Empirical Evaluation of DSGE Models

for Emerging Countries

by

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Duke University

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Juan Rubio-Ramírez

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Kent Kimbrough

Abstract
(Economics)

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An abstract of a dissertation submitted in partial fulfillment of the requirements for
the degree of Doctor of Philosophy in the Department of Economics
in the Graduate School of Duke University
2009

Abstract

This dissertation is the collection of three essays aimed to evaluate the empirical performance of dynamic stochastic general equilibrium (DSGE) models in explaining the behavior of macroeconomic dynamics in emerging countries.

Chapter 1, which is joint work with M. Uribe and R. Pancrazzi, investigates the hypothesis that a real business cycles model driven by permanent and transitory productivity shocks can explain well business-cycle facts of emerging countries. The model is estimated using more than a century of Argentine and Mexican data.

In Chapter 2 a comprehensive real DSGE model of an emerging country is estimated using Bayesian techniques, expanding the data set used in Chapter 1. The goal is to characterize the relative relevance of ten different business cycles' drivers: three sectorial technology shocks, embodied and disembodied non-stationary technology, terms of trade, the world interest rate, trade policy, government expenditures and the country premium.

Finally, Chapter 3 estimates (using Mexican data) a DSGE model of an emerging country containing many frictions, as has been recently argued, that impose non-trivial constraints for monetary-policy design. In particular, the framework features a sectorial decomposition of the productive sector, intermediate inputs, imperfect pass-through, endogenous premium to finance capital accumulation, a liability-dollarization problem, currency substitution, price and wage rigidities, and dynamics driven by eleven shocks.

To Marina

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Acknowledgements

The fact that my academic experience during my Ph.D. program at Duke University has been superlative is largely due to Martín Uribe, my advisor. He has been the source of numerous suggestions and comments, teaching me every day how to become a better economist. His guidance and support have been invaluable.

I would like to also thank to Stephanie Schmitt-Grohé, Juan Rubio-Ramírez, Kent Kimbrough, Barbara Rossi and Abel Rodriguez for many useful discussions, as well as to the participants in the Duke Macro reading groups.

I could not have completed the Ph.D. program without the continuous love and support from Marina, my wife. I cannot imagine my life without her, and all I have achieved in these last five years was because of her.

I would also like to thank to my parents, Hemilse and Daniel. Since I was very young they explained to me the importance of studying and having a strong professional formation. I may have taken their advice too seriously, but they have always made a tremendous effort to allow me to pursue these goals.

Finally, my friends have also been incredibly supportive during this process. And while the distance can easily erode any friendship, they made sure to strengthen our relationship even further. Thanks Paz, Pablo, Juli, Dario, Gabi, Nacho, Colo, Gus, Tato, Stefan, Javi and Gabi for everything.

Introduction

There is frequently quoted line in economics: *"All models are wrong, but some of them are useful"*. The first part of this phrase is obvious by definition; the big challenge is to identify which models to use. And while the choice of models is of course linked to the question one is trying to answer, ultimately models are judged by their ability to replicate relevant features of the data.

This dissertation is the collection of three essays. While the issues analyzed in each of them are somehow different, they share a motivational characteristic. Namely, to evaluate the empirical performance of dynamic stochastic general equilibrium (DSGE) models in explaining the behavior of macroeconomic variables in emerging countries. There is at this point an extensive literature using this type of tools to understand business cycles fluctuations in these economies (part of it is surveyed in Chapter 2). However, my feeling is that, in terms of confronting the models with the data, this research agenda is in an early stage of development; at least compared with studies trying to explain these same phenomena in more developed economies like the U.S.. These essays are then an attempt towards closing this gap.

The first chapter, which is joint work with Martin Uribe and Roberto Pancrazzi, starts with the simplest model one can find in the literature. In particular, we investigate the hypothesis that an RBC model driven by nonstationary productivity shocks can explain well observed business-cycle fluctuations in emerging countries. A drawback of existing studies is the use of short samples to identify permanent

shifts in productivity. We overcome this difficulty by using more than one century of Argentine and Mexican data to estimate the structural parameters of a small-open-economy RBC model. We find that the RBC model predicts a near random walk behavior for the trade balance-to-output ratio with a flat autocorrelation function close to unity. By contrast, in the data, the autocorrelation function of the trade balance-to-output ratio is significantly below unity and converges quickly to zero, resembling the one implied by a stationary autoregressive process. In addition, we show that the RBC model fails to capture a number of other important aspects of the emerging-market business cycle, including the excess volatility of consumption. We then show that an estimated augmented model that allow for country-premia and preference shocks and an empirically realistic debt elasticity of the country premium provides a satisfactory account of business cycles in emerging markets and assigns a negligible role to nonstationary productivity shocks.

The second chapter attempts to provide a more positive answer than the results found in the first essay. Although there is an extensive literature analyzing the sources behind business cycles fluctuations in emerging countries, there is an apparent lack of studies comparing the relative relevance of various alternative driving forces. This chapter attempts to fill this gap in the literature by specifying a comprehensive real DSGE model of an emerging country and estimating it with Bayesian techniques using almost a century of Argentine data. In particular, we evaluate the role of ten different business cycles' drivers: three sectorial technology shocks, embodied and disembodied non-stationary technology, terms of trade, the world interest rate, trade policy, government expenditures and the country premium. In sharp contrast with previous results, the estimated model assigns a predominant role to the stationary productivity shock in the non-traded sector, explaining more than 60% of output growth's variance. This result is robust to the inclusion of sectorial production shares for the estimation, a novel approach in this literature.

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In the final chapter, a DSGE model of an emerging country containing many frictions that, as has been recently argued, impose non-trivial constraints for monetary-policy design in these economies is considered. In particular, the framework features a sectorial decomposition of the productive sector, the use of intermediate inputs, imperfect pass-through, endogenous premium to finance capital accumulation, balance sheets effects due to liability dollarization, currency substitution, price and wage rigidities, and dynamics driven by eleven shocks. We use a Bayesian approach to Mexican data to estimate the model and address three main questions. First, can the model fit the data? Our answer is generally yes. Second, are the estimated parameters similar to those usually calibrated in policy-related studies? The answer is negative, particularly for those describing financial frictions, price stickiness and money demand. Finally, which mechanisms are more relevant in fitting the data? We found that including intermediate inputs is most important, financial frictions and liability dollarization are also relevant, while currency substitution does not seem to play a major role.

While I consider that these studies are a step forward in identifying, in the spirit of the opening paragraph, the usefulness of DSGE models to understand aggregate dynamics in emerging countries, the task if far from completed. But I think it is a path worth exploring. While in the first stages of the learning curve it is useful to work with stylized and controllable frameworks to build the intuition behind different mechanisms, using loose parameterizations for our models, eventually models have to be confronted with the data. And although this might not be a trivial task, it is a particularly relevant one if these models are to be used to draw policy recommendations. Unfortunately, in these environments policy analysis has to be performed using numerical exercises (theorems proving the superiority of one policy over another are generally not available). Given that results are frequently sensitive to the model's parametrization, to have one that makes the model closer to the data

is then extremely important.

1

Real Business Cycles in Emerging Countries?

(with M. Uribe and R. Pancrazzi)

1.1   Introduction[1]

A central characteristic of business cycles in developed countries is their remarkable dampening after the second world war. This phenomenon is often attributed to improved policy management. Policymakers and policy institutions are generally credited for avoiding large economic depressions like the one that took place in the interwar period. By contrast, business cycles in many emerging countries display no signs of moderation in the past fifty years. Large swings in aggregate activity are as likely to occur now as they were a century ago. For instance, following the debt crisis of the 1980s most countries in Latin America underwent output contractions of enormous dimensions, in many cases comparable to the one that took place during the U.S. Great Depression. Not surprisingly, misplaced government policies and

widespread market imperfections have been blamed for the failure to achieve and maintain aggregate stability in the region.

