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ESSAYS ON BUSINESS CYCLES IN EMERGING ECONOMIES

by

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ABSTRACT OF THE DISSERTATION

Essays on Business Cycles in Emerging Economies

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The central goal of this dissertation is to contribute to the understanding of business cycles in developing economies by combining the use of general equilibrium modeling, time series analysis and historical evidence. The dissertation is made of three separate but related chapters.

In the first chapter, I put to the test the two leading approaches for analyzing business cycles in emerging economies by building a model that combines stochastic trends, interest rate shocks and financial frictions. I then estimate the model using Bayesian methods and Mexican data from the 1980s. The results favor strong financial frictions, volatile shocks to the processes for interest rates and transient technology, and modest trend shocks. Financial frictions act as powerful amplifying mechanisms to interest rate and transient technology shocks. The results are thus supportive of the view that assuming foreign interest rate shocks in conjunction with financial imperfections is a superior approach to assuming stochastic trends if one is trying to explain fluctuations in emerging economies.

The second chapter presents an augmented model with two additional driving forces: terms of trade and government expenditure shocks. The model is estimated with Colombian data using both high frequency quarterly data and low frequency annual data. The results continue to suggest that financial frictions act as powerful amplifying mechanisms and that trend shocks are not relevant in explaining emerging market business cycles. Among the two new shocks added, just the terms of trade appear relevant and only in the low frequency data.

The third chapter focuses on business cycles in emerging economies from a historical perspective. It is argued that the significant capital flows observed in Latin America during the 1920s and early 1930s offer a good historical experiment to study the transmission mechanism by which external shocks to capital markets turn into large capital flows and wider business cycles in developing economies. The chapter uses a framework that combines a historical account of the 1920s-1930s Latin American episode with a dynamic general equilibrium model aimed at explaining the dynamics observed in the data. The model does well in matching the expansionary/contractionary phases in output dynamics, in accordance with the main stylized facts observed in the business cycles in Latin American countries between 1925 and 1931.

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Early in my doctoral studies, the seminal work by Professor Martin Uribe, at Columbia University, ignited my interest in the macroeconomics of developing economies. I was lucky to have met Martin in the process of making my dissertation and to have received from him his sharp guidance in some of the crucial moments of my writings. I thank Martin for showing me how to be a true researcher and teacher.

Modern macroeconomic analysis cannot be seriously addressed without good computational skills. In this front Professor John Landon-Lane's guidance was crucial for me. I thank him for all the time he took to painstakingly show me the intricacies of computational work among many other things.

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It was great to have had a study partner like Adam Gulan with whom I share the same passion for macroeconomics. My discussions with him were a key element in my learning process at Rutgers and I am grateful to him for that.

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Dedication

To my wife, Fana, the four pillars upon which this edifice was built, and to the memory of Lulita.

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1 INTRODUCTION

A good understanding of business cycle regularities in developing countries is a prerequisite in the process of designing appropriate stabilization policies and sound macroeconomic management in these countries. A first step toward this understanding must take into account the well documented differences on the business cycles properties in developing countries relative to their developed counterparts. Explaining these differences is therefore a necessary first step in the design of such policies and thus is “at the top of the research agenda in small-open-economy macroeconomics” (Uribe, 2009).

My dissertation contributes to this understanding by making use of the advances in modeling and estimation techniques of stochastic dynamic macroeconomic equilibrium models. There has been tremendous improvement over the last twenty years in the mathematical, statistical, probabilistic, and computational tools available to applied macroeconomists. These advances have helped researchers build a more solid bridge between theoretical and applied work (Canova, 2007). Under this methodological framework, the central goal of this work is the combination of theoretical and computational general equilibrium modeling, time series analysis and historical evidence on the business cycles in developing economies to come with answers as to why business cycles in emerging economies differ from the ones we observe in developed countries. The dissertation is made of three separate but related chapters. In what follows in this introductory note I will summarize the three chapters, give a general overview of the results from each one of them and explain how, taken together,

they contribute to the understanding of business cycles in developing economies.

I finish with a list of the unanswered questions and possible extensions.

In the first chapter, entitled **On the Sources of Aggregate Fluctuations in Emerging Economies** (joint with Roberto Chang), we put to the test the leading approaches for analyzing business cycles in emerging economies. Recent research has resulted in two leading approaches, both of which can be seen as extensions of Mendoza's (1991) basic dynamic stochastic model. The first approach, due to Aguiar and Gopinath (2007), introduces a stochastic productivity trend, in addition to the temporary productivity shocks already present in Mendoza's model. A second approach, exemplified by Neumeyer and Perri (2005) and Uribe and Yue (2006), relies instead on the introduction of foreign interest rate shocks coupled with financial frictions. This approach is motivated by the observation that the cost of foreign credit appears to be countercyclical in emerging economies data. We compare the two approaches empirically, taking advantage of recent developments in the theory and implementation of Bayesian methods, using data from Mexico. We build an encompassing model that combines both stochastic trends, interest rate shocks and financial frictions and estimate the parameters of the exogenous shocks processes, along with a few other crucial parameters. We find that the mode of the posterior distribution is characterized by strong financial frictions, volatile shocks to the processes for interest rates and transient technology, and modest trend shocks. Importantly, financial frictions act as powerful amplifying mechanisms to interest rate shocks. After conducting several robustness checks, we conclude that the results

are supportive of the view that assuming foreign interest rate shocks in conjunction with financial imperfections is a superior approach to assuming stochastic trends if one is trying to explain fluctuations in emerging economies.

In the second chapter, entitled **“Tropical” Real Business Cycles? A Bayesian Exploration**, I further test the robustness of the idea that business cycles in these economies are driven solely by stochastic shifts to the technology trend. I do so by allowing for potential model misspecification in the Aguiar and Gopinath (2007) model, arising from omitted real driving forces other than technology shocks. Based on the literature that I survey in the paper and the findings in my first chapter, I include three structural driving forces to the standard neoclassical framework: (i) a procyclical government spending process; (ii) terms of trade fluctuations; and (iii) shocks to the foreign interest rate amplified by financial frictions. For the empirical purpose of the paper I use data from Colombia, a developing -and "tropical"- economy. And among many other robustness checks, I compare the results using both high frequency quarterly data and low frequency annual data. The results continue to suggest that trend shocks are not as relevant in explaining emerging market business cycles. The data rejects the baseline model driven solely by technology shocks and favors virtually all the alternative models where real driving forces other than these impulses come into play. Other structural shocks, intrinsic to these economies appear to be relevant. For the case of the Colombian economy, the low frequency data suggest that the terms of trade have been important driving forces behind the business cycle. From a policy perspective, the results then lend

support to the idea that successful stabilization policies in emerging economies ought to be aimed at attenuating the effects of terms of trade variations.

In the third chapter, entitled **Capital Flows and Business Cycles in Latin America During the 1920s-30s. A Second Look From a Neoclassical Perspective**, I focus on the role of external shocks to financial markets as a potential driving force behind the sizeable macroeconomic volatility exhibited by Latin American countries during the “Roaring Twenties” and the Great Depression. It is argued that the significant capital flows observed in the region during the 1920s and early 1930s offer a good historical experiment to study the transmission mechanism by which external shocks turn into large capital flows and wider business cycles. Moreover, this episode presents additional interesting policy elements because of the efficacy of the countercyclical monetary policy undertaken in the recovery phase. This paper uses a framework that combines a historical account of the 1920s-1930s Latin American episode with a dynamic general equilibrium model aimed at explaining the dynamics observed in the data from these economies in this period. The findings show that the model does well in matching the expansionary/contractionary phases in output dynamics, in accordance with the main stylized facts observed in the business cycles in Latin American countries between 1925 and 1931. Two key transmission channels in the model through which capital inflows/outflows turn into economic booms/busts are interest rates and the banking system. Additionally, although monetary policy shocks appear to have been responsible for part of the recovery phase in the early 1930s, not all of it appears to have been driven

by countercyclical policy, a result that is taken as indirect evidence of the role played by relative prices in the import substitution process that accompanied the strong recovery.

Taken together, the findings in the three chapters suggest the presence of important driving forces intrinsic to emerging economies' aggregate fluctuations other than pure technology shocks. In particular, capital flows, channeled via perturbations to the interest rate emerging markets face in international markets, and terms of trade volatility are significant sources of macroeconomic instability in emerging economies. Furthermore, financial frictions appear to be relevant in the transmission mechanism by which these shocks drive macroeconomic fluctuations in emerging market economies. These findings are robust for a pool of Latin American countries both today and in the historical interwar period.

There is plenty of research to be done following these findings. First, my results so far are silent regarding the role of optimal policy. It would be thus interesting to examine the extent by which welfare can be enhanced by reducing the level of financial frictions which, as mentioned above, act as a powerful amplifying mechanism of business cycles in emerging economies. Second, given the relevance of the interest rate process for the business cycles dynamics in emerging economies, a fruitful area of research would be to endogeneize the process for the country interest rate along the lines of Mendoza and Yue (2008). Third, on a more applied front, one could compare the performance of the highly stylized dynamic general equilibrium models used so far against atheoretical VARs

in order to gauge the predictive power of the theory. Fourth, I am considering expanding the analysis of the “historical experiment” in Latin America during the interwar period by extending the analysis to a larger pool of countries and focusing on the explanations behind the rapid recovery experienced throughout the region in the early 1930s within a general equilibrium framework.

2 ON THE SOURCES OF AGGREGATE FLUCTUATIONS IN EMERGING ECONOMIES¹

2.1 Introduction

Recent research on macroeconomic fluctuations in emerging economies has resulted in two leading approaches, both of which can be seen as extensions of Mendoza's (1991) basic dynamic stochastic model. The first approach, due to Aguiar and Gopinath (2007), introduces a stochastic productivity trend, in addition to the temporary productivity shocks already present in Mendoza's model. This seemingly small addition, Aguiar and Gopinath argue, goes a very long way towards addressing well known empirical failures of the model when taken to data from emerging market economies, including the strong counter cyclical behavior of the trade surplus and the higher volatility of consumption relative to output's.

A second approach, exemplified by Neumeyer and Perri (2005) and Uribe and Yue (2006), relies instead on the introduction of foreign interest rate shocks coupled with financial frictions. This approach is motivated by the observation that the cost of foreign credit appears to be countercyclical in emerging economies data. Accordingly, both Neumeyer and Perri (2005) and Uribe and Yue (2006) develop models in which country risk spreads are stochastic and interact with financial imperfections. Then they argue that those models are consistent with the empirical regularities of emerging economies.

¹Co-authored with Roberto Chang.

In this paper, we compare the two approaches empirically, taking advantage of recent developments in the theory and implementation of Bayesian methods. We build an encompassing model that combines stochastic trends with interest rate shocks and financial frictions. We then estimate the parameters of the exogenous shock processes, along with a few other crucial parameters. The stochastic trend model and the random interest rates/financial frictions model can be then regarded as restricted versions of the encompassing model. The relative performance of these alternative models is evaluated by comparing their marginal likelihood as well as their ability to match a subset of selected moments of the data. We employ the Mexican dataset of Aguiar and Gopinath (2007), thus ensuring that our results can be compared with the findings of that paper.

We obtain several results of interest. In our benchmark estimations, the mode of the posterior distribution of the estimated parameters of the encompassing model is characterized by strong financial frictions, volatile shocks to the processes for interest rates and transient technology, and modest trend shocks. The random walk component, a measure of the relative importance of trend shocks, is less than a fifth of what Aguiar and Gopinath (2007) obtained using a model with no financial frictions. Consequently, when we evaluate the relative contribution of the different shocks to aggregate fluctuations, we find that, while temporary productivity shocks are responsible for the bulk of the variance of aggregates, interest rate shocks have a sizeable role as well, generating about six to ten percent of the variance of output and consumption, one fourth the variance of investment, and close to half the variance of the trade balance/output ratio.

In contrast, the share of those variances due to trend shocks is three percent or less.

In formal, likelihood based, model comparisons, the financial frictions model beats the stochastic trends model more often than not, although the results are not decisive. This reflects that the likelihood has several local modes, and indeed we find that assuming less informative priors than in the benchmark implies a posterior parameter distribution with two local modes, each favoring one of the two approaches. In other words, the data appear not to speak strongly about which approach is empirically better.

In other ways, however, the data are quite informative. In particular, the benchmark model allows for two kinds of financial frictions: a working capital requirement (as in Uribe and Yue 2006) and an endogenous spread (as in Neumeyer and Perri 2005). Our estimations strongly indicate that it is the latter, not the former, that is crucial for a financial frictions view to be a reasonably good approximation to the data. Notably, this confirms previous analysis by Oviedo (2005).

Likewise, our estimations clearly imply that temporary productivity shocks cannot be dispensed with in the models under study, even if interest rate shocks and trend shocks are included, if these models are to match the volatility and persistence of output and other major macroeconomic aggregates. However, we show that the role of temporary productivity shocks is greatly enhanced by the presence of financial frictions.

Our results appear to be robust to a number of departures from our bench-

mark assumptions, such as preference specification, or the addition of data on interest rates to the Aguiar-Gopinath dataset. Finally, we estimate the contribution of temporary productivity shocks, trend shocks, and interest rate shocks in explaining the dynamics of the Mexican 1995 Tequila crisis. We argue that temporary productivity shocks seem to have dominated the episode but, again, that financial frictions were crucial to amplify their effects.

Overall, our results are supportive of the view that explaining fluctuations in emerging economies requires assuming financial imperfections that amplify conventional productivity shocks and, perhaps less crucially, interest rate shocks. Trend shocks add relatively little, although they become quantitatively relevant if financial frictions are assumed away.

Emphasis on the role of financial frictions is, of course, not new. In addition to the papers by Neumeyer-Perri and Uribe-Yue, financial imperfections have been stressed by the literature on balance sheet effects (Céspedes, Chang and Velasco 2004) and sudden stops (Calvo 1998, Mendoza 2006). A main contribution of this paper is to provide a quantitative perspective on the empirical accuracy of financial frictions models relative to their main competitor, the stochastic trend hypothesis.

Our work is related to at least two other strands of the literature. One is the debate of whether fluctuations in emerging economies are dominated by domestic shocks or foreign shocks. Several years ago now, Calvo, Leiderman, and Reinhart (1993) upset the then conventional wisdom by showing that foreign interest rate shocks were a major source of fluctuations in Latin America. Our

results are clearly complementary to theirs.

Finally, our paper belongs to a growing group of studies that apply developments in Bayesian methods to models and questions in open economy macroeconomics. Examples include Lubik and Schorfheide (2005), Rabanal and Tuesta (2006), and Justiniano and Preston (2006).

The rest of the paper is organized as follows. Section 2 presents the models under study. Section 3 discusses the details of our empirical approach. Section 4 presents and discusses our baseline results. Section 5 presents several robustness exercises. Section 6 concludes.

2.2 Competing Models

Currently competing views on the sources of shocks to emerging countries can be regarded as elaborations on the canonical real business cycle model of a small open economy first developed by Mendoza (1991) and discussed by Schmitt-Grohe and Uribe (2003). As stressed by Mendoza and others, the standard model has notable empirical shortcomings, which have motivated several extensions and amendments. In this paper we are concerned with two dominant extensions: one which we will call the *stochastic trend model*, which features permanent shocks to technology, as advocated by Aguiar and Gopinath (2007); and another, the *financial frictions model*, which introduces foreign interest rate shocks that interact with financial imperfections, as discussed by Neumeyer and Perri (2005) and Uribe and Yue (2006). This section discusses these alternatives and also describes an *encompassing* model that embeds both stochastic trends

and financial frictions.

2.2.1 The standard small open economy model

The standard model of a small open economy is well known. Time is discrete and indexed by $t = 0, 1, 2, \dots$. There is only one final good in each period, which can be produced with a technology given by

$$Y_t = a_t F(K_t, \Gamma_t h_t)$$

where Y_t denotes output, K_t capital available in period t , h_t labor input, and F is a neoclassical production function. We use upper case letters to denote variables that trend in equilibrium, and lower case letters to denote variables that do not². Also, a_t is a shock to total factor productivity, assumed to follow:

$$\log a_t = \rho_a \log a_{t-1} + \varepsilon_t^a \tag{1}$$

where $|\rho_a| < 1$, and ε_t^a is an i.i.d. shock with mean zero and variance σ_a^2 . In the standard model, the shock ε_t^a is the only source of uncertainty. Also, and importantly for our purposes, total factor productivity is a *stationary* process.

Finally, Γ_t is a term allowing for labor augmenting productivity growth. In the standard model, Γ_t is assumed to follow a deterministic path:

$$\Gamma_t = \mu \Gamma_{t-1} \tag{2}$$

²The only exceptions will be the spread, S_t , and the world and domestic gross interest rates, R_t^* and R_t , to be defined later, which do not trend in equilibrium.

Capital accumulation is given by a conventional equation:

$$K_{t+1} = (1 - \delta)K_t + I_t - \Phi(K_{t+1}, K_t) \quad (3)$$

where I_t denotes investment, δ the rate of depreciation, and $\Phi(K_{t+1}, K_t)$ costs of installing capital.

The economy is inhabited by a representative household with preferences of the form:

$$E \sum_{t=0}^{\infty} \beta^t U(C_t, h_t, \Gamma_{t-1}) \quad (4)$$

where β is a discount factor between zero and one, C_t denotes consumption, $U(\cdot)$ a period utility function, and $E(\cdot)$ the expectation operator. (We include Γ_{t-1} in the period utility function U to allow for balanced growth.)

The representative agent has access to a world capital market for noncontingent debt. Her budget constraint is, therefore,

$$W_t h_t + u_t K_t + q_t D_{t+1} = C_t + I_t + D_t$$

W_t denotes the wage rate and u_t the rental rate of capital, so the first two terms in the LHS are factor receipts in period t . In addition, q_t is the price at which the household can sell a promise to a unit of goods to be delivered at $t+1$, while D_{t+1} is the number of such promises issued. The LHS describes expenditures in period t , given by consumption, investment, and debt payments.

Residents of this country face an interest rate on foreign borrowing given by

the inverse of q_t , and assumed to take the form:

$$1/q_t = R^* + \kappa(\tilde{D}_{t+1}/\Gamma_t) \quad (5)$$

where R^* is the world interest rate, \tilde{D}_{t+1} denotes the country's aggregate debt (which is equal to the household's debt D_{t+1} in equilibrium) and $\kappa(\cdot)$ is an increasing, convex function. We assume that the interest rate faced by the household is sensitive to the debt to ensure that there is a well defined nonstochastic steady state. As shown by Schmitt-Grohe and Uribe (2003), this device is one of several that can be chosen to have negligible effects on the business cycle properties of the model.

Note that so far we have assumed that the world interest rate is a constant. In fact, Mendoza (1991) argued that assuming it to be stochastic makes little difference for the business cycle properties of the standard model.

The standard model is completed by specifying that factor payments are given by marginal productivities:

$$\begin{aligned} u_t &= a_t F_1(K_t, \Gamma_t h_t) \\ W_t &= a_t F_2(K_t, \Gamma_t h_t) \Gamma_t \end{aligned} \quad (6)$$

2.2.2 The Stochastic Trend Model

Aguiar and Gopinath (2007) have recently emphasized that the empirical failures of the standard model can be remedied, by and large, by allowing labor

augmenting growth to be not constant but random. Formally, the assumption (2) is replaced by

$$\Gamma_t = g_t \Gamma_{t-1} \quad (7)$$

where

$$\ln(g_{t+1}/\mu) = \rho_g \ln(g_t/\mu) + \varepsilon_{t+1}^g \quad (8)$$

$|\rho_g| < 1$, ε_t^g is an i.i.d. process with mean zero and variance σ_g^2 , and μ represents the mean value of labor productivity growth. A positive realization of ε_t^g implies that the growth of labor productivity is temporarily above its long run mean. Such a shock, however, is incorporated in Γ_t and, hence, results in a permanent productivity improvement.

That the addition of permanent productivity shocks has the potential to eliminate the departures between the model and the data is intuitive and explained by a permanent income view of consumption. After a favorable realization of ε_t^g , productivity increases permanently. Accordingly, permanent income, and therefore consumption, can increase more than current income; this explains why consumption may be more volatile than income in emerging economies. The same reasoning implies that the representative household may want to issue debt in the world market to finance consumption in excess of current income, leading to a countercyclical current account.

2.2.3 Financial frictions models

Neumeyer and Perri (2005) and Uribe and Yue (2006) have argued for a theoretical framework where business cycles in emerging economies are driven by random world interest rates that interact with financial frictions. An empirical motivation for this view is what Calvo (1998) has called "sudden stops", defined by abrupt and exogenous halts to the flow of international credit to the economy, which force a violent turnarounds in the current account.

To develop this view, one can modify the standard model along lines suggested by Neumeyer and Perri (2005). First, the price of the household's debt is assumed to be given by

$$1/q_t = R_t + \kappa(\tilde{D}_{t+1}/\Gamma_t) \quad (9)$$

instead of (5), where R_t is a country specific rate,

$$R_t = S_t R_t^* \quad (10)$$

R_t^* is the world interest rate and S_t a country specific spread. The world interest rate is now assumed to be random, and fluctuates around its long run value R^* according to the process:

$$\ln(R_t^*/R^*) = \rho_R \ln(R_{t-1}^*/R^*) + \varepsilon_t^R \quad (11)$$

where $|\rho_R| < 1$ and ε_t^R is an i.i.d. innovation with mean zero and variance σ_R^2 .

In addition, deviations of the country spread from its long-run level are assumed to depend on expected future productivity as follows

$$\log(S_t/S) = -\eta E_t \log a_{t+1} \quad (12)$$

Adding shocks to the world interest rate to the basic model has, in fact, been considered in the literature, with little success (see, for instance, Mendoza 1991 and Aguiar and Gopinath 2008). But random interest rates become a more compelling addition when coupled with financial frictions. So, for example, one can argue that country risk must depend inversely on expected productivity, as high productivity in the future should reduce the risk of default. Neumeyer and Perri (2005) advocated (12) as a shortcut to capture this idea.

An additional friction, developed by Neumeyer and Perri (2005) and Uribe and Yue (2006), is to assume that firms must finance a fraction of the wage bill in advance. Again, we follow Neumeyer and Perri's formulation, the net result of which is that equilibrium in the labor market requires

$$W_t [1 + \theta (R_{t-1} - 1)] = a_t F_2(K_t, \Gamma_t h_t) \Gamma_t \quad (13)$$

instead of (6). In words, the typical firm hires workers to the point at which the marginal product of labor (the RHS of the previous expression) equals the wage rate inclusive of financing costs (the LHS). Firms are assumed to borrow from households and forced to pay for a fraction θ of the wage bill in advance of production.

As discussed by Oviedo (2005), the working capital assumption (13) and the assumptions of a spread linked to expected productivity (12) are two separate alternatives, in spite of Neumeyer and Perri's imposing both. Indeed, they emphasize different possibilities for improving the performance of the basic model. With the working capital assumption, a fall in the world interest rate reduces the cost of labor, which stimulates output. At the same time, it stimulates demand, as the cost of borrowing for consumption and investment falls. Hence the trade balance may in principle deteriorate at the same time as output is expanding, which can explain an acyclical or countercyclical trade balance.

With a spread process determined by expected productivity, a favorable productivity shock increases output and, because the shock is persistent, reduces the interest rate applicable to the representative household's debts, thus boosting consumption and investment even beyond the boost to output. A countercyclical trade balance may then emerge, as with working capital, although it is due to a different mechanism.

2.2.4 An Encompassing Model

While the literature has naturally considered stochastic trends and financial frictions separately, it is relatively straightforward to specify a model in which both extensions of the standard model are present. In this subsection we indeed describe our preferred version of such an *encompassing* model, which will be a focus of our empirical analysis below.

Our encompassing model follows the spirit of Aguiar and Gopinath (2008),

which extend the stochastic trend model to allow for shocks to the consumption and investment Euler equations that operate through the interest rate. But we differ from Aguiar and Gopinath (2008) in three fundamental dimensions. First, our encompassing model includes both financial frictions, spreads that react to fundamentals and working capital requirements, embedded in the parameters η and θ , respectively. Aguiar and Gopinath (2008) considered the former but did not allow for a working capital requirement. Second, while Aguiar and Gopinath (2008) only allowed the spread to be affected by transient technology shocks, our encompassing model allows for permanent shocks to also affect the spread. This is more natural, since the logic behind an endogenous spread is often based on the idea that default risk falls with expected productivity, regardless of whether shocks to the latter are permanent or transitory. To implement this idea, however, we need to modify the assumption (12) on country risk. So, in our encompassing model the country spread will be assumed to be given by

$$\log(S_t/S) = -\eta_1 E_t \log a_{t+1} - \eta_2 E_t \log(\mu_{t+1}/\mu)$$

One particular version of this, which we will examine, assumes that the spread is given by (12), except that the temporary productivity shock a_{t+1} is replaced by total factor productivity (Solow residual):

$$\log(S_t/S) = -\eta E_t \log(SR_{t+1}/SR)$$

where $SR_t = a_t g_t^\alpha$ and $SR = \mu^\alpha$ according to the Cobb-Douglas technology

specified below.

Third, and perhaps most importantly, Aguiar and Gopinath (2008) considered only Cobb-Douglas preferences, which have been shown to reduce the extent to which business cycles can be driven by interest rate shocks (Neumeyer and Perri, 2005). We assume preferences of the Greenwood-Hercowitz-Huffman type; later, we explore the robustness of this choice with a more flexible specification due to Jaimovich and Rebelo (2008).

Our encompassing model is then given by the combination of one of the preceding two assumptions for the spread together with the assumptions of stochastic interest rates (9-11), the working capital requirement (13), and trend shocks (8), in addition to temporary productivity shocks (1).

With this formulation, one way to evaluate the relative merits of the hypotheses of stochastic trends and financial frictions is to analyze the contribution to different macro aggregates of trend shocks versus shocks to the foreign interest rate. A different but complementary perspective is to compare directly the stochastic trend model against the financial frictions model. Clearly, each of the two can be seen as suitably restricted versions of the encompassing model, but none is a special version of the other.

2.3 Empirical Approach

2.3.1 Bayesian Analysis, in a nutshell

We adopt a Bayesian viewpoint because of its conceptual simplicity and because it allows for a logically coherent comparison between models that are not nec-

essarily nested, as is the case of the stochastic trend model and the financial frictions model. To implement that viewpoint, we draw on recent theoretical and computational advances, usefully summarized by DeJong and Dave (2007), Canova (2007), Geweke (2005), and others. For completeness, this section provides a very succinct description of how we implement the Bayesian approach.

Let X denote a vector of observed data. Each one of the models reviewed in the previous section implies a probability distribution for the data, say $p_M(X|\theta^M)$, where M is an index for each model and θ^M is a vector of parameters, possibly model specific, that we want to learn about. Given a particular parameter vector, say $\bar{\theta}^M$, $p_M(\cdot|\bar{\theta}^M)$ is a probability distribution function whose value depends on X . On the other hand, having observed a realization of X , say \bar{X} , $p_M(\bar{X}|\cdot)$ can be seen as a function of the parameter vector θ^M . This function is the likelihood, usually denoted by $L_M(\theta^M|\bar{X})$ to emphasize that it is a function of θ^M . The likelihood functions associated with the models in the previous sections can be computed in a straightforward fashion: following Sargent (1989), we linearize each model around its nonstochastic steady state, solve the resulting linear system via standard methods, and map the solution into a state space representation from which the likelihood can be computed using the Kalman filter.

The Bayesian framework is concerned with the way our views about models and their parameters are revised in light of observed data. Prior beliefs about the parameters of each model M are given by a prior distribution, which we denote by $p_M(\theta^M)$. After observing the data \bar{X} , Bayes Theorem implies that

posterior beliefs about θ^M , denoted by $p_M(\theta^M|\bar{X})$, must respect:

$$\begin{aligned} p_M(\theta^M|\bar{X}) &= \frac{p_M(\bar{X}|\theta^M)p_M(\theta^M)}{\int p_M(\bar{X}|\theta^M)p_M(\theta^M)d\theta^M} \\ &= \frac{L_M(\theta^M|\bar{X})p_M(\theta^M)}{p_M(\bar{X})} \end{aligned}$$

where we have defined $p_M(\bar{X})$, model M 's *marginal likelihood*, as:

$$p_M(\bar{X}) = \int L_M(\theta^M|\bar{X})p_M(\theta^M)d\theta^M$$

If one can compute the posterior distribution $p_M(\theta^M|\bar{X})$ one can also compute, at least in principle, the posterior distribution of functions of the parameter vector θ^M . In the context of the dynamic models we are considering, such functions include impulse response functions, moments of different variables, and variance decompositions. In practice, the analytical derivation of both the posterior distribution $p_M(\theta^M|\bar{X})$ and the posterior distribution of functions of θ^M is intractable. However, recent simulation methods allow us to obtain draws from the posterior distribution $p_M(\theta^M|\bar{X})$. A histogram of the simulated draws (or a chosen function of them) then provides an approximation of $p_M(\theta^M|\bar{X})$ (or the posterior distribution of the corresponding function) with a level of accuracy that can be made arbitrarily close by increasing the number of draws.

Additionally, it is useful for our purposes that the marginal likelihood $p_M(\bar{X})$ is the probability of observing the data \bar{X} associated with model M . So one straightforward way to compare alternative models is to compute their respec-

tive marginal likelihoods. This is particularly appealing if the models to be compared are not nested, as in some of the cases examined below.

Given this framework, we conduct two complementary exercises. First, we estimate the encompassing model and focus on the posterior distribution of the variance decomposition of aggregate variables, including output, thus measuring the relative importance of temporary productivity shocks, trend shocks, and interest rate shocks when all of them are allowed to play a role in generating fluctuations. Second, we estimate the stochastic trend model and the financial frictions models separately and compare their marginal likelihoods, which amounts to a direct comparison of the two versions in terms of their predictive power.

2.3.2 Functional forms, and calibrated versus estimated parameters

We follow the current literature on emerging market business cycles when choosing functional forms for preferences and technology. For the most part, we impose a utility function of the Greenwood, Hercowitz and Huffman (1988) form:

$$u(C_t, h_t, \Gamma_{t-1}) = \frac{(C_t - \tau \Gamma_{t-1} h_t^\omega)^{1-\sigma}}{1-\sigma}$$

As discussed by Neumeyer and Perri (2005) and others, GHH preferences help reproducing some emerging economies' business cycles facts by allowing the labor supply to be independent of consumption levels. Note that, in contrast, Aguiar and Gopinath (2007) focused on their results with Cobb Douglas

preferences instead³. Accordingly, one of our robustness exercises later explores a more flexible preference specification due to Jaimovich and Rebelo (2008), which embed both GHH and Cobb Douglas as special cases.

The production function is assumed to be Cobb Douglas:

$$F(K_t, X_t h_t) = K_t^{1-\alpha} (\Gamma_t h_t)^\alpha$$

where α is the labor's share of income.

The capital adjustment cost function is assumed to be quadratic:

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

In turn, the function κ determining the interest rate elasticity to the country's debt has the form:

$$\kappa(D_{t+1}/\Gamma_t) = \psi \left[\exp\left(\frac{D_{t+1}}{\Gamma_t} - d\right) - 1 \right]$$

For each model, we estimate some parameters and calibrate the rest. The choice of which parameters to estimate or calibrate is guided by the objectives of our investigation as existing literature.

Since a main question is the relative importance of sources of fluctuations, in each case we estimate the parameters of exogenous driving forces. Hence, the parameters of the transitory productivity process (1), namely the AR coefficient

³ Although, in the working paper version, they also estimated their model with GHH preferences and found very little difference.

ρ_a and the standard deviation of the innovations σ_a , are always estimated. Where shocks to the trend are allowed, we also estimate the parameters ρ_g and σ_g of the permanent productivity process (8). And if the world interest rate is allowed to be stochastic, as in the financial frictions models and the encompassing model, we estimate ρ_R and σ_R in (11).

While the addition of the permanent productivity process is the only departure of the stochastic trend model from the standard, Mendoza-type model, allowing for financial frictions models introduces two other parameters: the elasticity of the spread with respect to expected productivity (η) and the working capital requirement parameter θ . Accordingly, we estimate those parameters in models that allow for financial frictions. Finally, in all cases we estimate the parameter ϕ governing the capital adjustment function.

We calibrate the remaining parameters of each model. A period is taken to be a quarter in our calibration. The calibrated parameters are given in Table I.1 and take conventional values: the coefficient of relative risk aversion is set at 2, and ω and τ are set so as to imply, respectively, a labor supply elasticity of 1.6 and a third of time spent working in the long run. The labor's share of income, α , is set to be 68%⁴. We calibrate the debt-to-GDP ratio to 0.1, the value used in Aguiar and Gopinath (2007).

In the models with financial frictions, we set the long-run levels of the annualized foreign and country specific gross real interest rates to 1.06 and 1.01,

⁴Note that in the models with financial frictions, α is not exactly equal to labor share in the Financial Frictions model but it is rather calibrated as $\alpha = LaborShare * [1 + (R - 1)\theta]$. Thus, it will have an entire distribution determined by the posterior distribution of θ .

respectively. These values were calibrated according to the data provided by Uribe and Yue (2006) on Mexican interest rates and are consistent with a five hundred basis points spread observed in Mexican sovereign bonds, and with the long-run mean of the real risk-free rate measured by the 3-month gross Treasury bill rate. In the stochastic trend model we set the spread to zero and use the value reported by Aguiar and Gopinath (2007) as the mean long run foreign interest rate.

The quarterly depreciation rate is assumed to be 5 percent. As common in the literature on small open economy models, we set the parameter ψ , determining the interest rate elasticity to debt, to a minimum value that guarantees the equilibrium solution to be stationary (Schmitt-Grohe and Uribe, 2003). Lastly, we calibrate the long-run productivity growth, μ , equal to 1.006 following the point estimate reported by Aguiar and Gopinath (2004) and consistent with a yearly growth rate of 2.4 percent.

2.3.3 Data and Implementation

For comparability, we used the Mexican data from Aguiar and Gopinath (2007) as our observed data, X . We retrieved their series for aggregate consumption (C), investment (I), output (Y), and the trade balance to output ratio (TB/Y). The data are quarterly for the period 1980:I to 2003:II.

Our empirical implementation requires at least three other decisions: how to deal with trends; whether and how to include measurement error; and how to draw samples from the posterior distribution. Our choices are best explained

in the context of the state space formulation of each model.

Once each model is linearized around its nonstochastic steady state, the system of equations that characterize its solution can be written in the form of a transition equation:

$$Z_t = PZ_{t-1} + Q\nu_t \quad (14)$$

where Z_t is a vector with the model variables, ν_t the vector of structural shocks, and P and Q system matrices that may depend on the model parameters. The Kalman filter then requires specifying a measurement equation,

$$X_t = F + GZ_t + \epsilon_t \quad (15)$$

mapping the elements in Z_t to a vector of observed data X_t by the conformable matrices $[F, G]$, while ϵ_t are exogenous i.i.d. measurement errors.

Given that the data is expressed in levels, and that the solution to our models is cast in terms of log-deviations from steady states, there is a straightforward way to map a transformation of the data to the elements in the models. For illustrative purposes, consider how to deal with data on aggregate output in levels, Y_t . In this case, the observed data can be directly linked to its theoretical counterpart, y_t , as follows:

$$\underbrace{Y_t}_{Data} = \underbrace{y_t \Gamma_{t-1}}_{Model}$$

Furthermore, since the solution of the model is given in terms of log-deviations from steady state, an additional transformation is needed. If there are shocks

to the trend, the measurement equation for output is

$$\underbrace{\Delta \ln(Y_t)}_{Data} = \underbrace{\ln \mu + (\widehat{y}_t - \widehat{y}_{t-1}) + \widehat{g}_{t-1}}_{Model}; \quad (16)$$

where Δ denotes the first difference and a hat $\widehat{\cdot}$ denotes log-deviations from steady state values (i.e. $\widehat{y}_t = \ln(y_t/y_{SS})$). Similarly, if there are no trend shocks, the measurement equation for output is

$$\underbrace{\Delta \ln(Y_t)}_{Data} = \underbrace{\ln \mu + (\widehat{y}_t - \widehat{y}_{t-1})}_{Model}; \quad (17)$$

Similar observations apply for the measurement equations of aggregate consumption and investment. The absence of a trend in the trade balance share makes the mapping from the observed data to the model based data independent of which case we are considering. Moreover, because we take a linear approximation (rather than log-linear) to the model-based measure of trade balance share, tby , the mapping in terms of first differences is

$$\underbrace{\Delta (TB/Y)_t}_{Data} = \underbrace{\widehat{tby}_t - \widehat{tby}_{t-1}}_{Model};$$

We choose a mapping in first differences of TB/Y , instead of levels, because typically small open economy models counterfactually deliver a quasi-random walk process in the trade balance level, inherited by the nature of the endowment process (see Garcia-Cicco, et.al., 2007).

