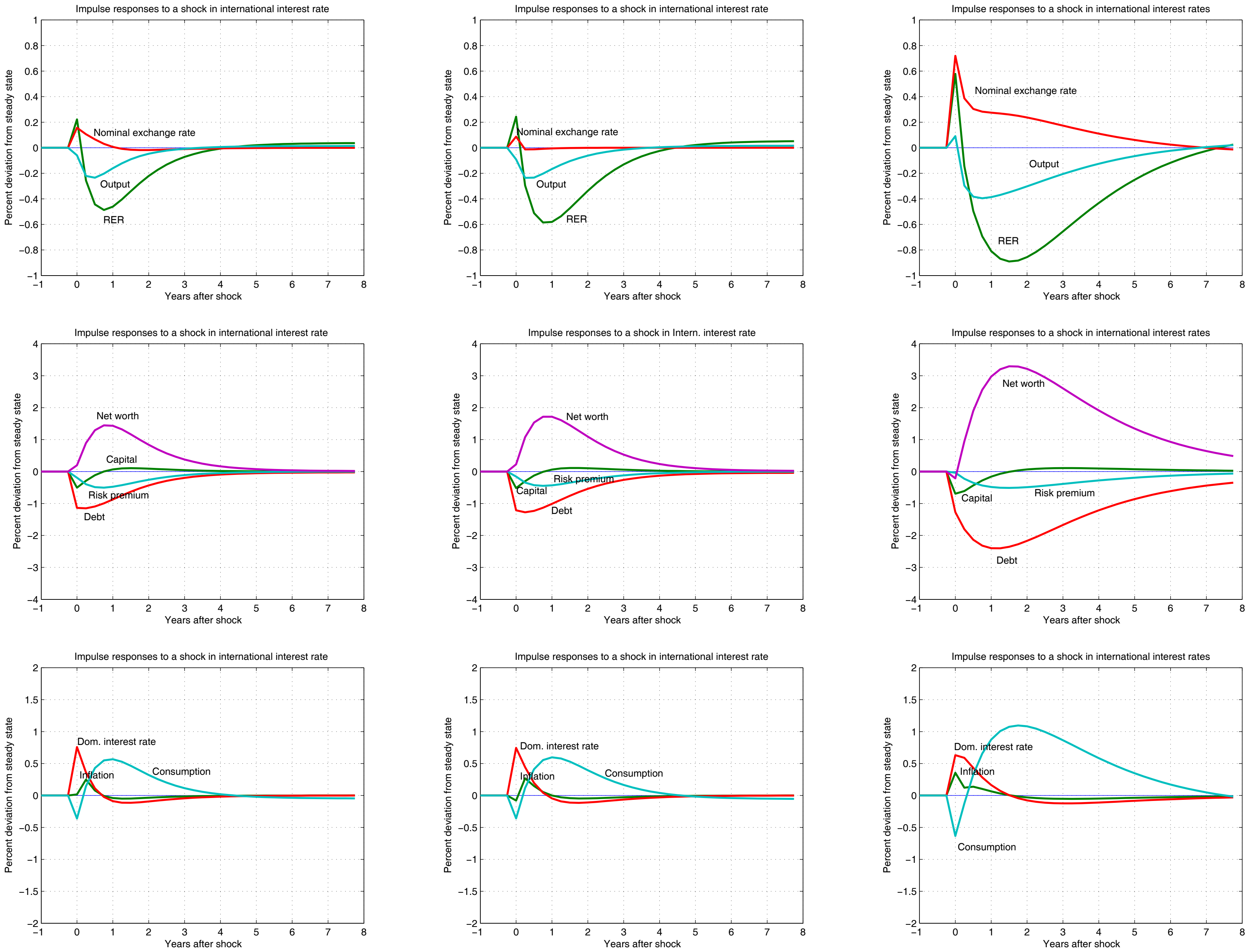

Table 14: **Latin America: impulse response to joint devaluationary and adverse external shock**