Recently, a number of studies have departed from the mainstream view that in order to understand economic fluctuations in emerging markets, theoretical models must take explicitly into account the role of policy and market failures. This line of research argues that business cycles in emerging countries can be explained well using an neoclassical model featuring no distortions and driven solely by shocks to total factor productivity. Kydland and Zarazaga (2002), for instance, adopt a strong view by arguing that the RBC model can replicate satisfactorily the 'lost decade' of the 1980s in Argentina. More recently Aguiar and Gopinath (2007) have suggested that an RBC model driven primarily by permanent shocks to productivity can explain well business cycles in developing countries. These authors acknowledge the fact that shocks impinging upon emerging countries are numerous and of different natures, but argue that their combined effect can be satisfactorily modeled as an aggregate shock to total factor productivity with a large nonstationary component. In addition, they argue that the neoclassical model is an adequate framework for understanding the transmission of such shocks.

In this paper, we undertake an investigation of the hypothesis that an RBC model driven by a combination of permanent and transitory shocks to total factor productivity can account satisfactorily for observed aggregate dynamics in developing countries. To this end, we conduct an econometric estimation of the parameters of a small open economy RBC model using Argentine and Mexican data over the period 1900-2005. The use of long time series is motivated by what we believe is an important drawback of the existing studies advocating the ability of the RBC model to explain business cycles in developing countries. Namely, the use of short samples both for characterization of observed business cycles and for estimation of the parameters of the theoretical model, particularly those defining the stochastic

process of the underlying driving forces.

We find that the RBC model does a poor job at explaining observed business cycles in Argentina and Mexico along a number of dimensions. One such dimension is the trade-balance-to-output ratio. Specifically, the RBC model predicts that the trade balance-to-output ratio is a near random walk, with a flat autocorrelation function close to unity. By contrast, in the data, the highest autocorrelation coefficient of the trade balance-to-output ratio takes place at the first order and is less than 0.6, with higher-order autocorrelations converging quickly to zero. In addition, we find that the RBC model fails to match several other important features of the business cycle in emerging countries. In particular, the model predicts consumption growth to be less volatile than output growth, whereas in Argentina and Mexico, as in many other developing economies, consumption growth is more volatile than output growth. Also, the model predicts the trade balance to be significantly more volatile than its corresponding empirical counterpart. Furthermore, the RBC model delivers the wrong signs for the autocorrelation functions of output growth and investment growth. These results are robust to a number of theoretical and econometric modifications, including shortening the time horizon to the postwar period.

To further gauge the role of nonstationary productivity shocks in explaining business cycles in emerging countries, we estimate using Bayesian methods an augmented version of the baseline RBC model that incorporates, preference shocks, country-premium shocks and a realistic debt elasticity of the country premium. The latter two features are meant to capture in a simplified form an economy facing international financial frictions. We find that the augmented model mimics remarkably well the observed business cycles in Argentina over the period 1900-2005. In particular, the model replicates the downward-sloping autocorrelation function of the trade-balance-to-output ratio, the excess volatility of consumption, the high volatil-

ity of investment, and a volatility of a trade-balance-to-output ratio comparable to that of output growth. Importantly, the estimated model assigns a negligible role to permanent productivity shocks lending little support to the hypothesis that the cycle is the trend.

The remainder of the paper is organized as follows. In section 1.2, we present a number of empirical regularities characterizing the emerging-economy business cycle over the period 1900-2005. In section 3.2, we lay out the theoretical model. In section 1.4, we discuss the estimation of the structural parameters of the model using Argentine data from 1900 to 2005. In section 1.5 we present the main results of the paper by comparing the predictions of the RBC model with Argentine data. In section 1.6, we discuss the results of an extensive robustness analysis. In section 1.7 we estimate the RBC model using Mexican data from 1900 to 2005. In section 1.8 we expand the baseline model to allow for a richer set of shocks and an empirically realistic value for the elasticity of the country premium with respect to the level of external debt. In section 3.6, we provide concluding remarks.

1.2 Business Cycles in Emerging Countries: 1900-2005

Our joint analysis of the pre- and post-world-war-two periods represents a departure from the usual practice in studies focused on developed countries. Typically, these studies concentrate either on the pre-world-war-two period—often emphasizing the Great Depression years—or on the post-world-war-two period—as do most of the many papers spurred by the work of Kydland and Prescott (1982) and King et al. (1988). There is a good reason for separating the pre- and post-world-war-two periods when examining developed-country data. For the volatility of business cycles in industrialized countries fell significantly in the second half of the twentieth century. In sharp contrast, in emerging countries business cycles do not appear to moderate after the second world war. This fact is clearly illustrated is figure 1.1, which depicts

FIGURE 1.1: Output Per Capita in Argentina and the United States: 1900-2005

(a) United States
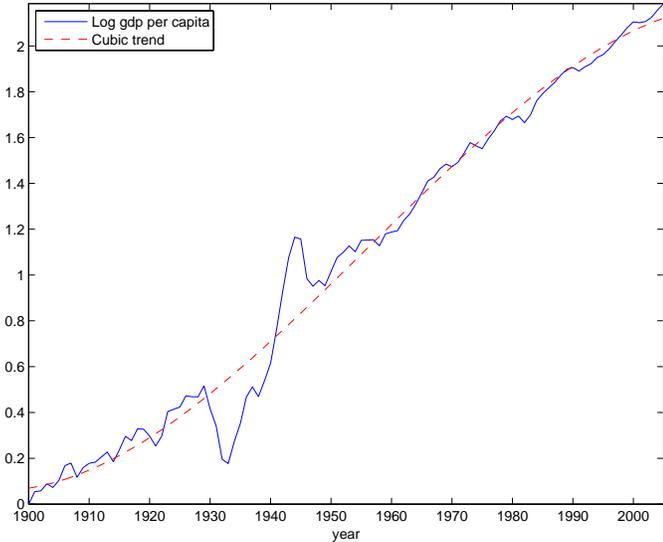
(b) Argentina
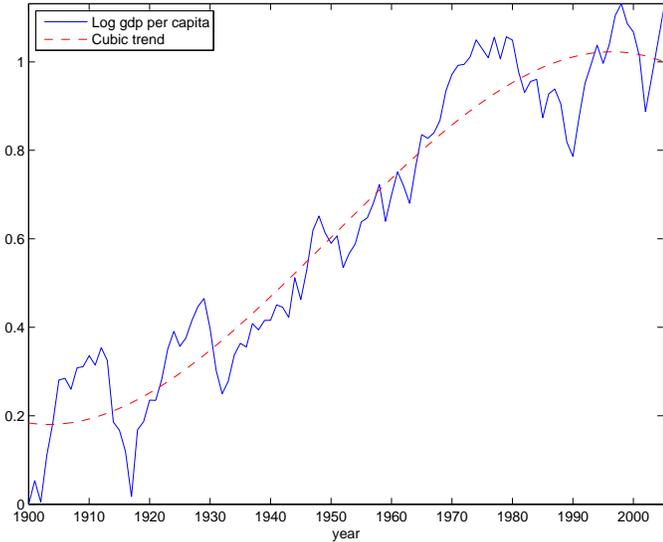
the evolution of output in Argentina (panel a) and the United States (panel b) over the period 1900-2005. Data sources are presented in the appendix. The figure shows with solid lines the logarithm of GDP per capita and with broken lines the associated cubic trend. In the United States, the first half of the twentieth century is dominated by the Great Depression and appears as highly volatile. By comparison, the half century following the end of World War II appears as fairly calm, with output evolving smoothly around its long-run trend. On the other hand, in Argentina output fluctuations appear equally volatile in the prewar period as in the postwar period.[2] More specifically, over the period 1900-2005 the United States and Argentina display similar volatilities in per-capita output growth of about 5 percent. However, in the United States the volatility of output growth falls significantly from 6.4 percent in the prewar period to 3.4 percent in the postwar period. By contrast, in Argentina the volatility of output growth falls insignificantly from 5.7 in the earlier half of the twentieth century to 5.2 percent in the later half.