The second issue is the treatment of the measurement errors ϵ_t . First, note

that neither the encompassing model nor any of its restrictions exhibit more structural shocks than the number of time series we observe. To overcome the resulting stochastic singularity two options are available: either basing estimation on as many observed variables as there are shocks; or adding measurement error shocks, completing the probability space of each model so as to render the theoretical covariance matrix of the variables in X_t no longer singular⁵. Within the context of our investigation each alternative offers advantages and disadvantages. While the addition of measurement errors may be warranted, given the well-known measurement issues surrounding macroeconomic data from emerging economies, it is still an arbitrary decision which variables will have errors and which ones will not. On the other hand, given that one of our central goals is to compare the performance of restricted versions of the encompassing model, we also want to know how this comparison looks like when each version is directly mapped to the data, without the addition of artificial statistical errors. Of course, under the latter alternative the tougher question arises of which of the four available time series to use. In light of this trade-off we choose to combine both methods. We estimate both the encompassing model and its two restricted versions using all four time series vectors and adding measurement errors to all four. In addition, for comparing the stochastic trend and financial frictions models, we also report results when no measurement errors are added. In the latter case we explore the implications of using different pairs of

⁵A third option, known in the literature as the multiple-shock approach, is to include additional structural shocks. This option, however, would take us further away from the scope of this paper so we discard it.

observable vector time series.

The third issue is how to sample from the posterior distribution. We follow, for the most part, the Random Walk Metropolis algorithm presented in An and Schorfheide (2007) to generate draws from the posterior distribution $p_M(\theta^M|X)$. The algorithm constructs a Gaussian approximation around the posterior mode, which we find via a numerical optimization of $\ln L_M(\theta^M|X) + \ln p_M(\theta^M)$, and uses a scaled version of the inverse of the Hessian computed at the posterior mode to efficiently explore the posterior distribution in the neighborhood of the mode. We found it useful to repeat the maximization algorithm using random starting values for the parameters drawn from their prior support in order to gauge the possible presence of multiple modes in the posterior distribution⁶. Once this step was completed, we used the algorithm to make 150,000 draws from the posterior distribution in each case. The initial 50,000 draws were burned.

To overcome the high serial correlation of the draws, we used every 100th draw and posterior distributions were generated with the resulting 1000 draws. Convergence of the Markov chains was verified informally through graphical methods.

2.4 Results

This section presents our baseline results. We first summarize our prior beliefs and present the parameters' posterior distributions and the distribution of other

⁶The MATLAB codes that solve all the model's extensions as well as the ones that carry out the estimation are available upon request.

key moments. We estimate the encompassing model as well as the two restricted versions of interest, the stochastic trend model and the financial frictions model. For the most part we report results obtained with and without measurement errors. We conclude the section with an assessment of the relative fit of the two competing approaches to business cycles in emerging economies.

2.4.1 Priors

Our prior beliefs over the estimated parameters are described in Table I.2 and were based, to the extent possible, on earlier studies on emerging market business cycles.

Key parameters are those governing the temporary and permanent technology processes: $\sigma_a, \sigma_g, \rho_a, \rho_g$. Unfortunately, existing evidence on the relative importance of each of these parameters is ambiguous. While Aguiar and Gopinath (2004)⁷ estimated a ratio $\sigma_a/\sigma_g = 0.41/1.09 = 0.4$ for Mexico, Garcia-Cicco et.al. (2007) found the much higher ratio $\sigma_a/\sigma_g = 3.3/0.71 = 4.6$ for Argentina. Given this, we chose our prior to be a Gamma function with parameters (2.06, 0.0036). This prior has a mean of 0.74 for both σ_a and σ_g , which mimics the average between the two point estimates found by Aguiar and Gopinath (2004).

Our prior for ρ_a , the autoregressive coefficient of the temporary productiv-

⁷The reader should note that we use the working paper version of Aguiar and Gopinath's work (Aguiar and Gopinath, 2004) when forming our priors, instead of the published version (Aguiar and Gopinath, 2007). This is because only in the working paper version the estimation is done using the same GHH preferences we use in our work whereas in the published version the authors use Cobb-Douglas preferences instead. While they show that the business cycles implications of using the two preferences are similar, the point estimates of the key parameters they estimate do differ substantially. In the next sections we explore the robustness of our results to other set of preferences.

ity shock, was a Beta function with parameters (356, 19), implying a mean of 0.95 and a standard deviation of 1.1 percent. The mean is close to the point estimate found by Aguiar and Gopinath (2004), and equals the value calibrated by Neumeyer and Perri (2005). Our prior for the autoregressive coefficient of permanent productivity shocks, ρ_g , was also a Beta function with parameters (285, 111), yielding a mean of 0.72, and a standard deviation of 2.3 percent. This follows the point estimate found by Aguiar and Gopinath (2004).

Similarly, we based our priors over parameters governing the world interest rate process and the degrees of financial frictions ($\rho_R, \sigma_R, \eta, \theta$) upon earlier studies. Our prior for ρ_R , was a Beta function with parameters (44.3, 9.06), consistent with beliefs that the mean value was 0.83, the point estimate found by Uribe and Yue (2006), and a standard deviation of 5.1 percent. For σ_R we specified as prior a Gamma function with parameters (5.6, 0.0013), which is centered at 0.72 percent, the value reported by Uribe and Yue, and has a standard deviation of 0.31 percent.

Previous studies provide little statistical information on the size of the elasticity of the spread to the country's fundamentals, η , and the fraction of the wage bill held as working capital, θ . We use a prior with mean of 1.0 and a standard deviation of 10 percent for η , close to the value calibrated by Neumeyer and Perri (2005) to match the volatility of the interest rate faced by Argentina's residents in international capital markets. As for θ , we decided to specify a fairly diffuse prior, with the only restriction that it must lie between zero and one. For this purpose we used a Beta(2, 2) function with mean 0.5, and a considerable

standard deviation of 22.4 percent reflecting the little information we have *a priori* on this parameter.

Lastly, our prior on ϕ was a Gamma function with parameters (3, 2). This is a considerably diffuse prior, as given by the large 90 percent confidence interval, reflecting that previous studies have found different values for this parameter when trying to mimic the investment volatility.

2.4.2 Posteriors

We estimated various scenarios. We estimated the encompassing model as well as the two restricted versions of it - the stochastic trend version and the financial frictions version- under a flexible framework allowing for measurement errors in the four time series observed. We also estimated the stochastic trend and financial frictions models without any measurement errors using several alternative pairs of observable time series.

Estimated posterior distributions, allowing for measurement errors, are summarized in Table I.3. The third and fourth column report posterior modes and means of the parameters of the encompassing model, while the next two columns report posterior modes for the two restricted models. As a benchmark, the last column reports the GMM estimates of Aguiar and Gopinath (2005). In addition, Table I.4 reports variance decompositions and Figure I.1 plots priors and posterior distributions for the encompassing model.

Several results deserve attention:

- The data are fairly informative, in particular with respect to the volatilities

of the shocks, in the sense that the estimated posteriors appear much more precise than the priors, as measured by the size of the 90 percent highest posterior density intervals.

- Interestingly, in the encompassing model, the role of permanent shocks does not appear to be as dominant as suggested by our prior beliefs. The estimated posterior mode ratio of volatilities is $\sigma_a/\sigma_g = 0.66/0.12 = 5.5$, which is clearly at odds with Aguiar and Gopinath's (2007) finding that volatility of innovations appears to be much stronger in the permanent technology process than in the transient one. While this ratio suggests a minor role of trend shocks in the Mexican business cycle, an overall assessment can be based on the random walk component of the Solow residual which, following Aguiar and Gopinath (2007), is defined as follows:

$$RWC = \frac{\alpha^2 \sigma_g^2 / (1 - \rho_g)^2}{\left[2 / (1 + \rho_z)^2 \right] \sigma_a^2 + \left[\alpha^2 \sigma_g^2 / (1 - \rho_g^2) \right]}$$

The mode and mean of the posterior distribution of the RWC for the encompassing model is given at the bottom of Table I.3. It is immediate to see that, given that the posterior of the ratio ρ_a/ρ_g is left pretty much unchanged relative to the prior, while the ratio σ_a/σ_g increases significantly, the posterior of the random walk component is largely reduced relative to the prior. Indeed, we obtain a RWC whose posterior mode is only 0.20, far below the 5.3 value recovered by Aguiar and Gopinath. Therefore, a full-information method does not assign such a relevant role to trend

shocks as a method that only looks at a selected subset of moments.

- To a large extent, the minor role of trend shocks is explained by the relevance of interest rate shocks and the financial frictions amplifying them. We find that the posterior distributions of the parameters θ and η governing the degree of financial frictions are far away from zero. The posterior mode for θ is 0.69, signaling that a little less than three quarters of the wage bill is kept as working-capital needs. The tight posterior mode for η , with its mean centered around 0.73, reveals a significant elasticity of the spread to expected movements in the country fundamentals, embedded in the Solow residual. While this is lower than our prior beliefs, which were centered around the value of 1.0 calibrated by Neumeyer and Perri (2005), it is still remarkable to obtain a high value given that Neumeyer and Perri's calibration was based on the observed process of the country interest rate, which we do not observe here. Notably also, the relative importance of trend shocks increases when the stochastic trend model is estimated and we shut down both interest rate shocks and financial frictions (fifth column).
- To assess the relative role of each structural shock in explaining macroeconomic fluctuations, we computed the posterior distribution of the variance decompositions implied by the encompassing model. The results over a time horizon of 40 quarters are reported in the top panel of Table I.4. The most remarkable result is the small role played by trend shocks when accounting for the variance of the observed macroeconomic aggregates. The

largest share of permanent shocks is only 3%, when explaining the variance of consumption, and it shrinks further when looking at the other three variables. On the other hand, world interest rate shocks play a nontrivial role, particularly when explaining the variance in the trade balance-to-GDP ratio (43%), investment (24%), and to a lesser extent in consumption (11%). Their role accounting for the variance of output (6%) falls within the estimates from other studies. For example, Neumeyer and Perri (2005) find that the percentage standard deviation of Argentina's GDP in a model with financial frictions but no shocks to international rates is 3% smaller than the one in a model with interest rate shocks; and Uribe and Yue (2006) find that US interest rate shocks explain about 20% of movements in aggregate activity in a pool of emerging market economies. The largest share of the variance in all four aggregates is however largely explained by transient shocks to the technology process. This is analyzed next.

- We mainly examined convergence of the MCMC algorithm via informal graphical methods. Following An and Schorfheide (2007) we compared draws and recursively computed means from multiple chains. For this purpose we chose six vectors of initial parameters by randomly drawing from their prior support; each vector was used to run six independent Markov chains. The results of these experiments are reported in Figure I.2 for the estimation of the encompassing model. Despite different initializations, the parameters' means converge in the long-run.
- The lower panel in Table I.4 presents the counterfactual experiment of

shutting off the link between technology shocks and spreads, $\eta = 0$. The results suggest that the large role of transient technology shocks in accounting for fluctuations in investment and the trade balance, and to a lesser extent in consumption, is driven by their impact on spreads. This is illustrated by looking at the impulse response functions in Figures I.3 and I.4. The responses of the main macroeconomic aggregates to a transitory technology shock depend strongly on whether the financial friction embedded in η is included or not. With $\eta > 0$ transitory technology shocks are greatly amplified, which explains the large share of interest rate shocks when this channel is turned off in the lower panel of Table I.4. Still, surprisingly, output's variability continues to be explained by "pure" technology shocks even if $\eta = 0$.

- Another noteworthy result in Table I.3 is that measurement errors appear to be quantitatively significant. This is robust across the three cases in Table I.3 and signals that a non trivial fraction of the volatility in the main macro aggregates, particularly consumption and investment, is left unexplained by all three models.
- Nonetheless, one could ask how the posterior results would differ for the two restricted models if we estimated them without any measurement error. The results of this experiment, using three separate pairs of observables, are given in Table I.5. What we observe across the three pairs of results is that the size of the shocks increases in order to account for the volatility that was soaked up before by the measurement errors. In all

three cases considered for the stochastic trend model, the RWC increases with respect to the benchmark case with measurement errors. In the case of the financial frictions model, however, most of the volatility is now soaked up by increasing the size of the parameter governing the capital adjustment cost. This may signal a complementary explanation as to why our results differ from Aguiar and Gopinath (2007), given that they did not consider the possibility of measurement errors.

2.4.3 Model Comparison

Marginal Data Densities We turn next to formal comparisons of the models considered above. Table I.6 reports values of the likelihood and posterior (in logs) computed at the posterior mode, $(\log L_M(\theta^M|X))$ and $\log p_M(\theta^M|X)$ in terms of our previous discussion) and the values of the marginal data density ($\log p_M(X)$) for each model.

Overall, the results reported in Table I.6 tend to mildly favor the financial frictions model. All values for the log-likelihood evaluated at each model's posterior mode are highest for the financial frictions model. When judging by the log-marginal likelihood, the results are a little bit more ambiguous. Allowing for measurement errors implies superiority for the stochastic trend model, yet this is probably because the likelihood of the financial frictions model peaks at a value that is at odds with the information used to construct the prior distribution (An and Schorfheide, 2007).

With no measurement errors, in two of the three cases the financial frictions

model attains a better relative fit than the stochastic trend model, both in terms of a higher log-likelihood and, more markedly, in terms of marginal data densities and hence predictive performance. Indeed, the posterior odds of the financial frictions model against the stochastic trend model (the ratios of their respective marginal likelihoods) are in the order of $1 : \exp(10)$ or higher, well above the thresholds considered as "decisive evidence" in favor of the financial frictions model (see e.g. DeJong and Dave, 2007). In the third case, when only consumption and output are observed, the log-marginal likelihood favors the stochastic trend model, but only with a posterior odds in the order of $1 : 2$, which constitutes only "very slight evidence" in favor of that model.

Note that the two restricted models, the stochastic trend and financial frictions models, can attain higher likelihood and marginal likelihood levels than the encompassing model. This result can be explained by the different priors used implicitly when estimating the two restricted models. As an illustration, consider the case of ρ_R , the AR(1) parameter in the R^* process. When estimating the encompassing model, the 90 percent prior distribution over this parameter lies in the interval $[0.74, 0.91]$, so that values close to zero are highly penalized by the prior. Yet, when estimating the stochastic trend model as a restricted version of the encompassing model, ρ_R is set to zero, or, more precisely, a unit mass prior is defined over zero. A similar case occurs with all the other parameters that are set equal to zero in the restricted models, $\{\sigma_R, \theta, \eta\}$ for the case of the stochastic trend model and $\{\rho_g, \sigma_g\}$ for the case of the financial frictions model. These differences in the priors imply that areas of the posterior

distribution that were not explored before in the estimation of the encompassing model are now explored in the two restricted models. This makes it essential to explore further the role of the priors, as we do in the next section.

For comparison purposes, we report in Table I.6 the log-likelihood value for the stochastic trend model evaluated at the point GMM estimates of the parameters reported by Aguiar and Gopinath (2004)⁸. The log-likelihood value implied by the GMM-estimated parameters is far below the levels we obtain. This gives further quantitative evidence that, within the context of the models analyzed here, a full-information method can deviate substantially from an estimation method that, like GMM, only looks at a selected subset of moments. And from the evidence just discussed, we learn that this deviation takes mainly the form of a significantly higher variance of the transient technology shock.

Selected Moments It could be argued that, for macroeconomists, predictive performance may not be the only relevant metric to evaluate the relative merits of alternative models. As mentioned above, the literature on emerging market business cycle has emphasized some key moments in model evaluation. Two moments have drawn much attention: the marked countercyclicity of the trade balance and the high volatility of consumption and investment relative to output. This section compares the models under study along a particular subset of moments, including the two just mentioned. In doing so we are implicitly conducting a more stringent test of each model, as the estimation was

⁸The parameters are reported in Table I.3. When computing the log-likelihood value at this vector, we use the posterior mode of the four measurement errors.

not designed to match this particular set of moments.

The results are gathered in Tables I.7.1 and I.7.2, where the filtered sample moments of the data, in terms of standard deviations, correlations with output and the trade balance, and serial correlations, are compared to the theoretical moments from the encompassing model as well as the two restricted models. Consistent with the measurement equations used in the above section, we filter the data using simple log-differences for income, consumption and investment, and first differences for the trade balance share. Model-based moments are computed at posterior mode estimates⁹. For comparison purposes, the moments associated with Aguiar and Gopinath (2004)'s GMM estimation are reported in the last column of Table I.7.1¹⁰.

The main findings are as follows:

- The encompassing model delivers a reasonably close match to the facts emphasized in the literature: it delivers a more volatile path for consumption and investment with respect to output and reproduces the strong countercyclicality of the trade balance share observed in the data. Recall that this is obtained without resorting to significant trend shocks. This is further confirmed by the moments of the financial frictions model, which are quite similar to those of the encompassing model. This indicates that financial frictions can amplify interest rate shocks to the point of causing

⁹Standard errors are omitted for brevity but are available upon request.

¹⁰To be precise, Aguiar and Gopinath (2004) conduct the GMM estimation based upon 11 moments of which only two, the standard deviation and serial correlations of gY , are reported in Table I.7.1. The other 9 moments used in that work refer to Hodrick-Prescott filtered moments which we don't present here given that we don't use this filtering technique.

a response of consumption that exceeds the response in output leading to countercyclical net exports, a result obtained previously by Neumeyer and Perri (2005) for Argentina.

- A salient failure of the stochastic trend model is its inability to reproduce a significantly more volatile consumption with respect to output. This failure occurs consistently both with and without measurement errors. In addition, when measurement errors are not included, the model's implied variance of the main macro aggregates is excessively high, notably for gY and gC .
- A comparison between the moments implied by the estimated stochastic trend model and the ones derived from the GMM point estimates suggests why our full-information estimation differs from the GMM results. While the GMM approach, by construction, assigns more weight to the standard deviations, the full-information method assigns weights also the correlations among the four observed variables and thus attains a better match in that dimension. Obviously, other dimensions, different than the ones presented in Tables I.7.1 and I.7.2, will be also better matched in a full-information approach.

2.5 Robustness Checks

In this section we assess the robustness of our baseline results along five dimensions. First, we gauge the robustness of the results when using less informative priors. Second, we investigate the separate role of the two financial frictions

under consideration. Third, we examined the role of GHH preferences. Fourth, we assess whether our results change if we estimate the rate of long-run productivity growth. Finally, we include the country specific and foreign interest rates into the vector of observables and use the reestimated model and estimated shocks to simulate the macro dynamics during the Tequila Crisis.

2.5.1 Less Informative Priors

The first six columns of Table I.8 examine the implications of less informative priors. To do this, for almost all parameters we choose flat priors given by uniform distributions. The exceptions are the AR(1) coefficients of the driving forces' processes, for which we choose a quasi flat priors given a Beta function with parameters (2,2), implying a mean of 0.5 and a large standard deviation of 22.4 percent.

The first result of interest is the presence of two local modes in the posterior distribution. Each mode favors one of the two approaches to business cycles in emerging economies. The higher mode, with a likelihood and posterior values of 1004.6 and 1014.6 respectively, is characterized by the virtual disappearance of trend shocks -the posterior mode for σ_g is 0.02-, while the transitory technology shocks exhibit values larger than the ones obtained under the initial priors. The parameters estimated for the interest rate process characterize a lower volatility but a higher persistence relative to the benchmark case. As a consequence of this, the value of the random walk component is negligible. On the other hand, a lower posterior mode, with a likelihood and posterior values of 997.8

and 1009 respectively, is characterized by the predominance of trend shocks: its technology shocks ratio is $\sigma_a/\sigma_g = 0.46/1.12$, and the parameters governing the elasticity of the spread, η , is virtually zero.

A challenge for the Bayesian estimation is, therefore, to fine tune the Metropolis-Hasting algorithm so as to properly sample from the regions surrounding each of the two modes. For the results reported in the sixth column of Table I.8, we were able to make the Markov chain cross over the two modes with enough regularity. The Markov chain explored more the posterior around the high mode, and hence the mean values are closer to those of the high posterior mode. Interestingly, the mean posteriors are not too far from the mode reported for the encompassing model under the initial priors. This explains why the results from the variance decomposition exercise under the less informative priors, reported in the upper panel of Table I.9, are quantitatively similar to the ones presented before. Indeed, we observe a much smaller role played by trend shocks as opposed to transitory technology shocks when accounting for the variance of the observed macroeconomic aggregates. We view these results as evidence that our baseline results are robust to assuming less informative priors.

2.5.2 One Financial Friction at a Time

The results presented thus far favor the view that financial frictions amplify shifts in market fundamentals through spreads that react to fundamentals and, through the presence of working-capital needs, have supply side effects following exogenous interest rate perturbations. It is therefore of interest to investigate

the extent to which each of the two financial frictions is responsible for these results. We address this question by shutting down one of the two frictions at a time.

We start by estimating the encompassing model without the assumption of working capital needs, $\theta = 0$, but still allowing for the spread to be affected by expected changes in the Solow residual and estimating the parameter η governing the elasticity of the spread. Next, we run the estimation by considering the opposite: we shut down the endogenous spread, $\eta = 0$, while we allow for the possibility of working capital needs, estimating the parameter θ . Last, we consider the case where none of the two financial frictions is present, $\theta = \eta = 0$.

The results of these experiments, in terms of the new posterior distributions, are reported in Table I.10, and the results in terms of variance decompositions and selected second moments are presented in Tables I.11 and I.12. Two results are worth mentioning. First, relative to the benchmark case in Table I.3, the results are virtually unaltered when the working-capital assumption is dropped, $\theta = 0$. Indeed, the posterior mode continues to be characterized, as in the encompassing model, by a strong elasticity of the spread to fundamentals, volatile shocks in interest rates and transient technology, and modest trend shocks. A sharply different outcome is obtained when $\eta = 0$. In this case the exploration of the posterior favors the mode where stochastic trend shocks are the leading driving forces. This is further emphasized by the variance decompositions in Table I.11. The results in the upper panel, where $\theta = 0$, are virtually unchanged relative to the benchmark case in Table I.4. However the variance decomposi-

tions change drastically when $\eta = 0$. In this case, the lion's share of the variance of most of the macro variables is explained by growth shocks. Second, the moments presented in Table I.12 show that, if working capital needs are the only financial friction in place, the model fails to generate a consumption process more volatile than the output process, and this in turn prevents the model from generating a strong countercyclical trade balance-to-GDP ratio.

These results are in line with Oviedo (2005), who argues that the presence of an endogenous spread is a necessary ingredient when building models that aim at replicating emerging market business cycles and that the presence of working capital requirements is not a necessary requirement in getting business cycles models closer to emerging economies' macroeconomic data.

2.5.3 Jaimovich-Rebelo preferences

Our baseline parameterization for preferences has been of the kind first suggested by Greenwood, Hercowitz and Huffman (1988). This is because GHH preferences improve the ability of business cycles models to reproduce some stylized facts both in advanced open economies (Mendoza (1991), Correia et.al. (1995)) and developing market economies (Neumeyer and Perri (2005), Garcia-Cicco et.al. (2007)).

A well documented reason for the empirical success of GHH preferences is the fact that they allow for labor supply to be independent of consumption levels. This leads to high substitutability between leisure and consumption, low income effect on labor supply, and large responses of consumption and labor

to productivity shocks. In contrast, in the case of Cobb-Douglas preferences, the income effect mitigates the response of labor to productivity shocks because labor supply is no longer independent of consumption levels. Compared to the case of GHH preferences, leisure and consumption are not easily substitutable because the income effect is strong. As a consequence, there is an incentive to smooth consumption excessively over the business cycle by saving, in response to a positive shock. Aguiar and Gopinath (2004), however, suggested that the role of preferences was minor, and in particular that their main result concerning the relative importance of trend shocks was robust to these alternative assumptions on preferences.

To investigate this issue, and more generally to test the robustness of our results to our specification of preferences, we repeated our estimations with preferences of the form introduced by Jaimovich and Rebelo (2008), which embed both GHH and Cobb Douglas as special cases:

$$u(C_t, h_t) = \frac{(C_t - \tau h_t^\omega X_t)^{1-\sigma}}{1-\sigma}$$

where the representative household internalizes in her maximization problem the dynamics of X_t given by:

$$X_t = C_t^\gamma X_{t-1}^{1-\gamma}, \quad 0 \leq \gamma \leq 1$$

The presence of X_t makes preferences non-time-separable in consumption and hours worked. As shown in Jaimovich and Rebelo (2008), these preferences

nest as special cases the two classes of utility functions mentioned above. When $\gamma = 1$ we obtain preferences of the Cobb-Douglas type. Conversely, when $\gamma = 0$ we obtain GHH preferences. Therefore, lower values of γ will render the income effect of technology and interest rate shocks milder, producing short-run responses to shocks that are similar to those obtained under GHH preferences. Conversely, higher values of γ will have the opposite effect, as shifts in the labor supply will likely offset changes in labor demand. In the latter case, and according to the findings in Aguiar and Gopinath (2004), it is more likely that business cycles will be driven by trend shocks, and interest rate shocks coupled with financial frictions will play a minor role.

A key parameter to be estimated is γ . Our approach was agnostic in not imposing strong prior beliefs on the distribution of this parameter. To this end we used a uniform distribution over the support $\gamma \in (0, 1]$. Note that, by excluding the case $\gamma = 0$, hours worked were stationary so we did not need to introduce the trend in the utility function.

The results are reported in the second-to-last column in Table I.8. It is immediate to see that the estimation strongly favors very low levels of γ , as the posterior is tightly concentrated toward zero with a mean of 0.05. Moreover, the role of permanent shocks is even less important relative to our baseline results: before, the estimated posterior mode ratio of volatilities was $\sigma_a/\sigma_g = 0.66/0.12 = 5.5$; now, it increases to $\sigma_a/\sigma_g = 1.02/0.06 = 17$, and the posterior mean for the random walk component falls from 0.28 to 0.04. In addition, recomputing variance decompositions implies that trend shocks are now negli-

gible, accounting for at most 2 percent of the overall variance (upper-middle panel in Table I.9).

Taken together, these results are indicative that our baseline results, favoring a model with financial frictions and interest rate shocks do not hinge on the assumption of GHH preferences. To our knowledge Schmitt-Grohe and Uribe (2009) is the only work that has previously estimated γ within a fully-fledged DSGE model, for open developed economies, finding even lower posterior means for γ . Our results clearly extend theirs to developing economies.

2.5.4 Estimating Long-Run Growth

A key parameter in the hypothesis that business cycles in emerging economies are driven by stochastic productivity shocks is long-run productivity growth, μ , because it is around this value that the random shocks drive the productivity process. In the baseline encompassing model we calibrated the value of this parameter to match a yearly net growth rate of 2.4 percent, or $\mu = 1.006$, using the GMM-point estimate reported by Aguiar and Gopinath (2004). However, it is clear from the evidence presented so far that GMM estimates may differ from the values obtained by full-information methods.

To check the significance of this issue, we reestimated the encompassing model including net yearly growth, ζ , as one of the estimated parameters. We specified a diffuse prior over that parameter, with a Gamma function with parameters (25, 0.1) in accordance with our beliefs that long-run yearly net growth has a mean equal to 2.5 percent but allowing for substantial uncertainty, a stan-

dard deviation of 50 percent ¹¹. The results are reported in the last column of Table I.8 and indicate a slightly higher posterior mean of 2.51 percent, and the uncertainty is somewhat reduced relative to the prior beliefs. Importantly, the baseline results from the encompassing model appear to be robust. Notably, the posterior ratio among volatilities, σ_a/σ_g , and the random walk component posterior mean are both quite close to the baseline results. Likewise, the variance decomposition presented in the lower-middle panel of Table I.9 continues to assign a minor role of trend shocks.

2.5.5 Observing interest rate processes and simulating the Tequila Crisis

Our estimations have been based on the dataset of Aguiar and Gopinath (2007) and, accordingly, have not exploited observable data on interest rates. We proceeded in that way in order to maximize comparability with Aguiar and Gopinath's work, but also because of data availability. Data series of interest rates for emerging economies are not easy to obtain, and most times they are constructed from data on sovereign spreads, like the J.P. Morgan EMBI, which starts only after 1994. In contrast, Aguiar and Gopinath's data set starts in 1980.

In spite of these considerations, it may be of interest to check how our results change if we add interest rate data. Hence we estimated the encompassing model adding measures of the domestic and foreign interest rates, R and R^* ,

¹¹The link between the gross quarterly growth rate, μ , and ζ is thus: $\zeta = 100 * (\mu^4 - 1)$.

respectively, in the set of observable time series for estimation. As the country specific risky interest rate we used Uribe and Yue (2006)'s Mexican interest rate in international capital markets, computed as the sum of the J.P. Morgan's EMBI+ stripped spread for Mexico and the US real interest rate. As the foreign interest rate we used the sum the US real interest rate and a global index of eight emerging market economies¹². This definition of R^* may be somewhat unusual, but is the appropriate one if we are to regard the spread between R and R^* as a *country specific* one, which is the only view consistent with the theoretical model (and, in particular, with the assumption that the spread may depend on expected *domestic* productivity).

As noted already, data on sovereign spreads is available only since 1994. The two measures of interest rates are plotted in Figure I.5. The plot also presents the implied spread, computed as the ratio of the Mexican and foreign interest rates. The two interest rates exhibit a high but not perfect correlation, (equal to 0.78) and present two particular peaks around the Mexican Tequila Crisis in the mid 1990s and the Russian and Asian financial crises of the late 1990s.

We added the interest rate series to the four observables in the Aguiar-Gopinath dataset, and reestimated the encompassing model (for the subsample after 1994). The results of are presented in the bottom of Table I.9¹³. Shocks to the transitory component of the technology process continue to account for most

¹²For the period 1998 onward the EMBI+Emerging Market index was used. For the period 1994 to 1997, the index was interpolated using Countries for which data on sovereign yields spreads was available. These countries (and the first year for which data on spreads was available) are: Argentina (1994), Brazil (1994), Ecuador (1995), Mexico (1994), Peru (1997), Korea (1994), Thailand (1997) and South Africa (1995).

¹³For the sake of brevity, the posterior estimates are omitted but the tabulated results are available upon request.

of the variability in the Mexican macro variables. Notably, however, the significance of growth shocks in explaining the variability of output and consumption increases relative to our previous cases. In contrast, interest rate shocks become less relevant. In this sense, the inclusion of interest rate data appears to favor the stochastic trends hypothesis.

One should realize, however, that these results do not mean that financial frictions are unimportant, since financial frictions may be amplifying the impact of any of the exogenous shocks. To examine this, and also to have an alternative view of model performance, we attempted to quantify the accuracy of the encompassing model in reproducing the Mexican dynamics during the 1994-5 Tequila Crisis.

We computed a historical decomposition of the structural shocks, exploiting the smoothing properties of the Kalman filter, following Hamilton (1994) and DeJong and Dave (2007). From the state space representation (14) and the measurement equation (15) we backed out the state variables and innovations, using the information contained in the entire sample:

$$\{Z_{1t|T}, \nu_{t|T}\}_{t=1994:1}^{T=2003:4}$$

Next, we independently used each of the three structural shocks to simulate the evolution of the four Mexican macroeconomic aggregates during the 1995 Tequila Crisis and its aftermath.

Figure I.6 shows the results. Each row tracks the observed and model-based

simulated time series of the Mexican macro aggregates between 1994 and 1997. The model based simulations were obtained using only the smoothed shocks to the technology growth (first row), the foreign interest rate (second row), and the transitory technology processes (third row). It is immediate to see that neither growth shocks nor shocks to the foreign interest rate can reproduce the observed dynamics. The only shock that comes close to reproducing the deep fall in economic activity and the sharp reversal of the trade balance during the crisis is the one that transiently affects total factor productivity.

Here, again, we have to remember that these perturbations may also be largely amplified by the financial frictions embedded in the model. To evaluate this possibility, Figure I.7 reproduces the simulation of the Tequila Crisis using only transitory technology shocks but varying the severity of the two financial frictions embedded in the parameters η and θ . The first row reports the simulation shutting down both financial frictions by setting $\eta = \theta = 0$. The second and third rows set, separately, $\theta = 0$ and $\eta = 0$ respectively, while leaving the other one equal to its estimated value. It is quite clear after looking at these plots that the success of transitory technology shocks in reproducing the Tequila crisis comes, by and large, from the presence of financial frictions, particularly embedded in η , the parameter that governs the elasticity of the spread to expectations of future productivity.¹⁴

¹⁴A similar experiment was conducted by Fernandez (2009) using data for other developing countries and a wider spectrum of shocks. His results point also to the need for financial frictions in closing the gap between observed and simulated dynamics.

2.6 Concluding Remarks

One could ask, in particular, how our results can be reconciled with those of Aguiar and Gopinath (2007), who reported strong support for the stochastic trend model. The short answer, in our view, is that Aguiar and Gopinath's GMM procedure targeted only a few moments of the joint process of the aggregates observed, while our Bayesian procedure considers all moments of the process. One could, then, argue that Aguiar and Gopinath's estimates of the importance of the random walk component would be superior in terms of criterion functions that emphasize those moments targeted by their GMM procedure. But then one would also have to justify why those moments and not many others are the only ones that we may care about.

While our emphasis has been on the financial frictions/stochastic trend dichotomy, there is plenty of associated research to be done. One could, for example, compare the performance of the financial frictions model against atheoretical VARs. While the predictive performance of the latter is likely to be superior, recent work suggests that refined versions of stochastic dynamic models can be built that compete with VARs in terms of predictive power.

In terms of policy, our results lend support to the idea that attempts to ameliorate financial imperfections may result in less aggregate volatility. They are likely too to lead to increases in welfare, although this is a question about which our estimation exercises have nothing to say.

3 "TROPICAL" REAL BUSINESS CYCLES? A BAYESIAN EXPLORATION

3.1 Introduction

Understanding business cycle regularities in developing countries is a crucial step in the process of designing appropriate stabilization policies and sound macroeconomic management in these countries. A first step toward this understanding must take into account the differences on the business cycles properties in developing countries relative their developed counterparts. As will be shown bellow, observed business cycles in emerging countries are more volatile relative to their developed counterparts; their trade balance-to-output ratio is countercyclical; and consumption is more volatile than output's at business-cycle frequencies. Explaining these contrasts between emerging and industrialized economies is at the top of the research agenda in small-open-economy macroeconomics (Uribe, 2007).

What are the main driving forces of business cycles in developing countries? To what extent are they responsible for the differences in business cycles properties between developed and developing countries? More specifically, can technology shocks alone, in the spirit of the real business cycle literature, account for these differences? By addressing these questions, the goal of this paper is to contribute to the understanding of business cycles in developing countries.

To do so we use the following approach. First, we make a brief survey of the literature on business cycles in developing countries. As will be documented

bellow, the use of frictionless small open economy models, driven solely by technology shocks to account for business cycles in developing countries has been controversial. On one strand of the literature, some authors have claimed that to properly account for the business cycle in these economies one can rely exclusively on pure technology forces in the form of transitory deviations in the total factor productivity process (e.g. Kydland and Zaraga, 2002) or permanent shifts of it (e.g. Aguiar and Gopinath, 2007). Others have stressed as key driving forces the interaction between technology shocks and other real driving forces such as terms of trade (e.g. Mendoza, 1995), or interest rates in world capital markets coupled with financial frictions (e.g. Neumeyer and Perri, 2005). Second, we use data from Colombia, a developing -and "tropical"- economy that has not yet been analyzed by the literature surveyed above. Using both high frequency-quarterly and low frequency-yearly data, we document the similarities and differences of the Colombian business cycle relative to those observed in an average developing economy. Based upon these stylized facts about the Colombian business cycle, the third element of our approach is to build a dynamic stochastic general equilibrium (DSGE) model that can account for them. Motivated by the observation that, to date, there has been little empirical analysis of the role played by individual shocks, within a multiple-shock setting, in driving business-cycle movements in aggregate variables from developing countries, a central element in our DSGE model is the inclusion of real driving forces other than technology shocks. Based on the literature surveyed in the next section, we include separately three structural driving forces to the standard neoclassical

framework: (i) shocks to the interest rate in world capital markets coupled with financial frictions; (ii) terms of trade fluctuations; and (iii) a procyclical government spending process. While each one of the alternative driving forces has been independently stressed by different strands of the literature on emerging market business cycles, to our knowledge, this is the first time where they will be jointly considered as alternative driving forces to technology shocks. The role of each driving force is empirically quantified by estimating the parameters of the exogenous shocks processes, along with a few other crucial parameters, within a Bayesian-likelihood-based framework, using Colombian macroeconomic data. Thus, we take the model as provider of a complete statistical characterization of the data in the form of a likelihood function. The performance of the model in accounting for the Colombian business cycle is then assessed.

We obtain several results of interest. The data is informative, particularly in terms of the size of the structural shocks impacting the economy. Shocks to the interest rate in world capital markets are a key driving forces of the Colombian business cycle. Transitory technology shocks appear to be relevant as well, to a large extent because financial frictions amplify their macroeconomic effects in the economy. These two driving forces alone can account well for the observed properties of the Colombian business cycle, notably the smooth consumption process, the volatile investment and the strong countercyclicality of the trade balance-to-GDP ratio, and are almost entirely responsible for the sharp downturn experienced in the late 1990s. Other structural shocks such as terms of trade fluctuations and level shifts in the technology process do

not appear to be relevant in the past decade and a half, but their importance increases when a longer span of data is considered. Demand shocks, in the form of government consumption innovations account only for a trivial role of the variance of the macroeconomic aggregates but they appear to be relevant for the out-of-sample forecasting fit of the model.

