

Accounting for Business Cycles in Emerging Market Economies

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Abstract

This paper develops a small open economy model augmented to include temporary and permanent productivity shocks, shocks to the terms of trade, to the world real interest rate and to the country risk premium. The main goal is to assess the role played by these shocks in driving the business cycles fluctuations in emerging market economies. We depart from the standard small open economy formulation by assuming that domestic firms are subject to a working capital constraint. We implement a Bayesian likelihood estimation of the structural parameters of the model using Brazilian data over the period from the third quarter of 1994 to the last quarter of 2007. The main findings are: (1) output is mostly driven by temporary productivity shocks (77%), while shocks to the growth rate of trend productivity (growth shocks), explain about 14% of the fluctuations. (2) Terms of trade shocks and world interest rate shocks appear to be unimportant in driving the business cycles. (3) the country risk premium is driven by the domestic macroeconomic fundamentals.

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1 Introduction

This paper develops a small open economy model based on Mendoza (1991), augmented to include temporary and permanent productivity shocks, as in Aguiar and Gopinath (2007a), as well as shocks to the terms of trade, to the world interest rates and to the country risk premium. We pick these shocks because they have been identified in the recent literature as natural candidates to explain output fluctuations in emerging market economies.

The introduction of permanent and temporary productivity shocks allow us to assess the main argument of Aguiar and Gopinath (2007a; 2007b) analysis according to which business cycles in emerging market economies are mainly characterized by permanent shocks to productivity. They argue that frequent and drastic changes in economic policies and institutions in these economies explain why shocks to the trend productivity are the main source of fluctuations. On the other hand, given the more stable environment, business cycles in developed economies are driven fundamentally by temporary productivity shocks.

World price shocks (the terms of trade shocks and the world interest rate shocks) are natural candidates, because most of those economies relates with the rest of the world through the international trade and the international financial markets. Hence changes in the world prices are expected to affect the domestic business cycles at some extent. Obviously, the degree of importance depends on how integrated these economies are with the rest of the world. The higher the integration, higher will be the role played by world price shocks in driving domestic fluctuations. Likewise a number of authors has suggested that country risk premium shocks are important driving forces in the domestic business cycles (Neumeyer and Perri, 2005; Uribe and Yue, 2006). The introduction of risk premium also offers an additional explanation for the higher volatility of the interest rates faced by residents in emerging economies vis-à-vis residents in the developed world.

We argue that the results in the literature are mixed and inconclusive, at least from the perspective of the individual shocks. Shocks that do matter in some frameworks, do not matter in others. In part they do not matter, because they are not taken into account. But even when some of these shocks are incorporated into the same framework, they appear to be unimportant in driving the business cycles. Therefore, in our perspective, a natural step to further understand the main sources of business cycles in emerging economies consists in implementing an integrated

analysis incorporating all the relevant shocks into the same theoretical framework. This paper is a step in that direction.

We depart from the standard small open economy model formulation by assuming that domestic firms are subject to a working capital constraint. This feature introduces a direct channel through which financial shocks affect the supply side of the economy, allowing the model to produce more realistic behavior of domestic output in response to real interest rates shocks. Particularly, the decline of output following an increase in the interest rates. Real interest rates in emerging market economies are known to be countercyclical and to lead the business cycles, and consequently, increases in the real interest rates are expected to be followed by declines in the real GDP (Agénor et al., 2000; Neumeyer and Perri, 2005).¹ A standard RBC model without working capital constraint fails to replicate this important feature of the data.

We implement a Bayesian likelihood estimation of the structural parameters of the model using Brazilian data over the period from the third quarter of 1994 to the last quarter of 2007. Particularly, we use quarterly data on real output per capita, real consumption per capita, the terms of trade, real interest rates, and world real interest rates. We then use the estimated model to implement a forecast error variance decomposition to assess the role played by each structural shock in driving the business cycles. We also implement a formal test of the "endogeneity" hypothesis of the country risk premium.

The main results of this paper are: (1) output is mostly driven by temporary productivity shocks (77%), while shocks to the growth rate of trend productivity (growth shocks), explain about 14% of the fluctuations. (2) Terms of trade shocks and world interest rate shocks appear to be unimportant in driving the business cycles. (3) the country risk premium is driven by the domestic macroeconomic fundamentals.

Our paper is mainly related to Mendoza (1995), Kose (2002), Neumeyer and Perri (2005), Lubik and Teo (2005), Uribe and Yue (2006), and Aguiar and Gopinath (2007a; 2007b) in the effort of identifying the sources of fluctuations in emerging economies. This paper is also related to a branch of the literature that uses Bayesian techniques to estimate and evaluate DSGE models. For example, Smets and Wouters (2003), Lubik and Schorfheide (2005), Lubik and Teo (2005), An

¹The raw correlation between domestic GDP per capita and domestic real interest rates is -0.69 in the Brazilian data.

and Schorfheide (2007), Smets and Wouters (2007) among others.

The paper is organized as follows. The next section describes the theoretical model, section 3 outlines the estimation strategy pursued in this paper, while section 4 presents the main results. The last section summarizes the main conclusions.

2 Model

The theoretical framework is a two-good, single asset small open economy based on Mendoza (1991) and augmented to include a permanent and transitory productivity shock, as in Aguiar and Gopinath (2007a), as well as shocks to the terms of trade, to the world interest rate, and to the country risk premium. We depart from the standard small open economy framework by assuming that firms are subject to working capital constraint.

2.1 Firms

2.1.1 Technology

The economy is constituted by a large number of identical firms that hire labor, l_t , and capital, K_t , to produce a final good according to a constant returns to scale technology:

$$Y_t = z_t K_t^{1-\alpha} (\Gamma_t l_t)^\alpha \quad (1)$$

where Y_t , K_t and l_t represent output, capital and hours worked in period t , respectively. The level of output is affected by a temporary productivity disturbance z_t and by the level of the labor augmented technical progress Γ_t . The productivity shock z_t evolves according to:

$$\ln z_t = (1 - \rho_z) \ln z_{ss} + \rho_z \ln z_{t-1} + \epsilon_t^z \quad (2)$$

where $\rho_z \in [0, 1)$ and $\epsilon_t^z \sim NIID(0, \sigma_z)$. Γ_t is defined as:

$$\Gamma_t = g_t \Gamma_{t-1} = \prod_{j=0}^t g_j \quad (3)$$

where g_t is the gross growth rate of Γ_t .² This rate evolves according to:

$$\ln g_t = (1 - \rho_g) \ln g_{ss} + \rho_g \ln g_{t-1} + \epsilon_t^g \quad (4)$$

where $\rho_g \in [0, 1)$ and $\epsilon_t^g \sim NIID(0, \sigma_g)$. The term g_{ss} measures the non-stochastic growth rate of Γ_t , which in steady-state governs the growth rates of output, capital, consumption and investment. Shocks to the growth rate, g_t , shift the level of productivity permanently and thus the long-run growth rate of the economy. We shall refer to shocks to g_t as growth shocks hereafter.

In terms of notation, we use lower case letters to denote variables that do not have a trend in equilibrium and upper case letters to denote variables that contain a trend in equilibrium.

2.1.2 Timing and Optimization Problem

The timing in our model is as follows: at the beginning of the period t firms hire labor and capital, and use them to produce the final good, Y_t , which it will be available only at the end of the period t . Due to a friction in the technology of transferring resources to the working force, firms need to hold a fraction μ of the total labor payments, $W_t l_t$, in each period. Thus at the beginning of the period, firms borrow an amount $\mu W_t l_t$ at the rate r_{t-1} , without the possibility of investing this amount elsewhere (working capital constraint constitutes an extra cost for the firms). At the end of period, when output is available, firms sell the final good and make final of the period payments. An amount $r_{t-1} \mu W_t l_t$ is used to repay the initial loan plus interest, $(1 - \mu) W_t l_t$ to make final of the period labor payments, and finally $u_t K_t$ to pay the capital rental services.

The firm's problem is thus to choose labor and capital to maximize profits:

$$Y_t - (1 - \mu) W_t l_t - u_t K_t - r_{t-1} \mu W_t l_t \quad (5)$$

subject to the technology constraint (1) and given the processes for the real wages, W_t , the gross real interest rates, r_{t-1} , and the capital rental rate, u_t .

²One straightforward interpretation of Γ_t is that it denotes the cumulative product of growth shocks that have happened up to the current period.

The first order conditions for the firm's optimization problem are:

$$(1 - \alpha)z_t K_t^{-\alpha} l_t^\alpha \Gamma_t^\alpha = u_t \tag{6}$$

$$\alpha z_t K_t^{1-\alpha} l_t^{\alpha-1} \Gamma_t^\alpha = [1 + \mu(r_{t-1} - 1)] W_t \tag{7}$$

Notice that in the absence of working capital constraint, i.e., $\mu = 0$, the standard condition between real wages and the marginal productivity of labor is obtained. Therefore the presence of the working capital constraint drives a wedge between the real wages and the marginal productivity of labor. Under working capital constraint, an increase in the real interest rates increases the firm's effective cost of hiring labor.

2.2 Households

2.2.1 Preferences

The economy is populated by identical, infinitely lived households with preferences described by:

$$E_0 \sum_{t=0}^{\infty} \beta^t \frac{[C_t - \tau \Gamma_{t-1} h_t^\omega]^{1-\psi} - 1}{1 - \psi} \tag{8}$$

where C_t denotes consumption in period t , h_t hours supplied by the household in period t , and $\psi > 0$ defines the curvature of the utility function.³

We choose τ such that in steady-state the representative household spent approximately 30% of the total time working, and ω governs the elasticity of the labor supply (Frisch elasticity). The inclusion of Γ_{t-1} into the momentary utility function guarantees that the labor supply remains bounded along the long-run equilibrium, i.e., the disutility of work increases with the level of technical progress.⁴

³This functional form was first introduced by Greenwood, Hercowitz, and Huffman (1988) and has been used in the international macro literature since then (see, for example, Mendoza 1991, Correia et al. 1995, Neumeyer and Perri 2005, Uribe and Yue 2006, Aguiar and Gopinath 2007a, among others).

⁴As argued by Correia et al. (1995), this assumption can be interpreted as representing technology progress associated with home production activities.

2.2.2 Budget Constraint

At the beginning of the period t , households supply labor and rent capital out in competitive markets, which are used by domestic firms to produce the final good. At the end of period, households receive labor payments and capital rental services payments, and make consumption and investment decisions. Domestic residents can buy and sell foreign bonds in the international markets with each bond delivering an unit of foreign consumption good in the next period.

