ACCOUNTING FOR BUSINESS CYCLES IN EMERGING MARKET ECONOMIES

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The main goal of this study is to address the fundamental question: what drives business cycle fluctuations in emerging economies? The analysis of the literature does not deliver a clear and straight answer for this question. The results are mixed because different authors implement different methodologies, use different data set and countries, and mainly because they consider different number and type of shocks to explain aggregate fluctuations. In this study we focus on the later aspect. Our basic strategy consists in implementing an integrated analysis that incorporates shocks that have been identified in the recent literature as important driving forces into the same theoretical framework. We develop 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, to the country risk premium and to government expenditures. We implement a variance decomposition exercise to assess the role played by these shocks in driving business cycle fluctuations in our benchmark emerging market economy. 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 first quarter of 2008. The main findings are: (1) output is mostly driven by temporary productivity shocks, while shocks to the growth rate of trend productivity (growth shocks) are less important. (2) Terms of trade shocks explain about 13% of output growth volatility. (3) world real interest rate shocks and government expenditure shocks appear to be unimportant in driving the business cycles. (4) 10% of aggregate output fluctuations are explained by risk premium shocks.
To Karina, João Pedro, Lucas and Marcela com todo meu amor.

To my Lord and Savior Jesus Christ. He is my everything.
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Chapter 1

Introduction

1.1 Nature of the Problem

Business Cycle fluctuations in emerging market economies differ from those in small, open developed economies in some important aspects. For example, output is twice as volatile in emerging economies as in developed economies, consumption is more volatile than output, and the trade balance is highly countercyclical. Moreover, real interest rates are more volatile (on average 40% more volatile) and counter-cyclical in emerging economies, while in small, open developed economies they are procyclical. Explaining why business cycles are different in emerging economies relative to developed countries is at the top of the research agenda in small open economy macroeconomics (Uribe, 2007). Table 1.1 provides a comparison of business cycles statistics for emerging and small, open developed economies.
Table 1.1: Business Cycles Properties: Emerging vs. Developed Economies

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Emerging</td>
</tr>
<tr>
<td>(a) % Standard Deviation:</td>
<td></td>
</tr>
<tr>
<td>Output</td>
<td>2.79</td>
</tr>
<tr>
<td>Trade Balance to Output ratio</td>
<td>2.40</td>
</tr>
<tr>
<td>Real Interest Rates</td>
<td>2.32</td>
</tr>
<tr>
<td>(b) % Std. Deviation / %Std. Dev. Output</td>
<td></td>
</tr>
<tr>
<td>Consumption</td>
<td>1.30</td>
</tr>
<tr>
<td>Investment</td>
<td>3.29</td>
</tr>
<tr>
<td>Hours</td>
<td>0.89</td>
</tr>
<tr>
<td>(c) Correlation of Output with:</td>
<td></td>
</tr>
<tr>
<td>Real Interest Rates</td>
<td>-0.55</td>
</tr>
<tr>
<td>Trade Balance to Output Ratio</td>
<td>-0.61</td>
</tr>
<tr>
<td>Consumption</td>
<td>0.80</td>
</tr>
<tr>
<td>Investment</td>
<td>0.88</td>
</tr>
<tr>
<td>(d) Correlation of Interest Rates with:</td>
<td></td>
</tr>
<tr>
<td>Consumption</td>
<td>-0.55</td>
</tr>
<tr>
<td>Investment</td>
<td>-0.48</td>
</tr>
<tr>
<td>Trade Balance to Output ratio</td>
<td>0.51</td>
</tr>
</tbody>
</table>

Note: This table lists average values of the moments for 5 emerging countries and 5 developed countries. Emerging: Argentina, Brazil, Korea, Mexico, and Philippines. Developed: Australia, Canada, Netherlands, New Zealand, and Sweden. Data are logged, seasonally adjusted and detrended using HP filter. Source: Neumeyer and Perri (2005).

Two potential explanations for these differences are well known in the literature. First and foremost, emerging market economies are hit by numerous shocks of different
nature and size relative to small, open developed economies. Thus more shocks and
more uncertainty (i.e., more volatile shocks) may explain why business cycles are more
pronounced in emerging economies. It is also important to note that even if small open
developed and emerging economies are hit by shocks of the same nature (e.g., productivity
shocks, terms of trade shocks, etc.), if the stochastic processes that define those shocks
are different this may explain why business cycles are different between these two classes
of economies.

Second, government policies in emerging economies tend to exacerbate, rather than
dampen, business cycle fluctuations. This is in stark contrast with the way these policies
are conducted in developed economies. Indeed, one of the traditional explanations for the
phenomenon of the great moderation, observed in developed economies, is the role played
by countercyclical fiscal and monetary policies in offsetting business cycle fluctuations
(see Stock and Watson, 2002).¹

With respect to the first set of explanations, the starting point of the literature
assessing business cycle fluctuations in emerging economies has been the class of models
based on Mendoza (1991) and Correia, Neves and Rebelo (1995). As we will discuss in
the next section, the natural step has been to modify the otherwise standard Small Open
Economy - Real Business Cycle (SOE-RBC) model to include additional shocks and also
to introduce modifications that can allow this model to replicate important features of
the data. Traditionally, SOE-RBC models (e.g., Mendoza, 1991) yields consumption less
volatile than output, slightly counter-cyclical trade balance and procyclical real interest
rates, which are in line with the empirical evidence for small, open developed economies.²

¹Kaminsky, Reinhart and Végh (2004) report that fiscal policy is procyclical in the majority of the
emerging economies in their sample. Similarly, monetary policy appears to be procyclical (i.e., policy
rates are lowered in good times and raised in bad times) and periods of capital inflows are associated with
expansionary macroeconomic policies and periods of capital outflows with contractionary macroeconomic
policies. These facts led them to conclude that in emerging markets "when it rains, it pours ".

²Mendoza (1991) finds slightly countercyclical interest rates in the small open economy version with
investment adjustment costs. Without investment adjustment cost, the model implies procyclical real
However, as we have seen from Table 1.1, these business cycle implications are at odds with some empirical regularities of emerging market economies.

In what follows, we present an overview of the literature in the Real Business Cycle (RBC) tradition focusing on small open economy models, particularly the recent effort that has been made to explain the distinctive characteristics of the business cycles in emerging market economies, which are the main focus of our analysis.3

1.2 Literature Review

The starting point of the literature using the RBC framework to analyze business cycle fluctuations in small open economies is Mendoza (1991). He extends the basic real business cycles model to a small open economy set-up. The general question was to assess the ability of real business cycle models in replicating stylized facts of actual small open economies, in particular the positive correlation between savings and investment and the countercyclical behavior of the external accounts. The model economy is composed of identical, infinitely-lived households that choose consumption, labor supply, investment and international bond holdings to maximize a lifetime utility. One of the distinctive features of the open economy set up, vis-à-vis the closed economy formulation, is the decoupling of domestic savings and investment. The representative household may access international financial markets to smooth consumption and to invest independently of the level of domestic savings.

interest rates. However, Neumeyer and Perri (2005) finds procyclical real interest rates when the model is simulated without the working capital constraint despite of the presence of investment adjustment costs. Based on this evidence they argue that in order to generate countercyclical real interest rates one needs to introduce working capital constraint.

3We have structured this literature review following a cronological ordering. The papers are discussed in the order they first appear in the literature, which in most cases differ from the published date. The dates we refer the papers are the dates when the papers are published, in case of published papers, and the dates when they appear in the literature as a working paper, in case of unpublished papers.
The model is parameterized and calibrated to reflect long-run properties of the Canadian economy. The model is then simulated and its ability to reproduce some stylized facts of the actual economy is assessed. Mendoza (1991) points out that the model with moderate productivity shocks and capital adjustment costs is able to replicate the two aforementioned stylized facts. First and in contrast with the argument of Feldstein and Horioka (1980), the model is able to reproduce positive correlations between savings and investment even under perfect capital mobility. Second, the model is able to generate a slightly countercyclical trade balance-to-output ratio. One interesting result of Mendoza’s analysis is that world real interest rate shocks appear to be unimportant in driving business cycles, i.e., simulations results for the model with and without interest rate shocks are quite identical. As he points out the unimportance of interest rate shocks is likely to be the case when interest rates are low and foreign interest rates payments represent a small fraction of Gross Domestic Product (GDP). However, he speculates that this might not be the case in highly indebted economies, such as most of the emerging economies.

Following the work of Mendoza (1991), Correia, Neves and Rebelo (1995) develop a small open economy version of the real business cycle model to evaluate the ability of the model to replicate main features of the business cycles in Portugal over the period 1958-1991. Besides shocks to the world real interest rate and domestic productivity, their model includes shocks to government expenditures and to foreign transfers. Despite the greater number of shocks, relative to Mendoza (1991), the two papers reach similar conclusions, i.e., the model with only productivity shocks is able to replicate business cycle moments for the Portuguese economy quite well, while shocks to government expenditures, foreign transfers and world real interest rate are of secondary importance.

Furthermore, one interesting contribution of Correia et al.(1995) is to show that the ability of small open economy models to mimic business cycles properties depends heavily on the functional form of the utility function. When preferences are of the type
as commonly used in the closed economy literature, e.g., Cobb-Douglas preferences, the standard model is unable to replicate the volatility of consumption and the countercyclical behavior of the trade balance.\(^4\) Notwithstanding, when preferences are of the type as the one proposed by Greenwood, Hercowitz, and Huffman (1988), hereafter GHH preferences, the model is able to reproduce these two stylized facts about consumption volatility and trade balance counter-cyclicality reasonable well.

The distinctive feature of GHH preferences is that under these preferences labor supply depends solely on the marginal productivity of labor. Thus labor supply is highly procyclical, which makes consumption highly procyclical as well. To see this consider a typical household’s utility maximization problem (subject to a budget constraint).

\[
\max_{\{C_t, h_t\}_{t=0}^{\infty}} E_0 \left\{ \sum_{t=0}^{\infty} \beta^t \frac{1}{1-\psi} [u(C_t, 1-h_t) - 1] \right\}, \psi > 0, \beta > 0
\]

where \( C_t \) denotes consumption in period \( t \), and \( h_t \) denotes hours supplied by the household in period \( t \). For simplicity, assume that all markets (goods and inputs) are competitive and hence the representative firm chooses labor inputs and physical capital to maximize profits subject to an usual technology constraint.

\[
Y_t = z_t K_t^{1-\alpha} h_t^\alpha
\]

where \( Y_t, K_t \) and \( h_t \) represent output, capital and hours worked in period \( t \), respectively, and \( z_t \) represents total factor productivity process. From the household’s and firm’s first order conditions we obtain:

\[
\alpha \frac{Y_t}{h_t} = W_t = -\frac{U_h}{U_C}
\]

where \( \alpha \frac{Y_t}{h_t} \) is the marginal productivity of labor, \( W_t \) is the real wage, and \( U_i(C_t, h_t) \) is the first derivative of the utility function with respect to the argument \( i = C_t, h_t \). Now

\(^4\)This class of preferences is discussed in King, Plosser and Rebelo (1988).
consider two functional forms for the utility function:

Cobb-Douglas:

\[ u(C_t, 1 - h_t) = [C_t^\omega (1 - h_t)^{1-\omega}]^{1-\psi}, \text{where } 0 < \omega < 1 \]

GHH:

\[ u(C_t, 1 - h_t) = [C_t - \tau \Gamma h_t^\omega]^{1-\psi} \]

where \( \omega > 1, \tau > 0 \) and \( \Gamma \) is the level of the labor augmented productivity process.\(^5\)

Under the Cobb-Douglas specification the equilibrium condition above can be written as:

\[ \alpha \frac{Y_t}{h_t} = \frac{1 - \omega}{\omega} \frac{C_t}{1 - h_t} \]

while under GHH preferences we have:

\[ \alpha \frac{Y_t}{h_t} = \omega \tau \Gamma h_t^{\omega - 1} \]

Now consider the responses of labor supply and consumption to a positive productivity shock. In the Cobb-Douglas case as \( C_t \) and \( h_t \) are non-separable, the labor supply’s response is mitigated by consumption’s response, i.e., a higher level of consumption reduces the incentive to work. Thus it is clear that in this case both consumption and labor supply will be less responsive to productivity shocks. On the other hand, in the GHH case, labor supply depends exclusively on the current marginal productivity of labor, which implies a highly procyclical labor supply. The volatility of consumption will be higher relative to the Cobb-Douglas case due to the sharp drop in leisure.

Both Mendoza (1991) and Correia, Neves and Rebelo (1995) focus on small, open developed economies. Mendoza (1995) is the first attempt to assess the role of external

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\(^5\)The inclusion of the level of the labor augmented productivity process in the utility function allows hours worked to be bounded in equilibrium. We will discuss this point when we present our theoretical model.
factors in driving business cycles not only in the small, open developed case, but also in the small, open developing economy case. He points out that large and recurrent fluctuations in the terms of trade have been widely viewed as an important element explaining output fluctuations in small open economies. For instance, he observes that many developed and developing economies experienced sharp fluctuations in economic activity following the oil price shocks in the 1970s. In addition, many developing economies experienced large fluctuations in non-oil commodity prices in the 1980s.

While terms of trade shocks affect developed economies mainly by increasing energy prices (Hamilton, 1983), Mendoza (1995) argues that the impacts of terms of trade shocks on developing economies are magnified by the fact that these economies are, in general, dependent on imported capital goods and production inputs. Besides, developing economies also specialize in a few commodity exports and given the volatile behavior of commodities prices, exports earnings are highly unstable. Furthermore, as developing countries use their exports earnings to pay back foreign debt, fluctuations in the terms of trade are likely to be more important in these economies vis-à-vis developed economies.\(^6\)

To evaluate the role played by world (trade) price shocks in driving domestic aggregate fluctuations, Mendoza (1995) extends the small open RBC model to allow for terms of trade shocks. For this he develops a three sector small open economy model featuring a sector producing exportable goods, a sector producing importable goods and a non-tradable sector. Exportable goods are goods produced domestically that can be either sold in the domestic markets or in the foreign markets. Likewise, importable goods are goods that can be either bought in foreign markets or produced and sold domestically. A nontradable good is produced and sold domestically only, i.e., it is neither exportable

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\(^6\) Hamilton (2005) points out that despite the fact that 9 out of 10 recessions in the U.S. since the WW II were preceded by spikes in oil prices, the relationship between oil price shocks and output fluctuations is still a matter of controversy. He argues that there is not a simply mechanical relationship, even a non-linear one, between oil prices shocks and output fluctuations.
nor importable.\footnote{The distinction between exportable, importable and nontradable goods is somewhat arbitrary. Its only purpose is to allow the introduction of the terms of trade (the relative price of exportable in terms of importable goods) and the real exchange rate (the ratio between the price of nontradable goods to tradable goods) in the model. There is not a rigid distinction between exportable and importable across countries. In Colombia, for example, coffee is an exportable good, while cars are an importable good. On the other hand, cars are an exportable good in Japan, while coffee is an importable good.}

Mendoza (1995) assumes that both exportable and importable goods are produced using only physical capital, while the nontradable good is produced using only labor. The terms of trade is defined as the ratio between the price of exportable goods to the price of importable goods. As the importable good is used as the numeraire, fluctuations in the price of the exportable goods reflect changes in the terms of trade. Four exogenous shocks are considered: a productivity shock in each of the three sectors and a terms of trade shock.\footnote{One important issue is the assumption of exogeneity of the terms of trade. Even though the small open economy framework implies that domestic firms are price takers in international markets, this assumption may not be true when the domestic economy holds a considerable fraction of world’s exports.}

Mendoza (1995) parameterizes the model for two benchmarks: one reflecting a small, open developed economy and other a developing economy. The model is then simulated and its business cycle moments are compared with those of the data. Although the model is able to explain several features qualitatively, from a quantitative perspective, it fails to replicate several stylized facts. For example, even though the model is able to generate procyclical terms of trade (as in the data), it fails to generate less volatile terms of trade relative to GDP.

The key result of Mendoza’s analysis refers to the importance of the terms of trade as a driving force of business cycles in both benchmark economies. When the model is simulated with only terms of trade shocks, it can explain about 88\% of the predicted GDP volatility in the developed benchmark economy. Taking into account that the ratio of GDP-to-the terms of trade volatility in the model corresponds to 1/2 of the GDP-to-the-terms of trade volatility ratio average in Mendoza’s data, this implies that terms of trade
shocks can account for about 44% of the actual output volatility (or 1/3 of volatility when GDP is measured in domestic prices). On the other hand, in the developing economy case, the model implies that about of 37% of actual GDP volatility is explained by TOT shocks (or 56% of actual volatility when GDP is measured in domestic prices).

Kose (2002) extends Mendoza (1995) by assuming a richer production structure in order to capture some distinctive features of developing economies. In particular, the high dependence on imported capital goods and inputs, and the fact that these economies specialize in exports of primary goods. The model features two sectors: one sector producing exportable primary goods and another producing nontradable final goods. The primary good is produced using imported capital, domestic labor, and land. On the other hand, the nontradable final good is produced using domestic capital, imported intermediate inputs, and domestic labor.

One important distinction between Mendoza’s and Kose’s framework is that while in Mendoza’s framework world (trade) price shocks are aggregate terms of trade shocks, Kose (2002) "disaggregates" terms of trade shocks into shocks to the price of imported capital and shocks to the price of imported inputs. (The primary good is used as the numeraire). Moreover, while terms of trade shocks affect only the tradable (exportable and importable) sector in Mendoza (1995), in Kose’s (2002) framework they affect the tradable and nontradable sectors as both employ imported factors of production. In addition to the two relative trade price shocks, the model features three other shocks: one productivity shock in each of the two sectors and world real interest rate shocks. Recall that in Mendoza (1995) only productivity shocks and terms of trade shocks are present. The inclusion of world real interest rate shocks allows Kose (2002) to evaluate Mendoza’s (1991) conjecture that world real interest rate shocks are likely to be more important in highly indebted economies.

The model is calibrated to reflect a representative small, open developing economy. The productivity processes are estimated using Solow residuals, while the price of capital
goods and intermediate inputs are calculated as the ratio of the U.S. producer price index of capital equipment relative to the export price index of the domestic economy and the U.S. producer price index of intermediate materials relative to the same export price index, respectively. The model is simulated and business cycle implications are compared with those of the data. Although the model is able to replicate qualitatively some features of the business cycles, it fails to reproduce some important stylized facts. For instance, output is more volatile in the model than in the data, consumption volatility in the model is about 1/2 of the volatility in the data, and consumption is less volatile than output, while the ordering is the reverse in the data. Furthermore, the model exacerbates the volatility and the countercyclical behavior of the trade balance.

The main objective of Kose’s analysis is to investigate the relative contribution of world price shocks to the business cycles in developing economies. Using a variance decomposition similar to the one used in the Vector Auto-Regressive (VAR) literature, the model implies that world (trade) price shocks are responsible for about 88% of the (predictable) output fluctuations in the representative developing economy, while productivity shocks are responsible for about 11%. Kose (2002) argues that world price shocks explain a “larger” fraction of output volatility in her model vis-à-vis Mendoza (1995) for three reasons: first, these shocks affect directly the primary goods and the non-traded final goods sectors as both utilize imported factors. Second, a significant fraction of capital goods are imported in her model. Finally, relative price shocks are more volatile than terms of trade and productivity shocks.9

As in Mendoza (1991), world real interest rate shocks are unimportant in driving

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9 The statement that world price shocks explain a larger fraction of output volatility in Kose (2002) than in Mendoza (1995) is confusing. She compares the results for a variance decomposition, where world price shocks explain 88% of the predictable volatility of GDP with Mendoza’s (1995) results for actual (not predictable) output volatility. Unfortunately, Mendoza (1995) do not report statistics that would allow us to verify Kose’s claim. He neither reports the share of the predictable output volatility explained by terms of trade shocks nor he provides statistics that would allow us to obtain that information for the developing economy benchmark.
business cycle fluctuations in the representative developing economy. To assess Mendoza’s (1991) conjecture regarding the role of world interest shocks in highly indebted economies, Kose (2002) simulates the model with a larger trade deficit output ratio. She changes the trade deficit from 6.7% to 45.7%, which in her data set corresponds to the trade deficit of the Dominican Republic. This change increases the fraction of output volatility explained by world interest shocks from about 1% to 22%, which according to her is consistent with Mendoza’s conjecture.10

In a related work, Kose and Riezman (2001) apply the same model and methodology as in Kose (2002) to a representative African economy. However, their variance decomposition analysis reveals a different conclusion: shocks to sectoral productivity are the main driving force behind aggregate fluctuations. These shocks explain about 55% of output fluctuations, while trade shocks explain about 44% of the fluctuations. Again, world real interest rate shocks appear to be unimportant for business cycles. The main feature driving these different results is the persistence of the shocks. While in Kose (2002) trade price shocks appear to be more persistent, here the productivity process in the final sector presents the highest persistence. This explains why this shock accounts for almost 53% of predicted aggregate output volatility. As before, the model is able to mimic some qualitative features of the African data, but it fails to reproduce important empirical regularities.11 In accordance with the results of the variance decomposition, the model with only productivity shocks yields business cycles moments that are "closer"

10 Notice that given that the model generated output volatility is higher than in the data, the traditional approach largely used in the RBC literature of assessing the importance of shocks by comparing by how much the predicted volatility of GDP would change if one determined shock is shut off is no longer applicable. This is the approach used by Mendoza (1995). Furthermore, given that the two world (trade) price shocks are more volatile and more persistent than the sectoral productivity shocks (and given the transmission mechanism for world price shocks - they affect both the production structure directly), the results for the variance decomposition were somehow expected.

11 In the model output is more volatile than in the data, even though they are closer vis-à-vis the results reported in Kose (2002). Again consumption volatility is about 1/2 of the average African consumption volatility, and the model still exarcebates the volatility and countercyclical nature of the trade balance.
to the African data, while the model with only trade shocks performs worse.

Aside from Kose’s (2002) experiment, a general result from the above literature consists in the negligible role played by real interest rate shocks in driving business cycle fluctuations. A number of authors have emphasized the role of external financial factors on domestic macroeconomic developments in emerging economies. For instance, Calvo, Leiderman and Reinhart (1993) examining empirical evidence for a sample of 10 Latin American countries show that lower international interest rates, among other things, had encouraged international investors to shift resources to Latin America countries in the early 1990’s. Developing countries in Asia and Latin America had received about $670 billion of foreign capital in the period 1990-1994 (Calvo, Leiderman and Reinhart, 1996). The resurgence of capital inflows to Latin American countries has been associated with domestic expansions in these economies as examined by Kamisnyk, Reinhart and Vegh (2004).

In addition, recent evidence has showed that real interest rates are countercyclical and they lead the business cycles in emerging economies, while they are either acyclical or mildly procyclical and they lag the business cycles in the developed world (Agenor et al, 2000; Neumeyer and Perri, 2005). For illustration purpose consider Figure 1.1. From this Figure we can see that, in general, interest rates spikes are associated with recessions, while periods of growth are associated with low interest rates. The correlation coefficients between real output and real interest rate range from -0.78 in Argentina to -0.32 in Brazil. Mexico and Korea display correlations of order -0.5.
Figure 1.1: Real GDP per capita and Real interest rates in selected countries. Note: (1) Real GDP is logged, seasonally adjusted and HP Filtered. Real interest rates are seasonally adjusted and HP Filtered. The axis in the right refers to log deviations from trend of real GDP, while the axis in the left refers to deviations of real interest rates from trend. (2) Authors calculations. The raw data is from Neumeyer and Perri (2005).

Neumeyer and Perri (2005) claim that such strong relation between real interest rate and aggregate output fluctuations in emerging economies is at odds with the minor role played by real interest rate shocks in SOE-RBC models. They argue that two simple modifications in an otherwise standard RBC model can allow this model to be consistent with empirical regularities of emerging economies, in particular, with the cyclical properties of the real interest rates. The first modification is that firms have to pay

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12However, it is important to keep in mind that the "strong " relation between real interest rate and output fluctuations, as implied by the raw correlations, does not mean causation in any sense. Both variables might be moving altogether (in opposite directions) in response to an underlying common factor, such as a productivity shock.
for part of their factors of production in advance before cashing their sales. So, this constraint creates a need for firms to borrow a pre-determined amount in advance to finance labor payments. When firms are subject to a working capital constraint, real interest rate shocks affect the firm’s effective cost of hiring labor and consequently their labor demand. For a given stock of capital, output declines following a real interest rate shock.\textsuperscript{13} Second, as Mendoza (1991) and Correia, Neves and Rebelo (1995), they also use GHH preferences.

Although it seems obvious that a working capital constraint introduces a transmission mechanism that amplifies the impacts of real interest rate shocks on economic activity, it is important to make clear that a SOE-RBC model, without such constraint, is still able to reproduce dynamic responses of aggregate variables in response to real interest rate shocks in line with the empirical evidence. For instance, Correia, Neves and Rebelo (1995) show that following a real interest rate shock, output, consumption and investment decline in the quarters following the shock. It is still the case that real interest rate shocks can be of second order importance when no working capital constraint is imposed (e.g., Correia, Neves and Rebelo, 1995). However, a working capital constraint is not needed to generate dynamic responses in line with the empirical evidence.

Neumeyer and Perri (2005) attempt to account for the highly volatile real interest rates in emerging economies (interest rates are on average 40% more volatile in these economies relative to the rates in developed economies) by assuming that the interest rate process in emerging economies, \( r_t \), is given by the combination of the world real interest rate and a risk premium:

\[
 r_t = r^*_t s_t
\]

\textsuperscript{13}Similar devices have been used in the RBC closed economy literature, e.g. Christiano and Eichenbaum (1992), Christiano et al. (2005).
where $r_t^*$ is the international gross real interest rate and $s_t$ is the gross spread over the international rate. Thus the domestic rate may differ from the international rate because the loans to the domestic residents are subject to default risk. While the international rate reflects the preferences of the international lenders for risky assets, the risk premium, $s_t$, reflects the probability of default. Therefore, a highly volatile risk premium could explain why interest rates are more volatile in emerging economies.

The natural question is, thus, how to model these two elements. Given the small open economy assumption, the international rate is assumed to be determined outside the domestic economy. In this particular case, the international rate relevant for emerging economies is identified as the 3-month U.S. T-bill rate. Regarding the risk premium component, Neumeyer and Perri (2005) consider two alternative formulations. In the first, they assume that the risk premium is an exogenous process potentially driven by political factors, contagion, among other things. In this formulation the risk premium is defined as:

$$s_t = \rho_s s_{t-1} + \epsilon_t^s$$

In the second formulation, the risk premium is assumed to be a decreasing function of expected domestic productivity realization.

$$s_t = \eta(E_t z_{t+1})$$

where $\eta'(.) < 0$ and $E_t z_{t+1}$ is the expected productivity level in next period. This last formulation, which they name as country induced risk premium, embodies the idea that risk premium can be at the same time a source of output fluctuations and also a propagation mechanism of shocks hitting the domestic economy.\textsuperscript{14} In both formulations,

\textsuperscript{14}One alternative way would be to model the risk premium, in a reduced form fashion, as a function of some measures of domestic fundamentals, such as: output growth, debt-to-GDP ratio, trade balance, etc. However, in some respect, all of those variables would be a function of the underline structural shocks in the economy. We shall leave the discussion of the risk premium formulation when we present
the model is calibrated such that the volatility and persistence of GDP, investment and 
the real interest rate in the model matches the data exactly.

