Decreasing Returns, Risk Premium Shocks, and Optimal Monetary Policy

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Abstract

We show that the simultaneous existence of two key elements in an open economy—decreasing returns and risk premium shocks to the exchange rate that violate the UIP—produce significant changes in the implementation of optimal monetary policy. First, we demonstrate that it is optimal to accommodate inflation when a positive shock occurs, but it is preferable to intervene in the exchange rate when the shock is negative. Second, the empirical evidence of this study, based on five economies with different degrees of development, shows the relevance of these two elements and confirms that central banks should pursue an asymmetric and more complex policy to deal with these type of shocks, rather than a linear Taylor rule that includes the exchange rate.

Keywords:decreasing returns to scale, risk premium shock, exchange rate, and optimal monetary policy.

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1 Introduction

A key element in many small open economies is the absence of some markets, especially for trading certain types of capital in the short term. A simple but extreme example is firms that produce and export fruit or dairy products to international markets. In the event of a decline in demand for these goods at the international level, it is hard to imagine that these firms could find a market for reselling their capital stock, in this case fruit trees or livestock. The absence of these markets for specific inputs causes the economy to operate as if there were decreasing returns at the aggregate level in the short term.

Another key element is the existence of risk premium shocks that cause significant fluctuations in the real exchange rate and represent a clear deviation from uncovered interest parity (UIP).[1] García and González (2014, 2013) find evidence that in a heterogeneous group of small open economies, these shocks produce cyclical movements through the exchange rate, that is, they increase production and inflation at the same time. This type of shock has been more relevant in terms of explaining exchange rate variability than commodity price and productivity shocks. The main channel of transmission is as follows: the existence of rigid prices causes risk premium shocks to translate into fluctuations of the real exchange rate, which in turn cause fluctuations in the demand for exports, output, and finally inflation in the short term.

García and González (2014, 2013) further show that central banks have a low reaction to the exchange rate in practice, even though a stronger reaction would be optimal. The intuition of these authors is straightforward: with sticky prices, it is optimal to pursue a simple, linear monetary rule that includes the exchange rate to offset the procyclical effects of risk premium shocks on the economy.

First, we demonstrate theoretically that the combination of decreasing returns and risk premium shocks has important implications for the optimal monetary policy in small open economies. If a central bank has a strict inflation target (for example, zero) and the economy is characterized by decreasing returns, the level of production and consumption will be below the level of the second-best equilibrium. The intuition is as follows: with increasing marginal costs and the existence of sticky prices, a central bank's effort to keep the inflation rate low can only be achieved with an additional decline in output and consumption.

In this context, and counterintuitively, the central bank must accommodate more

[1] McCallum (1994) was one of the first authors to introduce the risk premium into linear macroeconomic models as an exogenous shock to improve the fit of the UIP. While this strategy is polemic and has important critiques (see Burnside, Eichenbaum, and Rebelo, 2007), there is some rationality to considering these shocks in macroeconomic models. A long literature, for instance, has rationalized these types of shocks as moral hazard problems (Gabaix and Maggiori, 2014).

inflation following a positive risk premium shock, because the economy may be much closer to the second-best equilibrium. Conversely, a negative shock must be neutralized with a currency intervention to keep the economy from moving even further away from the second-best equilibrium. Thus, central banks should pursue an asymmetric and more complex policy to deal with these type of shocks rather than a simple Taylor rule that includes the exchange rate.

One of the limitations of our study is that it takes as given the deviation of the UIP. Nevertheless, we confirm the relevance of this deviation in the empirical part of the paper. The connection between the factors that cause the deviation and the implementation of optimal monetary policy is left for future research.

Second, we show that for a heterogeneous set of open economies with different levels of development (namely, Australia, Chile, Colombia, New Zealand, and South Africa), the assumption of decreasing returns better explains the business cycle than the traditional assumption of constant returns to scale in the short term. In this regard, we estimate a dynamic stochastic general equilibrium (DSGE) model with Bayesian econometrics for the five open economies mentioned above. These estimates also confirm the importance of risk premium shocks in explaining the variability of the real change and its procyclical effects on the economy.

Finally, we show empirically that the correct monetary policy is not a simple linear Taylor rule, but rather an asymmetric policy. Again, when the economy faces a positive risk premium shock, the optimal policy is not to intervene in the exchange rate. Intervention is only desirable with a negative risk premium shock.

This study is a direct application of Galí (2008) and Sveen and Weinke (2007, 2005), where decreasing returns are introduced in a new Keynesian model for the case of a closed economy. Similar works for closed economies with specific capital in new Keynesian models include Altig and others (2011), Giuli and Tancioni (2009), Nolan and Thoenissen (2008), de Walque, Smets, and Wouters (2006), Woodford (2005), and Madeira (2012). Demonstration of the relevance of decreasing returns for the optimal monetary policy is based on Blanchard and Galí (2007), also for a closed economy.

On the empirical evidence, the estimation strategy directly or indirectly is based on García and González (2013, 2014), Cavoli (2009), Lubik and Schorfheide (2007), Bergin, Shin, and Tchakarov (2007), Wollmershauser (2006), Morón and Winkelried (2005), Batini, Harrison, and Millard (2003), Svensson (2000), and Ball (1999). Our selection of the sample countries follows Chen, Rogoff, and Rossi (2010).

The paper is organized as follows. In section 2, we prove the relevance of decreasing returns and risk premium shocks in the implementation of monetary policy. Section 3 presents the empirical model, section 4 describes the data and econometric strategy, and section 5 presents the estimation results. Finally, section 6 concludes.

2 Optimal Monetary Policy in the Presence of Decreasing Returns and a Risk Premium Shock

This section explains the welfare consequences for monetary policy of not having a rental market for capital in the presence of a risk premium shock in the exchange rate. In this section, we start by presenting a simplified version of the model used in section 3 to test econometrically the importance of these assumptions for the implementation of monetary policy.

The assumption of not having a rental market for capital is equivalent, at least in the short term, to assuming that the production function has decreasing returns. Thus, we can simplify the analysis by assuming that the production function has a single variable input (labor) and then analyze the welfare implications of decreasing returns. In the following section, we relax this assumption and allow the firm to produce its own capital, which provides a more realistic model for the econometric estimation.

2.1 Equilibrium with Constant Returns To Scale

We begin by assuming a production function with constant returns to scale that depends only on labor:

$$Y = N \tag{1}$$

The utility function can be separated into consumption, C, and labor, N:

$$U = \frac{C^{1-\sigma} - 1}{1-\sigma} - \chi \frac{N^{\varphi+1}}{\varphi+1} \tag{2}$$

For simplicity, we assume $\nu = 1.0$, $\chi = 1.0$, and $\sigma \to 1$. Also for simplicity, we assume in this small and open economy $\beta R^* = 1.0$, where β is the subjective discount rate and $R^*$is the foreign interest rate. This assumption is consistent with a constant level of consumption of $\bar{C}_1$[2].

In this economy, the first-best equilibrium is

$$mrs = mrn => N\bar{C}_1 = 1 \tag{3}$$

From equation (3), we can determine the level of labor and replace it into the production

[2]The economy budget constraint is , where is foreign debt. The first-order condition is , where is the marginal utility of consumption. If , then the consumption level is constant and equal to . Besides, if , then by using equation (3), we get .

function (1). In terms of logarithms, the first-best output level is

$$y_1 = -\overline{c_1} \tag{4}$$

If we introduce monopoly power to this simple model, the second-best condition with flexible prices is

$$\frac{1}{\mu} = N\bar{C}_2 \tag{5}$$

where $\mu^D > 1.0$ is the markup. In terms of the logarithm, the level of labor is

$$n_2 = -\mu^D - \overline{c_2} \tag{6}$$

Thus, the second-best output level is

$$y_2 = n_2 \tag{7}$$

If we subtract equations (4) and (7), then

$$y_1 - y_2 = -(\overline{c_1} - \overline{c_2}) + \mu^D \tag{8}$$

Equation (8) can be expressed as

$$(\overline{y_2} - \overline{c_2}) = -\mu^D \tag{9}$$

We can use equation (9) to compare the second-best equilibrium with sticky prices à la Calvo (1983), without price indexation and trend in the data (we relax these assumptions in the next section) and with constant returns:

$$\pi_t = \beta\pi_{t+1} + \lambda_D(mc_t^D + \mu^D) \tag{10}$$

where $\lambda_D = [(1 - \beta\theta_D)(1 - \theta_D)]/\theta_D$ and $(1 - \theta_D)$ is the probability of changing prices.

Marginal cost is

$$mc_t^D = w_t = \widetilde{n}_t + \widetilde{c}_t = \widetilde{y}_t + \widetilde{c}_t \tag{11}$$

Thus $mc_t^D + \mu^D$ is equal to

$$mc_t^D + \mu^D = (\widetilde{y}_t + \widetilde{c}_t) - (\overline{y_2} + \overline{c_2}) \tag{12}$$

If we replace equation (12) into equation (10), we can confirm that divine coincidence holds. In other words, if inflation is zero in this economy, not only does the central bank achieve its inflation target, but the economy can be closer to the second-best equilibrium. [3]

2.2 Equilibrium with Decreasing Returns

Under the assumption that there is not a market for an input (for example, capital stock), this input is specific, producing decreasing returns to scale to the others inputs (such as labor). Formally, the production function is

$$Y_t = N_t^{1-\alpha} \tag{13}$$

The new marginal costs, expressed as logarithms, are given by the equation (14):

$$mc_t^D = w_t - mpn_t = (\tilde{n}_t - \tilde{c}_t) - (\tilde{y}_t - \tilde{n}_t) - \log(1-\alpha) \tag{14}$$

Thus $mc_t^D + \mu^D$, after some transformations, is equal to

$$mc_t^D + \mu^D = 2\alpha\tilde{n}_t - \log(1-\alpha) + (\tilde{y}_t + \tilde{c}_t) - (\overline{y_2} + \overline{c_2}) \tag{15}$$

where $2\alpha\tilde{n} - \log(1-\alpha) > 0$.

This result ensures that $(\tilde{y}+\tilde{c}) < (\bar{y}_2+\bar{c}_2)$ to obtain a zero-inflation target, and divine coincidence does not hold in this case. In fact, the inflation rate is now given by the equation (16). A zero-inflation rate necessarily requires that both production and consumption are lower than the second-best levels.

$$\pi_t = \beta\pi_{t+1} + \Theta\lambda_D \left[2\alpha\tilde{n}_t - \log(1-\alpha) + (\tilde{y}_t + \tilde{c}_t) - (\overline{y_2} + \overline{c_2})\right] \tag{16}$$

where $\Theta < 1$ with decreasing returns. In practical terms, decreasing returns make inflation less sensitive to marginal costs. In other words, the aggregate supply is much flatter, sharpening the product fluctuations (Galí, 2008).