The paper is divided into six sections, including this introduction. The second section presents a brief review of the theoretical literature on business cycles in developing countries and describes the main aspects of the Colombian business cycle. The third section lays out the model. The fourth section describes the Bayesian estimation. The fifth section presents the results. Concluding remarks are given in the sixth section. An appendix summarizes the data sources.

3.2 Business Cycles in Developing Countries

3.2.1 A Brief Literature Review

As mentioned above, business cycles in developing countries are different from the ones observed in developed countries. Using the dataset by Aguiar and Gopinath (2007) for a sample of thirteen developed and thirteen developing countries, Table II.1 presents the main second moments for these two groups of countries. Comparing the upper and middle panels in Table II.1, three dimensions in which these differences manifest are: (i) observed business cycles in emerging countries are more volatile; (ii) the trade balance-to-output ratio is more countercyclical in emerging countries than in developed countries; and, (iii) consumption appears to be more volatile than output at business-cycle fre-

quencies. These stylized facts, among others, have been widely documented in Mendoza (1995), Agenor et.al (2000), Rand and Tarp (2002), Neumayer and Perri (2005), Aguiar and Gopinath (2007) and Garcia-Cicco et.al (2007).

Despite these important differences a brief review of the literature on general equilibrium emerging markets business cycles models does not show a consensus on the best approach to account for them. One strand of the literature has tried to explain business cycles in developing economies within a neoclassical growth framework augmented by real driving forces in addition to technology shocks. Mendoza (1995) expands a real business cycle model to account for tradable/non-tradable goods in which the terms of trade are an additional driving force. Since emerging countries typically specialize in exports of few primary commodities for which they are small players in the world markets for the goods they export or import, it follows that the terms of trade can be regarded as an exogenous source of aggregate fluctuations. Mendoza (1995) finds they account for 45 to 60 percent of the observed variability of GDP.

The argument of stronger real shocks has also been extended to financial markets. The idea is that developing economies exhibit low levels of aggregate savings forcing them to rely heavily on foreign investment, via capital inflows. Uribe and Yue (2006) explore the significant correlation between the business cycles in emerging markets and the interest rate that these countries face in international financial markets. They find that one third of business cycles in emerging economies is explained by disturbances in external financial variables (e.g. the foreign interest rate and the spread). Moreover, they find evidence of a

further increase in the volatility of domestic variables because of the presence of feedback from domestic variables to country spreads. Similarly, Neumayer and Perri (2005) find that eliminating country risk lowers Argentine output volatility by 27%. Another explanation for some of the stylized facts of the business cycles in developing economies explores the role of macroeconomic policies in amplifying the cycle (i.e. procyclical policies) as documented by Agenor et.al (2000) and Kaminsky et.al (2004).

On a more orthodox strand, some authors claim to properly account for the business cycle in developing economies by relying exclusively on pure technology forces in the line of the real business cycle school of thought. Kydland and Zaraga (2002) argue that nominal factors do not seem to be able to account for any significant fraction of the business cycles in Latin American countries, in general. They argue that, in the case of Argentina, the predictions of a standard neoclassical growth model conforms rather well with the observations during the Argentinean 'lost decade' years. More recently, Aguiar and Gopinath (2004, 2007), claim that accounting for possible regime switches giving rise to changes in the long-run growth trend in these economies is enough to account for the business cycle stylized facts. Their underlying premise is that emerging markets are characterized by frequent regime switches motivated mainly by dramatic reversals in economic policy. Which leads them to conclude that "*shocks to trend growth are the primary source of fluctuations in these [emerging] markets as opposed to transitory fluctuations around a trend*". Thus, the higher volatility of consumption can be explained as agents, seeking to smooth

their consumption levels, observe changes in the permanent component of the trend. Aguiar and Gopinath's conclusion is driven by an estimated volatility of the technological growth process in the Mexican economy four to five times higher than the volatility of the transitory technology shock. In another paper, Aguiar and Gopinath (2008) find this result to be robust under the presence of stochastic interest rate shocks.

The idea that developing countries' business cycles are, by and large, driven by trend shifts has not gone without criticism. On one hand, Garcia-Cicco et.al. (2007) have argued that in order to properly estimate the parameters of the stochastic trend, long time series are needed. Accordingly, they estimate the Aguiar and Gopinath model on a yearly dataset for Argentina covering over a century of aggregate data and find that the model performs poorly when trying to mimic some of the main moments in the Argentinian macroeconomic data, in particular the higher volatility of consumption relative to output, and the trade balance autocorrelation function. They show how another model that does not rely on growth shocks, but includes other structural shocks instead can overcome these empirical shortcomings. On the other hand, Chang and Fernandez (2009) have shown that a model with foreign interest rate shocks coupled with financial frictions as key amplifying mechanism outperforms the Aguiar and Gopinath model driven solely by transient and permanent technology shocks, if a ranking is made according to the models' marginal likelihood.

3.2.2 Business Cycles in Colombia

The lower panel of Table II.1 presents the second moments in the main Colombian quarterly macroeconomic aggregates for the period 1994:1 to 2008:4. Colombian data is characterized by some of the main stylized facts from the sample of developing economies highlighted in the middle panel of Table II.1. There is a higher macroeconomic volatility measured by the variance of output and the trade balance share is significantly more countercyclical, even when compared to the average developing country. The latter is almost entirely driven by the properties of the time series for investment which exhibit a volatility, relative to output's, that is also superior to the one in developing countries. There is, however, no evidence of a high volatility of Colombian aggregate consumption. In fact, the standard deviation of consumption appears even lower than the one observed for the average developed country. Importantly, when computing second moments from Colombian data we exclude durable (and semi-durable) goods consumption from aggregate consumption and include it on investment as it is standard in business cycles analysis (see Cooley and Prescott, 1996). It should be noted, however, that the low volatility of consumption with respect to output does not depend on this transformation¹⁵.

The last three rows in Table II.1 present additional data on three potential driving forces of the Colombian business cycle that will be included in the the-

¹⁵If aggregate consumption is measured including consumption of durables and semidurable goods (as reported by DANE) the standard deviation of consumption growth increases only to 1.04, which is still lower than output's volatility. It is not specified in Aguiar and Gopinath (2007) whether they also remove durable goods consumption from the aggregate consumption data they report.

oretical model presented in the next section: (i) gR^* , a proxy for the growth in the gross risky interest rate that countries similar to Colombia have faced in international capital markets, computed adding the real interest rate on U.S. T-Bills and the average EMBI+ spreads for Latin American economies; (ii) $gToT$, a proxy for the growth in the terms of trade faced by Colombian consumers and firms; and (iii) the growth in the level of public consumption¹⁶. Three key stylized facts emerge from the analysis of the second moments of these three variables. First, the proxy for the interest rate is countercyclical and leads the cycle, the same pattern that Neumeyer and Perri (2005) documented for a pool of emerging economies. Second, the terms of trade are highly volatile and procyclical, with a correlation of 0.33 between the terms of trade index and Colombian GDP, which is close to the value found by Mendoza (1995) for a pool of developing countries (0.39). Last, while government expenditure is procyclical, its correlation with output growth (0.17) is lower when compared to studies that have looked at other developing countries as Kaminsky et.al (2004).

To summarize business cycles in Colombia, within the last decade and a half, are characterized by (i) a moderately high variance of output; (ii) a trade balance share of income strongly countercyclical; (iii) a significantly volatile level of investment; (iv) a smooth aggregate consumption path; (v) a leading and countercyclical interest rate in world capital markets; (vi) volatile and procyclical terms of trade; and (vii) a moderately procyclical government expenditure. The following sections will build and estimate a business cycle model of the

¹⁶See the Data Appendix for more details.

Colombian economy and its performance will be assessed along these dimensions, among others.

3.3 A Business Cycle Model for a Small, Open, and "Tropical" Economy.

The model presented here is built following the canonical real business cycle model of a small open and centralized economy first developed by Mendoza (1991). A decentralized version of this model was extended by Chang and Fernandez (2009) by introducing permanent shocks to technology, as discussed by Aguiar and Gopinath (2007) and foreign interest rate shocks that interact with financial imperfections, as discussed by Neumeyer and Perri (2005) and Uribe and Yue (2006). In what follows we modify the model by Chang and Fernandez (2009) in two dimensions: first, we allow for the presence of domestically produced and foreign consumption and investment goods; second, we include the presence of a procyclical government expenditure process.

3.3.1 Firms and Technology

Time is discrete and indexed by $t = 0, 1, 2, \dots$. The domestic good is produced by a representative firm in each period with a Cobb-Douglas technology given by

$$Y_t = a_t K_t^{1-\alpha} (\Gamma_t h_t)^\alpha \quad (18)$$

where Y_t denotes output, K_t capital available in period t , h_t labor input. We use upper case letters to denote variables that trend in equilibrium, and lower

case letters to denote variables that do not¹⁷. The exogenous variables a_t and Γ_t represent productivity processes to be specified later.

The firm hires labor for which pays a wage W_t per worker and rents capital in competitive markets at a rental rate u_t . It faces a friction in the technology for transferring resources to its workers: in order hire workers, the firm needs to set aside a fraction θ of the wage bill, $W_t h_t$, at the beginning of each period. Thus, because it is assumed that production becomes available at the end of each period, the firm has to borrow $\theta W_t h_t$ in international markets for which it has to pay an interest rate of equilibrium at the end of the last period, R_{t-1} . There are no frictions in the market for capital. When output becomes available firms use the resources to honor the remaining debts to workers, $(1 - \theta) W_t h_t$, and to the financial system $\theta W_t h_t R_{t-1}$, and pay for rented capital $u_t K_t$.

Given W_t , u_t and R_{t-1} , the firm's problem is to choose labor and capital in order to maximize profits, Π_t , given by

$$\Pi_t = Y_t - W_t h_t - u_t K_t - (R_{t-1} - 1) \theta W_t h_t$$

subject to the technology available given by 18. The firm's two profit maximizing conditions are then given by

$$u_t = a_t (1 - \alpha) K_t^{-\alpha} (\Gamma_t h_t)^\alpha \tag{19}$$

¹⁷The only exceptions will be the spread, S_t , and the world and domestic gross interest rates, R_t^* and R_t , to be defined later, which do not trend in equilibrium.

$$W_t [1 + \theta (R_{t-1} - 1)] = a_t \alpha K_t^{1-\alpha} (\Gamma_t h_t)^{\alpha-1} \Gamma_t \quad (20)$$

where the latter implies that the marginal product of labor equals the wage rate inclusive of financing costs. This assumption, first introduced in the emerging markets business cycles literature by Neumeyer and Perri (2005) allows for a direct supply effect of changes in real interest rates.

3.3.2 Households

Households own the capital and labor stock available in the economy. At the beginning of each period a representative household supplies labor and rents its capital to the firms in competitive markets. At the end of the period, the household receives the salary and rents resources for the two inputs and makes consumption and investment decisions. These decisions are made according to the household's preferences given by the Greenwood, Hercowitz and Huffman - GHH (1988) form:

$$E \sum_{t=0}^{\infty} \beta^t \frac{(C_t - \tau \Gamma_{t-1} h_t^\omega)^{1-\sigma}}{1-\sigma} \quad (21)$$

where β is a discount factor between zero and one, C_t denotes consumption and $E(\cdot)$ the expectation operator. As discussed by Neumeyer and Perri (2005) and others, GHH preferences have been shown to help reproducing some emerging economies' business cycles facts by allowing the labor supply to be independent of consumption levels. We follow Aguiar and Gopinath (2007) in including Γ_{t-1} in the period utility function to allow for balanced growth.

The resources used for gross investment cover the net increase in the capital

stock, the depreciated capital and the costs incurred by adjusting capital as follows:

$$I_t = K_{t+1} - K_t + \delta K_t + \frac{\phi}{2} \left(\frac{K_{t+1}}{K_t} - \mu \right)^2 \quad (22)$$

where the last term is a quadratic capital adjustment cost function that is standard in business cycles models in order to avoid excessive volatility of investment.

Given that households can also consume goods produced abroad and that these goods are imperfect substitutes with domestically produced goods, consumption will be defined by an aggregator function:

$$C_t = \left[\gamma_C^{1/v_c} (C_t^F)^{\frac{v_c-1}{v_c}} + (1-\gamma_C)^{1/v_c} (C_t^H)^{\frac{v_c-1}{v_c}} \right]^{\frac{v_c}{v_c-1}}, \quad \gamma_C \in (0,1), \quad v_c > 0 \quad (23)$$

where C_t^F and C_t^H are the consumption levels of foreign and domestic goods, γ_C is the share of consumption of foreign goods in total consumption, and v_c is the elasticity of substitution between home and foreign goods. Total real expenditure on consumption can be written as follows:

$$p_t^C C_t = p_t^H C_t^H + p_t^F C_t^F \quad (24)$$

where p_t^C is the aggregate price level of consumption; p_t^H and p_t^F are, respectively, the price levels of home and foreign goods. Clearly, only two of these prices are independent, so we choose to express every price in terms of the foreign goods, noting that $p_t^H/p_t^F \equiv tot_t$ is therefore the terms of trade of this econ-

omy, which we assume to be an exogenous process. Given predetermined levels of aggregate consumption, and relative prices, the household's intratemporal problem is to maximize 23 subject to 24; with associated optimality conditions:

$$C_t^H = C_t (1 - \gamma_C) (p_t^{HC})^{-v_c} \quad (25)$$

$$C_t^F = C_t \gamma_C (p_t^{FC})^{-v_c} \quad (26)$$

and $p_t^{HC} \equiv p_t^H / p_t^C$, $p_t^{FC} \equiv p_t^F / p_t^C$, are relative prices that can be shown, after some algebra, to be determined by the terms of trade, as follows:

$$p_t^{HC} = [\gamma_C \text{tot}_t^{v_c-1} + (1 - \gamma_C)]^{\frac{1}{v_c-1}} \quad (27)$$

$$p_t^{FC} = [\gamma_C + (1 - \gamma_C) \text{tot}_t^{1-v_c}]^{\frac{1}{v_c-1}} \quad (28)$$

Households can also invest in home goods or foreign investment goods. Thus, gross investment will also be defined by an aggregator function:

$$I_t = \left[\gamma_I^{1/v_I} (I_t^F)^{\frac{v_I-1}{v_I}} + (1 - \gamma_I)^{1/v_I} (I_t^H)^{\frac{v_I-1}{v_I}} \right]^{\frac{v_I}{v_I-1}}, \quad \gamma_I \in (0, 1), \quad v_I > 0$$

where I_t^F and I_t^H are the investment levels of foreign and domestic goods, γ_I is the share of investment in foreign goods in total investment, and v_I is the elasticity of substitution between home and foreign investment goods. Total

real investment can be written as follows:

$$p_t^I I_t = p_t^H I_t^H + p_t^F I_t^F \quad (29)$$

It is thus straightforward to see that the optimality conditions for investment will be similar to the ones for consumption:

$$I_t^H = I_t (1 - \gamma_I) (p_t^{HI})^{-v_I} \quad (30)$$

$$I_t^F = I_t \gamma_I (p_t^{FI})^{-v_I} \quad (31)$$

$$p_t^{HI} = [\gamma_I t o t_t^{v_I - 1} + (1 - \gamma_I)]^{\frac{1}{v_I - 1}} \quad (32)$$

$$p_t^{FI} = [\gamma_I + (1 - \gamma_I) t o t_t^{1 - v_I}]^{\frac{1}{v_I - 1}} \quad (33)$$

Having specified the intratemporal problem of the household, we are ready to specify the household's sequential budget. Recalling that the representative agent has access to a world capital market for noncontingent debt, her budget constraint is, therefore,

$$p_t^{HC} W_t h_t + p_t^{HC} u_t K_t + p_t^{FC} q_t D_{t+1} = C_t + p_t^{IC} I_t + p_t^{FC} D_t + p_t^{HC} T_t \quad (34)$$

where the first two terms in the LHS are factor receipts in period t in terms of consumption goods. In addition, q_t is the price at which the household can sell a promise to a unit of goods to be delivered at $t + 1$, while D_{t+1} is the number of such promises issued. The first three terms in the RHS describe expenditures

in period t , given by consumption, investment, and debt payments; where

$$p_t^{IC} = p_t^{FI} / p_t^{FC} \quad (35)$$

and the last term is given by lump sum taxes paid to the government.

The household chooses consumption, labor, next period debt, and capital to maximize her utility function (21) subject to the sequential budget constraint (34), the capital law of motion (22) and a no-Ponzi condition of the form

$$\lim_{j \rightarrow \infty} \frac{E_t D_{t+j}}{(1+r^*)^j} \leq 0 \quad (36)$$

Letting λ_t denote the Lagrange multiplier associated with the sequential budget constraint, the first order conditions of the household's maximization problem are (34), (22), (36) holding with equality, and

$$\lambda_t = (C_t - \tau \Gamma_{t-1} h_t^\omega)^{-\sigma} \quad (37)$$

$$\tau \Gamma_{t-1} \omega h_t^{\omega-1} = p_t^{HC} W_t \quad (38)$$

$$\lambda_t p_t^{FC} q_t \Gamma_{t-1}^{-\sigma} = \beta \Gamma_t^{-\sigma} E_t \lambda_{t+1} p_{t+1}^{FC} \quad (39)$$

$$\begin{aligned} & p_t^{IC} \lambda_t \left[1 + \phi \left(\frac{K_{t+1}}{K_t} - \mu \right) \right] \Gamma_{t-1}^{-\sigma} \\ &= \beta \Gamma_t^{-\sigma} E_t \lambda_{t+1} \left[p_{t+1}^{HC} u_{t+1} + p_{t+1}^{IC} (1 - \delta) + p_{t+1}^{IC} \frac{\phi}{2} \left(\left(\frac{K_{t+2}}{K_{t+1}} \right)^2 - \mu^2 \right) \right] \end{aligned} \quad (40)$$

3.3.3 Government

The government in this economy simply sets taxes equal to an exogenous level of government expenditure in each period:

$$T_t = GOV_t \quad (41)$$

Finally, note that, in equilibrium, the trade balance-to-output ratio will be determined as follows:

$$TBY_t = \frac{Y_t - C_t - I_t - GOV_t}{Y_t} \quad (42)$$

3.3.4 Interest Rates and Country Risk

We close the model by providing a simple theory for R_t , the interest rate faced by emerging economies, following Neumeyer and Perri (2005) and Chang and Fernandez (2009). First, the price of the household's debt is assumed to be given by a debt-elastic interest rate function,

$$1/q_t = R_t + \psi \left[\exp\left(\frac{D_{t+1}}{\Gamma_t} - d\right) - 1 \right] \quad (43)$$

where R_t is the specific rate at which international investors are willing to lend to the small, open, and tropical economy. Formally, this interest rate is defined

as follows

$$R_t = S_t R_t^* \quad (44)$$

where R_t^* is the world interest rate for risky asset and S_t is the country specific spread over that rate, both of which will be assumed to be a stochastic processes to be defined next.

3.3.5 Driving Forces

There will be five sources of uncertainty in this economy. First, the transitory technology process is assumed to follow an AR(1) process in logs:

$$\log a_t = \rho_a \log a_{t-1} + \varepsilon_t^a \quad (45)$$

where $|\rho_a| < 1$, and ε_t^a is an i.i.d. shock with mean zero and variance σ_a^2 .

Second, Γ_t is a term allowing for labor augmenting productivity growth. Following Aguiar and Gopinath (2007), we allow it to grow at a stochastic growth rate, g_t . Formally,

$$\Gamma_t = g_t \Gamma_{t-1} \quad (46)$$

where

$$\ln(g_{t+1}/\mu) = \rho_g \ln(g_t/\mu) + \varepsilon_{t+1}^g \quad (47)$$

$|\rho_g| < 1$, ε_t^g is an i.i.d. process with mean zero and variance σ_g^2 , and μ represents the mean value of labor productivity growth. A positive realization of ε_t^g implies that the growth of labor productivity is temporarily above its long run mean.

Such a shock, however, is incorporated in Γ_t and, hence, results in a permanent productivity improvement.

Third, deviations of the world interest rate for risky asset, R_t^* , from its long-run level are assumed to follow an AR(1) process

$$\ln(R_t^*/R^*) = \rho_r \ln(R_{t-1}^*/R^*) + \varepsilon_t^r \quad (48)$$

where $|\rho_r| < 1$ and ε_t^r is an i.i.d. innovation with mean zero and variance σ_r^2 . Following Chang and Fernandez (2009) we allow for both permanent and transitory shocks to affect the country specific spread. To implement this idea, we assume that deviations of the country spread from its long-run level are a functions of deviations in the total factor productivity (Solow residual):

$$\log(S_t/S) = -\eta E_t \log(sol_{t+1}/sol) \quad (49)$$

where sol_t is the Solow residual, defined as $sol_t = a_t g_t^a$ and $sol = \mu^\alpha$.

Fourth, the terms of trade are assumed to evolve according to a simple AR(1) process in logs:

$$\log tot_t = \rho_{tot} \log tot_{t-1} + \varepsilon_t^{tot} \quad (50)$$

where $|\rho_{tot}| < 1$, and ε_t^{tot} is an i.i.d. shock with mean zero and variance σ_{tot}^2 . Importantly this specification differs from Mendoza (1995) in that we don't allow for domestic productivity and terms of trade to be correlated.

Finally, following Canova (2007), the government expenditure process is as-

sumed to be a function of its own past and lagged deviations in the level of output. Formally,

$$\ln(GOV_{t+1}/GOV) = \rho_{gov} \ln(GOV_t/GOV) + \rho_{GY} \ln(Y_t/Y) + \epsilon_{t+1}^{Gov} \quad (51)$$

where $|\rho_{gov}| < 1$, and ϵ_t^{gov} is an i.i.d. shock with mean zero and variance σ_{gov}^2 , and $\rho_{GY} \in \mathbb{R}$ is intended to capture the degree of procyclicality of public expenditure documented for developing economies.

3.3.6 Competitive Equilibrium

A competitive equilibrium path for this economy is a set of stationary processes along a balanced growth path for twelve allocations,

$$\{Y_t, K_t, D_t, C_t, C_t^H, C_t^F, I_t, I_t^H, I_t^F, h_t, TBY_t, T_t\}_{t=0}^{\infty}$$

and ten relative prices,

$$\{R_t, q_t, \lambda_t, W_t, u_t, p_t^{HC}, p_t^{HI}, p_t^{FC}, p_t^{FI}, p_t^{IC}\}_{t=0}^{\infty}$$

satisfying the three optimality conditions for firms, (18)-(19)-(20); the fifteen intratemporal and intertemporal optimality conditions for the household (22)-(25)-(26)-(27)-(28)-(32)-(30)-(31)-(33)-(34)-(35)-(37)-(38)-(39)-(40); the government balanced budget rule (41); the trade balance-to-output definition (42); the country specific interest rate and spread processes (43)-(44); given the initial

conditions for K_0 and D_0, Γ_{-1} and the stochastic processes $\{a_t, \Gamma_t, g_t, R_t^*, tot_t, GOV_t, sol_t\}_{t=0}^\infty$.

3.4 Estimation

We follow a Bayesian estimation strategy that has been increasingly used in the estimation of dynamic stochastic general equilibrium models¹⁸. The following sections briefly describe the estimation technique.

3.4.1 Bayesian Estimation Framework

We normalize the variables that trend in equilibrium by dividing them by the (lagged) trend level, Γ_{t-1} . Following Schmitt-Grohe and Uribe (2004), the stationary dynamic system of equations is log-linearized and written in the canonical state-space form:

$$\begin{aligned} x_{1,t+1} &= M(\Theta) x_{1t} + v_{t+1} \\ x_{2,t} &= C(\Theta) x_{1,t} \end{aligned} \tag{52}$$

where $\{x_1, x_2\}$ are, respectively, state and control variable vectors; v_{t+1} is a vector of structural perturbations; and the matrices $M(\Theta)$ and $C(\Theta)$ are a function of the vector of structural parameters, Θ . This system can be compactly written as a law of motion equation:

$$\Psi_{t+1} = \Phi(\Theta)\Psi_t + Bv_{t+1} \tag{53}$$

¹⁸See An and Schorfheide (2007) for an excellent survey of the theory and applications on DSGE models. For a textbook explanation see also DeJong and Dave (2007).

On the other hand, having observed a time series data on a vector X_t , it can be expressed as a non-invertible linear combination of the state variables in a measurement equation:

$$X_t = \Gamma \Psi_t + \epsilon_t \quad (54)$$

where Γ is a conformable matrix that maps the observable time series of the observable elements X_t to their theoretical counterparts in Ψ_t , while ϵ_t are exogenous i.i.d. measurement errors. Equations (53) and (54) are the starting point for a time invariant Kalman filter with which one can recursively construct the likelihood function over the T data points of X_t :

$$\mathcal{L}(X|\Theta) = \prod_{t=1}^T \mathcal{L}(X_t|\Theta) \quad (55)$$

From a Bayesian perspective, the observation of X is taken as given and inferences regarding Θ center on statements regarding probabilities associated with alternative specifications on Θ conditional on X . By satisfying the likelihood principle, the Bayesian approach uses all the information from the data to make the probability statements on Θ . Bayes Theorem is used to update our beliefs about Θ . Formally:

$$p(\Theta|X) \propto p(\Theta) \mathcal{L}(X|\Theta) \quad (56)$$

where $p(\Theta)$ is the prior distribution. The posterior distribution then allows

us to make probability statements regarding the unknown parameters in our model.

As mentioned in the Introduction, we use quarterly data from Colombia between 1994:1 to 2008:4 with four macroeconomic aggregates: gross domestic product (Y), consumption (C), investment (I), and the trade balance-to-GDP (TBY_t)¹⁹. While the first three are observed in log-differences, the latter is observed in first differences. Hence, the observation of X is:

$$X = \{\Delta \ln Y_t, \Delta \ln C_t, \Delta \ln I_t, \Delta TBY_t\}_{t=1994:1}^{2008:4} \quad (57)$$

and the system of measurement equations (54) is

$$\begin{aligned} \Delta \ln Y_t &= \ln \mu + (\hat{y}_t - \hat{y}_{t-1}) + \hat{g}_{t-1} + \epsilon_t^Y \\ \Delta \ln C_t &= \ln \mu + (\hat{c}_t - \hat{c}_{t-1}) + \hat{g}_{t-1} + \epsilon_t^C \\ \Delta \ln I_t &= \ln \mu + (\hat{i}_t - \hat{i}_{t-1}) + \hat{g}_{t-1} + \epsilon_t^I \\ \Delta TBY_t &= \widehat{tby}_t - \widehat{tby}_{t-1} + \epsilon_t^{TBY} \end{aligned} \quad (58)$$

where ϵ_t^N is distributed i.i.d. measurement error with mean zero and variance σ_N^2 , $N = Y, C, I, TBY$.

In order to report posterior statistics we need to be able to make random draws from the posterior distribution for which we will make use of advances in Monte Carlo Markov Chain (MCMC) theory to get dependent draws from the

¹⁹See Data Appendix for more details.

posterior distribution, $p(\Theta|X)$. We follow, for the most part, the Random Walk Metropolis algorithm presented in An and Schorfheide (2007) to generate draws from the posterior distribution $p(\Theta|X)$. The algorithm constructs a Gaussian approximation around the posterior mode, which we first find via a numerical optimization of $\ln \mathcal{L}(X|\Theta) + \ln p(\Theta)$, and use a scaled version of the inverse of the Hessian computed at the posterior mode to efficiently explore the posterior distribution in the neighborhood of the mode. It proved useful to repeat the maximization algorithm using random starting values for the parameters drawn from their prior support in order to gauge the possible presence of many modes in the posterior distribution²⁰. Once this step is completed, the algorithm is used to make 150,000 draws from the posterior distribution of each case. The initial 50,000 draws are burned.

Once $p(\Theta|X)$ is approximated, point estimates as well as confidence intervals of the parameters can be obtained from the generated draws, in addition to functions of these parameters. Given that one of our goals is to assess the relative role of each driving force, two functions we will be interested in are structural variance decompositions and impulse response functions.

3.4.2 Benchmark Calibration and Priors

We choose to calibrate some of the deep parameters in the model while we estimate the rest. The choice of which parameters to estimate or calibrate is guided by the objectives of our investigation which is the study of the sources of

²⁰The MATLAB codes that solve all the model's extensions as well as the ones that carry out the estimation are available upon request.

fluctuations. For that reason we mainly estimate the parameters of exogenous driving forces along with other key parameters in determining business cycles. Formally, let $\Theta = [\Theta_1, \Theta_2]'$, where Θ_1 is the vector of parameters that we calibrate:

$$\Theta_1 = [\sigma, \omega, \mu, \psi, \delta, d]' \quad (59)$$

The calibrated parameters are given in Table II.2 and take conventional values. The coefficient of relative risk aversion is set at 2, and ω is set so as to imply a labor supply elasticity of 1.6. The labor's share of income, α , is set to be 68%²¹. We calibrate the long-run productivity growth, μ , equal to 1.0077 following consistent with a mean yearly GDP growth rate of 3.1 percent in the dataset. As it is common in the literature on small open economy models, we set the parameter ψ , determining the interest rate elasticity to debt, to a minimum value that guarantees the equilibrium solution to be stationary (Schmitt-Grohe and Uribe, 2003). The quarterly depreciation rate is assumed to be 20 percent so as to get an investment to GDP ratio close to 0.3, as it is observed in Colombian data. We calibrate d , the debt-to-GDP ratio, to 0.23, the average of external debt as fraction of output in Colombia reported by Avella (2004). The steady state values of some of the variables in the model are also set according to long-run means in the data. We calibrate the government expenditure-to-GDP ratio to 0.19, and the annualized gross risky interest rate to 1.0816. We assume that there is no spread in the steady state, $S = 1$, and that τ is endogenously

²¹Note that in the models with financial frictions, α is not exactly equal to labor share in the Financial Frictions model but it is rather calibrated as $\alpha = LaborShare * [1 + (R - 1)\theta]$. Thus, it will have an entire distribution determined by the posterior distribution of θ .

determined so as to match a third of the time spent working in the long run, $h = 1/3$. Under this parameterization, the discount factor is pinned down in steady state to be $\beta = 0.9976$.

The vector Θ_2 gathers the other twenty two parameters we estimate:

$$\Theta_2 = \left[\begin{array}{c} \rho_a, \rho_g, \rho_r, \rho_{gov}, \rho_{tot}, \sigma_a, \sigma_g, \sigma_r, \sigma_{gov}, \sigma_{tot}, \\ \phi, \sigma_Y, \sigma_C, \sigma_I, \sigma_{TBY}, \theta, \gamma_C, \gamma_I, \eta, v_C, v_I, \rho_{GY} \end{array} \right]' \quad (60)$$

Our prior beliefs over the estimated parameters are described in Table II.3 and follow a rather agnostic approach as rather diffuse priors are assumed. All the priors over the AR(1) coefficients in the five stochastic processes are assumed to be distributed with a Beta distribution with mean 0.72 and a large standard deviation of 16 percent. The priors over the standard deviation of both the structural shocks and the data measurement errors are assumed to be distributed with a Gamma distribution with mean 2 percent and a standard deviation of 1 percent. The capital adjustment cost parameter is assumed to be distributed with a Beta distribution with mean 6 and a standard deviation of 346 percent.

Previous studies provide little statistical information on the size of the elasticity of the spread to the country's fundamentals, η , and the fraction of the wage bill held as working capital, θ . We use a Gamma prior with mean of 1.0 and a standard deviation of 50 percent for η , close to the value calibrated by Neumeyer and Perri (2005) to match the volatility of the interest rate faced by

Argentina's residents in international capital markets. As for θ , we decided to specify a very diffuse prior, with the only restriction that it must lie between zero and one. For this purpose we used a Beta function with mean 0.5, and a considerable standard deviation of 22.4 percent.

The weights of importables in the consumption and investment aggregator functions are assumed to be distributed with a Beta function with mean 0.2 and a 10 percent standard deviation. This is motivated by the fact that imports are between 15-25 percent of total GDP in Colombia. The elasticity of substitution in the aggregator of both functions is chosen to be a Gamma distribution with mean 1.0 and a large standard deviation of 50 percent. Finally, the parameter governing the degree of countercyclicality in government expenditure is chosen to be normally distributed with mean 0.0 and a standard deviation of 100 percent.

3.5 Results

This section presents the results of the paper. First the posterior distribution of the estimated parameters is reported, together with functions of these parameters, variance decompositions and impulse response functions. Second, the performance of the estimated model in matching some of the main stylized facts of the Colombian business cycle is assessed as well as its out-of-sample forecasting performance. Finally, a robustness analysis is conducted by using a much longer and yearly dataset spanning from 1925 to 2008.

3.5.1 Posterior distributions

Table II.4 reports the posterior distributions for the twenty two parameters estimated in Θ_2 . The table reports for each parameter both the posterior mode and mean together with the 90 percent confidence interval. In addition, a plot of prior and posterior distribution is also presented Figure II.1. Finally, impulse response functions and variance decompositions of the main macroeconomic aggregates are computed from the prior distributions and are presented, respectively, in Figure II.2 and Table II.5. A series of findings emerge from these results.

First, the data appears to be informative for most of the parameters as the posterior distributions significantly differ from the diffuse prior distributions, particularly for the parameters governing the standard deviations of the shocks, the degree of financial frictions, and the persistence of the shocks.

Second, the results clearly favor innovations in the transitory technology process and the interest rate faces in world markets as the most important driving forces of the Colombian business cycle. The forecast error variance decomposition results assign to technology shocks the 74 percent of the variance in output; 43 percent in consumption; 60 percent in investment; and 19 percent in the trade balance-to-GDP ratio. The share of the variability associated to interest rate shocks is most important for the trade balance-to-GDP ratio (76 percent); investment (37 percent); consumption (20 percent); and output (17 percent). From Figure II.2, the impulse response of output, measured as deviations from its steady state, following an estimated one standard deviation shock

to the transitory technology process peaks near 3 percent; while that associated to a positive interest rate shock makes output fall near 2 percent and its effects are more persistent through time.

Third, and perhaps surprisingly, the other three driving forces play a minor role in accounting for the Colombian business cycles. The estimated posterior mode ratio of the volatilities in the two technology processes is $\sigma_a/\sigma_g = 0.72/0.36 = 2.0$, which is clearly at odds with Aguiar and Gopinath (2007)'s finding for Mexico where they obtain a ratio $0.48/2.81 = 0.2$. Furthermore, using Aguiar and Gopinath (2007)'s measure for the random walk component of the Solow residual, a nonlinear function of the relevance of trend shocks relative to transitory shocks and defined as follows:

$$RWC = \frac{\alpha^2 \sigma_g^2 / (1 - \rho_g)^2}{\left[2 / (1 + \rho_z)^2 \right] \sigma_a^2 + \left[\alpha^2 \sigma_g^2 / (1 - \rho_g^2) \right]}$$

the mode of the RWC is found to be 0.77, close to two thirds the value estimated for Mexico in Aguiar and Gopinath (0.96). Consequently, the role played by growth shocks in accounting for the variance of the main macroeconomic aggregates is less than 7 percent, except for consumption (26 percent). Likewise, the share of government expenditure and terms of trade perturbations in accounting for the macro volatility is lower than 2 percent for any of the four time series, except for the share of terms of trade in accounting for consumption variability (11 percent). Finally, the impulse response functions for output after an estimated one standard deviation shock to any of these three struc-

tural shocks is either small and non persistent (0.2 following a growth shock) or non-statistically significant.

Fourth, while the posterior estimate for η was high, the one for θ was close to zero, implying that the degree of financial frictions is important but mainly through the effects that transitory technology shocks have on the spread. The role of this financial friction in propagating transitory technology shocks is of crucial importance. This is evident from the last row of impulse response functions presented in Figure II.2 where we plot the counterfactual case setting $\eta = 0$. It is immediate to see that more than half of the response in output and the other variables is reduced when we artificially set the elasticity of the spread to expected movements in the country fundamentals to zero.

Fifth, the size of the sum of the standard deviation in the measurement errors is rather small when compared to the size of the estimated structural shock's signaling that misspecification is not a serious problem and that the model successfully accounts for most part of the variability exhibited in the observables.

Sixth, the (little) information that appears to be in the data validates a small shares of importables in total consumption and investment and a low elasticity between home and foreign goods. Last, the data also shows evidence of a procyclical government expenditure.

3.5.2 Model Performance

The performance of the estimated model in matching some of the main stylized facts of the Colombian business cycle is assessed here by running two separate experiments. First, the model-based second moments of the main macroeconomic aggregates are computed and compared to those computed from the Colombian data. Second, a historical decomposition of the structural shocks is performed by using the smoothing properties of the Kalman filter and their accuracy in replicating the sharp business cycle observed in the late 1990s is assessed.

Selected Second Moments Table II.6 presents the unconditional second moments derived from the estimated model. The model-based moments were computed using the posterior modes for the estimated parameters. Thus, it should be noted that the comparison between the theoretical and sample second moments of the main four macroeconomic aggregates is clearly a stringent test on the model given that the estimation was not designed to match these moments in particular, unlike other methods like GMM. And it is clearly an even more stringent test for the comparison of the second moments in the main driving forces given that these were not even observed in the estimation.