They simulate the model under these two alternative formulations and also assuming 
a formulation with no risk premium. (In this case the persistence and volatility of the 
world real interest rate $r^*_t$ in the model matches exactly that of the data). They compare 
business cycle implications generated from the alternative models with those from the 
Argentine data. Then they argue that the model with country induced risk premium 
performs better vis-à-vis the model without risk premium or when the risk premium 
is modeled as an exogenous process. To assess the importance of world real interest 
rate shocks and domestic interest rates shocks they implement a counterfactual exercise. 
In particular, to evaluate the importance of world real interest rate, they recompute the 
model without shocks to this variable. Then they compare the predicted volatility of GDP 
in the model without shocks to the world real interest rate with the data. Similarly, they 
recompute the model when shocks to the risk premium are absent and again compare the 
predicted volatility of GDP with the data. They show that eliminating fluctuations in 
the risk premium would lower GDP volatility by approximately 27% in Argentina, while 
eliminating fluctuations in the world real interest rate, would lower the GDP volatility 
by 3%.

Given the results above they argue that risk premia appear to be deeply connected 
with domestic fundamentals, as the model with country induced risk premium performs 
better vis-à-vis the alternative models (one with exogenous risk premium and another 
with no risk premium). In particular, the model with country induced risk premium 
is able to generate consumption more volatile than output and a countercyclical trade 
balance close to the one observed in the Argentine data. (By construction the model with 
the induced country risk premium generates the same volatility for output, real interest 
our theoretical model.
rate, and investment as in the data). Second, they argue that risk premium fluctuations can be an important element in explaining why business cycles in emerging economies are more volatile than in developed economies.

One interesting (and controversial) result of Neumeyer and Perri (2005) is to show that their model’s ability to generate countercyclical real interest rates relies entirely on the working capital constraint. When the model is simulated without this financial constraint, interest rates are procyclical no matter the functional form of the utility function (GHH or Cobb-Douglas).\textsuperscript{15} This result is controversial for two reasons. First, as we have pointed out, Correia, Neves and Rebelo (1995) show that output, consumption, investment, capital stock, hours all fall in the quarters following a real interest rate shock. Second, Oviedo (2005) shows that when real interest rates are high in level and volatility the SOE-RBC model is still able to reproduce negative correlations between real interest rates and real GDP without the need to impose a working capital constraint.

The role of risk premia as a source of business cycle fluctuations and as a propagation mechanism has been also discussed by Uribe and Yue (2006). They also argue that fluctuations in the risk premium exarcebate aggregate fluctuations in emerging economies. To determine the importance of shocks to the risk premium and to the world real interest rate in driving output fluctuations, they estimate a first-order VAR system as follows:

\[
A \begin{bmatrix}
    y_t \\
    i_t \\
    bby_t \\
    R_{us} \\
    R_t 
\end{bmatrix} = B \begin{bmatrix}
    y_{t-1} \\
    i_{t-1} \\
    bby_{t-1} \\
    R_{us}^{t-1} \\
    R_{t-1} 
\end{bmatrix} + C\zeta
\]

\textsuperscript{15}They argue that the procyclicality of the real interest rate is because without the working capital constraint output does not change at impact, and when output starts to decline (following a decline in investment), the real interest rate also declines, reverting to its steady-state level (see footnote 25 in their paper). However, this is true even in their version of the model with the working capital constraint. (This because firms finance their working capital at the rate determined one period before the shock takes place).
where $y_t$ denotes real gross domestic output, $i_t$ represents real gross domestic investment, $tby_t$ denotes the trade balance to output ratio, $R_t^{us}$ is the international interest rate (U.S. 3-month T-bill rate), $R_t$ denotes the gross real emerging country interest rate, and $\xi$ is a vector of exogenous disturbances. The identification strategy consists of assuming that the matrix $A$ is given by

$$A = \begin{bmatrix}
1 & 0 & 0 & 0 & 0 \\
1 & a_{21} & 1 & 0 & 0 \\
1 & a_{31} & a_{32} & 1 & 0 \\
0 & a_{41} & a_{42} & a_{43} & 1 \\
0 & 0 & 0 & 1 & 0
\end{bmatrix}, \text{ and } B_{4i} = 0 \forall i \neq 4 \text{ and } C \text{ is an identity matrix.}
$$

The main implication of this identification scheme is that real domestic variables impact the domestic gross real interest rate contemporaneously, while real interest rate shocks (domestic and world real interest rate) affect domestic real variables with one period lag. The restrictions on the matrix coefficients associated with $R_t^{us}$ reflect the assumption that this variable follows an (exogenous) univariate Auto-Regressive - AR(1) process.\(^\text{16}\)

Uribe and Yue (2006) estimate the above system for a sample of emerging economies and perform variance decompositions.\(^\text{17}\) They show that shocks to the US interest rate account for about 20% of fluctuations in output in emerging economies, while shocks to the risk-premium explain roughly 12% of business cycle movements in output.

They assess the plausibility of their identification scheme using a small open economy model augmented to include several real frictions.\(^\text{18}\) They argue that if the estimated

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\(^\text{16}\) The assumption is that emerging economies are small with respect to the rest of the world. The small open economy assumption reflects the idea that domestic developments in small open economies do not affect world variables. See, for example, Cushman and Zha (1997), Zha (1999) and Canova (2005) for a more detailed discussion.

\(^\text{17}\) The countries are: Argentina, Brazil, Ecuador, Mexico, Peru, Philippine, and South Africa.

\(^\text{18}\) The frictions are gestation lags in the production of capital, habit formation in consumption, firms
shocks yield similar business cycles implications in the empirical as well as in the theoretical model, then the identification scheme is plausible. First, they feed the theoretical model with the estimated processes for the world real interest rate and domestic interest rate from the VAR system above. Then they generate impulse responses from the model and compare with impulse responses generated from the VAR. They show that the theoretical and empirical impulse responses can trace each other quite well, at least qualitatively.\textsuperscript{19}

In sum, both Neumeyer and Perri (2005) and Uribe and Yue (2006) claim that real interest rate shocks can be an important source of aggregate fluctuations in emerging economies.\textsuperscript{20} Neumeyer and Perri (2005) also emphasizes the important role played by the working capital constraint in helping their particular model to generate negative raw correlations between output and real interest rate. Besides, such constraint amplifies the impacts of real interest rate shocks on aggregate fluctuations.

Despite the fact that the results of Neumeyer and Perri (2005) and Uribe and Yue (2006) suggest that real interest rate shocks can be an important driving force of business cycles, it is not clear how important real interest rate shocks would be in a model with multiple shocks. For instance, Correia, Neves and Rebelo (1995) show that real interest rate shocks are of second order importance in their model, which includes more shocks than both Neumeyer and Perri (2005) and Uribe and Yue (2006).\textsuperscript{21}

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\textsuperscript{19}Although their identification scheme seems quite natural, the close matching among impulse response functions might be due to the estimation technique used to identify some of the structural parameters. This technique consists in minimizing the distance between the empirical and theoretical impulse response functions as in Christiano, Eichenbaum and Evans (2005).

\textsuperscript{20}They also suggest that risk premium is potentially an important propagation mechanism of shocks hitting the domestic economy. This is the case when the risk premium depends on domestic fundamentals.

\textsuperscript{21}Neumeyer and Perri (2005) consider only shocks to temporary productivity, to the world real interest rate and to the risk premium. On the other hand, Uribe and Yue’s (2006) model only features shocks to the world interest rate and to the domestic real interest rate (risk premium shocks). An interesting fact is that Uribe and Yue (2006) do not use their model to perform variance decomposition to assess
It is still the case that real interest rates are higher in level and volatility in emerging economies, but these facts *per se* do not imply necessarily that real interest rate shocks are going to drive aggregate fluctuations.\(^{22}\) Furthermore, other shocks (e.g., terms of trade shocks, productivity shocks, government expenditure shocks, etc.) can also be higher in level and volatility in emerging economies than in developed economies, and they can end up being more important in driving aggregate fluctuations than real interest rate shocks (e.g., Correia, Neves and Rebelo, 1995).

In an interesting contribution to the literature, Aguiar and Gopinath (2007a) argue that a standard small open economy model augmented to include shocks to the long run growth rate of the economy can account quite well for the different stylized facts in emerging and developed economies. Consider a typical standard production function

\[
Y_t = z_t K_t^{\alpha} (\Gamma_t l_t)^{\alpha}
\]

where \(Y_t\), \(K_t\) and \(l_t\) represent output, capital and hours worked in period \(t\), respectively. \(z_t\) and \(\Gamma_t\) are productivity process that differ in their time series properties. In the standard formulation (e.g., Correia et al., 1995), \(z_t\) is a stationary stochastic process and \(\Gamma_t\) is a deterministic process determined by

\[
\Gamma_t = a \Gamma_{t-1}
\]

where \(a\) is the (deterministic) long run growth rate of the economy. The key modification undertaken by Aguiar and Gopinath (2007a) is the introduction of a stochastic process for the long run growth rate, \(a_t\). They argue that this slight modification, in an otherwise

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\(^{22}\)Although the observation that real interest rate are higher in level and volatility in emerging economies and that they are more correlated with aggregate fluctuations, *vis-à-vis* small, open, developed economies, this does not imply necessarily causation of any sort from one variable to another.
standard RBC model, can take us quite far in explaining the distinctive features of the business cycles in emerging and developed economies. The basic premise is that emerging and developed economies mainly differ with respect to the behavior of the underlying productivity process. While developed economies enjoy a relatively stable long run growth rate of output, emerging economies are characterized by volatile long run growth rates.

This view is motivated by the observation that emerging economies are subject to drastic (and frequent) changes in fiscal, monetary and trade policies that are translated into more volatile growth rates of the economy. Thus, one should expect that shocks to trend growth to be the primary source of business cycle fluctuations and hence "the cycle is the trend" in emerging economies. To illustrate this point, Aguiar and Gopinath (2007) make reference to the work of Restuccia and Schmitz (2004) and Schmitz and Teixeira (2004). While the first study provide evidence of a 50% drop in productivity in the petroleum industry in Venezuela within the first 5 years following its nationalization in 1975, the latter provide evidence of greater productivity levels in the Brazilian Iron-Ore Industry after its privatization in 1991. In contrast, the more stable environment in developed economies would explain why shocks to trend productivity (growth shocks) are less important. Although they acknowledge that emerging market economies are hit by numerous shocks of different nature, they argue that their combined effect can be represented in a reduced form by a shock to trend productivity.23

The implications of the predominance of different productivity shocks to business cycles are a direct consequence of the permanent income hypothesis. When the underlying

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23 This view has been challenged by a number of authors. In particular, Garcia-Cicco, Pancrazi and Uribe (2006) have shown that a standard RBC model driven by productivity shocks (temporary and permanent shocks) cannot account for the empirical regularities of Argentina using annual data covering the period from 1900-2005. They show that the model fails to explain the behavior of the trade balance to output ratio. On important contribution of their analysis is that they use a long time series data set. Given that one of the shocks represent shocks to the long run growth rate of the economy, it is natural to think that a longer data set can produce reliable estimates.
productivity process is mainly characterized by permanent shocks, economic agents would increase consumption and investment (after a positive permanent productivity shock) by more than the initial increase in output, as they expect higher income levels in the future. Given the higher response of consumption and investment relative to the response of GDP, the trade balance is highly countercyclical. In contrast, when temporary productivity shocks are predominant, consumption would be less responsive than output and thus the countercyclically of the trade balance diminishes. (Given the short-lived nature of the shocks, agents would save part of the initial increase in income to smooth consumption over time).\textsuperscript{24} Therefore, the predominance of shocks to the long run growth rate of the economy would explain why consumption is more volatile than output and the highly countercyclical trade balance in emerging economies.

Aguiar and Gopinath (2007a) parameterize the model to reflect two benchmarks: a representative small, open, emerging economy (Mexico) and a small, open developed economy (Canada). The two parameterizations differ with respect to the parameters governing the persistence and standard deviations of the two productivity processes, the parameter governing the long run growth rate, and the coefficient governing capital adjustment costs. Table 1.2 reproduces the estimated parameters for the productivity processes when preferences of the Cobb-Douglas type.

\textsuperscript{24} A similar argument was made by Obstfeld and Razin (1982) and Svensson (1983) in the context of the relationship between the terms of trade and the current account. They point out that the impact of the terms of trade shocks on the current account depends on the nature of the shocks. If shocks to the terms of trade are temporary, then consumption increases by less than the output, which would imply an improvement in the current account. On the other hand, if shocks are permanent, then consumption increases more than output and hence we should expect a current account deterioration. This is now know as the Obstfeld-Razin-Svensson Effect.
Table 1.2: Selected Results of Aguiar and Gopinath (2007)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Developed Economy</th>
<th>Emerging Market</th>
</tr>
</thead>
<tbody>
<tr>
<td>Std. Dev. Temporary Productivity</td>
<td>$\sigma_z$</td>
<td>0.63</td>
</tr>
<tr>
<td>Autocorrelation Temp. Productivity</td>
<td>$\rho_z$</td>
<td>0.97</td>
</tr>
<tr>
<td>Std. Dev. Permanent Productivity</td>
<td>$\sigma_g$</td>
<td>0.47</td>
</tr>
<tr>
<td>Autocorrelation Perm. Productivity</td>
<td>$\rho_g$</td>
<td>0.29</td>
</tr>
</tbody>
</table>

Note: reproduced from Aguiar and Gopinath (2007). $z$ refers to temporary productivity process, while $g$ refers to the shocks to the trend productivity. Standard deviations are in percentage points.

Two important results can be derived from Table 1.2. First, the volatility of the permanent component is higher than the volatility of the stationary productivity process in the emerging market benchmark ($\sigma_g > \sigma_z$), while in the developed economy case the reverse is true. Second, shocks to the growth rate of the economy are much less persistent relative to the temporary productivity process in the two economies.

These two results are important when they contrast the importance of trend versus transitory shocks across the two benchmark economies. Recall that from the production function one can derive the log of the Solow residual, $sr_t$, as follows:

$$sr_t = z_t + \alpha \Gamma_t$$

As $\Gamma_t$ is a nonstationary process that means that $sr_t$ is itself nonstationary as well. From Beveridge and Nelson (1981), we know that any I(1) series can be decomposed into a transitory component and a random walk component ($\tau$). Aguiar and Gopinath (2007a) argue that by computing the relative importance of the random walk component in the total volatility of the Solow residual ($\sigma^2_{\Delta \tau}/\sigma^2_{\Delta sr}$), one should be able to assess whether or not emerging economies can be characterized as being essentially driven by shocks to the long run growth rate of the economy. Indeed, their results imply that the
random walk component is more important in the emerging market benchmark vis-à-vis the developed economy case. That ratio is 0.96 for Mexico and 0.37 for Canada. Given the estimated parameters reported in Table 1.2, the model is simulated under the two different parameterization and the business cycle implications are discussed. The model is, in general, able to replicate several business cycles features in both benchmarks.

Based on the relative importance of the permanent component in emerging economies and in the model’s ability to reproduce some business cycles stylized facts, Aguiar and Gopinath (2007a) conclude that "the cycle is the trend" in emerging economies. In contrast, given the relatively lower importance of the random walk component in the developed case, they claim that the business cycles in developed economies are mainly driven by fluctuations in temporary productivity.

One important caveat is that they do not perform variance decompositions based on model simulations. The results for the estimated parameters reveal why this is problematic. Despite the higher volatility of growth shocks in the emerging market benchmark relative to the developed economy case, these shocks are very short lived in the former case. Meanwhile, temporary productivity shocks are very long lived in the two economies, being more volatile in the developed case. Thus, it seems unlikely that model based variance decompositions would attribute a larger fraction of output fluctuations to growth shocks in the emerging market benchmark. This raises doubt about the main premise of Aguiar and Gopinath (2007) analysis that shocks to the trend productivity are the primary source of output fluctuations.

Moreover, it is clear from their analysis that fluctuations in consumption are going to be driven by permanent productivity shocks. If these shocks are predominant, consumption will be more volatile than output. However, they ignore fluctuations in the world real interest rate, which remains constant. Therefore, one can argue that the permanent productivity process is used to explain consumption and investment fluctuations which
may indeed be due to fluctuations in the real interest rate. Finally, they only present business cycle implications when the two productivity shocks are present. An alternative way to evaluate the role of permanent versus temporary productivity shocks in the two benchmark economies would be to simulate and compute business cycles implications using only one shock. Then business cycles implications of the model simulated with each shock separately could be compared with those of the data. In sum, although the volatility of growth shocks are higher than the volatility of temporary productivity shocks, this is not to say that the former is the main driving force of business cycles in emerging economies and hence the "cycle is the trend". Despite the intellectual appeal of their argument, further analysis is necessary to investigate their basic premise.

Motivated by the mixed evidence in the literature regarding the importance of world price shocks as driving forces of business cycles in small, open economies, Lubik and Teo (2005) estimate a canonical small open economy model featuring three shocks: terms of trade shocks, world real interest rate shocks, and domestic productivity shocks. The model is estimated for five countries (Australia, Canada, New Zealand, Chile and Mexico) using Bayesian techniques. They perform variance decomposition to determine the importance of each of the three shocks in explaining business cycle fluctuations. The results show that in contrast with the previous literature (e.g., Mendoza, 1995 and Kose, 2002) terms of trade shocks appear to be unimportant in driving business cycle fluctuations. They argue that this result might be due to the simple production structure in the model and allowing for a richer production structure would potentially increase the role played by terms of trade shocks.26

25 They argue that the results of a model augmented to include a stochastic process for the process are in line with their benchmark model. However, one can further argue that other important driving forces (e.g., terms-of-trade shocks, risk premium shocks, preference shocks, government spending and taxes shocks, among others) might be missing and hence their permanent productivity process is capturing the influence of those missing elements in explaining business cycles fluctuations in emerging markets.

26 However these results are in line with a previous VAR literature. For instance, Hoffmaister and Roldós (1997) reports that terms of trade shocks can explain up to 7% of the forecast variance of output
On the other hand, world real interest rate and domestic productivity shocks explain the bulk of output fluctuations. However, the ranking of the importance of the two is not uniform across countries. For instance, world real interest rate shocks are the main source of output fluctuations in Australia and Canada, while domestic productivity shocks are the main driving force of business cycle fluctuations in New Zealand, Mexico and Chile.

Lubik and Teo’s (2005) approach presents two important drawbacks. First, they do not use data on real interest rate to estimate the interest rate process in their model. Instead, the interest rate variable is treated as an unobservable variable (i.e., it is derived from the consumption Euler equation). As they properly acknowledge their data exhibits strong persistence, consequently the estimation technique may attempt to attribute this behavior in the data to the unobservable interest rate process. Second, their model yields unrealistic business cycles implications for emerging economies. For instance, after a positive interest rate shock, output and labor hours increase, while consumption declines. This implies that interest rates are procyclical and also that correlation between consumption and output is negative. These results are at odds with the evidence for emerging economies (Neumeyer and Perri, 2005; Uribe and Yue, 2006), where interest rates are countercyclical and both consumption and output decline after an interest rate shock.

Aguiar and Gopinath (2007b) extend their previous work to include interest rates that are allowed to co-vary with domestic productivity shocks. In particular, they assume the following process:

\[
\frac{1}{q_t} = 1 + r^* + e^{[r_t + \alpha_z a_t + \alpha_n (a_t - \bar{a})]}
\]

\[
r_t = \rho_r r_{t-1} + \epsilon_t^r
\]

in Asia and Latin America. Similarly, Hoffmaister, Roldós and Wickham (1998) report that terms of trade can explain up to 15% in sub-Saharan CFA (French Colonies of Africa) countries and up to 1% in non-CFA sub-Saharan African countries. They make this distinction because CFA countries keep an exchange rate pegged regime to the French franc throughout the sample period (1971-1993), while non-CFA countries did not.
where $q_t$ is the price of a debt due in period $t+1$, $r^*$ is a constant world real interest rate, $r_t$ is an exogenous process with a country-specific shock $e^r_t$, $z_t$ denotes temporary productivity process, and $a_t$ denotes the process for the growth rate of the permanent productivity process. Thus the domestic interest rates ($\frac{1}{q_t}$) equals the (constant) world real interest rate plus a process that depends on a country-specific element and the two productivity shocks. The idea underlying this formulation is close related to Neumeyer and Perri’s (2005) formulation and largely inspired by models of sovereign default based on Eaton and Gersovitz (1988) classic formulation (see Arellano, 2007; Mendoza and Yue, 2008; Yue, 2007). According to this class of models, low realizations of income are associated with default episodes.

Aguiar and Gopinath (2007b) consider three different formulations: (i) interest rates that are orthogonal to productivity shocks (i.e., $\alpha_a = \alpha_z = 0$); (ii) interest rates that are correlated with temporary productivity shocks only (i.e., $\alpha_a = 0$); and (iii) interest rates that are correlated with growth shocks (i.e., $\alpha_z = 0$).

Among the three, the model with interest rates that are correlated only with temporary productivity shocks does a better job in replicating some empirical regularities of emerging market economies. To understand why, suppose the economy is hit by a positive temporary productivity shock. On impact, output, consumption and investment increase, while the real interest rate declines for $\alpha_z < 0$. The decline in the interest rate leads to a further increase in current consumption via substitution effect. Therefore, a model economy driven by temporary productivity shocks and where the real interest rate that is allowed to co-vary with productivity shocks can generate consumption that is more volatile than output and countercyclical trade balance. On the other hand, the model with interest rate that is orthogonal to productivity shocks cannot replicate this feature. Under this formulation, after a temporary productivity shock consumption will increase no more than output, given that the representative household will save part of the initial increase in income to smooth consumption over time.
The more striking result however refers to the model whose interest rate depends on growth shocks only. Aguiar and Gopinath (2007b) argue that this model is unable to replicate the correlation of consumption with income and to generate highly countercyclical trade balance. As they acknowledge, this is due to the fact that trend growth shocks are short-lived in their model. As in the case for temporary productivity shock, after a growth shock output, consumption and investment increase, and interest rate declines (for $\alpha_g < 0$). Given the decline in the interest rate, households will increase consumption by more than the initial increase in output. However, as growth shocks are nearly a random walk in their formulation (the serial correlation of growth shocks are nearly zero, $\rho_g = 0.001$), interest rate goes back quickly to their initial level (i.e., increases) and hence consumption declines quickly as well. As interest rate does not display a supply side effect, as it is the case in a model with financial frictions (e.g., working capital constraint), output remains at a higher transition path. Consequently, this formulation fails to generate the correlation between consumption and output observed in the data as well as the high countercyclical trade balance.

Their approach raises two concerns. First, growth shocks are short lived by assumption. They do not estimate or offer an explanation for why they set the serial correlation of these shocks to 0.001 in both economies. This imposition compromises the influence of growth shocks in the interest rate process, i.e., the decline in the interest rate following a growth shock dies out quickly. On the other hand, they assume a very persistent serial correlation for temporary productivity shocks ($\rho_z = 0.95$), which leads to a equally persistent decline in the interest rate. Thus the transition of consumption back to the steady-state will be long-lived in this case. Consequently, the correlation between consumption and income will be high, and the trade balance will be highly countercyclical.

Second, in their baseline simulations the only source of fluctuations in the interest rate is due to either temporary productivity shocks or to growth shocks, i.e., they set the country-specific interest rate shock to zero. As a result the standard deviation of interest
rate in their model ranges from 0.001%, in Canada, to 0.008% in Mexico. This is at odds with the evidence for emerging economies that depicts highly volatile interest rates (Agenor et al, 2000; Neumeyer and Perri, 2005; Uribe and Yue, 2006). Furthermore, it is important to notice that in contrast with Neumeyer and Perri (2005) and Uribe and Yue (2006), Aguiar and Gopinath (2007b) do not use data on domestic real interest rate. Instead, the process for the real interest rate is derived from the model. This might explain why their model fails to yield realistic predictions for the domestic interest rates.

Recent contributions include De Bock (2008) and Chang and Fernandez (2008). De Bock (2008) develops a two-sector small open economy model, largely inspired in the work of Kose (2000), and calibrates the model using quarterly data for Argentina. The model is parameterized to be consistent with the fact that emerging economies import a substantial part of their capital goods from abroad and that the imports of capital goods are procyclical. He argues that such two-sector model is able to generate a countercyclical trade balance, while, according to him, one-sector small open economy models fail to do so. However, this is misleading. As we have discussed previously, more recent versions of the one-sector RBC small open economy model (e.g., Neumeyer and Perri, 2005; Uribe and Yue, 2006; Aguiar and Gopinath, 2007) can generate countercyclical trade balance and can indeed reproduce several stylized facts of emerging economies (e.g., consumption that is more volatile than output, and more volatile output relative to developed economies) without resorting to a multi-sector framework. Thus one does not need a multi-sector model if one is interested in replicating aggregate empirical regularities of emerging economies.²⁸

²⁷Moreover, in the model with only interest rate shocks, the correlation between interest rates and output is small and positive, while in the data interest rates are countercyclical in emerging economies. In that formulation, following a interest rate spike, consumption declines at impact, but given non-separable preferences between leisure and consumption, the labor supply increases and hence output increases.

²⁸De Bock (2008) argues that the key element of his model is the two-sector production structure consistent with the fact that emerging economies import most of their capital goods from abroad.
Chang and Fernández (2008) use Bayesian methods to assess the empirical validity of a small open economy model driven solely by productivity shocks, as in Aguiar and Gopinath (2007a), and a model with financial frictions (a working capital constraint) driven by temporary productivity shock and interest rate shocks. They use the same data set as Aguiar and Gopinath (2007a) and they show that the model with productivity shocks and real interest rate shocks is better supported by the data relative to the model with only productivity shocks. They argue that their results challenge the Aguiar and Gopinath’s view that "the cycle is the trend" in emerging economies. One important limitation of Chang and Fernández’s (2008) analysis is that they do not use data on real interest rate, instead the interest rate process is treated as an unobservable in the model. Again, as in the case of Lubik and Teo (2005), this important omission may induce the estimation technique to attribute the high persistence in the data to the unobservable interest rate process.

1.3 Discussion

"International macroeconomics is a field replete with truly perplexing puzzles, and we generally have five to ten (or more) alternative answers to each of them. These answers are typically very clever but far from thoroughly convincing, and so the puzzles remain" Obstfeld and Rogoff (2000)

The analysis of the literature on emerging market business cycles reveals that Obstfeld and Rogoff's (2000) observation regarding puzzles and "solutions" in international macroeconomics is a valid observation of the literature in the context of this study. As we have seen different authors implement different methodologies, use different data set

However, it seems that the key element that allows his model to replicate empirical regularities in Argentina is the choice of GHH preferences, something that we already knew from the work of Correia et al. (1995) and others. Unfortunately, De Bock (2008) does not show the results for model simulations using Cobb-Douglas preferences. This would help to address if indeed the key model feature is the two-sector framework.
and countries, and consider different number and type of shocks to explain business cycle fluctuations in emerging market economies. Each of them offer a very clever answer to the central question of our analysis: *what drives business cycles in emerging market economies?* However, each presents its own limitations and thus the answers are "far from thoroughly convincing".