This last result has important implications for the exchange rate level. In this regard, we assume that the uncovered interest parity condition does not hold, since we add a risk premium shock (rps_t) to this equation.

$$e_t = e_{t+1} - (r_t - \pi_{t+1}) + \left(r_t^* - \pi_{t+1}^*\right) + rps_t \tag{17}$$

We know that in a model with sticky prices, central banks can achieve a zero-inflation

[3] The simplifying assumption of a zero-inflation target together with constant returns to scale allows us to illustrate why it is optimal for central banks to achieve a low inflation rate.

rate if $(\tilde{y}+\tilde{c}) < (\bar{y}_2+\bar{c}_2)$. In practice, monetary policy is able to do this by setting a nominal interest rate, r_t, higher than the expected inflation rate, π_{t+1}. Thus, by equation (17), this higher interest rate also produces a lower exchange rate.

2.3 Optimal Monetary Policy and a Risk Premium Shock

García and González (2013) show that in a model without capital stock, the optimal monetary policy for a central bank that aims to stabilize inflation is to intervene directly in the exchange rate. This offsets the procyclical effects of a risk premium shock on the economy.[4] In other words, according to equation (17), if a positive risk premium shock, rps_t, increases the exchange rate, then the shock should be compensated by a direct increase in r_t.

Nevertheless, the recommendation of García and González (2013) is obtained under the assumption of constant returns to scale. In contrast, we show in this study that this recommendation does not always hold, and it depends strongly on the existence or absence of markets for certain inputs.

Indeed, in a context of decreasing returns and a central bank with a zero inflation target, it would be optimal to permit more inflation. Thus, a positive risk premium shock can help achieve this goal, by allowing the economy to be much closer to the second-best equilibrium $[(\tilde{y}+\tilde{c}) = (\bar{y}_2+\bar{c}_2)]$.

In this last case, the central bank should partially abandon its target of zero inflation and accommodate more inflation (see equation 16). In contrast, with a negative shock the central bank should intervene, as García and González (2013) propose, in order to keep this inequality from rising $[(\tilde{y}+\tilde{c}) < (\bar{y}_2+\bar{c}_2)]$.

This last result is reinforced by the parameter $\Theta < 1$, which is only present in the Phillips curve with decreasing returns (Galí, 2008; see equation 16). This parameter reduces the impact of the marginal cost on the inflation rate in the Phillips curve—that is, this curve is more flat. Indeed, if the central bank does not intervene when the real exchange rate falls, the economy moves even further away from the second-best equilibrium for the existence of Θ. Therefore, a central bank should abandon a simple linear Taylor rule and adopt a more complex and asymmetric rule. We explain in detail the existence of Θin the next section.

The results of this section capture in formal terms the intuition explained in the introduction of this article. Firms that produce goods for foreign markets often have no way to adjust their demand for inputs, especially in response to the fluctuations caused by risk premium shocks. Thus, some producers that export goods to international markets do not

[4] In this regard, the procyclical effect of a risk premium shock on the economy is also found when the production function includes capital stock as another input (García and González, 2014).

have a rental market for sending back its inputs (for example, fruit producers cannot return trees that already have been planted). These inputs are equivalent to specific capital, in that they cause decreasing returns in the short term. Therefore, it turns out to be optimal to protect the export sector when the exchange rate falls.

Thus, the absence of a rental market for some inputs deeply alters the nature of monetary policy in an inflation-targeting regime. Counterintuitively, central banks should allow inflation to rise when the real exchange rate increases. This results in a higher level of production and consumption. In contrast, central banks should intervene to avoid a decrease in the inflation rate.

3 The Empirical Model

In this section, we present the general equilibrium model to test the relevance of the rental market for certain types of capital stock when the economy faces important risk premium shocks to the real exchange rate.[5] We first present the model with a rental market (base model), then the model without a rental market (modified model). Both models are linearized around the same steady state. Both models are then estimated by Bayesian Econometrics for five open economies.

3.1 Households

We assume a continuum of infinitely lived households indexed by $i \in [0, 1]$. Following Galí, López-Salido, and Vallés (2007), a fraction of households, λ, does not have access to capital markets and thus neither saves nor borrows. The remaining households, $(1 - \lambda)$, have access to capital markets and are able to smooth consumption.

3.2 Ricardian household

The representative household maximizes expected utility. Here, the superscript o stands for Ricardian households or optimizing agents. We assume a separable utility function with habit persistence, γ:

$$E_o \sum_{t=0}^{\infty} \beta^t \left[\frac{\left(C_t^o(i) - \gamma C_{t-1}^o(i)\right)^{1-\sigma} - 1}{1-\sigma} - \chi \frac{N_t^o(i)^{\varphi}}{\varphi} \right] \tag{18}$$

where $1/\sigma$ is the intertemporal elasticity of substitution in consumption and $1/(\varphi - 1)$ is the elasticity of labor supply to wages. The value of χ is calibrated to obtain a realistic fraction of steady-state hours worked, subject to the following budget constraint:

$$\begin{aligned} P_t C_t^o(i) \leq\ & W_t(i) N_t^o(i) + B_t^o(i) - S_t B_t^{o*}(i) + D_t^o(i) - P_t T_t \\ & - R_t^{-1} B_{t+1}^o(i) + S_t \left\{ \Phi\left(\tfrac{b_{t+1}^{o*}}{GDP_t}, \tfrac{b_{t+1}^{o*}}{Q_t K_{t+1}}, u_t^{RK} \right) R_t^* \right\}^{-1} B_{t+1}^{o*}(i) \end{aligned} \tag{19}$$

[5] Our model resembles others found in the recent literature, but it has been adapted to capture the essentials of small open economies. General references on this type of model include Woodford (2003), Clarida, Galí, and Gertler (1999, 2002), Galí and Monacelli (2005), and Galí, López-Salido, and Vallés (2007). More specifically, the model is similar to the one proposed by Smets and Wouters (2002). Our model also includes restricted consumers (Galí, López-Salido, and Vallés, 2007), raw materials, consumer habits, wage indexation, the balance sheet effect of exchange rate changes (Céspedes, Chang, and Velasco, 2004), and country risk premiums that are dependent on the ratio of external debt to GDP (Schmitt-Grohé and Uribe, 2003). Our structure is also similar to Laxton and Pesenti (2003), since all imports are intermediate inputs. Thus, the model has imperfect pass-through of the exchange rate changes to domestic prices.

where $C^o_t(i)$ is consumption, $D^o_t(i)$ are dividends from ownership of firms, $\Phi\left(\right)$ represents the country risk premium (with $b^{o*}_{t+1} = S_{t+1}B^{o*}_{t+1}/P_{t+1}$), S_t is the nominal exchange rate, $B^{o*}_t(i)$ denotes private net foreign assets (a positive value means external debt), $W_t(i)$is the nominal wage, $N^o_t(i)$ is the number of hours of work, $B^o_t(i)$ 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 denotes lump-sum taxes.[6]

3.3 Risk premium

The risk premium, $\Phi\left(\right)$, depends on foreign debt, the value of investment, and gross domestic product (GDP). The risk premium consists of three 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.[7]

The second term in the equation says that the risk premium is an increasing function of the foreign debt to the value of investment. That is, it captures the adverse impact of currency depreciation on the domestic currency value of external debt—the balance sheet effect.[8]

The third term is the risk premium shock, which we define as unanticipated changes in credit risk conditions related to external debt. As can be seen in the budget constraint in equation (19), this type of shock directly reduces the resources that families have available for smoothing consumption over time.

3.4 Hand-to-mouth household consumption

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

$$P_t C^r_t(i) = W_t(i) N^r_t(i) - P_t T_t. \tag{20}$$

[6] In the appendix we explain how we transform the exchange rate in the budget constraint to obtain the first-order conditions.

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

[8] This liability-dollarization effect can be modeled in different ways, as described by Céspedes, Chang, and Velasco (2004), Cook (2004), Elekdag, Justiniano, and Tchakarov (2006), and Tovar (2006). We decided to follow a simple strategy proposed by Céspedes, Chang, and Velasco (2004) and Gertler, Gilchrist, and Natalucci (2007), which allows us to measure this effect in just one parameter, μ, measuring the elasticity of the risk premium to foreign debt.

3.5 The labor supply schedule

Following Erceg, Henderson, and Levin (2000), we assume 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.

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. Units of labor are then sold to the productive sector at their unit cost, W_t (with no profit):

$$W_t = \left(\int_0^1 W_t(i)^{1-\varepsilon_w} di \right)^{\frac{1}{1-\varepsilon_w}} \tag{21}$$

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

$$W_t(i) = \left(W_{t-1}\left(i\right)\right)^{1-\delta_W} \left(\frac{P_{t-1}}{P_{t-2}} \right)^{\delta_W} \tag{22}$$

3.6 Firms: Base model with a rental market for capital

We assume a continuum of monopolistically competitive domestic firms, indexed by $j \in [0, 1]$, producing differentiated intermediate goods. We take into account not only the role of investment in propagating the shocks that affect the real exchange rate, but also the role of including imported inputs in the production function (McCallum and Nelson, 2000). Thus, the production function of the representative intermediate-goods firm, indexed by (j), corresponds to a constant elasti ity of substitution (CES) combination of labor, $N_t(j)$, capital stock $K_t(j)$, and import inputs, $I_t(j)$, to produce $Y_t^D(j)$ and is given by

$$Y_t^D(j) = A_t \Big[\alpha_1 N_t(j)^{\frac{\sigma_s - 1}{\sigma_s}} + \alpha_2 I_t(j)^{\frac{\sigma_s - 1}{\sigma_s}} + (1 - \alpha_1 - \alpha_2) K_t(j)^{\frac{\sigma_s - 1}{\sigma_s}} \Big]^{\frac{\sigma_s}{\sigma_s - 1}} \tag{23}$$

where A_t is the technology shock, σ_s is the elasticity of substitution between capital, imported inputs, and labor, and both are greater than zero.

The firms' costs are minimized, taking as given the price of import inputs, $S_t P_t^*$, capital stock, Z_t, and the wage, W_t, subject to the production function technology. In other words, there are markets for all inputs. The relative factor demands are derived from the first-order conditions:

$$N_t^*(j) = \left[(1-\alpha_1-\alpha_2)\,/\,(\alpha_1)\right]^{\frac{1}{\sigma_s}} \left\{[W_t/Z_t]^{-\frac{1}{\sigma_s}}\right\} K_t(j) \tag{24}$$

and

$$I_t^*(j) = \left[(1-\alpha_1-\alpha_2)\,/\,(\alpha_2)\right]^{\frac{1}{\sigma_s}} \left\{[(S_tP_t^*)\,/Z_t]^{-\frac{1}{\sigma_s}}\right\} K_t(j) \tag{25}$$

As explained above, to replicate the inertia observed in the hiring of inputs, we assume that total inputs are a weighted average between its own lag and the values from equations (24) and (25):[9]

$$N_t = \left(N_{t-1}\right)^{\Omega_N} (N_t^*)^{1-\Omega_N} \tag{26}$$

and

$$I_t = \left(I_{t-1}\right)^{\Omega_M} (I_t^*)^{1-\Omega_M} \tag{27}$$

and the marginal cost is given by:

$$MC_t^D = (1/A_t)\left[{\alpha_1}^{\sigma_s}(W_t)^{1-\sigma_s} + {\alpha_2}^{\sigma_s}(S_tP_t^*)^{1-\sigma_s} + (1-\alpha_1-\alpha_2)^{\sigma_s}(Z_t)^{1-\sigma_s}\right]^{\frac{1}{1-\sigma_s}} \tag{28}$$

As the firms have a market for each input, constant returns to scale are operating, and therefore marginal costs are constant (not dependent on output) and equal for each firm.