The model achieves, nonetheless, a moderately good fit along most of the important dimensions highlighted in the second section. Indeed, the model successfully replicates the smooth consumption process, the volatile investment and the strong countercyclicality of the trade balance-to-GDP ratio, largely explained by investment variability. In terms of the driving forces, the model also

matches closely the leading and countercyclical properties exhibited by the real interest rate. As for the terms of trade, while the model partially replicates the procyclicality observed in this variable it misses in matching its large volatility. And the model fails completely by grossly overstating the procyclicality of the government expenditure.

Historical Decomposition The second experiment by which the performance of the estimated model is assessed starts by computing a historical decomposition of the structural shocks using the smoothing properties of the Kalman filter. Following DeJong and Dave (2007) we use the state space representation (53) together with the observable equation (54) to construct an estimate of the state vector of variables along with innovations to these variables using the information contained in the entire sample:

$$\{x_{1t|T}, v_{t|T}\}_{t=1994:1}^{T=2008:4}$$

where the latter can be thought of as a measure of the structural shocks. Next, we use a subset of these structural shocks to simulate the evolution of the main four Colombian macroeconomic aggregates. In particular we are interested in the accuracy of the model in replicating the sharp business cycle observed in the Colombian economy in the late 1990s where a sustained period of growth that started in 1994 was followed by a sharp reversal in 1998 and particularly in 1999.

The time series of the smoothed driving forces together with their innova-

tions are plotted in Figure II.3. It is immediate to see that a sharp volatility characterizes the years 1996 to 2000. Positive transitory technology shocks characterize the early years (1996-1997), while a reversal of this trend along with a sharp increase in the smoothed interest rate process characterized the following years (1998-1999).

The accuracy of the structural shocks in replicating the sharp Colombian business cycle in the late 1990s is assessed in Figure II.4. Only shocks to transitory technology and to the interest rate processes are considered. In order to gauge the relevance of financial frictions and interest rate shocks during this episode, the panels in the left column report the simulation using only transitory technology shocks and shutting down the degree of financial frictions, $\eta = \theta = 0$; while the panels to the right include interest rate shocks and set the value of η and θ equal to their posterior modes.

The results of this experiment are quite surprising. The simulation incorporating solely technology shocks and no financial frictions that propagate these shocks (left panels) misses virtually all the distinctive properties of the Colombian cycle in this period. While the simulation produces only a very moderate fall in GDP, it does not exhibit any fall in consumption nor investment and even counterfactually produces a fall in the trade balance-to-GDP ratio. On the contrary, the simulation that includes both interest rate shocks and financial frictions remarkably matches the evolution of the Colombian macroeconomic time series. In particular, the sharp reversal in the trade balance and the downfall in investment are properly recovered. This corroborates what was mentioned

above regarding (i) the relevance of interest rate shocks in accounting for the Colombian business cycle; and (ii) the central role played by financial frictions as propagating mechanism of other real driving forces (i.e. transitory technology shocks).

3.5.3 Bayesian Model Comparison and Forecasting Performance

When conducting Bayesian estimation of DSGE models, researchers often are interested in the out of sample forecasting performance of the model (see An and Schorfheide, 2007). This is done by computing the marginal likelihood which is done next. Rewriting (56) exactly, the Bayes Theorem implies that posterior beliefs about Θ , must respect:

$$p(\Theta|X) = \frac{\mathcal{L}(X|\Theta)p(\Theta)}{p(X)}$$

where $p(X)$ is the model's marginal likelihood, defined as:

$$p(X) = \int \mathcal{L}(X|\Theta)p(\Theta)d\Theta$$

Following An and Schorfheide (2007) the log-marginal likelihood can be rewritten as

$$\begin{aligned} \ln p(X) &= \sum_{t=1}^T \ln p(x_t|X^{t-1}) \\ &= \sum_{t=1}^T \ln \left[\int p(x_t|X^{t-1}, \Theta) p(\Theta|X^{t-1}) d\Theta \right] \end{aligned}$$

thereby implying that marginal data densities capture the relative one-step-ahead predictive performance of the model.

The upper panel in Table II.7 reports the log-marginal likelihood for the estimated model along with the likelihood and posterior values evaluated at the posterior mode. In order to gauge the forecasting performance of the various structural shocks, we conducted two separate experiments. First, we estimated the model adding only two structural shocks, one of which was always transitory technology shocks, yielding four possible combinations. Second, we estimated the model removing only one shock at a time, with the exception of transitory technology shocks, again yielding four possible combinations. The results in terms of likelihood, posterior and marginal likelihood for the first and second experiments are reported in the middle and lower panels of Table II.7. While the full model does better than most of the restricted models, interestingly, the out-of-sample performance of government shocks appears to be relevant. In that sense, while government expenditure shocks do not appear to contribute much to the in-sample fit of the model, they appear to be relevant for the out-of-sample fit of it.

3.5.4 A Longer Dataset, Colombia 1925-2008.

Garcia-Cicco et.al. (2007) have recently argued that a more accurate estimation of the relative weights of the growth component in developing countries' business cycles should be done using dataset that span over many years. Following this work, we estimate the model on a yearly dataset covering the period 1925-2008.

The upper panel of Table II.8 summarizes the main aspects of this dataset using the same second moments used for the quarterly dataset. While some of the stylized facts remain valid, particularly the strongly countercyclicality of the a trade balance share of income, two noticeable characteristics emerge. First, there is a sharp increase in the volatility of virtually all variables, particularly in investment, the terms of trade and government expenditure. Second, consumption exhibits now a higher volatility than output²².

We estimate the model using this longer dataset and run a similar analysis as before. Table II.9 reports posterior modes and compares them with the estimates using the shorter dataset; and Table II.10 presents the results of the variance decomposition. Several results stand out. First, the role of growth shocks becomes significantly more relevant now. The ratio σ_a/σ_g falls from 2.0 to 0.2 and the random walk component increases from 0.77 to 4.19. As a consequence of this almost half (46 percent) of output's variance is explained by growth shocks, although the share of these shocks in the variance of the other main aggregates is not higher than 19 percent. Second, the role of terms of trade shocks is now much more important, particularly when accounting for the variance of investment (48 percent) and the trade balance share (64 percent). Third, interest rate shocks continue to be relevant, notably in explaining the variance of consumption (81 percent) and their share in output variance remains close to the levels estimated in the quarterly sample (17 percent). Fourth, the

²²Importantly, due to data availability, in these dataset it was impossible to exclude durable (and semi-durable) goods consumption from aggregate consumption and include it on investment as was done before.

model successfully accounts for the new stylized facts as can be seen from the lower panel in Table II.8. In particular, the higher volatility of investment and government expenditure are matched together with the relative higher standard deviation of consumption. The model, nonetheless does not generate a countercyclical trade balance share.

3.6 Concluding Remarks

There exists a consensus regarding the differences in the business cycle patterns in developing and developed economies. Where a consensus does not seem to be emerging is on the key driving forces that can account for these differences. While some studies argue that a standard RBC-type model, driven only by transitory and/or permanent shocks to the technology process, is enough to properly model business cycles in developing economies, others present conflicting evidence based on dataset covering longer periods or stress the role of other real driving forces.

We contribute to this debate by exploring the business cycle properties of Colombia, a developing -and "tropical"- economy. Our approach is more ambitious in the sense that not only we test for role of technology shocks but we also incorporate other potential real impulses. Motivated by the observation that, to date, there has been little empirical analysis of the role played by individual shocks, within a multiple-shock setting, in driving business-cycle movements in aggregate variables from developing countries, we build a DSGE model including a menu of real driving forces in addition to technology shocks including shocks to

the interest rate in world capital markets coupled with financial frictions; terms of trade fluctuations; and a procyclical government spending process. The role of each driving force is empirically quantified by estimating the parameters of the exogenous shocks processes, along with a few other crucial parameters, within a Bayesian framework, using Colombian macroeconomic data.

We find interest rate shocks to be crucial in accounting for the Colombian business cycle while financial frictions play a central role as propagating mechanism for other real driving forces, in particular transitory technology shocks. These two driving forces alone can account well for the observed properties of the Colombian business cycle such as the smooth consumption process, the volatile investment and the strong countercyclicality of the trade balance-to-GDP ratio. They both are entirely responsible for the sharp economic downturn experienced in the late 1990s. Other structural shocks such as terms of trade fluctuations and level shifts in the technology process do not appear to be relevant in the past decade and a half, but their importance increases when a longer span of data is considered. Demand shocks, in the form of government consumption innovations account only for a trivial role of the variance of the macroeconomic aggregates but they appear to be relevant for the out-of-sample forecasting fit of the model.

We are thus skeptic as to whether business cycles in developing economies can be modeled with a standard RBC model augmented *solely* by technology shocks and hope that our findings help stimulate more research into more elaborated models of the business cycles observed in developing economies.

4 CAPITAL FLOWS AND BUSINESS CYCLES IN LATIN AMERICA IN THE 1920s-30s. A SECOND LOOK FROM A NEOCLASSICAL PERSPECTIVE

4.1 Introduction

A well-recognized stylized fact about emerging markets in general, and Latin American economies in particular, is the large macroeconomic volatility they exhibit. A recent study by Aguiar and Gopinath (2007) using macroeconomic data between 1980 and 2003, has shown that emerging markets exhibit, on average, a business cycle twice as volatile as that of their developed counterpart. And the number goes above two if one considers only the Latin American economies in their sample. A second striking feature in the emerging markets' business cycles is the strong countercyclicality of the trade balance relative to the one in developed markets. Furthermore, when looking at these regularities from a long-run perspective, other studies have not found any change in the pattern of large macroeconomic volatility. In their study of the Argentinean business cycle over the period 1900-2005, Garcia-Cicco, et.al. (2007) find no signs of moderation in the business cycle volatility in contrast to the remarkable "great moderation" experienced by developed countries. Similar conclusions are obtained by Fernandez (2008) studying the Colombian economy over the period 1925-2006.

Researchers trying to account for these empirical regularities in emerging markets within a dynamic general equilibrium framework have centered their focus on the predominance of at least four types of shocks intrinsic to these economies. First, Mendoza (1995) expands a real business cycle model to account for tradable/non-tradable goods and claims that stochastic shocks to the terms of trade process can account for 45 to 60 percent of the observed variability of GDP. Second, motivated by the frequent policy regime switches observed in emerging markets, Aguiar and Gopinath (2007) claim that these economies are subject to substantial shocks to the trend in the productivity process. Third, motivated by the literature on procyclical policies in Latin America (Agenor et.al (2000), Talvi and Vegh (2005) and Kaminsky et.al (2004)), Fernandez (2009) explores the role of fiscal shocks in amplifying the cycle. Fourth, and more importantly for this work, the argument of stronger real shocks has been extended to financial markets. The idea is that developing economies exhibit low levels of aggregate savings forcing them to rely heavily on foreign investment, via capital flows. Uribe and Yue (2006) explore the significant correlation between the business cycles in emerging markets and the interest rate that these countries face in international financial markets. They find that one third of business cycles in emerging economies are explained by disturbances in external financial variables (e.g. the foreign interest rate and the spread). Moreover, they find evidence of a further increase in the volatility of domestic variables because of the presence of feedback from domestic variables to country spreads. Similarly, Neumayer and Perri (2005) find that eliminating country risk lowers Argentine

output volatility by 27%. And Chang and Fernandez (2010) find evidence that models with interest rates shocks coupled with financial frictions match the macroeconomic data from emerging markets better than models stressing other types of real shocks.

A casual look at the business cycle data in five Latin American countries over the period 1910-2001 would seem to validate the fourth explanation emphasizing the role of capital inflows, at least for the episodes of higher business cycle volatility. In Figure III.1 I plot the average business cycle assuming a three years-expansion followed by a three years-contraction. The black line plots the average cycle over the entire period showing that at the peak/trough of the cycle, income deviates 2,5%/-3,3% above/bellow its long-run trend²³. The other lines depict the Latin American business cycle during the three episodes associated with large capital inflows and outflows to the region throughout the twentieth century: (i) the late 1920's and the years of the Great Depression; (ii) The late 1970s/early 1980s; and (iii) the late 1990s. Three features deserve attention. First, the three episodes are characterized by sharper deviations from the trend relative to the entire period's average; second, the contraction is preceded by a large and sustained boom; and, third, the 20's-30s episode stands out for its magnitude in both the large boom and the steep recession.

The idea of foreign financial shocks affecting the Latin American business cycle has been present in the literature well before it received theoretical atten-

²³This is obviously an ad-hoc measure of the business cycle. However, the main results appear to be robust to other filtering methods (log-linear trend); to the size of the year-window (+/-2 ; +/- 4 years); and to larger sample of countries (including Peru, Uruguay and Venezuela).

tion within a dynamic general equilibrium framework. Diaz-Alejandro (1983) highlights the similarities between the 1930s and 1970s episodes and underscores the role of financial shocks in the center affecting the periphery. In her extensive analysis of capital flows to Latin America during the twentieth century, Stallings (1987) concludes that because capital flows to Latin America appeared to be induced by external factors, most notably low US growth, and because they lead current account deficits in the region, they must have caused them. Furthermore, Calvo et.al (1993) stressed the role of external factors as the main driving force behind in the large capital inflows and accelerating growth in many Latin American countries during the early 1990s. They identify economic developments outside the region, most notably a fall in US interest rates, as the main cause that encouraged investors to reallocate resources to the Latin American region. More evidence on the transmission mechanism from foreign interest rates to domestic macroeconomic volatility is given by Gourinchas et.al. (2001) who find evidence that capital inflows triggered by external factors such as low levels of international real interest rates, spike during lending booms in Latin America. The authors stress the role of the banking system as it intermediates the funds by increasing credit to the private sector, raising both consumption and investment. More recently, further evidence favoring the importance of the interest rate channel in the transmission of US shocks to Latin America is given by Canova (2005) where US monetary disturbances are found to account for an important portion of the variability of Latin American macrovariables.

Despite the extensive literature on the role of capital flows and foreign in-

terest rates as external driving forces of the Latin American business cycle, most of the analysis has been devoted to the latest episodes in the 1970s and 1990s. And, in the cases where the 1920s episode has been studied in detail, the analysis has been mostly done using a historical emphasis without much use of a theoretical model to rationalize the trends in the data and with a particular emphasis on the recovery part of the cycle²⁴. Yet, as shown in Figure III.1, the capital inflows, and later outflows, experienced during this early episode appear to have had the strongest consequences over the business cycle in the region when compared to the other more recent episodes. And this impact seems to have been as strong in the peak as in the trough suggesting that the its analysis should not focus only on the recovery phase of the early 1930 but also on the dynamics observed in the 1920s. Therefore, this episode seems to offer an ideal “historical laboratory” to study the transmission mechanism by which external shocks turn into large capital inflows with real effects that later reverse when the opposite shocks occur. Moreover, this episode presents additional interesting policy elements as casual evidence has been used to show the efficacy of the countercyclical monetary policy undertaken in the recovery phase (Diaz-Alejandro, 1983).

This work tries to fill this gap by using a framework that combines a historical account of the 1920s-1930s Latin American episode with a formal theoretical macroeconomic model aimed at explaining the dynamics observed in the data.

²⁴Rigorous studies done by scholars of this period in Latin America, for example Thorp (1984), Della Paolera and Taylor (1999), or Diaz-Alejandro (1983) have a marked emphasis on the recovery phase of the cycle during the 1930s, and less attention is devoted to the expansionary phase of the 1920s.

The historical account describes the capital flows and tries to highlight the main channels through which these affected the real economy. On the theoretical ground, I construct a dynamic stochastic general equilibrium (DSGE) model of a small open economy aimed at capturing the dynamics induced by exogenous movements in the foreign financial markets. I also expand the model to account for monetary policy. As an application of the model, I run an experiment in which I assess the qualitative properties of the model by summarizing the impulse response functions of the model. On the quantitative part, I measure the extent with which the model-based dynamics, generated using the observed external and monetary policy shocks, match the dynamics observed in the macro aggregates. The historical analysis covers the largest Latin American economies at the time, but special attention is given to Colombia as this seems to be the country where the effects of capital flows were more severe and simultaneously the export sector was less affected. Thus, the assessment of the theoretical model uses Colombian time series as benchmark.

The main findings show that the model does well in matching the expansionary/contractionary phases in output dynamics, in accordance with the main stylized facts observed in the business cycles in Latin American countries between 1925 and 1931. Two key transmission channels in the model through which capital inflows/outflows turn into economic booms/busts are interest rates and the banking system. Evidence of the role played by these two elements is presented in the historical account of the period. Furthermore, the active role of countercyclical monetary policy in the years that followed the great rever-

sal of capital flows appears to have had real effects that are validated by the theoretical model. However, not all the recovery appears to have been driven by countercyclical policy, a result that is taken as indirect evidence of the role played by relative prices in the import substitution process that accompanied the strong recovery.

The paper is divided into six sections, including this introduction. The second section presents a brief historical account of Latin America economies, Colombia in particular, during the 1920s and 1930s with an emphasis in the role of capital flows. The third section lays out the DSGE model and its empirical performance is given in the fourth section. The role of countercyclical monetary policy is studied in the fifth section. Concluding remarks are given in the last section.

4.2 A Brief Historical Account

4.2.1 Capital Flows to Latin America in the 1920s-30s

In a thorough review of foreign capital in Latin America in the nineteenth and twentieth centuries, Taylor (2006) remarks that the region is certainly one whose economic fortunes have been most significantly shaped by external forces. The period ranging from 1920s-1930s clearly seems to be one of the best examples of this claim, because of the way external capital markets played a major role as engine of growth when capitals flew in and as a powerful destabilizing source when they flew out.

Before the World War I, portfolio and direct investments flowed to Latin

America, mainly from Europe while U.S. investments were small and concentrated in the Caribbean and Central American regions (Diaz-Alejandro (1983)). But, after a period of considerable financial distress in the region during the war years²⁵, the situation reversed. While the world capital market was gradually shifting from London to New York after the end of World War I, a sharp shift toward more favorable conditions for US investments in Latin America occurred and they soared throughout the region. An improvement for Latin American borrowers was possible as the financial distress period came to an end. For example, Taylor (2006) notes, that this period was marked by the fact that no Latin American government was formally in default. To get a sense of the international investors' perceptions on financial conditions within the Latin American countries, Figure III.2 plots the available data on government bond yields for five of these countries between 1919 and 1940. At least three comments deserve attention from this plot. First, a downward trend in government bond yields throughout the 1920s is observed in all the series signaling an increased confidence in foreign investors. This trend was nonetheless not uniformly synchronized across all the countries. It occurred early in the decade for some countries (e.g. Chile), late for others (e.g. Argentina and Uruguay), and steadily for the rest (e.g. Brazil). Second, there seems to be a positive co-movement between the government bond yields and the process for expected TBills yields in real terms. In fact, the correlation coefficient between an average of the regional bond yields and the US TBill rate is 0,5 and statistically

²⁵In the years after World War I, Brazil defaulted in its sovereign debt, as did Uruguay and Mexico (see Taylor (2006)).

significant. Third, there was a significant increase in all the bond yields in the early 1930s following the Wall Street crash in late 1929 and as the TBills rate peaked in the onset of the Great Depression. And, with the exception of Uruguay, the levels of government bond yields would remain at higher levels for the remainder of the period.

Other internal conditions favored the impression perceived by investors on the Latin American region. Among them, the most important were the structural reforms undertaken by many Latin American countries in the early 1920s. The reforms addressed a range of institutional topics from fiscal policy to the banking sectors and, most importantly, the foundation of central banks that would bring stability to the regional money and exchange rates markets. Just over the period between 1922 and 1929, nine central banks were created in the Latin American regions²⁶. A central person in this process was E.W. Kemmerer, a Princeton professor who served as foreign economic adviser to many of the American missions that would provide technical assistance to the Latin American governments. To that respect most economic historians that have documented the work of Kemmerer in Latin America (see Rosemberg (1985) and Drake (1989)) agree that these reforms were aimed at ensuring a proper functioning of the gold standard that would serve as the “good house-keeping-seal of approval” (Bordo and Rockoff (1996)) required in order to gain further access to U.S. financial markets and ensure a constant flow of capitals to the

²⁶These were: Peru (1922); Colombia (1923); Nicaragua (1924); Uruguay (1924); Mexico (1925); Chile (1926); Guatemala (1926); Ecuador (1927) and Bolivia (1929). Source: Meisel (1991).

region.

The combination of both external and internal factors allowed a period of unprecedented expansion of public borrowing in the New York bond market by Latin American countries and of US direct and indirect investment into the region. Using data from Avella (2007), Table 2.1 describes the boom in capital inflows of the 1920s by focusing on the Latin American share of the total new foreign bonds issues in US markets; and the distribution of the gross supply of US private funds to this region. The table is divided into four distinct periods observed between 1920 and 1935 for these two measures of capital inflows. After an initial boost in the early 1920s there was a pause in the pace of capital inflows during 1924-25. The most important period, the one that would accumulate almost 2/3 of the total inflow during the 1920s, would certainly be the years between 1926 and 1928. During this period the two measures peaked: the stock of Latin American foreign bonds issued in US markets doubled, and so did the flow of private funds into the region. In addition, it is important to point out that, while Argentina remained the first recipient of private funds throughout the 1920s, the distinctive surge in capital inflows during 1926-1928, was mainly due to the increase in the flow to other Latin American countries, most notably Brazil, Colombia, Chile and Peru. As emphasized by Avella (2007), the relevance gained by Latin America in terms of US investments was unprecedented at that time and would not be seen again until the 1970s. Finally a fourth period stands out for the years 1929-1935 with a sharp reversal of foreign bonds

issues where Latin America took a large part of the blow²⁷.

The period of capital outflows that started in the late 1920s in Latin America would set the stage to financial turmoil in the region. While much of the external debt was long-term denominated, the amortizations became harder to be honored as the drying up in foreign capital markets made rollover operations very difficult. In addition, as the world economy was entering into the Great Depression the regional terms of trade fell sharply, aggravating the availability of resources to honor the debt agreements. The situation became unsustainable by the end of 1931 when most Latin American countries suspended normal payments on their external debts and asked foreign creditors for conversations aimed at rescheduling and restructuring those debts (Diaz-Alejandro, 1983). These renegotiations were complex and in most cases took more than a decade to settle and would mark the beginning of a long period where capital flows never returned to the region until the late 1970s.

Despite the large macroeconomic consequences of the sharp reversal in capital flows, there seems to be a consensus about a rapid recovery from the economic downturn driven by a strong industrialization process (Thorp, 1984), and to the active role of countercyclical monetary policy (Diaz-Alejandro, 1983). The former had its origin in the permanent negative shock experienced by the regional terms of trade which encouraged a reallocation of resources to the incipient import-competing industrial sector. The latter has been pointed as the key determinant in boosting internal demand in the wake of deflationary pressures and

²⁷According to Taylor (2006), during this period no other region in the world saw quite dramatic a retreat of foreign capital from such high levels.

allowing a faster and less painful relative price adjustment. The abandonment of the gold standard in the early 1930s by some Latin American countries allowed them to pursue expansionary monetary policies and to devalue their exchange rate accelerating the adjustment towards the new equilibrium of relative prices.

This section has briefly highlighted some of the main stylized facts of the capital inflows and outflows to the Latin American region without emphasizing too much in the mechanisms linking the business cycles to the capital flows fluctuations. The next sections will tackle this issue by taking a closer look at Colombia. This will set the stage for the theoretical model to be laid out in the third section.

4.2.2 Colombia

In the first half of the decade, Colombia undertook a series of financial and fiscal reforms in order to guarantee the operation of the exchange rate regime under the Gold Standard. In the second half of the decade, it received a sizeable capital inflow and recorded an accelerating economic growth. The situation changed completely by the end of 1928 with a sharp reversal of the capital flows and a strong, albeit short, recession. By taking a closer look at the Colombian experience, this section will try to pin down the transmission mechanism from capital flows to the business cycle. It will be the working hypothesis that the interest rate and the banking system are the key channels to understand the mechanics by which capital inflows/outflows turn in economic booms/busts.

Following the advice given by a team of foreign experts led by E. W. Kem-

merer in 1922, one year later, the Banco de la Republica, Colombia's central bank, was established. Monetary orthodoxy under the rules of the Gold Standard characterized the operation of the newly established institution. Sixty percent of the Bank's bills in circulation were backed by gold, one of the highest levels across central banks at the time, and rigorous sanctions were established in the event that the reserves fell below this level. To that respect, in its early years, the Banco de la República's role was limited to maintaining convertibility (Sanchez et.al. (2007)).

The success of the Banco de la Republica in stabilizing the exchange rate around the gold points, following the Gold Standard rules, in combination with the other fiscal and banking reforms undertaken by the Pedro Nel Ospina Administration (1922-1926), boosted international investor's confidence in Colombia and paved the road to a full access to foreign capitals. A part of this access can be quantified by Colombian bonds traded in the New York Stock Exchange given that the vast majority of Colombian foreign debt, 92%, was issued in the American market (Avella, 2007). While consolidated data on Colombian government bond yields is only available from 1934 (see Fig. III.2), the first two columns in Table III.2 collect the scarce data on the price of Colombian bonds in New York. The first column, taken from Patino (1981) shows the evolution of the 7% bonds from 1927, while the second, taken from the Commercial and Financial Chronicle, presents the data for the 6,5% Bonds and covers a wider period starting in 1923. It is immediate to see an inverted-V shape with the price of the bonds peaking between 1926 and 1928 and then sharply falling

onwards.

Due to the lack of official balance of payments data, it is impossible to get an exact measure of the relative importance of the transfer of foreign wealth to Colombia. Yet, economic historians have come up with approximations and some of their estimates are presented in the rest of Table III.2. According to Meisel (1991) the net capital inflows increased steadily as the share of total foreign income during the booming years, from 1923 to 1928. A notable exception was the large share recorded in 1923, explained by the first and largest payment from the US indemnity for the independence of Panama. According to Meisel (1991), the net capital inflows to Colombia increased their share of total foreign income from 7% in 1925 to 28,6% in 1928. And even bigger estimates have been suggested by others. For example, Ocampo (1984) finds that the total transfer of resources via capital account surpluses between 1925 and 1929 came close to 35% of the total exports income. This is remarkable, especially given that during this period export income was also rising as a result of increasing Colombian terms of trade. The last two columns in Table III.2 use the data from Urrutia and Fernandez (2003) where the net capital inflows are quantified by two sources and find the same trend. The share of capital inflows with respect to GDP arrived to 3-4,1% during the years 1927 and 1928.

A clearer picture of the capital inflows process in Colombia can be seen from the data on the Colombian external debt compiled by Avella (2004) and plotted in Figure III.3, as percentage of GDP. It is immediate to see the remarkable growth of Colombian external debt over the second half of the 1920s, from a low

4% in 1924 to close to 35% in 1931. In addition, Figure III.3 brings new and relevant evidence from the large role played by the banking system. While the public debt had the largest share of the total external debt stock throughout the period analyzed, this share would decline because of the increasing relevance of external funds channeled to the banking system. This would be especially important during the period 1924-1930 when the banking system's access to foreign funds evolved from being virtually non-existent to have an external debt stock of US\$ 9M. in 1930, roughly one third of the Colombian external debt at the time. According to the history of the Colombian financial system by Caballero and Urrutia (2006), the increased availability of funds by the banking system fueled a period of unprecedented growth in this sector. As a raw measure of financial development, Table III.3 presents the evolution of the total loans by the financial system to GDP between 1924 and 1936 in Colombia. From a record low 1% in 1924 the loans-to-GDP measure peaks at around 10% in 1930.

The real effects of this spectacular growth in the financial system will be the main driving force in the transmission mechanism from capital flows to the business cycle. On one hand, its increased access to external funds allowed the private banks to extend the credit lines for imports to its customers (Caballero and Urrutia, 2006). Some of the effects of this can be appreciated by the significant increase in the imports of machinery during this period (see Table III.3). On the other hand, the increased availability of funds put downward pressure in domestic interest rates. Data collected on commercial mortgage annual interest rates by Patino (1981) and presented in Table III.3 give evidence of this

trend. It should be noted that the considerable reduction of the interest rate occurred despite the increased demand for real estate property, giving a sense of the strong positive supply shock in the banking sector.

An illustrative case of this transmission mechanism can be found in the mortgage banking industry. An explicit goal of the financial reforms of the early 1920s was to promote the mortgage sector. And the leading bank in the industry would be the Banco Agrícola Hipotecario (BAH), a public mortgage bank created in 1925 with the objective of supplying funds to the agriculture and construction sectors. The novelty of the BAH was that, from its early beginnings, it was thought as a channel for external funds as it was meant to finance its entire operation through foreign borrowing. This strategy would be followed successfully by the other mortgage banks to the point that, by 1929, the mortgage sector loans accounted for 45% of the total amount of loans in the financial system. And, most importantly, this brought a significant reduction in the interest rates. No systematic data on the interest rates charged by the BAH are available, but Patino (1981) documents how this bank, lowered its interest rates on agricultural loans from 18-36% to 9% after it managed to access the US bond market during the two years after it started operation.

The role of external factors in the increase of Colombian debt should not be forgotten. Indeed, it should be kept in mind that an important share of this capital inflow was explained by external driving forces in the world capital markets and were not intrinsic to the Colombian domestic dynamics. Avella (2007), for example, documents the way representatives of the American in-

vestment banking firms in charge of issuing and trading Colombian bonds in the international markets could often be found “in pursuit” of more clients and encouraging Colombian agents to increase their debt leverage.

The increase in the availability of funds provided by the financial system as well as the lower interest rates on the loans were the main channels through which the large capital inflows to Colombia turned the period 1925-1928 into a booming economic period. Table III.3 presents a series of aggregated and disaggregated economic indicators that illustrate this economic cycle. The first national accounts data available since 1925 exhibit a record high growth of 8,6% per year between 1926-1928, with two consecutive years (1926-27) of growth over 9%, an event that would never be recorded again in the Colombian macroeconomic statistics of the twentieth century. The other macroeconomic indicators reveal that aggregate consumption and investment also experienced important growth. In addition, the economic boom was characterized by a countercyclical trade balance and a real appreciation of the exchange rate. The sector indices reveal that most of the economic growth was concentrated in the agriculture and construction sectors. Which comes at no surprise given that, as described above, these were the sectors that received most of the increase in loans. Other economic indicators presented in the lower panel of Table III.3 reveal the widespread boom in the Colombian economy, among which the increase in the economic activities in the construction sector, as measured by new mortgages issues or new squared meters built, show a particularly active role. It is this type of increased economic activity in non-tradable sectors that explains

the large real exchange rate appreciation experienced in the booming phase of the cycle.

Both internal and external reasons determined the sharp reversal of capital flows to Colombia. On the external side, initially, the Wall Street rally in 1928 generated enough incentives for foreign investors to start re-allocating some of their resources back to American markets (Avella, 2007). In addition, there was a widespread belief among investors about the dangerously high levels of debt in the Latin American region. Figure III.2 reveals a break in the downward trend of the government yields in three out of the four Latin American countries with available data, from the second half of 1928. Around this time, in Colombia, Patino (1981) and Meisel (1991) document how the US government warned American investors about the excessive external debt levels in Colombia. Later, with the onset of the Great Depression, the US supply of private funds to Latin America drop extraordinarily. Table III.1 presents evidence that Colombia was one of the most affected countries where foreign capitals virtually evaporated.

The major effect of the world crisis on Colombia was the sharp reversal of the capital account (see Table III.2) yet the export sector was not severely affected, unlike other Latin American countries. Indeed, the evidence presented by Ocampo (1984) demonstrates that the expansion of coffee and gold exports during the 1930s was more than sufficient to counteract the decrease in other exports. In addition, the expansion of the aggregate export quantum counterbalanced the deterioration of the terms of trade, resulting in a relatively mild reduction in the export purchasing power. On the other hand, the domestic

effects were severe and most of them were, once more, transmitted through the banking sector via two channels. First, the inability to access external funds forced the banks to cut loans for import related activities. Evidence of this is presented in Table III.3 by a large drop in machinery imports and by the extraordinary surplus in the trade balance during the crisis years. Second, under the Gold Standard rules the Colombian central bank reacted in defense of the gold parity by increasing its discount rate (Sanchez, et.al., 2007). From the data on mortgage interest rates (Table III.3), it is immediate to see this contractionary policy significantly increased domestic interest rates levels between 1929 and 1931.

The real effects of these events were severe. On an aggregate level, GDP levels decreased consecutively during the year 1930 and 1931, by -0.9% and -1,6% respectively, with investment reducing even by half. Another important fact was that the contraction was mostly confined to the nontradable sectors as the economic indicators in Table III.3 reveal. Another consequence of the crisis was a widespread insolvency in the financial system as banks confronted a situation in which collateral prices fell; many debtors declared bankruptcy; and no new fresh sources of funds were readily available. This forced the government to intervene by doing a large and expensive domestic bank bail-out that prevented a systemic internal crisis while most of the external debt was repudiated (Caballero and Urrutia, 2006).

In summary, this narrative account has taken a closer look at Colombia during the 1920s and early 1930s in order to highlight the crucial role played by

capital flows in explaining the macroeconomic fluctuations. Importantly, casual evidence was given in favor of the interest rate and the banking system as being the key channels to understand the mechanics by which capital inflows/outflows turn into economic booms/busts. In the next section we build a theoretical model that rationalizes this transmission mechanism and its performance is modeled by comparing it to the dynamics observed in the Colombian data. Lastly, the reader should have noticed that little attention has been given to the role of countercyclical policy, especially in the contraction phase of the cycle. This issue will be addressed in later sections.

4.3 Model

The model follows closely Uribe and Yue (2006). Consider a small open economy populated by a continuum of identical households indexed by i , where $i \in [0, 1]$. A representative household i has preferences described by the following utility function

$$E_0 \sum_{t=0}^{\infty} \beta^t U(c_t^i, h_t^i) \quad (61)$$

where c_t^i and h_t^i denote consumption and the fraction of time devoted to work by the representative household i in period t ; U is the single-period utility index assumed to be increasing in its first argument decreasing in its second argument, concave and smooth. The parameter $\beta \in (0, 1)$ denotes the subjective discount factor.

Households have access to two types of assets, physical capital and an internationally traded bond. The capital stock is assumed to be owned entirely

by domestic residents. Households have three sources of income: wages, capital rents, and interests on financial asset holdings. Each period, households allocate their wealth to purchase consumption and investment goods and financial assets. The household's period-by-period budget constraint is given by

$$d_t^i = R_{t-1}^d d_{t-1}^i + c_t^i + i_t^i + \Phi(k_{t+1}^i, k_t^i) - w_t h_t^i - u_t k_t^i \quad (62)$$

where d_t^i denotes the household i 's debt position in period t , R_t^d denotes the gross interest rate faced by domestic residents in financial markets, w_t denotes the wage rate, u_t denotes the rental rate of capital, k_t^i denotes the household's stock of physical capital, and i_t^i denotes the gross domestic investment. The function $\Phi(\cdot)$ is used to induce adjustment costs to the process of capital accumulation and it is assumed to satisfy $\Phi(0) = \Phi'(\cdot) = 0$. This is used in order to avoid excessive investment volatility.

The stock of capital evolves according to

$$k_{t+1}^i = (1 - \delta)k_t^i + i_t^i \quad (63)$$

where $\delta \in (0, 1)$ denotes the rate of depreciation of physical capital.

Household i chooses contingent plans $\{c_t^i, h_t^i, i_t^i, k_{t+1}^i, d_t^i\}_{t=0}^{\infty}$ so as to maximize his utility function (61) subject to the budget constraint (62), the law of

motion for capital (63), and a no-Ponzi borrowing constraint of the form

$$\lim_{j \rightarrow \infty} E_t \frac{d_{t+j+1}^i}{j \prod_{s=0}^j R_{t+s}^d} \leq 0 \quad (64)$$

taking as given the processes for $\{R_t^d, w_t, u_t\}_{t=0}^\infty$.

Letting λ_t denote the Lagrange multiplier on the expanded budget constraint, the first order conditions for household i 's maximization problem are (62), (63) and the set of standard first order conditions given by

$$U_1(c_t^i, h_t^i) = \lambda_t \quad (65)$$

$$-U_2(c_t^i, h_t^i) = \lambda_t w_t \quad (66)$$

$$\lambda_t = \beta R_t^d E_t \lambda_{t+1} \quad (67)$$

$$\lambda_t [1 + \Phi_1(k_{t+1}^i, k_t^i)] = \beta E \lambda_{t+1} (u_{t+1} + 1 - \delta - \Phi_2(k_{t+2}^i, k_{t+1}^i)) \quad (68)$$

4.3.1 Banks

Suppose that financial transactions between domestic and foreign residents require financial intermediation by domestic banks and assume there is a continuum of them of measure one that behave competitively. They capture funds from foreign investors at the country interest rate R_t and lend to domestic agents at the rate R_t^d . In addition banks face operational costs, $\Psi(d_t - \bar{d})$, for some $\bar{d} > 0$, that are assumed to be increasing and convex in the volume of

loans made by banks, d_t and to satisfy $\Psi(0) = \Psi'(0) = 0$. It follows that the optimality condition for the banks is given by:

$$R_t^d = \frac{R_t}{[1 - \Psi'(d_t - \bar{d})]} \quad (69)$$

This assumption is introduced following Uribe and Yue (2006), and eliminates the unit-root in the debt process exhibited by small open economy models (Schmitt-Grohe and Uribe, 2003).