International interest rate and devaluationary policy shock

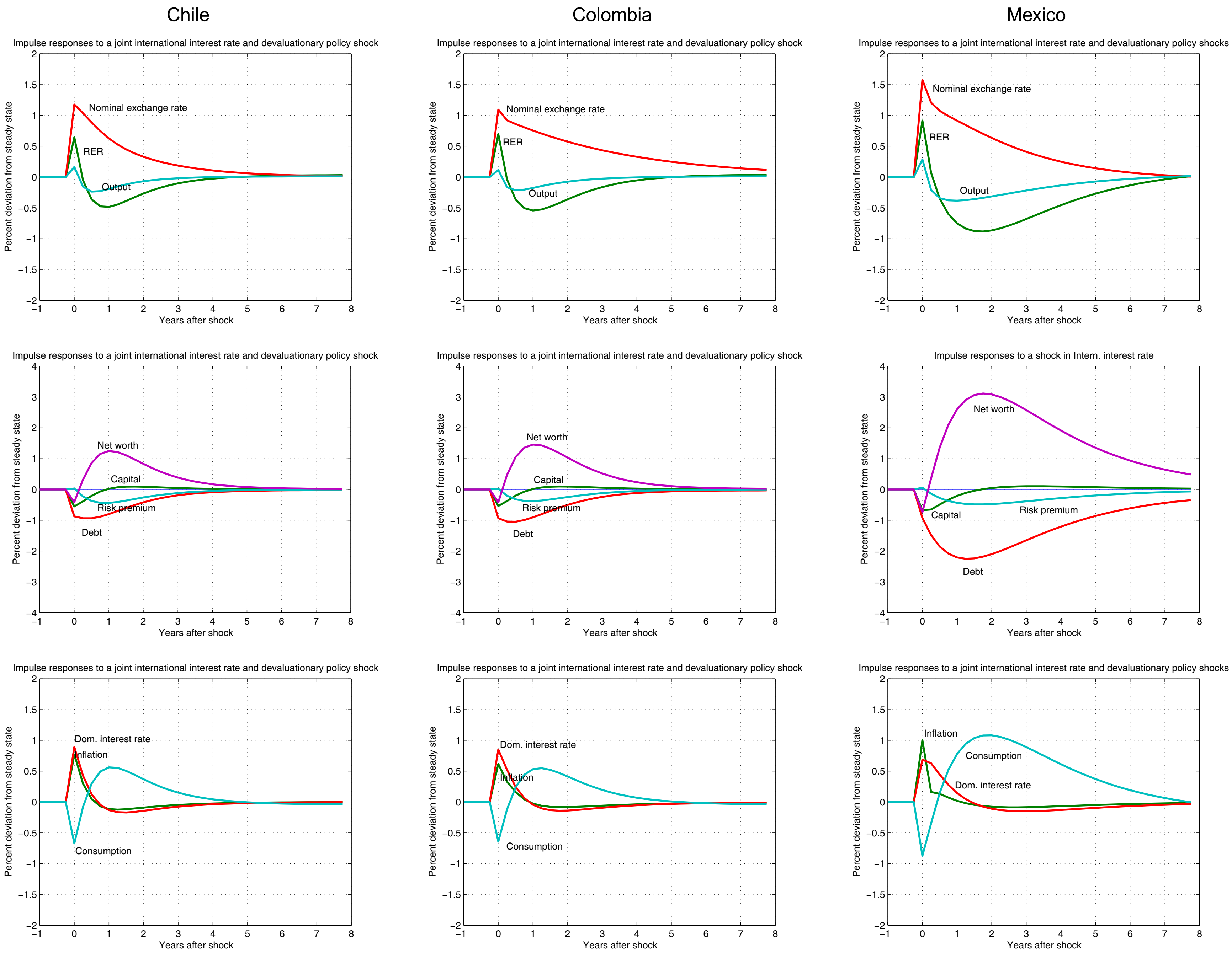

Table 15: **Maximum likelihood estimates with measurement erros: main parameter values**

