Rationale behind the responses of monetary policy to the real exchange rate in small open economies[1]

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Abstract

We estimate how monetary policy works in small open economies. To do so, we build a dynamic stochastic general equilibrium model that incorporates the basic features of these economies. We conclude that the monetary policy in a group of small open economies (including Australia, Chile, Colombia, Peru and New Zealand) is rather similar to that observed in developed countries. Nevertheless, our results also indicate that there are strong differences due to shocks from the international financial markets (risk premium shocks, mainly) that explain mostly the variability of the real exchange rate, which has important reallocation effects in the short run. In addition, we find that in practice central banks do not face any trade-off responding to these shocks through changes in the interest rate. This result is consistent with the fact that in each country under study, the exchange rate must be included in the policy reaction function.

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1. Introduction

Designing their monetary policy is one of the major challenges for small open economies. Some of them have chosen to implement the inflation-targeting framework to guide their monetary policy toward stabilizing the inflation rate. However, the design of monetary policy poses important challenges in these economies that are not present in developed ones. This happens because small open economies continuously must deal with stronger volatility in international financial markets and international trade, especially from the high variability of country risk premiums and commodity prices, often pushing the central banks to change their monetary stances.

The real exchange rate is one of the key variables through which the fluctuations of international markets are transmitted to domestic economies. For example, unexpected external shocks that alter the exchange rate may increase the cost of the external debt service, the value of income from commodity exports, the cost of imported inputs, and so on. Thus, the change in the real exchange rate may alter the expected path of inflation and hence central banks must adjust their monetary policy.

Much of the literature on monetary policy in open economies has focused on whether or not central banks respond to the real exchange rate. The evidence obtained from empirical studies indicates that many countries include the real exchange rate in their policy reaction function. Nevertheless, the evidence is not conclusive; countries like Australia and New Zealand would not incorporate the exchange rate in their policy reaction function (Lubik and Schorfheide, 2007). On the other hand, the welfare analysis has produced contradictory results depending on the model proposed (Bergin et al., 2007). For example, Ball (1999), Svensson (2000) and Batini et al. (2001) find that inclusion of the real exchange rate marginally improved macroeconomic performance of central banks. In contrast to studies such as Wollmershauser (2006), Moron and Winkelried (2005) and Cavoli (2009) show that defending the exchange rate may be useful in a context of financial instability or as a response to fear of floating.

Our goal is to estimate empirically how monetary policy works in small open economies and hence its connection with the exchange rate. To do so, we build a model which is sufficiently general to incorporate the basic structures observed in these economies, including a wide range of shocks that affect these economies. In this regard, we are interested in determining the differences of monetary policy between developed and small open economies. Especially, we are interested in understanding how these structures and shocks can influence the design and practice of monetary policy such that central banks must include the exchange rate in their policy reaction functions.

We build a dynamic stochastic general equilibrium (DSGE) model for a small open economy. This model considers imperfect capital markets (country risk premium depending on the ratio of external debt over GDP), restricted consumers, balance sheet effect of exchange rate devaluations, imported inputs, commodity exports, imperfect pass-through of the exchange rate and wage indexation. In addition to the traditional shocks (monetary, productivity, mark-up prices and wages, and aggregate demand), we include several external shocks: risk premium, commodity price, external demand, foreign interest rate and foreign inflation. In relation to the sample, we consider a group of countries that can be classified as small open economies, inflation targeters and producers of commodities (Australia, New Zealand, Chile, Colombia and Peru). These countries have been frequently hit by shocks that change the conditions for accessing international financial markets and the prices of their main exports (commodities). Finally, Bayesian econometrics is used in order to estimate all the equations and shocks simultaneously.

The results of the article are the following. First, risk premium shocks can explain most of the variance of the exchange rate. This confirm the importance of these shocks on the exchange rate that some authors have already found, for example Calvo and Reinhart (2002) find that lack of credibility for monetary policy is associated with the higher variance of the risk premiums shocks and its impact on the exchange rate and prices. Second, the changes in the real exchange rate cause important reallocation of resources across sectors in the short run. Third, monetary policy reacts to shocks in order to stabilize the economy (i.e. to return the economy to the steady state). In the case of a risk premium shock, the impulse response function shows that both the inflation rate and the growth rate increase simultaneously due to a real depreciation. Therefore, central banks can avoid this excess volatility by raising the interest rate. Fourth, the real exchange rate appears systematically in the policy reaction functions in all countries under study.

In summary, we conclude that the existence of the exchange rate in the policy reaction function would be the result that in practice central banks do not face an important trade-off between inflation and growth in the presence of risk premium shocks. Therefore, they decide to respond moderately by changing the interest rate when the exchange rate is fluctuating due to the effects of these shocks. Nevertheless, after the shock, the strong increase in the interest rate to reduce inflation produces a sharp reduction in output in each country. This is in line with the evidence presented for some authors that there is a countercyclical behavior between output and risk premium (Uribe and Yue, 2006; Neumeyer and Perri, 2001).