4.3.2 Firms

The productive sector of the small open economy is made of a continuum of identical firms indexed by f , where $f \in [0, 1]$. A representative firm f produces the one good using labor services, h_t^f , and physical capital, k_t^f , that it rents from the households in perfectly competitive markets, using a technology:

$$y_t^f = F(k_t^f, h_t^f) \quad (70)$$

where the function $F(\cdot)$ is assumed to be homogeneous of degree one, increasing in both arguments and concave. The production process is subject to a working capital constraint that requires firms to hold non-interest bearing assets to finance a fraction, η , of the wage bill each period. Formally:

$$\kappa_t \geq \eta w_t h_t^f; \quad \eta \geq 0$$

where κ_t is the amount of working capital held by the representative firm in period t .

The debt position of the firm evolves as follows:

$$d_t^f = R_{t-1}^d d_{t-1}^f - \kappa_{t-1} - y_t^f + w_t h_t^f + u_t k_t^f + \pi_t + \kappa_t$$

where π_t are profits distributed to households in period t and R_{t-1}^d is the same interest at which all households borrow and is defined by (69).

Defining the firm's total net liabilities at the end of period t as $a_t^f = R_t^d d_t^f - \kappa_t$, then assuming that the capital constraint always binds²⁸, it is possible to express:

$$a_t^f = R_{t-1}^d a_{t-1}^f - \kappa_{t-1} - y_t^f + w_t h_t^f \left[1 + \eta \left(\frac{R_t^d - 1}{R_t^d} \right) \right] + u_t k_t^f + \pi_t$$

The firm maximizes the present value of profits discounted at the household's marginal rate of substitution of consumption between periods:

$$E \sum_{t=0}^{\infty} \beta^t \frac{U_1(c_t^i, h_t^i)}{U_1(c_0^i, h_0^i)} \pi_t$$

with the following two optimality conditions for the two inputs

$$w_t \left[1 + \eta \left(\frac{R_t^d - 1}{R_t^d} \right) \right] = F_2(k_t^f, h_t^f) \quad (71)$$

²⁸This implies considering only cases where the interest rate is positive.

$$u_t = F_1 \left(k_t^f, h_t^f \right) \quad (72)$$

plus the household's Euler condition 67 and the no-Ponzi condition for a_t^f similar to (64).

It follows from (71) that the financial friction created by the working-capital constraint distorts the labor market by introducing a wedge between the marginal product of labor and the real wage rate. In equilibrium, this distortion will make demand for labor sensitive to the interest rate.

Lastly, it should be noted that any process for a_t^f satisfying the firm's budget constraint is optimal. Thus an equilibrium for the firm consists in holding no liabilities at all times and implying zero profits:

$$\pi_t, a_t^f = 0; \forall t$$

4.3.3 Driving Forces

A key variable in the model is R_t , the gross interest rate faced by financial domestic agents (i.e. Banks) in international markets. Following Uribe and Yue (2006) it will be assumed that the equilibrium level of this variable will be a function of the domestic economic conditions; the evolution of the international interest rate; its own history and exogenous innovations. Formally:

$$\widehat{R}_t = R \left(\Gamma_t, \widehat{R}_t^*, \widehat{R}_{t-1}, \epsilon_t^R \right) \quad (73)$$

where Γ_t is a vector containing domestic variables that could provide a reasonable description of the business cycle in the domestic country, thus affecting the equilibrium level of R_t , and that might affect the rate at which foreign lenders might be willing to supply funds to domestic banks; \widehat{R}_t^* is the world interest rate; and ϵ_t^R are *i.i.d.* innovations to the country interest rate that can equivalently be interpreted as a country spread shock. A hat " $\widehat{}$ " over the variables R_t^* and R_t indicate log-deviations from their long-run means.

The process for the world interest rate is assumed to be stochastic and exogenous to the domestic variables in the domestic small open economy. Formally

$$\widehat{R}_t^* = R^* \left(\widehat{R}_{t-1}^*, \epsilon_t^{R^*} \right) \quad (74)$$

where $\epsilon_t^{R^*}$ are *i.i.d.* innovations to the world interest rate.

4.3.4 Competitive Equilibrium

Since all of the unit mass of households are identical, we have as equilibrium conditions that the aggregate levels of consumption, labor, investment and debt are:

$$C_t = c_t^i \quad (75)$$

$$H_t = h_t^i \quad (76)$$

$$I_t = i_t^i \quad (77)$$

$$K_t = k_t^i \quad (78)$$

$$D_t = d_t^i \quad (79)$$

Likewise, since all unit mass of firms are identical, equilibrium in the competitive markets for labor and physical capital imply that

$$K_t = K_t^f = k_t^f \quad (80)$$

$$H_t = H_t^f = h_t^f \quad (81)$$

Note that in an equilibrium for the firms that consists in holding no liabilities at all times, D_t represents the domestic country's net debt position and is, by construction, equivalent to the amount of debt intermediated by the financial system. Therefore, the trade balance of this economy can be defined as

$$TB_t = Y_t - C_t - I_t - \Phi(K_{t+1}, K_t) - \Psi(D_t - \bar{d}) \quad (82)$$

where $Y_t = F(K_t, H_t)$ is gross domestic product. A key variable that can be derived from the trade balance is the capital account, KA , measured as the amount of resources needed to finance the trade balance plus debt interest transfers:

$$KA_t = (R_{t-1} - 1) D_{t-1} - TB_t \quad (83)$$

To summarize: a competitive equilibrium for the domestic small open econ-

omy is then the set of processes for allocations

$$\{C_t, K_t, D_t, H_t, Y_t, I_t, TB_t, KA_t\}_{t=0}^{\infty}$$

and prices

$$\{w_t, u_t, R_t, R_t^d, \lambda_t\}_{t=0}^{\infty}$$

satisfying conditions (62)-(63), (70), (82)-(83), the optimality conditions associated to the household's problem (65)-(68) and to the firm's problem (71)-(72), the endogenous process for the interest rates R_t and R_t^d (69) and (73); given the exogenous process for R_t^* in (74) and country interest rate shocks $\{\epsilon_t^R\}_{t=0}^{\infty}$ and given initial conditions for $\{K_0, D_{-1}, R_0^*\}$.

4.3.5 Parameterization

Here I present the functional forms chosen to model the technology; the household's preferences, the investment and operational adjustment costs.

The technology available to the firm is a Cobb-Douglas type

$$F(k_t, h_t) = (k_t)^\alpha (h_t)^{1-\alpha}$$

The lack of reliable data on the aggregate capital stock makes it difficult to get systematic values for capital depreciation and shares. I therefore use a yearly value of $\delta = 0.1$ and $\alpha = 1/3$, which is somewhat standard in both the literature on developed and developing countries (see Mendoza 1991, 1995,

respectively).

The instantaneous utility function assumed uses the preferences introduced by Greenwood et.al. (1988), usually labelled as GHH-type preferences:

$$u(c_t, h_t) = \frac{\left(c_t - \theta \frac{h_t^\omega}{\omega}\right)^{1-\sigma}}{1-\sigma}$$

These preferences have been used in open economy models since Mendoza (1991) and have been shown to improve the ability of dynamic stochastic general equilibrium models to reproduce some of the business cycles facts of small open developed economies (Correia et.al. (1995)) and developing economies (Aguiar and Gopinath (2007)).

The parameter σ governing the intertemporal elasticity of substitution, $\frac{1}{\sigma}$, is calibrated at 2 indicating the presence of relatively interest-inelastic consumption growth rates as has been suggested for developing economies (Ostry and Reinhart, 1992; Aguiar and Gopinath, 2007). The parameter ω , governing the elasticity of labor supply, $\frac{1}{\omega-1}$, is perhaps the hardest one to calibrate for developing countries given the virtual inexistence of systematic labor market databases. It is calibrated at 1.6 following studies for other developing countries that have set a lower elasticity, motivated by the higher degree of labor market imperfections observed in these economies²⁹. Lastly, the coefficient θ is calibrated so as to give a steady state level of labor equal to 0.28 as in Aguiar and Gopinath (2007). Following Schmitt-Grohe and Uribe (2003) the steady-state

²⁹For Argentina, Neumeyer and Perri (2005) set the elasticity at 1.51 and, in their calibration of the Mexican economy, Aguiar and Gopinath (2004) set it at 1.66.

level of debt, \bar{d} , is calibrated so as to match a long-run trade balance-to-income ratio, equal to -2% .

Standard quadratic cost functions are assumed for the capital accumulation process:

$$\Phi(k_{t+1}, k_t) = \frac{\phi}{2} (k_{t+1} - k_t)^2$$

and for the operational costs of banks

$$\Psi(d_t - \bar{d}) = \frac{\psi}{2} (d_t - \bar{d})^2$$

and the two parameters governing the two functions are calibrated as in Uribe and Yue (2006): $\phi = 72.8$; $\psi = 0.001$. Likewise, the parameter η governing the intensity of the working capital constraint is set to be 1.2.

Following Neumeyer and Perri (2005) and Uribe and Yue (2006), the process for the foreign exogenous interest rate $R^*(\cdot)$ is assumed to follow an AR(1) process:

$$\widehat{R}_t^* \equiv \ln(R_t^*/R^*) = \rho_{R^*} \ln(R_{t-1}^*/R^*) + \epsilon_t^{R^*}$$

and ρ_{R^*} is estimated to be 0.776 using a proxy for real ex-ante interest rates. The estimation is done by OLS for the period 1920-1940 using data on secondary market TBill yields deflated by the US CPI-inflation. To (partially) capture the forward looking measure of inflation expectations we use a three year moving average (see Figure III.2). Results using less and more forward looking measures of ex-ante real world interest rates are robust and are gathered in the an

appendix. In the estimation, the long-run mean of gross world interest rates R^* was set to be 1.04 as in Uribe and Yue (2006).

A challenge that the model presents lies in the lack of identification of the country interest rate process $R(\Gamma_t, \widehat{R}_t^*, \widehat{R}_{t-1}, \epsilon_t^R)$. What other researchers have done to overcome this is to estimate the process from *observed* time series of country interest rates in international financial markets. This is the approach followed by Neumeyer and Perri (2005) but they have no variables in the vector Γ_t . Uribe and Yue also follow this approach but they do include richer dynamics in Γ_t such as contemporaneous and lagged values of investment, income and trade balance. In this case, however, such approach cannot be undertaken because there are no consistent time series on interest rates for Colombian bonds in international markets for this period (see the scarce data collected in Table III.2). Thus, it was decided to treat R_t as a latent variable and postulate and ad-hoc -and very simple- process for $R(\cdot)$ based on the findings from other studies. In particular, three considerations were taken into account. First, both Neumeyer and Perri (2005) and Uribe and Yue (2006) coincidence in postulating a high correlation between R_t and R_t^* . Second, for the case of Colombia, other studies have documented a *lagged* relation between foreign and domestic interest rates (GRECO, 2002). Third, all three studies find a high degree of persistence in the country interest process. On these three considerations, the process for the country interest rate $R(\cdot)$ is assumed to be:

$$\ln(R_t/R) = \rho_{R^*} \ln(R_t^*/R^*) + \rho_{R_-} \ln(R_{t-1}^*/R^*) \quad (84)$$

with $\rho_{R^*} = 0.85$, $\rho_{R^*_-} = 0.05$, and the long-run gross country interest rate, R , is assumed to be 1.11 assuming a "natural" spread level of 700 basis points over the US interest rate. Note that no independent country spread dynamic are contemplated as this, while certainly relevant, is virtually impossible to capture given the available data.

4.4 Simulation Results

This section assesses the performance of the model in matching the main stylized facts of the Latin American countries described in the second section. The assessment is done both qualitatively and quantitatively. First, from a qualitative point of view, I ask whether the model delivers the dynamics observed in the data after an external financial shock. For that purpose, and in the spirit of Diaz-Alejandro (1983) and Calvo et.al. (1993), I simulate the impulse response functions after an exogenous negative shock to the world interest rate. Second, the model is assessed quantitatively by simulating the model using the *observed* process for the world interest rate as driving force. The simulated-based moments from the artificial time series are then compared to their empirical counterparts. Since the main purpose of the study is the analysis of the business cycle consequences of capital flows, particular attention is given to the dynamics of GDP. In particular, the observed dynamics of GDP are compared to the ones simulated by the model.

4.4.1 Impulse Response Functions

The model is solved by taking a log-linearization around its non-stochastic steady state and its state-space representation allows the computation of impulse response functions (IRF)³⁰. Figure III.4 plots the IRF of six key variables following a negative 100-basis points shock to the foreign interest rate, $\epsilon_t^{R^*} = 0.1$. The upper-left panel describes the first part of the transmission mechanism as the country interest rate deviates also negatively from its steady state. Note that while R_t reacts simultaneously with R_t^* , the full effect of the shock in R_t occurs one period after the shock. The upper-right panel shows the supply-side part of the transmission mechanism. On one hand, the drop in interest rates lowers the opportunity cost of investing and households increase the resources allocated to increasing the stock of capital. This is standard in neoclassical models. On the other hand, because of the financial frictions induced by the working capital constraint, the reduction in interest rates lowers the wage bill giving incentives to firms to increase their labor demand. The lower-left panel shows the full effect of the shock on the dynamics of output which raises by 2,5% with respect to trend. It is thus immediate to see that the supply side effects are non trivial. Last, but not least, the lower-right panel shows the imbalance created by these dynamics on the external front. As investment and consumption increases with the shock and the increase in income is not fully completed there is a temporary imbalance in the trade balance that must be financed by

³⁰The first order approximation and solution of the models are all done by adapting the MATLAB routines provided by Schmitt-Grohe and Uribe (2004). The codes used in this research as well as the entire dataset are available upon request.

capital inflows. Later, once output has reached its peak, the external imbalance reverses.

Summarizing, on a qualitative perspective, an external shock to the world interest rate generates the main stylized facts observed business cycles in the Latin American countries during the 1920s: important capital account surpluses in conjunction with significant positive deviations from their long-run trend.

4.4.2 Simulation based on observed driving forces

The next issue evolves around the quantitative performance of the model. To do so I cast the log-linearized version of the model in its canonical form (see Schmitt-Grohe and Uribe (2004) for details):

$$\begin{aligned} x_{1,t+1} &= Mx_{1t} + v_{t+1} \\ x_{2,t} &= Cx_{1,t} \end{aligned} \tag{85}$$

where $\{x_1, x_2\}$ are the vector of states $\{K_t, D_t, R_t^*\}$ and controls $\{C_t, H_t, Y_t, I_t, TB_t, KA_t, w_t, u_t, R_t, R_t^d, \lambda_t\}$, respectively; v_{t+1} is a vector of structural perturbations driven, in this case, by the unique random shock to the world interest rate, $\epsilon_t^{R^*}$; and the matrices M , C are functions of the structural parameters. This system can be compactly written as a law of motion equation:

$$\Psi_{t+1} = \Phi\Psi_t + B\epsilon_{t+1}^{R^*} \tag{86}$$

On the other hand, having data on a vector X_t , this can be expressed as a non-invertible linear combination of the state variables in a measurement equation:

$$X_t = \Gamma \Psi_t \quad (87)$$

where Γ is a conformable matrix that maps the observable time series of the observable elements X_t to their theoretical counterparts in Ψ_t . The equations (86)-(87) are the starting point for a time invariant Kalman filter.

The experiment undertaken here uses data on the *observed* driving force, e.g. the world interest rate (see Figure III.2), from the period 1920 to 1940, $X = \left\{ \widehat{R}_t^* \right\}_{t=1920}^{1940}$, and uses the Kalman filter to recursively construct one-step-ahead optimal forecasts of the entire vector, $\left\{ \widehat{\Psi}_t \right\}_{t=1920}^{1940}$. The simulated time series are then compared to the observed ones.

The first comparison is done by matching the empirical second moments against the simulated ones. As it is usually done in business cycles studies, both the simulated and empirical time series are filtered before using an HP-filter with $\lambda = 100$. Table III.4 presents the results of this experiment. The upper panel shows the empirical moments computed using the yearly data on five of the macroeconomic variables presented for Colombia during the period 1923-1940 (see Table III.3): aggregate output; consumption; investment; the trade balance share; and the real ex-ante world interest rate. The lower panel presents the simulated counterparts.

The model performs relatively well in terms of reproducing the observed second moments. First, the high volatility of consumption relative to output's,

a main business cycle property in developing economies (Aguiar and Gopinath, 2007), is replicated successfully. The covariance and serial cross correlations with output are relatively well matched, although some are a bit over estimated. A notable success of the model is to capture the countercyclical trade balance share, specially with lead values of output. Likewise, the negative correlation of the world interest rate with lead income is well captured, but not the contemporaneous or lagged negative correlations. A drawback of the model is, however, the small volatility in investment that is not borne out in the data. In fact, while the model does capture the high serial correlation between investment and output, it does so at the cost of reducing the volatility of investment vis a vis the observed one.

The second comparison between the simulated model and the data is carried out by plotting the log differences in the time series for output. Figure III.5 plots the model based log-differences for the simulated income and the Colombian data for the period 1925 to 1935 (this is the data shown in Table III.3). As was described in the second section, like most Latin American countries, Colombian GDP exhibited an expansionary phase of the business cycle between 1925 and 1929. The recession occurred in the two years after, between 1930 and 1931. And a sharp recovery was observed from 1932 onwards. Two results are immediate from looking at the model performance. First, the model does a pretty good job at replicating the expansionary phase of the cycle from 1925 to 1929. It also reproduces a contractionary phase with a recession in 1931. Second, the model fails by a large extent in replicating the strong recovery experienced from 1932.

In fact, it predicts a much bigger recession during the years 1932-1934, in sharp contrast to what is observed in the data.

Overall, the model does a good job in reproducing some of the key moments, and in particular, a countercyclical trade balance share, as well as the negative correlation of the world interest rate with lead income. In addition, the model does well in matching the expansionary phase and the fall in output dynamics that followed the capital inflows and outflows between 1925 and 1931. But the model misses completely the strong recovery experienced after 1932. This, however, is not surprising because, as will be documented with some detail in the next section, the model does not incorporate two key elements that were crucial in some Latin American economies during the early 1930s: the active role of countercyclical policy in an environment with virtually no capital flows and the incentives for import-substituting activities offered by the relative price changes. These will be analyzed next.

4.5 The Role of Countercyclical Policy

While capital outflows and aggregate demand contraction for Latin American exports during the Great Depression had severe real effects in the region, the story of rapid recovery in many countries in the region is also a salient characteristic of the 1930s. This is probably the most dramatic conclusion in the papers collected in Thorp (1984). The views about the recovery mechanisms are, nonetheless, diverse among scholars. While some stress the role of exports recovery, others point out the important role played by countercyclical fiscal and mon-

etary policies in conjunction with relative price adjustments. These views are presented by Diaz-Alejandro (1983, 1984) for whom a distinction must be made between the large and “reactive” Latin American countries (i.e. Argentina, Brazil, Chile, Colombia, Mexico, Peru and Uruguay) where active countercyclical policies were adopted, starting with the abandonment of the Gold Standard parities; and small or very dependent countries (i.e. Cuba, Panama, and other Central American and Caribbean countries) that maintained their peg to the US dollar throughout the 1930s. Reactive countries, it is argued by Diaz-Alejandro, were able to devalue their nominal exchange rate, thereby accelerating the domestic relative price adjustment and encouraging a reallocation of resources toward the import-competing sectors. Importantly for him, this process was backed by expansionary monetary and fiscal policies that minimized the negative consequences on internal aggregate demand from deflationary forces.

In Colombia, during the first two years of the international crisis, 1929-1930, the outflow of gold from the reversal of capital flows, worsened by the fall in the country’s terms of trade, led to very low levels of foreign reserves in the Banco de la Republica. Given the Gold Standard’s adjustment mechanisms, this trend brought about the country’s strongest deflation in the twentieth century in Colombia (Sanchez, et.al. 2007). The Banco de la Republica raised interest rates to defend the exchange rate parity, which had a transmission effect over the commercial interest rates, as can be seen from Table III.3. To further reaffirm Colombia’s commitment to the Gold Standard, hoping this would lead to resumption of foreign-capital flows, government authorities once again turned

to the “Money Doctor”: E.W. Kemmerer³¹. But the continuous drop in foreign reserves together with the pressure from interest groups made impossible to defend the exchange regime³². On September 24, 1931, a few days after England abandoned the Gold Standard, Colombia suspended the free trade of gold and the convertibility of the money supply, establishing controls over exchange operations (Sanchez, et.al. 2007).

Having direct control over the stock of international reserves, Colombia’s monetary authorities pursued an expansionary policy immediately after the Gold Standard was abandoned. The reflationary policy was implemented by increasing the credit to the central government and by lowering the banks’ discount rate³³. Following Meisel (1991), Figure III.6 presents the evolution of real money supply in Colombia for the period 1923-1936. It is immediate to see the extraordinary effect of the expansionary policy over the real money supply in the two years that followed the abandonment of the Gold Standard, from 1932 to 1933. In addition, it is important to note how this policy put downward pressure to the commercial interest rates, as can be seen from Table III.3.

While the real effects of capital outflows between 1930-31 were severe relative to Colombia’s long-run economic record during the twentieth century, compar-

³¹After a second mission, Kemmerer gave a series of proposals aimed at fighting deflation by expanding both the Banco de la República’s monetary supply capacity to commercial banks, while remaining under the Gold Standard.

³²Representative speakers from the export sector, coffee in particular, were very critical about maintaining the exchange rate peg and publicly pressured the government to devalue the currency (see Sanchez (1994)).

³³In particular, the Central Bank’s direct credit to the government was boosted after the partial financing of the expenditures during the brief war with Peru in 1932 (see Avella, 2004)). See Sanchez, et.al. (2007) for further details on the expansionary monetary policy measures implemented.

ative studies have found it to be one of the best stories of fast recovery among the Latin American countries during the Depression (Towmey, 1981). Partial evidence from key sector indicators in Table III.3 reveals that this was the result of highly uneven performance among sectors. On one hand non-tradable non-agricultural activities were highly affected. The construction indexes, for example, exhibit decreases of over 40% between 1929-32. Evidence in Ocampo (1984) shows this was also true for other sectors such as internal transportation and a few manufacturing activities. On the other hand, agricultural and mining production did very well during the crisis, showing actually a real decrease only in 1931. In addition, industrial and manufacturing activities suffered only mildly between 1930-31, and, more remarkably, initiated an extraordinary boom from 1932. This industrialization has been one of the most widely known examples of structural changes emanating from this period in Latin America (Echavarria, 1999).

To what extent this successful story of fast recovery can be attributed to the countercyclical role of monetary policy explained above? On a general Latin American perspective, Diaz-Alejandro (1983) assigns a key role to these policies to the extent that they appear to have successfully contained the deflationary pressures that could have overwhelmed the incentives to invest in import substitution activities. In the Colombian case, Ocampo and Montenegro (1984) conclude that government policy was also very effective in reorienting demand towards internal production³⁴. To others the countercyclical demand oriented

³⁴In particular, the presence of protectionist trade barriers is underscored by the authors.

measures only complemented the natural adjustment that went under way during the last years of the Gold Standard whereby deflationary forces depreciated the real exchange rate and generated enough movements in relative prices (Sanchez, 1994). Evidence of private entrepreneurs that were responsive to price incentives is extensively presented in Echavarría (1999) for the industry sector. The next section tackles the role of countercyclical policy formally by modifying the general equilibrium framework developed earlier.

4.5.1 Model

The model in Section III is modified to formally explore the role of countercyclical monetary policy in the rapid recovery from the crisis in the early 1930 in Latin America, using, again, Colombia as a benchmark. The model is modified in the following three dimensions. First, money is introduced via a cash-in-advance restriction (Lucas and Stokey (1987)) but where the use of cash is restricted to the purchase of consumption goods only. Second, the economy is closed with no trading or financial links with the rest of the world. This is clearly an oversimplification but it is justified under the basis that: (i) the foreign financial flows, once the key in explaining the business cycle in the 1920s, were virtually gone by the early 1930s and the Latin American countries had no access to foreign financial markets; and (ii) the recovery, as was described above, was mostly driven by import-substituting activities more related to a closed than to an open economy. Also, this assumption gives more scope to

The analysis of these measures, however, goes well beyond the scope of this study.

monetary policy. Third, monetary policy is assumed to take place via a simple constant Friedman-type rule except that temporary deviations from it are driven by exogenous monetary policy shocks. The financial sector and the role of financial frictions in the previous model become now the channels through which monetary policy has real effects by allowing money transfers from the central bank to go directly to the financial system.

Households The main modifications to the model follow McCandless (2008) closely. Consider now a *closed* economy populated by a continuum of identical households indexed by i , where $i \in [0, 1]$. A representative household i has preferences described by the same utility function as in (61). Households face now a cash-in-advance constraint on their consumption purchases. At the beginning of each period, households are holding money that they are carrying over from the previous period. They lend some of this money to a financial intermediary who lends it to the firms for working capital, and use the rest of this money to purchase consumption goods and invest in new capital. Formally, household i maximizes (61) subject to a cash-in-advance constraint

$$P_t c_t^i \leq M_{t-1}^i - N_t^i \quad (88)$$

a budget constraint

$$\frac{M_t^i}{P_t} + i_t^i = w_t h_t^i + u_t k_t^i + \frac{R_t^n N_t^i}{P_t} \quad (89)$$

and the capital law of motion (63); where the variables $\{k_t^i, w_t, h_t^i, i_t^i, u_t\}$ are as in the previous model; M_{t-1}^i is the amount of money holdings household i carries over from the previous period; N_t^i is the household's nominal lending to the financial intermediary in period t for which it receives a gross nominal interest rate equal to R_t^n ; and P_t is the price level in period t . Money is thus used for both paying for consumption goods and for deposits in the financial intermediary. The gross income from deposits appears in the budget constraint because it can be used to finance next period's capital or money holdings³⁵.

Banks Banks continue to operate in a perfectly competitive market and to finance the firms' need for working capital. This time, however, given that the economy is closed, banks cannot capture funds from foreign investors. Instead they rely on deposits from households and (stochastic) injections of money from the central bank. Under a zero-profit condition, the banks's budget constraint implies that income from lending to firms the funds they receive each period must be equal to the interest rate paid to deposits. Formally

$$R_t^f (N_t + (g_t - 1) M_{t-1}) = \int_0^1 R_t^n N_t^i di \quad (90)$$

where R_t^f is the gross interest rate firms pay on the working capital they borrow from banks; N_t is the the aggregate level of lending by households to the financial system; M_t is the aggregate stock of money; and g_t is the gross growth rate of

³⁵The reader should observe also that capital adjustment cost are taken out from the household's budget constraint. The results from the previous model suggest so.

money whose dynamics will be specified later.

Firms The productive sector operates similarly as in the previous model. It uses a technology equal to (70); its production process is subject to the same working capital constraint $\kappa_t \geq \eta w_t h_t^f$; $\eta \geq 0$. and operates under the following two optimality conditions

$$w_t \left[1 + \eta \left(\frac{R_t^f - 1}{R_t^f} \right) \right] = F_2(k_t^f, h_t^f) \quad (91)$$

$$u_t = F_1(k_t^f, h_t^f) \quad (92)$$

Central Bank To close the model we assume a central bank that conducts a very simple Friedman-type monetary policy rule,

$$M_t = g_t M_{t-1} \quad (93)$$

where g_t , the gross growth rate of money in period t , is assumed to evolve according to an AR(1) process

$$\ln g_{t+1} = (1 - \rho) \ln \bar{g} + \rho \ln g_t + \varepsilon_{t+1}^g \quad (94)$$

and \bar{g} is assumed to be the long-run gross growth rate of the money supply and ε_{t+1}^g are *i.i.d.* innovations to the process that can be viewed as independent and transitory monetary policy shocks. Thus, while in steady state the central bank supplies money following an "exact" Friedman-type of rule, in the short-

run, however, it temporarily deviates from it by producing exogenous monetary policy shocks.

I calibrate \bar{g} to be 1.084 using the mean growth rate for the money supply (M1) for the period 1920-1940 using data from the Colombian monetary history by Sanchez, et.al. (2007). Equation (94) is now the only driving force of the model.

Competitive Equilibrium Market clearing conditions for allocations and inputs (75)-(78), and (80)-(81) from the previous model apply here as well. In addition

$$M_t = M_t^i \quad (95)$$

$$N_t = \int_0^1 N_t^i di \quad (96)$$

Also, an equilibrium condition for the financial market requires that all of the funds that households have lent to banks plus net financial injections or withdrawals from the monetary authority are lent to firms to finance the working-capital needs:

$$N_t + (g_t - 1) M_{t-1} = P_t \eta w_t H_t \quad (97)$$

To summarize: a competitive equilibrium for the closed economy is the set of processes for allocations

$$\{C_t, K_t, M_t, H_t, Y_t, I_t, N_t\}_{t=0}^{\infty}$$

and prices

$$\{w_t, u_t, R_t^n, R_t^f, P_t\}_{t=0}^\infty$$

satisfying conditions (88); (89); (63); (70), (90), (97), all holding with equality; the three optimality conditions associated to the household's problem (not shown) and to the firm's problem (91)-(92), and the endogenous process for the money supply (93); given the exogenous process for g_t described by (94) and given initial conditions for $\{K_0, M_{-1}, g_0\}$.

4.5.2 Results

In this section the model is solved by taking a log-linear approximation around the non-stochastic steady state and using the same parameterization as in the previous case. Next, the same quantitative experiment undertaken in section III is replicated: the monetary model is assessed quantitatively by simulating the model using the *observed* time series for the money supply growth in Colombia as the driving force, $X = \{g_t\}_{t=1930}^{1940}$, and the Kalman filter is employed to recursively construct one-step-ahead optimal forecasts of income, $\{\widehat{Y}_t\}_{t=1930}^{1940}$. The observed dynamics of output are compared to the ones simulated by the monetary model. Importantly, the model is simulated only from 1930, i.e. one year prior the abandon of the Gold Standard and the year which marked the beginning of the recession and the inability of Colombia to access the international financial markets. In other words, the model is simulated for the most part, during the period where the monetary authority had effective control over the money supply.

Figure III.7 plots the simulation results. Three aspects are worth noticing. First, the model is capable to reproduce the 1930-31 recession. This is, however, not too surprising because one should expect that under a Gold Standard regime, on a recession money supply follows closely the income process. Second, on the overall picture, the monetary model does reproduce the economic recovery in the years that followed after the reversal of the capital flows unlike the previous model. The monetary model does get a response of output after the countercyclical policy undertaken by the monetary authorities, particularly from 1933. Yet, third, the model is unable to capture the *timing* of the fast recovery. And the year to focus here is 1932 when the model still predicts null aggregate growth but the economy exhibited a strong recovery with income growing over 6%. This particular year, looking once again to the economic indicators in Table III.3, had two distinctive trends. On one hand this year is the beginning of the a period of accelerating industrialization driven by import-substitution activities with yearly growth averages of over 14%. On the other hand, this year appears as one in which the real exchange rate depreciation process consolidated with a fall of over 13% in this indicator.

In summary, the active role of countercyclical monetary policy in the years that followed the great reversal of capital flows to Colombia appears to have had a real effect that is validated by the theoretical model. Nonetheless, the implied monetary shocks do not appear to be enough to account for the early strong recovery, particularly in the first years of the 1930s. I view this fact, together with the other macroeconomic evidence (real exchange depreciation and the

strong recovery in the industry sector) as indirect evidence of the important role played by relative prices in the import substitution process that accompanied the strong recovery in Colombia.

4.6 Concluding Remarks

A well-recognized stylized fact about Latin American economies is the large macroeconomic volatility they exhibit. This study has focused on one of the explanations to this fact offered by the literature: the relevance of external shocks to financial markets. The idea is that Latin American economies exhibit low levels of aggregate savings forcing them to rely heavily on foreign investment, via capital inflows. However, this makes them vulnerable to external shocks to financial markets that make capital flows highly exogenous to domestic conditions resulting in large macroeconomic fluctuations. Evidence of this is given by the sizeable economic fluctuations observed in the Latin American business cycles during three famous episodes of large capital inflows and outflows to the region throughout the twentieth century. In particular the episode of large capital inflows and outflows of the 1920s and early 1930s stands out for its magnitude in both the large boom and the steep recession recorded in most Latin American countries.

This study uses this "historical experiment" to study the transmission mechanism by which external shocks turn into large capital flows with sizeable macroeconomic fluctuations. In addition it studies the role of countercyclical policy undertaken in the recovery phase among many "reactive" Latin American coun-

tries. While an overview of the Latin American is offered, particular attention is given to Colombia which appears as a representative country in terms of the main trends observed in the region.

The framework of analysis combines a historical account of the main stylized facts, with a theory for the transmission mechanism of external shocks and an empirical analysis. The historical account made the case that the interest rate and the banking system are the key channels to understand the mechanics by which capital inflows/outflows turn in economic booms/busts. The model rationalizes, within a dynamic general equilibrium framework, the external forces that drive capital flows and, simultaneously, generate macroeconomic fluctuations. It does so by relying on two key features: the presence of random foreign financial shocks and the presence of domestic financial frictions. A modified version of the model is offered to account for the role of countercyclical monetary policy in the recovery phase of the early 1930s. Lastly, the empirical analysis assesses the performance of the model in matching the main stylized facts in the data. It does so by running an experiment in which the observed processes for the model's driving forces, the world interest rate and the growth rate of the money supply, coupled with the dynamic nature of the model, serve as the basis for simulation. The simulated-based time series are then compared to their empirical counterparts. In particular, the observed dynamics of GDP are compared to the ones simulated by the model.

Using a full-fledged model to understand the macroeconomic fluctuations experienced by Latin American economies during this turbulent time forces, by

construction, to obviate many other dynamics that were certainly important. Nonetheless it is shown that the models offer a reasonably good approximation to the observed dynamics. From a qualitative perspective, the model is able to reproduce important capital account surpluses in conjunction with significant positive deviations from their long-run trend, in accordance with the main business cycles' stylized facts observed in the Latin American countries during the 1920s. From a quantitative perspective, the model does well in matching the expansionary/contractionary phases in output dynamics that followed the capital inflows/outflows between 1925 and 1931. Moreover, the active role of countercyclical monetary policy in the years that followed the great reversal of capital flows appears to have had a real effect that is validated by the theoretical model.

Many issues remain unresolved. On the empirical front, for example, the obvious extension is to assess the model performance with Latin American countries other than Colombia, and in particular for those countries on which data on government yields exist and could be used as proxies for the country interest rates. On the theoretical front, no serious attention was given to the repudiation of the sovereign debt by many of the Latin American countries, nor to the role of terms trade fluctuations. It would be interesting to assess, for example, the connection between the business cycle and the debt dynamics along the lines of Mendoza and Yue (2008). Likewise indirect evidence of the important role played by relative prices suggests that a model with terms of trade, along the lines of Mendoza (1995), could improve the performance in the fast recovery

period. I leave this for future research.

More generally, a central goal of this paper is the combination of theoretical general equilibrium modeling, time series analysis and historical evidence on Latin American business cycles in order to improve our understanding of business cycles in developing countries. This is a crucial step in the process of designing appropriate stabilization policies and sound macroeconomic management in these countries.

TABLES AND FIGURES

Table I.1. Calibrated Parameters

<i>Parameter</i>	<i>Description</i>	<i>Models</i>		
		<i>Encompassing</i>	<i>Stochastic Trend</i>	<i>Financial Frictions</i>
σ	Intertemporal Elasticity of Substitution $[1/\sigma]$	2.000	2.000	2.000
ω	Labor Supply Elasticity $\left[\frac{1}{\omega-1}\right]$	1.600	1.600	1.600
α	Labor Share of Income	0.6868	0.6800	0.6867
R^*	Gross Foreign Interest Rate	1.0025	1.0323	1.0025
μ	Long-run Productivity Growth	1.006	1.006	1.006
τ	Labor Parameter so that $h^{ss} = 1/3$	1.7168	1.5662	1.7169
ψ	Debt Elastic Interest Rate Parameter	0.001	0.001	0.001
β	Discount Factor	0.9976	0.9804	0.9976
S	Long-run Gross Country Interest Rate Premium	1.0120	1.0000	1.0120
δ	Depreciation Rate of Capital	0.050	0.050	0.050
d	Debt-to-GDP Ratio (D/Y)	0.100	0.100	0.100
R	Gross Country-specific Interest Rate	1.0145	1.0323	1.0145

Note: A period is taken to be a quarter in the calibration. Note that in the encompassing and financial friction models α is not exactly equal to labor share (*h-Share*) but it is rather $\alpha = h\text{-Share} * [1 + (R - 1)\theta]$. In the Table, values are computed using the posterior mode of θ .