	Chile		Colombia		Mexico	
	Estimate	Std Error	Estimate	Std. Error	Estimate	Std. Error
Transmission channels of devaluations						
- Balance sheet, μ	0.24	0.003	0.30	0.0151	0.18	0.002
- Expenditure switching, γ	0.59	0.018	0.68	0.013	0.63	0.002
Interest rate response to:						
- Lagged interest rate, ω_i	0.49	0.036	0.71	0.034	0.74	0.006
- Expected inflation, ω_p	1.60	0.012	2.15	0.084	1.50	0.070
- Output, ω_y	0.70	0.201	0.53	0.410	1.14	0.036
- Nominal exchange rate, ω_s	0.71	0.001	0.89	0.005	0.67	0.007
Nominal rigidities						
- Price rigidities, ψ_p	5.10	0.53	6.37	1.212	4.78	0.125
- Wage rigidities, ψ_w	1.60	0.012	1.74	0.436	1.14	0.036

Table 16: **Maximum likelihood estimates with measurement errors: structural shocks' persistence and standard deviation estimates**

	Chile		Colombia		Mexico	
	Estimate	Std Error	Estimate	Std. Error	Estimate	Std. Error
Persistence parameters						
- Technology, ζ_A	0.84	0.049	0.85	0.052	0.93	0.004
- Mark-up, ζ_θ	0.75	0.064	0.92	0.005	0.98	0.004
- Preferences, ζ_a	0.29	0.161	0.91	0.008	0.88	0.174
- Devaluationary policy, ζ_χ	0.83	0.075	0.93	0.042	0.85	0.027
- International interest rate, ζ_β	0.72	0.057	0.77	0.077	0.90	0.008
- Exports, ζ_x	0.91	0.057	0.77	0.023	0.85	0.042
- Inflation target, $\zeta_\varkappa$	0.70	0.084	0.94	0.019	0.49	0.004
- Output Target, ζ_ϑ	0.30	0.499	0.66	0.313	0.76	0.098
Standard deviations						
- Technology, σ_A	0.10	0.001	0.06	0.004	0.25	0.006
- Mark-up, σ_θ	0.06	0.002	0.01	0.010	0.05	0.011
- Preferences, σ_a	0.04	0.002	0.08	0.009	0.05	0.171
- Devaluationary policy, σ_χ	0.29	0.011	0.06	0.019	0.16	0.006
- International interest rate, σ_ρ	0.07	0.001	0.01	0.002	0.15	0.003
- Exports, σ_x	0.02	0.009	0.32	0.034	1.19	0.263
- Inflation target, $\sigma_\varkappa$	0.03	0.013	0.20	0.014	0.09	0.007
- Output Target, σ_ϑ	0.01	0.002	0.20	0.095	0.10	0.010

Table 17: **Maximum likelihood estimates with measurement errors: Standard deviation of measurement error shocks**

	Chile		Colombia		Mexico	
	Estimate	Std Error	Estimate	Std. Error	Estimate	Std. Error
v_π^2	0.17	0.001	0.23	0.032	0.23	0.009
$v_{\pi y}$	-0.58	0.000	0.36	0.032	-0.31	0.007
v_y^2	0.22	0.002	0.47	0.241	0.26	0.002
$v_{\pi l}$	-0.38	0.012	-0.36	0.048	0.34	0.030
v_{yl}	-0.41	0.005	-0.53	0.035	0.59	0.017
v_l^2	0.37	0.001	0.48	0.059	0.37	0.027
$v_{\pi r}$	0.34	0.141	-0.26	0.057	0.73	0.031
v_{yr}	-0.45	0.073	-0.12	0.020	0.16	0.037
v_{lr}	-0.34	0.039	-0.08	0.048	0.26	0.058
v_r^2	0.38	0.098	0.14	0.534	0.38	0.031
$v_{\pi c}$	-0.82	1.353	0.75	0.062	0.86	0.073
v_{yc}	-0.33	0.767	0.35	0.113	-0.35	0.089
v_{lc}	-0.74	0.102	-0.62	0.039	0.14	0.059
v_{rc}	-0.62	0.115	0.54	0.093	-0.38	0.007
v_c^2	0.89	0.964	1.86	1.701	0.38	0.091