Households spend their labor and capital income, and their bonds returns, on consumption, investment, bond purchases, and the cost of adjusting bonds. Consequently the household's budget constraint is given by:

$$P_{f,t}D_{t+1} + P_t C_t + P_t I_t + \Omega(D_{t+1}) \leq r_t P_{f,t} D_t + P_t W_t h_t + P_t u_t K_t \quad (9)$$

where D_{t+1} denotes bonds that are traded by the household in the international market and are denominated in terms of foreign consumption goods, $P_{f,t}$ is the price of foreign goods, r_t denotes the gross real interest rates, u_t is the capital services rental rate, P_t is a consumption-based price index, C_t is the composite consumption good, I_t is the composite investment good, and $\Omega(D_{t+1})$ is the bond adjustment cost function. $\Omega(D_{t+1})$ is a convex function and has the property that $\Omega(\bar{d}) = \Omega'(\bar{d}) = 0$, for some $\bar{d} > 0$. This device is introduced with the only purpose of inducing stationarity in the euler equation associated with bonds holdings.⁵ The functional form of $\Omega(D_{t+1})$ is given by:

$$\Omega(D_{t+1}) = \frac{\varphi}{2} \left(\frac{P_{f,t} D_{t+1}}{P_t Y_t} - \bar{d} \right)^2 P_t Y_t$$

where $\bar{d} \equiv d_{ss} g_{ss}$ and d_{ss} is the steady-state debt-to-output ratio. To avoid that the representative household engages in a Ponzi game in the international financial markets we assume that the following condition holds at all time:

$$\lim_{j \rightarrow \infty} E_t \frac{D_{t+j}}{r_t^j} \leq 0$$

Aggregate consumption and investment are Cobb-Douglas composites of domestic and foreign

⁵ A typical RBC model exhibits log-linearized equilibrium dynamics that are not stationary, thus we introduce this term to guarantee stationarity. Schimtt-Grohé and Uribe (2003) present similar devices to induce stationary and they show that all of them yield similar dynamics at business cycle frequencies.

goods.

$$C_t = \frac{C_{h,t}^{1-\gamma} C_{f,t}^\gamma}{(1-\gamma)^\gamma \gamma^\gamma}$$

$$I_t = \frac{I_{h,t}^{1-\gamma} I_{f,t}^\gamma}{(1-\gamma)^\gamma \gamma^\gamma}$$

where $C_{h,t}$ is the consumption of domestic produced goods and $C_{f,t}$ is the consumption of foreign produced goods. Similarly $I_{h,t}$ and $I_{f,t}$ denote investment goods produced in the domestic and foreign economy, respectively. γ represents the share of foreign goods in the aggregate consumption and, by simplicity, we assume the same share holds for investment goods. Given these assumptions, the consumption-based price index is defined as:⁶

$$P_t = P_{h,t}^{1-\gamma} P_{f,t}^\gamma$$

The stock of physical capital accumulates according to:

$$K_{t+1} = I_t + (1-\delta)K_t - \Phi(K_{t+1} - K_t) \quad (10)$$

where $\delta \in (0, 1)$ represents the depreciation rate. The last term represents quadratic capital adjustment costs, which is typically introduced in small open economy models to avoid excessive volatility of investment in response to interest rate differentials across countries. This term is assumed to satisfy $\Phi(0) = \Phi'(0) = 0$, which means that in the non-stochastic steady-state adjustment costs are nil and the domestic interest rates are exactly equal to the marginal productivity of capital net of depreciation. The functional form for the capital adjustment cost is given by:

$$\Phi(K_{t+1} - K_t) = \frac{\phi}{2} \left(\frac{K_{t+1}}{K_t} - g_{ss} \right)^2 K_t$$

The terms of trade, tot_t , is defined as the ratio of the price of domestic good over the price of foreign good, i.e., $tot_t \equiv \frac{P_{h,t}}{P_{f,t}}$. Given this definition the household's budget constraint can be rewritten as:

⁶From the expenditure minimization problem, the optimal choice of foreign and domestic goods are given by: $C_{f,t} = \gamma \left(\frac{P_h}{P_f} \right)^{1-\gamma} C_t$ and $C_{h,t} = (1-\gamma) \left(\frac{P_f}{P_h} \right)^\gamma C_t$, respectively. The consumption price index is obtained by plugging these optimal choices into the expenditure function.

$$tot_t^{\gamma-1} D_{t+1} + C_t + I_t + \frac{\varphi}{2} \left(\frac{D_{t+1}}{tot_t^\gamma Y_t} - \bar{d} \right)^2 tot_t^\gamma Y_t = r_t tot_t^{\gamma-1} D_t + W_t h_t + u_t K_t \quad (11)$$

2.2.3 Optimality conditions

Given initial conditions $C_0, h_0, K_0, r_0 D_0$, and a sequence of prices $\{W_t, r_t, u_t\}_{t=0}^\infty$ the representative household chooses processes $\{C_t, h_t, I_t, K_{t+1}, D_{t+1}\}_{t=0}^\infty$ to maximize (8) subject to (10) - (11), the non-Ponzi game constraint, the stochastic processes for productivity, the terms of trade, the world interest rates, and the country risk premium.

Letting $\lambda_t \Gamma_{t-1}^{-\psi}$ denote the lagrange multiplier associated with the budget constraint, the optimality conditions for the representative household's maximization problem are the non-Ponzi game constraint, equations (10) and (11) all holding with equality, and:

$$\left[\frac{C_t}{\Gamma_{t-1}} - \tau h_t^\omega \right]^{-\psi} = \lambda_t \Gamma_{t-1}^{-\psi} \quad (12)$$

$$\left[\frac{C_t}{\Gamma_{t-1}} - \tau h_t^\omega \right]^{-\psi} \tau \omega \Gamma_{t-1} h_t^{\omega-1} = W_t \lambda_t \Gamma_{t-1}^{-\psi} \quad (13)$$

$$\lambda_t \Gamma_{t-1}^{-\psi} tot_t^{\gamma-1} \left[1 + \varphi \left(\frac{D_{t+1}}{tot_t^\gamma Y_t} - \bar{d} \right) \right] = \beta \Gamma_t^{-\psi} E_t \left[r_{t+1} \lambda_{t+1} tot_{t+1}^{\gamma-1} \right] \quad (14)$$

$$\lambda_t \Gamma_{t-1}^{-\psi} \left[1 + \phi \left(\frac{K_{t+1}}{K_t} - g_{ss} \right) \right] = \beta \Gamma_t^{-\psi} E_t \lambda_{t+1} \left[u_{t+1} + 1 - \delta + \phi \left(\frac{K_{t+2}}{K_{t+1}} - g_{ss} \right) \frac{K_{t+2}}{K_{t+1}} - \frac{\phi}{2} \left(\frac{K_{t+2}}{K_{t+1}} - g_{ss} \right)^2 \right] \quad (15)$$

Combining equations (12) and (13) yields:

$$\tau \omega h_t^{\omega-1} = W_t$$

which implies that the labor supply depends only on the current real wages rate. This is a feature of the specific functional form for the momentary utility function.⁷ Equations (14) and (15) are the Euler equations associated with bonds holdings and capital accumulation, respectively.

⁷Under GHH preferences, the labor supply always increases in response to positive technology shocks. In the Cobb-Douglas preferences the labor supply depends on the current level of consumption and hence a higher level of consumption reduces the incentives to work (the substitution effect is mitigated by the income effect).

2.3 Driving Forces

Besides the two aforementioned productivity shocks, our model economy presents three other driving forces: the terms of trade shocks, world interest rate shocks and country risk premium shocks. We now present the assumptions regarding these driving forces.

2.3.1 The Terms of Trade

A typical assumption in small open economies models is that the terms of trade are determined outside the domestic economy. However this assumption may not be suitable for economies that are relatively important players in the world markets. With this in mind, we use Granger causality tests to assess the extent of this possibility here. The results reject the hypothesis of endogeneity of the terms of trade at any usual significance level (the appendix A presents the test results). Therefore the terms of trade are assumed to follow a first-order autoregressive process:

$$\ln tot_t = (1 - \rho_{tot}) \ln tot_{ss} + \rho_{tot} \ln tot_{t-1} + \epsilon_t^{tot} \quad (16)$$

where $\rho_{tot} \in [0, 1)$, $\epsilon_t^{tot} \sim NIID(0, \sigma_{tot})$ and tot_{ss} represent the steady-state value of the terms of trade.⁸

2.3.2 The World Interest Rates and the Country Risk Premium

One well documented fact is that residents in emerging market economies face not just higher, but also more volatile interest rates than residents in the developed world. Neumeyer and Perri (2005), for example, report that for a sample of emerging economies (Argentina, Brazil, Korea, Mexico and Philippines) the volatility of the real interest rates was on average 40% higher than in a sample of developed economies (Australia, Canada, Netherlands, New Zealand, and Sweden).

In order to capture this more volatile behavior we assume the following structure: the international financial market is composed by a large number of international investors willing to lend any amount at a rate r_t to the domestic residents. However, this rate may differ from the gross interna-

⁸Broda (2004) performs a similar analysis for a sample of 75 developing countries and also finds that the terms of trade are exogenous. Lubik and Schorfheide (2007) adopted an exogenous process for the terms of trade even though in their formulation domestic firms have market power and thus the terms of trade should be endogenously determined. However, they report that the bayesian estimation process turned out to be problematic.

tional rate, r_t^* , because the loans to the domestic residents are subject to default risk. Consequently the interest rate faced by domestic residents, r_t , is given by:

$$r_t = r_t^* s_t \tag{17}$$

where s_t is the gross spread over the international rate, r_t^* . According to this formulation the domestic interest rate, r_t , has two sources of volatility. The first one is the international rate, which reflects the preferences of the international lenders for risky assets and it is not related to any specific country in particular. The second is the country risk premium, s_t , which reflects the probability of default.

Default decisions are not made by the domestic household, which are assumed to pay in full their financial obligations, instead, as Neumeyer and Perri (2005), we assume that in each period there is a exogenous probability that all the payments from local borrowers to international lenders be confiscated by the local government. Fluctuations in the probability of confiscation govern the evolution of s_t over time. This simplification makes our task easier, without the need of designing a complete theory of default decisions (see Arellano, 2007, for a much more elaborate model of default decisions).

The international interest rate is determined outside the domestic economy, which again it is in line with the premise of small open economy model. This rate follows a first-order autoregressive process:

$$\ln r_t^* = (1 - \rho_{r^*}) \ln r^* + \rho_{r^*} \ln r_{t-1}^* + \epsilon_t^* \tag{18}$$

where $\rho_{r^*} \in [0, 1)$ governs the autoregressive component, $\epsilon_{r,t} \sim NIID(0, \sigma_{r^*})$ and r^* is the constant long-run world interest rate.