Table I.2. Prior Distributions

Parameter	Range	Density	Mean	S.D (%)	90% Conf. Interval	
Parameters Common to Both Models						
ρ_a	AR(1) Coeff. Transitory Tech. Process.	[0,1)	Beta [356.2 ; 18.753]	0.95	1.12	[0.92 ; 0.97]
σ_a	S.D. of Transitory Tech. Shock (%)	R^+	Gamma [2.060 ; 0.0036]	0,74	0.56	[0.12 ; 1.67]
ϕ	Capital Adjustment Cost Fct. Parameter	R^+	Gamma [3.000 ; 2.0000]	6.00	346	[1.62 ; 12.6]
σ_X	S.D. (%) of Measurement Error in $X = Y, C, I, TB/Y$	R^+	Gamma [4.000 ; 0.0050]	2.00	1.00	[0.67 ; 3.86]
Parameters Specific to the Stochastic Trend Model						
ρ_g	AR(1) Coeff. Permanent Tech. Process.	[0,1)	Beta [285.1 ; 110.88]	0.72	2.25	[0.68 ; 0.76]
σ_g	S.D. of Permanent Tech. Shock (%)	R^+	Gamma [2.060 ; 0.0036]	0,74	0.56	[0.12 ; 1.67]
Parameters Specific to the Financial Frictions Model						
ρ_R	AR(1) Coeff. Foreign Interest Rate Process.	[0,1)	Beta [44.26 ; 9.0655]	0.83	5.10	[0.74 ; 0.91]
σ_R	S.D. of Foreign Interest Rate Shock (%)	R^+	Gamma [5.552 ; 0.0013]	0,72	0.31	[0.30 ; 1.29]
θ	Working Capital Parameter	[0,1]	Beta [2.000 ; 2.0000]	0.50	22.4	[0.13 ; 0.87]
η	Spread Elasticity	R^+	Gamma [99.22 ; 0.0101]	1.00	10.1	[0.84 ; 1.17]

Table I.3. Posterior Distributions. Encompassing and Separate Models

Parameter	Prior	Encompassing Model		Separate Models: Posterior Modes		AG-GMM Estimates
		Mode	Mean	Stochastic Trend M.	Fin. Frictions M	
ρ_a	0.95 [0.92, 0.97]	0.89	0.89 [0.87, 0.92]	0.94	0.89	0.94
$100\sigma_a$	0.74 [0.12, 1.67]	0.66	0.66 [0.51, 0.82]	0.69	0.66	0.41
ϕ	6.00 [1.62, 12.6]	14.78	14.86 [11.99, 18.81]	3.69	14.77	3.79
$100\sigma_Y$	2.00 [0.67, 3.86]	0.64	0.62 [0.32, 0.88]	0.48	0.64	
$100\sigma_C$	2.00 [0.67, 3.86]	1.13	1.16 [0.99, 1.35]	1.15	1.14	
$100\sigma_I$	2.00 [0.67, 3.86]	3.04	3.09 [2.58, 3.66]	3.08	3.03	
$100\sigma_{TB/Y}$	2.00 [0.67, 3.86]	0.78	0.78 [0.54, 0.99]	0.92	0.78	
ρ_g	0.72 [0.68, 0.76]	0.72	0.72 [0.68, 0.75]	0.73		0.72
$100\sigma_g$	0.74 [0.12, 1.67]	0.12	0.11 [0.01, 0.29]	0.73		1.09
ρ_R	0.83 [0.74, 0.91]	0.81	0.81 [0.70, 0.88]		0.81	
$100\sigma_R$	0.72 [0.30, 1.29]	0.42	0.41 [0.26, 0.57]		0.42	
θ	0.50 [0.13, 0.87]	0.69	0.69 [0.25, 0.98]		0.69	
η	1.00 [0.84, 1.17]	0.73	0.73 [0.61, 0.85]		0.73	
RWC	3.15 [0.18, 6.37]	0.20	0.28 [0.00, 1.14]	3.25	0.00	5.33

Note: Estimates obtained using four observables, {gY, gC, gI, dTB/Y} from the Mexican Data, 1980.1-2003.2. For the separate models standard errors are omitted for brevity but are available upon request. All estimations were done using measurement errors in all four variables. AG-GMM Estimates refer to the generalized method of moment estimates reported by Aguiar and Gopinath (2004) which we present here as benchmark. RWC refers to the random walk component, see text for details.

Table I.4. Forecast Error Variance Decompositions in the Encompassing Model

Structural Shock	gY	gC	gI	dTB/Y
ε^a	91.52	86.36	74.95	55.22
ε^g	2.38	3.12	1.32	1.78
ε^{R^*}	6.10	10.52	23.72	43.01
Counterfactual, No Endogenous Spread: $\eta = 0$				
ε^a	93.04	66.84	5.95	17.38
ε^g	1.53	5.08	1.47	0.82
ε^{R^*}	5.43	28.08	92.59	81.81

Note: gX denotes log-differences, dX denotes first differences. Variance decompositions computed from the estimation using four observables and measurement errors in all variables. Numbers reported using posterior means estimates. Standard Errors are omitted for brevity but are available upon request. In the variance decomposition computations only the role of the structural shocks was taken into account. In the counterfactual exercise, all parameters are set equal to their posterior mode levels except for $\eta = 0$. A time horizon of 40 quarters was used when computing the variance decomposition.

Table I.5. Posterior Distributions. Estimations Without Measurement Errors

Parameter	Observables: { g^Y , dTB/Y}		Observables: { g^Y , g^I }		Observables: { g^Y , g^C }	
	Stochastic Trend M.	Financial Frictions M.	Stochastic Trend M.	Financial Frictions M.	Stochastic Trend M.	Financial Frictions M.
ρ_a	0.93	0.90	0.91	0.93	0.93	0.89
$100\sigma_a$	0.87	0.76	1.21	0.84	1.03	0.87
ϕ	5.66	31.45	3.59	27.81	10.87	18.37
ρ_g	0.76		0.77		0.78	
$100\sigma_g$	1.04		1.15		1.09	
ρ_R		0.88		0.92		0.91
$100\sigma_R$		0.58		0.72		0.63
θ		0.77		0.24		0.59
η		0.79		0.88		0.75
<i>RWC</i>	4.46	0.00	3.92	0.00	4.67	0.00

Note: Estimates obtained using pairs of observables, from the Mexican Data, 1980.1-2003.2 and no measurement errors. Numbers reported are posterior modes, which are very similar to the posterior means. Standard errors are omitted for brevity but are available upon request.

Table I.6. Bayesian Model Comparison

Models	Log-Likelihood	Log-Posterior	Marginal Log-Likelihood
Observables: {gY, gC, gI, dTB/Y}; Measurement Errors in all Variables			
Encompassing Model	991.5	1010.1	956.2
Stochastic Trend Model	989.7	1015.0	973.8
Financial Frictions Model	991.9	1003.4	960.4
AG - GMM	975.2		
Observables: {gY, dTB/Y}; No Measurement Errors			
Stochastic Trend Model	516.1	525.0	506.8
Financial Frictions Model	540.1	535.7	514.9
Observables: {gY, gI}; No Measurement Errors			
Stochastic Trend Model	387.0	391.7	372.9
Financial Frictions Model	430.1	432.6	408.0
Observables: {gY, gC}; No Measurement Errors			
Stochastic Trend Model	512.7	517.0	499.9
Financial Frictions Model	524.4	519.5	499.3

Note: Log-Likelihood levels computed in the posterior mode. Results on marginal data densities are approximated by Geweke's harmonic mean estimator with truncation parameter 0.5. Except for the cases with no measurement errors and measurement errors in all 4 variables, results are computed observing the time series for output, consumption, investment and the trade balance-to-GDP ratio, and i.i.d. measurement errors were added to the observation of all variables. AG-GMM stands for the log-likelihood value evaluated using the estimated parameters in Aguiar and Gopinath (2004) and the measurement errors from the posterior mode.

Table I.7.1. Second Moments. Encompassing and Separate Models

Variable	Mexican Data	Encompassing Model	Stochastic Trend Model	Financial Frictions Model	Aguiar-Gopinath GMM
Standard Deviations (%)					
<i>gY</i>	1.53	1.23	1.54	1.22	1.58
<i>gC</i>	1.94	1.68	1.62	1.65	1.71
<i>gI</i>	5.66	4.63	4.47	4.60	5.52
<i>dTB/Y</i>	1.38	1.46	0.98	1.44	1.12
S.D. (X) / S.D. (gY)					
<i>gC</i>	1.27	1.36	1.05	1.36	1.08
<i>gI</i>	3.71	3.76	2.90	3.77	3.49
<i>dTB/Y</i>	0.91	1.18	0.64	1.18	0.71
Correlation with <i>gY</i>					
<i>gC</i>	0.76	0.95	0.95	0.95	0.98
<i>gI</i>	0.75	0.79	0.90	0.79	0.88
<i>dTB/Y</i>	-0.44	-0.65	-0.54	-0.64	-0.71
Correlation with <i>dTB/Y</i>					
<i>gC</i>	-0.50	-0.83	-0.78	-0.83	-0.82
<i>gI</i>	-0.67	-0.97	-0.85	-0.97	-0.95
Serial Correlation					
<i>gY</i>	0.27	0.19	0.15	0.19	0.27
<i>gC</i>	0.20	0.18	0.08	0.18	0.19
<i>gI</i>	0.44	-0.06	-0.02	-0.06	-0.01
<i>dTB/Y</i>	0.33	-0.08	-0.05	-0.08	-0.02

Note: *gX* denotes log-differences, *dX* denotes first differences. Model-based moments using observables {*gY*, *gC*, *gI*, *dTB/Y*} from the Mexican Data, 1980.1-2003.2. Moments are computed using posterior mode estimates. Standard Errors are omitted for brevity but are available upon request. All estimations were done using measurement errors in all four variables. Aguiar and Gopinath (2004) conduct the GMM estimation based upon 11 moments of which only two, the standard deviation and serial correlations of *gY*, are reported in Table 7.1, the other 9 moments refer to Hodrick-Prescott filtered moments which we don't present here given that we don't use this filtering technique.

Table I.7.2. Second Moments. Estimations Without Measurement Errors

Variable	Mexican Data	Observables: { g^Y , dTB/Y }		Observables: { g^Y , g^I }		Observables: { g^Y , g^C }	
		Stochastic Trend	Financial Frictions	Stochastic Trend	Financial Frictions	Stochastic Trend	Financial Frictions
Standard Deviations (%)							
g^Y	1.53	2.06	1.43	2.66	1.52	2.32	1.63
g^C	1.94	2.33	2.25	2.78	3.17	2.63	2.43
g^I	5.66	5.07	3.57	7.71	6.08	3.94	6.39
dTB/Y	1.38	1.37	1.58	1.93	2.89	1.33	2.56
S.D. (X) / S.D. (gY)							
g^C	1.27	1.13	1.57	1.05	2.08	1.13	1.49
g^I	3.71	2.46	2.50	2.90	4.00	1.69	3.93
dTB/Y	0.91	0.67	1.10	0.72	1.90	0.57	1.57
Correlation with g^Y							
g^C	0.76	0.92	0.90	0.91	0.84	0.91	0.82
g^I	0.75	0.86	0.70	0.84	0.73	0.84	0.59
dTB/Y	-0.44	-0.41	-0.45	-0.38	-0.57	-0.20	-0.34
Correlation with dTB/Y							
g^C	-0.50	-0.73	-0.80	-0.72	-0.92	-0.59	-0.81
g^I	-0.67	-0.82	-0.95	-0.82	-0.98	-0.71	-0.96
Serial Correlation							
g^Y	0.27	0.17	0.19	0.16	0.15	0.14	0.17
g^C	0.20	0.08	0.21	0.09	0.05	0.07	0.17
g^I	0.44	-0.29	-0.04	-0.02	-0.03	0.02	-0.04
dTB/Y	0.33	-0.05	-0.06	-0.05	-0.04	-0.05	-0.05

Note: g^X denotes log-differences, dX denotes first differences. Model-based moments using different pairs of observables and no measurement errors from the Mexican Data, 1980.1-2003.2. Moments are computed using posterior mode estimates. Standard Errors are omitted for brevity but are available upon request.

**Table I.8. Posterior Distributions.
Robustness Cases 1-3-4**

Parameter	Robustness 1: Uninformative Priors					Robustness 3 and 4		
	Prior Distribution	Prior Mean	High Posterior Mode	Low Posterior Mode	Posterior Mean	Prior Distribution	Robustness 3: Posterior Mean	Robustness 4: Posterior Mean
ρ_a	Beta (2,2)	0.50	0.89	0.67	0.91 [0.83, 0.98]	0.95 [0.92, 0.97]	0.88 [0.87, 0.90]	0.89 [0.87, 0.92]
$100\sigma_a$	Uniform (0.01,10)	5.00	0.82	0.46	0.84 [0.74, 0.96]	0.74 [0.12, 1.67]	1.02 [0.82, 1.25]	0.66 [0.50, 0.83]
ϕ	Uniform (0.0,40)	20.0	8.75	2.30	7.92 [4.02, 11.95]	6.00 [1.62, 12.6]	16.40 [12.40, 20.79]	14.87 [11.92, 18.01]
$100\sigma_Y$	Uniform (0.01,10)	5.00	0.01	0.01	0.09 [0.01, 0.31]	2.00 [0.67, 3.86]	0.43 [0.16, 0.68]	0.59 [0.20, 0.90]
$100\sigma_C$	Uniform (0.01,10)	5.00	1.19	1.19	1.20 [1.05, 1.37]	2.00 [0.67, 3.86]	1.19 [1.04, 1.36]	1.18 [1.00, 1.38]
$100\sigma_I$	Uniform (0.01,10)	5.00	2.89	2.82	3.02 [2.47, 3.54]	2.00 [0.67, 3.86]	2.96 [2.44, 3.47]	3.08 [2.57, 3.66]
$100\sigma_{TB/Y}$	Uniform (0.01,10)	5.00	0.64	0.81	0.48 [0.03, 0.84]	2.00 [0.67, 3.86]	0.65 [0.37, 0.90]	0.71 [0.18, 0.97]
ρ_g	Beta (2,2)	0.50	0.50	0.50	0.52 [0.06, 0.96]	0.72 [0.68, 0.76]	0.72 [0.68, 0.75]	0.72 [0.68, 0.76]
$100\sigma_g$	Uniform (0.01,10)	5.00	0.02	1.12	0.03 [0.01, 0.08]	0.74 [0.12, 1.67]	0.06 [0.00, 0.16]	0.11 [0.01, 0.30]
ρ_R	Beta (2,2)	0.50	0.93	0.87	0.94 [0.86, 0.99]	0.83 [0.74, 0.91]	0.82 [0.72, 0.89]	0.82 [0.72, 0.90]
$100\sigma_R$	Uniform (0.01,10)	5.00	0.17	0.04	0.16 [0.07, 0.30]	0.72 [0.30, 1.29]	0.36 [0.25, 0.49]	0.41 [0.26, 0.57]
θ	Beta (2,2)	0.50	0.65	0.76	0.62 [0.13, 0.96]	0.50 [0.13, 0.87]	0.56 [0.18, 0.88]	0.69 [0.26, 0.96]
η	Uniform (0.0,5.0)	2.50	0.32	0.00	0.25 [0.01, 0.52]	1.00 [0.84, 1.17]	0.67 [0.56, 0.79]	0.73 [0.60, 0.87]
γ	Uniform (0.001,1.0)					0.50 [0.05, 0.95]	0.05 [0.00, 0.13]	
ξ	Gamma (25,0.1)					2.50 [1.72, 3.35]		2.51 [1.97, 3.06]
RWC		1.01	0.00	2.48	0.33 [0.00, 0.40]		0.04 [0.00, 0.16]	0.28 [0.00, 1.18]
Log-Posterior at Mode			1014.6	1009.0			1011.3	1009.9
Log-Likelihood at Posterior Mode			1004.6	997.8			1000.5	991.6

Note: All robustness cases were estimated using observables {gY, gC, gI, dTB/Y} from the Mexican Data, 1980.1-2003.2 using measurement errors in all four variables.

**Table I.9. Forecast Error Variance Decompositions.
Robustness Cases 1-3-4-5**

Structural Shock	gY	gC	gI	dTB/Y
Robustness 1: Uninformative Priors				
ε^a	97.56	87.37	64.59	22.11
ε^g	0.16	0.68	0.17	0.78
ε^{R^*}	2.28	11.95	35.24	77.11
Robustness 3: Jaimovich-Rebelo Preferences				
ε^a	87.57	94.91	85.64	58.68
ε^g	1.09	1.82	0.66	2.05
ε^{R^*}	11.34	3.27	13.71	39.27
Robustness 4: Estimating Long-Run Growth				
ε^a	91.38	85.74	73.72	53.37
ε^g	2.46	3.19	1.34	1.76
ε^{R^*}	6.16	11.07	24.94	44.87
Robustness 5: Observing $\{R^*,R\}$				
ε^a	61.72	53.16	76.70	67.45
ε^g	37.96	46.20	17.98	16.01
ε^{R^*}	0.32	0.65	5.32	16.55

Note: gX denotes log-differences, dX denotes first differences. Model-based moments using different pairs of observables and no measurement errors from the Mexican Data, 1980.1-2003.2. Moments are computed using posterior means. Standard Errors are omitted for brevity but are available upon request.

Table I.10. Posterior Distributions. Robustness Case 2

Parameter	Prior	No Working Capital $\theta = 0$		No Endogenous Spread $\eta = 0$		No Financial Frictions $\theta = \eta = 0$	
		Posterior Mode	Mean	Posterior Mode	Mean	Posterior Mode	Mean
ρ_a	0.95 [0.92, 0.97]	0.89	0.89 [0.87, 0.91]	0.96	0.96 [0.94, 0.97]	0.96	0.96 [0.94, 0.97]
$100\sigma_a$	0.74 [0.12, 1.67]	0.78	0.78 [0.64, 0.91]	0.71	0.73 [0.58, 0.85]	0.73	0.74 [0.61, 0.89]
ϕ	6.00 [1.62, 12.6]	15.14	15.41 [12.43, 18.8]	4.11	4.28 [2.90, 5.92]	4.02	4.13 [2.94, 5.51]
$100\sigma_Y$	2.00 [0.67, 3.86]	0.53	0.54 [0.26, 0.80]	0.35	0.34 [0.15, 0.58]	0.35	0.31 [0.11, 0.54]
$100\sigma_C$	2.00 [0.67, 3.86]	1.17	1.18 [1.00, 1.39]	1.12	1.14 [0.98, 1.32]	1.13	1.15 [1.01, 1.33]
$100\sigma_I$	2.00 [0.67, 3.86]	2.87	2.99 [2.51, 3.54]	2.65	2.68 [2.15, 3.21]	2.66	2.70 [2.16, 3.22]
$100\sigma_{TB/Y}$	2.00 [0.67, 3.86]	0.79	0.80 [0.56, 1.03]	0.73	0.74 [0.54, 0.94]	0.72	0.73 [0.52, 0.94]
ρ_g	0.72 [0.68, 0.76]	0.72	0.72 [0.68, 0.75]	0.71	0.71 [0.67, 0.75]	0.71	0.71 [0.68, 0.75]
$100\sigma_g$	0.74 [0.12, 1.67]	0.12	0.10 [0.01, 0.26]	0.62	0.57 [0.27, 0.81]	0.62	0.59 [0.29, 0.84]
ρ_R	0.83 [0.74, 0.91]	0.84	0.84 [0.75, 0.91]	0.86	0.85 [0.77, 0.92]	0.86	0.86 [0.78, 0.93]
$100\sigma_R$	0.72 [0.30, 1.29]	0.37	0.37 [0.22, 0.53]	0.14	0.15 [0.09, 0.22]	0.14	0.14 [0.09, 0.20]
θ	0.50 [0.13, 0.87]			0.65	0.61 [0.10, 0.96]		
η	1.00 [0.84, 1.17]	0.71	0.71 [0.60, 0.83]				
RWC	3.15 [0.18, 6.37]	0.13	0.14 [0.00, 0.57]	2.62	2.31 [0.69, 3.60]	2.38	2.20 [0.61, 3.49]

**Table I.11. Forecast Error Variance Decompositions.
Robustness Case 2**

Structural Shock	gY	gC	gI	dTB/Y
No Working Capital Needs: $\theta = 0$				
ε^a	97.97	91.62	78.79	56.52
ε^g	1.38	2.09	0.88	1.34
ε^{R^*}	0.65	6.29	20.33	42.14
No Endogenous Spread: $\eta = 0$				
ε^a	72.67	47.53	32.11	3.50
ε^g	25.84	49.65	30.55	39.22
ε^{R^*}	1.50	2.82	37.34	57.28
No Financial Frictions: $\theta = \eta = 0$				
ε^a	73.23	47.78	33.99	4.16
ε^g	25.98	50.41	31.66	41.57
ε^{R^*}	0.79	1.81	34.35	54.28

Note: gX denotes log-differences, dX denotes first differences. Variance decompositions computed from the estimation using four observables and measurement errors in all variables. Numbers reported using posterior means estimates. Standard Errors are omitted for brevity but are available upon request. In the variance decomposition computations only the role of the structural shocks was taken into account.

Table I.12. Second Moments. Robustness Case 2

Variable	Mexican Data	No Working Capital $\theta = 0$	No Endogenous Spread $\eta = 0$	No Financial Frictions $\theta = \eta = 0$
Standard Deviations (%)				
<i>gY</i>	1,53	1,38	1,49	1,51
<i>gC</i>	1,94	1,79	1,50	1,51
<i>gI</i>	5,66	4,76	4,58	4,64
<i>dTB/Y</i>	1,38	1,44	1,24	1,26
S.D. (X) / S.D. (gY)				
<i>gC</i>	1,27	1,30	1,00	1,00
<i>gI</i>	3,71	3,45	3,07	3,07
<i>dTB/Y</i>	0,91	1,04	0,83	0,83
Correlation with <i>gY</i>				
<i>gC</i>	0,76	0,96	0,94	0,94
<i>gI</i>	0,75	0,87	0,72	0,73
<i>dTB/Y</i>	-0,44	-0,70	-0,35	-0,36
Correlation with <i>dTB/Y</i>				
<i>gC</i>	-0,50	-0,88	-0,60	-0,61
<i>gI</i>	-0,67	-0,96	-0,88	-0,88
Serial Correlation				
<i>gY</i>	0,27	0,00	0,11	0,11
<i>gC</i>	0,20	-0,04	0,08	0,07
<i>gI</i>	0,44	-0,06	-0,04	-0,04
<i>dTB/Y</i>	0,33	-0,07	-0,07	-0,07

Note: *gX* denotes log-differences, *dX* denotes first differences. Model-based moments using observables {*gY*, *gC*, *gI*, *dTB/Y*} from the Mexican Data, 1980.1-2003.2. Moments are computed using posterior mode estimates. Standard Errors are omitted for brevity but are available upon request. All estimations were done using measurement errors in all four variables.

Table II.1. Business Cycles Moments

Variable	sd(X)	sd(X) / sd(gY)	Corr(X _t , X _{t-1})	Corr(X _t , gY _{t-s})			Corr (X _t , dTBY _t)
				s = 1	s = 0	s = -1	
Developed Countries							
<i>gY</i>	0.97	1.00	0.10	0.10	1.00	0.10	0.06
<i>gC</i>	0.87	0.91	0.07	0.17	0.43	0.19	-0.18
<i>gI</i>	3.41	3.50	0.06	0.17	0.46	0.22	-0.29
<i>dTBY</i>	0.98	1.07	-0.15	-0.12	0.06	-0.10	1.00
Developing Countries							
<i>gY</i>	1.87	1.00	0.23	0.23	1.00	0.23	-0.27
<i>gC</i>	2.82	1.62	0.11	0.21	0.53	0.21	-0.51
<i>gI</i>	7.14	4.13	0.11	0.34	0.51	0.22	-0.45
<i>dTBY</i>	2.49	1.56	0.11	-0.24	-0.27	-0.21	1.00
Colombia							
<i>gY</i>	1.22	1.00	0.20	0.20	1.00	0.20	-0.53
<i>gC</i>	0.83	0.67	0.33	0.36	0.65	0.34	-0.49
<i>gI</i>	6.05	4.94	0.25	0.29	0.81	0.11	-0.84
<i>dTBY</i>	1.05	0.86	0.30	-0.43	-0.53	-0.16	1.00
<i>gR*</i>	0.46	0.37	0.05	0.00	0.03	-0.21	-0.11
<i>gToT</i>	5.29	4.32	0.12	0.01	0.33	0.09	-0.39
<i>gG</i>	2.29	1.87	0.30	0.07	0.17	0.06	0.06

Note: *gX* and *dX* denote log differences and linear difference, respectively. *Y* is output; *C* is private consumption; *I* is investment; *TBY* is trade balance-to-GDP ratio; *R** is a proxy for the gross risky interest rate available to emerging economies similar to Colombia; *ToT* is a proxy of Colombian terms of trade index; and *G* is the level of public consumption. The source of data for Developed and Developing countries was Aguiar and Gopinath (2007). Colombian data is quarterly from 1994:1 to 2008:4. See appendix for more data sources and details.

Table II.2. Calibrated Parameters

<i>Parameter</i>	<i>Description</i>	<i>Calibrated Value</i>
σ	Intertemporal Elasticity of Substitution $[1/\sigma]$	2.0
ω	Labor Supply Elasticity $[\frac{1}{\omega-1}]$	1.6
<i>h-Share</i>	Labor Share of Income	0.68
R^*	Gross Annual Foreign Interest Rate	1.0816
μ	Long-run Gross Productivity Growth Rate	1.0077
ψ	Debt Elastic Interest Rate Parameter	0.001
β	Discount Factor	0.9976
S	Long-run Gross Country Interest Rate Premium	1.0
δ	Depreciation Rate of Capital	0.20
d	Debt-to-GDP Ratio (D/Y)	0.100
G/Y	Government Expenditure Share of Income	0.19
h	Labor in steady state	1/3

Note: Note that α is not exactly equal to labor share (***h-Share***) but it is rather $\alpha = \mathbf{h-Share} * [1 + (R^* - 1)\theta]$ and its distribution is a function of the distribution of θ .

Table II.3. Prior Distributions

Parameter	Range	Density	Mean	S.D (%)	90% Conf. Interval	
ρ_S	AR(1) Coeff. in five driving processes, $S = a, g, r, gov, tot$	[0,1)	Beta [5.0 ; 2.0]	0.72	16	[0.42 ; 0.94]
σ_S	S.D. of Shock in five driving processes (%), $S = a, g, r, gov, tot$	R^+	Gamma [4.0 ; 0.005]	2.00	1.0	[0.70 ; 3.91]
ϕ	Capital Adjustment Cost Fct. Parameter	R^+	Gamma [3.0 ; 2.0]	6.00	346	[1.62 ; 12.6]
σ_X	S.D. (%) of Measurement Error in $X = Y, C, I, TBY$	R^+	Gamma [4.0 ; 0.005]	2.00	1.0	[0.70 ; 3.91]
θ	Working Capital Parameter	[0,1]	Beta [2.0 ; 2.0]	0.50	22.4	[0.13 ; 0.87]
γ_J	Weight of Importables in aggregator of $J = C, I$	[0,1]	Beta [3.0 ; 12.0]	0.20	10.0	[0.06 ; 0.39]
η	Spread Elasticity	R^+	Gamma [4.0 ; 0.25]	1.00	50	[0.35 ; 1.95]
ν_J	Elasticity of substitution in aggregator of $J = C, I$	R^+	Gamma [4.0 ; 0.25]	1.00	50	[0.35 ; 1.95]
ρ_{GY}	Elasticity of Gov. Expenditure to lagged deviations in output	R	Normal [0.0 ; 1.0]	0.00	100	[-1.66 ; 1.66]

Table II.4. Prior / Posterior Distributions

Parameter	Prior Distribution	Posterior Distribution		Parameter	Prior Distribution	Posterior Distribution	
		Mode	Mean			Mode	Mean
ρ_a	0.72 [0.42, 0.94]	0.97	0.97 [0.94, 0.99]	$100\sigma_Y$	2.00 [0.70, 3.91]	0.27	0.30 [0.11, 0.51]
ρ_g	0.72 [0.42, 0.94]	0.65	0.69 [0.43, 0.96]	$100\sigma_C$	2.00 [0.70, 3.91]	0.37	0.43 [0.15, 0.67]
ρ_r	0.72 [0.42, 0.94]	0.98	0.96 [0.83, 0.99]	$100\sigma_I$	2.00 [0.70, 3.91]	2.32	2.58 [1.96, 3.24]
ρ_{gov}	0.72 [0.42, 0.94]	0.78	0.70 [0.51, 0.86]	$100\sigma_{TBY}$	2.00 [0.70, 3.91]	0.26	0.25 [0.09, 0.51]
ρ_{tot}	0.72 [0.42, 0.94]	0.86	0.85 [0.64, 0.98]	γ_C	0.20 [0.06, 0.39]	0.18	0.16 [0.02, 0.34]
$100\sigma_a$	2.00 [0.70, 3.91]	0.72	0.71 [0.56, 0.87]	γ_I	0.20 [0.06, 0.39]	0.15	0.16 [0.03, 0.37]
$100\sigma_g$	2.00 [0.70, 3.91]	0.36	0.27 [0.09, 0.50]	η	1.00 [0.35, 1.95]	0.89	0.79 [0.41, 1.21]
$100\sigma_r$	2.00 [0.70, 3.91]	0.66	0.55 [0.25, 0.81]	ν_C	1.00 [0.35, 1.95]	0.75	0.78 [0.23, 1.61]
$100\sigma_{gov}$	2.00 [0.70, 3.91]	0.84	0.90 [0.30, 1.72]	ν_I	1.00 [0.35, 1.95]	0.75	0.76 [0.21, 1.58]
$100\sigma_{tot}$	2.00 [0.70, 3.91]	1.64	1.65 [0.40, 3.38]	ρ_{GY}	0.00 [-1.66, 1.66]	1.04	1.30 [0.66, 1.94]
ϕ	6.00 [1.62, 12.6]	6.89	5.77 [3.15, 9.38]	RWC	2.73 [0.70, 24.59]	0.77	0.64 [0.04, 27.84]
θ	0.50 [0.13, 0.87]	0.04	0.04 [0.00, 0.12]				

Note: Estimates obtained using four observables, {gY, gC, gI, dTBY} from the Colombian quarterly data, 1994:1-2008:4 (see Appendix for data sources). Estimations were done using measurement errors in all four variables. RWC refers to the random walk component, see text for details. Numbers in brackets report the 90 percent confidence intervals from each posterior distribution.

Table II.5. Forecast Error Variance Decompositions

Structural Shock	gY	gC	gI	$dTBY$
ε^a	74.2	43.1	60.4	19.3
ε^g	6.9	26.0	2.1	1.9
ε^r	17.0	19.9	37.4	75.5
ε^{gov}	0.0	0.0	0.0	2.0
ε^{tot}	1.9	11.0	0.2	1.4

Note: gX denotes log-differences, dX denotes first differences. Variance decompositions computed from the estimation using four observables and measurement errors in all variables. Numbers reported using posterior mode estimates. Standard Errors are omitted for brevity but are available upon request. In the variance decomposition computations only the role of the structural shocks was taken into account. A time horizon of 40 quarters was used when computing the variance decomposition.

Table II.6. Sample and Model-Based Business Cycles Moments

Variable	sd(X)	sd(X) / sd(gY)	Corr(X_t, X_{t-1})	Corr(X_t, gY_{t-s})			Corr ($X_t, dTBY_t$)
				s=1	s=0	s=-1	
Colombia							
gY	1.22	1.00	0.20	0.20	1.00	0.20	-0.53
gC	0.83	0.67	0.33	0.36	0.65	0.34	-0.49
gI	6.05	4.94	0.25	0.29	0.81	0.11	-0.84
$dTBY$	1.05	0.86	0.30	-0.43	-0.53	-0.16	1.00
gR^*	0.46	0.37	0.05	0.00	0.03	-0.21	-0.11
$gToT$	5.29	4.32	0.12	0.01	0.33	0.09	-0.39
gG	2.29	1.87	0.30	0.07	0.17	0.06	0.06
Model Based Moments							
gY	1.79	1.00	0.53	0.53	1.00	0.53	-0.30
gC	1.26	0.71	0.55	0.55	0.81	0.48	-0.28
gI	5.62	3.14	0.08	0.12	0.61	0.37	-0.59
$dTBY$	1.18	0.66	0.20	-0.31	-0.30	-0.38	1.00
gR^*	0.66	0.37	-0.01	0.01	0.02	-0.19	0.80
$gToT$	1.70	0.95	-0.07	-0.01	0.13	-0.02	0.10
gG	5.56	3.11	0.92	0.74	0.52	0.44	-0.51

Note: gX and dX denote log differences and linear difference, respectively. See appendix for data sources. Model-based moments were computed using posterior mode. Confidence intervals are omitted for brevity but are available upon request.

Table II.7. Bayesian Model Comparison

Models	Log-Likelihood	Log-Posterior	Marginal Log-Likelihood
Estimating the Full Model: with 5 Structural Shocks: $\{\varepsilon^a, \varepsilon^g, \varepsilon^r, \varepsilon^{gov}, \varepsilon^{tot}\}$			
Full Model	702.59	723.72	650.92
Estimating the Model with Only Two Structural Shocks: $\{\varepsilon^a, \varepsilon^x\}$			
$\{\varepsilon^a, \varepsilon^g\}$	669.86	680.68	642.43
$\{\varepsilon^a, \varepsilon^r\}$	668.73	680.01	638.08
$\{\varepsilon^a, \varepsilon^{gov}\}$	685.94	694.58	654.96
$\{\varepsilon^a, \varepsilon^{tot}\}$	672.06	687.46	645.25
Estimating the Model Removing Only One Shock at a Time			
No Interest Rate Shocks $\{\varepsilon^a, \varepsilon^g, \varepsilon^{gov}, \varepsilon^{tot}\}$	699.87	715.59	655.23
No Terms of Trade Shocks $\{\varepsilon^a, \varepsilon^g, \varepsilon^r, \varepsilon^{gov}\}$	701.53	716.27	651.94
No Growth Shocks $\{\varepsilon^a, \varepsilon^r, \varepsilon^{gov}, \varepsilon^{tot}\}$	702.66	721.25	657.31
No Government Expenditure Shocks $\{\varepsilon^a, \varepsilon^g, \varepsilon^r, \varepsilon^{tot}\}$	669.42	687.35	627.28

Note: Log-Likelihood levels computed in the posterior mode. Results on marginal data densities are approximated by Geweke's harmonic mean estimator with truncation parameter 0.5.

Table II.8. Sample and Model-Based Business Cycles Moments. Annual Data: 1925-2008

Variable	sd(X)	sd(X) / sd(gY)	Corr(X _t , X _{t-1})	Corr(X _t , gY _{t-s})			Corr (X _t , dTBY _t)
				s=1	s=0	s=-1	
Colombia							
<i>gY</i>	2.44	1.00	0.32	0.32	1.00	0.32	-0.28
<i>gC</i>	6.12	2.51	-0.23	0.11	0.55	0.00	-0.46
<i>gI</i>	17.78	7.29	-0.21	0.27	0.26	0.30	-0.60
<i>dTBY</i>	3.72	1.53	-0.16	-0.25	-0.28	-0.15	1.00
<i>gR</i> *	n.a						
<i>gToT</i>	14.44	5.92	0.00	0.02	0.09	-0.01	-0.06
<i>gG</i>	11.28	4.63	-0.09	0.15	0.20	0.01	-0.05
Model Based Moments							
<i>gY</i>	3.29	1.00	0.42	0.42	1.00	0.42	0.11
<i>gC</i>	5.71	1.74	-0.05	0.18	0.44	-0.07	-0.24
<i>gI</i>	17.66	5.37	-0.13	-0.11	0.24	0.43	-0.48
<i>dTBY</i>	3.80	1.16	0.02	0.18	0.11	-0.03	1.00
<i>gR</i> *	0.79	0.24	-0.02	0.03	0.03	-0.33	-0.01
<i>gToT</i>	4.75	1.45	-0.22	0.03	0.17	-0.16	0.67
<i>gG</i>	14.79	4.50	0.95	0.30	0.10	0.02	-0.22

Note: gX and dX denote log differences and linear difference, respectively. See appendix for data sources. Model-based moments were computed using posterior mode. Confidence intervals are omitted for brevity but are available upon request.

**Table II.9. Prior / Posterior Distributions. Estimation with
Annual Data: 1925-2008**

Parameter	Prior Mode	Posterior Distribution		Parameter	Prior Mode	Posterior Distribution	
		Mode 1994:1-2008:4	Mode 1925-2008			Mode 1994:1-2008:4	Mode 1925-2008
ρ_a	0.72	0.97	0.98	$100\sigma_Y$	2.00	0.27	0.49
ρ_g	0.72	0.65	0.63	$100\sigma_C$	2.00	0.37	1.19
ρ_r	0.72	0.98	0.96	$100\sigma_I$	2.00	2.32	2.73
ρ_{gov}	0.72	0.78	0.99	$100\sigma_{TBY}$	2.00	0.26	0.95
ρ_{tot}	0.72	0.86	0.55	γ_C	0.20	0.18	0.07
$100\sigma_a$	2.00	0.72	0.37	γ_I	0.20	0.15	0.25
$100\sigma_g$	2.00	0.36	1.86	η	1.00	0.89	0.61
$100\sigma_r$	2.00	0.66	0.78	ν_C	1.00	0.75	0.67
$100\sigma_{gov}$	2.00	0.84	1.36	ν_I	1.00	0.75	0.72
$100\sigma_{tot}$	2.00	1.64	4.19	ρ_{GY}	0.00	1.04	0.04
ϕ	6.00	6.89	2.41	RWC	2.73	0.77	4.19
θ	0.50	0.04	0.80				

Note: Estimates obtained using four observables, {gY, gC, gI, dTBY} from the Colombian annual data, 1925-2008 (see Appendix for data sources). Estimations were done using measurement errors in all four variables. RWC refers to the random walk component, see text for details.