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 assume that the 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 (that is, complete indexation is when δ_D equal to one):

$$\max \sum_{k=0}^{\infty} \theta_D^k E_t \left\{\Lambda_{t,t+k} Y_{t+k}^D(j) \left[P_t^{D*}(j) \prod\nolimits_{l=1}^{k} \left(\pi_{t+l-1}^k\right)^{\delta_D} - MC_{t+k}^D\right]\right\} \tag{29}$$

subject to

$$Y_{t+k}^D(j) \leq \left(P_t^{D*}(j)/P_{t+k}^D\right)^{-\varepsilon_D} Y_{t+k}^D \tag{30}$$

where the probability that a given price can be reoptimized in any particular period is constant and is given by $(1-\theta_D)$, ε_D is the elasticity of substitution between any two

[9] This approach similar to Laxton and Pesenti (2003).

differentiated goods, and $\Lambda_{t,t+k}$ is the stochastic discount factor. P_t^{D*} must satisfy the first-order condition, where this price can be indexed to past inflation:

$$\sum_{k=0}^{\infty} \theta_D^k E_t \left\{ \Lambda_{t,t+k} Y_{t+k}^D(j) \left[P_t^{D*}(j) \prod\nolimits_{l=1}^{k} \left(\pi_{t+l-1}^k \right)^{\delta_P} - \frac{\varepsilon_D}{\varepsilon_D - 1} MC_{t+k}^D \right] \right\} = 0 \tag{31}$$

Firms that did not receive the signal will not adjust their prices. Those that do reoptimize choose a common price, P_t^{D*}. Finally, the dynamics of the domestic price index, P_t^D, are described by the following equation:

$$P_t^D = \left[\theta_D (P_{t-1}^D \pi_{t-1}^{\delta_D})^{1-\varepsilon_D} + (1-\theta_D)(P_t^{D*})^{1-\varepsilon_D} \right]^{\frac{1}{1-\varepsilon_D}} \tag{32}$$

After solving problem (31) and using (32), we have the log linearization of the Phillis curve in terms of real marginal cost:

$$\pi_t = \frac{\tilde{\beta}}{\left(1+\tilde{\beta}\delta_D\right)} E_t\left(\pi_{t+1}\right) + \frac{\delta_D}{\left(1+\tilde{\beta}\delta_D\right)} \pi_{t-1} + \lambda_D \left(mc_t^D + \mu^D \right) \tag{33}$$

where $\lambda_D = \left(1 - \tilde{\beta}\theta_D\right)(1-\theta_D) / \left(1+\tilde{\beta}\delta_D\right)\theta_D$ and $\tilde{\beta} = \beta(\zeta)^{1-\sigma}$ is the subjective discount factor adjusted for the trend observed in the data.

On the other hand, there are firms that produce homogeneous capital goods and rent them to the intermediate-goods firms (the rental market for capital stock). Firms are owned exclusively by Ricardian households. Firms invest the amount INV_t so as to maximize firm value:

$$V^t(K_t^o) = Z_t K_t^o - P_t INV_t + E_t\left[\Lambda_{t,t+1} V^{t+1}\left(K_{t+1}^o\right)\right] \tag{34}$$

subject to a capital accumulation constraint that includes an adjustment cost function $\phi()$. The parameter η_I measures adjustment cost in the log-linear model.

$$K_{t+1}^o = (1-\delta) K_t^o + \phi\left(\frac{INV_t^o}{K_t^o}\right) K_t^o \tag{35}$$

3.7 Model without a rental market for capital

In the alternative model, we assume that there is not a rental market for capital stock. Therefore, firms make decision not only about fixing prices, but also about investing in capital stock. Following Sveen and Weinke (2005), the problem of the firm which fixed prices is now defined by

$$\max \sum_{k=0}^{\infty} \theta_D^k E_t \left\{ \Lambda_{t,t+k} Y_{t+k}^D (j) \left[P_t^{D*} (j) \prod_{l=1}^{k} (\pi_{t+l-1}^k)^{\delta_D} - MC_{t+k}^D (j) - P_{t+k}^D INV_{t+k}^o (j) \right] \right\} \tag{36}$$

subject to

$$Y_{t+k}^D (j) \leq \left(\frac{P_t^D (j)}{P_{t+k}^D} \right)^{-\varepsilon_D} Y_{t+k}^D \tag{37}$$

and

$$K_{t+1}^o = (1-\delta) K_t^o + \phi \left(\frac{INV_t^o}{K_t^o} \right) K_t^o \tag{38}$$

The main difference between the two models is that once capital stock is produced, the absence of a rental market for this input causes means that there are no longer constant returns to scale, and marginal costs depend now on the level of production.

To clarify this point, we assume for simplicity that $\sigma_S \to 1$ and $A_t = 1$. Then the marginal costs for a firm $j$that sets its price in t for $t+k$ periods is

$$MC_{t,t+k}^D (j) = \left(\frac{W_{t+k}}{P_{t+k}^D} \right) \frac{1}{MP_{t,t+k}^N (j)} = \left(\frac{W_{t+k}}{P_{t+k}^D} \right) \frac{1}{\alpha_1} \frac{N_{t,t+k} (j)}{Y_{t,t+k}^D (j)} \tag{39}$$

From the production function and the assumptions that $\sigma_S \to 1$ and $A_t = 1$, we have

$$N_{t,t+k} (j) = \left(Y_{t,t+k}^D (j) \right)^{\frac{1}{\alpha_1}} \left(I_{t,t+k} (j) \right)^{\frac{\alpha_2}{\alpha_1}} \left(K_{t,t+k} (j) \right)^{\frac{1-\alpha_2-\alpha_2}{\alpha_1}} \tag{40}$$

Substituting equation (40) into equation (39) yields

$$MC_{t,t+k}^D (j) = \left(\frac{W_{t+k}}{P_{t+k}^D} \right) \frac{1}{\alpha_1} \left(Y_{t,t+k}^D (j) \right)^{\frac{1-\alpha_1}{\alpha_1}} \left(I_{t,t+k} (j) \right)^{\frac{\alpha_2}{\alpha_1}} \left(K_{t,t+k} (j) \right)^{\frac{1-\alpha_2-\alpha_2}{\alpha_1}} \tag{41}$$

On average, the marginal cost in the economy is

$$MC_{t+k}^D = \left(\frac{W_{t+k}}{P_{t+k}^D} \right) \frac{1}{\alpha_1} \left(Y_{t+k}^D \right)^{\frac{1-\alpha_1}{\alpha_1}} \left(I_{t+k} \right)^{\frac{\alpha_2}{\alpha_1}} \left(K_{t+k} \right)^{\frac{1-\alpha_2-\alpha_2}{\alpha_1}} \tag{42}$$

whereMP_t^N is the marginal productivity of labor. We now combine equations (41) and (42):

$$MC_{t,t+k}^{D}(j) = MC_{t+k}^{D}\left(\frac{Y_{t,t+k}^{D}(j)}{Y_{t,t+k}^{D}}\right)^{\frac{1-\alpha_1}{\alpha_1}}\left(\frac{I_{t,t+k}(j)}{I_{t,t+k}}\right)^{\frac{\alpha_2}{\alpha_1}}\left(\frac{K_{t,t+k}(j)}{K_{t,t+k}}\right)^{\frac{1-\alpha_2-\alpha_2}{\alpha_1}} \tag{43}$$

Since we assume that only the rental market for capital is not operating, equation (43) can be simplified as follows:

$$MC_{t,t+k}^{D}(j) = MC_{t+k}^{D}\left(\frac{Y_{t,t+k}^{D}(j)}{Y_{t,t+k}^{D}}\right)^{\frac{1-\alpha_1}{\alpha_1}}\left(\frac{K_{t,t+k}(j)}{K_{t,t+k}}\right)^{\frac{1-\alpha_2-\alpha_2}{\alpha_1}} \tag{44}$$

Furthermore, Sveen and Weinke (2005) find that the capital gap, $K_{t,t+k}(j)/K_{t,t+k}$, is reduced rapidly by the forward-looking nature of capital formation, so that only the output gap $Y_{t,t+k}^{D}(j)/Y_{t,t+k}^{D}$ is relevant.

Independent of the assumptions $\sigma_S \to 1$ and $A_t = 1$, the absence of the rental market for the capital is equivalent to having decreasing return, and marginal costs therefore depend positively on the level of activity, given $(1-\alpha_1)/\alpha_1 > 0$ in equation (44).

Finally, given Sveen and Weinke's (2005) result on the capital gap, combining equations (37) and (44) yields a simpler expression for marginal costs:

$$MC_{t,t+k}^{D}(j) = MC_{t+k}^{D}\left(\frac{P_t^{D}(j)}{P_{t+k}^{D}}\right)^{-\varepsilon_D\left(\frac{1-\alpha_1}{\alpha_1}\right)} \tag{45}$$

Galí (2008) shows that if marginal costs are equal to equation (45), then the new Keynesian Phillips curve is similar to the traditional Phillips curve with constant returns to scale. Nevertheless, the parameter that multiplies marginal costs must be adjusted by a constant Θ indicating the presence of decreasing returns. Thus, the log-linear version of the new Phillips curve is

$$\pi_t = \frac{\tilde{\beta}}{\left(1+\tilde{\beta}\delta_D\right)}E_t(\pi_{t+1}) + \frac{\delta_D}{\left(1+\tilde{\beta}\delta_D\right)}\pi_{t-1} + \tilde{\lambda}_D\left(mc_t^D + \mu^D\right) \tag{46}$$

where

$$\tilde{\lambda}_D = \Theta\left(1-\tilde{\beta}\theta_D\right)(1-\theta_D)/\left(1+\tilde{\beta}\delta_D\right)\theta_D \quad \text{and} \quad \Theta = \alpha_1/\alpha_1 + \varepsilon_D(1-\alpha_1) < 1.$$

Therefore $\tilde{\lambda}_D < \lambda_D$ from equation (33).