The literature has treated the country risk premium either as a complete exogenous process or as a process determined by elements within the domestic economy, the so called "macroeconomic fundamentals". We shall refer to the later as the "endogenous" case, even though the term "endogenous" can be misleading. In the exogenous case, the country premium is determined by elements that are outside the domestic economy, such as foreign events, contagion, or political factors that are independent of domestic shocks, while in the "endogenous" case, the country premium is determined by the macroeconomic fundamentals (see Neumeyer and Perri 2005, Aguiar

and Gopinath 2007b and Uribe and Yue 2006). We follow the latter approach, even though our formulation nests the exogenous case as a special case. Therefore we define the risk premium as:

$$\ln s_t = (1 - \rho_s) \ln s_{ss} + \rho_s \ln s_{t-1} + \alpha_z E_t \ln \left(\frac{z_{t+1}}{z_{ss}} \right) + \alpha_{tot} E_t \ln \left(\frac{tot_{t+1}}{tot_{ss}} \right) + e_t^s \quad (19)$$

where $\rho_s \in [0, 1)$ governs the autoregressive component, s_{ss} is the level of country-spread in steady-state, and $e_t^s \sim NIID(0, \sigma_s)$. The parameter α_z governs the response of the risk premium to (temporary) productivity shocks, while α_{tot} governs the response to the terms of trade shocks. Notice that the independent case is obtained when $\alpha_z = \alpha_{tot} = 0$. We formally test this hypothesis in the estimation procedure.⁹

The intuition behind equation (19) is straightforward, an economy facing positive productivity shocks and/or positive shocks to its terms of trade (which in the model translates into a positive wealth effect) would face lower spreads and, consequently, lower interest rates (if the world interest rate stays unchanged, of course).

In short, the underlying assumption is that countries are more likely to default in bad times rather than in good ones. Arellano (2007), for example, reports that in recent default episodes output was 14% below the trend in Argentina (2001), 6% in Ecuador (1999) and 12% in Russia (1999) at the time of the default. Similarly, Tomz and Wright (2007) using a data set covering the period from 1820 to 2004 for both developed and developing countries report that the frequency of default episodes was higher during bad times (about 62% of 162 default episodes had began when the output was below the trend).¹⁰ Likewise the empirical literature has pointed out the close link between the terms of trade and risk premia, particularly, the negative association between terms of trade shocks and yield spreads (Min et al 2003). Calvo et al. (2004) also has shown that a negative terms of trade shock increase the likelihood of a sudden stop in capital inflows and drastic changes in the interest rates. Under the "endogenous" formulation, the country risk premium works as an amplification mechanism for the terms of trade and productivity shocks.

⁹We also tested an alternative formulation for the country risk premium, which included growth shocks. However, the model performs badly vis-à-vis the formulation with only temporary productivity shocks and terms of trade shocks.

¹⁰However, as they point out, bad times were neither sufficient nor necessary for default episodes. In several occasions countries avoided defaulting during bad times, while in other occasions they had defaulted even when the economy was doing well. For example, the Chilean defaults of 1826 and 1880 occurred in good times.

2.4 Competitive Equilibrium

Given initial conditions K_0, h_0, C_0 and D_0 , and given the stochastic processes for the terms of trade, tot_t , world real interest rates, r_t^* , country risk premium, s_t , temporary productivity shock, z_t , and growth shocks, g_t , a competitive equilibrium is a set of allocations $\{C_t, h_t, I_t, K_{t+1}, D_{t+1}, l_t, K_t\}_{t=0}^{\infty}$ and prices $\{u_t, r_t, W_t\}_{t=0}^{\infty}$ such that (i) the allocations solve the firm's and household's optimization problems at the equilibrium prices and (ii) the labor market clears.

The equilibrium conditions are not stationary because some variables exhibit a trend in equilibrium, hence for any non-stationary variable X_t , we define the correspondent normalized variable as $x_t \equiv \frac{X_t}{\Gamma_{t-1}}$. Thus a stationary competitive equilibrium is given by the following set of equations:

$$[c_t - \tau h_t^\omega]^{-\psi} = \lambda_t \quad (20)$$

$$[c_t - \tau h_t^\omega]^{-\psi} \tau \omega h_t^{\omega-1} = w_t \lambda_t \quad (21)$$

$$\lambda_t g_t^\psi tot_t^{\gamma-1} \left[1 + \varphi \left(\frac{d_{t+1} g_t}{tot_t^\gamma y_t} - \bar{d} \right) \right] = \beta E_t \left[r_{t+1} \lambda_{t+1} tot_{t+1}^{\gamma-1} \right] \quad (22)$$

$$\lambda_t g_t^\psi \left[1 + \phi \left(\frac{k_{t+1}}{k_t} g_t - g_{ss} \right) \right] = \beta E_t \lambda_{t+1} \left[u_{t+1} + 1 - \delta + \phi \left(\frac{k_{t+2}}{k_{t+1}} g_{t+1} - g_{ss} \right) \frac{k_{t+2}}{k_{t+1}} g_{t+1} - \frac{\phi}{2} \left(\frac{k_{t+2}}{k_{t+1}} g_{t+1} - g_{ss} \right)^2 \right] \quad (23)$$

$$tot_t^{\gamma-1} d_{t+1} g_t + c_t + i_t + \frac{\varphi}{2} \left(\frac{d_{t+1} g_t}{tot_t^\gamma y_t} - \bar{d} \right)^2 tot_t^\gamma y_t = r_{t-1} tot_t^{\gamma-1} d_t + w_t h_t + u_t k_t \quad (24)$$

$$k_{t+1} g_t = i_t + (1 - \delta) k_t - \frac{\phi}{2} \left(\frac{k_{t+1}}{k_t} g_t - g_{ss} \right)^2 k_t \quad (25)$$

$$Y_t = z_t k_t^{1-\alpha} (g_t l_t)^\alpha \quad (26)$$

$$(1 - \alpha) z_t k_t^{-\alpha} l_t^\alpha g_t^\alpha = u_t \quad (27)$$

$$\alpha z_t k_t^{1-\alpha} l_t^{\alpha-1} g_t^\alpha = [1 + \mu(r_{t-1} - 1)] w_t \quad (28)$$

$$l_t = h_t \tag{29}$$

We compute the model solution by performing a first order Taylor approximation of the log-linear equilibrium conditions around the non-stochastic steady state. The appendix B presents the log-linearized equilibrium conditions.

3 Econometric Methodology

3.1 Preliminaries

The solution of the log-linearized DSGE model can be written in a state space form as following:

$$X_{t+1} = A(\theta)X_t + B(\theta)\omega_{t+1} \tag{30}$$

where ω_{t+1} denotes the innovations of the exogenous process and $\omega_{t+1} \sim \mathcal{N}(0, Q)$, and X_t denotes the vector of model variables. The matrices $A(\theta)$ and $B(\theta)$ collect the structural parameters, $\theta = (\theta_C, \theta_E) \in \Theta$. The subset $\theta_C = \{\delta, \omega, \tau, \psi, \alpha, \beta, \gamma, \varphi, g_{ss}, d_{ss}\}$ denotes the parameters that are calibrated and $\theta_E = \{\phi, \mu, \rho_{r^*}, \rho_{tot}, \rho_s, \rho_g, \rho_z, \sigma_{r^*}, \sigma_{tot}, \sigma_s, \sigma_g, \sigma_z, \alpha_{tot}, \alpha_g, \alpha_z\}$ denotes the free parameters to be estimated. A measurement equation links a vector of observable variables Ψ_t to the model variables X_t .

$$\Psi_t = C(\theta)X_t + v_t \tag{31}$$

Measurement errors $v_t \sim \mathcal{N}(0, R)$ can be added to the measurement equation to incorporate the idea that some or all variables are not measured correctly. Measurement errors are also introduced to avoid stochastic singularity.

Our vector of observable variables is composed by quarterly (gross) growth rates of real GDP per capita, real consumption per capita, gross domestic and world real interest rates, and the terms of trade, i.e., $\Psi_t = \{\Delta gdp_t, \Delta c_t, r_t, r_t^*, tot_t\}_{t=1}^T$. Recall that due to the non-stationarity of some of the model variables, we normalize those variables by the level of the labor augmented technology progress, Γ_{t-1} . In the appendix C we show how we link the observable variables to the respective (normalized) model correspondent.

Given the model solution in state space form and a vector of observable, we can build the likelihood function $\mathcal{L}(\Psi_t | \theta)$ with the help of the Kalman Filter (see Hamilton, 1994, chapter 13 for details). Priors distributions $p(\theta)$ are then set for the structural parameters, where these priors represent beliefs that the researcher might have about the distribution of the parameters.¹¹ Given these beliefs and the likelihood function, the Bayes Theorem provides the way to derive the posterior distribution as follows:

$$P(\theta | \Psi_t) = \frac{\mathcal{L}(\Psi_t | \theta)p(\theta)}{\int_{\theta} \mathcal{L}(\Psi_t | \theta)p(\theta)d(\theta)} \quad (32)$$

where $\int_{\theta} \mathcal{L}(\Psi_t | \theta)p(\theta)d(\theta)$ denotes the marginal data density. Given the model and the vector of observable, this term is obtained by integrating out the posterior distribution over the set of parameters.

3.2 Estimation Strategy

The estimation task is to derive the joint posterior distribution of the deep parameters. This is accomplished using a Metropolis-Hastings algorithm, which is a Markov Chain Monte Carlo (MCMC) method that allow us to draw sequences of any distribution and, in particular, of non-standard ones (see Chibb and Greenberg, 1995 for a nice introduction to Metropolis-Hastings algorithm).

The idea behind MCMC is to find a posterior kernel that has the posterior distribution as its invariant distribution. First note that the marginal data density integrates to a constant and hence all the information about θ from the data can be obtained through the posterior kernel:

$$P(\theta | \Psi_t) \propto \mathcal{L}(\Psi_t | \theta)p(\theta) \quad (33)$$

The Metropolis-Hastings algorithm generates draws from the posterior kernel $\log \mathcal{L}(\Psi_t | \theta) + \log p(\theta)$ to derive an Gaussian approximation of the joint posterior distribution around the posterior mode. (Walker, 1969 shows that under certain regularity conditions the posterior distribution of the deep

¹¹These beliefs can either come from related work, micro-evidence or still from the economic theory. Priors also reflect the degree of uncertainty of the researcher's beliefs. The use of informative priors can avoid the posterior distribution peaking in subspaces where there is no economic meaning, and they also help the identification task (See Del Negro and Schoferheide, 2008).

parameters are asymptotically normal).¹² In the appendix D we present the Metropolis-Hastings algorithm in more details.