The patterns of aggregate volatility observed in Argentina and the United States extend to larger sets of developed and emerging countries. Figure 1.2 displays the cyclical component of the log of real GDP per capita for seven Latin American countries and thirteen small developed countries over the period 1900-2005. In the figure, the cycle is computed as percent deviations of GDP from a cubic trend. Three main conclusions emerge from the data presented in figure 1.2. First, over the period 1900-2005, business cycles are equally volatile in the group of Latin American countries as in the group of developed countries. The average standard deviation of detrended output is about 10 percent for both groups. Second, in the group of

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[2] Basu and Taylor (1999) also find no differences in output volatility in Argentina in the prewar and postwar eras (see their table A3). Using data from Argentina for the period 1884 to 1990, Sturzenegger and Moya (2003) find that business cycles in the pre world war II period were more volatile than in the postwar period. This different result is due to the fact that their sample does not include the years 1991-2005, which are among the most volatile of the postwar era and that their sample includes the period 1884-1900, which was particularly volatile (see Basu and Taylor, 1999, table A3).

FIGURE 1.2: Business Cycles in Small Economies: 1900-2005

(a) Latin America
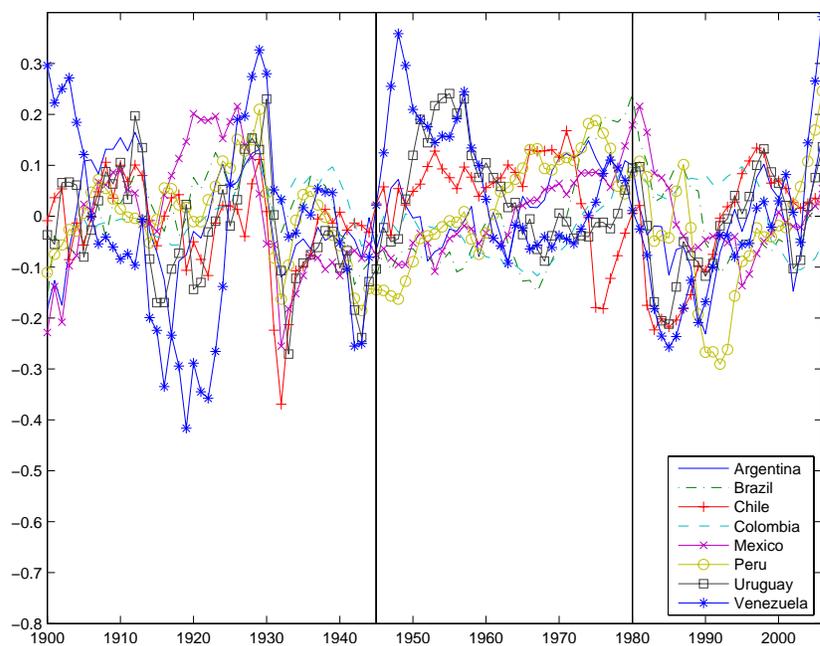
(b) Small Developed Economies
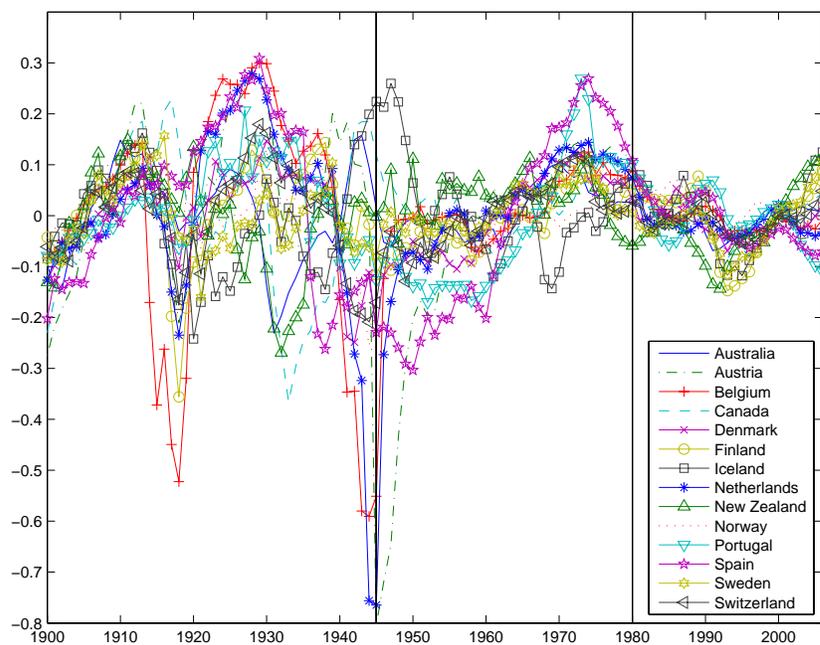
Note. Percent deviations of real GDP per capita from a cubic trend. Source: Data base compiled by R. Barro and J. Ursúa, available on line at `http://www.economics.harvard.edu/faculty/barro/data_sets_barro`.

Latin American economies, business cycles are as volatile in the period 1900-1945 as in the period 1946-2005, with average standard deviations of 10.1 and 9.8 percent, respectively. By contrast, in the group of developed countries business cycles are significantly more volatile in the period 1900-1945 than in the period 1946-2005, with average standard deviations of 12.7 percent versus 7.2 percent, respectively. Third, the period 1980-2005 contains only between one and a half and two cycles for most of the Latin American economies included in the figure. This fact suggests that if one is to uncover the importance of permanent productivity shocks as drivers of business cycles in emerging countries , limiting the empirical analysis to the post 1980 period—as do many recent related studies—may be problematic. The empirical evidence presented thus far serves as motivation for our focus on a long sample for the analysis of business cycles in emerging countries.

1.2.1   The Autocorrelation Function of the Trade-Balance-To-Output Ratio

At center stage in every study of the business cycle in emerging economies is the trade balance. Examples of strands of the literature in which this variable features prominently include the literatures on balance of payments crises, sudden stops, sovereign debt, and exchange-rate-based stabilization. It is therefore natural to ask whether the RBC model can capture observed movements of the trade balance over the business cycle. More specifically, one of the dimensions along which we will scrutinize the empirical performance of the RBC model is the autocorrelation function of the trade-balance-to-output ratio.

Figure 1.3 displays the autocorrelation function of the trade-balance-to-output ratio of sixteen emerging countries.[3] Although there is some variation across countries,

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[3] The data is annual. The samples are: Argentina, 1900-2005, Brazil, 1947-2007; Chile, 1967-2007; Colombia, 1925-2007; Ecuador, 1950-2006; India, 1950-2007; South Korea, 1953-2006; Malaysia, 1955-2007,; Mexico, 1900-2005; Paraguay, 1953-2008; Peru, 1950-2007; Philippines, 1948-2007; South Africa, 1950-2006; Thailand, 1950-2007; Uruguay, 1955-2007; and Venezuela, 1950-2007; The source is IFS, except for Brazil (IBGE), Colombia (Departamento Nacional de Planeacion),