Although the literature has identified reasonably well the potential sources of fluctuations in emerging economies, we argue that as these alternative sources of fluctuations are not investigated within the same framework, this has naturally led us to reach different conclusions regarding the importance of each shock. Shocks that do matter in some frameworks, do not matter in others. For example, Neumeyer and Perri (2005) in a model with temporary productivity shocks, world real interest rate and risk premium shocks argue that the latter is a crucial element explaining why business cycles in emerging economies are so much pronounced than in developed economies. On the other hand, Aguiar and Gopinath (2007a), in a model with permanent and temporary productivity shocks, claim that the main driving force of business cycles in emerging economies are indeed growth shocks (i.e., shocks to trend productivity). Kose (2002) and Mendoza (1995), in a model with productivity shocks and terms of trade shocks, argue that shocks to the terms of trade are the main driving force of business cycles. Thus, it is clear that these answers cannot be all correct if one accounts literally for the contribution of each shock in driving aggregate output fluctuations.

Therefore, from our perspective, an important and necessary step to further understand and somehow to reconcile different explanations for the business cycles in emerging economies consists in implementing an integrated analysis that can incorporate all the relevant shocks into the same theoretical framework. This is the main contribution of this study.

In this study we develop a small open economy model based on Mendoza (1991), augmented to include temporary and permanent productivity shocks, as well as shocks to the
terms of trade, to the world real interest rate, to the risk premium, and to government expenditure. We pick these shocks because they have been identified in the recent literature as potential candidates to explain output fluctuations in emerging market economies. The model is then used to assess the importance of these shocks in explaining business cycle fluctuations in our benchmark emerging economy - Brazil. In particular, differently from most of the previous literature, we implement a variance decomposition exercise to identify the main driving forces of the Brazilian business cycles.29

The introduction of permanent and temporary productivity shocks allow us to assess the main argument of Aguiar and Gopinath’s (2007a; 2007b) analysis according to which business cycles in emerging market economies are mainly characterized by shocks to trend 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 (terms of trade shocks and world real interest rate shocks) are potential candidates to explain business cycles because most of those economies relate with the rest of the world through international trade and international financial markets. Hence, fluctuations in world prices are expected to affect domestic fluctuations to some extent. Similarly, a number of authors have suggested that risk premium shocks may matter for domestic fluctuations in emerging economies (Neumeyer and Perri, 2005; Uribe and Yue, 2006). Moreover, fluctuations in the risk premium offers an additional explanation for the higher volatility of the real interest rates faced by residents in emerging economies vis-à-vis residents in the developed world.

29Model based variance decomposition has become the common practice to assess the importance of shocks in driving business cycles fluctuations. For example, this is the approach of Smets and Wouters (1999), and Smetses and Wouters (2008), Lubik and Teo (2005), Schoferheide and Lubik (2007), among others.
1.4 The Remainder of the Study

The remainder of the study is structured as follows. In chapter 2 we present an empirical analysis using Brazilian data. First, we present statistics that summarize some stylized facts, then we present impulse response functions generated using a Bayesian structural vector autoregression model. Chapter 3 outlines the theoretical model used to assess the role of the 6 structural shocks in driving business cycle fluctuations in our benchmark economy. Chapter 4 discusses the econometric methodology used to estimate structural parameters in the model, while Chapter 5 presents the estimated parameters and also reports impulse responses and variance decomposition generated using our theoretical model. We also present the results for historical decompositions. In chapter 6 we present some additional results and discuss in more details some of our main results. We also provide some insights for future research. Chapter 7 concludes the study.
Chapter 2

Empirical Analysis

Before we present the model, it is important to assess the Brazilian data to establish some stylized facts that can help us to assess the extent to which our theoretical model is able to replicate these facts. First, we present some unconditional moments from the data, and then we report impulse responses functions from an estimated Bayesian structural vector autoregression using the Brazilian data. The data used covers the period from the third quarter of 1994 to the first quarter of 2008.

2.1 Business Cycles Moments

Table 2.1 reports unconditional sample moments obtained from the Brazilian data.
### Table 2.1: Business Cycles Properties

<table>
<thead>
<tr>
<th>Statistic</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Standard Deviation:</td>
<td></td>
</tr>
<tr>
<td>Output Growth</td>
<td>1.51%</td>
</tr>
<tr>
<td>Consumption Growth</td>
<td>3.68%</td>
</tr>
<tr>
<td>Investment Growth</td>
<td>5.9%</td>
</tr>
<tr>
<td>Trade Balance to Output ratio</td>
<td>2.49%</td>
</tr>
<tr>
<td>Real Interest Rates</td>
<td>1.08%</td>
</tr>
<tr>
<td>(b) Correlation of Output Growth with:</td>
<td></td>
</tr>
<tr>
<td>Consumption Growth</td>
<td>0.29</td>
</tr>
<tr>
<td>Investment Growth</td>
<td>0.63</td>
</tr>
<tr>
<td>Trade Balance to Output Ratio</td>
<td>0.17</td>
</tr>
<tr>
<td>(c) Correlation of Interest Rates with:</td>
<td></td>
</tr>
<tr>
<td>Output growth</td>
<td>-0.08</td>
</tr>
<tr>
<td>Consumption growth</td>
<td>0.05</td>
</tr>
<tr>
<td>Investment growth</td>
<td>-0.18</td>
</tr>
<tr>
<td>Trade Balance to Output ratio</td>
<td>-0.49</td>
</tr>
</tbody>
</table>

Note: Authors’ calculations. Unconditional sample moments computed using Brazilian data from the third quarter of 1994 to the first quarter of 2008. Growth rates are computed as the log (natural log) differences of the variables in levels. The variables are demeaned.

From the unconditional moments we can derive some facts about the Brazilian business cycles:

1. Real output is less volatile than real consumption and real investment, and the latter is the most volatile variable over the business cycles. The same facts are reported for several other authors when assessing emerging market economies (e.g., Neumeyer and Perri, 2005; Aguiar and Gopinath, 2007a).
2. The trade balance-to-output ratio is more volatile than real output.

3. Consumption, Investment and the trade balance-to-output ratio are procyclical, while the real interest rate is countercyclical.

Next we present some stylized facts derived from a Bayesian structural vector autoregression (VAR) using Brazilian data.

2.2 Bayesian Structural Vector Autoregression

2.2.1 Introduction

The analysis based on unconditional sample moments provides some insights about the relationship of aggregate variables in the Brazilian data. However, in order to better understand the dynamic relationships of the variables along the business cycles, the analysis of impulse response functions generated by a vector autoregression is equally appropriate. Since we want to give economic interpretation to our impulse response functions, we use a structural approach to define some stylized facts for the Brazilian data.

In this study we use a Bayesian approach to estimate a structural vector autoregressive model. The Bayesian approach appears to be superior when the data length is short and the VAR model is relatively large. In such situations the likelihood function tends to be ill behaved and, therefore, the parameters estimates are likely to be unreliable (Waggoner and Zha, 2003). To deal with this kind of problem, the Bayesian framework introduces prior information to down-weight models with large coefficients on distant lags or explosive dynamics.\(^1\) In the next subsection we discuss the identification scheme.

\(^1\)Litterman (1986) introduces a Bayesian prior distribution for reduced-form VARs, while Sims and Zha (1998) show how to implement the Bayesian prior in structural models.
2.2.2 Identification

Consider the following structural VAR model:

$$y_t' A = \sum_{i=1}^{p} y_{t-i}' A_i + \varepsilon_t' \quad \text{for} \quad 1 \leq t \leq T$$

(2.1)

where $y_t$ is a $n \times 1$ column vector of endogenous variables, $A$ is a $n \times n$ matrix of parameters, $A_i$ is a $n \times n$ matrix of parameters for $1 \leq l \leq p$, $\varepsilon_t$ is a $n \times 1$ column vector of structural disturbances, $p$ is the lag length, and $T$ is the sample size.

The distribution of $\varepsilon_t$, conditional on past information, is Gaussian with mean and covariance matrix given by $E(\varepsilon_t|y_1, ..., y_{t-1}) = 0_{n \times 1}$ and $E(\varepsilon_t\varepsilon_t'|y_1, ..., y_{t-1}) = I_{n \times n}$, respectively.

Let

$$z_t' = [y_{t-1}' ... y_{t-p}']$$

and

$$F' = [A_1 ... A_p]$$

where $z_t'$ is a $1 \times k$ matrix and $F'$ is a $n \times k$, where $k = np$. Given the definitions above, we can write the structural model in compact form as

$$y_t' A = z_{t-l}' F + \varepsilon_t'$$

(2.2)

The parameters of the structural model are $(A, F)$ and $A$ is assumed to be invertible. Right multiplying (2.2) by $A^{-1}$ we obtain the usual reduced-form representation implied by our structural model

$$y_t' = z_{t-l}' B + u_t'$$

The parameters of the structural model are $(A, F)$ and $A$ is assumed to be invertible. Right multiplying (2.2) by $A^{-1}$ we obtain the usual reduced-form representation implied by our structural model

$$y_t' = z_{t-l}' B + u_t'$$

---

2 In our model we have 10 endogenous variables, $n = 10$, and we use 5 lags, $p = 5$, thus $k = 50$. 
where $B = FA^{-1}, u'_t = \varepsilon'_t A^{-1}$, and $E[u'_t u'_t'] = \Omega = (AA')^{-1}$ is the reduced-form variance-covariance matrix.

The vector $y_t$ is composed of two blocks of variables. A foreign block composed of $[\Delta y_{t}^{us}, (1 + r_t^{us}), tot_t]$ and a domestic block composed of $[\Delta g_t, \Delta y_t, \Delta i_t, tby_t, (1 + r_t), \Delta p_t, \Delta rer_t]$, where $\Delta y_{t}^{us}$ is the growth rate of world output, $(1 + r_t^{us})$ is the gross international real interest rate, $tot_t$ denotes the terms of trade (the ratio of export prices to import prices), $\Delta g_t$ is the growth rate of government expenditure, $\Delta y_t$ denotes the growth rate of real domestic output, $\Delta i_t$ denotes the growth rate of real domestic investment, $tby_t$ is the trade balance-to-output ratio, $(1 + r_t)$ denotes the gross real domestic interest rate, $\Delta p_t$ denotes the growth rate of domestic prices and, finally, $\Delta rer_t$ denotes the growth rate of the real exchange rate in Brazil.\textsuperscript{3}

Given the two blocks of variables the issue is how to treat the relationship between them. Our baseline assumption is that the Brazilian economy is small with respect to the world economy. (We use the U.S. economy as a proxy for the world economy). This implies that variables determined in the rest of the world are not affected by domestic variables developments either contemporaneously or in lags. This assumption will imply the imposition of a block recursive structure in our VAR model. Recent papers that impose block recursive structure when modelling VAR’s in small open economy environments include: Cushman and Zha (1997), Zha (1999), Hoffmaister and Roldós (2001), Canova (2005), Uribe and Yue (2006), Mackowiak (2007), and Bhuiyan (2008).\textsuperscript{4}

\textsuperscript{3}In choosing the variables to be included in our empirical model, we focus on variables that will be assessed in the theoretical model. The exemption is the U.S. output and inflation, which are not included in the theoretical model. We use variables in first differences because in our theoretical model we assume that some variables contain a stochastic trend in equilibrium. As we do not know the process for this stochastic trend, we use growth rates in our measurement equation (Kalman Filter).

\textsuperscript{4}Both Canova (2005) and Uribe and Yue (2006) do not use the Bayesian framework as we use here. Canova (2005) breaks the estimation in two steps. First he estimates a reduced form VAR for US variables (exogenous variables in his framework) and then he estimates a structural VAR for Latin American countries, taking as exogenous the estimated US shocks. Uribe and Yue (2006) also imposes a block recursive structure in their panel VAR for 6 emerging economies: Argentina, Brazil, Ecuador, Mexico, Peru, Philippines, and South Africa. In their case, they impose that the process for the
Some authors have pointed out that the failure to impose the small open economy restriction (block recursive structure) may result in misleading conclusions. For instance, Zha (1999) shows that in an estimated model for the Canadian economy without imposing the block recursive structure, Canadian shocks contribute 67% to fluctuations in the U.S. interest rate, 62% in the U.S. general price level, and 45% in the U.S. output in a 4 year horizon. Clearly, as he points out, these results are at odds with the actual relationship between the U.S. and the Canadian economy. We impose the same block recursive structure in our structural model (Small Open Economy - SOE assumption) for the Brazilian economy.\textsuperscript{5}

To understand the implications of the block recursive structure, consider our model in matrix notation

$$
\begin{bmatrix}
A_{11} & A_{12} \\
A_{21} & A_{22}
\end{bmatrix}
\begin{bmatrix}
w_t \\
x_t
\end{bmatrix} =
\begin{bmatrix}
F_{11}(l) & F_{12}(l) \\
F_{21}(l) & F_{22}(l)
\end{bmatrix}
\begin{bmatrix}
w_{t-l} \\
x_{t-l}
\end{bmatrix} + C\xi
$$

where $w_t = [\Delta y^u_t, (1+r^u_t), tot_t]$ collects the foreign block and $x_t = [\Delta y_t, \Delta i_t, tby_t, (1+r_t), \Delta p_t, \Delta rer_t]$ collects the variables of the domestic block. The block recursive structure (SOE assumption) implies $A_{12} = 0$ and $F_{12} = 0$. In other words, foreign variables are assumed to be determined independently either contemporaneously or in lags of domestic

\textsuperscript{5}We also estimated a VAR model without imposing the small open economy restriction and found that domestic Brazilian shocks (government expenditure shock, output shock, investment shock, trade balance to output shock) end up affecting U.S. variables, which we think does not reflect the relationship between these two economies. As Canova (2005) points out, the relationship between the U.S. and Latin American economies (Brazil included) is unidirectional. This is the same argument used by Hoffmaister and Roldós (2001) to impose the block recursive structure for their structural VAR model for Brazil and Korea using U.S. variables as proxy for the rest of the world. We implement a posterior odds ratio to assess if the model with the block recursive structure is better supported by the data vis-à-vis a model without the block recursive structure. The result shows that the data favors the VAR with the block recursive structure. To compute the marginal likelihood of the data we use the algorithm proposed by Chibb (1995).
variables. Thus our system becomes

\[
\begin{bmatrix}
A_{11} & 0 \\
A_{21} & A_{22}
\end{bmatrix}
\begin{bmatrix}
w_t \\
x_t
\end{bmatrix} =
\begin{bmatrix}
F_{11}(l) & 0 \\
F_{21}(l) & F_{22}(l)
\end{bmatrix}
\begin{bmatrix}
w_{t-l} \\
x_{t-l}
\end{bmatrix} + C\xi
\]

To complete our identification scheme we assume that the foreign block, \(A_{11}\), and the domestic block, \(A_{22}\), are both lower triangular, with the ordering defined as above. \(C\) is assumed to be an identity matrix and \(\xi\) is a vector of exogenous disturbances. No further restrictions are imposed on the remaining matrices.\(^6\)

### 2.2.3 Data set

The data covers the period from the third quarter of 1994 to the first quarter of 2008. Growth rates are computed as log differences of the respective variables in levels, while the gross interest rates and the terms of trade are logged. National account real variables are obtained by dividing the corresponding nominal value by the GDP deflator. For the US GDP we use the US GDP deflator and obtain the per capita variable by dividing the real US GDP by the labor force. For Brazil we use the Brazilian GDP deflator and obtain per capita variables by dividing the real GDP, real government expenditures, real investment by occupied population in Metropolitan areas from Instituto Brasileiro de Geografia e Estatística (IBGE). National account variables are seasonally adjusted using the Census X-12 method. All variables are demeaned prior to estimation.

The international interest rate, \(r_t^{us}\), is identified here as the gross U.S. 3-month T-bill rate. The domestic gross interest rate is computed as \(1 + r_t = (1 + r_t^{us}).(1 + s_t)\), where \(s_t\) is the Emerging Market Bond Index (EMBI+) for Brazil from JP Morgan. This

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\(^6\)This gives us 45 restrictions, and hence we have an exactly identified system. Our model satisfies not just the conditions for local identification (Rothenberg’s order condition), but also the requirements for global identification as established in Theorem 7 of Rubio-Ramírez, Waggoner and Zha (2008). See their paper for examples of SVAR models that are locally identified, but fail to be globally identified.
variable measures the difference between the Brazilian T-bill rate (in US$) and the US T-bill rate. The domestic interest rate denotes the cost of borrowing faced by Brazilian residents in international markets and is meant to capture the role of external financial factors on domestic macroeconomic developments in emerging economies, which it will be our focus in the theoretical analysis. The domestic and the world real interest rates are 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.  

The real exchange rate, $rer_t$, is computed as the ratio between the product of the nominal exchange rate (the price of foreign currency in terms of domestic currency), $e_t$, times the foreign price index, $P^{US}$, and the domestic price index, $P^{BR}$, i.e., $rer_t = e_t \frac{P^{US}}{P^{BR}}$. Hence an increase (depreciation) in the real exchange rate means a gain in domestic competitiveness. The terms of trade is defined as the ratio between the price of exports (in US$) and the price of imports (in US$).

The nominal national account variables, CPI, 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 nominal exchange rate is the end of the period market rates from Brazilian Central Bank (BCB), available at IPEADATA. The Brazilian quarterly GDP deflator is obtained by dividing the GDP nominal index by the GDP chained volume index from Instituto Brasileiro de Geografia e Estatística (IBGE).

### 2.2.4 Estimation

We estimate the model using the Gibbs sampler for Bayesian inference of structural VAR models developed by Waggoner and Zha (2003). An important advantage of this sampler is that it can be applied to situations where the variance-covariance matrix of

---

7 Using current inflation as a proxy for expected inflation does not alter the results.
residuals, $\Omega = (AA')^{-1}$, is both unrestricted (as is the case in exactly identified VARs) or restricted (overidentified VARs).\footnote{In the unrestricted case, one can also use the importance sampler popularized by Doan (1992) to make draws from the posterior distribution of $\Omega$ and then recover the parameters of $A$ (see Cushman and Zha, 1997; Mackowiak, 2007; among many others). However, in the restricted case, the posterior density tends to be non-Gaussian making the use of the importance sampler inefficient. Waggoner and Zha (2003) show that the inference based on the importance sampler in cases where $\Omega$ is restricted can be misleading. The Gibbs sampler developed by Waggoner and Zha (2003) can be applied in both cases.} To understand how the Gibbs sampler works, consider our structural system in its compact form

$$y_t' A = z_{t-1}' F + \varepsilon_t'$$

Let $a_i$ be the $i$th column of the matrix $A$, and $f_i$ be the $i$th column of the lagged coefficient matrix $F$, where $1 \leq i \leq n$. Now let $Q_i$ be any $n \times n$ matrix of rank $q_i$, and $R_i$ be any $k \times k$ matrix of rank $r_i$.\footnote{The presentation here draws heavily from Waggoner and Zha (2003).} The linear restrictions on the contemporaneous matrix $A$ and on the lagged-coefficient matrix $F$ in our structural system can be summarized as follows:

$$Q_i a_i = 0, \quad i = 1, \ldots, n. \quad (2.3)$$

$$R_i f_i = 0, \quad i = 1, \ldots, n. \quad (2.4)$$

Besides linear restrictions, the Bayesian framework also introduces prior information about the parameters $a_i$ and $f_i$ to deal with the dimensionality problem that arises in typical SVAR models estimation (Litterman, 1986; Sims and Zha, 1998). We follow Sims and Zha (1998) in defining priors over $a_i$ and $f_i$ which are given by

$$a_i \sim N(0, S_i) \text{ and } f_i | a_i \sim N(P_i a_i, H_i) \quad (2.5)$$

where $S_i$ is a $n \times n$ symmetric, positive definite matrix, $H_i$ is a $k \times k$ symmetric, positive definite matrix.

$$\begin{align*}
\text{Let } a_i = \begin{bmatrix} a_{i1} \\ a_{i2} \\ \vdots \\ a_{in} \end{bmatrix}, \quad \text{and } f_i = \begin{bmatrix} f_{i1} \\ f_{i2} \\ \vdots \\ f_{ik} \end{bmatrix}.
\end{align*}$$

$$\begin{align*}
\text{Then } Q_i a_i = 0 & \Rightarrow a_i = Q_i^{-1} z_{t-1}' F + Q_i^{-1} \varepsilon_t' \quad (2.3) \\
R_i f_i = 0 & \Rightarrow f_i = R_i^{-1} z_{t-1}' F + R_i^{-1} \varepsilon_t' \quad (2.4)
\end{align*}$$

43
definite matrix and \( P_i \) is a \( n \times n \) matrix. Restrictions are imposed on \( S_i, H_i, \) and \( P_i \) to reflect Litterman’s (1986) original random walk idea.\(^\text{10}\)

Combining the linear restrictions (2.3) and (2.4), with the prior information (2.5), we want to obtain a functional form for the conditional prior distribution of the parameters

\[
\Phi(a_i, f_i | Q_i a_i = 0; R_i f_i = 0) \tag{2.6}
\]

Assume there exists a non-degenerate solution to the problem (2.3) and (2.4). Let \( U_i \) be an \( n \times q_i \) whose columns form an orthonormal basis for the null space of \( Q_i \) and let \( V_i \) be an \( k \times r_i \) matrix whose columns form an orthonormal basis for the null space of \( R_i \). Therefore, the columns \( a_i \) and \( f_i \) will satisfy the restrictions (2.3) and (2.4) if and only if there exist a \( q_i \times 1 \) vector \( b_i \) and \( r_i \times 1 \) vector \( g_i \) such that

\[
a_i = U_i b_i \tag{2.7}
\]

\[
f_i = V_i g_i \tag{2.8}
\]

Waggoner and Zha (2003) show that the prior distributions of \( b_i \) and \( g_i \) are given respectively by

\[
b_i \sim N(0, \mathbf{S}_i) \text{ and } g_i | b_i \sim N(\mathbf{P}_i b_i, \mathbf{H}_i) \tag{2.9}
\]

The prior distributions (2.9) for \( b_i \) and \( g_i \) are equivalent to the prior distribution (2.6) for \( a_i \) and \( f_i \), where the original parameters \( a_i \) and \( f_i \) can be recovered through the linear transformations \( U_i \) and \( V_i \). Combining the prior distribution with the likelihood function for \( b_i \) and \( g_i \), and using Bayes’ rule, we obtain a joint posterior probability distribution

\(^{10}\text{Litterman’s (1986) prior (Minnesota prior) for a reduced-form VAR reflects the idea that a random-walk model for each variable in the system is a reasonable center for the beliefs regarding the behavior of the variables. Sims and Zha (1998) show how to incorporate Litterman’s (1986) random walk idea into a structural framework. See Sims and Zha (1998) and Sims (1999) for a more detailed discussion.}
function of \( b \) and \( g \)

\[
p(b_1, ..., b_n|Z, Y) \prod_{i=1}^{n} p(g_i|b_i, Z, Y) \tag{2.10}
\]

where \( p(b_1, ..., b_n|Z, Y) \) is the marginal posterior distribution of \( b \) and \( p(g_i|b_i, Z, Y) \) is the conditional posterior distribution of \( g \).

The posterior distribution of \( b \) and \( g \) is non-standard, hence, to obtain inferences on these parameters (and its functions) we need to simulate the joint posterior distribution. The Gibbs sampler is a technique that generates an irreducible aperiodic Markov chain that has as its stationary distribution our target distribution (the non-standard posterior distribution of the parameters).

Waggoner and Zha (2003) show that the simulation of the posterior involves two steps. First, we simulate draws of \( b \) from its marginal posterior distribution \( p(b_1, ..., b_n|Z, Y) \). And then, given each draw of \( b \), we simulate \( g \) from its conditional posterior distribution \( p(g_i|b_i, Z, Y) \). Once we have the draws of \( b \) and \( g \), we can make inferences about the structural parameters and compute any function of interest, e.g., impulse responses. In the next subsection we present the results for impulse response functions using the Gibbs sampler developed by Waggoner and Zha (2003).

### 2.2.5 Empirical Results

For the purposes of this study, we focus attention on the dynamic responses of endogenous (domestic) variables to some of the structural shocks. In particular, we are interested in how output, investment, the trade balance-to-output ratio, the real interest rate, inflation and real exchange rate respond to shocks to the U.S. real output, to the U.S. real interest rate, to the terms of trade, to government expenditures, to domestic output, to domestic real interest rate, and to domestic inflation. In what follows, we present the impulse responses derived from our structural model.
U.S. Real output shock

Figure 2.1 plots the responses of our domestic variables to one standard deviation shock to the U.S. real output growth. After one standard deviation shock in the U.S. real output growth, domestic output and investment increase, while the trade balance-to-output ratio declines. The real interest rate increases after several quarters of the shock.

Figure 2.1: Bayesian IRF - U.S. Real Output Shock. Note: The solid line corresponds to one standard deviation shock. The shaded region corresponds to one standard error bands computed using the algorithm of Sims and Zha (1999).
U.S. Real Interest Rate Shock

Figure 2.2 plots the responses of our domestic variables to one standard deviation shock to the U.S. real interest rate. The impacts of one standard deviation shock in the U.S. real interest rate appear to be small on most of the domestic variables. The trade balance-to-output ratio declines and remains low for several quarters after the shock, eventually returning to the long run equilibrium level. The domestic real interest rate increases following the U.S. real interest rate shock.

Figure 2.2: Bayesian IRF- U.S. Real Interest Rate Shock. Note: The solid line corresponds to one standard deviation shock. The shaded region corresponds to one standard error bands computed using the algorithm of Sims and Zha (1999).
Terms of Trade Shock

Figure 2.3 plots the responses of our domestic variables to one standard deviation shock to the terms of trade. On impact, the response of output is nil followed by a small decline shortly after the shock takes place. The impacts of terms of trade shocks on the remaining variables are quite small.

Figure 2.3: Bayesian IRF - Terms of Trade Shock. Note: The solid line corresponds to one standard deviation shock. The shaded region corresponds to one standard error bands computed using the algorithm of Sims and Zha (1999).
Government Expenditure Shock

Figure 2.4 depicts the dynamic responses of aggregate variables to one standard deviation shock to government expenditure. On impact, output increases and then declines shortly after the shock. Investment does not change on impact, but it declines in the quarters following the shock. Both the trade balance-to-output ratio and the real interest rate decline after the shock.

Figure 2.4: Bayesian IRF- Government Expenditure Shock. Note: The solid line corresponds to one standard deviation shock. The shaded region corresponds to one standard error bands computed using the algorithm of Sims and Zha (1999).
Domestic Real Output Shock

Figure 2.5 shows the responses of domestic variables to one standard deviation shock to domestic output growth. Investment increases on impact following the increase in output and its dynamics is similar to that of output. There is a fairly small increase in inflation in quarters following the output shock.

Figure 2.5: Bayesian IRF - Domestic Output Shock. Note: The solid line corresponds to one standard deviation shock. The shaded region corresponds to one standard error bands computed using the algorithm of Sims and Zha (1999).
**Domestic Real Interest Rate Shock**

Figure 2.6 shows that after one standard deviation shock to the domestic real interest rate, domestic output and investment decline after a few quarters and remain below the equilibrium level for some period eventually returning to the initial level. The trade balance-to-output ratio increases, as does inflation and the real exchange rate.