**Table II.10. Forecast Error Variance Decompositions.
Estimation with Annual Data**

Structural Shock	gY	gC	gI	$dTBY$
ε^a	26,9	1,4	9,9	1,0
ε^g	45,7	15,3	18,6	12,3
ε^r	16,8	80,9	23,1	22,6
ε^{gov}	0,0	0,1	0,0	0,0
ε^{tot}	10,6	2,3	48,3	64,0

Note: gX denotes log-differences, dX denotes first differences. Variance decompositions computed from the estimation using four observables and measurement errors in all variables. Numbers reported using posterior mode estimates. Standard Errors are omitted for brevity but are available upon request. In the variance decomposition computations only the role of the structural shocks was taken into account. A time horizon of 40 quarters was used when computing the variance decomposition.

**Table III.1. Capital Inflows to Latin America, 1920-1935
(Millions of Dollars)**

Period	New Foreign Bonds Issues in US Markets		Gross Supply of US Private Funds to Latin America						
	TOTAL Gross Nominal Value	From Latin America	Total	Argentina	Brazil	Chile	Colombia	Peru	Others
1920	497	45	-	-	-	-	-	-	-
1921 - 1923	1808	568	411	151	139	62	7	3	50
1924 - 1925	2045	345	317	257	9	18	13	15	5
1926 - 1928	3713	1038	990	263	198	178	183	94	74
1929 - 1931	1805	377	288	171	41	64	2	2	8
1932 - 1935	85	2	-	-	-	-	-	-	-

Source: Avella (2007)

Table III.2. Colombian Bonds in US and Net Capital Flows to Colombia, 1923-1934.

Year	Price Index of Colombian Bonds in New York (1927=100)		Net Capital Inflows to Colombia			
	7% Bonds	6,5% Bonds	Source: Meisel (1990)		Source: Urrutia y Fernandez (2003)	
			Total Value (Thousands of Dollars)	Share of Total foreign Income (%)	Using BoP data (% of GDP)	Using National Accounts Data (% of GDP)
1923		103,28	8655	12,2		
1924		108,61	8195	8,3		-1,8
1925		109,56	6708	7,0	2,0	2,2
1926		109,70	28164	18,4	0,8	1,0
1927	100,00	100,00	52957	28,0	3,7	1,9
1928	101,19	97,13	66235	28,6	4,1	3,0
1929	93,61	75,96			-1,3	-2,0
1930	80,30	66,12			-7,8	-6,3
1931	51,68	25,14			-11,0	-9,3
1932	17,66	33,33			-7,9	-5,3
1933	18,09	23,50			-2,9	-3,0
1934	17,44				-5,2	-6,2

Note: Data on 7% and 6,5% bonds taken from Patino Roselli (1981) and The Commercial and Financial Chronicle Journal, respectively.

Table III.3. Aggregate, Sectoral and Other Economic Indicators of Colombia: 1923-1936

Year	Macro. Indicators					Sector Indicators		
	GDP	Private Consumption	Investment	Trade Balance to GDP (%)	Real Exchange Rate	Agriculture and Mining	Industry and Manufacturing	Construction
1923	90				120			
1924	95				106			
1925	100	100	100	2,3	100	100	100	100
1926	110	106	124	2,4	89	113	110	200
1927	119	110	147	-0,5	79	115	108	202
1928	128	110	180	-1,0	73	126	109	325
1929	133	119	152	3,7	83	128	113	246
1930	132	109	99	15,1	104	134	107	163
1931	130	113	81	14,6	110	127	105	139
1932	138	110	115	14,8	124	133	120	143
1933	146	132	95	11,9	141	139	140	177
1934	155	153	95	9,5	163	144	149	159
1935	159	148	113	12,1	187	146	164	202
1936	167	154	122	12,0	169	155	179	216
Other Economic Indicators								
Year	Loans by the Financial System to GDP (%)	Tons of Cargo shipped through the Magdalena River.	Girardot Livestock Trade Fair	Machinery Imports to GDP (%)	Flow of exchanged checks	Real Estate: Squared Mts. Of New Licenses.	Real Estate: New Mortgages Issued	Mortgages: Annual Average Interest Rates (%)
1923		75	76	3,6			163	13,81
1924	1,1	87	93	4,0	40	61	145	13,89
1925	6,7	100	100	4,8	100	100	100	12,12
1926	7,1	126	130	4,8	143	158	96	11,23
1927	8,1	146	119	3,1	201	228	145	11,63
1928	8,0	158	114	1,2	194	366	180	11,19
1929	8,7	149	75	0,8	184	387	219	12,4
1930	9,6	105	68	0,8	136	231	210	15,08
1931	9,5	91	66	1,5	135	141	204	14,42
1932	7,7	101	42	2,3	151	128	65	10,63
1933	6,2	111	58	2,8	200	445	33	9,13
1934	4,0	135	79	3,1	217	464	27	10,02
1935	4,3	146	115	4,5	256	485	73	10,07
1936	4,7	158	128	4,1	273	483	76	10,64

Note: Unless specified, all variables are in real terms using the GDP deflator by GRECO (2002) and are presented as indices using 1925 as the base year. Sources: GDP taken from GRECO(2002); Uses and Sectors of GDP taken from DNP using CEPAL (1957); Loans taken from Superbancaria (1990); Machinery Imports taken from Ocampo y Montenegro (1984); All the other economic indicators taken from Patino (1981).

Table III.4. Empirical and Simulated Second Moments

Variable (X)	s.d(X) / s.d(Y)	cov(X)	Cross Correlation of X_(0) with		
			Y_(-1)	Y_(0)	Y_(+1)
Empirical Moments: Colombian Yearly data, 1925-1940					
Y	1,0	0,61 0,063	0,61 0,063	1,00 0,000	0,61 0,063
C	1,9	0,39 0,263	0,22 0,549	0,55 0,081	0,54 0,108
I	6,3	0,50 0,145	0,44 0,203	0,89 0,000	0,67 0,034
TB/Y	0,7	0,57 0,088	-0,31 0,381	-0,74 0,009	-0,84 0,003
R*	1,1	0,57 0,000	-0,37 0,290	-0,26 0,444	-0,31 0,390
Simulated Moments					
Y	1,0	0,87 0,001	0,87 0,001	1,00 0,000	0,87 0,001
C	1,6	0,92 0,000	0,65 0,040	0,92 0,000	0,99 0,000
I	0,1	0,88 0,001	0,95 0,000	0,96 0,000	0,74 0,014
TB/Y	0,3	0,74 0,014	0,41 0,243	-0,04 0,906	-0,71 0,020
R*	1,1	0,57 0,000	0,77 0,010	0,44 0,180	-0,21 0,560

Note: Moments taken from HP-filtered empirical and simulated variables. Small numbers are p-values for the Null of no significance.

Figure I.1. Priors and Posteriors: Encompassing Model

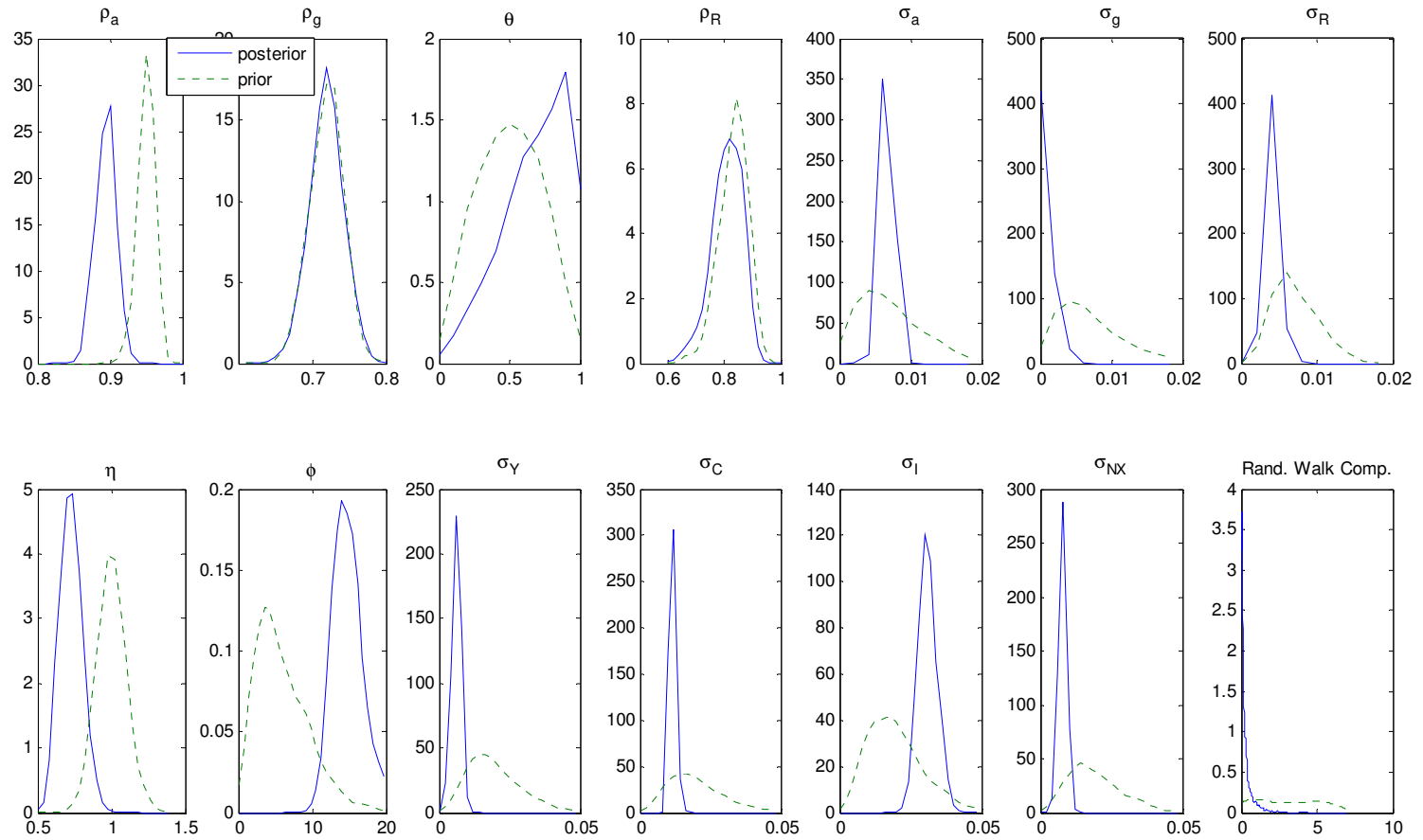
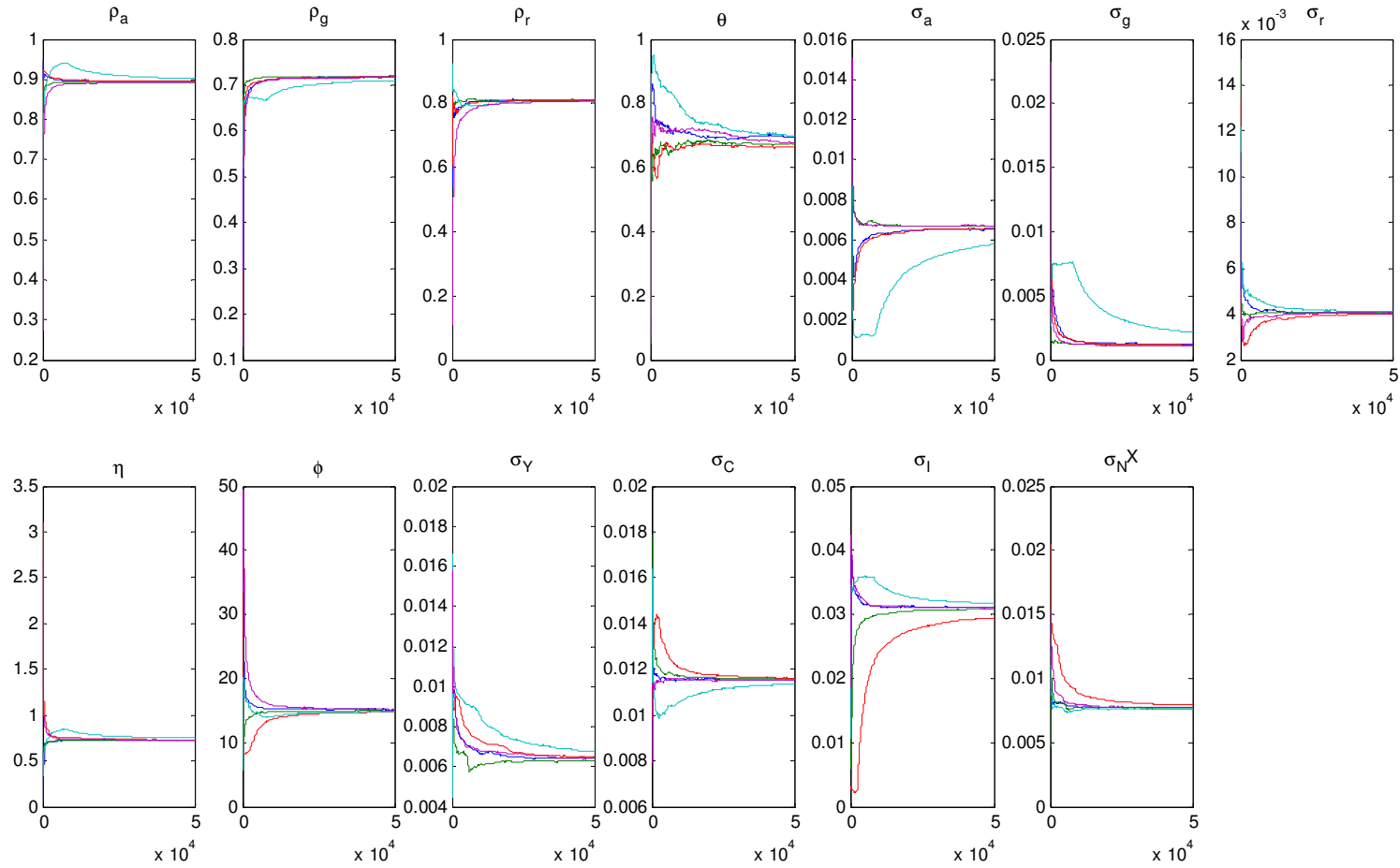
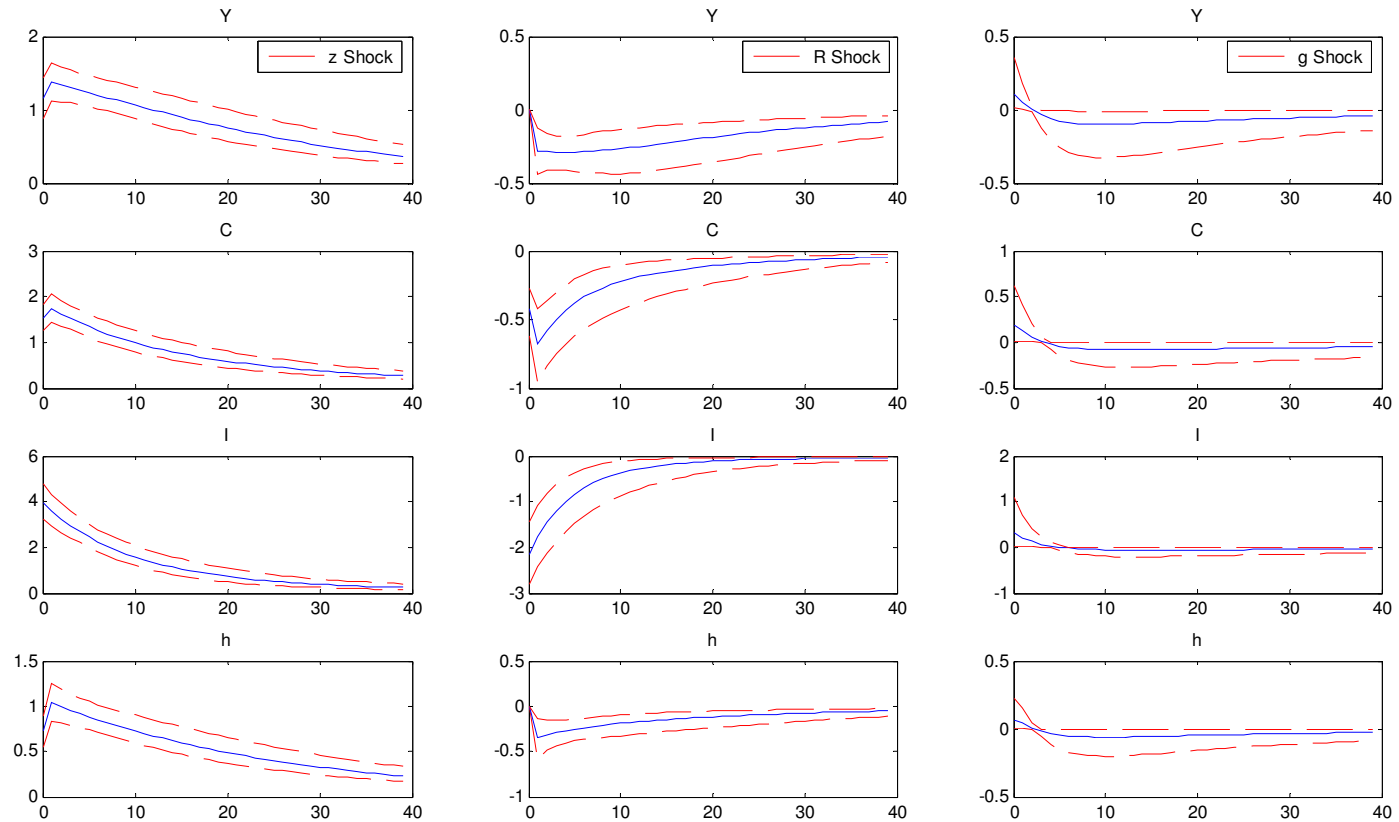


Figure I.2. Convergence Analysis



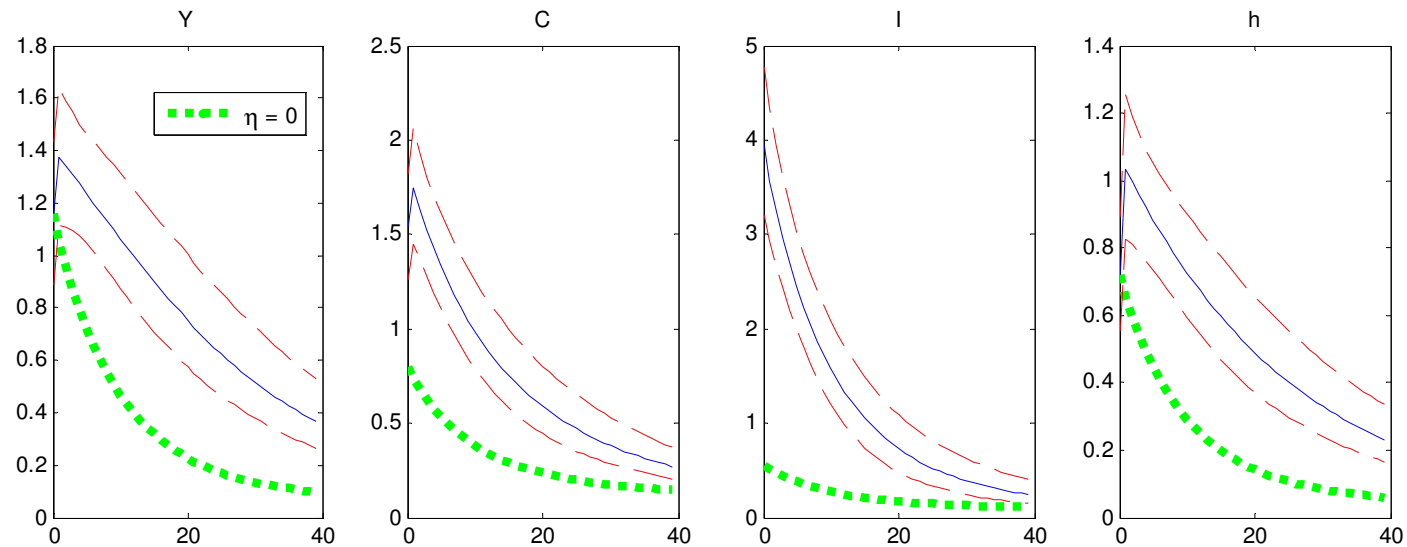
Note: Each line corresponds to recursive means for the 13 parameters as a function of the number of draws, computed from 6 independent MCMC chains using random starting values.

Figure I.3 Impulse Response Functions



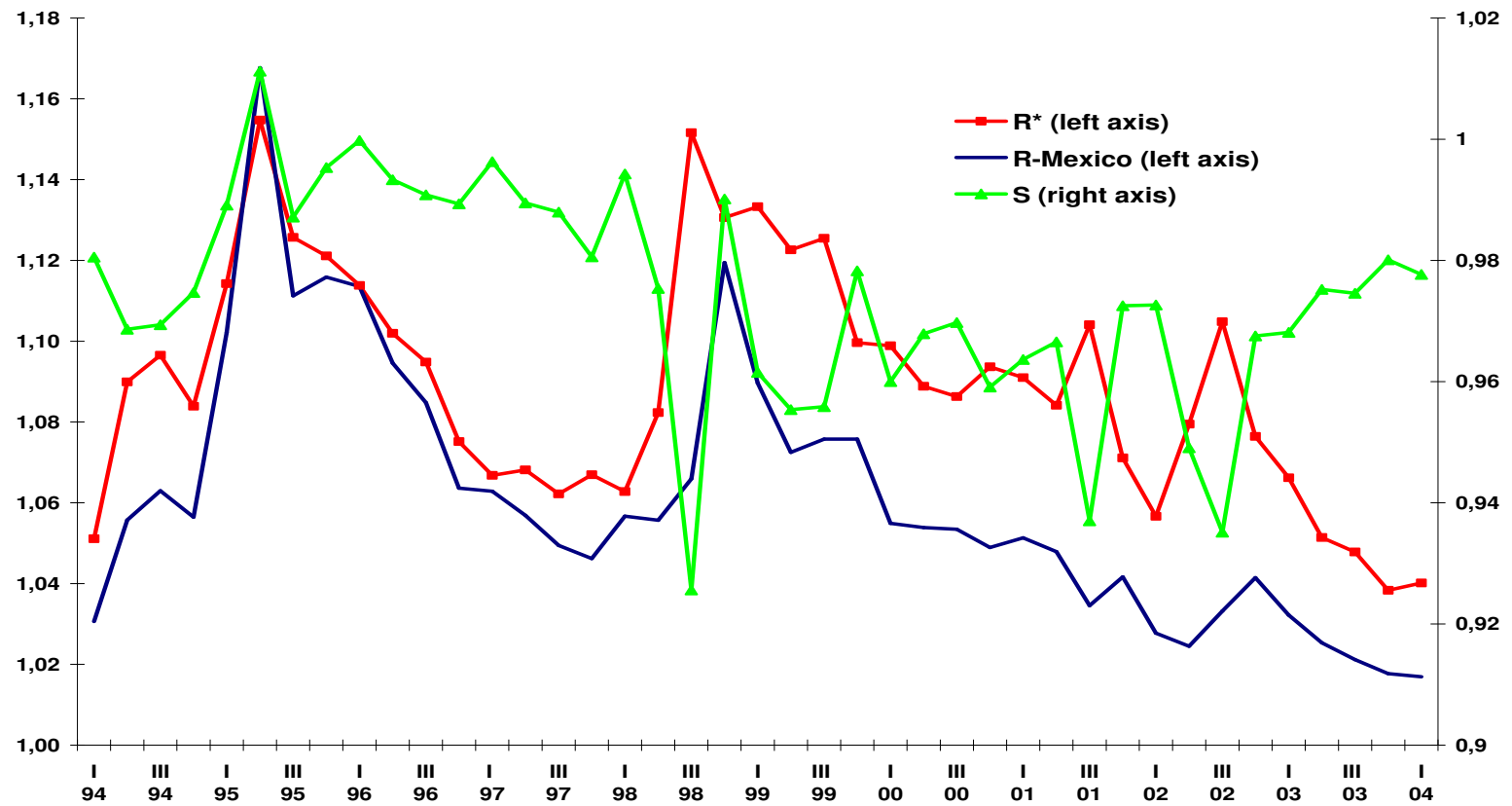
Note: Each column tracks the response of output (Y); consumption (C); investment (I), and employment (h) as deviations from steady states, after a 1 S.D. shock to the transitory technology process (Column 1); the foreign interest rate process (Column 2); and the growth process (Column 3). Dashed lines depict 90% confidence interval based upon the posterior distribution.

Figure I.4. Impulse Response Functions Following a Transitory Technology Shock: A Counterfactual Experiment



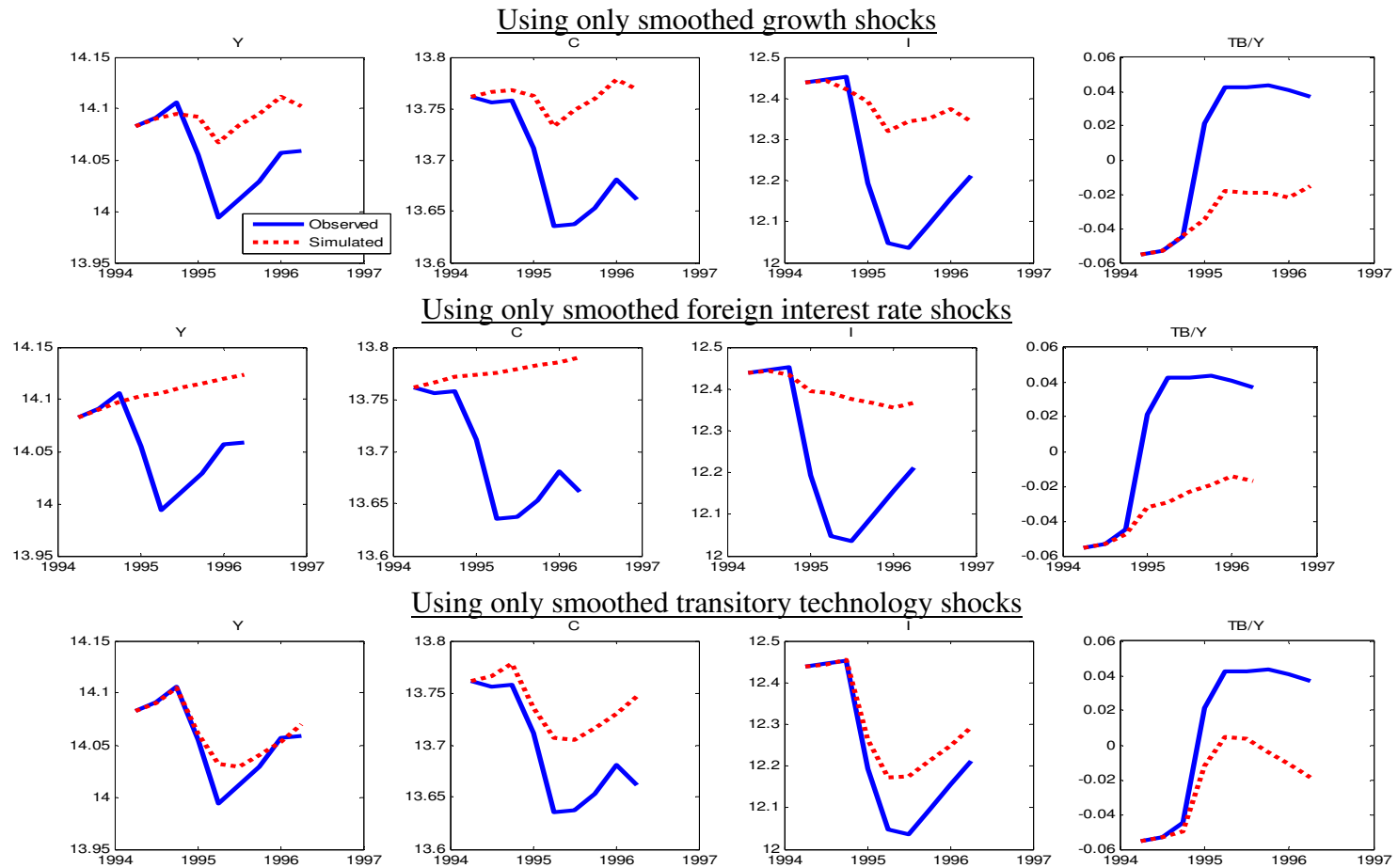
Note: Each column tracks the response of output (Y); consumption (C); investment (I), and employment (h) as deviations from steady states, after a 1 S.D. shock to the transitory technology process. Dashed lines depict 90% confidence interval based upon the posterior distribution. The green dotted line depicts the mean posterior distribution of the same impulse response function except that we counterfactually assume the parameter η to be zero.

Figure I.5. Time Series for Domestic and Foreign Interest Rates



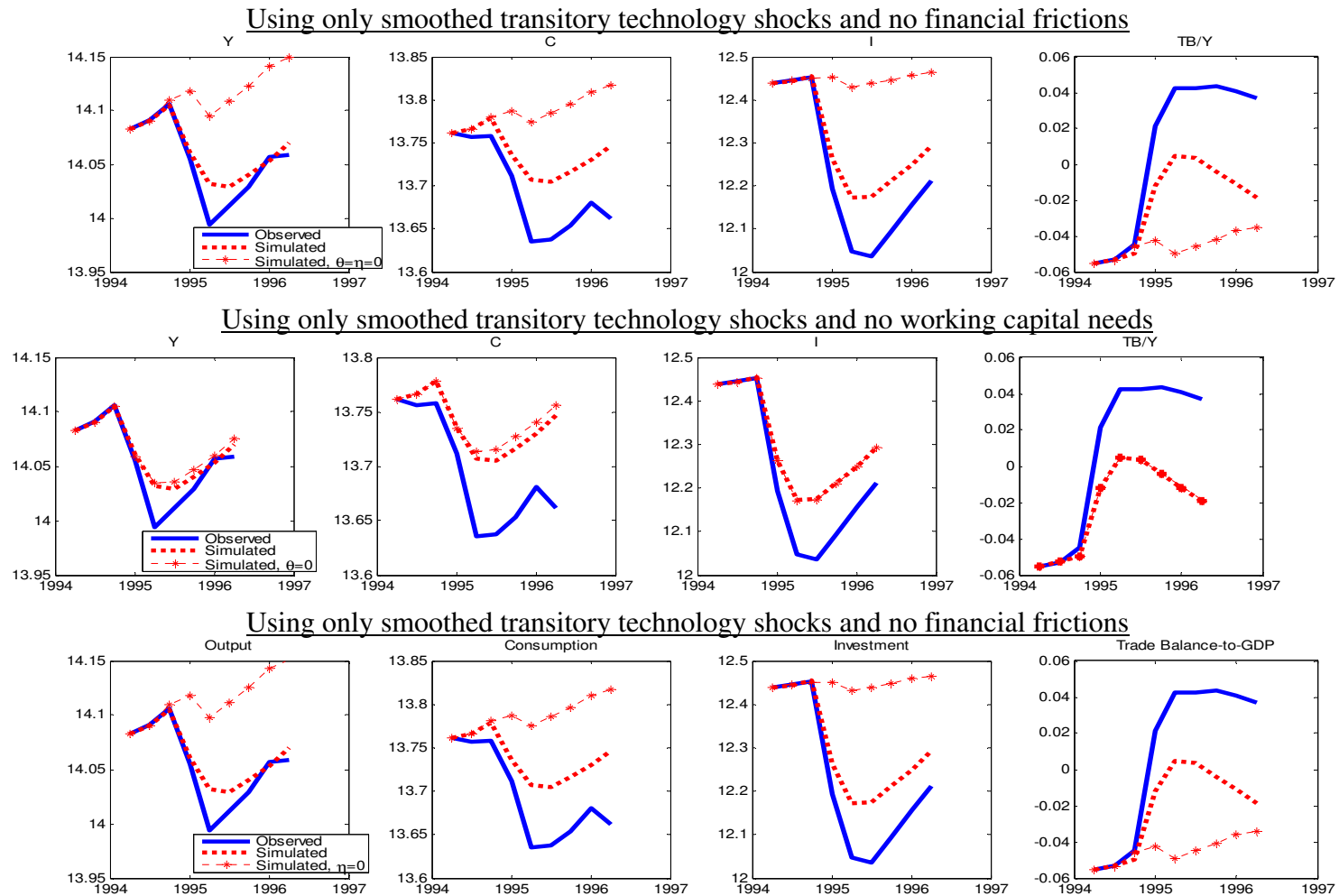
Note: R^* is the risky world interest rate measured as the safe interest rate (taken from the TBills rate) plus the EMBI+ for a pool of developing emerging market economies; R is the Mexican interest rate measured as the safe interest rate plus the EMBI+ Mexico; S is the implied spread between the two interest rates. Sources: Uribe and Yue (2006) and Global Financial Data.

Figure I.6. Simulating The Tequila Crisis



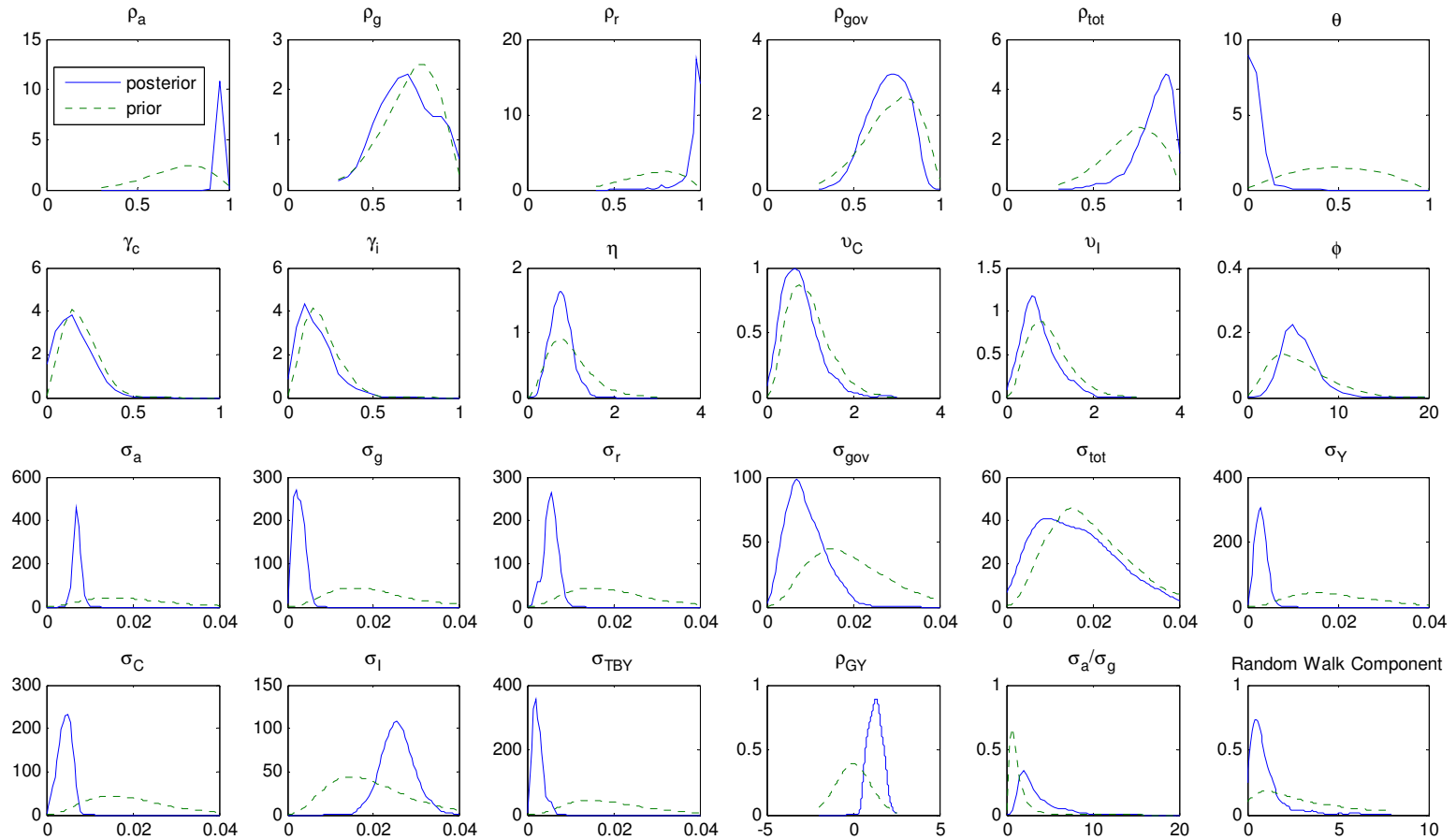
Note: Each row tracks the observed (solid line) and model-based simulated (dashed line) time series of log-output (Y); log-consumption (C); log-investment (I), and the trade balance-to-GDP (TB/Y). The model-based simulations were obtained using the smoothed state shocks. Simulations do not include measurement errors.