FIGURE 1.3: The Autocorrelation Function of the Trade Balance-to-Output Ratio in Emerging Countries
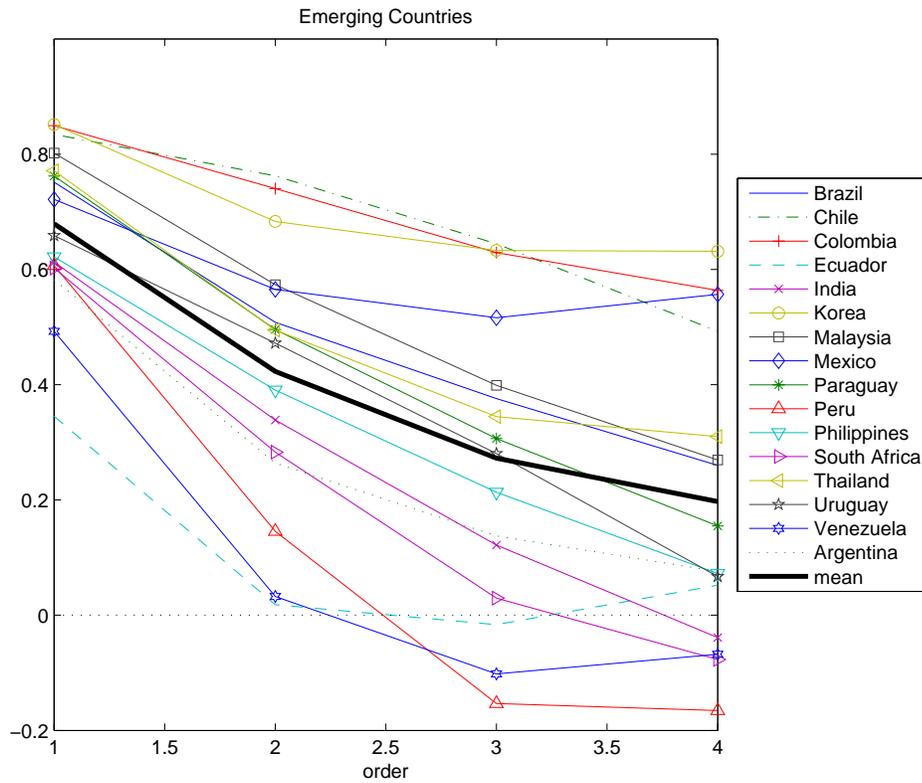
the pattern that emerges is that of a downward-sloping function with a first-order autocorrelation of about 0.65 and that approaches zero monotonically at the fourth or fifth order.

1.2.2   Second Moments: Argentina 1900-2005

Table 2.1 displays empirical second moments of output growth, consumption growth, investment growth, and the trade-balance-to-output ratio for Argentina over the period 1900-2005. Argentina is one of two countries for which we constructed long time series for the four variables considered in the table. The other country is Mexico, which we analyze in section 1.7.

and Argentina and Mexico (see the appendix).

Table 1.1: Second Moments: Argentina 1900-2005

Statistic	g^Y	g^C	g^I	tby
Standard Deviation	5.3	7.5	20.0	5.2
	(0.4)	(0.6)	(1.8)	(0.5)
Correlation with g^Y	—	0.72	0.67	-0.03
	—	(0.07)	(0.09)	(0.09)
Correlation with tby	—	-0.27	-0.19	—
	—	(0.07)	(0.08)	—
Serial Correlation	0.11	0.00	0.32	0.58
	(0.09)	(0.08)	(0.10)	(0.07)

Note: g^Y, g^C, and g^I denote the growth rates of output per capita, consumption per capita, and investment per capita, respectively, and tby denotes the trade balance-to-output ratio. Standard deviations are reported in percentage points. Standard errors are shown in parenthesis. The data is annual, and the sources are given in the appendix.

Notably, unlike in developed countries, per-capita consumption growth in Argentina is significantly more volatile than per-capita output growth. Others have documented this fact for Argentina and other emerging countries using post-1980 data (Neumeyer and Perri, 2005, Aguiar and Gopinath, 2007, and Uribe, 2007). Here, we show that the high volatility of consumption relative to output remains present after augmenting the sample to include the first three quarters of the twentieth century. Gross investment growth is enormously volatile. Its standard deviation is about four times as large as that of output growth. At the same time, the trade balance-to-output ratio is about as volatile as output growth. The observed correlation between the trade balance-to-output ratio and output growth is negative but insignificantly different from zero. By contrast the domestic components of aggregate demand, private consumption growth and investment growth, are significantly negatively correlated with the trade balance. Finally, the bottom row of table 2.1 shows that the first-order autocorrelation of output growth is positive but small and not significantly different from zero. This fact represents a significant impediment for

the ability of the estimated RBC model to account for the observed excess volatility of consumption. The reason is that, a productivity shock produces a deterioration in the trade balance and large increases in consumption (as is required for consumption growth to be more volatile than output growth) if current increases in the level of output are accompanied by further expected increases in output. That is, if output growth is sufficiently positively serially correlated. The reason is that if in response to a productivity shock future output is expected to be even larger than current output, then households will wish to borrow against future expected income thereby increasing today's consumption beyond the current increase in income.

1.3   The Model

The theoretical framework is the small open economy model presented in Schmitt-Grohé and Uribe (2003) augmented with permanent and transitory productivity shocks as in Aguiar and Gopinath (2007). The production technology takes the form

$$Y_t = a_t K_t^\alpha (X_t h_t)^{1-\alpha}, \tag{1.1}$$

where Y_t denotes output in period t, K_t denotes capital in period t, h_t denotes hours worked in period t, and a_t and X_t represent productivity shocks. We use upper case letters to denote variables that contain a trend in equilibrium, and lower case letters to denote variables that do not contain a trend in equilibrium.

The productivity shock a_t is assumed to follow a first-order autoregressive process in logs. That is,

$$\ln a_{t+1} = \rho_a \ln a_t + \epsilon_{t+1}^a.$$

The productivity shock X_t is nonstationary. Let

$$g_t \equiv \frac{X_t}{X_{t-1}}$$

denote the gross growth rate of X_t. We assume that the logarithm of g_t follows a first-order autoregressive process of the form

$$\ln(g_{t+1}/g) = \rho_g \ln(g_t/g) + \epsilon^g_{t+1}.$$

The innovations ϵ^a_t and ϵ^g_t are assumed to be uncorrelated i.i.d. processes with mean zero and variances σ^2_a and σ^2_g, respectively. The parameter g measures the deterministic gross growth rate of the productivity factor X_t. The parameters $\rho_a, \rho_g \in [0, 1)$ govern the persistence of a_t and g_t, respectively.

Household face the following period-by-period budget constraint:

$$\frac{D_{t+1}}{1 + r_t} = D_t - Y_t + C_t + I_t + \frac{\phi}{2} \left(\frac{K_{t+1}}{K_t} - g \right)^2 K_t, \tag{1.2}$$

where D_{t+1} denotes the stock of debt acquired in period t, r_t denotes the domestic interest rate on bonds held between periods t and $t + 1$, C_t denotes consumption, I_t denotes gross investment, and the parameter ϕ introduces quadratic capital adjustment costs. The capital stock evolves according to the following law of motion:

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

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

In order to induce independence of the deterministic steady state from initial conditions, we assume that the country faces a debt-elastic interest-rate premium as in Schmitt-Grohé and Uribe (2003). Specifically, the domestic interest rate is assumed to be the sum of the world interest rate $r^* > 0$, assumed to be constant, and a country premium that is increasing in a detrended measure of aggregate debt as follows:

$$r_t = r^* + \psi \left(e^{\tilde{D}_{t+1}/X_t - \bar{d}} - 1 \right),$$

The variable $\tilde{D}_t$ denotes the aggregate level of external debt per capita, which the household takes as exogenous. In equilibrium, we have that $\tilde{D}_t = D_t$.

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Table 1.2: Calibration

Parameter	γ	δ	α	ψ	ω	θ	β	$\bar{d}$
Value	2	0.1255	0.32	0.001	1.6	2.24	0.9224	0.007

Consumers are subject to a no-Ponzi-scheme constraint of the form $\lim_{j\to\infty}$ $E_t \frac{D_{t+j}}{\prod_{s=0}^{j}(1+r_s)} \leq 0$. The household seeks to maximize the utility function

$$E_0 \sum_{t=0}^{\infty} \beta^t \frac{[C_t - \theta\omega^{-1}X_{t-1}h_t^\omega]^{1-\gamma} - 1}{1-\gamma}, \tag{1.3}$$

subject to (1.1), (1.4), and the no-Ponzi-game constraint, taking as given the processes a_t, X_t, and r_t and the initial conditions K_0 and D_{-1}. Appendix B presents the first-order conditions associated with the household's optimization problem, and appendix C presents the equilibrium conditions of this economy expressed in terms of stationary variables.