We generate 4 independent sequences each one composed by 400,000 draws with a stepsize of 0.35 using the Metropolis-Hastings algorithm. The average acceptance ratio along the chains was 32%, and we assess convergence using the methods proposed by Brooks and Gelman (1998). We then compute statistics of interest from the ergodic joint posterior distributions of the deep parameters. In the next section we present the results from the Bayesian estimation.¹³

3.3 Model Comparison

We perform model comparison using a posterior odds ratio. This ratio assess which model, among multiple alternatives, delivers the highest probability given the data. In the context of this paper, we are interested in assessing if the risk premium is endogenously determined. This translates in testing the hypothesis $H_0 : \alpha_z \neq 0, \alpha_{tot} \neq 0$ against the alternative $H_a : \alpha_z = \alpha_{tot} = 0$.

Denoting by \mathcal{M}_0 the model under H_0 and \mathcal{M}_a the model under the alternative, the posterior odds ratio is defined as:

$$\frac{P(\mathcal{M}_0 | \Psi_t)}{P(\mathcal{M}_a | \Psi_t)} = \frac{p(\mathcal{M}_0) p(\Psi_t | \mathcal{M}_0)}{p(\mathcal{M}_a) p(\Psi_t | \mathcal{M}_a)} \quad (34)$$

where $p(\mathcal{M}_0)$ is the prior probability that the full model is the "true" model and $p(\mathcal{M}_a)$ the prior probability that the "true" model is the restricted one instead. The first term in equation (34) is the prior odds ratio in favor of \mathcal{M}_0 . The second term is called the *Bayes Factor*, which is the ratio of the marginal data densities associated with both models. $p(\Psi_t | \mathcal{M}_i)$ is obtained by integrating out the structural parameters θ_i from the posterior kernel:

$$P(\Psi_t | \mathcal{M}_i) = \int \mathcal{L}(\Psi_t | \theta_i, \mathcal{M}_i) p(\theta_i | \mathcal{M}_i) d(\theta_i) \quad \text{where } i = 0, a. \quad (35)$$

We use the modified harmonic mean estimator, which uses the information contained in the

¹² In the words of An and Schorfheide (2007) "the algorithm constructs a Gaussian approximation around the posterior mode and uses a scaled version of the asymptotic covariance matrix as the covariance matrix for the proposal distribution ". Recall that in the maximum likelihood estimation, the asymptotic covariance matrix is approximated by the negative inverse Hessian.

¹³ Besides the standard statistics, e.g., means, modes, standard deviations, etc., we compute posterior distributions of parameters transformations such as Impulse Response Functions, variance decompositions, etc. This is accomplished by using the moving average representation of the state space model (30)-(31). These steps are implemented using Matlab-Dynare.

Metropolis-Hastings draws, to estimate the marginal data density of the two competing models (the appendix E presents more details on the estimator).¹⁴

3.4 Data Description

Our data set consist of quarterly data on real GDP per capita, real consumption per capita, the terms of trade, world real interest rates and domestic real interest rates. The data covers the period from the third quarter of 1994 to the third quarter of 2007. For real GDP per capita and real consumption per capita we use gross growth rates. Following the literature, we identify the world interest rates as the 90-day U.S. T-bill rate.

The national account real variables are obtained by dividing the corresponding nominal value by the GDP deflator. GDP and consumption per capita are obtained by dividing the real GDP and real consumption by occupied population in Metropolitan areas from Instituto Brasileiro de Geografia e Estatística (IBGE). As in Neumeyer and Perri (2005) and Uribe and Yue (2006), we compute the domestic nominal interest rate in dollars as the 90-day U.S. T-bill rate plus the J.P. Morgan EMBI + Spread. The real rate is constructed by subtracting the expected U.S. GDP deflator inflation from the nominal rate. Expected inflation is constructed as the average of inflation in the current quarter and in the three preceding quarters.¹⁵

The nominal national account variables, the terms of trade and nominal interest rates are from the International Financial Statistics - IFS/IMF. The J.P. Morgan EMBI Spread is from Global Financial Data. The growth rates of output and consumption are computed as log differences. These rates are demeaned prior to estimation. The terms of trade are seasonally adjusted, logged, HP-filtered ($\lambda = 1600$), and demeaned prior to the estimation procedure. The real interest rates are HP-filtered and demeaned prior to estimation.

¹⁴There are different methods to compute the marginal data density. One easily implementable method is the Laplace transformation, which assumes an integrable form for the posterior kernel. Other options use the information contained in the draws. Our results are inaltered either by using the Laplace transformation or the modified harmonic mean estimator. See Geweke (2005) chapter 8 to more details on alternative methods.

¹⁵ Using current inflation as a proxy for expected inflation does not alter the results.

3.5 Calibrated parameters

The choice of priors for the parameters that are kept fixed along the estimation procedure, θ_C , was straightforward given that all of them are widely used in the literature.¹⁶

Time preference parameter $[\beta]$: we set to 0.983 to match an average real interest rate of 9% per year, which matches the average real interest rate in the Brazilian data. This is close to the 0.98 used by Aguiar and Gopinath (2007a) (although in their model this value for the time preference parameter implies a real interest rate of 14% per year) and the 0.973 used by Uribe and Yue (2006), which matches a real interest rate of 11% per year.

Labor coefficient $[\tau]$: we set to 5.7. We choose this number such that the representative household allocates approximately 30% of the total time to work in steady-state.

Coefficient of risk aversion $[\psi]$: we set to 2.0 which is the same number used by Mendoza (1991), Uribe and Yue (2006) and Aguiar and Gopinath (2007a).

Labor exponent coefficient $[\omega]$: we set this parameter to 1.6, which is the same used by Neumeyer and Perri (2005) and Aguiar and Gopinath (2007a). This value is between the 1.455 used by Mendoza (1991) and Uribe and Yue (2006) and the 1.7 used by Correia et al (1995). This term governs the labor supply elasticity (Frisch Elasticity), which is given by $\left(\frac{1}{\omega-1}\right)$.

Labor share in the production function $[\alpha]$: we set at 0.68, which is a standard value in the literature (see, for example, Mendoza 1991, Uribe and Yue 2006, and Aguiar and Gopinath 2007a).

Import share $[\gamma]$: this number is set at 0.20, which is the same number used by Lubik and Teo (2005).

Depreciation rate $[\delta]$: we follow Uribe and Yue (2006) in setting this parameter at 0.024, which corresponds to a 10% depreciation rate per year. This is smaller than the 0.044 used by Neumeyer and Perri (2005) and the 0.03 used by Aguiar and Gopinath (2007a).

Steady-state debt to GDP ratio $[d_{ss}]$: we set this parameter at 0.10, which is the number used by Aguiar and Gopinath (2007a).

Coefficient on the bonds-adjustment cost function $[\varphi]$: we set at 0.001, which is in line with the

¹⁶ In a Bayesian framework keeping a set of parameters fixed means to set the standard deviation of the distribution to zero. The attempt to estimate some of these parameters turned out to be troublesome. For some parameters the posterior distributions were nearly flat, meaning lack of identification given the vector of observables. We have made the attempt to set priors to add curvature to the posterior distributions, but this attempt worsened the ability of the optimization algorithm to find the maximum for others parameters in the model.

literature.

Long-run productivity growth [g_{ss}] : We set the long-run productivity gross growth rate at 1.002, which corresponds to a growth rate of real GDP per capita of 0.8% per year (the average rate observed in the Brazilian data). Table 1 summarizes the parameter values.

Table 1: Parameter Values

| Symbol | Value | Parameter Description |
|-----------|-------|---|
| β | 0.983 | Subjective discount factor |
| τ | 5.7 | Labor coefficient (utility) |
| ψ | 2 | Risk aversion |
| ω | 1.6 | Labor exponent (utility) |
| α | 0.68 | Labor share (production) |
| γ | 0.2 | Import share |
| δ | 0.024 | Depreciation rate |
| d_{ss} | 0.1 | Steady-state debt to GDP ratio |
| φ | 0.001 | Coefficient on the bonds-adjustment cost |
| g_{ss} | 1.002 | long-run productivity gross growth rate (trend) |

3.6 Prior distributions of the estimated parameters

In defining priors distributions for the estimated parameters, θ_E , we follow the common practice in the Bayesian literature of DSGE models in setting Beta distributions for parameters that are known to lie in the unit interval, Gamma distributions for parameters that lie in \mathbb{R}^+ , Inverse Gamma distributions for standard deviations of the shocks, and Normal distributions for parameters that can take any value in \mathbb{R} . Moreover we use fairly loose and harmonized priors over the set of parameters that belong to same class. We now describe the assumptions regarding the priors distributions of the deep parameters.

Coefficient governing the investment adjustment cost [ϕ] : This coefficient is described by a Gamma distribution with mean 4 and standard deviation 1. The mean is close to the 3.79 estimated for Mexico by Aguiar and Gopinath (2007a).

Parameter of the working capital constraint [μ] : This coefficient is described by a Gamma distribution with mean 1 and standard deviation 0.1. This is the same to say that firms hold all the wages bill in advance. The prior mean is equal to the parameterized value used by Neumeyer and Perri (2005) for Argentina and it is close to 1.2, which it was estimated by GMM by Uribe and Yue (2006) for a sample of emerging economies (Argentina, Brazil, Ecuador, Mexico, Peru, Philippine, and South Africa).

Coefficients of shocks in the country risk premium equation [α] : They are described by a Normal distribution with mean -1 and standard deviation 1. The mean of these coefficients are close to the parameterized number used by Neumeyer and Perri (2005) to describe the impact of productivity shocks on the risk premium -1.04 using Argentine data. Given the wide standard deviation that we use, that number lies within the confidence interval.

Autocorrelation of the shocks [ρ] : We use Beta distribution with mean 0.5 and standard deviation 0.1. These are the same priors used by Smets and Wouters (2007) for the autocorrelation of shocks in their model for the U.S. economy.

Standard deviation of the shocks [σ] : They are represented by Inverted Gamma Distribution with mean 0.015 and standard deviation 1. These are the same priors used by Lubik and Teo (2005) in their analysis. Table 2 summarizes the priors used in this paper.