The work is organized as follows; section 2 provides a detailed description of the model and empirical strategy. In section 3 we present the results of the estimations; parameters, variance decomposition and impulse response functions. Section 4 concludes.

2. The structural model

Our model resembles others found in the recent literature but has been adapted to capture the essentials of small open economies. General references of this type of models include Woodford (2003) and Clarida et al. (1999), Galí and Monacelli (2005), and Galí et al. (2007). More specifically, the model is similar to the one proposed by Smets and Wouter (2002). Our model also includes: restricted consumers (Galí et al., 2007), raw materials, consumer habits, wage indexation, balance sheet effect of exchange rate changes (Céspedes et al., 2002) and country risk premium depending on external debt-GDP ratio (Schmitt-Grohé and Uribe, 2003). Our structure is also similar to the one proposed by Laxton and Pesenti (2003) since all imports are intermediate inputs. Thus, the model has imperfect pass-through of exchange rate changes to domestic prices.

2.1 Households

We assume a continuum of infinitely lived households indexed by $i \in [0,1]$. Following Galí et al. (2007), a fraction of households λ consume their current labor income; they do not have access to capital markets and hence they neither save nor borrow. Such agents have been called "hand-to-mouth" consumers. The remainder 1-λ: have access to capital markets, and are able to smooth consumption. Therefore, their intertemporal allocation between consumption and savings is optimal (Ricardian or optimizing consumers).

2.1.1 Ricardian Household Consumption

The representative household maximizes expected utility.

$$. \; E_o \sum_{t=0}^{\infty} \beta^t U\left(C_t^o(i), N_t^o(i)\right), \tag{1}$$

Subject to the budget constraint

$$\begin{aligned} P_t C_t^o(i) &= W_t(i) N_t^o(i) + B_t^o(i) + S_t B_t^{o*}(i) + D_t^o(i) - P_t T_t \\ &- R_t^{-1} B_{t+1}^o(i) + S_t(\Phi(\frac{B_t^*}{Y_t}, Q_t) R_t^*)^{-1} B_{t+1}^{o*}(i), \end{aligned} \tag{2}$$

where $C_t^o(i)$ is consumption, $D_t^o(i)$ are dividends from ownership of firms, $\Phi[(B^*_t/Y_t), Q_t]$ epresents the country risk premium, S_t is the nominal exchange rate, $B_t^{o*}(i)$ denotes private net foreign assets (we suppose if this value is positive, it means external debt), $W_t(i)$ is nominal wage, $N_t^o(i)$ is the number of hours of work, $B_t^o(i)$ is government debt held by households, R_t and R_t^* are the gross nominal return on domestic and foreign assets (where $R_t = 1 + i_t$ and $R_t^* = 1 + i_t^*$) and T_t are lump-sum taxes.

We have two alternative functional forms for the utility function: separable and the GHH case. We include the GHH utility function because some authors (e.g. Correia et al., 1995) claim that this function may replicate better than the standard case the consumption volatility observed in small open economies. We also include the possibility of habit persistence to capture some lags in the response of consumption to different shocks.

$$U(C(i),N(i)) = \frac{(C_t(i) - \gamma C_{t-1}(i))^{1-\sigma} - 1}{1-\sigma} - \psi \frac{N_t(i)^{\varphi}}{\varphi}. \quad (3.1)$$

in the separable case, and

$$U(C(i),N(i)) = \frac{(C_t(i) - \gamma C_{t-1}(i) - \psi N_t(i)^{\varphi})^{1-\sigma} - 1}{1-\sigma}. \quad (3.2)$$

in the GHH case

where $1/\sigma$. is the intertemporal elasticity of substitution in consumption and $1/(\varphi\text{-}1)$ is the elasticity of labor supply to wages in both cases. The value of ψ is calibrated to obtain a realistic fraction of steady-state hours worked. The first-order condition for consumption is:

$$\left(C_t^0(i)\right)^{-\sigma} = \beta \; E_t\left(\left(C_{t+1}^0(i)\right)^{-\sigma} R_t\left(\frac{P_t}{P_{t+1}}\right)\right) \quad (4.1)$$

in the separable case, and $\left(C_t^0(i) - \psi N_t^{\;0}(i)^{\varphi}\right)^{-\sigma} = \beta \; E_t\left(\left(C_{t+1}^0(i) - \psi N_{t+1}^{\;0}(i)^{\varphi}\right)^{-\sigma} R_t\left(\frac{P_t}{P_{t+1}}\right)\right)$

(4.2)

in the GHH case.