Figure I.7. Simulating The Tequila Crisis Using Only Transitory Technology Shocks and Various Degrees of Financial Frictions



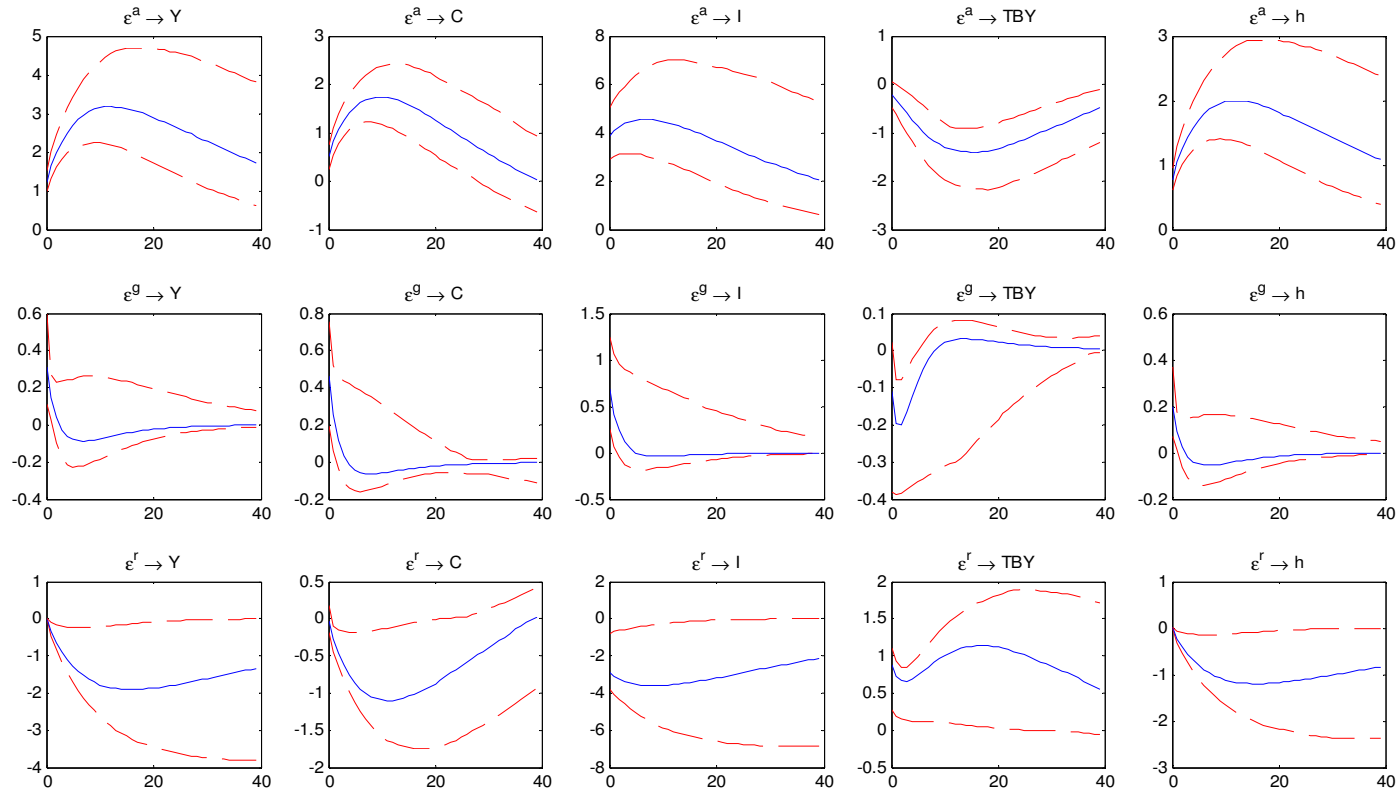
Note: Each row tracks the observed (solid line) and model-based simulated (dashed and starred lines) time series of log-output (Y); log-consumption (C); log-investment (I), and the trade balance-to-GDP (TB/Y). The model-based simulations were obtained using the smoothed state transitory technology shocks.

Figure II.1. Priors and Posterior Distribution Plots



Note: Each plot presents the kernel smoother of prior and posterior distributions.

Figure II.2. Estimated Impulse Response Functions



Note: Each column tracks the response of output (Y); consumption (C); investment (I), trade balance-to-GDP ratio (TBY); and employment (h) as deviations from steady states, after an estimated one standard deviation shock to the transitory technology process (first row); the growth process (second row); the interest rate process (third row); the government expenditure process (fourth row); the terms of trade process (fifth row). Red dashed lines depict 90% confidence interval based upon the posterior distribution. The fifth row presents the estimated impulses after a one standard deviation shock to the transitory technology process (blue) and the impulse under the counterfactual experiment $\eta = 0$.

Figure II.2. Estimated Impulse Response Functions (*cont*)

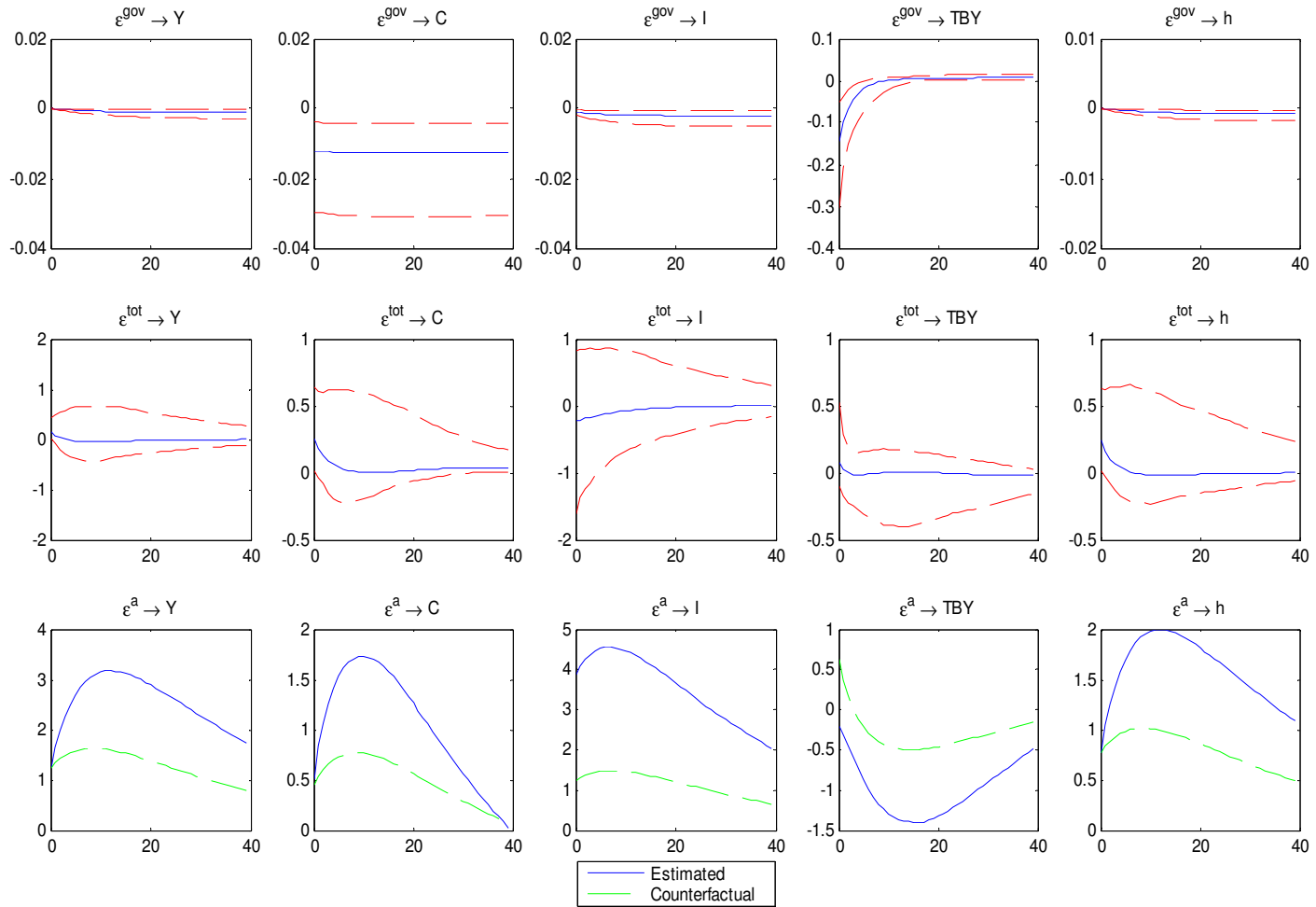
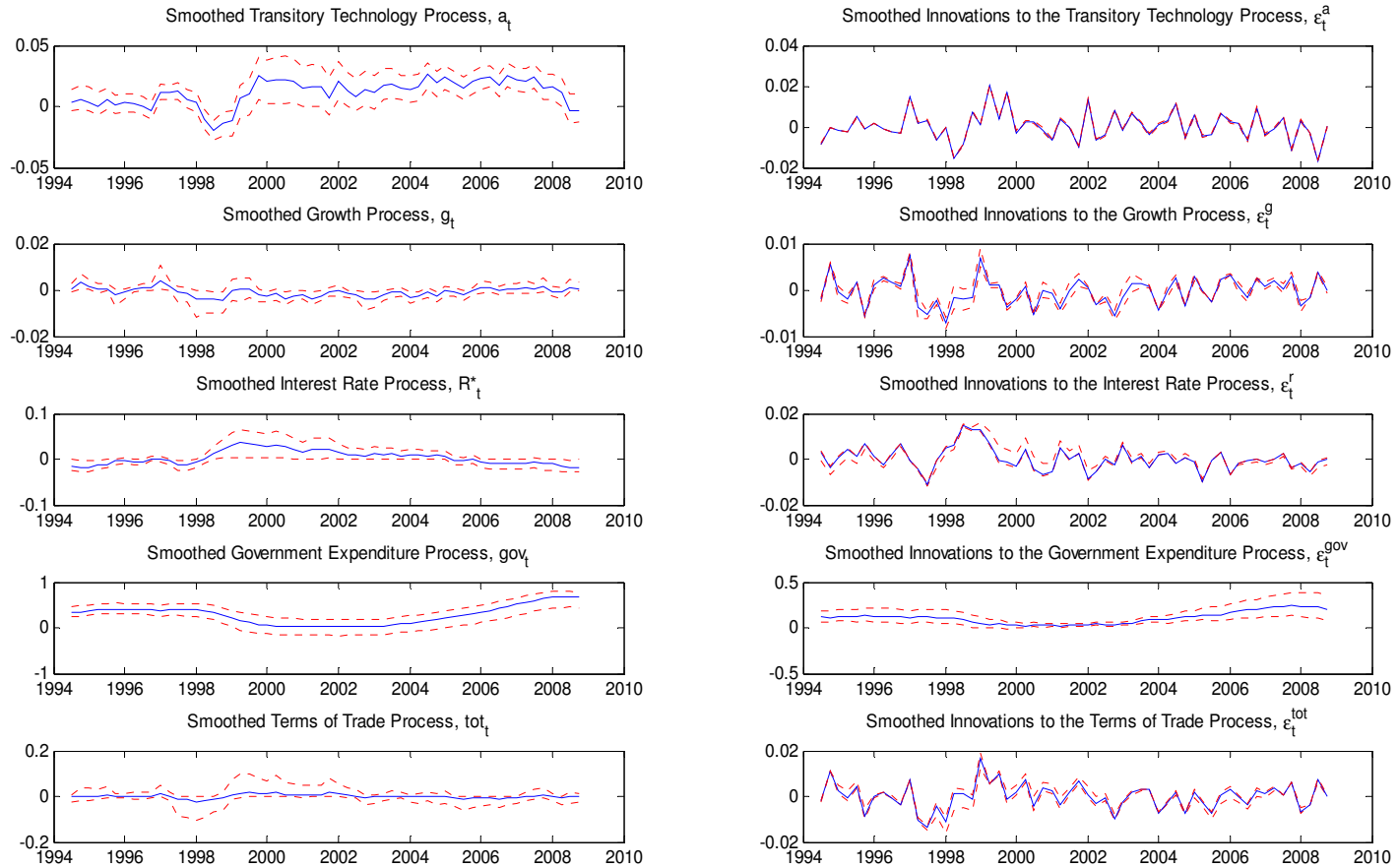
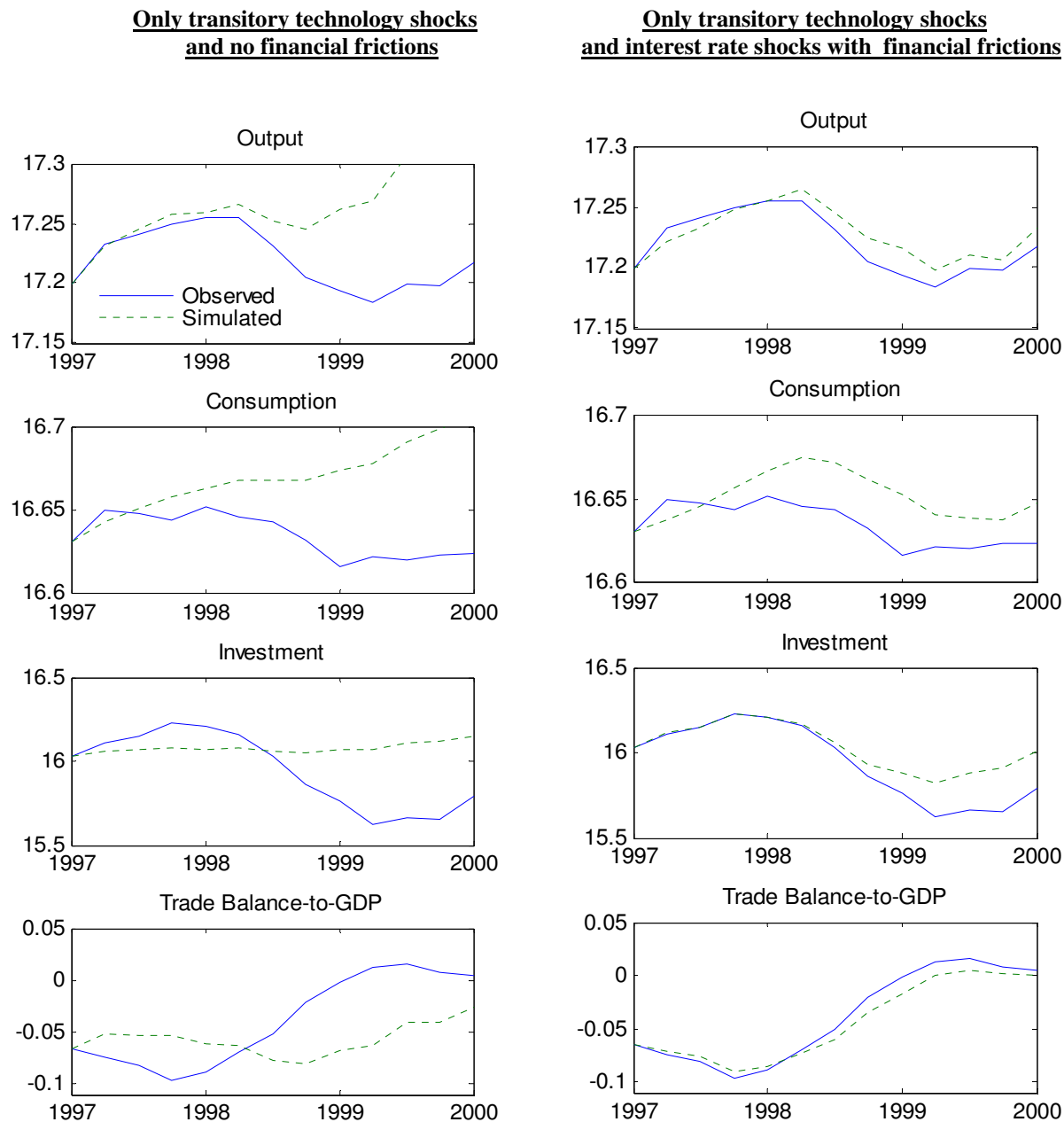


Figure II.3. Smoothed Driving Forces and Innovations



Note: The first column tracks the smoothed driving force processes and the second column plots the smoothed innovations to these driving forces. Both are computed using the Kalman smoother and red dashed lines depict 90% confidence interval based upon the posterior distributions.

Figure II.4. Simulating the Colombian Business Cycle 1997-2000



Note: The first column tracks the evolution of the main Colombian macro aggregates in logs (except for the trade balance-to-GDP ratio) using the Kalman-smoothed process of the transitory technology process assuming no financial frictions ($\eta = \theta = 0$). The second column tracks the evolution of the same aggregates using the Kalman-smoothed processes of the transitory technology and the interest rate and setting the parameters governing the degree of financial frictions (η, θ) equal to their posterior mode estimates. The smoothed innovations were obtained using posterior modes. The simulations were computed without the smoothed measurement errors.

Figure III.1. Latin American Real GDP pc Cycle (HP-Filtered). Average (1910-2001) Vs Capital Inflows/Outflows Episodes

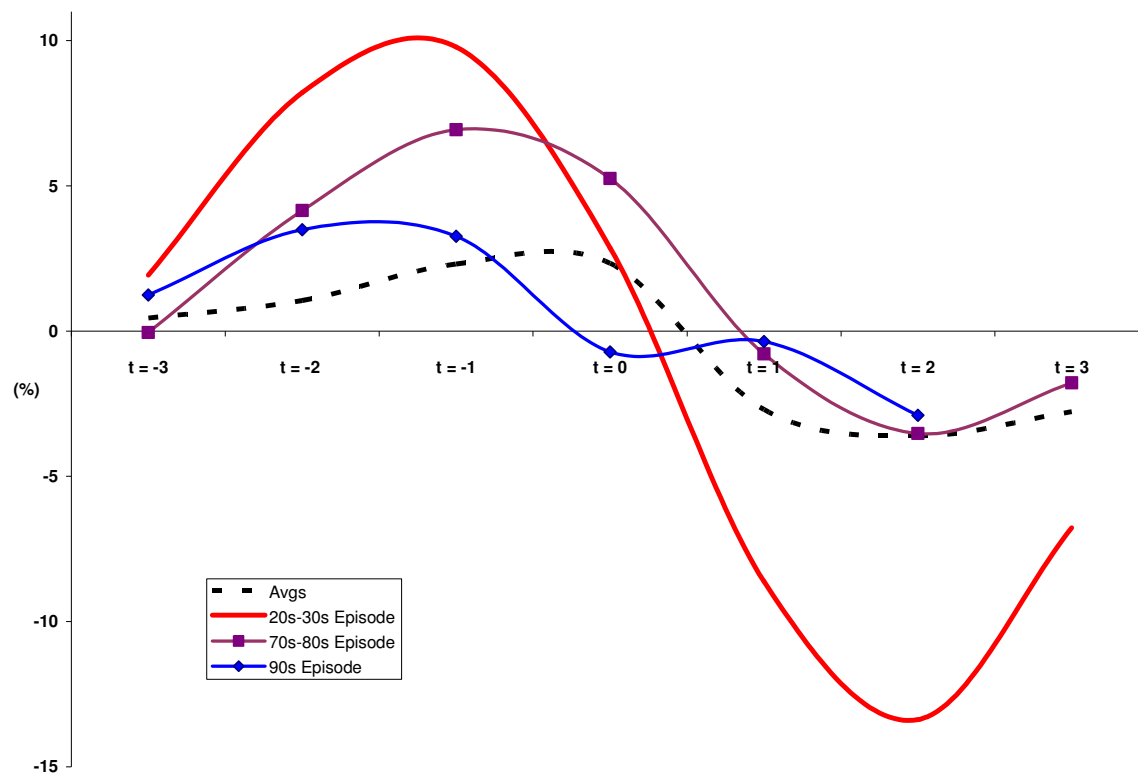


Figure III.2. Latin American Governments Bond Yields and Real (ex ante) Tbills Yield, 1919-1940

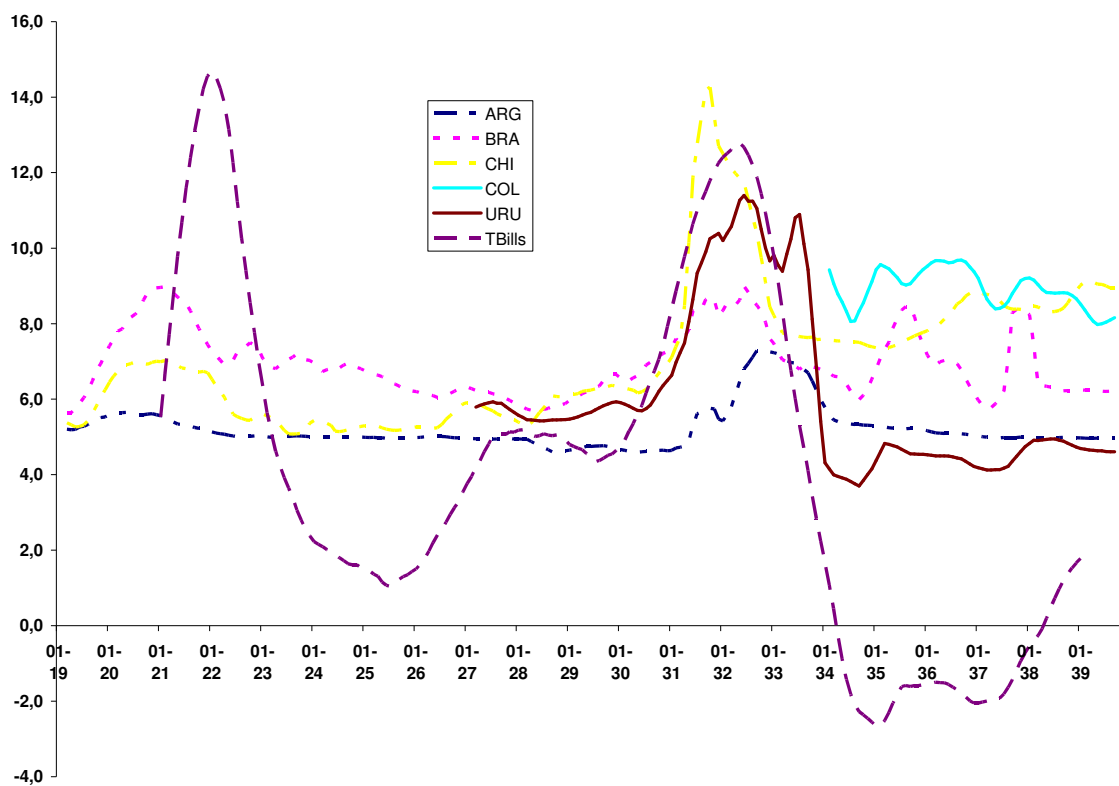


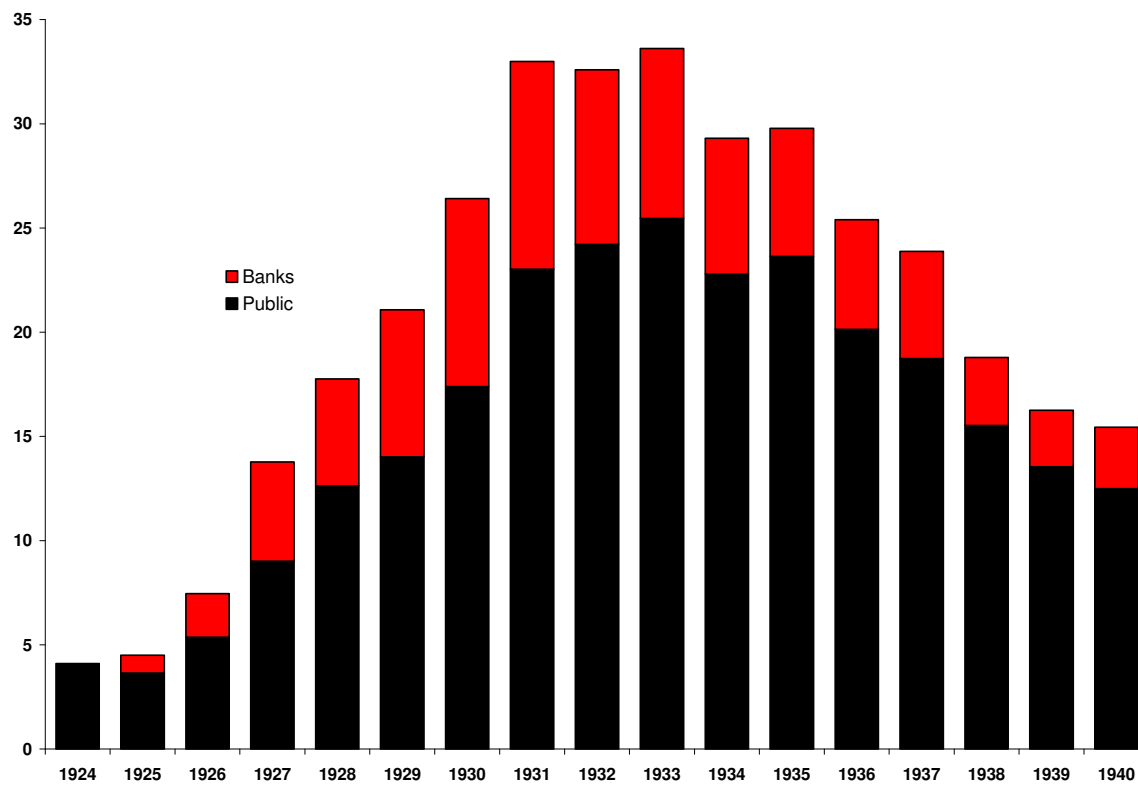
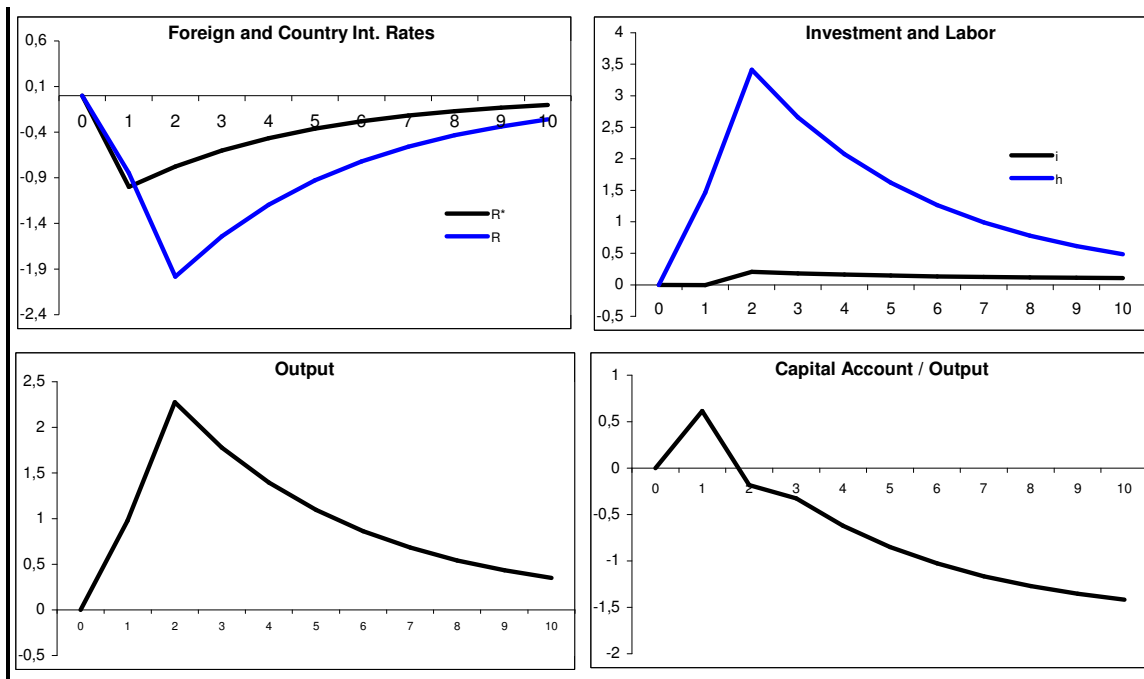
Figure III.3. Colombian External Debt, (% of GDP)

Figure III.4. Impulse Response Functions after a negative 100-basis points shock to the Foreign Interest Rate



Note: Values are percentage deviations from steady state levels.

**Figure III.5. Data and Model Based GDP Growth Dynamics:
Colombia, 1925-35**

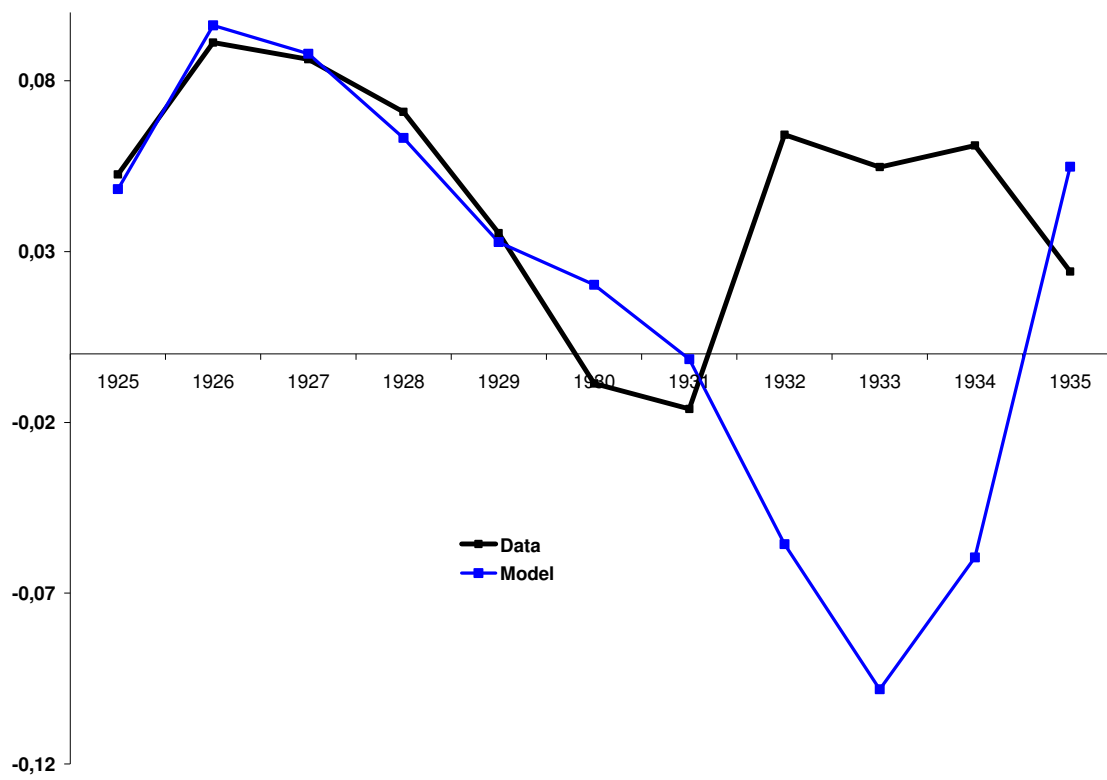


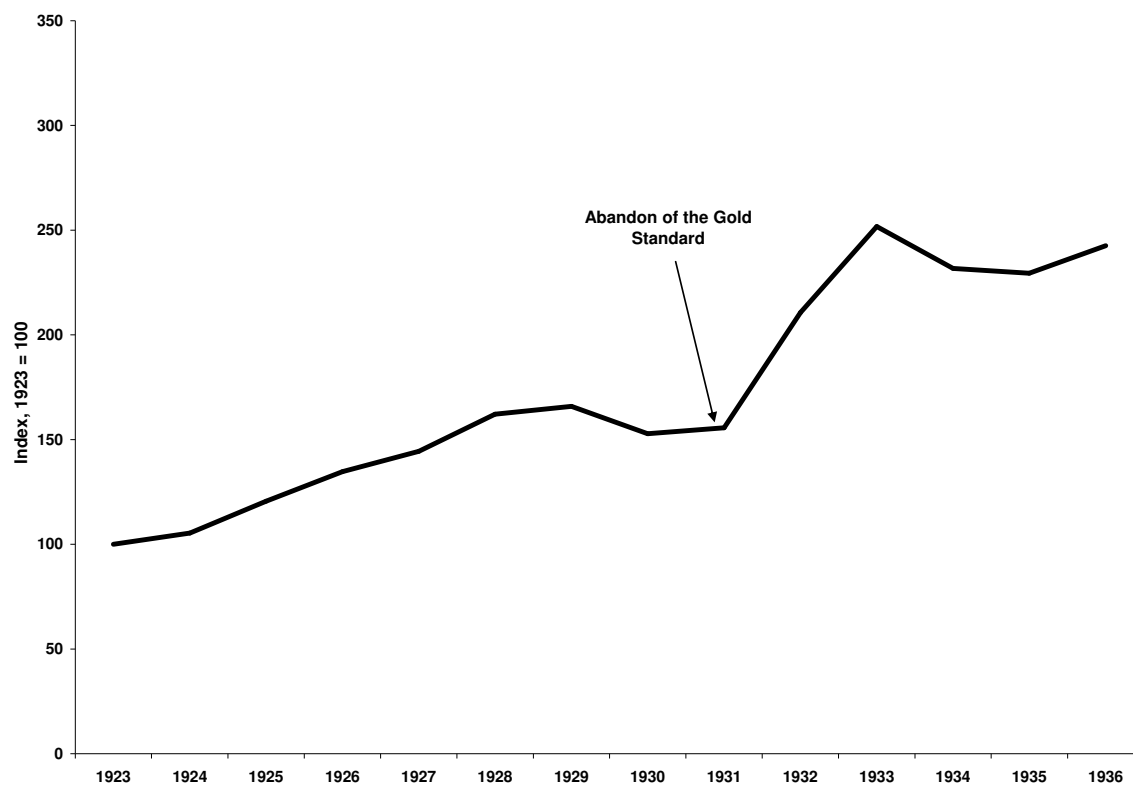
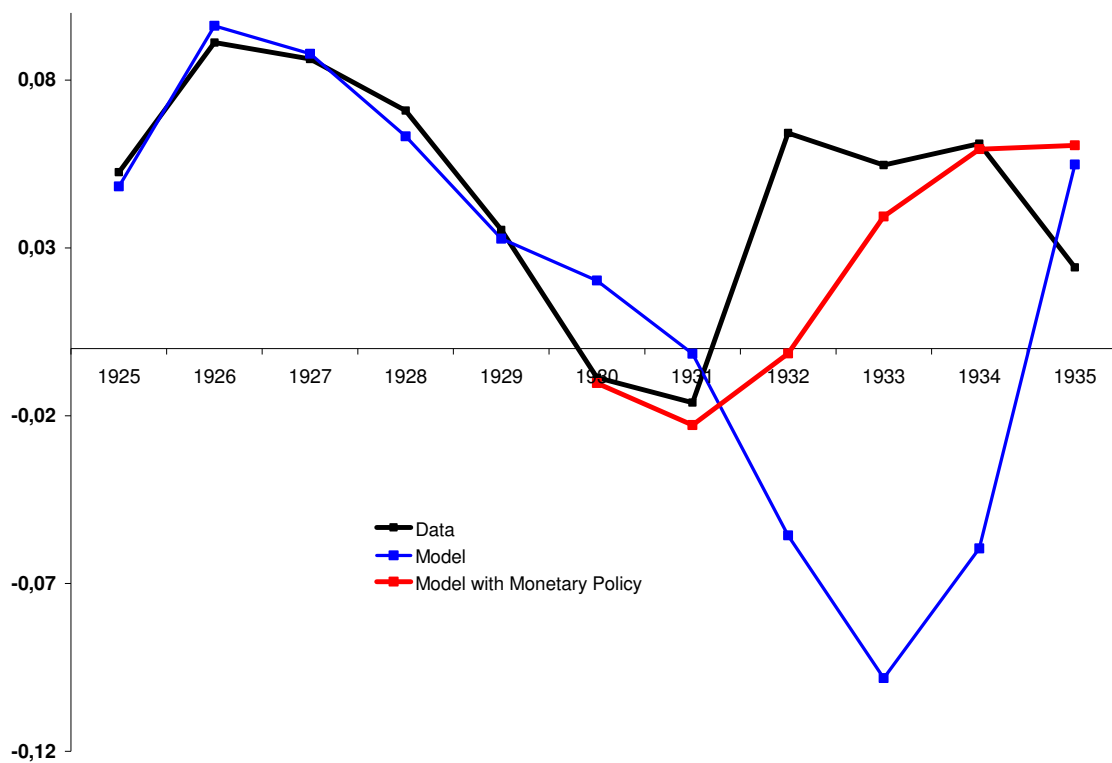
Figure III.6. Real Money Supply in Colombia, 1923-1936

Figure III.7. Data and Models Based GDP Growth Dynamics, 1925-35



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