![Graphs showing output growth, investment growth, trade balance, inflation, and real exchange rate](image)

**Figure 2.6:** Bayesian IRF - Domestic Real Interest Rate Shock. Note: The solid line corresponds to one standard deviation shock. The shaded region corresponds to one standard error bands computed using the algorithm of Sims and Zha (1999).
Inflation Shock

The inflation shock does not appear to matter for domestic variables. Figure 2.7 shows that the responses of output growth, investment growth, the trade balance-to-output ratio, and real interest rate are not significantly different from zero after one standard deviation shock to inflation. The only variable that appears to be responsive to the inflation shock is the real exchange rate, which declines after a few quarters, but it rapidly returns to its equilibrium level.

![Inflation Shock](image)

Figure 2.7: Bayesian IRF - Inflation Shock. Note: The solid line corresponds to one standard deviation shock. The shaded region corresponds to one standard error bands computed using the algorithm of Sims and Zha (1999).

In sum, the results from the impulse responses allow us to established a few stylized facts for the Brazilian data over the period from the third quarter of 1994 to the first quarter of 2008.

1. Output growth seems to be more responsive to its own shock, followed by shocks to the U.S. output and to the domestic real interest rate.
2. Shocks to the world real interest rate appear to have little impact on the behavior of domestic variables, with the exception of the domestic real interest rate.

3. After a domestic real interest rate shock, output and investment decline and then return to their long-run equilibrium.

4. Output first increases and then declines after a government expenditure shock. The response of investment is nil on impact, then it declines shortly after the shock takes place.

5. Inflation shock does not seem to have a first order importance on domestic fluctuations.
Chapter 3

Model

3.1 Introduction

In chapter 1 we have pointed out that the literature focusing on emerging market business cycles is relatively new and one characteristic of this literature is the attempt to find sources of fluctuations that can account for the distinctive characteristics of business cycles in emerging economies vis-a-vis developed economies. As we have shown, in this effort, the literature has proposed different alternatives, however, the analyses in the literature lack one approach that can evaluate all those alternative explanations within the same theoretical framework.

We believe that this is important because when different sources of fluctuations are analyzed in different theoretical frameworks, the results are not comparable across models and they also may be misleading, i.e., the explanatory power of one shock in one particular framework may be due to omitted shocks. Hence, in our perspective, an important and necessary step to further understand and somehow to reconcile different explanations for business cycles in emerging economies consists in implementing an integrated analysis that can incorporate all the relevant shocks into the same theoretical framework. This is what our theoretical model attempts to accomplish. At the same time, we want to evaluate the extent that our simple model is able to explain features of the business cycles
in our emerging economy benchmark. This is also important because it can generate insights for future formulations that can do better at explaining the facts that our model is unable to reproduce.

The theoretical framework is a two-good one-sector small open economy model based on Mendoza (1991) where the only asset traded in international financial markets is a non-contingent real bond. Our model features six driving forces that encompasses recent approach undertaken in the related literature. The driving forces are: permanent and transitory productivity shocks, terms of trade shocks, world real interest rate shocks, risk premium shocks, and government expenditure shocks.

Households choose consumption and labor supply to maximize a lifetime utility subject to a budget constraint. They access international financial markets in order to smooth consumption over time. Firms are competitive and hire labor and capital to produce a final good according to a production technology. The production technology available for domestic firms is subject to temporary productivity shocks as well as permanent (labor augmented) productivity shocks.

We introduce terms of trade by assuming that consumption and investment goods are composites of domestically and internationally produced final goods. As both goods are tradable in international goods markets, the terms of trade is defined as the ratio between the price of the domestically produced good to the price of the foreign good, which in our model is used as the *numeraire*. Hence, fluctuations in the price of the domestically produced good reflect fluctuations in the terms of trade.\(^1\)

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\(^1\) An alternative way of introducing terms of trade would be in a multi-sector model, e.g., a model with a tradable sector featuring exportable and importable goods, and a non-tradable sector. In that model the terms of trade would be defined as the ratio between the price of exportable goods to the price of importable goods. The presence of a non-tradable sector offers, for example, an explanation for the Balassa-Samuelson observation that rich countries tend to display higher real exchange rates as compared with poor countries. The Harrod-Balassa-Samuelson Effect is the tendency of countries with higher productivity in the tradable sector to present increasing real exchange rates. See Obstfeld and Rogoff (1995, chapter 4) for a detailed discussion. It is important to keep in perspective that our theoretical model does not attempt to provide a complete (or even partial) explanation to real exchange rate movements. This task is beyond the scope of this work. Recent research has shown that RBC
Real interest rate plays two roles in our model. First, it reflects the intertemporal price of consumption affecting the household’s consumption-saving decision. Second, it represents an additional cost for domestic firms as they are subject to a working capital constraint whereby firms have to borrow a fraction of total labor payments in advance before cashing their sales. This feature introduces a direct channel through which financial shocks affect the supply side of the economy. Some authors (Neumeyer and Perri, 2005; Uribe and Yue, 2006) argue that this constraint allows the model to produce more realistic relationship between domestic output and real interest rate, in particular, the negative correlation between these two variables. We will assess the importance of this constraint in our model simulations.

As in the related small open economy literature, based on the Real Business Cycle formulation, we abstract from monetary developments. This is the approach undertaken, for example, by Mendoza (1991), Mendoza (1995), Kose (2002), Lubik and Teo (2005), Neumeyer and Perri (2005), Uribe and Yue (2006), Aguiar and Gopinath (2007) to mention a few. Implicitly we assume that the monetary authority set the nominal anchor such that nominal prices are stable. This simplifying assumption allow us to focus only on the real sources of aggregate fluctuations in emerging market economies.²

3.2 Firms

3.2.1 Technology

The economy is constituted of 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 models coupled with nominal and real frictions are better suited for such task. (For a recent survey see Obstfeld, 2001; and Lane, 2001).

²The initial idea was to write a model that could encompass recent contributions in one same framework while remaining as comparable as possible with the strand of the literature that focus on emerging market business cycles.
technology

\[ Y_t = z_t K_t^{1-\alpha} (\Gamma_t l_t)^{\alpha} \]  

(3.1)

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 two productivity processes \( z_t \) and \( \Gamma_t \) that differ from each other with respect to their time series properties. \( z_t \) represents a stationary process and \( \Gamma_t \) corresponds to the level of the labor augmented technical progress. Thus \( \Gamma_t l_t \) represents units of effective labor. \( \Gamma_t \) is defined as

\[ \Gamma_t = a_t \Gamma_{t-1} = \prod_{j=0}^{t} a_j \]

where \( a_t \) is the gross growth rate of \( \Gamma_t \), and \( \Gamma_{-1} = 1 \).\(^3\) Shocks to the growth rate, \( a_t \), shift the level of productivity permanently and thus the long-run growth rate of the economy. We shall refer to shocks to \( a_t \) as growth shocks hereafter. We will describe the processes for \( z_t \) and \( a_t \) later.

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.

3.2.2 The timing and Optimization Problem

The timing in the model is as follows: at the beginning of the period \( t \), firms hire labor and capital, and use them to produce a 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 make labor payments, firms are required to borrow working capital at the beginning

\(^3\)One straightforward interpretation of \( \Gamma_t \) is that it denotes the cumulative product of growth shocks that have happened up to the current period.
of each period. Alternatively, this working capital constraint (financial friction) can be thought as a cash-in-advance constraint in production whereby firms pay in advance for part of the labor services. Hence, in order to make labor payments of the order $W_t l_t$, firms need to hold a fraction $\mu$ of it along the production process. 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 (the 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 end-of-period payments. An amount $(1 + r_{t-1})\mu W_t l_t$ is used to repay the initial loan plus interest, $W_t l_t$ is used to pay for labor services, 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 ($\Pi_t$)

$$\Pi_t = p_{h,t} Y_t - W_t l_t - u_t K_t - \mu r_{t-1} W_t l_t$$

(3.2)

or alternatively

$$\Pi_t = p_{h,t} Y_t - u_t K_t - [1 + \mu r_{t-1}] W_t l_t$$

subject to the technology constraint (3.1) and given the price of the home produced good $p_{h,t}$, the real wage, $W_t$, the real interest rate, $r_{t-1}$, and the capital rental rate, $u_t$. The relative prices $p_{h,t}, W_t, r_{t-1}, u_t$ are expressed in terms of the foreign good, which is used as the numeraire.4

4The numeraire is typically either a currency, e.g., dollars, or a good. As our model abstracts from nominal developments and nominal rigidities, and focuses on real variables only, we use a (tradable) good as our unit of measure, i.e., numeraire. Hence prices in our model are relative prices in terms of the foreign good. Mendoza (1995) uses the price of importable good as the numeraire, while Kose (2002) uses the price of imported capital goods as the numeraire. See Obstfeld and Rogoff (1995, Chapter 4) for a brief discussion about the numeraire.
The first order conditions for the firm’s optimization problem are:

\[(1 - \alpha)z_t K_t^{-\alpha} \Gamma_t^\alpha = u_t\]

\[\alpha z_t K_t^{1-\alpha} \Gamma_t^{\alpha - 1} = [1 + \mu r_{t-1}] W_t\]

or alternatively

\[(1 - \alpha) = \frac{u_t K_t}{p_{h,t} Y_t} \quad (3.3)\]

\[\alpha = [1 + \mu r_{t-1}] \frac{W_d l_t}{p_{h,t} Y_t} \quad (3.4)\]

These first order conditions imply that the shares of capital and labor in total income is constant and equal to \((1 - \alpha)\) and \(\alpha\), respectively.\(^5\)

Notice that in the absence of a working capital constraint, i.e., \(\mu = 0\), the standard condition between the real wage and the marginal productivity of labor is obtained. Therefore, the presence of the working capital constraint drives a wedge between the real wage and the marginal productivity of labor. Under this constraint, an increase in the real interest rate increases the firm’s effective cost of hiring labor, which, \textit{ceteris paribus}, reduces the labor demand.

The working capital constraint is typically introduced (e.g., Neumeyer and Perri, 2005; Kanczuk, 2005; Uribe and Yue, 2006) to allow SOE-RBC models to generate countercyclical real interest rates. In particular, Neumeyer and Perri (2005) show that without a working capital constraint their model fails to generate (highly) countercyclical real interest rates, which appears to be the case for emerging economies.\(^6\) The empirical

\(^5\)Conditions (3.3) and (3.4) imply that in steady-state the marginal productivity of capital and the marginal productivity of labor input in efficiency units are constant (King, Plosser and Rebelo, 1988).

\(^6\) Notice however that the model is still able to generate output drops following real interest rate spikes. We will discuss this aspect later. Christiano, Eichenbaum and Evans (2005) use working capital constraint in order for their New Neoclassical Synthesis model to generate inflation declines after a
analysis in chapter 2 has shown that the real interest rate is countercyclical and hence we introduce a working capital constraint to help our model in generating a negative correlation between real output and the real interest rate.

Although this constraint is included to allow the model to replicate features of real economies, it is interesting to discuss briefly its reasonableness. In practice, firms need to borrow working capital every time their current level of assets (cash, accounts receivable and inventory) fall short their short-term liabilities (which also include things other than labor payments). Moreover, money that is tied up in inventory or money that customers still owe to the company cannot be used to pay off any of the firms’ obligations. Hence, firms have to rely on internal capital, bank financing, credit cards, government funds, and other sources of funding to meet their short-term obligations. In our model, this fact is translated in the firms’ need to hold a fraction of their wages’ bill along the production process.

3.3 Households

3.3.1 Preferences

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

\[
E_0 \sum_{t=0}^{\infty} \beta^t \frac{[C_t - \nu \Gamma_{t-1} h_t^\psi]^{1-\psi} - 1}{1 - \psi}
\]

where \( C_t \) denotes composite consumption in period \( t \), \( h_t \) hours supplied by the household in period \( t \), and \( \psi > 0 \) defines the curvature of the utility function. This functional form was first introduced by Grenwood, 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, monetary policy shock.)
among others). The Grenwood, Hercowitz, and Huffman (GHH) preference specification is particularly useful, in small open economy models, because it improves the volatility of hours, the correlation between hours and output, and makes the behavior of consumption closer to the data.

The inclusion of cumulative growth $\Gamma_{t-1}$ into the 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 (or alternatively the marginal utility of leisure increases along with technological progress). As pointed out by Aguiar and Gopinath (2007) such formulation can be motivated as a reduced form utility function of a model with home production activities (or non-market activities), where the productivity in the home sector grows at the same rate (with a lag) as the market sector.\(^7\) Appendix F presents a basic home production model based on the work of Benhabib, Rogerson and Wright (1991) that motivates such reduced form utility function.\(^8\)

In a model with GHH preferences and sustained growth in productivity as ours, in order for the model to exhibit a balanced growth path, the disutility of work must increase with the level of technical progress. Absent this feature, the substitution effect of changes in real wages associated with sustained growth in productivity will lead to unbounded growth in hours worked. As pointed out by King, Plosser and Rebelo (2002) as time is bounded, it cannot grow in steady state. Hence the form of the momentary utility function "must be such that there are exactly offsetting income and substitution effects of the changes in real wages associated with sustained growth in productivity" (p.95).\(^9\)

\(^7\)Benhabib et al (1991) show that momentary utility functions as the one represented by (3.5) are observationally equivalent to an utility function that defines preferences over market and nonmarket components.

\(^8\)The derivation in the appendix drives heavily from Benhabib, Rogerson and Wright (1991).

\(^9\)In a more technical perspective, the absence of cumulative growth in the utility function in a model with GHH preferences and sustained productivity growth would imply equilibrium conditions (first order conditions) that are non-stationary as some variables exhibits a trend in equilibrium. Moreover, as cumulative growth is a stochastic process, this would imply that our typical solution method of log-linearizing equilibrium conditions around the non-stochastic steady state would not be longer available.
As we will discuss later, when we present the first order conditions for the household problem, the distinctive feature of GHH preferences is that under these preferences labor supply depends solely on the real wage (which in a competitive model equals the marginal productivity of labor). Given the pro-cyclical nature of the real wage, labor supply will be highly procyclical. Thus the inclusion of cumulative growth guarantees that our model exhibits a balanced growth, i.e., the substitution effect due to higher real wages associated with higher productivity is offset by an increasing marginal disutility of work (or alternatively an increasing marginal utility of leisure) as technical progress increases. One can easily show that in the preference specification above the marginal disutility of work (marginal utility of leisure) is decreasing (increasing) with cumulative growth $\Gamma_{t-1}$.

Ramey and Francis (2006) show that over almost a century, despite the steadily increase in productivity in market and nonmarket activities, hours worked in market activities are relatively stable with a slightly decline in the last part of the 20th century, which they argue it can be associated with an increase in the time spent in school. Moreover, they show that time spent in leisure has been quite stable and the average hours worked at home is a little bit higher than it was in the early parts of the 20th century. Therefore, the implications of our model are in line with the stylized facts reported by Ramey and Francis (2006) as well as the idea of a balanced growth path as emphasized by King, Plosser and Rebelo (2002) among others.

### 3.3.2 Budget Constraint

Households supply labor and capital in competitive markets, which are used by domestic firms to produce a final good. Households receive labor payments, capital rental services payments, receive (pay) lump-sum transfers (taxes), and make consumption and investment decisions. Domestic residents can buy and sell a non-state contingent foreign bond in the international markets with each bond delivering a unit of foreign consumption good in the next period.
The household’s budget constraint expressed in terms of the *numeraire* is given by:

\[ p_{c,t}C_t + p_{c,t}I_t + \Omega(D_t) + T_t + (1 + r_{t-1})D_{t-1} \leq D_t + W_t h_t + u_t K_t \]  \hfill (3.6)

where \( p_{c,t} \) is the relative price of consumption goods in terms of foreign goods (*numeraire*), \( I_t \) denotes aggregate investment, \( D_t \) denotes bonds that are traded by the household in the international market and are denominated in terms of foreign consumption goods, \( T_t \) denotes lump-sum taxes/transfers, \( (1 + r_{t-1}) \) denotes the gross real interest rate faced by domestic agents, and \( \Omega(D_t) \) is the bond adjustment cost function. This function is a convex function that has the property \( \Omega(\tilde{d}) = \Omega'(\tilde{d}) = 0 \), for some \( \tilde{d} > 0 \). This device is introduced with the only purpose of inducing stationarity in the euler equation associated with bonds holdings. \(^{10}\) The functional form of \( \Omega(D_t) \) is given by:

\[ \Omega(D_{t+1}) = \frac{\varphi}{2} \left( \frac{D_{t+1}}{p_{h,t} Y_t} - \bar{d} \right)^2 p_{h,t} Y_t \]

where \( \bar{d} \equiv \frac{d_{ss}}{p_{h,ss}} \) and \( d_{ss} \) is the steady-state debt-to-output ratio, and \( p_{h,ss} \) is the terms of trade in steady state. To rule out Ponzi schemes in international financial markets, we assume that the following condition holds at all time:

\[ \lim_{j \to -\infty} E_t \left[ \frac{D_{t+j}}{\Pi_{s=0}^{j}(1 + r_s)} \right] = 0 \]

This condition excludes the possibility that the domestic household borrows any initial large amount and finances interest rate payments with further borrowing, and never repays the initial debt.

---

\(^{10}\) A typical RBC model exhibits log-linearized equilibrium dynamics that are not stationary, thus we introduce this term to guarantee stationarity. Schmitt-Grohé and Uribe (2003) present similar devices to induce stationarity and they show that all of them yield similar dynamics at business cycle frequencies.
The stock of physical capital accumulates according to

\[ K_{t+1} = I_t + (1 - \delta)K_t - \Phi(K_{t+1} - K_t) \]  

(3.7)

where \( \delta \in (0, 1) \) represents the depreciation rate. The last term represents quadratic capital adjustment costs, which are 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 rate is exactly equal to the marginal productivity of capital net of depreciation. The functional form for the capital adjustment cost is given by

\[ \Phi(K_{t+1} - K_t) = \frac{\phi}{2} \left( \frac{K_{t+1}}{K_t} - \overline{\pi} \right)^2 K_t \]

where \( \overline{\pi} \) is the long run (gross) growth rate of the economy.

### 3.3.3 Consumption, Investment, the Terms of Trade and the Real Exchange Rate

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

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

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

where \( C_{h,t} \) is consumption of domestic produced goods and \( C_{f,t} \) is consumption of foreign produced goods. Similarly, \( I_{h,t} \) and \( I_{f,t} \) denote investment goods produced in the domestic and foreign economy, respectively. \( \gamma \) represents the share of foreign goods in the aggregate consumption and, for simplicity, we assume the same share holds for investment goods.
Without loss of generality, we assume that the representative household solves a optimization sub-problem (expenditure minimization problem) from which we can derive the optimal shares of foreign and domestic goods in the composite goods. They are given by

\[ C_{f,t} = \gamma (p_h)^{1-\gamma} C_t \]

\[ C_{h,t} = (1 - \gamma) (1/p_h)^{\gamma} C_t \]

The variable \( p_h \) is the relative price of home produced goods in terms of foreign goods, which is used as the \textit{numeraire}. Similarly, the optimal shares of foreign and domestic goods in the composite investment good are given by

\[ I_{f,t} = \gamma (p_h)^{1-\gamma} I_t \]

\[ I_{h,t} = (1 - \gamma) (1/p_h)^{\gamma} I_t \]

Given the optimal choices of foreign and domestic goods, the consumption based price index is obtained by plugging these optimal choices into the expenditure function. From that, we can derive our measure of the domestic (consumption based) price index in terms of the \textit{numeraire} as

\[ p_{c,t} = p_{h,t}^{1-\gamma} \]

Since the foreign good is used as the \textit{numeraire}, \( p_h \) denotes the relative price of domestic good in terms of the foreign good, which corresponds to the terms of trade in our model, i.e., \( tot_t = p_{h,t}. \)

Finally, our measure of real exchange rate is given by

\[ rer_t = 1/p_{c,t} \]

\[ ^{11}\text{By definition terms of trade } \equiv \frac{p_h}{P_f}, \text{ as } P_f \text{ is the numeraire, this implies that } tot = p_h. \]
which represents the relative cost of living between the rest of the world and the small open economy, hence the domestic economy experiences a real depreciation as the real exchange rate, \(rer_t\), increases. The Law of One Price holds for both goods (domestic and foreign), i.e., a good should sell for the same price everywhere, when it is expressed in the same numeraire. This is true in our model since it contains no restrictions on arbitrage, uncertainty, strategic pricing, rigidities or transaction costs of any nature. Appendix G discuss the conditions under which Purchase Power Parity (PPP) holds.

### 3.3.4 Household’s optimality conditions

Given initial conditions and a sequence of prices \(\{W_t, r_t, u_t, r^*_t, p_{h,t}, p_{c,t}\}_{t=0}^{\infty}\) the representative household chooses processes \(\{C_t, h_t, I_t, K_{t+1}, D_t\}_{t=0}^{\infty}\) to maximize (3.5) subject to (3.6) - (3.7), the non-Ponzi scheme constraint, and the stochastic processes for temporary and permanent productivity, the terms of trade, the domestic and the world real interest rates, and government expenditure. (We shall describe these processes in more details later).

Letting \(\lambda_t \Gamma^{-\psi}_{t-1}\) denote the Lagrange multiplier associated with the budget constraint, the optimality conditions for the representative household’s maximization problem are: the non-Ponzi scheme constraint, equations (3.6) and (3.7) all holding with equality, and

\[
[C_t - v \Gamma_{t-1} h_t^\omega]^{-\psi} = \lambda_t p_{c,t} \Gamma^{-\psi}_{t-1}
\]  

(3.8)

\[
[C_t - v \Gamma_{t-1} h_t^\omega]^{-\psi} v \omega \Gamma_{t-1} h_{t-1}^{\omega-1} = \lambda_t \Gamma^{-\psi}_{t-1} W_t
\]  

(3.9)

---

12 The real exchange rate is the relative cost of living among two different economies, i.e., \(rer = P/f/P_c\), where \(P_f\) is the foreign price index, \(P_c\) is the domestic price index (both expressed in some common numeraire), and the time subscripts are dropped for the sake of exposition. As \(P_f\) is used as the numeraire this implies \(rer = \frac{P_f}{P_c} = 1/p_c\), which corresponds to our measure in the text. See Appendix G for more details.
\[ \lambda_t \Gamma_{t-1}^{-\psi} \left[ 1 - \varphi \left( \frac{D_t}{p_{h,t} Y_t} - \overline{\alpha} \right) \right] = \beta (1 + r_t) \Gamma_{t-1}^{-\psi} E_t \left( \lambda_{t+1} \right) \]  
(3.10)

\[ \lambda_t \Gamma_{t-1}^{-\psi} p_{c,t} \left[ 1 + \phi \left( \frac{K_{t+1}}{K_t} - \overline{\alpha} \right) \right] = \ldots \]  
(3.11)

\[ .. = \beta \Gamma_{t-1}^{-\psi} E_t \left\{ \lambda_{t+1} \left[ u_{t+1} + p_{c,t} \left( 1 - \delta + \phi \left( \frac{K_{t+2}}{K_{t+1}} - \overline{\alpha} \right) \frac{K_{t+2}}{K_{t+1}} - \frac{\phi}{2} \left( \frac{K_{t+2}}{K_{t+1}} - \overline{\alpha} \right)^2 \right) \right] \right\} \]

Equation (3.8) says that the representative household equates the marginal utility of consumption (L.H.S) to the marginal utility of wealth (R.H.S).\(^{13}\) Equation (3.9) says that the marginal disutility of labor equates real wages. Combining equations (3.8) and (3.9) yields:

\[ h_t = \left( \frac{1}{u_{t} \omega \Gamma_{t-1}} W_t \right)^{1/(\omega-1)} \]

which implies that hours worked depend only on the current real wage. Notice here the importance of having the marginal disutility of work increasing as productivity increases.

In the long run equilibrium, the model economy exhibits sustained growth in productivity, and hence the real wage, \( W_t \) (which in a competitive model equates the marginal productivity of labor) grows at the rate \( \overline{\alpha} \), the growth rate of the labor augmented productivity process, \( \Gamma_t \). Therefore, in the long run, both real wages and labor augmented productivity grow at the same rate, making hours worked stable over the balanced growth path.\(^{14}\)

Finally, equations (3.10) and (3.11) are the Euler equations associated with bonds

\(^{13}\)We follow Garcia-Cicco, Pancrazi and Uribe (2007) and define the lagrange multiplier as \( \lambda_t \Gamma_{t-1}^{-\psi} \). This device makes our task of normalizing the first order conditions easier. As both \( \lambda_t \) and \( \Gamma_{t-1}^{-\psi} \) are non-negative, the non-negativity restriction for the lagrange multiplier is always satisfied, i.e., \( \lambda_t \Gamma_{t-1}^{-\psi} \geq 0 \) \( \forall t \).

\(^{14}\)As we have pointed out this result is a feature of the specific functional form for the momentary utility function. Under 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).
holdings and capital accumulation, respectively. These first order conditions are fairly standard, except for the presence of labor productivity parameter and the relative prices $p_{c,t}$ and $p_{h,t}$. Eliminating these, in the above first order conditions, yield standard first order conditions as commonly found in small open economy RBC models (see Schmitt-Grohé and Uribe, 2003 for details).

### 3.4 Government

The government is assumed to consume an exogenous and stochastic stream of consumption goods, which we denote by $G_t$. The government maintains a balanced budget at all time and its consumption is financed via lump-sum transfers/taxes, thus the government budget constraint is given by

$$p_{c,t}G_t = T_t$$

(3.12)

### 3.5 Some additional relationships

The trade balance (the difference between domestic output and domestic absorption) is defined as

$$TB_t = p_{h,t}Y_t - p_{c,t}(C_t + I_t + G_t)$$

(3.13)

and, consequently, the trade balance-to-output ratio is given by $tby_t = TB_t/(p_{h,t}Y_t)$.

Using the definition above (eq. 3.13) into the household’s budget constraint (eq. 3.6) and rearranging terms, we obtain the evolution of the real debt outstanding at time $t$ as:

$$D_t = (1 + r_{t-1})D_{t-1} - TB_t + \Omega(D_t) + r_{t-1}\mu W_t I_t$$

(3.14)
or alternatively
\[ CA_t = TB_t - r_{t-1}D_{t-1} - \Omega(D_t) - r_{t-1}\mu W_{t} \] (3.15)

where we have defined the current account as \( CA_t = D_{t-1} - D_t \) to reflect the idea that positive values of \( D_t \) reflects debt. Similarly, the current account-to-output ratio is given by \( CAY_t \equiv CA_t/(p_{h,t}Y_t) \).

It is important to keep in mind that the trade balance and the evolution of foreign debt position do not constitute additional equilibrium conditions, but both are determined in equilibrium by the remaining variables in the model.

### 3.6 Driving Forces

The main goal of this study is to determine the role of domestic productivity shocks, world price shocks, risk premium shocks and government expenditure shocks in driving business cycle fluctuations in emerging economies. We now present the assumptions regarding these driving forces.