3.8 Final goods distribution

There is a perfectly competitive aggregator, which distributes the final good using a constant-returns-to-scale technology:

$$Y_t^D = \left(\int_0^1 Y_t^D(j)^{\frac{\varepsilon_K - 1}{\varepsilon_K}} dj \right)^{\frac{\varepsilon_K}{\varepsilon_K - 1}} \tag{47}$$

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

$$P_t^D = \left(\int_0^1 P_t^D(j)^{1-\varepsilon_K} dj \right)^{\frac{1}{1-\varepsilon_K}} \tag{48}$$

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

$$Y_t^D(j) = \left(\frac{P(j)}{P_t} \right)^{-\varepsilon_K} Y_t^D \tag{49}$$

3.9 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, C_t^{D*}, which is considered as a shock in the estimations, and on the home price of domestic goods relative to its price in the foreign country:

$$X_t^{D^*} = \left[P_t^D / (S_t P_t^{D^*} \right]^{-\eta} C_t^{D^*} \tag{50}$$

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, $X_t^{D^*}$
:

$$X_t^D = \left(X_{t-1}^D \right)^{\Omega} \left(X_t^{D^*} \right)^{1-\Omega} \tag{51}$$

Since we are considering small economies' natural resource exports (commodities), the total value of these products is$S_t P_t^{cu} Q_c$, where P_t^{cu} denotes the international price of the commodity, which is considered a shock in the estimations, and Q_c is the constant quantity supplied. For simplicity, supply is assumed to be price invariant in the business cycle (short-run) horizon.

3.10 Aggregation

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

$$C_t = \lambda C_t^r + (1-\lambda) C_t^o = \int_0^{\lambda} C_t^r(i) d_i + \int_{\lambda}^{1} C_t^o(i) d_i \tag{52}$$

Since only Ricardian households hold assets, these are equal to

$$B_t = (1-\lambda)(B_t^o) \tag{53}$$

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

$$B_t^* = B_t^{G^*} + (1-\lambda) B_t^{o^*} \tag{54}$$

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

$$N_t = \lambda N_t^r + (1-\lambda) N_t^o \tag{55}$$

Since only Ricardian households invest and accumulate capital, total investment, , is equal to times optimizing investment,INV_t^o:

$$INV_t = (1-\lambda)(INV_t^o) \tag{56}$$

Likewise, the aggregate capital stock is

$$K_t = (1-\lambda)(K_t^o) \tag{57}$$

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

$$N_t = N_t^r = N_t^o \tag{58}$$

3.11 Monetary policy

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

$$IR_t = \overline{R} \left[\left(\Pi_t/\bar{\Pi}\right)^{\phi_\pi} \left(YR_t/\bar{Y}\bar{R}\right)^{\phi_y} \left(Q_t/\bar{Q}\right)^{\zeta_e^1} \left(Q_t/Q_{t-1}\right)^{\zeta_e^2} \right] \tag{59}$$

where $\overline{R}$ is the steady-state nominal interest rate, Π_t is total inflation, Π is total inflation in steady state (which is zero in our model), YR_t represents GDP excluding natural resources, $\overline{YR}$ is its steady-state value, Q_t denotes the real exchange rate, and $\overline{Q}$ is the steady state level. Thus, central banks can react to both the level and the change of the real exchange rate.

We assume that central banks do not immediately move the interest rate to its target level (equation 59), but rather take some time to respond to changes in the inflation rate, output, and the exchange rate (equation 60). In addition, there are monetary policy shocks, u_t^{MP}, which are normally distributed.

$$R_t = \left(R_{t-1}\right)^{\Omega_R} \left(IR_t\right)^{1-\Omega_R} e^{u_t^{MP}} \tag{60}$$

3.12 Government

The government budget constraint is

$$P_t T_t + R_1^{-1} B_{t+1}^G + S_t \left\{ \Phi \left(\frac{b_{t+1}^{o^*}}{GDP_t}, \frac{b_{t+1}^{o^*}}{Q_t K_{t+1}}, u_t^{RK} \right) R_t^* \right\}^{-1} B_{t+1}^{G^*} \geq B_t^G + S_t B_t^{G^*} + P_t^G G_t \tag{61}$$

where B_t^Gdenotes public domestic assets (debt), $P_t T_t$ corresponds to government nominal (lump-sum) tax revenues, and $P_t^G G_t$is public spending. For simplicity, we assume that $G_t = 0$.

3.13 Market-clearing conditions

The two market-clearing conditions in the factor market are total employment by all firms j,

$$N_t = \int_0^1 N_t(j) dj \tag{62}$$

and imported inputs,

$$I_t = \int_0^1 I_t(j) dj \tag{63}$$

In the goods market, the market-clearing condition is

$$Y_t^D = C_t + X_t^D + INV_t \tag{64}$$

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

$$\begin{aligned} P_tC_t + P_tINV_t \leq P_t^DY_t^D - S_tP_t^*I_t + S_t\left\{\Phi\left(\frac{b_{t+1}^{o*}}{GDP_t}, \frac{b_{t+1}^{o*}}{Q_tK_{t+1}}, u_t^{RK}\right)R_t^*\right\}^{-1}B_{t+1}^* \\ -S_tB_t^* + (S_tP_t^{cu}Q\_c) \end{aligned} \tag{65}$$

which we can define excluding natural resources as the sum of domestically produced goods minus import inputs:[10]

$$P_tYR_t = P_t^DY_t^D - S_tP_t^*I_t \tag{66}$$

[10]In our model, GDP with natural resource is , but the relevant concept for monetary policy is the definition of equation (59).

4 Estimation Methodology and Data

We proceed with a discussion of our econometric methodology for the estimation of our model in a context of a small open economy. We then describe the construction of the data sets that are used for the empirical estimation.

4.1 Econometric Methodology

The model is estimated using a Bayesian approach (see Fernández-Villaverde and Rubio-Ramírez, 2004; Smets and Wouter, 2007). The estimation is based on the likelihood function generated by the solution of the log-linear version of the model. Prior distributions for the parameters of interest are used to incorporate additional information into the estimation. The whole set of linearized equations forms a linear rational expectation system that can be written in canonical form as follows:

$$\Gamma_0(\vartheta)\, z_t = \Gamma_1(\vartheta)\, z_{t-1} + \Gamma_2(\vartheta)\, \varepsilon_t + \Gamma_3(\vartheta)\, \Theta_t \tag{67}$$

where z_t is a vector containing the model's variables expressed as log-deviation from their steady-state values, vector ε_t is a vector containing white noise innovations to the exogenous shocks of the model, and Θ_t is a vector containing rational expectations forecast errors. The matrices Γ_1 are a nonlinear function of the structural parameters contained in vector ϑ. Vector z_t collects the endogenous variables of the model and the ten exogenous shocks: monetary policy shock (ξ_M), productivity shock (ξ_M), preference shock (ξ_{Z2}), mark-up prices shock (ξ_{Z3}), risk premium shock (ξ_{Z4}), investment shock (ξ_{Z5}), commodity price shock (ξ_{PC}), foreign interest rate(ξ_{M^*}), foreign inflation(ξ_{P^*}), and foreign output(ξ_{Y^*}).

The solution to this system can be expressed as follows:

$$z_t = \Omega_z(\vartheta)\, z_{t-1} + \Omega_\varepsilon(\vartheta)\, \varepsilon_t \tag{68}$$

where Ω_z and Ω_ϵ are functions of the structural parameters. Let $y_t$be a vector of observable variables, which is related to the variables in the model through a measurement equation:

$$y_t = H z_t \tag{69}$$

where H is a matrix that selects elements from z_t.

Those equations correspond to the state-space form representation of y_t. If we assume that the white noise innovations, ε_t, are normally distributed, we can compute the conditional likelihood function for the structural parameters using the Kalman filter. Let $p(\vartheta)$be a prior density on the structural parameters and $L\left(\vartheta | Y^T\right)$, where $Y^T = \{y_1, \ , y_T\}$ collects observable variables. The joint posterior density of the parameters is computed using the Bayes theorem:

$$p\left(\vartheta | Y^T\right) = \frac{L\left(\vartheta | Y^T\right) p\left(\vartheta\right)}{f L\left(\vartheta | Y^T\right) p\left(\vartheta\right) d\vartheta} \tag{70}$$

Since the conditional likelihood function has no analytical expressions, we approximate it using numerical methods based on the Metropolis–Hastings algorithm. The estimates were obtained with Dynare.[11]

4.2 Description of the Data

We use quarterly data from 1994 to 2012. The observed variables are real GDP, real consumption, real private investment, exports, imports, inflation, the nominal interest rate, CPI inflation, the real exchange rate, and commodity prices. Commodity prices are measured in real terms. For Chile, we use the London Metal Exchange (LME) copper price; for Colombia, the West Texas Intermediate (WTI) oil price; for South Africa, the World Bank Metals and Mineral Index; for Australia, the commodity price index published by the Reserve Bank of Australia; for New Zealand, the soft commodity price index published by the Reserve Bank of New Zealand. The data sources for Australia, Chile, and New Zealand are their respective central banks, with the exception of the real exchange rate index, which is published by World Bank, and commodity prices, which are from Bloomberg and from the World Bank commodity database. In Colombia and South Africa, all the data are from the International Financial Statistics (IFS) database published by the International Monetary Fund (IMF), except for real exchange rates, which are from the World Bank.

External variables are taken from the FRED database maintained by the Federal Reserve Bank of St. Louis. We use real GDP, the GDP deflator as a measure of inflation, and the U.S. Federal funds interest rate.

Given the observed variables, we need ten shocks to estimate the model. In section 3, we explicitly defined five shocks: productivity, monetary, commodity price, risk premium, and foreign demand. We then added five more shocks: a preference shock in the Euler equation, a markup shock in the Phillips curve, a foreign inflation shock, an investment shock, and a Federal funds shock. The model was estimated in first differences, following the strategy of Smets and Wouters (2007).

[11]We used the Metropolis–Hastings algorithm with two chains of 70,000 draws (neglecting the first 28,000 draws) and an acceptation rate of 0.33.

5 Results

The values of the priors (table 1) are in line with the earlier literature and incorporate our beliefs about possible ranges based on the nature and behavior of the variables (see Smets and Wouters, 2002, 2007; Laxton and Pesenti, 2003).[12] The values of the parameters used in DSGE models in the different countries fall within the literature's typical ranges. Accordingly, almost the same prior values are used for the countries in the sample, and we let the data inform on the degree of fit of these values to the realities of the sample countries.

See figure 1 on page 34

The estimated parameters are all related directly to the dynamics of the model (habit persistence, fraction of hand-to-mouth consumers, wage indexation, adjustment cost for investment, and so forth). Parameters related to the steady state are calibrated to be consistent with each economy (consumption over GDP, exports over GDP, external debt over GDP, and so on).

5.1 Estimation of Parameters

We focus on the estimation of the parameters that measure the impact of monetary policy and the risk premium shock on the economies in the sample. The results are presented in table 2. We define the base model (B) as the model that has constant returns to scale and the modified model (M) as the model that has decreasing returns to scale.