From the first-order conditions, it is also possible to derive the interest parity condition, where $Q^*_t = S_t/P_t$.

$$Q_t^* = E_t\left[\left(Q_{t+1}^*\right)\frac{R_t^*\Phi\left(\frac{B_t^*}{Y_t}, Q_t\right)}{R_t\left(\frac{P_t}{P_{t+1}}\right)}\right] \quad (5)$$

Empirically, equation (5) is unable to generate a hump-shaped response of the real exchange rate after a shock to monetary policy (Adolfson et al., 2008). Thus, we assume that the real exchange rate Q_t (equation 6) is a weighted average between a lag of it and the real exchange rate from the interest parity condition Q_t^* (equation 5).

$$Q_t = \left(Q_{t-1}\right)^{\Omega_Q} \left(Q_t^*\right)^{1-\Omega_Q} . \tag{6}$$

2.1.2 Risk premium

Following Céspedes et al. (2002), the risk premium, $\Phi[(B^*_t/Y_t),Q_t]$, depends on debt, the exchange rate, and GDP. The risk premium consists of two elements. The first term in the equation says that the risk premium is an increasing function of the ratio of external debt to GDP. This friction in the international capital markets is required to ensure stationarity of the external-debt-to-GDP ratio.[2]

The second term captures the adverse impact of currency depreciation on the domestic currency value of external debt—the balance sheet effect. As the debt service burden on borrowers rises, the risk premium increases. We measure this effect for the parameter μ, that is the elasticity of the risk premium to the real exchange rate Q_t.[3]

2.1.2 Hand-to-mouth household consumption

The utility of the credit-restricted households is given by:

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[2] See Schmidt-Grohé and Uribe (2003).

[3] See Céspedes et al. (2002) and Morón and Winkelried (2005).

$$U(C_t^r(i), N_t^r(i)). \tag{7}$$

We assume that these households neither save nor borrow (Mankiw, 2000). As a result, their level of consumption is given by their disposable income:

$$P_t C_t^r(i) = W_t(i) N_t^r(i) - P_t T_t. \tag{8}$$

2.1.3 The labor supply schedule

Following Erceg et al. (2000), we suppose that households act as price setters in the labor market. There is a representative labor aggregator, and wages are staggered *à la* Calvo (1983). Therefore, wages can only be optimally changed after some random "wage-change signal" is received. A continuum of monopolistically competitive households is assumed to exist, and each one of them supplies a differentiated labor service to the intermediate-goods-producing sector. The representative labor aggregator combines, with a constant-returns technology, household labor hours in the same amount firms demand. The aggregate labor index N_t has the CES or Dixit-Stiglitz form, where ε_w is the elasticity of substitution between any two differentiated households (see equation 11 below).

$$N_t = \left[\int_0^1 N_t(i)^{\frac{\varepsilon_w - 1}{\varepsilon_w}} di \right]^{\frac{\varepsilon_w}{\varepsilon_w - 1}}, \tag{9}$$

where $N_t(i)$ is the quantity of labor provided by each household.

The representative labor aggregator takes each household's wage rate $W_t(i)$ as given, and minimizes the cost of producing a given amount of the aggregate labor index. Then, units of labor index are sold at their unit cost W_t (with no profit) to the productive sector:

$$W_t = \left[\int_0^1 W_t(i)^{1-\varepsilon_w} di \right]^{\frac{1}{1-\varepsilon_w}} \tag{10}$$

Households set their nominal wages that maximize their intertemporal objective function (1), subject to the intertemporal budget constraint (2), and to the total demand for its labor services, which is given by:

$$N_t(i) = \left[\frac{W_t(i)}{W_t} \right]^{-\varepsilon_w} N_t . \tag{11}$$

Additionally, we impose two important conditions. First, rule-of-thumb households set their wages equal to the average wage of optimizing households. Second, Ricardian household consumers that do not receive the "signal" to change they nominal wage, can index they wages to past inflation. We measure the level of indexation for δ_W. Thus, the wages of households that can not re-optimize adjust according to:

$$W_t(i) \; = \left(W_{t-1}(i)\right)^{1-\delta_W} \left(\frac{P_{t-1}}{P_{t-2}} \right)^{\delta_W} . \tag{12}$$

2.2 Firms

2.2.1 Domestic intermediate-goods firms

We assume a continuum of monopolistically competitive firms, indexed by $j \in [0,1]$ producing differentiated intermediate goods. The production function of the representative intermediate-goods firm, indexed by (j). corresponds to a CES combination of labor $N_t(j)$. and import inputs $I_t(j)$, to produce $Y_t^D(j)$ and is given by

$$Y_t^D(j) = A_t\left[\alpha N_t(j)_t^{\frac{\sigma_s-1}{\sigma_s}} + (1-\alpha)I_t^{\frac{\sigma_s-1}{\sigma_s}}(j)\right]^{\frac{\sigma_s}{\sigma_s-1}} \quad , \tag{13}$$

where A_t, the technology parameter, and σ_s, the elasticity of substitution between capital and labor, are both greater than zero.