1.4 Estimation: Argentina 1900-2005

The time unit in the model is meant to be a year. We assign values to the structural parameters using a combination of calibration and econometric estimation techniques.

We calibrate the parameters α, δ, ψ, $\bar{d}$, θ, ω, and γ using long-run data relations from Argentina as well as parameter values that are common in related business-cycle studies. Table 2.3 presents the calibrated parameter values. We set the parameter $\bar{d}$ to induce a small steady-state trade balance-to-output ratio of about 0.25 percent, as observed on average in Argentina over the period 1900-2005. We follow Schmitt-Grohé and Uribe (2003) and assign a small value to the parameter ψ, measuring the sensitivity of the country interest-rate premium to deviations of external debt from trend, with the sole purpose of ensuring independence of the deterministic steady

state from initial conditions, without affecting the short-run dynamics of the model. The value assigned to the depreciation rate δ implies an average investment ratio of about 19 percent, which is in line with the average value observed in Argentina between 1900 and 2005. The value assumed for the discount factor β implies a relatively high average real interest rate of about 8.5 percent per annum, which is empirically plausible for an emerging market like Argentina. There is no reliable data on factor income shares for Argentina. We therefore set the parameter α, which determines the average capital income share, at 0.32, a value commonly used in the related literature. We set $\theta = 2.24$, to ensure that in the steady state households allocate about 20 percent of their time to market work. The parameter γ, defining the curvature of the period utility function, takes the value 2, which is standard in related business-cycle studies. Finally, ω is calibrated at 1.6, which implies a labor-supply elasticity of $1/(\omega - 1) = 1.7$. This value is frequently used in calibrated versions of small open economy models (see Mendoza, 1991; Schmitt-Grohé and Uribe, 2003; and Aguiar and Gopinath, 2007).

We estimate econometrically the five parameters defining the stochastic process of the productivity shocks, g, σ_g, ρ_g, σ_a, and ρ_a and the parameter governing the degree of capital adjustment costs, ϕ. To estimate these six parameters, we apply the generalized method of moments (GMM) using annual data from Argentina. The sample period is 1900 to 2005. (See appendix A for data sources.) We include 16 moment conditions: the variances and first- and second-order autocorrelations of output growth (g^Y), consumption growth (g^C), investment growth (g^I), and the trade balance-to-output ratio, (tby), the correlation of g^Y with g^C, g^I, and tby, and the unconditional mean of g^Y. (See appendix D for more details on the estimation procedure.) The estimated parameters are presented in table 1.3. The permanent shock, g_t, is estimated to be more volatile and persistent than the transitory shock a_t. The standard deviation and autoregressive coefficient of g_t are estimated with

Table 1.3: Estimated Structural Parameters

Parameter	Point Estimate	Standard Error
g	1.001	0.005
σ_g	0.030	0.004
ρ_g	0.399	0.048
σ_a	0.020	0.002
ρ_a	0.006	0.076
ϕ	0.580	0.161
Overidentifying Restrictions Test	p value	0.069

Note: GMM estimates using Argentine data from 1900 to 2005.

precision. The same is true for the standard deviation of a_t and for the adjustment cost parameter ϕ. However, the autoregressive coefficient of a_t is not significantly different from zero. The p value of the test of overidentifying restrictions, shown at the bottom of table 1.3, indicates that the null hypothesis that the 16 moment conditions included in the GMM estimation are nil is rejected at a confidence level of 6.9 percent.

1.5   Model Performance

Figure 1.4 displays with a circled line the theoretical autocorrelation functions of the trade balance-to-output ratio. To facilitate comparison with the data, the figure reproduces with a solid line the corresponding estimated autocorrelation function, and with broken lines a two-standard-deviation confidence interval around the point estimate. All four autocorrelations predicted by the RBC model take values close to unity, indicating that in the model the trade balance-to-output ratio behaves as a near random walk. By contrast, the empirical autocorrelation function takes a value slightly below 0.6 at order one and then declines quickly toward zero, resembling a variable with a stationary autoregressive behavior. Further, the theoretical au-

FIGURE 1.4: The Predicted Autocorrelation Function of the Trade Balance-to-Output Ratio
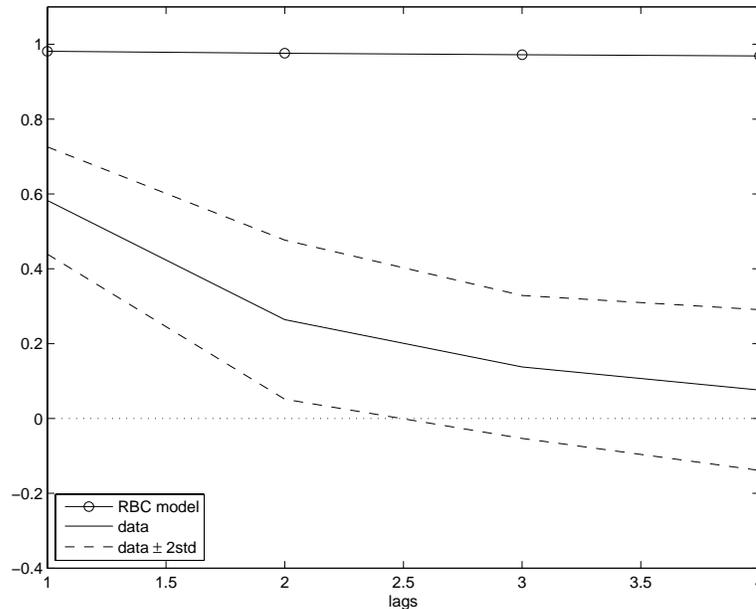
tocorrelation function lies entirely outside the two-standard-deviation band around the empirical point estimate. To understand why the trade balance displays quasi-random-walk dynamics in equilibrium, it is useful to think of an endowment economy in which the endowment follows a random walk process. Consider the response to an unanticipated innovation in the endowment. In response to this shock, consumption experiences a once-and-for-all increase about equal in size to the increase in the endowment, as households, realizing that the increase in endowment is permanent, feel no need to increase savings. It follows that the trade balance is more or less unaffected by the shock and, as a result, that the ratio of the trade balance to output inherits the random walk nature of the endowment process.

The flat nature of the autocorrelation function of the trade balance-to-output ratio is a quite general property of the RBC model. In particular, it is not a consequence of the presence of a nonstationary productivity shock. We find that the

autocorrelation function of tb/y continues to be horizontal even if the nonstationary productivity shock is shut down by setting $\sigma_g = 0$. The reason for this result is that with stationary productivity shocks, although output and investment become stationary variables, consumption follows a near random walk typical of small open economies.

One way to eliminate the near random walk behavior of the trade balance is to introduce financial imperfections as in the sovereign debt literature. In such environments trade deficits that result in increases in the net foreign debt position cause increases in the country premium, because, for instance, of elevated risks of default. In turn, larger country premia tend to incentivate domestic savings and discourage private investment, thereby dampening the increase in trade deficits. An ad-hoc way of capturing this channel in the context of the present model would be to sufficiently raise the value of the parameter ψ governing the debt-elasticity of the country premium. By placing financial frictions at center stage, however, this type of transmission mechanism would represent a significant departure from the RBC paradigm. We explore the empirical relevance of such a departure in section 1.8. Similarly, a downward-sloping autocorrelation function of the trade-balance-to-output ratio could be obtained by adopting a sufficiently elastic subjective discount factor with respect to consumption or a sufficiently large cost of adjusting the net foreign asset position. Again, assigning to any of these avenues a role larger than that of merely inducing stationarity, would imply a departure from the RBC paradigm.