The estimation results are relatively standard with respect to the previous literature on new Keynesian models for small open economies: we find a high elasticity of differentiated goods exports to the real exchange rate, together with price and wage rigidity. This indicates that shocks in the real exchange rate have significant reallocation effects in the economies analyzed (Colacelli, 2008).

See figure 2 on page 35

A first important result is that, on average, the estimation of σ for all countries is not substantially different between the two models, at around 2.0 in both cases. This means an intertemporal substitution elasticity of 0.5, which confirms that the interest rate has a moderate effect on consumption in small open economies (Agénor and Montiel, 1996).[13]

[12] All tables and graphs can be found at the end of the article.

[13] We have problems to estimate the real wage elasticity in the labor supply. Thus we chose to calibrated it; we set a value for this parameter of 0.75 (Chetty and others, 2011).

Another parameter that is related to the response of consumption to the interest rate is the habit parameter, γ. Our estimations indicate that the presence of habit is a little more moderate than in closed economies such as the United States (0.6–0.7).[14] Specifically, we find values of around 0.4–0.7 for this parameter, except for South Africa (0.8). The share of restricted agents, λ, is generally around 0.2.

Prices and wages remain rigid, $1/(1--\theta_D)$ and $1/(1--\theta_W)$, between three and five quarters after the shock. Although there is substantial dispersion in the level of indexation in prices, δ_D, and wages, δ_W, price indexation is always high and significant (0.4–0.7). Furthermore, since all imported goods are production inputs in the model, price rigidity also indicates a low pass-through of the exchange rate to domestic prices.

Another result that is relevant for understanding monetary policy transmission is the elasticity of differentiated goods exports to the real exchange rate, τ_D. The estimated values are between 1.0 and 3.0, except for Colombia in the modified model (0.4). In general, the estimations are consistent with Imbs and Méjean (2010), who estimate values of around 2.0 for small open economies, and García and Gonzalez (2013), also at around 2.0 for a similar sample of countries to this article.

We find that the inertia of domestic exports, Ω, is 0.3–0.5, on average. This confirms the strong impact of the real exchange rate on the economy in the short run in the DSGE model for all countries.

The balance sheet effect may be positive or negative, depending on the structure of the economy. In our model, this effect is captured arbitrarily by incorporating the real exchange rate in the risk premium through the parameterμ. Our results indicate that μ is generally positive (except for New Zealand in the base case) but small, at less than 0.2.

In our model, the uncovered interest parity (UIP) condition does not hold by definition, because we introduce risk premium shocks directly into the UIP. As you can see below, the relevance of the risk premium shocks is confirmed for the variance decomposition analysis. In addition, and as we explain in the appendix, we introduce persistence in the UIP to produce sensible dynamics of the real exchange rate. In this regard, the persistence of the real exchange rate, Ω_D, is less than 0.1, on average. This confirms that the dynamic of the real exchange rate is caused by the occurrence of risk premium shocks and not by other factors.

On the Taylor rule, we find that the parameter for persistence, , is 0.8, on average. Inflation, ϕ_Π, is around 1.6–2.0, which is similar to results for the Taylor rule in other economies. Output, ϕ_Y, is generally high and over 0.7 (except for Australia).

In contrast to closed economies, central banks in these small open economies also

[14]Christiano, Eichenbaum, and Evans (2005) and Christiano, Boldrin, and Fisher (2001).

respond to the level of the real exchange rate, ζ_e^1, and its volatility, ζ_e^2. This response is small, however, with parameters rarely exceeding 0.1.[15] In sum, central banks do not intervene directly in exchange rate fluctuations, but rather try to smooth the business cycle once exchange rate fluctuations have caused output fluctuations.

This last result this may explain the high estimated value of the output parameter in the Taylor rule. Furthermore, the low estimates for the exchange rate parameters in the Taylor rule are why García and González (2013) find the monetary policy based on the estimated Taylor rule to be suboptimal. In other words, central banks can improved this linear rule if they directly increase the weight of the exchange rate and its variability in this rule.

5.2 Comparison between Models

We test the hypotheses of constant returns to scale versus decreasing returns to scale by directly comparing the two models, one with constant returns to scale (base model, B) and the other with decreasing return (modified model, M) (see table 3). We follow the criterion of Kass and Raftery (1995) for choosing between two models by using Bayes factors: if the modified model has the largest marginal likelihood, then there is evidence against the base model. We consider that there is positive evidence if $2 * (Bayes\ factor\ M\ -\ B)$ is larger than two, strong evidence if this expression is larger than six, and definitive evidence if it is larger than ten.

The value of $2 * (Bayes\ factor\ M\ -\ B)$ is arbitrary in the same sense that a significance level of $\alpha = 0.05$ is arbitrary in classical statistics. However, just like this value of , these categories seem to give an appropriate rule. As shown in 3, we have strong evidence that the modified model is better than the base model.

See figure 3 on page 40

5.3 Variance Decomposition

One result that emerges from the variance decomposition n periods ahead of the modified model is that in addition to the standard shocks studied in closed economies, we need to consider the risk premium shock to explain macroeconomic variables in small open economies (see figure 1). As García and González (2013, 2014) find, this shock largely explains the variability of the real exchange rate. This shock also helps explain the GDP

[15]This is small because should be equal to , with a large , (for example equal to six), due to the fixed exchange rate.

fluctuations and the nominal interest. By far, it appears to be the most significant external shock. In contrast, the commodity price shock is relevant for explaining the volatility of GDP and, to a lesser extent, the exchange rate. The external GDP shock, the external inflation shock, and the productivity shock appear to be marginally relevant in explaining the variability of the exchange rate in the period considered.

See figure 1 on page 41.

5.4 Impulse Response

Figure 2 shows that after a risk premium shock, the increase in output and inflation causes a strong increase in the interest rate, which produces a sharp reduction in output some quarters after of the shock. In other words, the economy only begins to contract after the central bank reacts by raising the interest rate to reduce inflation.

On the one hand, our model confirms the traditional effect of the Mundell-Fleming model: given sticky good prices and a rapidly clearing asset market, the devaluation of the domestic currency is an essential element in the adjustment mechanism following a negative external shock. On the other, our results are clearly different from some traditional literature on business cycles in emerging economies. Some authors find a countercyclical behavior between output and the risk premium (Uribe and Yue, 2006; Neumeyer and Perri, 2005). One reason of this difference is that studies that report a GDP contraction in the first period all include working capital in the model. Thus, more expensive working capital should have a negative effect on output.

Our model includes two additional effects for explaining the impact of a real depreciation: the so-called balance sheet effect, in which a real depreciation may be contractionary due to the presence of foreign currency debt (Krugman, 1999; Aghion, Bacchetta, and Banerjee, 2004; Céspedes, Chang, and Velasco, 2004), and the J curve effect, in which a real depreciation may be contractionary because of imported inputs (Bahmani-Oskooee and Ratha, 2004).

As García and Gonzalez (2014) explain, two parameters in our model are crucial for explaining the positive impact of the risk premium shock on GDP: the elasticity of the risk premium to external debt, μ, and the velocity of the real exchange rate's impact on foreign demand for exports, τ_D. In our estimation, the first parameter is low, while the second parameter is high, as expected. Therefore, a depreciation of the real exchange rate is expansive, , as illustrated in figure 2, because exports react more strongly than other factors such as the balance sheet effect and J curve effect.

See figure 2 on page 41.

5.5 Comparing a Risk Premium Shock between Models

In this section, we compare the two models in terms of their response to a risk premium shock. However, since the parameter estimates between the two models (constant versus decreasing returns) do not exactly produce the same results for the same country, we decided to consider only the estimates based on the alternative model. In other words, the counterfactual exercise consists of using only the values estimated for the parameters obtained from the modified model, with decreasing return. We then simulate the modified model with the two types of Phillips curve, that is, alternatively with constant and decreasing returns. This allows us to compare the results attributable solely to the different assumptions about the returns to scale (equation 46).

See figure 3 on page 42.

Figure 3 shows that inflation is much less responsive in the model with the Phillips curve with decreasing returns, which is a standard result in many works that introduce decreasing returns and specific capital in new Keynesian models (see section 1 for the references). In contrast, output fluctuates marginally more in this model, as do consumption and investment.

The marginal difference between the GDP response in the two models is crucial to understanding the main result of the paper. This difference happens because the policy rule in the modified model is responding to both GDP and, to a much lesser extent, the real exchange rate. In other words, the central bank is stabilizing the economy in the face of the procyclical effects of a positive risk premium shock.

From the perspective of the results shown in section 2, the central bank is preventing the economy from reaching the second-best equilibrium because the bank is responding to the increase in output. This happens because inflation rises less in the model with the modified Phillips curve, so the real interest rate rises more. As a result, consumption and investment fall, and output does not expand much.

To clarify the consequences of this key result, we analyze what happens if the central bank does not react to either GDP or the real exchange rate after a positive risk premium shock (figure 4). Crucially, we are primarily considering the central bank's reaction to GDP, since the results of table 3 indicate that the central bank only reacts slightly to direct changes the real exchange rate. This illustrates the point of section 2: under the assumption of decreasing returns to scale, it would be best not to respond to a positive risk premium shock in order to allow the economy to stay much closer to the second-best equilibrium.

See figure 4 on page 43.

Since the model is linear, the impact and dynamics of a negative risk premium shock on the economy are identical, but in the opposite direction. We conclude that in this case, the policy should be the opposite one: intervene in the exchange rate to prevent the economy from moving even further away from the second-best equilibrium.

6 Conclusions

We have demonstrated both theoretically and empirically how two key elements present in open economies radically change the implementation of monetary policy, in particular the currency intervention by the central bank. These elements are the decreasing returns caused by the absence of rental markets for certain types of capital and risk premium shocks to the exchange rate with pro-cyclical effects on the economy. According to our findings, when these elements are present, a central bank must modify a simple linear monetary rule, for example a Taylor rule that includes the exchange rate, to allow for a more complex and asymmetric policy.

The existence of risk premium shocks with procyclical effects on the economy could lead a central bank to intervene in the exchange rate in an attempt to quickly stop the resulting fluctuations. However, in a context of strict inflation targeting, the existence of decreasing returns with sticky prices causes output and consumption to be below their second-best equilibrium levels. Therefore, and counterintuitively, it is optimal to accommodate more inflation caused by a positive risk premium shock. This allows output and consumption to move much closer to the second-best equilibrium (caused by the decreasing returns). In contrast, it is optimal intervene the foreign exchange market when the shock is negative to prevent the economy from moving even further away from the second-best equilibrium.

Finally, empirical evidence from this study, based on five economies with different degrees of development, shows the relevance of these two elements and confirms that central banks should pursue a more complex and asymmetric policy in order to deal with these shocks and improve welfare.