The firms' costs are minimized taking as given the price of import inputs, $S_t P_t^*$ and the wage, W_t, subject to the production function technology. The relative factor demands are derived from the first-order conditions:

$$\frac{S_t P_t^*}{W_t} = \left(\frac{\alpha}{1-\alpha}\right)\left(\frac{N_t(j)}{I_t^*(j)}\right)^{\frac{1}{\sigma_s}} \tag{14}$$

or

$$I_t^*(j) = \left(\frac{\alpha}{1-\alpha}\right)^{\frac{1}{\sigma_s}}\left(\frac{S_t P_t^*}{W_t}\right)^{-\frac{1}{\sigma_s}} N_t(j) . \tag{15}$$

In order to replicate the inertia observed in the process of import of inputs, we assume that total imports I_t (equation 16) are a weighted average between a lag of it and the imports I_t^* from (equation 15):

$$I_t = \left(I_{t-1}\right)^{\Omega_M}\left(I_t^*\right)^{1-\Omega_M} , \tag{16}$$

and the marginal cost is given by:

$$MC^D = \frac{1}{A_t}\left[\alpha^{\sigma_s}(S_t P_t^*)^{1-\sigma_s} + (1-\alpha)^{\sigma_s}(W_t)^{1-\sigma_s}\right]^{\frac{1}{1-\sigma_s}} . \tag{17}$$

When firm (j) receives a signal to optimally set a new price *à la* Calvo (1983), it maximizes the discounted value of its profits, conditional on the new price. Furthermore, we suppose that prices of firms that do not receive a price signal are indexed to the last period's inflation π_{t-1}, according to the parameter δ_D (i.e., complete indexation is with $\boldsymbol{\delta_D}$ equal to one).

$$\max \sum_{k=0}^{\infty} \theta_D^k E_t \left\{ \Lambda_{t,t+k} Y_{t+k}^D (j)(P_t^{D*}(j) \prod_{l=1}^{k} \left(\pi_{t+l-1}^k\right)^{\delta_D} - MC_{t+k}^D) \right\} \tag{18}$$

subject to

$$Y_{t+k}^D (j) \leq \left(\frac{P_t^{D*}(j)}{P_t^D} \right)^{-\varepsilon_D} Y_{t+k}^D, \tag{19}$$

where the probability that a given price can be re-optimized in any particular period is constant and is given by *(1-θ_D)*, and ε_D is the elasticity of substitution between any two differentiated goods. P_t^{D*} must satisfy the first-order condition, where this price can be indexed to past inflation:

$$\sum_{k=0}^{\infty} \theta_D^k E_t \left\{ \Lambda_{t,t+k} Y_{t+k}^D (j) \left(P_t^{D*}(j) \prod_{l=1}^{k} \left(\pi_{t+l-1}^k\right)^{\delta_P} - \frac{\varepsilon_D}{\varepsilon_D - 1} MC_{t+k}^D \right) \right\} = 0. \tag{20}$$

Note that the discount factor $\Lambda_{t,t+k}$ is equal to $\beta^k \left(C_{t+k}^0 / C_t^0 \right)^{-\sigma} \left(P_t / P_{t+1} \right)$. Firms that did not receive the signal will not adjust their prices. Those which do reoptimize choose a common price, P_t^{D*}. ~ Finally, the dynamics of the domestic price index, P_t^D are described by the equation:

$$P_t^D = \left[\theta_D (P_{t-1}^D \pi_{t-1}^{\delta_D})^{1-\varepsilon_D} + (1-\theta_D)(P_t^{D*})^{1-\varepsilon_D} \right]^{\frac{1}{1-\varepsilon_D}}. \tag{21}$$

2.2.3 Final goods distribution

There is a perfectly competitive aggregator, which distributes the final good using a constant return to scale technology.

$$Y_t^D = \left(\int_0^1 Y_t^D(j)^{\frac{\varepsilon_K - 1}{\varepsilon_K}} dj \right)^{\frac{\varepsilon_K}{\varepsilon_K - 1}} \tag{22}$$

$Y_t^D(j)$ is the quantity of the intermediate good (domestic or imported) included in the bundle that minimizes the cost of any amount of output Y_t. The aggregator sells the final good at its unit cost P_t with no profit:

$$P_t^D = \left(\int_0^1 P_t^D(j)^{1-\varepsilon_K} dj \right)^{\frac{1}{1-\varepsilon_K}} \quad , \tag{23}$$

where P_t is the aggregate price index. Finally, the demand for any good $Y_t^D(j)$ depends on its price $P(j)$, which is taken as given, relative to the aggregate price level, P_t:

$$Y_t^D(j) = \left(\frac{P(j)}{P_t} \right)^{-\varepsilon_K} Y_t^D \ . \tag{24}$$

2.4 Exports

The demand for domestic exports from foreign countries is modeled as follows; there is a demand for each set of differentiated domestic goods, which by assumption depends on total consumption abroad, and on the home price of domestic goods relative to its price in the foreign country:

$$X_t^{D*} = \left[\left(\frac{P_t^D}{S_t P_t^{D*}} \right) \right]^{-\eta*} C_t^{D*} . \tag{25}$$

Nevertheless, we assume that in practice exports, X_t^D, respond more slowly to real exchange rates and foreign demand than the export demand obtained from the model, X_t^{D*}:

$$X_t^D = \left(X_{t-1}^D\right)^{\Omega} \left(X_t^{D*}\right)^{1-\Omega} . \tag{26}$$

On the other hand, as we are considering small economies' exports of natural resources (commodities), total values from these products are $S_t P_t^{cu} Q\_c$, where P_t^{cu}. denotes the international price of the commodities, and Q_c is the constant quantity supplied. For simplicity, supply is assumed to be price-invariant in the business cycle (short-run) horizon.