Table 2: Priors

| Parameter | Name | Domain | Density | Mean | St. Dev. |
|----------------|---|----------------|------------|-------|----------|
| ϕ | Capital adjustment cost parameter | \mathbb{R}^+ | Gamma | 4.0 | 1.0 |
| μ | Fraction of the wages bill held in advance | \mathbb{R}^+ | Gamma | 1.0 | 0.1 |
| α_{tot} | Coeff. of the terms of trade in the risk premium | \mathbb{R} | Normal | -1.0 | 1.0 |
| α_z | Coeff. of the temporary prod. in the risk premium | \mathbb{R} | Normal | -1.0 | 1.0 |
| ρ_z | AR coeff. productivity (temporary) | [0,1) | Beta | 0.50 | 0.1 |
| ρ_g | AR coeff. productivity (trend) | [0,1) | Beta | 0.50 | 0.1 |
| ρ_s | AR coeff. risk premium | [0,1) | Beta | 0.50 | 0.1 |
| ρ_{r^*} | AR coeff. world interest rate | [0,1) | Beta | 0.50 | 0.1 |
| ρ_{tot} | AR coeff. terms of trade | [0,1) | Beta | 0.50 | 0.1 |
| σ_z | Stand. dev. productivity shocks (temp.) | \mathbb{R}^+ | Inv. Gamma | 0.015 | 1.0 |
| σ_g | Stand. dev. productivity shocks (trend) | \mathbb{R}^+ | Inv. Gamma | 0.015 | 1.0 |
| σ_s | Stand. dev. risk premium | \mathbb{R}^+ | Inv. Gamma | 0.015 | 1.0 |
| σ_{r^*} | Stand. dev. world interest rate shocks | \mathbb{R}^+ | Inv. Gamma | 0.015 | 1.0 |
| σ_{tot} | Stand. dev. terms of trade | \mathbb{R}^+ | Inv. Gamma | 0.015 | 1.0 |

4 Results

4.1 Priors and Posteriors

Table 3 gives the prior and posterior means, and the 10th and 90th percentiles of the posterior distributions of the parameters obtained using the Metropolis-Hastings algorithm. Overall the data appears to be informative on the estimated parameters, as the posterior means differ from the priors.

Table 3: Priors and Posteriors

| Parameter | Prior Means | Posterior Means | 90% Interval | |
|----------------|-------------|-----------------|--------------|--------|
| ϕ | 4.0 | 5.32 | 3.49 | 7.77 |
| μ | 1.0 | 0.82 | 0.69 | 0.95 |
| α_{tot} | -1.0 | -0.073 | -0.098 | -0.047 |
| α_z | -1.0 | -0.71 | -1.104 | -0.295 |
| ρ_z | 0.50 | 0.77 | 0.69 | 0.85 |
| ρ_g | 0.50 | 0.43 | 0.30 | 0.56 |
| ρ_s | 0.50 | 0.52 | 0.44 | 0.60 |
| ρ_{r*} | 0.50 | 0.57 | 0.45 | 0.69 |
| ρ_{tot} | 0.50 | 0.84 | 0.80 | 0.89 |
| σ_z | 0.015 | 0.0036 | 0.0028 | 0.0046 |
| σ_g | 0.015 | 0.0039 | 0.0031 | 0.0047 |
| σ_s | 0.015 | 0.0079 | 0.0063 | 0.0095 |
| σ_{r*} | 0.015 | 0.002 | 0.0018 | 0.0023 |
| σ_{tot} | 0.015 | 0.099 | 0.0836 | 0.1145 |

The coefficient governing the investment adjustment cost is estimated to be higher than the prior mean. The parameters in the risk premium equation are estimated to be negative, which reflect one of the assumptions carried out along the paper, i.e., countries are more likely to default in bad times rather than in good ones.

The terms of trade, temporary productivity shocks and world interest rates are estimated to be more persistent, the risk premium shocks are as much as persistent, while growth shocks are less persistent. The estimated means for the standard errors are in general lower than the priors means, except for the terms of trade, which is higher than the respective prior mean. The Appendix E presents the priors and posteriors distributions for the structural parameters.

4.2 Impulse Responses

The analysis of the impulse response functions can help us to further understand the dynamics of the economy. We rapidly describe the dynamic behavior of the artificial economy in response to the structural shocks.

Temporary Productivity Shocks: in response to a positive temporary productivity shock output, consumption, investment and hours increase, while the trade balance declines. This decline reflects mainly the behavior of investment. The response of hours is driven by the procyclicality of the real wages, i.e., after a positive productivity shock, the opportunity cost of leisure increases as the real wages increase, and therefore the representative household substitutes away from leisure (with GHH preferences this effect is amplified given that the labor supply does not depend on the level of consumption). Higher productivity and labor result in higher output, which in turns yield more consumption and investment. Figure 1 depicts the impulse responses functions to a temporary productivity shock.

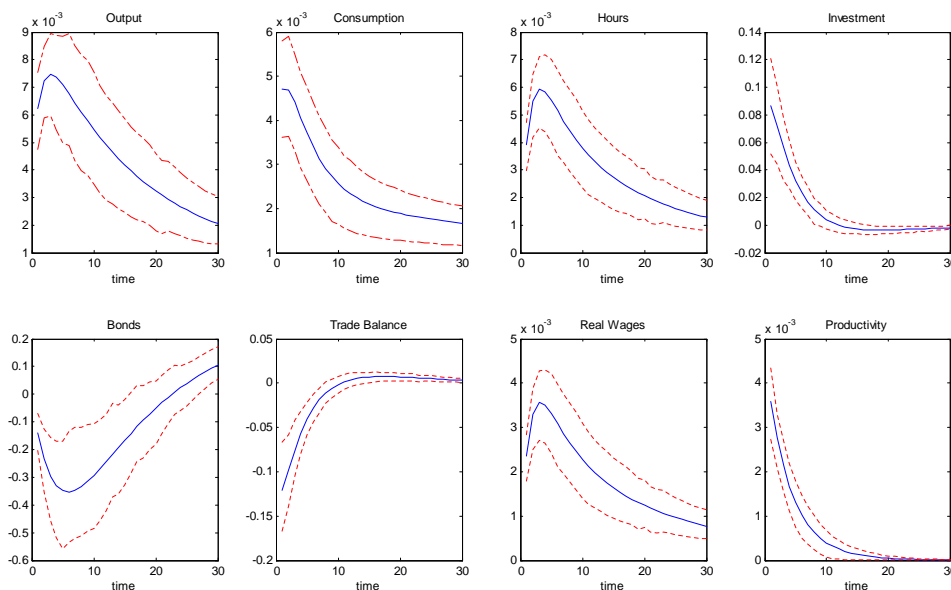


Fig.1: Impulse response to a temporary productivity shock. Notes: (1) Solid lines depict the mean values of impulse response, and broken lines depict the 90% confidence interval. (2) The responses of Output, Hours, Investment and Consumption, and Bonds are in log-deviations from their respective steady-states. The responses of the trade balance-to-output ratio are (linear) deviations from the steady-state. (3) The impulse corresponds to one standard deviation.

Growth Shocks: the initial responses of output, consumption, investment, and hours worked are positive, while the trade balance declines at impact. However in the quarters following the shock, hours worked decline and remain below the steady-state for several quarters after the shock. The response of hours worked is due to the assumption regarding the disutility of labor supply. Recall that in order to labor supply to remain bounded in equilibrium, we assume that the disutility of work increases as the level of technical progress Γ_t increases. Thus, one quarter after a growth shock, the labor supply begins to decline. Output and consumption initially increases and then they decline as the labor supply declines. Both consumption and output stay in a lower steady state level in the subsequent quarters after the shock and eventually they return to their original steady-state, as the labor supply adjusts to the new productivity level. However notice that the unnormalized consumption and output permanently increase after the shock. Figure 2 presents these results.

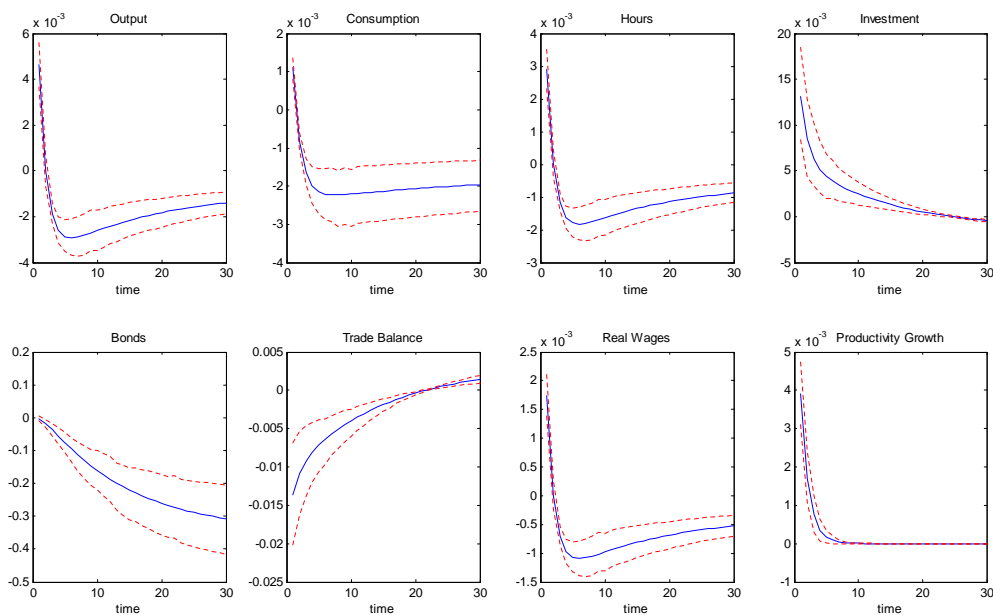


Fig.2: Impulse response to a growth shock. Notes: (1) Solid lines depict the mean values of impulse response, and broken lines depict the 90% confidence interval. (2) The responses of Output, Hours, Investment and Consumption, and Bonds are in log-deviations from their respective steady-states. The responses of the trade balance-to-output ratio are (linear) deviations from the steady-state. (3) The impulse corresponds to one standard deviation.

Terms of Trade Shocks: in response to a positive terms of trade shock output, consumption

and hours increase, while investment declines. The trade balance initially improves and then returns to its steady-state. Once again the behavior of the trade balance reflects the response of investment. The dynamic behavior of the economy after a terms of trade shock is almost identical to the behavior after a temporary productivity shock, the only exception is due to the behavior of investment. Thus in response to a temporary windfall in the economy's wealth, households increase consumption and asset bonds holdings, while reducing investment. The response of hours again reflects the procyclicality of the real wages. Notice that the Harberger-Laursen-Metzler effect applies here, i.e., in response to a positive terms of trade shock the trade balance improves at the time of the shock (Obstfeld, 1982; Svensson and Razin, 1983). Figure 3 presents the impulse responses functions to shocks to the terms of trade.