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Appendix: Modeling the Exchange Rate in the Model

To obtain the real exchange rate, we first transform the external debt into domestic real terms in the budget constraint ($S_t B_t^{o*}/P_t = b_t^{o*}$):

$$\begin{aligned} &S_t\left\{\Phi\left(\tfrac{b_{t+1}^{o*}}{GDP_t},\tfrac{b_{t+1}^{o*}}{Q_t K_{t+1}},u_t^{RK}\right)R_t^*\right\}^{-1}B_{t+1}^{o*}(i) = \\ &\qquad \left(Q_t^*/Q_{t+1}^*\right)\left\{\Phi\left(\tfrac{b_{t+1}^{o*}}{GDP_t},\tfrac{b_{t+1}^{o*}}{Q_t K_{t+1}},u_t^{RK}\right)R_t^*\right\}^{-1}\left(P_{t+1}^*/P_t^*\right)b_{t+1}^{o*}(i). \end{aligned} \quad \text{(A.1)}$$

From the first-order conditions, it is possible to derive the interest parity condition, where $Q_t^* = S_t P_t^*/P_t$:

$$1 = E_t\left[\Lambda_{t,t+1}\tfrac{Q_{t+1}^*}{Q_t^*}R_t^*\Phi\left(\tfrac{b_{t+1}^{o*}}{GDP_t},\tfrac{b_{t+1}^{o*}}{Q_t K_{t+1}},u_t^{RK}\right)\right], \quad \text{(A.2)}$$

where the stochastic discount factor, $\Lambda_{t,t+1}$,is equal to$\beta\left(MU_{t+1}^0/MU_t^0\right)\left(P_t/P_{t+1}\right)$, and $MU$is marginal utility.

Empirically, equation (A.2) is unable to generate a hump-shaped response of the real exchange rate after a shock to monetary policy (Adolfson and others, 2008). We therefore assume that the real exchange rate, Q_t(equation A.3), is a weighted average between its own lag and the real exchange rate from the interest parity condition, Q_t^*. This approach is necessary to produce sensible dynamics in key variables of the model, such as output, inflation, and the exchange rate:

$$Q_t = \left(Q_{t-1}\right)^{\Omega_D}\left(Q_t^*\right)^{1-\Omega_D}. \quad \text{(A.3)}$$

Table 1: Priors for Parameters and Shocks

Parameters	Prior		
	Dist	mean	std
pondempl	beta	0.5	0.1
pondeimp	beta	0.5	0.1
adj_cost	gamma	1	0.1
σ	gamma	2.01	0.2
τ_D	gamma	2.76	0.75
Ω	beta	0.4	0.1
γ	beta	0.4	0.1
λ	beta	0.3	0.1
Ω_R	beta	0.66	0.1
φ_Π	gamma	1.87	0.2
φ_Y	gamma	0.66	0.2
ζ_e^1	gamma	0.13	0.2
ζ_e^2	gamma	0.17	0.2
$\mu(*)$	uniform	0.0	1.0
Ω_D	beta	0.26	0.2
Θ_D	beta	0.64	0.1
δ_D	beta	0.41	0.1
Θ_W	beta	0.64	0.1
δ_w	beta	0.44	0.1
ρ_Y foreign output	beta	0.5	0.2
ρ_P foreign inflation	beta	0.5	0.2
ρ_R foreign interest rate	beta	0.5	0.2
ρ_A productivity	beta	0.5	0.2
ρ_{PC} price commodity	beta	0.5	0.2
ρ_{Z2} preference	beta	0.5	0.2
ρ_{Z3} mark-up prices	beta	0.5	0.2
ρ_{Z4} risk premium	beta	0.5	0.2
ρ_K invesment	beta	0.5	0.2
TREND_M	gamma	0.5	0.2
CONST_I	gamma	0.5	0.2
CONST_R	gamma	0.5	0.2
CTREND	gamma	0.5	0.2
CONSTEPINF	gamma	0.5	0.2
CONSTER	gamma	0.5	0.2
σ_M interest rate	inv_gamma	0.25	0.5
σ_Y foreing output	inv_gamma	1	0.5
σ_P foreing inflation	inv_gamma	1	0.5
σ_R foreing interest rate	inv_gamma	1	0.5
σ_A productivity	inv_gamma	1	0.5
σ_{PC} price commodity	inv_gamma	10	2
σ_{Z2} preference	inv_gamma	1	0.5
σ_{Z3} mark-up prices	inv_gamma	1	0.5
σ_{Z4} risk premium	inv_gamma	1	0.5
σ_K investment	inv_gamma	1	0.5

Table 2: Estimation Of Parameters and Shocks

Parameters	Australia					
	Base (BM)			Modified (MM)		
	mean	5%	95%	mean	5%	95%
pondempl	0,625	0,531	0,706	0,000	0,000	0,000
pondeimp	0,793	0,709	0,858	0,678	0,473	0,953
adj_cost	0,801	0,696	0,916	0,954	0,799	1,120
σ	2,087	1,922	2,279	2,160	1,776	2,482
τ_D	2,112	1,730	2,476	1,799	1,223	2,422
Ω	0,417	0,319	0,506	0,549	0,359	0,735
γ	0,423	0,366	0,477	0,540	0,370	0,725
λ	0,235	0,168	0,303	0,283	0,091	0,630
Ω_R	0,766	0,705	0,832	0,775	0,698	0,856
φ_Π	1,652	1,534	1,770	2,173	1,834	2,486
φ_Y	0,326	0,214	0,412	0,437	0,282	0,575
ζ_e^1	0,069	0,000	0,131	0,033	0,000	0,082
ζ_e^2	0,073	0,036	0,109	0,081	0,043	0,119
$\mu(*)$	0,010	0,002	0,022	0,083	0,011	0,152
Ω_D	0,029	0,000	0,066	0,068	0,000	0,160
Θ_D	0,913	0,878	0,944	0,808	0,716	0,879
δ_D	0,578	0,513	0,646	0,268	0,156	0,378
Θ_W	0,696	0,606	0,775	0,725	0,610	0,848
δ_w	0,373	0,289	0,435	0,418	0,246	0,574
ρ_Y foreign output	0,940	0,904	0,986	0,946	0,906	0,988
ρ_P foreign inflation	0,800	0,732	0,866	0,882	0,810	0,968
ρ_R foreign interest rate	0,922	0,875	0,970	0,934	0,885	0,990
ρ_A productivity	0,830	0,731	0,941	0,915	0,867	0,963
ρ_{PC} price commodity	0,977	0,962	0,995	0,981	0,966	0,997
ρ_{Z2} preference	0,449	0,345	0,566	0,457	0,233	0,680
ρ_{Z3} mark-up prices	0,122	0,033	0,202	0,127	0,033	0,215
ρ_{Z4} risk premium	0,801	0,715	0,894	0,936	0,888	0,986
ρ_K invesment	0,905	0,870	0,947	0,797	0,736	0,864
TREND_M	0,202	0,118	0,294	0,184	0,109	0,263
CONST_I	0,624	0,578	0,671	0,644	0,620	0,673
CONST_R	1,264	1,218	1,308	1,274	1,226	1,322
CTREND	0,493	0,423	0,561	0,506	0,435	0,582
CONSTEPINF	0,150	0,099	0,205	0,158	0,099	0,229
CONSTER	0,714	0,613	0,840	0,551	0,441	0,658
σ_M interest rate	0,326	0,257	0,392	0,275	0,222	0,332
σ_Y foreing output	0,326	0,277	0,376	0,327	0,276	0,376
σ_P foreing inflation	0,707	0,588	0,824	0,701	0,588	0,824
σ_R foreing interest rate	0,719	0,574	0,873	0,563	0,468	0,662
σ_A productivity	2,214	1,925	2,549	1,587	0,829	2,195
σ_{PC} price commodity	7,514	6,631	8,496	6,890	5,840	7,909
σ_{Z2} preference	0,537	0,413	0,681	0,450	0,322	0,575
σ_{Z3} mark-up prices	0,332	0,273	0,393	0,368	0,303	0,435
σ_{Z4} risk premium	1,509	1,147	1,910	1,337	0,796	1,823
σ_K investment	0,540	0,376	0,719	0,589	0,423	0,753

Parameters	Chile					
	Base (BM)			Modified (MM)		
	mean	5%	95%	mean	5%	95%
pondempl	0,503	0,423	0,572	0,000	0,000	0,000
pondeimp	0,559	0,486	0,624	0,553	0,484	0,630
adj_cost	0,881	0,781	0,983	0,898	0,807	0,976
$sigma$	1,990	1,840	2,128	2,179	1,925	2,395
τ_D	3,255	2,916	3,631	2,917	2,519	3,301
Ω	0,277	0,196	0,358	0,296	0,203	0,388
γ	0,715	0,618	0,807	0,646	0,552	0,727
λ	0,058	0,025	0,089	0,159	0,087	0,219
Ω_R	0,784	0,754	0,811	0,827	0,800	0,852
φ_Π	1,300	1,116	1,505	1,700	1,522	1,880
φ_Y	0,730	0,596	0,855	0,952	0,821	1,128
ζ_e^1	0,013	0,000	0,036	0,017	0,000	0,048
ζ_e^1	0,041	0,000	0,077	0,024	0,000	0,053
$\mu(*)$	0,005	-0,004	0,013	0,022	0,009	0,034
Ω_D	0,151	0,000	0,291	0,142	0,000	0,257
θ_D	0,882	0,836	0,931	0,756	0,678	0,818
δ_D	0,400	0,315	0,484	0,611	0,546	0,706
θ_W	0,718	0,621	0,826	0,825	0,744	0,907
δ_w	0,449	0,328	0,613	0,626	0,509	0,753
ρ_Y foreign output	0,941	0,903	0,986	0,946	0,905	0,989
ρ_P foreign inflation	0,873	0,817	0,931	0,900	0,841	0,958
ρ_R foreign interest rate	0,964	0,941	0,989	0,948	0,903	0,993
ρ_A productivity	0,733	0,629	0,849	0,781	0,702	0,850
ρ_{PC} price commodity	0,906	0,856	0,962	0,948	0,916	0,980
ρ_{Z2}preference	0,387	0,222	0,559	0,568	0,411	0,722
ρ_{Z3} mark-up prices	0,597	0,473	0,724	0,342	0,229	0,470
ρ_{Z4} risk premium	0,939	0,891	0,982	0,980	0,962	0,998
ρ_K invesment	0,870	0,818	0,924	0,670	0,597	0,738
TREND_M	0,656	0,572	0,736	0,633	0,573	0,701
CONST_I	0,734	0,653	0,806	0,744	0,664	0,822
CONST_R	1,045	0,961	1,134	1,014	0,921	1,107
CTREND	0,520	0,472	0,567	0,504	0,440	0,578
CONSTEPINF	0,170	0,117	0,226	0,182	0,112	0,256
CONSTER	0,614	0,509	0,701	0,541	0,437	0,647
σ_M interest rate	0,260	0,206	0,307	0,249	0,206	0,290
σ_Y foreing output	0,330	0,272	0,380	0,330	0,271	0,384
σ_P foreing inflation	0,717	0,611	0,824	0,670	0,570	0,771
σ_R foreing interest rate	0,582	0,490	0,684	0,573	0,468	0,672
σ_A productivity	3,163	2,680	3,643	2,542	2,200	2,824
σ_{PC} price commodity	14,611	12,776	16,472	12,995	11,930	14,226
σ_{Z2} preference	0,505	0,389	0,627	0,453	0,364	0,550
σ_{Z3} mark-up prices	0,351	0,277	0,428	0,420	0,315	0,514
σ_{Z4} risk premium	0,998	0,773	1,232	1,007	0,711	1,299
σ_K investment	0,738	0,536	0,973	1,480	1,195	1,757