2.5 Aggregation

The weighted sum of consumption by Ricardian and rule-of-thumb agents makes aggregate consumption

$$C_t = \lambda C_t^r + (1-\lambda) C_t^o = \int_0^{\lambda} C_t^r(i)di + \int_{\lambda}^{1} C_t^o(i)di . \tag{27}$$

Since only Ricardian households hold assets, these are equal to

$$B_t = (1-\lambda)(B_t^o) . \tag{28}$$

Foreign assets (or debt) include fiscal B_t^{G*}. and privately held assets, B_t^{o*}:

$$B_t^* = B_t^{G*} + (1-\lambda) B_t^{o*} \tag{29}$$

Hours worked are given by a weighted average of labor supplied by each type of consumer:

$$N_t = \lambda N_t^r + (1-\lambda) N_t^o . \tag{30}$$

Finally, in equilibrium each type of consumer works the same number of hours:

$$N_t = N_t^r = N_t^o . \tag{31}$$

2.6 Monetary policy

The central bank sets the nominal interest rate according to the following rule:

$$R_t^* = \overline{R}\left(\left(\frac{\Pi_t}{\overline{\Pi}}\right)^{\phi_\pi}\left(\frac{YR_t}{\overline{YR}_t}\right)^{\phi_y}\left(\frac{Q_t}{\overline{Q}}\right)^{\zeta_e^1}\left(\frac{Q_t}{Q_{t-1}}\right)^{\zeta_e^2}\right) \tag{32}$$

with $\overline{R}$ being the steady-state nominal interest rate, Π_t total inflation, $\overline{\Pi}$ total inflation in steady state—which is zero in our model—, YR_t standing for GDP without the natural resource and $\overline{YR}$ its steady-state value, Q_t the real exchange rate and $\overline{Q}$ its steady state level. Thus, central banks can react to both the level and the change of the real exchange rate.

We suppose that central banks do not change immediately the interest rate to its target level (equation 32); instead, they take some time to respond to changes in the inflation rate, output and the exchange rate (equation 33).

$$R_t = \left(R_{t-1}\right)^{\Omega_R}\left(R_t^*\right)^{1-\Omega_R}. \tag{33}$$

2.7 Government

The government budget constraint is:

$$P_tT_t + R_t^{-1}B_{t+1}^G + S_t(\Phi(\frac{B_t^*}{Y_t},Q_t)R_t^*)^{-1}B_{t+1}^{G*} = B_t^G + S_tB_t^{G*} + P_t^GG_t \tag{34}$$

The country risk premium is a positive function of foreign debt: $\phi\left(B_t^*/Y_t,Q_t\right)$, Also, B_t^G denotes public domestic assets (debt) $P_t\,T_t$ corresponds to government nominal (lump-sum) tax revenues, and $P_t^GG_t$ is public spending. For simplicity, we assume that $G_t = 0$.

2.8 Market-clearing conditions

The factor market-clearing conditions are total employment by all firms *j*:

$$N_t = \int_0^1 N_t(j)dj \tag{35}$$

and import inputs

$$I_t = \int_0^1 I_t(j)dj \,. \tag{36}$$

The goods market-clearing condition is:

$$Y_t^D = (C_t + X_t^D)\,, \tag{37}$$

where total supply of domestic goods equals total demand of the domestically produced good for consumption and export.

Finally, the economy-wide budget identity can be expressed as:

$$P_t C_t = P_t^D Y_t^D - S_t P_t^* I_t + S_t \left(\Phi\left(\frac{B_t^*}{Y_t}, Q_t \right) R_t^* \right)^{-1} B_{t+1}^* - S_t B_t^* + (S_t P_t^{cu} Q\_c)\,, \tag{38}$$

which we can define without the natural resource as the sum of domestically produced goods minus import inputs:

$$P_t YR_t = P_t^D Y_t^D - S_t P_t^* I_t \,. \tag{39}$$

3. Econometric methodology: a VAR prior from the general equilibrium model

We proceed with a discussion of our econometric methodology in order to measure the effect of monetary policy on macroeconomic variables in different small open economies. We then describe the construction of the data sets that are used for the empirical work and present our choice of prior distributions for the Bayesian analysis. After that we analyze the results.