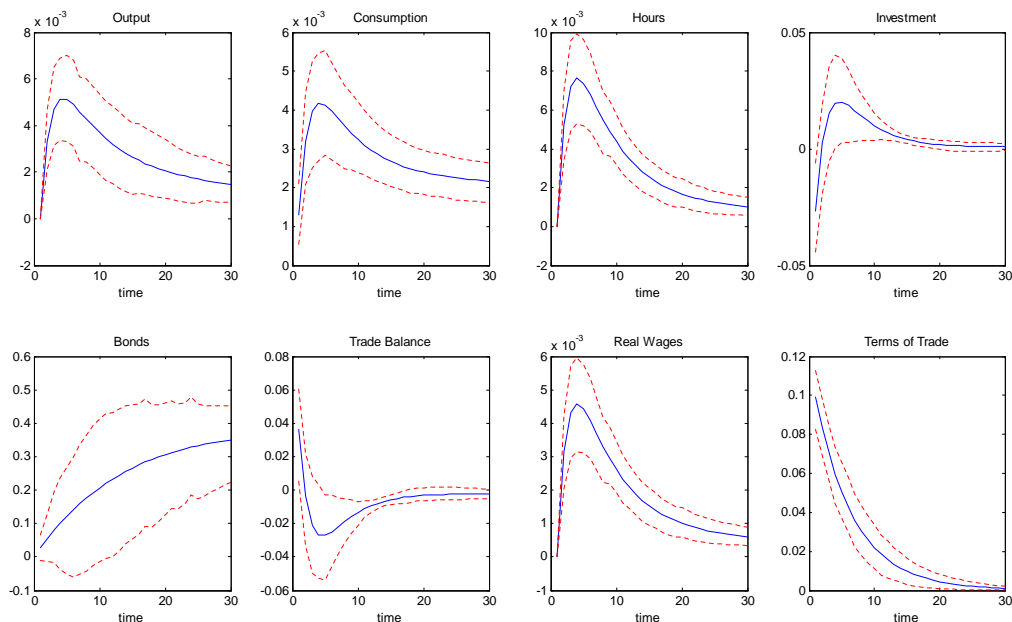


Fig.3: Impulse response to a terms of trade shock. Notes: (1) Solid lines depict the mean values of impulse response, and broken lines depict the 90% confidence interval. (2) The responses of Output, Hours, Investment and Consumption, and Bonds are in log-deviations from their respective steady-states. The responses of the trade balance-to-output ratio are (linear) deviations from the steady-state. (3) The impulse corresponds to one standard deviation.

World Interest Rates and Risk Premium Shocks: in response to an increase in the domestic interest rates (due to a positive shock either to the world interest rates, or to the risk premium, or

both) output, consumption, investment and hours worked all decline and stay in a low steady-state for several quarters after the shock. They eventually return to their initial steady-state as the shock dissipates over time. Given the response of investment, the trade balance improves.

The dynamic response of our artificial economy following an domestic interest rate shock reflect relatively well the fact that real interest rates are countercyclical and they lead the business cycles in emerging economies (Agénor et al., 2000; Neumeyer and Perri, 2005). As we had pointed out a standard RBC model without working capital constraint fails to replicate this dynamic behavior (Uribe and Yue, 2006). Figure 4 depicts the impulse responses functions of selected variables to a world interest rate shocks. (The impulse responses to a country risk premium shock are virtually identical to the impulses responses to a world interest rate shock. Therefore we present only one set of impulse responses).

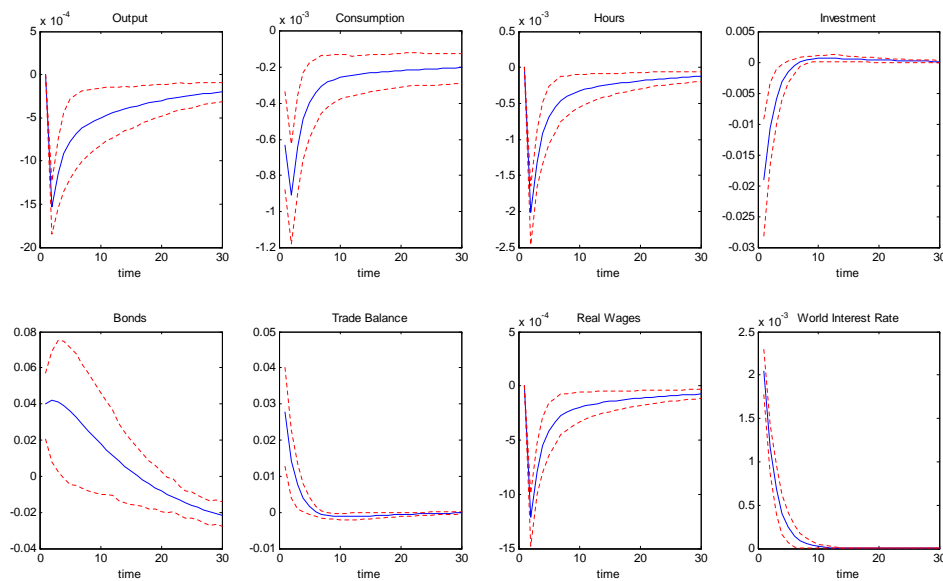


Fig. 4: Impulse response to a world interest rate shock. Notes: (1) Solid lines depict the mean values of impulse response, and broken lines depict the 90% confidence interval. (2) The responses of Output, Hours, Investment and Consumption, and Bonds are in log-deviations from their respective steady-states. The responses of the trade balance-to-output ratio are (linear) deviations from the steady-state. (3) The impulse corresponds to one standard deviation.

4.3 Variance Decomposition

Table 4 presents the forecast error variance decomposition of output for different horizons. At the business cycles frequencies, defined as the period covering from 6 to 32 quarters (Stock and Watson, 1999), output is mostly driven by temporary productivity shocks, followed by growth shocks, and risk premium shocks. World interest rate shocks and the terms of trade shocks appear to be unimportant in explaining output volatility.

Table 4: Variance Decomposition of Output

| Quarter | Temp. Prod. | Growth Shocks | Terms of Trade | World Int. Rates | Risk Premium |
|-------------------|-------------|---------------|----------------|------------------|--------------|
| 2 | 69.76 | 15.17 | 0.31 | 3.21 | 11.55 |
| 6 | 77.21 | 11.60 | 1.04 | 2.58 | 7.57 |
| 12 | 77.96 | 13.32 | 1.16 | 2.06 | 5.50 |
| 24 | 77.29 | 15.06 | 1.15 | 1.83 | 4.67 |
| 32 | 76.71 | 15.84 | 1.16 | 1.79 | 4.51 |
| Average B. Cycles | 77.29 | 13.95 | 1.12 | 2.07 | 5.56 |

Notes: The average over the Business Cycles are computed at frequencies covering from 6 to 32 quarters.

A number of observations are worth making. First, these results contrast the basic premise of Aguiar and Gopinath (2007a; 2007b) analysis, according to which business cycles in emerging economies are mainly characterized by shocks to the trend productivity (growth shocks). They argue that these economies face frequent and drastic changes in their fiscal, monetary and trade policies, which are translated into shocks to the trend productivity. On the other hand, given the more stable environment, business cycles in developed economies are mainly characterized by temporary productivity shocks. They report, for example, that for their benchmark emerging market economy (Mexico), growth shocks explain roughly 82% of output volatility. Here temporary productivity shocks are the main driving force, while growth shocks account for about 14% of output fluctuations in our benchmark emerging market economy.

A natural question is hence whether or not Brazil is a good benchmark for an emerging market economy. As the Brazilian economy has experimented a relatively stable environment since the

third quarter of 1994, this may explain the prevalent role of temporary productivity shocks vis-à-vis growth shocks. (The data on country spreads is only available since the third quarter of 1994, which prevent us of using a longer sample period). This suggest that our analysis should be applied to other emerging and developed countries to assess the robustness of these results.

Second, the results for the terms of trade shocks suggest that these shocks do not matter for domestic fluctuations. Lubik and Teo (2005) and Lubik and Schorfheide (2007) obtain similar results in their estimated structural models. These results however contrast with an earlier literature (Mendoza, 1995; Kose, 2002), which point out that the terms of trade shocks are the main driving force in emerging economies. Mendoza (1995) shows that the terms of trade shocks can explain roughly 50% of output volatility. Kose (2002) gets an even higher number, according to her the terms of trade can account for 88% of domestic output fluctuations. Both Mendoza (1995) and Kose (2002) adopt a more complex production structure than the one we use in this paper. While here the terms of trade plays a minor role, affecting the household's wealth only, in their framework, the terms of trade enters into the production structure of the economy, affecting the behavior of domestic firms, and consequently the domestic output.¹⁷ We think that a more complex production structure would allow the terms of trade to have bigger effects on the output fluctuations.

Third, world interest rates shocks are also unimportant to the output fluctuations. The results for the world interest rates are similar to Neumeyer and Perri (2005) and Aguiar and Gopinath (2007b) analysis, but they contrast with the results of Lubik and Teo (2005) and Uribe and Yue (2006). While in Neumeyer and Perri (2005) and Aguiar and Gopinath (2007b) world interest rates shocks plays an almost insignificant role in the domestic business cycles, in Lubik and Teo (2005) and Uribe and Yue (2006), these shocks are important driving forces. In the former, the contribution of the world interest rate to output fluctuations ranges from 40%, in New Zealand, to 75% in Australia.

However, it is important to notice that while we use data on real interest rates, Lubik and Teo (2005) do not. Instead the process for the interest rate is derived from the consumption Euler equation. Therefore it is likely that in their case the estimation technique is associating most of the output fluctuations to the latent interest rate process. On the other hand, in Uribe and Yue (2006)

¹⁷Mendoza (1995) model feature three sectors - exportable, importable and non-tradable. The price of importables is the numeraire and hence the price of exportables define the terms of trade. Kose (2002) disagregates the terms of trade into relative prices of capital goods and relative prices of intermediate goods.

formulation country spreads are determined directly by domestic variables (output, investment and the trade balance-to-output ratio) and by the world interest rates. Thus besides its direct effect on output (they also adopt a working capital constraint), world interest rates affect the domestic output through its effect on the country spread. The country spread acts as an amplification mechanism, increasing the impact of world interest rates shocks on the domestic output.

4.4 Is the country risk premium endogenously determined?

In this subsection we formally test the hypothesis that the country risk premium is determined by the macroeconomic fundamentals. We use a posterior odds ratio to assess if this hypothesis is supported by the data. Particularly, we run two versions of the model. One assuming $\alpha_z \neq 0$ and $\alpha_{tot} \neq 0$, which corresponds to the baseline unrestricted model, and the second imposing the restriction $\alpha_z = \alpha_{tot} = 0$.

We set the same priors for both models meaning that we are delegating to the data the decision power regarding the two competing models. Table 5 presents the results for the posterior odds ratio.