	Colombia					
Parameters	Base (BM)			Modified (MM)		
	mean	5%	95%	mean	5%	95%
pondempl	0,221	0,117	0,324	0,000	0,000	0,000
pondeimp	0,680	0,596	0,795	0,455	0,323	0,597
adj_cost	0,831	0,730	0,945	0,680	0,553	0,794
σ	2,176	1,970	2,381	2,063	1,737	2,357
τ_D	1,030	0,714	1,336	0,466	0,247	0,658
Ω	0,260	0,139	0,385	0,356	0,196	0,515
γ	0,611	0,472	0,747	0,467	0,301	0,646
λ	0,300	0,171	0,426	0,257	0,113	0,386
Ω_R	0,696	0,639	0,754	0,693	0,636	0,745
φ_Π	1,994	1,838	2,153	2,084	1,928	2,243
φ_Y	0,714	0,476	0,894	0,945	0,728	1,174
ζ_e^1	0,021	0,000	0,051	0,017	0,000	0,042
ζ_e^2	0,020	0,000	0,048	0,004	0,000	0,010
$\mu(*)$	0,050	0,018	0,084	0,195	0,014	0,401
Ω_D	0,289	0,040	0,494	0,103	0,000	0,219
θ_D	0,714	0,654	0,777	0,747	0,642	0,888
δ_D	0,578	0,470	0,691	0,711	0,559	0,883
θ_W	0,776	0,673	0,902	0,715	0,614	0,818
δ_W	0,453	0,248	0,648	0,438	0,287	0,619
ρ_Y foreign output	0,951	0,920	0,987	0,945	0,908	0,988
$\rho_P$foreign inflation	0,865	0,800	0,932	0,873	0,800	0,949
ρ_R foreign interest rate	0,899	0,855	0,939	0,927	0,884	0,973
ρ_A productivity	0,975	0,955	0,997	0,985	0,959	1,000
ρ_{PC} price commodity	0,792	0,691	0,893	0,768	0,666	0,868
ρ_{Z2} preference	0,588	0,464	0,735	0,699	0,597	0,808
ρ_{Z3} mark-up prices	0,929	0,894	0,968	0,362	0,091	0,626
ρ_{Z4} risk premium	0,887	0,814	0,958	0,938	0,883	0,994
ρ_K invesment	0,884	0,848	0,925	0,823	0,772	0,877
TREND_M	1,196	1,020	1,395	1,000	0,705	1,195
CONST_I	1,023	0,877	1,150	1,086	0,894	1,343
CONST_R	2,223	2,060	2,355	2,269	2,055	2,544
CTREND	0,475	0,400	0,555	0,478	0,407	0,546
CONSTEPINF	0,154	0,096	0,208	0,165	0,096	0,234
CONSTER	0,501	0,433	0,563	0,526	0,434	0,620
σ_M interest rate	0,301	0,235	0,364	0,288	0,230	0,344
σ_Y foreing output	0,327	0,279	0,371	0,331	0,276	0,383
σ_P foreing inflation	0,704	0,593	0,817	0,702	0,582	0,819
σ_R foreing interest rate	0,553	0,462	0,634	0,556	0,468	0,647
σ_A productivity	1,940	1,606	2,259	2,167	1,708	2,607
σ_{PC} price commodity	12,843	11,179	14,546	13,202	11,141	15,000
σ_{Z2} preference	0,479	0,351	0,591	0,422	0,313	0,518
σ_{Z3} mark-up prices	0,404	0,283	0,525	0,367	0,284	0,452
σ_{Z4} risk premium	1,610	1,138	2,083	1,570	0,719	2,405
σ_K investment	0,684	0,508	0,866	0,633	0,480	0,798

	New Zealand					
Parameters	Base (BM)			Modified (MM)		
	mean	5%	95%	mean	5%	95%
pondempl	0,397	0,254	0,531	0,000	0,000	0,000
pondeimp	0,524	0,421	0,624	0,394	0,252	0,525
adj_cost	0,781	0,652	0,900	0,780	0,643	0,914
σ	2,039	1,713	2,333	1,988	1,694	2,297
τ_D	1,020	0,790	1,254	0,900	0,696	1,098
Ω	0,290	0,161	0,416	0,431	0,259	0,608
γ	0,774	0,669	0,873	0,520	0,302	0,750
λ	0,171	0,080	0,243	0,243	0,103	0,377
Ω_R	0,833	0,783	0,886	0,831	0,782	0,882
φ_Π	1,999	1,670	2,347	2,234	1,837	2,631
φ_Y	1,115	0,879	1,338	1,354	1,071	1,626
ζ_e^1	0,165	0,000	0,311	0,136	0,000	0,271
ζ_e^1	0,058	0,000	0,108	0,118	0,036	0,201
$\mu(*)$	-0,005	-0,010	0,003	0,120	0,011	0,221
Ω_D	0,047	0,000	0,104	0,058	0,000	0,130
θ_D	0,854	0,801	0,906	0,751	0,680	0,823
δ_D	0,474	0,340	0,608	0,386	0,238	0,532
θ_W	0,818	0,731	0,912	0,766	0,643	0,893
δ_W	0,405	0,249	0,548	0,450	0,304	0,595
ρ_Y foreign output	0,950	0,909	0,992	0,947	0,906	0,992
ρ_P foreign inflation	0,831	0,777	0,891	0,873	0,804	0,943
ρ_R foreign interest rate	0,891	0,856	0,930	0,936	0,889	0,986
ρ_A productivity	0,733	0,599	0,875	0,854	0,782	0,928
ρ_{PC} price commodity	0,905	0,828	0,985	0,914	0,846	0,982
ρ_{Z2} preference	0,528	0,390	0,671	0,765	0,637	0,880
ρ_{Z3} mark-up prices	0,294	0,114	0,468	0,167	0,039	0,296
ρ_{Z4} risk premium	0,928	0,887	0,974	0,953	0,916	0,990
ρ_K invesment	0,912	0,880	0,944	0,883	0,848	0,922
TREND_M	0,309	0,229	0,386	0,211	0,154	0,266
CONST_I	0,565	0,493	0,637	0,630	0,590	0,667
CONST_R	1,247	1,167	1,325	1,322	1,241	1,410
CTREND	0,523	0,442	0,601	0,504	0,431	0,576
CONSTEPINF	0,142	0,079	0,193	0,152	0,091	0,213
CONSTER	0,542	0,465	0,613	0,564	0,455	0,673
$\sigma_M$interest rate	0,315	0,217	0,402	0,343	0,252	0,425
σ_Y foreing output	0,329	0,274	0,383	0,333	0,279	0,386
σ_P foreing inflation	0,731	0,610	0,855	0,706	0,595	0,825
σ_R foreing interest rate	0,591	0,489	0,686	0,570	0,469	0,670
σ_A productivity	2,048	1,525	2,484	1,827	1,432	2,186
σ_{PC} price commodity	6,393	5,392	7,358	6,292	5,380	7,190
σ_{Z2} preference	0,454	0,344	0,562	0,407	0,319	0,506
σ_{Z3} mark-up prices	0,478	0,327	0,640	0,427	0,323	0,532
σ_{Z4} risk premium	0,675	0,449	0,863	1,131	0,676	1,590
σ_K investment	0,750	0,520	0,951	0,684	0,485	0,870

	South Africa					
	Base (BM)			Modified (MM)		
Parameters	mean	5%	95%	mean	5%	95%
pondempl	0,280	0,168	0,390	0,000	0,000	0,000
pondeimp	0,559	0,395	0,699	0,423	0,339	0,507
adj_cost	0,614	0,489	0,764	0,737	0,636	0,836
σ	2,210	1,779	2,691	2,142	1,896	2,429
τ_D	1,593	1,190	1,945	1,040	0,757	1,315
Ω	0,244	0,113	0,364	0,508	0,362	0,646
γ	0,806	0,704	0,906	0,842	0,776	0,906
λ	0,164	0,044	0,295	0,138	0,068	0,204
Ω_R	0,932	0,913	0,953	0,929	0,911	0,946
φ_Π	1,665	1,450	1,894	1,652	1,417	1,905
φ_Y	0,779	0,569	0,963	0,656	0,405	0,867
ζ_e^1	0,050	0,000	0,134	0,030	0,000	0,072
ζ_e^2	0,277	0,147	0,437	0,280	0,173	0,380
$\mu(*)$	0,015	-0,005	0,035	0,038	0,008	0,064
Ω_D	0,098	0,000	0,201	0,062	0,000	0,130
θ_D	0,885	0,771	0,983	0,679	0,588	0,771
δ_D	0,597	0,409	0,793	0,556	0,442	0,686
θ_W	0,834	0,670	0,978	0,914	0,880	0,952
θ_W	0,296	0,201	0,401	0,275	0,160	0,391
ρ_Y foreign output	0,953	0,918	0,986	0,950	0,914	0,991
ρ_P foreign inflation	0,890	0,826	0,948	0,897	0,840	0,962
ρ_R foreign interest rate	0,902	0,860	0,945	0,914	0,876	0,951
ρ_A productivity	0,962	0,934	0,989	0,792	0,645	0,943
ρ_{PC} price commodity	0,872	0,804	0,946	0,867	0,801	0,930
ρ_{Z2} preference	0,586	0,446	0,731	0,586	0,485	0,687
ρ_{Z3} mark-up prices	0,722	0,468	0,963	0,910	0,866	0,955
ρ_{Z4} risk premium	0,830	0,766	0,891	0,911	0,849	0,983
ρ_K invesment	0,921	0,869	0,979	0,950	0,930	0,969
TREND_M	2,021	1,804	2,190	2,124	1,911	2,324
CONST_I	1,443	1,220	1,686	1,178	1,040	1,293
CONST_R	2,135	1,985	2,290	1,959	1,830	2,072
CTREND	0,492	0,394	0,577	0,484	0,408	0,557
CONSTEPINF	0,173	0,105	0,239	0,196	0,122	0,271
CONSTER	0,490	0,411	0,571	0,487	0,410	0,561
σ_M interest rate	0,378	0,294	0,450	0,405	0,322	0,487
σ_Y foreing output	0,329	0,274	0,381	0,329	0,278	0,381
σ_P foreing inflation	0,698	0,574	0,807	0,703	0,587	0,812
σ_R foreing interest rate	0,547	0,459	0,625	0,545	0,458	0,633
σ_A productivity	3,565	2,531	4,378	2,773	2,340	3,170
σ_{PC} price commodity	10,661	8,840	12,380	10,000	8,888	11,124
σ_{Z2} preference	0,455	0,329	0,592	0,430	0,332	0,527
σ_{Z3} mark-up prices	0,397	0,308	0,481	0,370	0,285	0,462
σ_{Z4} risk premium	2,148	1,631	2,631	1,555	1,240	1,884
σ_K investment	0,834	0,446	1,196	0,508	0,393	0,616