3.1. Econometric methodology

In order to measure monetary policy, we use the strategy proposed by Del Negro et al. (2007). Specifically, our empirical strategy consists of using the model of the last section to get the prior information in the estimation of a VAR model. First, we use a Bayesian approach for estimating the DSGE model. Thus we define a prior distribution for the vector of parameters θ of the DSGE model and then we use these priors to get the priors for the VAR model: the vector of parameters ϕ and the covariance matrix Σ_u. These new priors are denoted by $\phi(\theta)$ and $\Sigma_u(\theta)$, but we allow deviations from the restrictions imposed by the DSGE in order to capture potential misspecification. Thus, the accuracy of the prior is measured by a hyperparameter λ_{DSGE}. This creates a continuum of models, that Del Negro et al. (2006) have termed DSGE-VAR. They show that when the hyperparameter λ_{DSGE} is close to zero, the model converges to an unrestricted VAR; and when such hyperparameter λ_{DSGE} tends to infinity, the model converges to the DSGE model.

In this approach, the parameter λ_{DSGE} is estimated by achieving the highest marginal density. Indeed, by construction, this estimation attains a better fit and tends to deliver more reliable impulse responses than the restricted model (i.e., the DSGE model). The spirit of this approach is to maintain the sequence of auto covariance associated DSGE-VAR as close as possible to the DSGE model without sacrificing the ability of the DSGE-VAR model to match historical data.

On the other hand, DSGE-VAR allows us also to use it as a benchmark for evaluating our dynamic general equilibrium models. Thus, strong deviations of the parameters of the DSGE-VAR with respect to the restrictions imposed by the DSGE indicate problems of misspecification of our DSGE model.

3.2 Description of data and method of solution

We use quarterly data ranging from 1994 to 2007. The variables that are observed are real GDP, real consumption, inflation, the nominal interest rate, the real exchange rate and price of commodities. The price of commodities is measured in real terms. For Chile and Peru, it is the price of copper; in the case of Colombia it is the WTI oil. For Australia, we use the commodity price index published by the Reserve Bank of Australia. For New Zealand, we choose the price index for soft commodities published by the Reserve Bank of New Zealand. The source of the data is the following. In the cases of Chile, Colombia and Peru it is their respective central bank. The exception is the real exchange rate index, which is published by JP Morgan. The source for the price of each commodity is Bloomberg. In Australia and New Zealand all the data, except for real exchange rates, come from their respective central bank.

External variables come from the FRED database of the Federal Reserve Bank of St. Louis. The variables that are observed are the following: real GDP, the GDP deflator as a measure of inflation, and the interest rate correspond to the Fed Fund.

The equations for measuring variables are given by:

$$
Y_t = \begin{bmatrix} Y_{obs} \\ C_{obs} \\ W_{obs} \\ Q_{obs} \\ PCM_{obs} \\ \Pi_{obs} \\ R_{obs} \\ Y^*_{obs} \\ R^*_{obs} \\ \Pi^*_{obs} \end{bmatrix} = \begin{bmatrix} \bar{\gamma} \\ \bar{\gamma} \\ \bar{\gamma} \\ \bar{\gamma} \\ \bar{\gamma} \\ \bar{\pi} \\ \bar{r} \\ \bar{\gamma}^* \\ \bar{r}^* \\ \bar{\pi}^* \end{bmatrix} + \begin{bmatrix} y_t - y_{t-1} \\ c_t - c_{t-1} \\ w_t - w_{t-1} \\ q_t - q_{t-1} \\ pcm_t - pcm_{t-1} \\ \pi_t \\ r_t \\ y^*_t - y^*_{t-1} \\ r^*_t \\ \pi^*_t \end{bmatrix}.
$$

We detrend the model with a deterministic trend Ξ, which was also estimated. The procedure was implemented for the example in this way: $c_t = C_t / \Xi^t$, $y_t = Y_t / \Xi^t$, and so on (Smets and Wouter, 2007). Then the model was log-linearized around a non stochastic steady state. The estimates, impulse responses, and variance decomposition were obtained with DYNARE[4]. In our study we followed the econometric methodology proposed by the Del Negro and Schorfheide (2004), but with the improvements proposed by Adjemian et al. (2008) for increasing the efficiency of the calculations through a direct estimation of the parameter λ_{DSGE}.

4. Priors and results

The values of the priors (Table 1) are in line with the earlier literature and incorporate the beliefs about possible ranges regarding the nature and behavior of the variables (see Smets and Wouter, 2002; Laxton and Pesenti, 2003). One of the properties of the Bayesian method is that it gives a

[4] All this information, (code and steady state) is available upon request.

voice to the data, supplying information about the fit of the parameters to the data and the economic reality. The values of the parameters used in DSGE models in the different countries fall within the literature's typical range. Accordingly, the same prior values are used for the countries in the sample and, thus, we let the data to inform on the degree of fit of these values to the realities of the sample countries

4.1 Utility Functions

First, the model was estimated by assuming two different types of utility functions—separable and GHH. Surprisingly, in all countries except Colombia, the utility function that gave the best results was the separable case (see Table 2 with posterior odds). This could be explained by the presence of heterogeneous agents (hand-to-mouth) that can replicate more properly the high volatility observed in these economies, instead of assuming directly a GHH utility function. This is an important result since some authors have proposed that this last utility function would better capture the higher volatility of consumption observed in the small open economies (Correia et al., 1995). So, our results indicate that the presence of the restricted agents and low levels of habit would be a better alternative in order to produce this volatility in some countries.