Table 5: Posterior Odds Ratio

| Competing Models | Log Marginal Data Density | Prior | Odds Ratio |
|--|---------------------------|-------|------------|
| Benchmark ($\alpha_z \neq 0, \alpha \neq 0$) | 864.42 | 0.5 | 1 |
| Restricted ($\alpha_z = \alpha_{tot} = 0$) | 728.69 | 0.5 | 1.20 |

Note: the log marginal data density is the Harmonic Mean estimator (Geweke 1999)

The odds ratio favor the unrestricted model against the alternative specification, and therefore we can conclude that country risk premium is determined by the "fundamental shocks hitting the domestic economy", borrowing an expression of Neumeyer and Perri (2005).¹⁸ These results also support the analysis of Neumeyer and Perri (2005) and Aguiar and Gopinath (2007b). Although, they do not formally test this hypothesis, they argue that the endogenous country risk case outperforms the exogenous risk premium case in explaining business cycles facts. Similarly, Uribe and Yue (2006) show that the risk premium responds systematically to domestic macroeconomics variables.

¹⁸We also had performed the computation of the posterior odds ratio for several alternatives of the benchmark model. We had tested different combinations of the alternative hypothesis, making one or two coefficients of the individual shocks equal to zero. However, the benchmark model is better supported by the data. To compute the posterior odds ratio, we had used the Laplace Approximation, which avoided the use of MCMC.

4.5 Sensitivity Analysis

In our baseline model we assume that the terms of trade and the world interest rates are described by first-order autoregressive processes, and their innovations are orthogonal to each other. However, as pointed out by Lubik and Teo (2005), these two processes are likely to share similar underlying sources of their dynamics. For example, business cycles fluctuations in the U.S. are likely to affect the demand and supply for international tradable goods (and hence the terms of trade) and capital (and thus the world interest rate). We follow Lubik and Teo (2005) and define a simple alternative shock process for these two variables. Thus we replace equations (16) and (18) in our baseline model by the following process:

$$\begin{bmatrix} \widehat{r}_t^* \\ \widehat{tot}_t \end{bmatrix} = \begin{bmatrix} \rho_{r^*} & \rho_{rt} \\ \rho_{tr} & \rho_{tot} \end{bmatrix} \begin{bmatrix} \widehat{r}_{t-1}^* \\ \widehat{tot}_{t-1} \end{bmatrix} + \begin{bmatrix} \epsilon_t^{r^*} \\ \epsilon_t^{tot} \end{bmatrix} \quad (36)$$

where the hat over the variable means log deviations from the respective steady-state, and ρ_{rt} captures the lag dependence of the world interest rates on the terms of trade, and ρ_{tr} captures the lag dependence of the the terms of trade on the world interest rates. The innovations $\epsilon_t^{r^*}$ and ϵ_t^{tot} are mean zero processes with standard deviations σ_{r^*} and σ_{tot} , respectively. The correlations between the innovations are denoted by σ_{rt} .

The prior distributions for the three new parameters ρ_{rt} , ρ_{tr} , and σ_{rt} are denoted by Normal Distributions with mean zero and standard deviations 0.1. We perform the estimation task using the alternative shock specification and keeping the same priors distributions for all the other parameters as before.

The results for the estimated parameters using the alternative shock process are quite similar to those in our baseline model. Indeed all the estimated values under our baseline model lie within the 90% confidence band of the respective parameter estimate under the alternative model. The lag dependence parameter ρ_{rt} is estimated to be negative, while the lag dependence parameter ρ_{tr} is estimated to be positive. The correlation of the shocks is estimated to be negative. Table 7 in the appendix G presents these results in more details.

Table 8 in the appendix G presents the results for the variance decomposition exercise. Again the results are in line with our baseline model, i.e., temporary productivity shocks are the main

driving force of the business cycles fluctuations, while growth shocks explain a smaller share. Even though growth shocks explain a bigger share of output fluctuations vis-à-vis our baseline model, these results do not change the main conclusion of this paper. World price shocks (terms of trade and world interest rates shocks) and country risk premium shocks again are negligible driving forces of the domestic fluctuations at the business cycles frequencies. Notice that the estimates for the lag dependence parameters and for the correlation of the shocks are all close to zero. Indeed the 90% interval for the parameter ρ_{tr} and σ_{rt} includes zero. This can explain the similarity between the results under the two specifications.¹⁹

5 Conclusion

We believe that our approach is a natural step to further understand the business cycles in emerging market economies, and particularly to assess the role played by world price shocks, country risk premium shocks and domestic productivity shocks in driving domestic fluctuations. Our main finding consists that temporary productivity shocks are the main source of output fluctuations in our benchmark economy, while growth shocks explain a smaller fraction. These results are at the odds with the basic premise of Aguiar and Gopinath's (2007a; 2007b) analysis, according to which emerging market economies business cycles are mainly characterized by growth shocks. We argue that one possible explanation for such results relies on the fact that the Brazilian economy has experimented a relatively stable environment along our sample. Thus if their basic premise is to be blamed, or if instead our choice of the benchmark emerging market is to be blamed is object of further analysis.

The striking result consists in the negligible role played by world interest rate shocks and country risk premium shocks. These two shocks appear to be unimportant in driving domestic fluctuations. Moreover, we show that the terms of trade shocks do not matter as well. We think that these results are in part due to the simple production structure adopted in this paper. We also emphasize that the country risk premium acts as an important amplification mechanism of the shocks hitting the domestic economy (terms of trade shocks and productivity shocks), which support the common

¹⁹We also compute Impulse Response for our model variables under the alternative specification. They are virtually identical to the correspondent Impulses Responses in our baseline model. Thus we do not present them in this paper.

assumption in the recent literature of "endogenous" risk premium.

This paper can be extended in several directions. First, a richer production structure as in Mendoza (1995) or Kose (2002) would allow the terms of trade to have bigger effects on output fluctuations. Second, other potential shocks and frictions could be incorporated into the basic framework, such as: government spending and taxes shocks, investment-specific technology shocks, news shocks, wage mark-up shocks, variable capital utilization, consumption habit formation, etc. Finally, the model and the estimation technique could be applied to other emerging and developed economies in order to assess the robustness of the findings reported here.

Appendix

A. Granger Causality Tests

Table 6: Granger Causality Tests

| Null Hypothesis | F statistic | Probability |
|---|-------------|-------------|
| Export does not Granger cause TOT | 0.965 | 0.43 |
| Import does not Granger cause TOT | 0.558 | 0.69 |
| GDP growth does not Granger cause TOT | 0.480 | 0.74 |
| GDP does not Granger cause the Terms of Trade | 0.543 | 0.70 |
| TOT does not Granger cause GDP | 2.870 | 0.03* |
| TOT does not Granger cause GDP growth | 2.419 | 0.06** |
| GDP does not Granger cause Interest Rates | 2.775 | 0.03* |

* significant at 5% level **Significant at 10% level n = 50 observations

B. (log)Linearized Model

$$c_{ss}\widehat{c}_t - \tau h_{ss}^\omega \omega \widehat{h}_t = -\lambda_{ss}^{-1/\psi} \frac{\widehat{\lambda}_t}{\psi} \quad (\text{C.1})$$

$$(\omega - 1)\widehat{h}_t = \widehat{w}_t \quad (\text{C.2})$$

$$\widehat{\lambda}_t + \psi \widehat{g}_t + (\gamma - 1)\widehat{tot}_t + \zeta \left(\widehat{d}_{t+1} - \widehat{tot}_t - \widehat{y}_t \right) = \widehat{r}_{t+1} + \widehat{\lambda}_{t+1} + (\gamma - 1)\widehat{tot}_{t+1} \quad (\text{C.3})$$

$$g_{ss}^\psi \left[1 + \widehat{\lambda}_t + \psi \widehat{g}_t + \phi g_{ss} (\widehat{k}_{t+1} - \widehat{k}_t + \widehat{g}_t) \right] = \dots \quad (\text{C.4})$$

$$\dots = \beta [(u_{ss} + 1 - \delta)(1 + E_t \widehat{\lambda}_{t+1}) + u_{ss} \widehat{u}_{t+1} + \phi g_{ss}^2 (k_{t+2} - k_{t+1} + g_{t+1})]$$

$$c_{ss} \widehat{c}_t + i_{ss} \widehat{i}_t + \text{tot}_{ss}^{(\gamma-1)} d_{ss} g_{ss} \left((\gamma - 1) \widehat{\text{tot}}_t + \widehat{d}_{t+1} + \widehat{g}_t \right) = r_{ss} d_{ss} \text{tot}_{ss}^{(\gamma-1)} \left(\widehat{r}_t + \widehat{d}_t + (\gamma - 1) \widehat{\text{tot}}_t \right) + \dots \quad (\text{C.5})$$

$$\dots + w_{ss} h_{ss} (\widehat{w}_t + \widehat{h}_t) + u_{ss} k_{ss} (\widehat{u}_t + \widehat{k}_t)$$

$$\widehat{i}_t = k_{ss} g_{ss} (\widehat{k}_t + \widehat{g}_t) - (1 - \delta) k_{ss} \widehat{k}_t \quad (\text{C.6})$$

$$\widehat{y}_t = \widehat{z}_t + (1 - \alpha) \widehat{k}_t + \alpha \widehat{l}_t + \alpha \widehat{g}_t \quad (\text{C.7})$$

$$\widehat{u}_t = \alpha (\widehat{l}_t - \widehat{k}_t + \widehat{g}_t) \quad (\text{C.8})$$

$$\alpha \frac{y_{ss}}{l_{ss}} (\widehat{y}_t - \widehat{l}_t) = w_{ss} [1 + \mu(r_{ss} - 1)] \widehat{w}_t + \mu w_{ss} r_{ss} \widehat{r}_{t-1} \quad (\text{C.9})$$

$$\widehat{z}_t = \rho_z \widehat{z}_{t-1} + e_t^z \quad (\text{C.10})$$

$$\widehat{g}_t = \rho_g \widehat{g}_{t-1} + e_t^g \quad (\text{C.11})$$

$$\widehat{\text{tot}}_t = \rho_{\text{tot}} \widehat{\text{tot}}_{t-1} + e_t^{\text{tot}} \quad (\text{C.12})$$

$$\widehat{r}_t^* = \rho_{r^*} \widehat{r}_{t-1}^* + e_t^{r^*} \quad (\text{C.13})$$

$$\widehat{l}_t = \widehat{h}_t \quad (\text{C.14})$$

$$\widehat{r}_t = \widehat{r}_t^* + \widehat{s}_t \quad (\text{C.15})$$

$$\widehat{s}_t = \rho_s \widehat{s}_{t-1} + \alpha_z \widehat{z}_{t+1} + \alpha_{\text{tot}} \widehat{\text{tot}}_{t+1} + e_t^s \quad (\text{C.16})$$

C. Linking observable variables to the model

Denote by Y_t a observable variable that contains a trend in equilibrium Γ_{t-1} , therefore we have:

$$Y_t = y_t \Gamma_{t-1} \tag{B.1}$$

where y_t is the model correspondent stationary variable. We can write equation B.1 in terms of gross rates:

$$\frac{Y_t}{Y_{t-1}} = \frac{y_t}{y_{t-1}} \frac{\Gamma_{t-1}}{\Gamma_{t-2}} \tag{B.2}$$

Let $z_t = \frac{Y_t}{Y_{t-1}}$ and $x_t = \frac{y_t}{y_{t-1}}$, we can rewrite equation B.2 as:

$$z_t = x_t \cdot g_{t-1} \tag{B.3}$$

Log-linearizing B.3 around the non-stochastic steady-state yields:

$$\hat{z}_t = \hat{x}_t + \hat{g}_{t-1} \tag{B.4}$$

where the hat over the variable means log-deviations from the steady-state and $\hat{x}_t = \hat{y}_t - \hat{y}_{t-1}$. Hence, for any variable that contains a trend in equilibrium, we use B.4 to make the link between observable and its model correspondent.