Table 1.4 reports second moments implied by the theoretical model. To facilitate comparison, the table reproduces the empirical counterparts and their associated standard errors from table 2.1. In the RBC model, consumption growth is less volatile than output growth. This prediction represents a significant difficulty of the estimated RBC model, as excess consumption volatility is a key characteristic of emerging economies. To understand why the model fails to replicate the observed

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Table 1.4: Comparing Model and Data: Second Moments

Statistic	g^Y	g^C	g^I	tby
Standard Deviation				
– Model	6.1	4.5	13.5	17.6
– Data	5.3	7.5	20.4	5.2
	(0.4)	(0.6)	(1.8)	(0.6)
	**	***	***	***
Correlation with g^Y				
– Model		0.96	0.54	0.003
– Data		0.72	0.67	-0.04
		(0.07)	(0.09)	(0.09)
			**	
Correlation with tby				
– Model		-0.03	-0.08	
– Data		-0.27	-0.19	
		(0.07)	(0.08)	
		**		
Serial Correlation				
– Model	-0.31	-0.17	-0.17	0.98
– Data	0.11	-0.005	0.32	0.58
	(0.09)	(0.08)	(0.10)	(0.07)
	***		***	***

Note: Standard deviations are reported in percentage points. Standard errors of sample-moment estimates are shown in parenthesis. One, two, or three asterisks indicate that the hypothesis that an individual theoretical moment equals its empirical counterpart is rejected at the 10, 5, or 1 percent confidence level, respectively, using the test proposed by Tauchen (1985).

high volatility of consumption, it is important to note that the consumption-output volatility ratio depends positively upon the importance of nonstationary shocks relative to stationary shocks in driving business cycles. The two diagrams in 1.5 are useful to convey the intuition behind this statement. They display qualitatively the responses of output and consumption to transitory and permanent output shocks in a small open economy. A transitory productivity shock produces an increase in the level of current output followed by a gradual decline toward its pre-shock level. Because output is expected to fall in the future, it is optimal for consumption-

Stationary Shock   Non-Stationary Shock
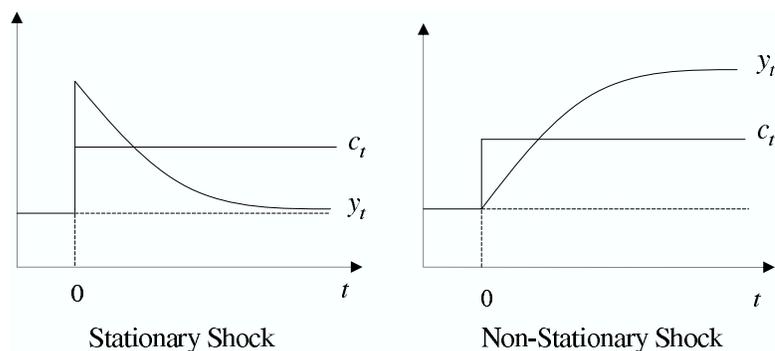
smoothing households to save, causing consumption to increase by less than income. By contrast, in response to a positive and persistent shock to productivity growth, current output increases on impact and is expected to continue to grow in the future. This increasing profile for future expected income levels induces households to consume beyond the increase in current output. When both, trend stationary and permanent shocks to productivity are present, whether consumption growth turns out to be more or less volatile than output becomes a quantitative issue. In our estimated RBC model the tradeoff is resolved, counterfactually, in favor of consumption smoothing. As far as the volatility of consumption is concerned, therefore, the estimated model appears to assign too much importance to transitory shocks. The reason why the estimation procedure does not allocate a larger role to nonstationary shocks, is, or course, that the GMM technique sets parameter values to match a relatively large set of statistics (16 in our case), of which the volatilities of output and consumption growth are just two elements.

For instance, there is a dimension along which permanent productivity shocks appear to be too volatile in the estimated model. Namely, the volatility of the trade balance. In the data, the trade-balance share in output is about as volatile as output growth, where as in the model the trade-balance share is more than three

times as volatile as output growth. Much of this discrepancy between data and model is due to the permanent component of productivity shocks. Shutting off the permanent productivity shock by setting σ_g equal to zero while holding constant all other parameter values results in a significant reduction in the volatility of the trade-balance share relative to the volatility of output growth.

Furthermore, there is a sense in which both the permanent and the transitory components of total factor productivity are estimated to be insufficiently volatile. For the model predicts too little volatility in investment growth. Higher volatility in either source of uncertainty would contribute to ameliorating this significant mismatch between data and model.

The RBC model correctly predicts a near-zero correlation between output growth and the trade balance-to-output ratio. However, it significantly underpredicts the negative correlations of the trade-balance-to-output ratio with consumption growth and investment growth. The fact that the trade-balance share is more correlated with the components of aggregate demand than with output growth may be an indication that shocks other than movements in total factor productivity could be playing a role in driving business cycles in Argentina. We explore this possibility in section 1.8. Finally, the RBC model significantly underpredicts the serial correlations of output growth and consumption growth. In the model, both of these autocorrelations are negative, while in the data both are positive and significant.

1.6   Robustness

To establish the robustness of our results, we examine the sensitivity of the predictions of the model to a number of perturbations to the theoretical structure, to the estimation procedure, and to the data sample.

FIGURE 1.6: The Postwar Autocorrelation Function of TB/Y
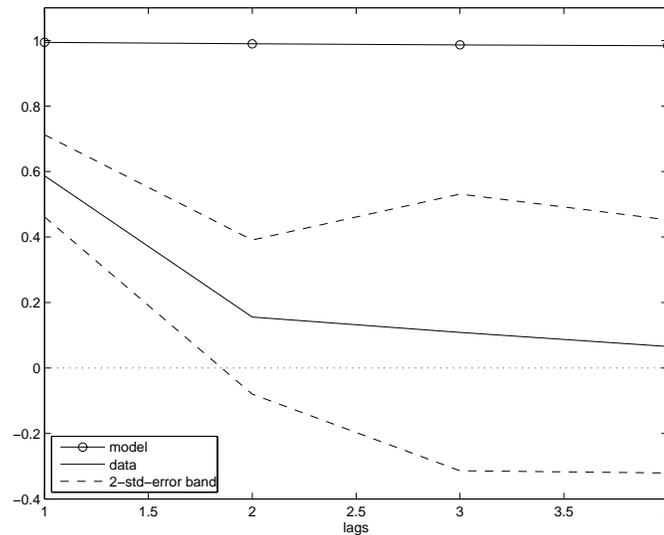
1.6.1 The Postwar period

Figure 1.6 displays with a solid line the autocorrelation function of the trade balance-to-output ratio estimated over the subsample 1946-2005. Over the postwar period the autocorrelation function of the trade balance-to-output ratio takes a value of about 0.6 at order one and then decreases quickly toward zero, resembling the autocorrelation function of an AR(1) process. This is essentially the same pattern obtained under the longer bench mark sample. The figure also displays, with circles, the autocorrelation function of the trade balance-to-output ratio predicted by the model reestimated over the postwar period. In contrast to the data, the predicted autocorrelation function is flat and close to unity, as in a random walk process. It follows that the problem of excess persistence in the predicted behavior of the trade balance-to-output ratio continues to arise under a shorter sample that eliminates the early period 1900-1945.