INSERT TABLE 1

INSERT TABLE 2

4.2 Parameters

The estimates of the parameters of most interest that measure the impact of monetary policy on the economies are presented in Table 3. A first important result is that the estimation of σ for all countries is around 2. This means an intertemporal substitution elasticity of 0.5, confirming a moderate effect of the interest rate on consumption in small open economies (Agénor and Montiel, 1996).

A parameter that is also related to the response of consumption to the interest rate is the habit parameter, γ. Our estimations indicate that the presence of habit is only moderate (20% -10%) compared to developed economies (Christiano et al., 2005). In relation to the effect of restricted agents on aggregate consumption, λ, our estimations indicate that in these countries the proportion of these agents' consumption is around 15% to 20%.

On the other hand, prices on average remain rigid between $1/(1-\theta_D)$ three and five quarters. Importantly, the rigidity of prices and wages $1/(1-\theta_W)$ tends to be quite similar for all countries under study. Another important result is that the level of indexation is between 40% and 50% and again is similar to prices, δ_D, and wages, δ_W. This indicates that in these economies there is some degree of connection in the setting of prices and wages which produces important real rigidities in the labor market. Furthermore, since in the model all imported goods are inputs for production, price rigidity also indicates a low pass-through of the exchange rate to domestic prices.

Other results relevant to understand monetary transmission is the elasticity of differentiated goods exports to the real exchange rate, τ_D. The estimated value is between 1.5 and 2.0. This result, together with the rigidity of prices, indicates that reallocations of the real exchange rate in these economies are significant (Colacelli, 2008). On the contrary, we find that the inertia of domestic exports Ω and imports of inputs Ω_M are below 0.2, reaffirming the strong impact of the real exchange rate on the economy in the short run.

The balance sheet effect may be positive or negative, depending on the structure of each economy. In our model, this effect is captured in an arbitrary manner by incorporating the real exchange rate in the risk premium, $\Phi[(B^*_t/Y_t),Q_t]$. In the cases of Australia, New Zealand and Chile the parameter μ, the elasticity of risk premium to the real exchange rate Q_t, turns out to be positive. In contrast, in Peru and Colombia this parameter is negative. Thus, monetary policy in the first group of countries has a stronger impact on the exchange rate and therefore in the all macro variables.

Another important theoretical relationship to be tested is the uncovered interest parity condition. Our results indicate that in all countries this parity does not hold as expected. The persistence of the real exchange rate Ω_Q according to our estimations is around 0.3, while for Peru it was 0.6. This result is half the value obtained by Adolfson et al. (2008) in a DSGE model estimated with Bayesian econometrics for the case of Sweden.

On the Taylor rule, we find that the parameter for the persistence Ω_R, inflation ϕ_Π and output ϕ_Y are around 0.7, 2.0, and 0.5, respectively (Woodford, 2003). In this sense, the Taylor rule is very similar to that found in other economies. The fundamental difference is that central banks in these small open economies also respond, in a moderate way, to the real exchange rate, both the level, ζ^1_e, and the volatility ζ^2_e. This is a result that is repeated systematically in all countries and in contradiction to other studies such as that of Lubik and Schorfheide (2007).

INSERT TABLE 3

4.3 Variance decomposition

One result that emerges from the decomposition of variance n periods ahead (see Graph 1[5]**)** is that, in addition to the standard shocks studied in developed economies, we need to consider the risk premium shock to explain macroeconomic variables in small open economies. This largely explains the variability of the real exchange rate in conjunction with the external interest rate. It

[5] All graphs can be found in the appendix.

also explains a lower percentage of GDP fluctuations and, to a lesser extent, what happens to the nominal interest rate. This shock is not involved in the explanation of the variability of inflation. By far, it appears to be the most significant external shock. On the contrary, the commodity price shock is only relevant to explain the volatility of GDP in Chile and Peru. The external GDP shock and the external inflation shock do not appear to be relevant in the period considered.

Moreover, other shocks that have been used in the literature to explain the fluctuations also appear in our results. Preference shocks are important in explaining fluctuations in GDP. Moreover, mark-up shocks are decisive to explain the variability of inflation and interest rates. Also productivity shocks are important in explaining all the variables. In contrast, monetary shocks are present in all the variables but their relevance is small. This does not mean that monetary policy is ineffective; on the contrary, and as we see below, monetary policy is working through the response to all other shocks in order to stabilize the economy.