D. Metropolis-Hastings Algorithm

The Metropolis-Hastings algorithm is implemented by the following steps:

1. Find the mode of the posterior distribution by maximizing $\log \mathcal{L}(\Psi_t | \theta) + \log p(\theta)$. Denote by θ^* the posterior mode computed at the maximum using an optimization routine (we use Chris Sims' CSMINWELL). The starting value for the MH chain is drawn from $N(\theta^*, c\Sigma^*)$, where c is a scale factor. The idea is to randomly select the initial value for the parallel Markov chains from a stretched out distribution. This is done to increase the probability of the initial values not being too close to each other (this is important to access convergence).

2. At the s^{th} iteration generate a proposal $\bar{\theta}$ from $\mathcal{N}(\theta^{(s-1)}, d\Sigma^{(s-1)})$, where $\theta^{(s-1)}$ is the mean of the distribution up to the $(s-1)^{\text{th}}$ draw and $\Sigma^{(s-1)}$ is the inverse of the Hessian computed at the posterior mode. The parameter d is called the scale factor and it determines the acceptance ratio of the proposals. The idea is to choose d such that the acceptance ratio is between 20 - 40%. Particularly, we choose $c = 2 * d$.
3. Evaluate the proposal according to the following rule: if $u \sim \mathcal{U}(0, 1) \leq \alpha = \min \left[\frac{\mathcal{L}(\Psi_t | \bar{\theta}) p(\bar{\theta})}{\mathcal{L}(\Psi_t | \theta^{(s-1)}) p(\theta^{(s-1)})}, 1 \right]$, then accept the proposal and set $\theta^{(s)} = \bar{\theta}$. Otherwise, set $\theta^{(s)} = \theta^{(s-1)}$. Update, if needed, the jumping distribution and go to step 2.

E. Harmonic Mean Estimator

Gelfand and Dey (2004) show that for any p.d.f. $f(\theta)$ with support on Θ (the support of θ) we have:

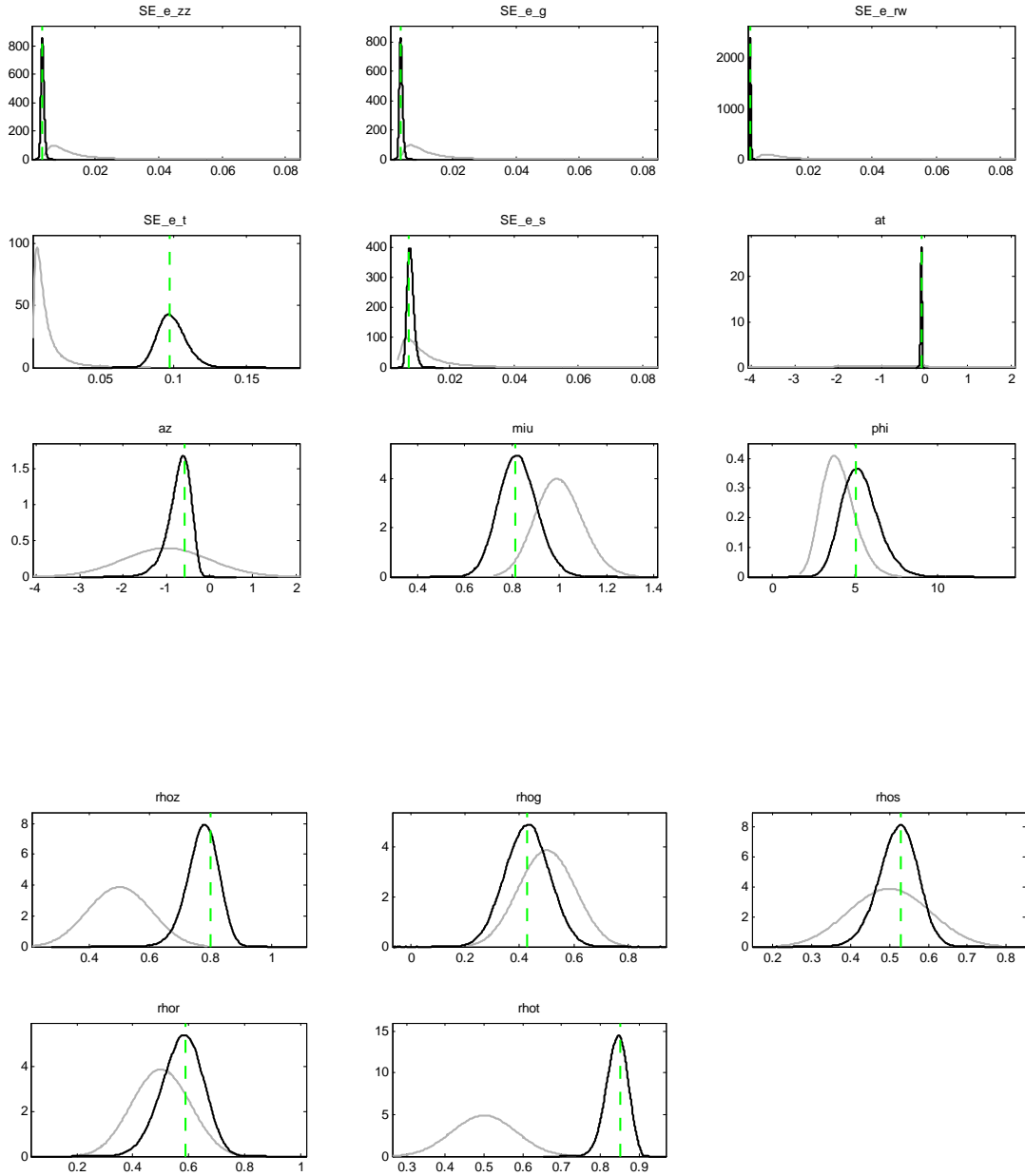
$$E \left[\frac{f(\theta)}{\mathcal{L}(\Psi_t | \theta, \mathcal{M}) p(\theta | \mathcal{M}) d(\theta)} \mid \Psi_t, \mathcal{M} \right] = \int_{\Theta} \frac{f(\theta)}{\mathcal{L}(\Psi_t | \theta, \mathcal{M}) p(\theta | \mathcal{M}) d(\theta)} d\theta = \frac{1}{P(\Psi_t | \mathcal{M})}$$

The harmonic mean estimator is given by:

$$\hat{p}(\Psi_t | \mathcal{M}) = \left[\frac{1}{m} \sum_{s=1}^m \frac{f(\theta^{(s)})}{\mathcal{L}(\Psi_t | \theta^{(s)}, \mathcal{M}) p(\theta^{(s)} | \mathcal{M}) d(\theta)} \right]^{-1}$$

where m is the number of iteration. At each iteration s we compute $\frac{f(\theta^{(s)})}{\mathcal{L}(\Psi_t | \theta^{(s)}, \mathcal{M}) p(\theta^{(s)} | \mathcal{M}) d(\theta)}$, where $f(\theta)$ is chosen to minimize the significance of extreme values of θ . As point out by Geweke (1999), the asymptotic theory behind the results of Gelfand and Dey (1994) requires that $\frac{f(\theta)}{\mathcal{L}(\Psi_t | \theta, \mathcal{M}) p(\theta | \mathcal{M}) d(\theta)}$ be finite for any $\theta \in \Theta$. Particularly, we follow Geweke (1999) and use a truncated (in the tails) Normal distribution.

F. Priors and Posteriors Distributions



G. Robustness Exercise Results

Table 7: Posteriors under the Baseline and Alternative Models

| Parameter | Baseline Model | | Alternative Model | |
|----------------|-----------------|-----------------|-------------------|--------|
| | Posterior Means | Posterior Means | 90% Interval | |
| ϕ | 5.32 | 8.21 | 3.98 | 12.30 |
| μ | 0.82 | 0.82 | 0.69 | 0.95 |
| α_{tot} | -0.073 | -0.053 | -0.077 | -0.029 |
| α_z | -0.71 | -0.662 | -1.032 | -0.286 |
| ρ_z | 0.77 | 0.78 | 0.69 | 0.86 |
| ρ_g | 0.43 | 0.43 | 0.30 | 0.56 |
| ρ_s | 0.52 | 0.50 | 0.41 | 0.59 |
| ρ_{r*} | 0.57 | 0.56 | 0.44 | 0.69 |
| ρ_{tot} | 0.84 | 0.85 | 0.81 | 0.90 |
| σ_z | 0.0036 | 0.0036 | 0.0028 | 0.0043 |
| σ_g | 0.0039 | 0.004 | 0.0031 | 0.0048 |
| σ_s | 0.0079 | 0.0072 | 0.0057 | 0.0086 |
| σ_{r*} | 0.002 | 0.0021 | 0.0018 | 0.0023 |
| σ_{tot} | 0.099 | 0.099 | 0.0835 | 0.1144 |
| ρ_{rt} | | -0.009 | -0.015 | -0.002 |
| ρ_{tr} | | 0.004 | -0.162 | 0.171 |
| σ_{rt} | | -0.139 | -0.305 | 0.031 |

Table 8: Variance Decomposition of Output under the Alternative Model

| Quarter | Temp. Prod. | Growth Shocks | Terms of Trade | World Int. Rates | Risk Premium |
|-------------------|-------------|---------------|----------------|------------------|--------------|
| 2 | 70.40 | 16.48 | 0.02 | 2.92 | 10.18 |
| 6 | 76.07 | 15.02 | 0.09 | 2.27 | 6.54 |
| 12 | 74.34 | 19.10 | 0.10 | 1.77 | 4.69 |
| 24 | 71.72 | 22.78 | 0.10 | 1.54 | 3.86 |
| 32 | 70.59 | 24.14 | 0.10 | 1.48 | 3.68 |
| Average B. Cycles | 73.18 | 20.26 | 0.10 | 1.76 | 4.70 |

Notes: The average over the Business Cycles are computed at frequencies covering from 6 to 32 quarters.

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