#### 3.6.1 Productivity

**Temporary Productivity**

The productivity process \( z_t \) evolves according to

\[ \ln z_t = (1 - \rho_z) \ln z_{ss} + \rho_z \ln z_{t-1} + \epsilon_t^z \] (3.16)

where \( \rho_z \in [0, 1] \) and \( \epsilon_t^z \sim NIID(0, \sigma_z) \).
Permanent Productivity

The growth rate of the labor augmented productivity process \((\Gamma_t)\) evolves according to

\[
\ln a_t = (1 - \rho_a) \ln \bar{a} + \rho_a \ln a_{t-1} + \epsilon^a_t
\]

(3.17)

where \(\rho_a \in [0, 1]\) and \(\epsilon^a_t \sim NIID(0, \sigma_a)\). The term \(\pi\) measures the non-stochastic growth rate of \(\Gamma_t\), which in steady-state governs the growth rates of output, capital, consumption and investment.

3.6.2 The Terms of Trade

The terms of trade follows a first-order autoregressive process

\[
\ln tot_t = (1 - \rho_{tot}) \ln tot_{t-1} + \rho_{tot} \ln tot_{t-1} + \epsilon^{tot}_t
\]

(3.18)

where \(\rho_{tot} \in [0, 1]\), \(\epsilon^{tot}_t \sim NIID(0, \sigma_{tot})\) and \(tot_{ss}\) represents the steady-state value of the terms of trade.15

3.6.3 The World Real Interest Rate and the Risk Premium

The international financial market is composed of a large number of international investors willing to lend any amount at a rate \(r_t\) to domestic residents. This rate may differ from the international interest rate, \(r^*_t\), because loans to domestic residents are subject to default risk. Consequently, the gross real interest rate faced by domestic

\[\text{15}\quad \text{A typical assumption in small open economies models is that the terms of trade are determined outside the domestic economy. However this assumption may not be suitable for economies that are relatively important players in the world markets. With this in mind, we use Granger causality tests to assess the extent of this possibility. Appendix H presents the results for the Granger causality test.}\]
residents in international financial markets is defined as

\[(1 + r_t) \equiv (1 + r_t^*) (1 + s_t)\]  \hspace{1cm} (3.19)

where \((1 + s_t)\) is the (gross) spread over the international rate, denoted by \((1 + r_t^*)\). The international rate reflects the preferences of the international lenders for risky assets and it is not related to any specific country in particular. On the other hand, the risk premium, \(s_t\), captures the premium that domestic residents must pay in order to borrow in the international financial market (the only source of borrowing in our model). Therefore, there are two sources of fluctuations in the domestic real interest rate: one due to movements in the international real interest rate and other due to fluctuations in the risk premium. \(^{16}\)

The main objective with this formulation is to capture the role of international financial factors on business cycle fluctuations in our emerging market benchmark. A number of studies have emphasize the role of external financial factors on domestic macroeconomic development in emerging economies. For instance, Calvo, Leiderman and Reinhart (1993) have shown how lower international interest rates, among other things, encouraged international investors to shift resources to Latin America countries in the early 1990’s. This increase in capital inflows to Latin America fuelled domestic expansions in most of these economies (Kaminsky, Reinhart and Vegh, 2004).

Although the international real interest rate is determined by factors outside the domestic economy, we allow the risk premium to be determined by domestic variables as well as an exogenous shock. We will describe the processes for the two variables

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\(^{16}\)This formulation for the domestic real interest rates also offers an explanation for one well documented fact 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% more volatile than in a sample of developed economies (Australia, Canada, Netherlands, New Zealand, and Sweden).
bellow. As in the related literature (e.g., Neumeyer and Perri, 2005; Uribe and Yue, 2006) the international interest rate is identified as the 90-day U.S. T-bill rate, while the risk premium is identified as the J.P. Morgan Emerging Market Bond Index (EMBI +) Spread for Brazil (see the section on data description for more details). The EMBI+ spread is computed as the difference between the yield of dollar denominated (Brazilian) sovereign bonds relative to the yield of similar U.S. government bonds.\(^{17}\)

**The World Real Interest Rate**

The international real interest rate follows a first-order autoregressive process (in logs)

\[
\ln(1 + r^*_t) = (1 - \rho_{r^*}) \ln(1 + r^*) + \rho_{r^*} \ln(1 + r^*_{t-1}) + \epsilon^*_t
\]

where \(\rho_{r^*} \in [0, 1]\) governs the autoregressive component, \(\epsilon_{r,t} \sim \text{NID}(0, \sigma_{r^*})\) and \((1 + r^*)\) is the constant long-run world real interest rate. This rate is exogenous to the domestic economy.

**The Risk Premium**

**Discussion** In modelling the risk premium the RBC literature abstracts from default decisions and uses a reduced form approach largely inspired by models of sovereign default and by empirical models of risk premium determination. While in the first class of models the goal is to show that sovereign default occur as an optimal response in face of adverse (exogenous) shocks to a country’s wealth, the goal of the empirical literature

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\(^{17}\) As in the related literature we use sovereign interest rate as a proxy for interest rate faced by domestic private agents in international financial markets. Dittmar and Yuan (2008) using daily data covering the period 1996 to 2000 on governent sovereign bonds and private corporate bonds for a group of emerging economies show that the series for corporate and sovereign yield spreads trace each other quite well over the sample period. As the data on corporate yields spread are not public, we use sovereign spreads as a proxy for corporate yield spreads. We have also constructed an alternative measure of private spread by using the average lending rate and the average saving rate in Brazil. This is the same approach used by Arellano and Kocherlakota (2008). We show that these two measures of spread are somehow alike, but not as close as the case of corporate and sovereign bonds computed by Dittmar and Yuan (2008).
is to identify elements that may explain the evolution of risk premium over time.

Sovereign default models follow Eaton and Gersovitz’s (1981) recursive formulation of strategic default in which a sovereign borrower makes optimal default choices by comparing payoffs of repayment and default. The main insight of this literature is the idea that countries are more likely to default in bad times than in good ones.\(^{18}\) On the other hand, the empirical literature has shown that the evolution of the risk premium can be explained by two general classes of factors: country-specific factors that reflect solvency, liquidity and macroeconomic conditions of a particular country, and elements that are not necessarily related to a specific country - or market sentiments (for instance, Edwards, 1986, Eichengreen and Mody, 2000; Min et al, 2003; and more recently Hartelius, Kashiwase and Kodres, 2008). The RBC literature has incorporated these ideas either by linking some measure of solvency, liquidity and macroeconomic conditions to the risk premium or by assuming that the risk premium is determined by factors that are outside of the domestic economy.

Two nonexclusive cases are considered in the small open economy literature.\(^{19}\) In one view, the risk premium is assumed to be determined by elements that are outside the domestic economy, such as foreign events, contagion, or political factors that are not necessarily related to macroeconomic conditions. This exogenous case is considered by Neumeyer and Perri (2005), for example. On the other hand, there is the case where the risk premium is determined by domestic macroeconomic fundamentals, or at least by

\(^{18}\)If the sovereign chooses to default the economy becomes an autarky for a certain period of time with an exogenous given probability of redemption. In case of redemption, the sovereign starts the new phase with no past obligations. There is no debt renegotiation whatsoever, i.e., the defaulted amount is lost forever. The basic framework is an endowment economy where output fluctuations are taken as exogenous with ad-hoc default costs. Aguiar and Gopinath (2006), Yue (2006), Arellano (2007), Mendoza and Yue (2008).

\(^{19}\)It is important to keep in mind that the goal of the small open economy literature is not to present a complete description of the determinants of the risk premium, instead the idea is to capture, at least in reduced form, the insights derived from the sovereign default literature and the empirical literature on risk premium determination. This study falls into this category, i.e., we neither attempt to offer a theory of default decisions nor do we want to explain the determinants of risk premium.
domestic shocks (e.g., Neumeyer and Perri 2005, Aguiar and Gopinath 2007b and Uribe and Yue 2006).

To illustrate the first view consider Figure 3.1. This Figure depicts the evolution of the domestic real interest rate during our sample period. Figure 3.1 also depicts the behavior of the domestic interest rates around five important recent episodes: the Mexican crisis of 1995, the Asian crisis of 1997, the Russian crisis of 1998, the Argentine crisis of 2001 and the "fear of default" that preceded the 2002 presidential elections in Brazil.

![Graph](image)

Figure 3.1: Brazil: Real Interest Rate. This rate is computed as the 90-day U.S. T-bill rate plus the J.P. Morgan EMBI + Spread for Brazil. Source: Authors’ calculations.

During the 1990’s emerging market economies were buffered for several episodes of contagion. For example, the Mexican crisis of 1995 dubbed as the "Tequila Effect" affected most of emerging economies.\footnote{This crisis occur immediately after the Mexican peso was devalued in the early days of the Presidency of Ernesto Zedillo, South American countries suffered rapid currency depreciation. It was a known fact that the peso was overvalued, but the extent of Mexico’s economic vulnerability was not well known. Since governments and businesses in the area had high levels of U.S. dollar-denominated debt, the devaluation meant that it would be increasingly difficult to pay back the debts.} The Asian crisis in 1997 and the Russian Crisis
in 1998 also yielded contagion effects to the rest of emerging economies. In particular, the Brazilian economy suffered the most with the "Tequila effect" and the "Vodka effect", the later referring to the Russian crisis in the last quarter of 1998. As it can be seen in Figure 3.1, the interest rates faced by Brazilian borrowers in international markets reached peaks around these two episodes. At some extent, the Argentine crisis of 2001 also affected the interest rates, but in a smaller degree.

Besides contagion effects, political factors also affect the cost of borrowing by increasing the perception of default. Indeed, it was around a recent political episode that the international interest rate faced by Brazilian borrowers reached its highest level. Before the presidential elections of 2002 in Brazil there was a fear that if the left-wing candidate Luís Ignácio Lula da Silva - who appeared in the first position in the polls - win the election he would default on the Brazilian public (external) debt. His political platform included at that time conditioning the payment of Brazil’s foreign debt (US$ 90 Billion) to a prior thorough audit, which for several investors meant that default was inevitable. This possibility made credit rating agencies such as Moody and Fitch to downgrade Brazilian credit rating despite the relative good performance of the Brazilian economy at that time, which grew roughly 2% in that year. Lower ratings effectively meant that Brazilian borrowers would have to pay higher interest rates to compensate international lenders for the perceived greater risk of default.

Figure 3.1 shows that interest rates faced by Brazilian borrowers in international markets started to increase and reached its peak in the quarter before the presidential elections took place (October 2002). The increase in the fear of default made the left wing candidate to write an open letter - Carta aos Brasileiros (Letter to the Brazilians) - where he publicly promised that if elected his government would keep and uphold all contracts. This action helped to reduce the fear of default and consequently the cost of borrowing in the following months as it can be seen from Figure 3.1. However, it is important to point out that to attribute all political episodes to exogenous factors
disconnected from domestic fundamentals is, at minimum, naive. We do have enough episodes in recent history where elections are lost or won depending if the economy was in recession or in a boom. In spite of that, we think that the fear of default that preceded the 2002 presidential election was disconnected from macroeconomic fundamentals (the risk premium component of the real interest rate had increased and decreased although the macroeconomic fundamentals had remained stable). This was indeed one of the arguments that the Brazilian authorities tried to use to offset the fear of default.21

In terms of formulation, the common approach is to assume a particular (ad hoc) functional form that links risk premium to some endogenous variable, which it is associated with domestic macroeconomic fundamentals. Neumeyer and Perri (2005), for example, consider two cases. One assuming a complete exogenous process for the risk premium and other assuming that risk premium is determined by the "fundamental shocks hitting the domestic economy". For this they assume a particular functional form for such relationship. Aguiar and Gopinath (2007) also impose an ad hoc formulation similar in spirit to that of Neumeyer and Perri (2005). They assume in their model that the domestic interest rates are correlated with temporary and permanent productivity shocks, i.e., positive productivity shocks occur in times when spreads are low, and vice-versa. Gertler, Gilchrist and Natalucci (2007), inspired by agency cost models (for instance, Bernanke, Gertler and Gilchrist, 2000, Carlstrom and Fuerst, 1997) assume an ad hoc functional form to establish an inverse relationship between the borrower’s (entrepreneur in their model) net worth and the risk premium. The intuition is the greater the net worth, the smaller expected bankruptcy rates are. Similarly, Sarquis (2008) assumes a functional form positing a negative relationship between the risk premium and the debt-to-output ratio. As we have pointed out an alternative approach was undertaken by Uribe and Yue (2006). They estimate a VAR for a sample of 6 emerging market economies and use

21See the article published by BBC for more details http://news.bbc.co.uk/2/hi/business/2057137.stm.
the estimated process for domestic interest rates in their theoretical model to assess the importance of country risk premium shocks.

**Risk premium formulation** In the present study the risk premium evolves according to:

\[
\ln(1 + s_t) = (1 - \rho_s) \ln s_{ss} + \rho_s \ln(1 + s_{t-1}) + \alpha_1 \Delta y_t + \alpha_2 cay_t + \epsilon_t^s \quad (3.21)
\]

where \(\rho_s \in [0,1]\) governs the autoregressive component, \(s_{ss}\) is the level of country-spread in steady-state, and \(\epsilon_t^s \sim NIID(0, \sigma_s)\). \(\Delta y_t\) represents the growth rate of real output per capita, and \(cay_t\) is the current account-to-output ratio.\(^{22}\)

The sign of \(\Delta y_t\) is a priori uncertain. As pointed out by Min et al (2003) "while a decline in the growth rate of output can contribute to a long-term insolvency problem leading to higher spread, on the other hand, a decline in the GDP growth rate may ameliorate an external liquidity constraint through lower imports and can lead to a lower spread". For instance, Eichengreen and Mody (2000) have found that for Latin America and East Asia countries this sign is positive, while for the whole set of countries in their sample this sign is negative. (The coefficient of \(\Delta y_t\) in Min et al was positive as well, but it was statistically insignificant).\(^ {23} \)

The sign of \(cay_t\) is expected to be negative, i.e., an increase in \(cay_t\) means that the country is experiencing an improvement in its net debt position (less debt) and hence this should lower the risk premium *ceteris paribus* (Min et al, 2003; Uribe and Yue, 2006).\(^ {24} \)

---

\(^{22}\)Notice that the independent case is obtained when \(\alpha_1 = \alpha_2 = 0\).

\(^{23}\)In defining the support of the prior distribution of the \(\alpha'\)'s we account for this uncertain regarding the sign.

\(^{24}\)One variable that could be potentially explored here is the world interest rate. The idea is that the world interest rate affect the domestic interest rate directly and indirectly, i.e., increases in the world interest rate leads to a "search for yield" among international investors and this would lead to
The underlying idea behind our formulation for the risk premium is that countries are more likely to default in bad times 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 bellow the trend).

However, it is important to notice that bad times were neither sufficient nor necessary for default episodes. As Tomz and Wright (2007) point out 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.

### 3.6.4 Government Expenditure

Government purchases follows a first-order autoregressive process (in logs)

\[
\ln g_t = (1 - \rho_g) \ln g_{ss} + \rho_g \ln g_{t-1} + \epsilon_{g,t} \tag{3.22}
\]

where \(\rho_g \in [0, 1]\) governs the autoregressive component, \(\epsilon_{g,t} \sim NIID(0, \sigma_g)\) and \(g_{ss}\) is the level of government expenditure in steady-state. In our model, government expenditure shocks can stand in for pure aggregate demand shocks.

---

an increase in the spreads paid by emerging economies (Min et al, 2003; Eichengreen and Mody, 2000; Uribe and Yue, 2006; Sarquis, 2008; Hartelius et al, 2008). However, to keep things simple, we have decided not to include world interest rates into the risk premium formulation. (We did not want ask too much from the model and estimation technique).
3.7 Competitive Equilibrium

Given initial conditions and given the stochastic processes for the terms of trade, the world real interest rate, the risk premium, temporary productivity, permanent productivity, and government expenditure, a competitive equilibrium is a set of allocations \( \{ C_t, h_t, I_t, K_t, 1_t, l_t, K_t \}_{t=0}^{\infty} \) and prices \( \{ W_t, r_t, u_t, r^*_t, p_{h,t}, p_{c,t} \}_{t=0}^{\infty} \) such that: (i) the allocations solve the firm’s and household’s optimization problems at the equilibrium prices and (ii) the labor market clears.

Notice that the first order conditions for the household, along with the firms’ first order conditions, are not stationary because some variables exhibit a trend in equilibrium. Thus, before solving the model, we normalize the first order conditions by defining for any non-stationary variable \( X_t \) the correspondent normalized variable as \( x_t \equiv \frac{X_t}{\Gamma_{t-1}} \). We normalize by \( \Gamma_{t-1} \) to guarantee that if the variable \( X_t \) belongs to the agent’s information set at \( t \), the normalized variable \( x_t \) belongs as well. Thus a stationary competitive equilibrium is given by the following set of equations:

\[
[c_t - v h_t^\omega]^{-\psi} = \lambda_t p_{c,t} \tag{3.23}
\]

\[
[c_t - v h_t^\omega]^{-\psi} v \omega h_t^\omega - 1 = w_t \lambda_t \tag{3.24}
\]

\[
\lambda_t a_t^\psi \left[ 1 - \varphi \left( \frac{d_t}{p_{h,t}y_t} - \bar{d} \right) \right] = \beta(1 + r_t) E_t \lambda_{t+1} \tag{3.25}
\]

\[
\lambda_t a_t^\psi p_{c,t} \left[ 1 + \phi \left( \frac{k_{t+1}}{k_t} a_t - \bar{a} \right) \right] = \ldots \tag{3.26}
\]

\[
\ldots \beta E_t \left\{ \lambda_{t+1} \left[ u_{t+1} + p_{c,t+1} \left( 1 - \delta + \phi \left( \frac{k_{t+2}}{k_{t+1}} a_{t+1} - \bar{a} \right) \frac{k_{t+2}}{k_{t+1}} a_{t+1} - \phi \frac{1}{2} \left( \frac{k_{t+2}}{k_{t+1}} a_{t+1} - \bar{a} \right)^2 \right) \right] \right\}
\]

79
\[
p_{c,t}(c_t + i_t) + (1 + r_{t-1}) \frac{d_{t-1}}{a_{t-1}} + \varphi \left( \frac{d_t}{p_{h,t}y_t} - \bar{d} \right)^2 \quad (3.27)
\]

\[
k_{t+1}a_t = i_t + (1 - \delta)k_t - \frac{\phi}{2} \left( \frac{k_{t+1}a_t - \bar{a}}{k_t} \right)^2 
\quad (3.28)
\]

\[
y_t = z_t k_t^{1-\alpha} (a_t l_t)^\alpha 
\quad (3.29)
\]

\[
(1 - \alpha) = \frac{u_t k_t}{p_{h,t}y_t} 
\quad (3.30)
\]

\[
\alpha = [1 + \mu r_{t-1}] \frac{w_t l_t}{p_{h,t}y_t} 
\quad (3.31)
\]

\[
l_t = h_t 
\quad (3.32)
\]

\[
p_{c,t}g_t = \tau_t 
\quad (3.33)
\]

\[
p_{c,t} = p_{h,t}^{1-\gamma} 
\quad (3.34)
\]

\[
rer_t = 1/p_{c,t} 
\quad (3.35)
\]

Finally, the stationary versions of the trade balance and the evolution of foreign debt position are given, respectively, by

\[
tb_t \equiv p_{h,t}y_t - p_{c,t}(c_t + i_t + g_t) 
\quad (3.36)
\]
\[ ca_t = tb_t - r_{t-1}d_{t-1} - \Omega(d_t) - r_{t-1}\mu w_t l_t \] (3.37)

The stationary version of the trade balance-to-output ratio is \( tby_t \equiv tb_t/(p_{t-1}y_t) \), while the current account-to-output ratio is given by \( ca_t \equiv ca_t/(p_{t-1}y_t) \). In the next chapter we discuss the solution method and the econometric methodology employed to estimate the structural parameters in the model.
Chapter 4

Solution Method and Econometric Methodology

4.1 Preliminaries

We compute a first order Taylor approximation of the log-linear equilibrium conditions around the non-stochastic steady state and we use the method proposed by Klein (2000) and Sims (2002) to find the model solution. Appendix B presents the log-linearized equilibrium conditions.

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

\[ X_{t+1} = A(\theta)X_t + B(\theta)\omega_{t+1} \]  \hspace{1cm} (4.1)

where \( \omega_{t+1} \) 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 \( B(\theta) \) collects the structural parameters, where \( \theta = (\theta_C, \theta_E) \in \Theta \). The subset \( \theta_C = \{ \delta, \omega, \nu, \psi, \alpha, \beta, \gamma, \varphi, \bar{\pi}, d_{ss} \} \) denotes the parameters that are calibrated and \( \theta_E = \{ \phi, \mu, \rho_r^*, \rho_{tot}, \rho_s, \rho_g, \rho_z, \rho_a, \sigma_r^*, \sigma_{tot}, \sigma_s, \sigma_g, \sigma_z, \sigma_a, \alpha_1, \alpha_2 \} \) denotes the free parameters to be estimated.
A measurement equation links a vector of observable variables $\Psi_t$ to the model variables $X_t$.

$$\Psi_t = C(\theta)X_t + v_t$$

(4.2)

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. More generally, they are introduced to avoid stochastic singularity following the work of Sargent (1989). As we have the same number of observable variables as shocks, we do not employ measurement errors in the estimation process.

Our vector of observable variables is composed of: quarterly (gross) growth rates of real GDP per capita, real government expenditures, real investment per capita, (gross) domestic real interest rate, world real interest rate and the terms of trade, i.e., $\Psi_t = \{\Delta Y_t, \Delta G_t, \Delta I_t, r_t, r^*_t, tot_t\}_{t=1}^T$. Appendix C shows 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 variables, we can build the likelihood function $\mathcal{L}(\Psi_t \mid \theta)$ 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. Given these beliefs and the likelihood function, the Bayes’ Theorem provides the way to derive the posterior distribution as follows:

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

(4.3)

where $\int_\theta \mathcal{L}(\Psi_t \mid \theta)p(\theta)d(\theta)$ denotes the marginal data density.

---

1Recall 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, $\Gamma_{t-1}$.

2These beliefs can either came from related work, micro-evidence or still from 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 indentification task (See Del Negro and Schoferheide, 2008).
4.2 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, therefore, all the information about $\theta$ from the data can be obtained through the posterior kernel

$$P(\theta \mid \Psi_t) \propto \mathcal{L}(\Psi_t \mid \theta)p(\theta)$$ (4.4)

The Metropolis-Hastings algorithm generates draws from the posterior kernel $\log \mathcal{L}(\Psi_t \mid \theta) + \log p(\theta)$ to derive a 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 parameters is asymptotically normal).\(^3\) Appendix D presents the Metropolis-Hastings algorithm in more detail.

We generate 2 independent sequences each composed of 1,000,000 draws using the Metropolis-Hastings algorithm. The average acceptance ratio along the chains was 30%, and we assess convergence using the methods proposed by Brooks and Gelman (1998). We discard the first 500,000 draws to assure independence of initial conditions and we

---

\(^3\) 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.
compute statistics of interest from the ergodic joint posterior distributions of the deep parameters. In the next chapter we present the results from the Bayesian estimation.\footnote{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 (4.1)-(4.2). These steps are implemented using Matlab-Dynare.}

### 4.3 Model Comparison

The Bayesian methodology provides a natural environment for model comparison. This is implemented using a posterior odds ratio. This ratio assesses which model, among multiple possible alternatives, delivers the highest probability given the data. For instance, suppose one is interested in assessing two alternative formulations for the risk premium. For exposition’s sake, we rewrite equation (3.21) here:

\[
\ln s_t = (1 - \rho_s) \ln s_{s-1} + \rho_s \ln s_{t-1} + \alpha_1 \Delta y_t + \alpha_2 c y_t + e_t^s
\]

The first formulation assumes, as in our model, that \(\alpha_1\) and \(\alpha_2\) are all different from 0, while the second one may assume that \(\alpha_1 = \alpha_2 = 0\). Denoting by \(\mathcal{M}_1\) the model under the first formulation and \(\mathcal{M}_2\) the model under the alternative, the posterior odds ratio is defined as:

\[
\frac{P(\mathcal{M}_1 \mid \Psi_t)}{P(\mathcal{M}_2 \mid \Psi_t)} = \frac{p(\mathcal{M}_1) p(\Psi_t \mid \mathcal{M}_1)}{p(\mathcal{M}_2) p(\Psi_t \mid \mathcal{M}_2)}
\quad (4.5)
\]

where \(p(\mathcal{M}_1)\) is the prior probability that the full model is the "true" model and \(p(\mathcal{M}_2)\) the prior probability that the "true" model is the restricted one instead. The first term in equation (4.5) is the prior odds ratio in favor of \(\mathcal{M}_1\). The second term is called the Bayes Factor, which is the ratio of the marginal data densities associated with each model. The marginal data density \(p(\Psi_t \mid \mathcal{M}_i)\) is obtained by integrating out the structural parameters
\( \theta_i \) from the posterior kernel:

\[
P(\Psi_t \mid \mathcal{M}_i) = \int \mathcal{L}(\Psi_t \mid \theta_i, \mathcal{M}_i)p(\theta_i \mid \mathcal{M}_i)d(\theta_i) \quad \text{where} \quad i = 1, 2. \tag{4.6}
\]

We use the modified harmonic mean estimator, which uses the information contained in the Metropolis-Hastings draws, to estimate the marginal data density of the two competing models (Appendix E presents more details on the estimator). \(^5\)

Posterior odds ratio can be used despite of possible model misspecification, since we do not have to assume that we do know the true model. This is quite useful since misspecification is frequently (or always) true in our DSGE models as they are mere approximations of reality.

### 4.4 Data Description

The data covers the period from the third quarter of 1994 to the first quarter of 2008. Growth rates are computed as log differences of the respective variables in levels, while the gross interest rates and the terms of trade are logged. National account real variables are obtained by dividing the corresponding nominal value by the Brazilian GDP deflator. Per capita variables are obtained by dividing the real GDP, real government expenditures, and real investment by occupied population in Metropolitan areas from Instituto Brasileiro de Geografia e Estatística (IBGE).

The international interest rate, \((1 + r^*_i)\), is identified here as the gross U.S. 3-month T-bill rate. The domestic gross interest rate is computed as \((1 + r_t) = (1 + r^*_i).(1 + s_t)\), where \(s_t\) is the Emerging Market Bond Index (EMBI+) for Brazil from JP Morgan. This

\(^5\)There 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.
variable measures the difference between the Brazilian T-bill rate (in US$) and the US T-bill rate. The domestic and the world real interest rates are 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.

Government expenditure, domestic output, and investment are seasonally adjusted using the Census X-12 method. All variables are demeaned prior to estimation. The nominal national account variables, CPI, 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 Brazilian quarterly GDP deflator is obtained by dividing the GDP nominal index by the GDP chained volume index from Instituto Brasileiro de Geografia e Estatística (IBGE).

4.5 Fixed parameters

In choosing values for the parameters that are fixed along the estimation procedure, $\theta_C$, we follow three basic approaches: (i) when data is available, we use the correspondent data average to get an estimate of the parameter, (ii) when data is not available, we pick parameters values that have been widely used in the related literature, and (iii) for some parameters, we use previous model’s parameters and steady-state relationships to compute parameter values.

4.5.1 From Brazilian data

*Import share* $[\gamma]$ : this number is set at 0.10, which corresponds to the average of imports-to-GDP ratio. *Steady-state debt to GDP ratio* $[d_{ss}]$ : we set this parameter at 0.35, which corresponds to the average of debt-to-GDP ratio in the data. *Long-run productivity growth* $[\bar{a}]$ : We set the long-run productivity gross growth rate at 1.002,
which corresponds to the average growth rate of real GDP per capita in the Brazilian data. Government expenditure-to-GDP ratio \([g_{ss}]\) is set at 0.22, which corresponds to average in the data. The gross real interest rate \((1 + r_{ss})\) is set at 1.0217, which is the average quarterly domestic real interest rate in the data.