4.4 Impulse responses

As we explained above, impulse responses are used to evaluate potential problems of identification in DSGE models. In other words, the discrepancies between the impulse response between the DSGE-VAR and DSGE allow us to detect problems for the identification of shocks in the DSGE model. Thus, if the variable's responses of the DSGE model are outside the confidence bands for the estimated DSGE-VAR, then we have a problem of identification in the DSGE. This is crucial because the problems of identification invalidate the economic analysis (Del Negro and Schorfheide, 2004). According to graphs 2-8, the impulse responses from the DSGE are in general very similar to those from the DSGE-VAR and they are inside the confidence bands. Consequently, we find that the DSGE model does not present important problems of misspecification in all shocks.

Regarding the effects of a monetary shock on the economy, this shock produces results in line with the discussion in the literature (Graph 2). After a monetary shock, output decreases sharply and the real exchange rate appreciates both in the DSGE and in the DSGE-VAR. But there is an important discrepancy between both models in explaining the dynamics of the inflation rate. In the DSGE-VAR, the inflation rate returns to its steady-sate level more slowly that in the DSGE, indicating even that there appears to be a hump-shaped response of the inflation rate in some countries (Australia, Colombia, and Peru), probably this is caused by higher levels of price indexation that the DSGE model is unable to generate properly.

Also in line with other studies (Galí and Rabanal, 2004), the response of monetary policy to a positive productivity shock is a reduction in the monetary policy interest rate (Graph 3). This occurs through a strong deflationary effect on the price level and a sharp appreciation of the real exchange rate. This happens even though the increase in output growth tends to generate a positive output gap and hence inflationary pressures on the demand side.

In the case of a consumer preference shock (Graph 4) we observe a strong increase in consumption and output growth, followed by a minor increase in prices. This is the result of an important increase in the monetary policy rate that stops inflationary pressures and also causes a sharp appreciation of the real exchange rate.

In the case of a mark-up shock on inflation and wages (Graphs 5 and 6), we find that the effects of these shocks have a negative effect on output growth and a positive effect on prices. As expected, the central bank reacts by raising the interest rate. There is not a strong response of the real exchange rate. Our results indicate that the reaction of the inflation rate is the same for both kinds of shocks. What is important is that with these shocks the central banks of merging economies face the standard trade-off between inflation and growth that in developed economies: if they want to control inflation, they have to reduce output.

Considering the external shocks, which turned out to be relevant in the analysis (see Section 4.3), we have that a price commodity shock (Graph 7) increases especially output growth in some countries. The effect of this shock on inflation is small but tends to appreciate the real exchange rate. The monetary policy response to this shock is a small reduction in the interest rate due to the exchange rate appreciation. Interestingly, the central banks do not respond in the standard way i.e., increasing the interest rate when output goes up. Instead, they prefer to avoid further appreciation of the exchange rate with smaller reductions in the policy rate.

The attempt to smooth the fluctuations of the real exchange rate is stronger in the case of a risk premium shock (Graph 8). Indeed, the monetary policy response to this shock is a sharp increase in the monetary policy interest rate, because this shock generates a strong increase of the real exchange rate. The increase in the real exchange rate stimulates exports and thus growth, increasing inflation as well. In this scenario, increasing the interest rate is not contradictory with several goals: reducing inflation, stabilizing growth and the real exchange rate as in the case of a mark-up shock.

Finally, this evidence is not contradictory with the literature of business cycles in emerging economies where some authors have found a countercyclical behavior between output and risk premium (Uribe and Yue, 2006; Neumeyer and Perri, 2001). After risk premium shock, the increase in output and inflation causes a strong increase in the interest rate, which produces a sharp reduction in output in each country (Graph 8). In other words, once the interest rate goes up, the economy goes into a contraction.

5. Conclusion

This article concludes first that the responses of monetary policy in a representative group of typical small open economies (i.e., inflation targeter, commodity exporter and open to international financial markets) is similar to that observed in developed economies. Thus, this policy responds to productivity shocks, demand shocks and mark-up shocks in a very standard way. Our results are obtained by estimating a DSGE model for a small open economy with Bayesian econometrics.

However, our results also indicate that monetary policy in these small open economies face more challenges than in developed economies. For instance, we find that the risk premium shock could explain most of the variability of the real exchange rate. This can have important implications on the economy because the results also indicate that the real exchange rate causes significant reallocation of resources across sectors in the short run.

In addition to this evidence, the article shows that monetary policy is working actively through its response to the other shocks. In the case of a positive risk premium shock, the response is a sharp increase in the interest rate. This happens because this shock increases the real exchange rate, which stimulates exports and thus growth. As a result, the inflation rate increases as well. In this scenario, there is no trade-off for the central bank between inflation and output because both variables are increasing simultaneously. Therefore, in practice central banks could respond quickly to this volatility by increasing the interest rate in order to stabilize both variables. This conclusion is confirmed in the paper since in each country in the sample the exchange rate results significant into the policy reaction function.

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