Table 3: Bayes Factors

	Australia	Chile	Colombia	New Zealand	South Africa
Base (BM)	-905,6	-996,4	-993,0	-912,2	-1104,1
Modified (MM)	-832,8	-975,6	-951,7	-894,2	-1092,4
2*(Bayes factor MM-BM)	146	42	83	36	23

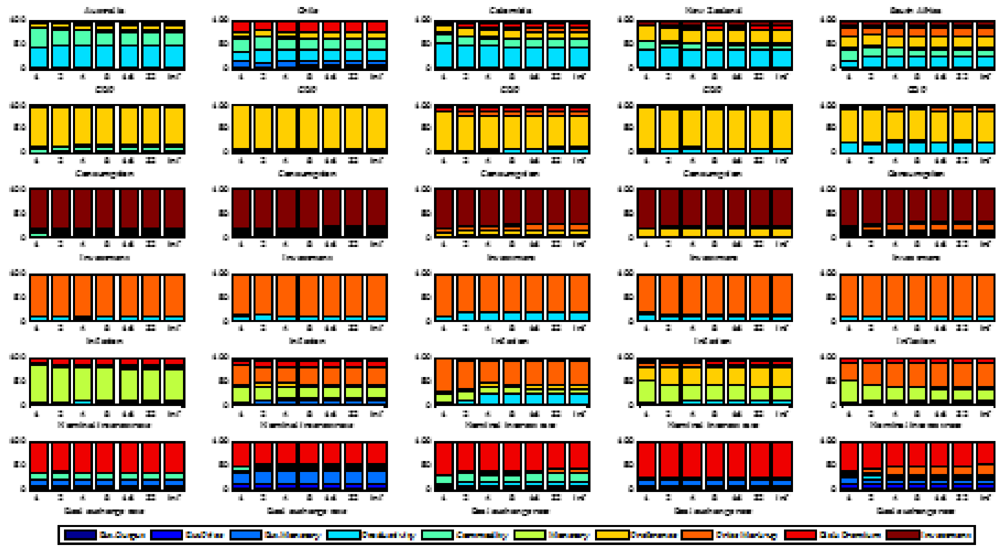

Figure 1: Variance Decomposition

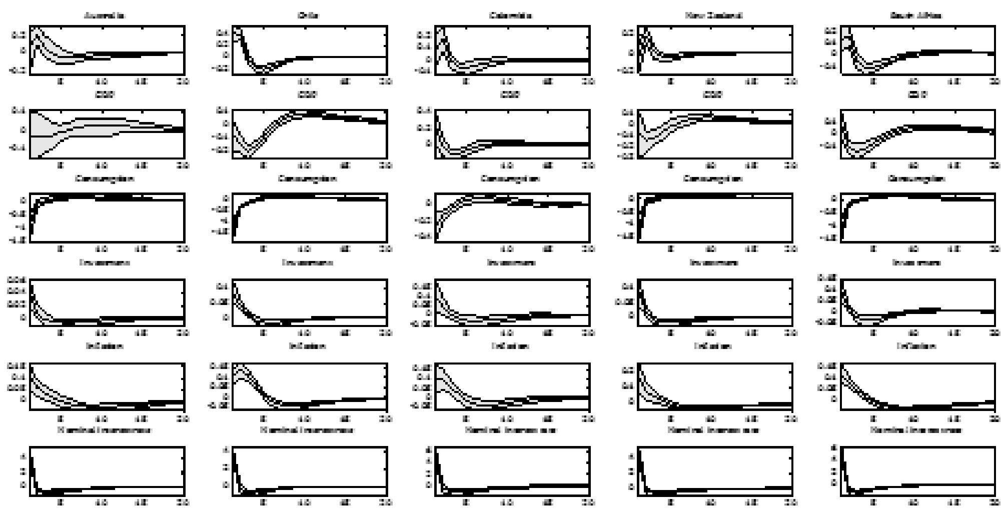

Figure 2: Impulse Response to a Risk Premium Shock

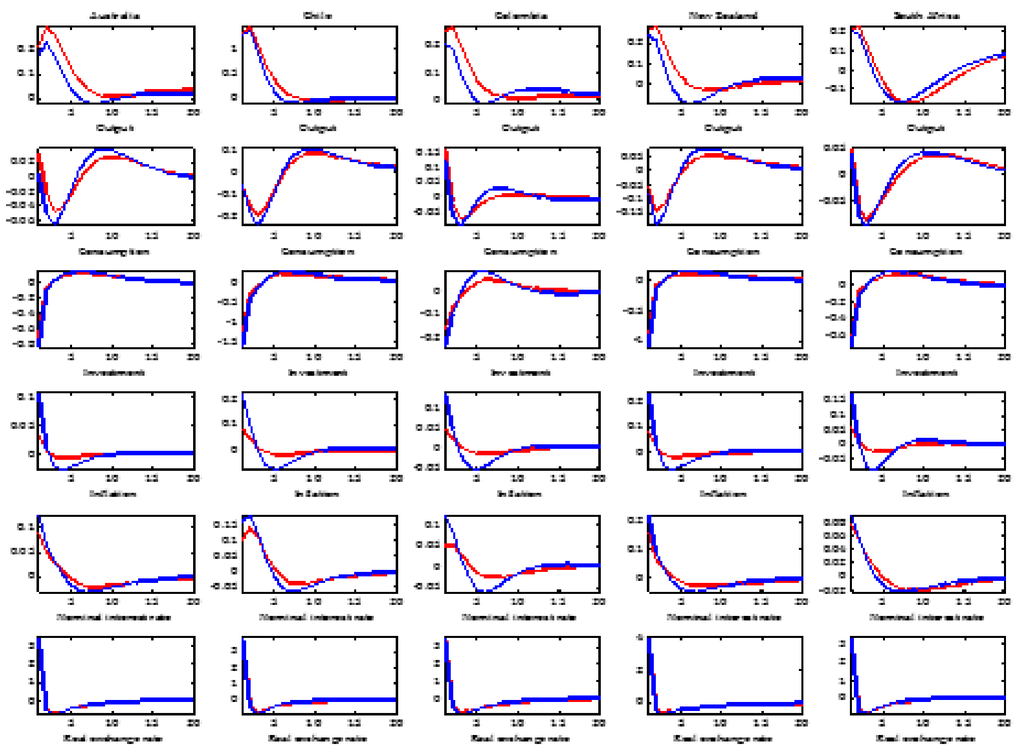

Figure 3: Risk Premium Shock with Different Phillips Curves[a]

Notes:

a. Blue lines represent the modified model with the Phillips curve with constant returns to scale. Red lines represent the modified model with the Phillips curve with decreasing returns to scale. .

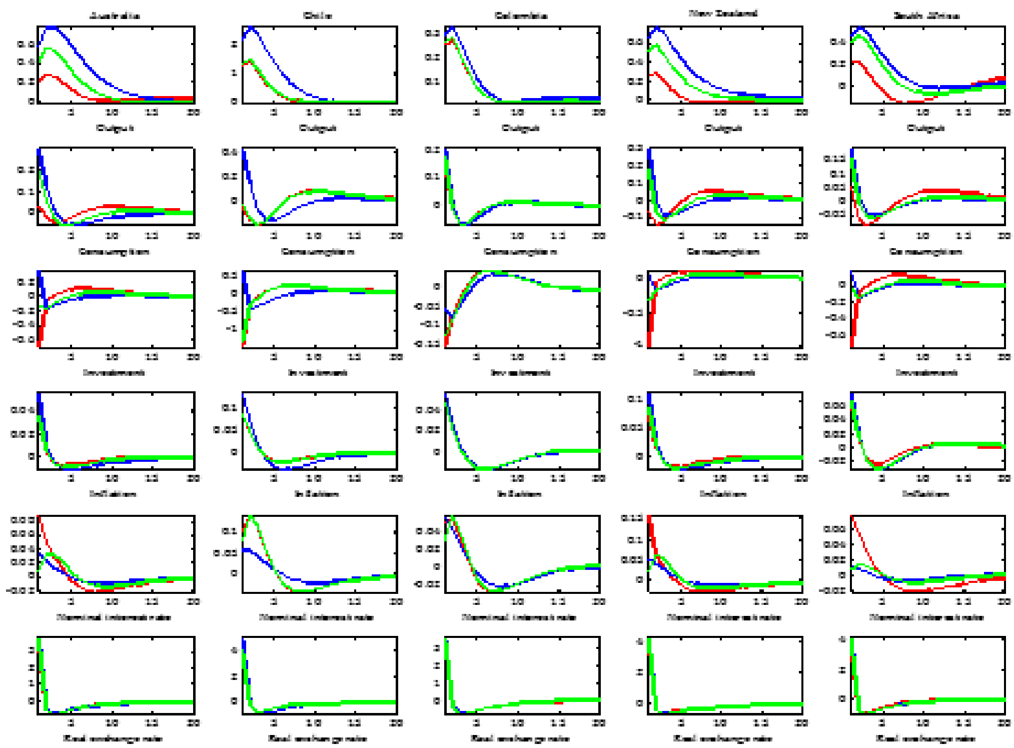

Figure 4: Risk Premium Shock with different Taylor Rules[a]

a. The Taylor rule is $IR_t = \overline{R}\left[\left(\Pi_t/\bar{\Pi}\right)^{\phi_\pi}\left(YR_t/\bar{Y}\bar{R}\right)^{\phi_y}\left(Q_t/\bar{Q}\right)^{\zeta_e^1}\left(Q_t/Q_{t-1}\right)^{\zeta_e^2}\right]$ (see equation 59). All lines represent the modified model with a Phillips curve with decreasing returns to scale.

—Blue lines: $\phi_y = \zeta_e^1 = \zeta_e^2 = 0$;

—Red lines: $\phi_\pi > 0$, $\phi_y > 0$, $\zeta_e^1 > 0$, $\zeta_e^2 > 0$;

—Green lines: $\zeta_e^1 = \zeta_e^2 = 0$.