### 4.5.2 From related literature

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). As pointed out by Kanczuk (2004) Brazilian national accounts tend to sub-estimate the labor share due to the exclusion of the remuneration of the self-employed, which is included within the capital share remuneration. Coefficient on the bonds-adjustment cost function \([\phi]\) : we set at 0.0001, a commonly small number used in the literature to ensure that the adjustment cost function does not drive our results. Depreciation rate \([\delta]\) : we set this parameter at 0.024, which corresponds to a 10% depreciation rate per year.

### 4.5.3 From previous parameters and long-run relationships

Labor coefficient \([\psi]\) : 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, which corresponds to the average implied by the Brazilian decennial census and PNAD
(National Survey of Household Sample) as discussed in Kanczuk (2004) and Gomes, Bugarin and Ellery (2003). Subjective discount rate \([\beta]\): we set the subjective discount rate according to \(\beta = \frac{\pi^0}{(1 + r_{ss})}\). Table 4.1 summarizes the parameter values.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Value</th>
<th>Parameter Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\beta)</td>
<td>0.983</td>
<td>Subjective discount factor</td>
</tr>
<tr>
<td>(\nu)</td>
<td>5.7</td>
<td>Labor coefficient (utility)</td>
</tr>
<tr>
<td>(\psi)</td>
<td>2</td>
<td>Risk aversion</td>
</tr>
<tr>
<td>(\omega)</td>
<td>1.6</td>
<td>Labor exponent (utility)</td>
</tr>
<tr>
<td>(\alpha)</td>
<td>0.68</td>
<td>Labor share (production)</td>
</tr>
<tr>
<td>(\gamma)</td>
<td>0.1</td>
<td>Import share</td>
</tr>
<tr>
<td>(\delta)</td>
<td>0.024</td>
<td>Depreciation rate</td>
</tr>
<tr>
<td>(d_{ss})</td>
<td>0.35</td>
<td>Steady-state debt-to-GDP ratio</td>
</tr>
<tr>
<td>((1 + r_{ss}))</td>
<td>1.0209</td>
<td>average quarterly gross real interest rate</td>
</tr>
<tr>
<td>(g_{ss})</td>
<td>0.22</td>
<td>Steady state government expenditure-to-GDP ratio</td>
</tr>
<tr>
<td>(\varphi)</td>
<td>0.0001</td>
<td>Coefficient on the bonds-adjustment cost</td>
</tr>
<tr>
<td>(\bar{\alpha})</td>
<td>1.002</td>
<td>long-run productivity gross growth rate (trend)</td>
</tr>
</tbody>
</table>

### 4.6 Prior distributions of the estimated parameters

In defining priors distributions for the estimated parameters, \(\theta_E\), 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* \([\phi]\) : This coefficient is described by a Gamma distribution with mean 10 and standard deviation 1. We choose this prior mean such that the volatility of investment in the model (based on smaller number of simulations) is close to that in the data.

*Parameter of the working capital constraint* \([\mu]\) : This coefficient is described by a Gamma distribution with mean 1.2 and standard deviation 0.1. The prior mean equals the coefficient number estimated by GMM by Uribe and Yue (2006) for a sample of emerging economies (Argentina, Brazil, Ecuador, Mexico, Peru, Philippine, and South Africa). This is also close to the parameterized value used by Neumeyer and Perri (2005) for Argentina.

*Coefficients in the country risk premium equation* \([\alpha]\) : They are described by a Normal distribution with mean 0 and standard deviation 1. We decide to set the prior mean around zero to reflect our prior uncertainty regarding the sign of these coefficients. Hence our choice of priors allows the data to decide the sign of these coefficients.

*Autocorrelation of the shocks* \([\rho]\) : We use Beta distribution with mean 0.5 and standard deviation 0.2. These are the same priors used by Smets and Wouters (2007) for the autocorrelation of shocks in their model for the U.S. economy. We could potentially add more prior information about the persistence of the shocks based on previous analysis, but we have decided not to do so. For example, we could have used the idea that growth shocks appear to be less persistent according to the analysis of Aguiar and Gopinath (2007 a).

*Standard deviation of the shocks* \([\sigma]\) : They are represented by Inverted Gamma Distribution with mean 0.01 and standard deviation 1. Table 4.2 summarizes the priors used in this paper.
<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter Description</th>
<th>Domain</th>
<th>Density</th>
<th>Mean</th>
<th>St. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\phi$</td>
<td>Capital adjustment cost parameter</td>
<td>$\mathbb{R}^+$</td>
<td>Gamma</td>
<td>10.0</td>
<td>1.0</td>
</tr>
<tr>
<td>$\mu$</td>
<td>Parameter working capital constraint</td>
<td>$\mathbb{R}^+$</td>
<td>Gamma</td>
<td>1.2</td>
<td>0.1</td>
</tr>
<tr>
<td>$\alpha_1$</td>
<td>Coeff. of $\Delta y$ (risk premium)</td>
<td>$\mathbb{R}$</td>
<td>Normal</td>
<td>0.0</td>
<td>1.0</td>
</tr>
<tr>
<td>$\alpha_2$</td>
<td>Coeff. of the $cay$ (risk premium)</td>
<td>$\mathbb{R}$</td>
<td>Normal</td>
<td>0.0</td>
<td>1.0</td>
</tr>
<tr>
<td>$\rho_z$</td>
<td>AR coeff. productivity (temporary)</td>
<td>[0,1]</td>
<td>Beta</td>
<td>0.50</td>
<td>0.2</td>
</tr>
<tr>
<td>$\rho_a$</td>
<td>AR coeff. productivity (trend)</td>
<td>[0,1]</td>
<td>Beta</td>
<td>0.50</td>
<td>0.2</td>
</tr>
<tr>
<td>$\rho_s$</td>
<td>AR coeff. risk premium</td>
<td>[0,1]</td>
<td>Beta</td>
<td>0.50</td>
<td>0.2</td>
</tr>
<tr>
<td>$\rho_{rs}$</td>
<td>AR coeff. world interest rate</td>
<td>[0,1]</td>
<td>Beta</td>
<td>0.50</td>
<td>0.2</td>
</tr>
<tr>
<td>$\rho_{tot}$</td>
<td>AR coeff. terms of trade</td>
<td>[0,1]</td>
<td>Beta</td>
<td>0.50</td>
<td>0.2</td>
</tr>
<tr>
<td>$\rho_g$</td>
<td>AR coeff. government expenditure</td>
<td>[0,1]</td>
<td>Beta</td>
<td>0.50</td>
<td>0.2</td>
</tr>
<tr>
<td>$\sigma_z$</td>
<td>Stand. dev. temp. prod. shocks</td>
<td>$\mathbb{R}^+$</td>
<td>Inv. Gamma</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>$\sigma_a$</td>
<td>Stand. dev. growth shocks</td>
<td>$\mathbb{R}^+$</td>
<td>Inv. Gamma</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>$\sigma_s$</td>
<td>Stand. dev. risk premium</td>
<td>$\mathbb{R}^+$</td>
<td>Inv. Gamma</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>$\sigma_{rs}$</td>
<td>Stand. dev. world interest rate shocks</td>
<td>$\mathbb{R}^+$</td>
<td>Inv. Gamma</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>$\sigma_g$</td>
<td>Stand. dev. government exp. shocks</td>
<td>$\mathbb{R}^+$</td>
<td>Inv. Gamma</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>$\sigma_{tot}$</td>
<td>Stand. dev. terms of trade</td>
<td>$\mathbb{R}^+$</td>
<td>Inv. Gamma</td>
<td>1.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Note: authors’ calculations. Standard deviations are in percentage points.
Chapter 5

Results

5.1 Priors and Posteriors

Table 5.1 gives the prior and posterior means, and the 10\textsuperscript{th} and 90\textsuperscript{th} percentiles of the posterior distributions of the parameters obtained using the Metropolis-Hastings algorithm.
Table 5.1: Priors and Posteriors

<table>
<thead>
<tr>
<th>Parameter Description</th>
<th>Prior Means</th>
<th>Posterior Means</th>
<th>90% Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\phi$ Capital adjustment cost parameter</td>
<td>10.0</td>
<td>12.35</td>
<td>10.64 14.03</td>
</tr>
<tr>
<td>$\mu$ Coeff. working capital constraint</td>
<td>1.2</td>
<td>1.16</td>
<td>1.00 1.3</td>
</tr>
<tr>
<td>$\alpha_1$ Coeff. GDP growth (risk premium)</td>
<td>0.0</td>
<td>0.048</td>
<td>-0.036 0.133</td>
</tr>
<tr>
<td>$\alpha_2$ Coeff. cay (risk premium)</td>
<td>0.0</td>
<td>-0.0025</td>
<td>-0.006 0.001</td>
</tr>
<tr>
<td>$\rho_z$ AR coeff. productivity (temporary)</td>
<td>0.50</td>
<td>0.60</td>
<td>0.40 0.81</td>
</tr>
<tr>
<td>$\rho_a$ AR coeff. productivity (trend)</td>
<td>0.50</td>
<td>0.92</td>
<td>0.88 0.96</td>
</tr>
<tr>
<td>$\rho_s$ AR coeff. risk premium</td>
<td>0.50</td>
<td>0.48</td>
<td>0.36 0.60</td>
</tr>
<tr>
<td>$\rho_{rs}$ AR coeff. world interest rate</td>
<td>0.50</td>
<td>0.86</td>
<td>0.81 0.91</td>
</tr>
<tr>
<td>$\rho_{tot}$ AR coeff. terms of trade</td>
<td>0.50</td>
<td>0.37</td>
<td>0.16 0.56</td>
</tr>
<tr>
<td>$\rho_g$ AR coeff. government expenditure</td>
<td>0.50</td>
<td>0.62</td>
<td>0.45 0.79</td>
</tr>
<tr>
<td>$\sigma_z$ Stand. dev. temporary prod. shocks</td>
<td>1.0</td>
<td>0.84</td>
<td>0.70 0.98</td>
</tr>
<tr>
<td>$\sigma_a$ Stand. dev. growth shocks</td>
<td>1.0</td>
<td>0.68</td>
<td>0.43 0.92</td>
</tr>
<tr>
<td>$\sigma_s$ Stand. dev. risk premium</td>
<td>1.0</td>
<td>0.70</td>
<td>0.57 0.83</td>
</tr>
<tr>
<td>$\sigma_{rs}$ Stand. dev. world int. rate shocks</td>
<td>1.0</td>
<td>0.17</td>
<td>0.14 0.19</td>
</tr>
<tr>
<td>$\sigma_{tot}$ Stand. dev. terms of trade shocks</td>
<td>1.0</td>
<td>9.31</td>
<td>7.82 10.77</td>
</tr>
<tr>
<td>$\sigma_g$ Stand. dev. government exp. shocks</td>
<td>1.0</td>
<td>4.03</td>
<td>3.37 4.65</td>
</tr>
</tbody>
</table>

Note: authors’ calculations. Standard deviations are in percentage points.

In general, the data is informative leading us to revise our priors beliefs. The parameter governing the response of the risk premium with respect to output growth is estimated to be positive, while the parameter governing the response to the current account-to-output is estimated to be negative. The parameter that captures investment adjustment cost was estimated to be higher than the prior mean, while the parameter associated with working capital constraint is lower than the prior mean.

The processes for the world real interest rate and for growth shocks exhibit higher
persistence, while terms of trade shocks and risk premium shocks are less persistent. The processes for growth shocks and world real interest rate shocks are less volatile, while terms of trade shocks and government expenditure shocks are more volatile.

5.2 Impulse Responses

In what follows, we present the dynamic response of selected variables to each one of our 6 structural shocks in our model economy. We also briefly describe the behavior of the economy in response to each shock.

5.2.1 Temporary Productivity Shock

Figure 5.1 depicts the responses of endogenous variables to a temporary productivity shock. On impact, output, consumption, and hours worked increase. The response of hours is driven by the pro-cyclicality of real wages. After a positive productivity shock, the opportunity cost of leisure increases as the real wage increases, 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). Investment slightly increases on impact. However, the responses are not significantly different from zero. The responses of the trade balance-to-output ratio and the current account are not significantly different from zero either.
Figure 5.1: Bayesian Impulse Responses. Notes: (1) Solid lines depict the responses of the endogenous variables to 1% shock to temporary productivity. (2) The shaded area depicts the 90% confidence interval. (3) The responses of output growth, consumption growth, investment growth and hours worked are in log-deviations from their respective steady-states. The responses of the trade balance-to-output ratio and the current account are (linear) deviations from their respective steady-states. Source: authors’ calculations.

5.2.2 Growth Shock

Figure 5.2 depicts the responses of endogenous variables to a permanent productivity shock (growth shock).
Figure 5.2: Bayesian Impulse Responses. Notes: (1) Solid lines depict the responses of the endogenous variables to 1% shock to permanent productivity. (2) The shaded area depicts the 90% confidence interval. (3) The responses of output growth, consumption growth, investment growth and hours worked are in log-deviations from their respective steady-states. The responses of the trade balance-to-output ratio and the current account are (linear) deviations from their respective steady-states. Source: authors’ calculations.

In response to a shock to trend productivity (growth shock), the initial responses of output, consumption, investment, and hours worked are all positive, while the trade balance and the current account decline on impact. In the quarters following the shock, hours worked decline and remain below the steady-state for several quarters after the shock before returning to their long run equilibrium. Recall that the disutility of work increases with the level of technical progress (which with GHH preferences guarantees that the labor supply remains bounded along the long-run equilibrium), hence in the quarters following a growth shock the labor supply declines as the disutility of work increases. The combined responses of investment and consumption growth are greater than the increase in output, leading to a decline in the trade balance and to a deterioration of the current account.
5.2.3 Terms of Trade Shock

Figure 5.3 shows that in response to a positive terms of trade shock output and hours increase on impact, while investment and consumption slightly decline. (Even though the response of consumption growth is not significantly different from zero). The initial increase in output is due to the increase in hours worked, which follows an increase in real wages (equation 3.31). On the other hand, investment declines following an increase in the capital rental rate, $u_t$ (equation 3.30). In the quarters following the shock, output declines following the decline in investment and eventually returns to its steady-state level. The trade balance improves on impact as domestic absorption declines. The current account also improves as the representative household reduces its foreign liability.

![Shock to the terms of trade](image)

**Figure 5.3:** Bayesian Impulse Responses. Notes: (1) Solid lines depict the responses of the endogenous variables to 1% shock to the terms of trade. (2) The shaded area depicts the 90% confidence interval. (3) The responses of output growth, consumption growth, investment growth and hours worked are in log-deviations from their respective steady-states. The responses of the trade balance-to-output ratio and the current account are (linear) deviations from their respective steady-states. Source: authors’ calculations.

Notice that similarly to our empirical analysis in Chapter 2 (Figure 2.3), our model
is able to reproduce the decline in output growth in the quarters following the terms of trade shock. The main difference between our model based impulse response function (Figure 5.3) and the empirical impulse response function (Figure 2.3) consists in the different initial response of output growth to a terms of trade shock. While in the model output increases on impact (due to an increase in hours worked), in our empirical analysis output growth does not change at the time of the shock.

5.2.4 World Real Interest Rate Shock

Figure 5.4 shows that in response to a positive shock to the world real interest rate, consumption and investment decline on impact. According to equation (3.10) an increase in the real interest rate \( r_t \) (either by an increase in the world real interest rate or by an increase in the risk premium) raises the marginal utility of consumption \( \lambda_t \) leading to a fall in consumption. Hours worked do not change on impact and for a given stock of capital (and since productivity does not change), output remains the same on impact.
Figure 5.4: Bayesian Impulse Responses. Notes: (1) Solid lines depict the responses of the endogenous variables to 1% shock to the world real interest rate. (2) The shaded area depicts the 90% confidence interval. (3) The responses of output growth, consumption growth, investment growth and hours worked are in log-deviations from their respective steady-states. The responses of the trade balance-to-output ratio and the current account are (linear) deviations from their respective steady-states. Source: authors’ calculations.

The increase in the real interest rate also raises the debt service payment, which forces a decrease in the level of debt (since now it is more costly to finance the debt). As the economy is not more productive than before, the only way to reduce debt is to increase net exports by either working more or by reducing domestic absorption (the sum of consumption and investment). As hours worked do not change on impact, the representative household reduces domestic absorption leading to an improvement in the trade balance-to-output ratio. The current account improves as the trade balance improves and also because the representative household reduces debt due to the higher cost of borrowing. Notice that the process for the world real interest rate exhibits one of the highest persistence among our estimated structural shocks, which leads to a more long-lived response of our endogenous variables, in particular of hours worked. However, eventually all variables return to their long run level as the effects of the shock dissipates.
over time.

5.2.5 Risk Premium Shock

Figure 5.5 shows the dynamic responses of our endogenous variables to a risk premium shock.

![Graphs showing dynamic responses of endogenous variables](image)

Figure 5.5: Bayesian Impulse Responses. Notes: (1) Solid lines depict the responses of the endogenous variables to 1% shock to risk premium. (2) The shaded area depicts the 90% confidence interval. (3) The responses of output growth, consumption growth, investment growth and hours worked are in log-deviations from their respective steady-states. The responses of the trade balance-to-output ratio and the current account are (linear) deviations from their respective steady-states. Source: authors’ calculations.

As expected the dynamic responses of endogenous variables to a risk premium shock are similar to the responses of our endogenous variables to a shock to the world real interest rate. On impact, consumption and investment decline, while output and hours worked do not change. The decline in investment leads to a decline in output and hours worked in the quarters following the shock. Eventually all variables return to their initial steady-state as the shock dissipates over time. Notice that the responses of our domestic
variables to a risk premium shock (Figure 5.5) are more short-lived than in the case of a world real interest rate shock (Figure 5.4). The trade balance improves following the decline in domestic absorption, as does the current account.

Finally, notice that consistently with our empirical results (Figure 2.6), our model generates output drops following a real interest rate shock.

5.2.6 Government Expenditure Shock

Figure 5.6 presents the dynamic responses of our artificial economy to a government expenditure shock. A positive shock to government expenditure implies a negative wealth effect on the representative household, which leads to a fall in consumption. However, the decline in consumption does not offset the impact of higher government expenditure, and as output does not change on impact, this implies a deterioration of the trade balance as well as of the current account (more debt). The deterioration of the debt position drives up risk premium (equation 3.21) and consequently increases the real interest rate (cost of debt). Higher cost of borrowing leads to a decline in investment, which lowers output. (Although the response of output growth is not significantly different from zero). As the shock dissipates over time, all variables return to their steady-state level.

---

1The estimated process for the risk premium exhibits lower persistence vis-à-vis the estimated world real interest rate process. While the coefficient governing the persistence of the risk premium shock is 0.48, this coefficient is 0.86 for the world real interest rate process.
Figure 5.6: Bayesian Impulse Responses. Notes: (1) Solid lines depict the responses of the endogenous variables to 1% shock to government expenditure. (2) The shaded area depicts the 90% confidence interval. (3) The responses of output growth, consumption growth, investment growth and hours worked are in log-deviations from their respective steady-states. The responses of the trade balance-to-output ratio and the current account are (linear) deviations from their respective steady-states. Source: authors’ calculations.

5.3 Variance Decomposition

The main objective of this study is to evaluate the role played by productivity shocks (temporary and permanent), world price shocks (terms of trade and world real interest rate), risk premium shocks and government expenditure shocks in driving business cycle fluctuations in our emerging market benchmark economy. We do so by performing a forecast error variance decomposition exercise for real output growth, real consumption growth, real investment growth and the trade balance-to-output ratio. Table 5.2 depicts the results of the forecast error variance decomposition exercise for a 20 quarters horizon.²

²Business cycles frequencies are commonly defined as the period covering from 6 to 32 quarters (Stock and Watson, 1999), thus we choose a period somewhere in between.
Table 5.2: Variance Decomposition

<table>
<thead>
<tr>
<th>Variables</th>
<th>Output Growth</th>
<th>Consumption Growth</th>
<th>Investment Growth</th>
<th>TBY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temporay Prod.</td>
<td>51.85</td>
<td>28.82</td>
<td>0.12</td>
<td>0.10</td>
</tr>
<tr>
<td>Growth shocks</td>
<td>23.92</td>
<td>44.14</td>
<td>59.6</td>
<td>77.65</td>
</tr>
<tr>
<td>Terms of Trade</td>
<td>13.44</td>
<td>0.10</td>
<td>1.65</td>
<td>1.54</td>
</tr>
<tr>
<td>World Int. Rate</td>
<td>0.61</td>
<td>1.78</td>
<td>10.63</td>
<td>8.69</td>
</tr>
<tr>
<td>Risk Premium</td>
<td>10.15</td>
<td>24.97</td>
<td>27.91</td>
<td>6.32</td>
</tr>
<tr>
<td>Government Exp.</td>
<td>0.03</td>
<td>0.17</td>
<td>0.05</td>
<td>5.68</td>
</tr>
</tbody>
</table>

Note: The table shows the % of the variance of the endogenous variables explained by each of structural shocks. TBY is the trade balance to output ratio. Authors’ calculations.

A number of observations emerge from this Table. First, domestic productivity shocks explain the bulk of fluctuations in all domestic variables considered. Temporary productivity shocks appear to be the most important driving force behind output growth fluctuations, while permanent productivity shocks (growth shocks) explain most of the behavior of investment growth, consumption growth and the trade balance-to-output ratio over the business cycles. Second, the results of our variance decomposition exercise contrast with the basic premise of Aguiar and Gopinath (2007a; 2007b) analysis, according to which business cycles in emerging economies are mainly characterized by growth shocks.³

Third, shocks to the relative international prices (terms of trade) explain about 13% of output fluctuations. The evidence in the literature about the importance of term of trade shocks in small open economies is mixed. While an earlier DSGE literature (e.g., Mendoza, 1995; Kose, 2002) points out that the terms of trade shocks can be the main

³Recent contributions have also challenged Aguiar and Gopinath’s (2007) proposition that "the cycle is the trend" in emerging economies (see for instance García-Cicco, Pancrazi and Uribe, 2007 and Chang and Fernandez, 2008).
driving force in small open economies, a more recent literature (e.g., Lubik and Teo, 2005; Lubik and Schorfheide, 2007), does not find strong evidence supporting this idea. Our results lie somewhere in between.\footnote{It is important to point out that the VAR evidence is also mixed regarding the role of the terms of trade. While some studies support the idea that terms of trade are important for domestic business cycles in small open economies, others offer support in the opposite direction. For instance, Hoffmaister and Roldós (2001) present some VAR evidence that terms of trade shocks can explain up to 27\% of aggregate fluctuations in Korea, but these shocks can explain only 5\% of the Brazilian business cycles.}

Fourth, interest rate shocks, in particular risk premium shocks, explain a fairly important fraction of output fluctuations in our benchmark economy. They also appear to be important in driving the aggregate behavior of consumption and investment growth over the business cycles. As in the case for the terms of trade shocks, the evidence in the literature is mixed regarding the importance of real interest rate shocks. On the one hand, Neumeyer and Perri (2005), Lubik and Teo (2005) and Uribe and Yue (2006) are examples of papers emphasizing the role played by the cost of borrowing as a source of aggregate fluctuations in small open economies. On the other hand, Aguiar and Gopinath (2007b) do not find a significant role for real interest rate shocks in their analysis. Again our results lie somewhere in between these two strands of the literature.

Finally, government expenditure shocks are not relevant in driving aggregate output fluctuations in our model economy. Appendix J presents Forecast Error Variance Decompositions for our endogenous variables considering different time horizons. Overall our conclusions regarding the sources of business cycle fluctuations remain unchanged in spite of different time horizons considered.

\section*{5.4 Historical Decomposition}

In this section we perform a historical decomposition of output growth. We do so by simulating the response of our system to one estimated shock at a time, to see how history would have evolved with only that shock. This exercise allows us to evaluate the
forces behind economic fluctuations in our benchmark economy. Figure 5.7 presents the structural shocks recovered from the estimation procedure and used to implement the historical decomposition exercise, while Figure 5.8 depicts the results of the historical decomposition exercise. Figure 5.8 also shows the actual output growth observed in the data, which serves as a benchmark for comparison.\footnote{In computing the historical decomposition we have added the mean of output growth to the predicted and actual variable. Recall that we have demeaned the vector of observable variables to reflect the idea that our model variables are in log-deviations from steady-state.}

Figure 5.7: Structural Shocks. Source: Authors’ calculations.
Figure 5.8: Historical Decomposition of Output Growth. Each line represents the predicted output growth using the correspondent shock as the only driving force of business cycles. Source: Authors’ calculations.

Overall, the decomposition above reveals that expansions and contractions of the economic activity are a result of different combinations of type and direction of shocks. For instance, while the expansion in output observed in the first quarter of 1997 appears to have been caused mostly by a positive productivity shock, this expansion occurred in spite of adverse risk premium and terms of trade shocks. On the other hand, although favorable productivity and risk premium shocks had occurred in the last quarter of 1998, which *ceteris paribus* would have led to an expansion in output, an adverse terms of trade shock appears to be behind the contraction actually observed in output in that period.

Among the predicted time series for output growth, the one generated by temporary productivity shocks is the most correlated with observed output growth, while the
time series for output growth generated by world real interest rate shocks presents the lowest correlation with actual output growth. The raw correlations are 0.63 and 0.01, respectively. These results seems to be consistent with the fact that temporary productivity shocks appear to be the most important driver behind business cycle fluctuations in Brazil along our sample period, while world real interest rate shocks are of the second order importance.\footnote{The correlations between predicted output and observed output is of the order of 0.1 when growth shocks are the only source of business cycles, of the order of 0.25 for terms of trade shocks, 0.06 for risk premium, and finally of 0.15 for government expenditure shocks.}

An interesting point in the data is the contraction observed in the first quarters of 2003. Figures 5.7 and 5.8 show that the contraction was preceded by a bad risk premium shock (i.e., an increase in the risk premium) and was mostly caused by a bad productivity shock. That period is marked by an environment of high uncertainty surrounding the presidential elections and the consequent lower level of confidence by consumers and investors. As we can observe from Figure 5.7, the peak in the estimated time series for the risk premium shock (bad shock) and the trough in the estimated time series for productivity shocks reflect exactly these facts. Figure 5.8 also shows that if only risk premium shocks or terms of trade shocks had occurred in that period (first quarters of 2003) the contraction would have been lower than the one actually observed. Similarly, Figure 5.8 reveals that the expansion observed in the last quarters of our sample period (2006 onward) would have been higher if only risk premium shocks had occurred.

5.5 Model Fit

In this section we assess the fit of our model. First, we compare business cycle statistics obtained from the data and from model simulations. Second, we compare predicted and actual time series for our observable variables.
5.5.1 Business Cycle Moments

In the first exercise, we use our model to generate 1,000 replications, each simulation of same length as the data sample, and compute averages of the statistics of interest. Table 5.3 depicts the results of simulations along with the statistics from the data.