A similar conclusion can be derived from examining other statistics of interest. Table 1.5 shows that most of the empirical regularities identified using the sample

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Table 1.5: Robustness Analysis

	Data	Bench-mark	No AC Order 2	HP Filter Data	HP Filter Model	Cobb Douglas	1946-2005 Data	1946-2005 Model
A. Standard Deviation								
g^Y	5.30	6.10	6.10	6.48	8.33	5.50	5.10	4.20
g^C	7.50	4.50	4.50	7.75	7.52	3.60	6.40	3.80
g^I	20.40	13.50	13.60	28.82	18.89	12.60	16.70	10.20
tby	5.20	17.50	17.50	5.20	17.54	19.40	3.00	16.10
B. Correlation with g^Y								
g^C	0.72	0.96	0.96	0.80	0.98	0.49	0.90	0.98
g^I	0.67	0.54	0.54	0.84	0.84	0.00	0.86	0.86
tby	-0.04	0.00	0.00	-0.52	-0.03	-0.01	-0.23	-0.05
C. Correlation with tby								
g^C	-0.27	-0.03	-0.03	-0.71	-0.06	-0.20	-0.24	-0.06
g^I	-0.19	-0.08	-0.08	-0.65	-0.12	-0.22	-0.32	-0.06
D. Autocorrelation Function of tby								
1st Order	0.58	0.98	0.98	0.58	0.98	0.95	0.59	0.99
2nd Order	0.26	0.98	0.98	0.26	0.98	0.92	0.16	0.99
3rd Order	0.14	0.97	0.97	0.14	0.97	0.91	0.11	0.99
4th Order	0.08	0.97	0.97	0.08	0.97	0.90	0.07	0.99
D. Autocorrelation Function of g^Y								
1st Order	0.11	-0.31	-0.30	0.68	0.74	-0.19	0.12	-0.10
2nd Order	-0.08	0.03	0.02	0.35	0.65	0.11	-0.17	0.02
3rd Order	-0.04	0.03	0.03	0.11	0.55	0.07	-0.02	0.05
4th Order	-0.05	0.02	0.02	-0.06	0.46	0.04	0.04	0.05

Note: g^Y, g^C, and g^I denote the growth rates of output per capita, consumption per capita, and investment per capita, respectively, and tby denotes the trade balance-to-output ratio. Standard deviations are reported in percentage points.

Table 1.6: Robustness Analysis Continued

	Data	Bench-mark	Shares	1913-2005 Data	1913-2005 Model	1880-2005 Data	1880-2005 Model	1865-2005 Data	1865-2005 Model
A. Standard Deviation									
g^Y	5.3	6.1	6	5.1	4.2	6.4	6.1	6.4	6.1
g^C	7.5	4.5	4.4	7.3	3.8	8.3	4.4	8.3	4.3
g^I	20	14	13	19	10	26	14	26	14
tby	5.2	18	18	4.9	16	6.3	19	6.8	21
B. Correlation With g^Y									
g^C	0.72	0.96	0.96	0.77	0.97	0.6	0.96	0.59	0.96
g^I	0.67	0.54	0.54	0.66	0.8	0.64	0.52	0.64	0.52
tby	-0.04	0	0	-0.08	-0.05	-0.07	0.01	-0.09	0.00
C. Correlation with tby									
g^C	-0.27	-0.03	-0.03	-0.3	-0.06	-0.18	-0.02	-0.16	-0.02
g^I	-0.19	-0.08	-0.08	-0.21	-0.06	-0.15	-0.07	-0.16	-0.07
D. Autocorrelation Function of tby									
1st Order	0.58	0.98	0.98	0.58	0.99	0.74	0.98	0.77	0.98
2nd Order	0.26	0.98	0.98	0.25	0.99	0.54	0.97	0.60	0.97
3rd Order	0.14	0.97	0.97	0.07	0.98	0.47	0.96	0.52	0.96
4th Order	0.08	0.97	0.97	0.00	0.98	0.41	0.96	0.47	0.96
E. Autocorrelation Function of g^Y									
1st Order	0.05	0.11	-0.3	0.05	-0.13	-0.01	-0.32	-0.01	-0.32
2nd Order	-0.16	-0.08	0.02	-0.16	0.02	-0.13	0.02	-0.12	0.02
3rd Order	-0.11	-0.04	0.03	-0.11	0.05	0.04	0.03	0.02	0.03
4th Order	-0.09	-0.05	0.02	-0.09	0.05	-0.04	0.02	-0.07	0.02

1900-1946 also emerge when one restricts attention to the postwar period. In particular, consumption is more volatile than output, investment is significantly more volatile than output, and the correlation of the trade-balance share with output growth is negative but fairly modest. When estimated over the period 1946-2005, the RBC model fails to mimic the data along the same dimensions as when it is estimated using the baseline sample 1900-2005. In particular, the model counterfac-

tually predicts consumption growth to be less volatile than output growth, investment growth to be significantly less volatile than its empirical counterpart, and the trade-balance ratio to be much more volatile than it is in the data.

1.6.2 Small Number of Overidentifying Restrictions

To gauge the sensitivity of our results to reducing the number of overidentifying restrictions, we eliminate all autocorrelations of order two from the moment conditions used in the GMM estimation. This modification reduces the total number of moment conditions from 16 to 12. The results appear in the column labeled 'No AC Order 2' in table 1.5. The implied dynamics of the model are virtually unaffected by the adoption of this alternative specification.

1.6.3 HP Filtering

In both the model and the data, output, consumption, and investment are nonstationary variables. Therefore studying the business-cycle properties of these macroeconomic indicators necessarily involves the use of filtering techniques to eliminate trend components. Thus far, we have focused on growth rates as a way to filter out movements at business-cycle frequency. But one need not limit the analysis to this particular way of inducing stationarity. A common way of describing business cycles, is to apply the Hodrick-Prescott filter. Here we follow this route by filtering both the data and the model predictions. In the case of the model, we compute the unconditional HP filter of the variables of interest. In both cases, we use a value of 400 for the smoothing parameter that defines the HP filter. The results are presented in columns 5 and 6 of table 1.5. The notation g^Y, g^C, and g^I now refers to percent deviations of output, consumption, and investment from their respective HP-filter trends. The model matches well the volatility of consumption and its correlation with output. However, consumption continues to be more volatile than output in

the data but less volatile than output in the model. And the model continues to underpredict the volatility of investment and to overpredict the volatility of the trade balance. Also, in the model, the trade balance is virtually uncorrelated with output, whereas in the data the two variables display a significant negative correlation. In addition, the autocorrelation function of output falls quickly to zero in the data but is relatively flat in the model. Finally, because the trade balance-to-GDP ratio is a stationary variable, the difficulties of the model to replicate the observed autocorrelation function of this variable remain.

1.6.4   Cobb-Douglas Preferences

The column labeled 'Cobb Douglas' in table 1.5 displays the equilibrium dynamics implied by a version of the model featuring a Cobb Douglas specification for the aggregator of consumption and leisure in preferences. Formally, we assume that the utility function is given by

$$E_0 \sum_{t=0}^{\infty} \beta^t \frac{[C_t(1-h_t)^\omega]^{1-\gamma} - 1}{1 - \gamma}.$$

Unlike the preference specification assumed in the baseline model, the Cobb Douglas period utility function implies a nonzero wealth elasticity of labor supply. We set the parameter ω at 3.4 to ensure that in the deterministic steady state households supply 20 percent of their time to the labor market. We reestimate the structural parameters of the model following the same procedure as in the benchmark case.

Under Cobb-Douglas preferences, a positive (permanent) productivity shock produces a wealth effect that induces agents to reduce their labor supply. In fact, in response to a positive innovation in the permanent technology shock g_t hours fall under the Cobb Douglas specification, but increases under the baseline specification. The negative effect on labor supply mitigates the response of output. At the same time, a positive permanent productivity shock increases the future expected

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marginal productivity of capital inducing firms to invest more. But at the same time the negative wealth effect on labor supply and the fact that the marginal product of capital is increasing in labor imply that the incentives to invest in response to a positive permanent productivity shock are weaker under Cobb Douglas preferences than under the baseline preference specification.

The main effect of introducing Cobb-Douglas preferences is a dramatic decline in the procyclicality of investment growth. Indeed, under Cobb-Douglas preferences investment growth becomes virtually acyclical.