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Brazilian Data</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Standard Deviation:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output Growth</td>
<td>1.51%</td>
<td>2.23%</td>
</tr>
<tr>
<td>Consumption Growth</td>
<td>3.68%</td>
<td>2.21%</td>
</tr>
<tr>
<td>Investment Growth</td>
<td>5.95%</td>
<td>8.59%</td>
</tr>
<tr>
<td>Trade Balance to Output ratio</td>
<td>2.5%</td>
<td>20.34%</td>
</tr>
<tr>
<td>Real Interest Rates</td>
<td>1.08%</td>
<td>0.81%</td>
</tr>
<tr>
<td>(b) Correlation of Output Growth with:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consumption Growth</td>
<td>0.29</td>
<td>0.86</td>
</tr>
<tr>
<td>Investment Growth</td>
<td>0.63</td>
<td>0.22</td>
</tr>
<tr>
<td>Trade Balance to Output Ratio</td>
<td>0.17</td>
<td>0.10</td>
</tr>
<tr>
<td>(c) Correlation of Interest Rates with:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output growth</td>
<td>-0.08</td>
<td>-0.0004</td>
</tr>
<tr>
<td>Consumption growth</td>
<td>0.05</td>
<td>-0.14</td>
</tr>
<tr>
<td>Investment growth</td>
<td>-0.18</td>
<td>-0.26</td>
</tr>
<tr>
<td>Trade Balance to Output ratio</td>
<td>-0.49</td>
<td>0.31</td>
</tr>
</tbody>
</table>

Note: Authors’ calculations. Model statistics are averages across 1,000 simulations, each simulation of same length as the data sample. The column "Data" refers to unconditional sample moments computed using Brazilian data from the third quarter of 1994 to the first quarter of 2008.

From Table 5.3 we can derive the following conclusions:
1. The model generates investment more volatile than output and consumption as in the data. However, consumption in the model appear to be less volatile than output, while in the data the reverse is true.

2. Both output and investment are more volatile in the model than in the data, while consumption is less volatile. The model is able to generate real interest rate as much volatile as in the data.

3. Although the model is able to generate counter-cyclical real interest rates as in the data, the correlation in the model is practically nil.

4. The correlations between output growth and consumption growth, output growth and investment, and output growth and the trade balance-to-output ratio are all positive as in the data. However, notice that the first two are bigger than the data correspondent, while the last one is smaller vis-à-vis the correlation in the data.

5.5.2 Predicted versus Actual Data

Figure 5.9 reports the data and the benchmark model’s Kalman filtered one-sided estimates of the observed variables, computed at the posterior mode of the estimated parameters.
Figure 5.9: Model Fit. Data (thin line) and one-sided predicted values from the model (thick line).

Overall, the in-sample fit of the model seems to be satisfactory with some exceptions. For instance, the model’s time series for investment is predicted to grow slowly than in the data in the last quarters of the sample. Similarly, the predicted series for domestic real interest rate appears to be higher than the one actually observed in the data in the same period. The model also misses the contraction observed in the first quarters of 2003 in output and investment growth, although it captures, at least qualitatively, the spike observed in the domestic real interest rate in the last quarters of 2002. On the other hand, Figure 5.9 shows that the model does a good job in tracking the behavior of the world real interest rate.
Chapter 6

Discussion and Additional Results

6.1 The importance of interest rate shock and the working capital constraint

Despite the fact that real interest rate shocks, in particular risk premium shocks, are important in driving aggregate fluctuations in our benchmark economy, it seems interesting to discuss our results vis-à-vis some recent similar studies involving small open economies, in particular those focusing on emerging economy business cycles. For instance, Neumeyer and Perri (2005) reports that risk premium shocks can play an important (not predominant) role in driving business cycles in emerging market economies. They show that by eliminating fluctuations in risk premium would lower GDP volatility by approximately 27% in Argentina, while eliminating fluctuations in the world real interest rate, would lower the GDP volatility by 3%.

We think that there are at least two reasons why the role of real interest rate shocks (world real interest rate and risk premium shocks) are more modest in our study. First, the fact that risk premium shocks explain a larger fraction of aggregate fluctuations in Neumeyer and Perri’s (2005) framework may be due to the fact that they consider a smaller number of shocks than we do in our model. Hence risk premium shocks may
be capturing the importance of omitted shocks in their framework. Second, Neumeyer and Perri’s (2005) analysis covers a period of financial turmoil for emerging economies. On the other hand, our sample period covers periods of financial turmoil (1994 to 2002) and tranquil times (2003 onward).\(^1\) In what follows, we examine whether the period of estimation and the number of shocks matter.

### 6.1.1 "Turmoil" versus "Tranquil" times

A first inspection of the behavior of the real interest rate allows us to identify two periods. In the first period, which it goes from the third quarter of 1994 to the first quarter of 2003, real interest rates appear to be high in level and in volatility. These "turmoil" times are marked by several financial crisis and important contagion effects in emerging economies. For instance, the period from the third quarter of 1994 to the first quarter of 2003 is marked by 5 crisis: the Mexican crisis of 1995, the Asian crisis of 1997, the Russian crisis of 1998, the Argentine crisis of 2001 and the "fear of default" that preceded the 2002 presidential elections in Brazil. This is roughly the period examined by Neumeyer and Perri (2005) and Uribe and Yue (2006). In contrast, during "tranquil" times, from the second quarter of 2003 onward, real interest rates are low in level and volatility. Table 6.1 resumes the behavior of the real interest rate and the world real interest rate in these two periods.

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\(^1\)Third, despite of what the title of this dissertation may suggest, emerging economies are not all alike. Hence the fact that risk premium shocks explain a larger fraction of the Argentine business cycles does not imply that they are going to explain similar fraction of the Brazilian (or any other emerging economy) business cycles. With this regard it would be interesting to implement the same methodology to other emerging economies.
Table 6.1: Real Interest Rates

<table>
<thead>
<tr>
<th>Period</th>
<th>Real Interest Rate</th>
<th>US Real Interest Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average per quarter</td>
<td>Std Dev</td>
</tr>
<tr>
<td>Turmoil (1994:3-2003:1)</td>
<td>2.78%</td>
<td>0.81%</td>
</tr>
<tr>
<td>Tranquil (2003:2-2008:1)</td>
<td>0.95%</td>
<td>0.24%</td>
</tr>
<tr>
<td>Full sample</td>
<td>2.12%</td>
<td>1.11%</td>
</tr>
</tbody>
</table>

Note: Authors’ calculations.

Table 6.1 shows that both the level and volatility of domestic real interest rate in tranquil times are about 1/3 of the values in turmoil times. The world real interest rate is also higher in level and in volatility during the first period. However, notice that despite the fact that real interest rates are higher in level and in volatility during turmoil times vis-à-vis tranquil times this does not mean necessarily that shocks to the real interest rate (either domestic or international) are going to explain a larger fraction of aggregate fluctuations in our benchmark economy. It is still the case that other shocks might end up explaining larger fractions of output fluctuations. Besides, notice that both the level and volatility of real interest rates for the full sample are high and still this does not imply that 1/3 of output fluctuations would be attributable to real interest rate shocks, as it is the case in Neumeyer and Perri (2005).

Just to get an idea whether or not the period of estimation matters, we reestimate our benchmark model covering only the turmoil period and investigate whether the results change dramatically. On the other hand, to assess whether the number of shocks matter, we also simulate a restricted version where only shocks to the risk premium, to the world real interest rate and to domestic temporary productivity shocks are present. In this simulation, we set the parameters governing government expenditure shocks, permanent productivity shocks and terms of trade shocks to zero. All the other parameters are set at their baseline value (when all shocks are included and the model is estimated over the
turbmoil period only). This is done so this version can be compared, for example, with the results of Neumeyer and Perri (2005), which include exactly the same driving forces in a similar model for Argentina.

Similarly, we also report the results from a variance decomposition exercise using our baseline model (all shocks) and the restricted version (less shocks) using the full sample. Table 6.2 reports the results of this exercise.

<table>
<thead>
<tr>
<th>Model</th>
<th>% of variance of $\Delta y$ due to shocks to</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Risk Premium</td>
</tr>
<tr>
<td>Turmoil Period (1994:3-2003:1)</td>
<td></td>
</tr>
<tr>
<td>Restricted Version</td>
<td>11.5%</td>
</tr>
<tr>
<td>Baseline Model</td>
<td>7.1%</td>
</tr>
<tr>
<td>Full Period (1994:3-2008:1)</td>
<td></td>
</tr>
<tr>
<td>Restricted Version</td>
<td>16%</td>
</tr>
<tr>
<td>Baseline Model</td>
<td>10.1%</td>
</tr>
</tbody>
</table>

Note: The restricted version contains only shocks to temporary productivity, risk premium and world real interest rate. Authors’ calculations.

At least two results emerge from Table 6.2. First, the estimation (and simulation) over the "turbmoil" period does not increase the fraction of output volatility explained by risk premium shocks. Indeed, these shocks end up explaining smaller fractions of aggregate fluctuations in both versions of the model during the turmoil period. Second, the fraction of aggregate fluctuations that can be attributable to real interest shocks increases as we consider a smaller number of shocks. This suggests that the relatively higher importance of risk premium shocks in Neumeyer and Perri (2005), for instance, may be due to model’s misspecification, i.e., these shocks may be capturing the importance of omitted shocks in their theoretical framework.
6.1.2 The role of the working capital constraint

One last concern consists in the role played by the working capital constraint in helping the model to generate negative correlations between output and real interest rate in line with the data. Recently, a number of authors (e.g., Neumeyer and Perri, 2005; Uribe and Yue, 2006; Kanczuk, 2005) have stressed the crucial role played by this constraint. In particular, Neumeyer and Perri (2005) show that absent this constraint, their small open RBC model fails to generate (highly) countercyclical real interest rates, which is at odds with the empirical evidence.\(^2\) The presence of the working capital constraint creates an additional mechanism whereby real interest rate shocks affect aggregate fluctuations. Under the working capital constraint, an increase in the real interest rate affect the firm’s effective cost of hiring labor and, consequently, the firm’s labor demand. A decline in labor demand affect directly domestic output and, hence, the response of output to a real interest rate shock is amplified when firms are subject to a working capital constraint.

To determine the importance of the working capital constraint, we perform two additional exercises. First, we simulate a version of our baseline model without imposing this constraint and compute business cycle implications (Model II). We also simulate a version of the model with a higher value for the parameter governing the working capital constraint (Model III). Then we compare the results of these two simulations with the same statistics in the data and also with the results of our baseline model, which includes the working capital constraint (Model I). Table 6.3 depicts the results.

\(^2\)However the role of working capital constraint in generating countercyclical interest rates has been challenged recently by Oviedo (2005). He argues that the standard small open economy model (e.g., Mendoza, 1991) is able to reproduce countercyclical interest rates even without imposing that firms are subject to a working capital constraint. He shows that when interest rates are high in level and in volatility, the standard small open economy model is able to reproduce countercyclical real interest rates.
Table 6.3: Business Cycles Properties under alternative formulations

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Brazilian Data</th>
<th>Model I</th>
<th>Model II</th>
<th>Model III</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>$\mu = 0$</td>
<td>High $\mu$</td>
<td></td>
</tr>
<tr>
<td>(a) Standard Deviation:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output Growth</td>
<td>1.51%</td>
<td>2.23%</td>
<td>2.11%</td>
<td>2.55%</td>
</tr>
<tr>
<td>Real Interest Rates</td>
<td>1.08%</td>
<td>0.81%</td>
<td>0.82%</td>
<td>0.8%</td>
</tr>
</tbody>
</table>
| (b) Correlation of Interest Rates with:
  Output growth             | -0.08          | -0.0004 | 0.072    | -0.025    |
  Consumption growth         | 0.05           | -0.14   | -0.009   | -0.16     |
  Investment growth          | -0.18          | -0.26   | -0.23    | -0.28     |

Note: Model I corresponds to our baseline model estimated over the full sample. Model II corresponds to a version of the baseline model where no working capital constraint is imposed. Model III corresponds to the baseline model with a high value for the parameter governing the working capital constraint $\mu$. Authors’ calculations.

A few conclusions can be derived from the results above. First, notice that the presence of the working capital constraint (Model I and Model III) increases output volatility. As we have pointed out before, this constraint creates an additional transmission mechanism in our model economy. Second, although the correlation between output and real interest rate is negative in our baseline model (model I), this correlation is quite small when compared with the data. Furthermore, in the absence of the working capital constraint the model fails to generate countercyclical real interest rates (model II). Finally, the negative correlation between output and real interest rate increases (in absolute terms) as we increase the parameter governing the working capital constraint (model III).

It is interesting to keep in mind that although a working capital constraint amplifies the impacts of real interest rate shocks on aggregate fluctuations, this constraint is not essential for the model to generate output drops following real interest rate shocks (see Correia, Neves and Rebelo, 1995). Consider, for instance, the dynamic responses of our
artificial economy to a risk premium shock when no working capital constraint is imposed on domestic firms. Figure 6.1 depicts these responses.3

![Graphs showing the response of various economic indicators to a shock to risk premium.](image)

Figure 6.1: Bayesian IRF - Risk Premium Shock when no Working Capital Constraint is imposed in the model.

Notice that output, consumption and investment all decline following a real interest rate shock. Nevertheless, observe that, in the absence of the working capital constraint, the impacts of real interest rate shocks on aggregate fluctuations are substantially smaller, when compared with the model that features that constraint (figure 5.5). Consequently, the importance of these shocks in driving aggregate fluctuations diminishes (Correia, Neves and Rebelo, 1995; Neumeyer and Perri, 2005).

To understand why a model without a working capital constraint is able to reproduce output declines we need to consider the equilibrium conditions in our model. Consider, for example, the bonds Euler equation (equation 3.10) without the bonds adjustment

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3We have reestimated our baseline model without imposing a working capital constraint. From the model solution and estimated parameters we compute the responses to a 1% shock to risk premium (Bayesian impulse response function).
cost function.\footnote{Since the parameter governing the bonds adjustment cost $\varphi = 0.0001$ is sufficiently close zero, this does not compromise the analysis.} Rearranging terms we obtain

$$a_t^\psi \frac{1}{1 + r_t} = \beta \frac{E_t \lambda_{t+1}}{\lambda_t}$$

According to this equation an increase in the real interest rate $r_t$ (either by an increase in the world real interest rate or by an increase in the risk premium) raises the marginal utility of consumption $\lambda_t$, leading to a decline in consumption. Investment also declines due to the non-arbitrage condition between the returns to physical capital and to foreign assets. On impact, hours worked do not change and for a given stock of capital (and since productivity does not change), output remains the same. Both output and hours worked start to decline in the quarters following the real interest rate shock. Figure 6.1 above depicts these results.

The increase in the real interest rate also raises the debt service payment, which forces a decrease in the level of debt (since now it is more costly to finance debt). As the economy is not more productive than before, the only way to reduce debt is to increase net exports by either working more or by reducing domestic absorption (the sum of consumption and investment). As hours worked do not change on impact, the representative household reduces domestic absorption.

In sum, the working capital constraint matters in helping the model to generate more realistic countercyclical real interest rates in emerging economies.

### 6.2 The cycle is not the trend

We have seen that domestic productivity shocks explain of the aggregate fluctuations in our benchmark economy. In particular, shocks to temporary productivity are the main
driving force behind output growth fluctuations. We have argued that these results contrast with Aguiar and Gopinath’s (2007a) proposition, according to which business cycles in emerging economies are mainly characterized by shocks to trend productivity (growth shocks). Their basic premise is that emerging and developed economies mainly differ with respect to the behavior of the underlying productivity process. While developed economies enjoy a relatively stable long run growth rate of output, emerging economies are characterized by more volatile long run growth rates due to drastic changes in fiscal, monetary and trade policies. Thus, according to them, one should expect that shocks to trend productivity to be the primary source of aggregate fluctuations and hence "the cycle is the trend" in emerging economies. Our results, however, suggest the opposite, i.e., "the cycle is not the trend".

There are at least two reasons why our results differ from those of Aguiar and Gopinath (2007a), where apparently growth shocks explain a larger fraction of aggregate fluctuations in their benchmark emerging economy - Mexico - vis-à-vis their benchmark developed small open economy - Canada. First, Aguiar and Gopinath (2007) do not use their model to perform a variance decomposition exercise. Instead, they use an univariate method (King, Plosser, Stock and Watson, 1991) that decomposes the variance of output into a permanent and temporary component, and then they compare the fraction of total volatility explained by each of these components. They arrive at the conclusion that the "cycle is the trend" in emerging economies based on their model’s ability to reproduce some business cycles moments in line with the data, and by showing that the permanent component, identified using the univariate time series method, is larger than the temporary component.

In our perspective this is not the most appropriate exercise if one is interested in assessing the importance of structural shocks within the context of dynamic general equilibrium models. We think that the role of shocks in driving business cycles should not be judged by univariate time series methods as the one used by Aguiar and Gopinath
(2007a). Instead, they should be evaluated using the very structural model used to identified them.

We also suspect that a variance decomposition exercise would attribute a smaller role for growth shocks in explaining aggregate fluctuations in Aguiar and Gopinath’s benchmark emerging economy. This is because the parameter governing the persistence of growth shocks in their model is practically nil. Therefore, it is unlikely that growth shocks would end up explaining large fractions of aggregate fluctuations in their framework.

It is important to stress that we are not alone in challenging the main argument of Aguiar and Gopinath’s (2007) analysis. Recently a number of authors have also challenged their proposition that "the cycle is the trend" in emerging economies. For instance, Garcia-Cicco, Pancrazi and Uribe (2006) have shown that a standard RBC model driven by productivity shocks (temporary and permanent shocks) cannot account for empirical regularities of the Argentine business cycles using annual data covering the period from 1900-2005. They show that the model fails to explain the behavior of the trade balance-to-output ratio. Similarly, Chang and Fernandez (2008) using Bayesian techniques, as we do in this study, show that a small open economy model driven by temporary and permanent productivity shocks only (as in Aguiar and Gopinath, 2007a) is not better supported by the Mexican data (the same data set as Aguiar and Gopinath, 2007a) than a small open economy model driven by temporary productivity shocks, world real interest rate shocks and risk premium shocks (as in Neumeyer and Perri, 2005).

The second reason why growth shocks explain a smaller fraction of aggregate fluctuations in our benchmark economy is that, paraphrasing Martinez-Dias and Brainard (2009), Brazil is now a "stable and vibrant democracy that has enjoyed a sustained period of low inflation and sound macroeconomic management". Thus better fundamentals and better governance would be translated in relatively fewer "growth shocks" when compared to less stable economies with poorer macroeconomic management and
fundamentals.\footnote{A third reason could be the difference in the number of shocks considered, i.e., our model features more shocks than theirs. However, even if we attribute the importance of all other shocks in our model to growth shocks (except for temporary productivity shocks), the fraction of output volatility explained by this shock would be far from being predominant, as temporary productivity shocks would still account for half of output fluctuations.}

6.3 The unimportance of the fiscal policy

The results of our variance decomposition exercise show that government expenditure shocks are not important in driving aggregate fluctuations in our model economy. In the context of small open economy models, Correia, Neves and Rebelo (1995) also obtain the result that government expenditure shocks are of the second-order importance in driving aggregate fluctuations. Rebelo (2005) argues that it might be the case that there is not enough cyclical variation in tax rates and government expenditure for fiscal shocks to be a major source of fluctuations.

In spite of that, we think that the small role played by government expenditure shocks may be related to the simple role played by fiscal policy in our model. It was assumed that government expenditures are financed solely through lump sum taxation and, therefore, no distortions from taxation are allowed in our analysis. We think that it would be interesting to investigate whether allowing for distortionary taxation, which affect the household’s labor supply and consumption-saving decisions, would yield significantly different results.

McGrattan (1994), for example, introduces distortionary taxation in a basic RBC (closed economy) model (e.g., Kydland and Prescott, 1982) and shows that a significant fraction of aggregate fluctuations in the U.S. can be attributable to shocks in labor and capital tax rates and government consumption. Hence, future work should assess if distortionary taxation would increase the role played by fiscal policy in explaining
business cycle fluctuations in Brazil and in others emerging economies.⁶

6.4 The role of the terms of trade

Although productivity shocks are the main source of aggregate fluctuations in our model economy, our results also show that terms of trade shocks can also be an important force driving business cycle fluctuations. As we have emphasized in chapter 1, the evidence in the small open economy literature is mixed with respect to the importance of terms of trade shocks. On the one hand, an earlier literature (e.g., Mendoza, 1995; Kose, 2002) argue that these shocks are the main driving force behind aggregate fluctuations in small open economies (both developed and developing). On the other hand, some recent studies (e.g., Lubik and Teo, 2005) suggest that this is not the case. Our results lie somewhere in between these two views.⁷

As in the more recent literature, the production structure in our model is relatively simpler than the ones used in the earlier literature, which pointed out the predominant role played by terms of trade shocks. So, one may argue that it might be the case that a richer production structure, where the terms of trade affect the supply side directly (as in Mendoza, 1995; and Kose, 2002), could increase the fraction of aggregate fluctuations due to terms of trade shocks in Brazil.⁸ Nonetheless, even though a richer production structure could potentially increase the role played by terms of trade shocks, it is still

⁶The task here is to find reliable data on effective capital and labor taxes rates for Brazil.

⁷It is important to notice that Brazil is not a typical emerging (developing) economy. Both Mendoza (1995) and Kose (2002) argue that a typical developing economy depends heavily on imports of intermediate inputs and capital goods and are specialized in exports of primary goods (commodities). However, 64% of the Brazilian exports are composed by intermediate inputs of production and capital goods. Source: FUNCEX - Fundação de Comércio Exterior - available in their website: www.funcex.org.br.

⁸This exercise is particularly interesting because most of the Brazilian imports are composed by intermediate inputs and capital goods, as both account for roughly 72% of the total imports, while consumption goods (durable and non-durables) account for about 11% of total imports. Thus it might be the case that the relevant channel through which terms of trade affect aggregate fluctuations is through the production side of the economy.
the case that shocks to the terms of trade may not be as important as other shocks in our benchmark economy. The empirical analysis in chapter 2 seems to suggest this.\textsuperscript{9} It is possible that the importance of terms of trade shocks, as a source of business cycle fluctuations, can increase as the Brazilian economy deeps its integration with the rest of the world.

6.5 The current global financial crisis and the Brazilian economy

Although an extensive and complete analysis of the causes and implications of the current financial crisis is beyond the scope of this dissertation, it seems interesting to discuss briefly some evidence about the recent performance of the Brazilian economy and also how our model would capture the impact of this crisis. However, before we present some evidence, it is opportune to discuss briefly the channels of transmission of global crisis to economies like Brazil.

There are, at least, three nonexclusive main channels through which the effects of a global crisis are transmitted: a credit channel, an international trade channel and a confidence channel. The credit channel affects both the cost of funding and the availability of credit. When financial conditions are tight, banks’ and other financial institutions’ willingness to lend is lower and the cost of borrowing tends to be higher. On the other hand, global crises hit the domestic economy through the international trade channel by lowering the international demand and prices for domestically produced goods. Finally, the confidence channel captures the higher risk aversion in international markets that drives up risk premia, the reversals in capital flows reflecting the "flight" to safer currencies that have exchange rate implications, and last, but not least, the fall in consumers’

\textsuperscript{9}Moreover, Hoffmaister and Roldós (2001), for example, report that terms of trade shocks can account for up to 5\% of GDP volatility in Brazil in their VAR analysis.
and investors’ confidence that leads them to curtail their consumption and investment
decisions. Even though this classification is somewhat arbitrary, it helps to summarize
the effects of a global crisis in small open economies. In what follows, we present some
evidence about the impacts of the recent crisis on the Brazilian economy and discuss how
our model would capture such effects.

6.5.1 Economic context and current conditions in Brazil

The current financial crisis, originated in the developed world, has had important
impacts in all regions of the world and emerging economies are no exception. Never-
theless, a brief look at recent economic performance of some economies, Brazil included,
suggests that those economies have shown some signs of resilience to the crisis and they
might be the first ones to recover (RGE Monitor report, 2009). In particular, despite
the fact that the global financial crisis had "started" in the middle of 2007, the Brazilian
economy seems to have been impacted mostly in the last months of 2008 and in the first
months of 2009. The data also shows that there are some incipient signs of recovery.

Industrial Sector

For instance, Figure 6.2 shows that both industrial production and industrial sales
were relative higher in the first months of 2008, but both of them have declined sharply
by the end of 2008. Nonetheless, even though both indicators are in historically low
levels, they have shown some evidence of relative recovery in the first months of 2009.

10Cecchetti, Kohler and Upper (2009), for instance, present seven channels: funding costs, credit
availability, risk aversion, firms’ net worth, households’ net worth, exchange rates and confidence.
Figure 6.2: Industrial Production and Industrial Sales. Source: the industrial production index is from Pesquisa Industrial Mensal from Instituto Brasileiro de Geografia e Estatística (IBGE) and Industrial Sale index is from Confederação Nacional da Indústria (CNI). Both indexes are seasonally adjusted. Authors’ calculations.

The fall in real production was felt in all industrial segments, but it was especially important in the capital goods sector. The signs of relative recovery are also present in all sectors, although this is less evident in the nondurable sector.
Figure 6.3: Industrial Production. Source: the indexes are from Pesquisa Industrial Mensal (PIM - PF) from Instituto Brasileiro de Geografia e Estatística (IBGE). All indexes are seasonally adjusted. Authors’ calculations.

Retail Sector

The retail sector was also affected by the crisis, but to a lesser extent. Figure 6.4 shows that total sales in the retail sector presented a sharp decline in the last quarter of 2008, but they appear to have recovered most of their previous dynamism. The decline seems to have been led by the automotive segment and by the furniture and housing appliances segment, while supermarket sales, which corresponds to roughly 50% of the total index, seem stable over the period.
Figure 6.4: Retail Sector Real Sales. Source: the indexes are from Pesquisa Mensal do Comércio (PMC) from Instituto Brasileiro de Geografia e Estatística (IBGE). All indexes are seasonally adjusted. Authors’ calculations.

**Labor Market and Earnings**

Figure 6.5 shows that the unemployment rate has increased in the first months of 2009, when compared to the previous year, but it shows signs of decline in the second quarter of 2009. Moreover, note that despite of the crisis the unemployment rate has remained in historically low levels.\(^\text{11}\)

\(^{11}\)We can also justify this by the labor hoarding behavior of firms, refusing to lay off employees at the first sight of crisis. (Burnside, Eichenbaum and Rebelo, 1993).
Figure 6.5: Unemployment rates. Source: Instituto Brasileiro de Geografia e Estatística (IBGE). Authors’ calculations.

Figure 6.6 shows that real earnings had declined in the end of 2008, but again there are signs of relative recovery. The layoffs in the beginning of 2009 were greater than in previous years, maybe reflecting the lack of confidence by the end of 2008.

Figure 6.6: Real Earnings and Job Creation. Source: Real Earnings index is from Pesquisa Mensal do Emprego from Instituto Brasileiro de Geografia e Estatística (IBGE). Jobs creation index is from Ministério do Trabalho e Emprego (MTE). Authors’ calculations.
Consumer confidence has declined to historically low levels in the last months of 2008 and first months of 2009, but it appears that consumers are restoring their confidence on future developments of the Brazilian economy.

![Consumer Confidence Graph]

Figure 6.7: Consumer Confidence. Source: the confidence index is from Fundação Getúlio Vargas (FGV). The index is seasonally adjusted. Authors’ calculations.

The same signs of confidence recovery can be observed in the industrial confidence index. Figure 6.8 shows that the industrial confidence has declined in the last quarter of 2008 and first quarter of 2009, but as in the consumer confidence case there is some evidence of relative recovery.
Industrial Confidence

![Graph of Industrial Confidence](image)

Figure 6.8: Source: the confidence index is from Confederação Nacional da Indústria (CNI). The index is seasonally adjusted. Authors’ calculations.

**International Trade and Financial Markets**

The global crisis has also affected the Brazilian economy through the international trade channel. As Figure 6.9 shows there was an important decline in the volume of exports and imports, and also the terms of trade have deteriorated. Nonetheless, as in most of the other conjuncture indicators, there are signs of relative recovery, although this is less evident for exports.

![Graph of Exports and Imports](image)

Figure 6.9: Source: Exports and Imports indexes are from IBGE. The indexes are seasonally adjusted. The terms of trade index is from IPEA. Authors’ calculations.
Figure 6.10 shows that the international global crisis also affected the cost of borrowing. Both the EMBI + index for Brazil and for all emerging economies have presented an increase in the end of 2008. Notwithstanding, by December of that year, the indicators have declined. Figure 6.10 also shows that the Brazilian currency (Real) had depreciated against the U.S. dollar, which could have been a consequence of lack of confidence of international investors leading to a flight to safer currencies. However, as it can be observed, that movement was reverted in the beginning of 2009.

![EMBI Brazil and Emerging Markets](image1)

![Nominal Exchange Rates](image2)

Figure 6.10: Source: the EMBI indexes are from JP Morgan available at Global Financial Data. The nominal exchange rate is from Banco Central do Brasil (BCB). Authors’ calculations.

### 6.5.2 Better Fundamentals

In part the relative strength of the Brazilian economy can be credited to better fundamentals and a healthier financial system when compared to other emerging economies and to its own recent history. Brazil has enjoyed a relatively long period of low inflation and a strong commitment to sound macroeconomic policies. Moreover, Brazil took advantage of the recent boom years (2003-2008) reducing external vulnerabilities and
increasing savings, either in terms of international reserves or in terms public savings.

Figure 6.11 shows that both the total net debt and external net debt have been declining over the years, although in the last months of 2008 the Brazilian economy has experienced a slightly increase in the total debt-to-GDP ratio (mostly due to the fall in GDP). Furthermore, international reserves today are at the order of US$ 214 billion, almost 4 times as larger than it was in 2004. Foreign direct investment has also remaining high despite of the global financial crisis.

Figure 6.11: Source: all data is from Banco Central do Brasil (BCB). Authors’ calculations.

The financial sector in Brazil has also benefiting from a series of regulation put in place starting in 1995 in response to an incipient banking crisis at that time.\textsuperscript{12} For instance, the Programme of Incentives for Re-Structuring and Strengthening the National

\textsuperscript{12}Inflation revenue accounted for a sizable fraction of the Brazilian banks revenue during high inflation periods (pre-1994). Some estimates indicate that about 35% of the banks revenue were due to inflation (OECD, 2001). With the end of the high inflation period, Brazilian banks saw one of their main source of resources to vanish completely. This fall in revenue lead many banks to struggle and some "closed their doors ". For more details, we refer the reader to the OECD Economic Report 2001.
Financial System (PROER) fostered the liquidation of distressed private banks to prevent interruption of services and disruption to clients. As a result large and more competitive banks were able to strengthen their competitive position through the acquisition of weaker institutions hit by the banking crisis at that time. Besides, the National Monetary Council (CMN) imposed more restrictive capital requirements making the already conservative Brazilian banks more strict in the amount of risk they could afford. For example, beginning in 1995 financial institutions just starting up were required a minimum risk-weighted capital-asset ratio of 32 percent, and this ratio (Basel index) would be reduced to 16 percent over their first six years of operation (Rennharck, 2000). Today, the regulatory minimum is 11%, while the international standard is 8%. However, on average, the relation between capital and risk-weighted assets is 16% in Brazil. On the other hand, Brazilian banks have very low foreign liabilities, which somewhat has protected the country from major contraction in international financial markets (Cárdenas, 2009). Therefore, we believe that the combination of better fundamentals, sound macroeconomic policy and healthy financial system can explain why the Brazilian economy has been more resilient to the current global crisis when compared with past episodes.

**How would the model explain the current economic conditions in Brazil**

As we have pointed out there are, at least, three channels whereby global shocks are transmitted to small open economies: a credit channel, an international trade channel and a confidence channel. Our model only focuses on two of these channels. The first is through the cost of borrowing in international markets, while the second is through movements in relative prices of goods traded in international markets (terms of trade). As we have discussed before higher cost of borrowing affects firm’s decision to hire workers and affects the household’s consumption and saving decision. Moreover, shocks to international relative prices in traded goods affects the domestic wealth *ceteris paribus.*
Accordingly, in our model, the current global crisis would affect our benchmark economy through higher costs of borrowing (real interest rate shock) and lower prices for domestically produced goods (negative terms of trade shock).

As we have seen in the previous subsection, the global financial crisis has affected the Brazilian economy through both of these channels, by increasing the cost of borrowing and by depressing the relative prices of goods (the terms of trade). We think that as more data become available it would be interesting to assess other elements and channels in explaining the response of the Brazilian economy to the current global financial crisis. For instance, we think that models that include news shocks (news about the future), as in Jaimovich and Rebelo (2006), or models that feature noise shocks (signal extraction problem, where agents face imperfect information about the nature of the shock), as in Boz, Daude and Durdu(2008), or models that include financial intermediation as the one examined by Oviedo (2005) would be interesting starting points.
Chapter 7

Conclusion

The main goal of this study is to address the fundamental question: *what drives business cycle fluctuations in emerging economies?* We have shown that the analysis of the literature does not deliver a clear and straight answer to this question. The results in the literature are mixed for different authors implement different methodologies, use different data set and countries, and mainly because they consider different number and type of shocks to explain aggregate fluctuations. In this study we focus on the later aspect.

We have argued that although the potential sources of fluctuations have been well identified, as these alternative sources are not investigated within the same framework this has naturally led us to reach different conclusions regarding the importance of each shock, i.e., the importance of a particular shock in frameworks with a smaller number of shocks may be due to the fact that this particular shock is indeed capturing the importance of shocks that have not been accounted for in the theoretical model. Therefore, our study is motivated by the lack of consensus in the literature regarding the main driving forces of business cycle fluctuations. Our basic strategy consists in implementing an integrated analysis that incorporates shocks that have been identified in the recent literature as important driving forces into the same theoretical framework. By doing so, we believe
that we can increase our understanding about the driving forces of aggregate fluctuations in emerging economies.

We develop a small open economy model based on Mendoza (1991) augmented to include temporary and permanent productivity shocks, as well as shocks to the terms of trade, to the world real interest rate, to the country risk premium, and to government expenditure. Although we acknowledge that many other driving forces may exist, we picked shocks that have been pointed out recently as important driving forces. Besides the inclusion of more shocks, we modify the standard small open economy RBC model by assuming that domestic firms are subject to a financial constraint whereby firms are required to hold a fraction of labor payments before final output sales are realized.

We use the model to assess the importance of these shocks in explaining business cycle fluctuations in our benchmark emerging economy. Our main result consists that domestic productivity shocks explain the bulk of fluctuations in all domestic variables considered. In particular, temporary productivity shocks appear to be the most important driving force behind output growth fluctuations. The fact that temporary productivity shocks play a predominant role in aggregate fluctuations in small open economies is not at all new as the same result has been obtained in the related literature, even among those that have emphasized the importance of other driving forces (Correia, Neves and Rebelo, 1995 for the developed case and Neumeyer and Perri, 2005 for the emerging economy case). Besides productivity shocks, shocks to the terms of trade and to the risk premium appear to be important as well in driving business cycles in our benchmark economy.

In sum, the results of this study support the idea that a multi-shock model provides a better framework to evaluate the role of alternative explanations (structural shocks) in accounting for business cycle fluctuations in emerging economies. Future work should attempt to include additional shocks and elements that can help better account for business cycles in emerging economies.
Appendix A. Steady-State Relationships

From the model’s stationary equilibrium conditions we can obtain steady-state relationships.

\[ \beta = \frac{\bar{a}^\psi}{1 + r_{ss}} \]  
(A.1)

\[ u_{ss} = p_c(r_{ss} - \delta) \]  
(A.2)

\[ \frac{k_{ss}}{l_{ss}} = \frac{(1 - \alpha)p_h z_{ss}}{u_{ss}} \left( \frac{k_{ss}}{l_{ss}} \right)^{1/\alpha} \bar{a} \]  
(A.3)

\[ w_{ss} = \frac{\alpha p_h z_{ss} \bar{a}^\alpha}{[1 + \mu r_{ss}]} \left( \frac{k_{ss}}{l_{ss}} \right)^{1 - \alpha} \]  
(A.4)

\[ h_{ss} = \left( \frac{w_{ss} t_{ss}}{\tau \omega} \right)^{\frac{1}{\gamma - 1}} \]  
(A.5)

\[ c_{ss} = \frac{1}{p_c} \left[ d_{ss} + w_{ss} h_{ss} + u_{ss} k_{ss} - \tau - p_c i_{ss} - \frac{r_{ss} d_{ss}}{\bar{a}} + \pi_{ss} \right] \]  
(A.6)

\[ i_{ss} = k_{ss+1} \bar{a} - (1 - \delta)k_{ss} \]  
(A.7)

\[ y_{ss} = z_{ss} k_{ss}^{1-\alpha} (\bar{a}_{ss})^\alpha \]  
(A.8)

\[ \lambda_{ss} = \frac{[c_{ss} - \psi h_{ss}]^{-\psi}}{p_c} \]  
(A.9)

\[ l_{ss} = h_{ss} \]  
(A.10)
\begin{align*}
\pi_{ss} &= p_h y_{ss} - u_{ss} k_{ss} - [1 + \mu r_{ss} \lambda_{ss}] w_{ss} l_{ss} \tag{A.11} \\
p_c g_{ss} &= \tau_{ss} \tag{A.12} \\
d_{ss} &= \gamma^d y_{ss} \tag{A.13} \\
p_c &= p_h^{1 - \gamma} \tag{A.14} \\
g_{ss} &= \gamma^g y_{ss} \tag{A.15} \\
tb y_{ss} &\equiv 1 - p_h^{-\gamma} (c_{ss} + i_{ss} + g_{ss})/y_{ss} \tag{A.16}
\end{align*}
Appendix B. (log)Linearized Model

The log-linearized equilibrium conditions are given by the following set of equations:

\[
\begin{align*}
c_{ss}c_t - v h_{ss}^{\omega} \hat{h}_t &= -\lambda_{ss}^{-1/\psi} \frac{\hat{\lambda}_t + \hat{p}_{c,t}}{\psi} \\
\hat{c}_t - v h_{ss}^{\omega} \hat{h}_t &= -\left(\frac{\lambda_{ss} w_{ss}}{h_{ss}^{\omega-1}} \frac{1}{\omega V}\right)^{-1/\psi} \frac{1}{\psi} \left[\hat{\lambda}_t + \hat{w}_t - (\omega - 1)\hat{h}_t\right] \\
\hat{\lambda}_t + \psi \hat{a}_t - d \varphi \left(\hat{d}_t - \hat{p}_{h,t} - \hat{y}_t\right) &= \hat{r}_t + \hat{\lambda}_{t+1} \\
\pi^\psi p_c \left[1 + \hat{\lambda}_t + \psi \hat{a}_t + \phi \pi (\hat{k}_{t+1} - \hat{k}_t + \hat{a}_t)\right] &= \ldots \\
\ldots &= \beta \left\{[u_{ss} + p_c(1 - \delta)] (1 + E_t \hat{\lambda}_{t+1}) + u_{ss} \hat{a}_{t+1} + p_c(1 - \delta) \hat{p}_{c,t+1} + p_c \phi \pi^2 (\hat{k}_{t+2} - \hat{k}_{t+1} + \hat{a}_{t+1})\right\} \\
\hat{c}_t = \hat{p}_{c,t} + p_c c_{ss} (\hat{c}_t + \hat{p}_{c,t}) + \frac{r_{ss} d_{ss}}{\alpha} \left(\hat{r}_{t-1} + \hat{a}_{t-1} - \hat{a}_{t-1}\right) &= d_{ss} \hat{d}_t + \ldots \\
\ldots + w_{ss} h_{ss} (\hat{w}_t + \hat{h}_t) + u_{ss} k_{ss} (\hat{u}_t + \hat{k}_t) - \tau \hat{r}_t + \pi_{ss} \hat{a}_t \\
i_{ss} \hat{t}_t &= k_{ss} \pi (\hat{k}_{t+1} + \hat{a}_t) - (1 - \delta) k_{ss} \hat{k}_t \\
\hat{y}_t &= \hat{z}_t + (1 - \alpha) \hat{k}_t + \alpha \hat{t}_t + \alpha \hat{a}_t
\end{align*}
\]
\[ \hat{p}_{h,t} + \hat{y}_t = \hat{u}_t + \hat{k}_t \]  

(B.8)

\[ \alpha p_h y_{ss}(\hat{y}_t + \hat{p}_{h,t}) = w_{ss} I_{ss} \left[ (1 + \mu_r) (\hat{w}_t + \hat{l}_t) + \mu r_{ss} \hat{r}_{t-1} \right] \]  

(B.9)

\[ \hat{p}_{c,t} = (1 - \gamma) \hat{p}_{h,t} \]  

(B.10)

\[ \hat{p}_{c,t} + \hat{g}_t = \hat{r}_t \]  

(B.11)

\[ \hat{r}_t = \hat{r}_t^a + \hat{s}_t \]  

(B.12)

\[ \hat{l}_t = \hat{h}_t \]  

(B.13)

\[ \hat{r}_{cr} = -\hat{p}_{h,t} \]  

(B.14)

The log-linear approximation for the shocks

\[ \tilde{z}_t = \rho_z \tilde{z}_{t-1} + \epsilon_t^z \]  

(B.15)

\[ \tilde{a}_t = \rho_a \tilde{a}_{t-1} + \epsilon_t^a \]  

(B.16)

\[ \hat{p}_{h,t} = \rho_p \hat{p}_{h,t-1} + \epsilon_t^p \]  

(B.17)
\( \hat{r}_t^* = \rho_{r^*} \hat{r}_{t-1}^* + e_{t}^* \) \hspace{1cm} (B.18)

\( \hat{g}_t = \rho_g \hat{g}_{t-1} + e_{t}^g \) \hspace{1cm} (B.19)

\( \hat{s}_t = \rho_s \hat{s}_{t-1} + \alpha_1 \hat{\Delta} y_{t+1} + \alpha_2 \hat{ca}_{t+1} + e_{t}^s \) \hspace{1cm} (B.20)

The trade balance and the trade balance-to-output ratio are linearized instead

\[
\hat{tb}_t = p_h \hat{y}_t + y_{ss} \hat{p}_{h,t} - p_c(\hat{c}_t + \hat{i}_t + \hat{g}_t) - (c_{ss} + i_{ss} + g_{ss}) \hat{p}_{c,t} \tag{B.21}
\]

\[
\hat{tb}_{y_t} = \frac{1}{p_h y_{ss}} \hat{tb}_t - \frac{tb_{ss}}{p_h^2 y_{ss}} \hat{p}_{h,t} - \frac{tb_{ss}}{p_h y_{ss}^2} \hat{y}_t \tag{B.22}
\]

The current account and the current account-to-output ratio are linearized as well

\[
\hat{ca}_t = \hat{tb}_t - \frac{1}{d} (r_{ss} \hat{d}_{t-1} + d_{ss} \hat{r}_{t-1} - \frac{r_{ss} d_{ss}}{d} \hat{a}_{t-1}) - \mu (r_{ss} w_{ss} \hat{h}_t + r_{ss} h_{ss} \hat{w}_t + h_{ss} w_{ss} \hat{r}_{t-1}) \tag{B.23}
\]

\[
\hat{ca}_{y_t} = \frac{1}{p_h y_{ss}} \hat{ca}_t - \frac{ca_{ss}}{p_h^2 y_{ss}} \hat{p}_{h,t} - \frac{ca_{ss}}{p_h y_{ss}^2} \hat{y}_t \tag{B.24}
\]
Appendix C. Model Variables and Measurement Equations

Denote by $X_t$ a observable variable that contains a trend in equilibrium $\Gamma_{t-1}$. Therefore, we have

$$X_t = x_t \Gamma_{t-1}$$

(C.1)

where $x_t$ is the model correspondent stationary variable. We can write equation (C.1) in terms of gross rates

$$\frac{X_t}{X_{t-1}} = \frac{x_t \Gamma_{t-1}}{x_{t-1} \Gamma_{t-2}}$$

(C.2)

Let $\xi_t = \frac{X_t}{X_{t-1}}$ and $\varsigma_t = \frac{x_t}{x_{t-1}}$, we can rewrite equation (C.2) as

$$\xi_t = \varsigma_t \gamma_{t-1}$$

(C.3)

Log-linearizing (C.3) around the non-stochastic steady-state yields

$$\widehat{\xi}_t = \widehat{\varsigma}_t + \gamma_{t-1}$$

(C.4)

where the hat over the variable means log-deviations from the steady-state and $\widehat{\varsigma}_t = \widehat{x}_t - \widehat{x}_{t-1}$. Hence, for any variable that contains a trend in equilibrium, we use (C.4) to make the link between observable and its model correspondent. For variables that do not contain a trend in equilibrium we link them directly, i.e., the model variable is associated with the respective data correspondent (demeaned).
Appendix D. Metropolis-Hastings Algorithm

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

1. Find the mode of the posterior distribution by maximizing \( \log L(\Psi_t \mid \theta) + \log p(\theta) \).
   Denote by \( \theta^* \) 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 assess convergence).

2. At the \( s^{th} \) iteration generate a proposal \( \overline{\theta} \) from \( N(\theta^{(s-1)}, d\Sigma^{(s-1)}) \), where \( \theta^{(s-1)} \) is the mean of the distribution up to the \( (s - 1)^{th} \) 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\%. In particular, we choose \( c = 2 \times d \).

3. Evaluate the proposal according to the following rule: if \( u \sim \mathcal{U}(0, 1) \leq \alpha = \min \left[ \frac{L(\Psi_t \mid \overline{\theta})p(\overline{\theta})}{L(\Psi_t \mid \theta^{(s-1)})p(\theta^{(s-1)})}, 1 \right] \), then accept the proposal and set \( \theta^{(s)} = \overline{\theta} \). Otherwise, set \( \theta^{(s)} = \theta^{(s-1)} \). Update, if needed, the jumping distribution and go to step 2.
Appendix E. Harmonic Mean Estimator

Gelfand and Dey (1994) show that for any p.d.f. $f(\theta)$ with support on $\Theta$ (the support of $\theta$) 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:

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

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 $\theta$. 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 $\theta \in \Theta$. In particular, we follow Geweke (1999) and use a truncated (in the tails) Normal distribution.
Appendix F. On GHH Preferences

Consider a representative individual that has utility function $U = U(c_m, c_n, h_m, h_n)$ defined over consumption of market goods $c_m$, consumption of nonmarket goods $c_n$, hours worked in the market sector $h_m$, and hours worked in nonmarket sector $h_n$. Thus the problem of this individual is:

$$\text{Max} \, U(c_m, c_n, h_m, h_n)$$ (F.1)

s.t. $c_m \leq x + wh_m$ and $c_n \leq g(h_n)$

$$c_j \geq 0, h_j \geq 0 \text{ for } j = m, n, \text{ and } h_n + h_m \leq 1$$

where $w$ denotes real wage and $x$ denotes an exogenous income. The constraint $c_n \leq g(h_n)$ implies that the consumption of the nonmarket good (or home produced good) $c_n$ depends solely on the available technology $g(.)$ and on the amount of time spent in nonmarket activities $h_n$. We assume that $U_1 > 0, U_2 > 0, U_3 < 0, U_4 < 0$, and $g'(.) > 0$. Also $U$ is strictly concave and $g(.)$ is concave.

If we use the nonmarket (home produced) constraint at equality into the utility function above, the maximization problem becomes (nonnegativity constraints are nonbinding hereafter):

$$\text{Max} \, U(c_m, g(h_n), h_m, h_n) \text{ s.t. } c_m \leq x + wh_m$$ (F.2)

Define $h_n = h(c_m, h_m)$ to be the unique value of $h_n$ that maximizes (F.2) for given values of market variables $(c_m, h_m)$ and define the nonmarket consumption function as $c_n = c(c_m, h_m) = g \circ h(c_m, h_m)$. Defining the reduced form utility function over market quantities only as

$$V(c_m, h_m) = U(c_m, c(c_m, h_m), h_m, h(c_m, h_m))$$ (F.3)
This implies that problem (F.1) is equivalent to a problem that does not include explicitly home production (nonmarket) activities, i.e.,

$$\max V(c_m, h_m) \quad s.t. \quad c_m \leq x + wh_m$$ (F.4)

As Benhabib, Rogerson and Wright (1991) argue "for any model with home production, there is a model without home production but with different preferences, that generates the same outcome for market quantities", so there is a sense in which they are observationally equivalent (P. 1170). If we define $h_n = \Gamma_{t-1} h(c_m, h_m)$ then the productivity in the home sector grows at the same rate (with a lag) as the market sector, which it will imply a reduced form utility function specification as the one used in the main text.
Appendix G. Real Exchange Rate Determination

Even though our model is a Real Business Cycle Small Open Economy (RBC-SOE) model that abstracts from nominal variables, it is interesting to discuss the conditions under which PPP holds in our model. The PPP condition is based on the Law of One Price (LOP), according to which one good should sell for the same price (when expressed in the same numeraire) everywhere. The principle of absolute purchasing power parity (PPP) states that the real exchange rates should be constant in equilibrium and deviations from this equilibrium should be short-lived.

Suppose LOP holds for each tradable good, this implies

\[ P_h = \varepsilon P_h^* \]  \hspace{1cm} (G.1)

where \( P_h \) denotes the price of the domestically produced in domestic currency, \( \varepsilon \) is the price of the foreign currency in domestic currency and \( P_h^* \) denotes the price of the home produced good in foreign currency. Similarly, we have

\[ P_f = \varepsilon P_f^* \]  \hspace{1cm} (G.2)

where \( P_f \) denotes the price of the foreign good in domestic currency and \( P_f^* \) denotes the price of the foreign produced good in foreign currency. Thus the price indexes in the domestic and foreign economies are respectively

\[ P_c = P_h^{1-\gamma} P_f^\gamma \]  \hspace{1cm} (G.3)

\[ P_c^* = P_h^{1-\gamma^*} P_f^{\gamma^*} \]  \hspace{1cm} (G.4)
Plugging (G.1) and (G.2) into (G.3) we get

\[ P_c = (\varepsilon P^*_h)^{1-\gamma} (\varepsilon P^*_f)^{\gamma} \approx \varepsilon P^*_c \]

or

\[ rer = \frac{\varepsilon P^*_c}{P_c} = q \]

Thus *in the long run equilibrium* the real exchange rate, *rer*, equals some constant *q*. Assuming that \( \gamma^* \approx 1 \) this implies \( P^*_c \approx P^*_f \), giving our measure of real exchange rate

\[ rer = 1/p_c \]

Notice that if the weights of the consumption baskets are the same in the small open economy and in the world, then *q*=1, i.e., absolute PPP would hold. However, for the weights be the same we must have same preferences over "home" type good and "foreign" type good across consumers in the small open economy and in the rest of the world (This is a typical imposition in models with complete markets and perfect risk sharing). We abstract from this discussion and just assume that if anything, relative PPP holds *in the long run equilibrium*, i.e., first differences of real exchange rates should be zero (Relative PPP is a weaker version of the PPP condition).

\(^1\)

Obviously, we can imagine situations where PPP does not hold. For example, whenever there are transaction costs, shipping costs, strategic pricing, uncertainty, limits to arbitrage, etc. the Law of One Price fails to hold as does the PPP condition. However our model does not display any of these "frictions" and hence the PPP condition does hold as an equilibrium condition.

Although there is a consensus in the empirical literature that real exchange rates may be stationary and tend to converge to parity level in the long run, the rate at which this

---

\(^1\)See Obstfeld and Rogoff (1995) for a textbook discussion about absolute and relative PPP.
happens appears to very slow. This motivated what it has been called the PPP puzzle (see Obstfeld and Rogoff, 2000 for a discussion of the six big puzzles in international macroeconomics). The PPP puzzle has ignited an intensive and important debate in the international macro literature. However, this conventional view has been recently challenged by the work of Imbs, Mumtaz, Ravn and Rey (2005a) that show that the puzzle is indeed a failure to account for heterogeneity in the dynamics of disaggregated relative prices. When this heterogeneity is accounted for the puzzle disappears (Chen and Engel, 2005 criticism about Imbs et al. paper and the reply by Imbs, Mumtaz, Ravn and Rey, 2005b).

Despite the importance of real exchange rate movements, our model does not attempt to provide an even partial explanation for the behavior of this variable along the business cycles. This task is beyond the scope of this work.
Appendix H. Granger causality test

The table below shows the results for the Granger causality tests.

<table>
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<tr>
<th>Null Hypothesis</th>
<th>F statistic</th>
<th>Probability</th>
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<tr>
<td>Export does not Granger cause TOT</td>
<td>0.965</td>
<td>0.43</td>
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<tr>
<td>Import does not Granger cause TOT</td>
<td>0.558</td>
<td>0.69</td>
</tr>
<tr>
<td>GDP growth does not Granger cause TOT</td>
<td>0.480</td>
<td>0.74</td>
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<tr>
<td>GDP does not Granger cause the TOT</td>
<td>0.543</td>
<td>0.70</td>
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<tr>
<td>TOT does not Granger cause GDP</td>
<td>2.870</td>
<td>0.03*</td>
</tr>
<tr>
<td>TOT does not Granger cause GDP growth</td>
<td>2.419</td>
<td>0.06**</td>
</tr>
<tr>
<td>GDP does not Granger cause Interest Rates</td>
<td>2.775</td>
<td>0.03*</td>
</tr>
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</table>

Note: * significant at 5% level, **Significant at 10% level, n = 50 observations. TOT represents terms of trade shocks, GDP represents Gross Domestic Output. Source: authors’ calculations.

The results reject the hypothesis of endogeneity of the terms of trade at any usual significance level. Therefore, based on these test results we can assume that terms of trade are exogenous to the domestic economic, which are in line with the small open economy assumption carried out along this paper. We also test if terms of trade does Granger cause output growth and domestic interest rates. As we can see from the Table, terms of trade does Granger cause both of them. This offers additional support for including terms of trade shocks as a driving force of business cycle fluctuations.²

²Broda (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.
Appendix I. Priors and Posterior Distributions

Figure 7.1: Prior and Posterior Distributions of Structural Parameters.

Figure 7.2: Prior and Posterior Distributions of Structural Parameters.
### Appendix J. Forecast Error Variance Decomposition

<table>
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</table>

Note: $\Delta Y$, $\Delta C$, $\Delta I$ denote output, consumption and investment growth, respectively. TBY denotes trade balance-to-output ratio. Source: authors’ calculations.
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