1.6.5 Using Shares for Estimation

Another sensitivity experiment consists in replacing the growth rates of consumption and investment by the shares of these variables in GDP in the GMM estimation. This modification is motivated by the fact that in the model consumption and investment are cointegrated with output. The results are shown in the column labeled Shares in table 1.6. Both the fit and business-cycle implications of the model are similar whether it is estimated in growth rates or shares.

1.6.6 Long Samples

We study the performance of the RBC model using different data samples. In particular, we consider three different starting points: 1865, 1880 and 1913. These three starting dates are relevant for different reasons. The longest span of data for which all four series are available is 1865 (the source for the pre 1900 data is Ferreres, 2005). In 1880 Argentina reached its current territorial composition as the government completed the conquest of most of Patagonia and the southern part of the Pampa region from local aboriginal tribes. Finally, 1913 is the starting point of the series constructed by IEERAL (1986). Table 1.6 compare theoretical and empirical business-cycle statistics over the three samples. The empirical regularities identified

using the baseline sample 1900-2005 continue to characterize the data when using the different starting points. Specifically, (a) consumption is more volatile than output, (b) investment is significantly more volatile than output, (c) the trade balance-to-output ratio is not significantly more volatile than output, (d) the correlation between the trade balance and output growth is negative but modest, (e) all autocorrelations of output growth are insignificant, except the second, which is significantly negative, and (f) the autocorrelation function of the trade balance-to-output ratio is decreasing, resembling that of an AR(1) process.

Whether it is estimated using the shorter sample, 1913-2005, or the longer samples 1865-2005 and 1880-2005, the RBC model fails to mimic the data along the same dimensions as when it is estimated using the baseline sample, 1900-2005. In particular, the model counterfactually predicts consumption growth to be less volatile than output growth, investment growth to be half as volatile as its empirical counterpart, and the trade-balance ratio to be much more volatile than it is in the data. Also the model does a poor job replicating the autocorrelation functions of output and the trade-balance-to-output ratio.

1.7   Mexico 1900-2005

In this section, we gauge the robustness of our main results to using data from a different emerging country. Specifically, we estimate the RBC model using data on output, consumption, investment, and the trade balance from Mexico over the period 1900-2005.[4] Table 1.7 displays empirical and theoretical second moments. The RBC model estimated using Mexican data counterfactually predicts that output is more volatile than consumption. In addition, the model overpredicts the volatilities of

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[4]   The appendix provides data sources. All calibrated parameters are set as in the baseline case, except for d and δ, which were set at 0.05 and 0.082, respectively, to match the Mexican average trade-balance-to-GDP ratio (1.25 percent) and average investment-to-GDP ratio (14.7) over the sample period. The point estimate of the parameter vector $[g\,\sigma_g\,\rho_g\,\sigma_a\,\rho_a\,\phi]$ is $[1.00\ 0.02\ 0.25\ 0.02\ -0.02\ 0.00]$, and the associated standard deviations are $[0.0013\ 0.003\ 0.10\ 0.0008\ 0.03\ 0.002]$.

Table 1.7: Mexico 1900-2005

Statistic	g^Y	g^C	g^I	tby
Standard Deviation				
—Model	5.17	3.12	50.28	9.80
—Data	4.09	6.15	19.86	4.28
	(0.64)	(1.08)	(2.91)	(0.42)
Correlation with g^Y				
—Model		0.98	0.08	-0.02
—Data		0.66	0.55	-0.20
		(0.14)	(0.08)	(0.13)
Correlation with tby				
—Model		-0.13	-0.44	
—Data		-0.29	-0.07	
		(0.07)	(0.09)	
Serial Correlation				
—Model	-0.38	-0.27	-0.55	0.62
—Data	0.09	-0.07	0.23	0.72
	(0.10)	(0.08)	(0.13)	(0.10)

Note: Standard deviations are reported in percentage points. Standard errors of sample-moment estimates are shown in parenthesis.

investment and the trade balance and underpredicts the volatility of consumption. The high volatility of investment growth predicted by the model is a consequence of the fact that the GMM estimate of the parameter ϕ governing the degree of capital adjustment costs is virtually zero. The model also overestimates the cyclicalities of consumption and the trade balance and overestimates the cyclicality of investment. Further, the RBC model severely underestimates the serial correlations of output, consumption, and investment.

The model predicts a first-order autocorrelation of the trade-balance-to-output ratio significantly less than unity and close to its empirical counterpart. This result is due to the behavior of gross investment. The virtual absence of adjustment costs induces firms to bunch investment rather than spread this type of expenditure over time. As a result, investment growth is highly negatively serially correlated. In turn,

FIGURE 1.7: Mexico 1900-2005: The Autocorrelation Function of the Trade Balance-to-Output Ratio
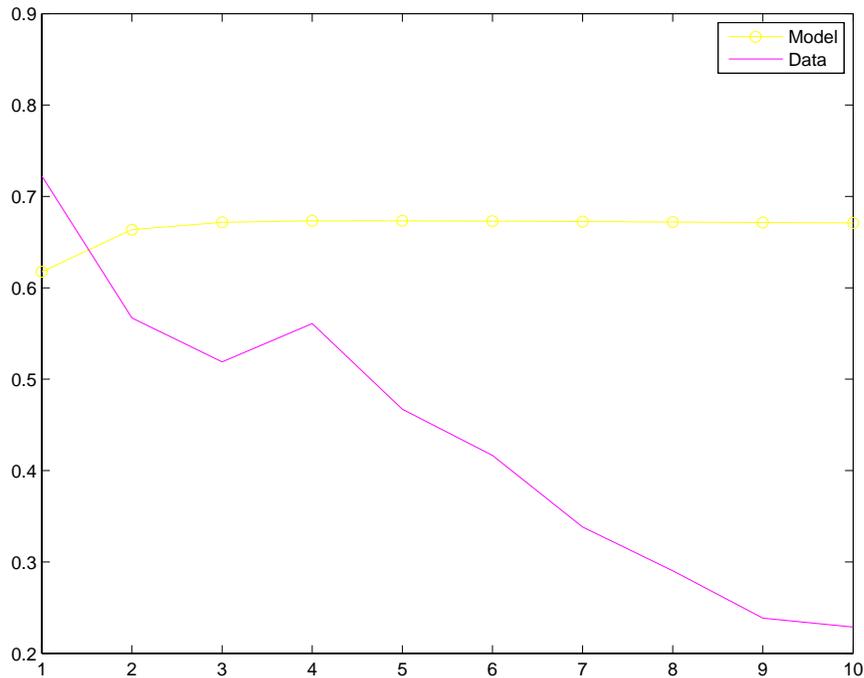
the negative serial correlation of investment growth has a depressing effect on the first-order serial correlation of the trade balance. However, this effect represents only a parallel downward shift in the autocorrelation function of the trade balance, which is counterfactually flat. This point is conveyed graphically by figure 1.7, which shows that the autocorrelation function of the trade balance predicted by the model starts at around 0.6 but, is flat (indeed slightly increasing). To highlight the flatness of the predicted autocorrelation function of the trade-balance-to-output ratio, the figure displays autocorrelations up to order 10. However, the theoretical autocorrelation function remains above 0.6 way beyond order 100. By contrast, the empirical auto-correlation function is strictly decreasing and converges relatively quickly to zero.

1.8 Financial Frictions, Country-Spread Shocks, and Domestic Demand Shocks

An important message of the analysis conducted thus far is that the difficulty of the RBC model to explain business cycles in emerging countries stems from two equally important sources: the nature of the driving forces which cannot produce the volatility pattern observed in the data, and the transmission mechanism, which is unable to produce the observed persistence in macroeconomic aggregates, particularly in the trade-balance-to-output ratio.

To further quantify these theoretical deficits, we augment the RBC model with a simple form of financial friction, and with shocks to the country premium and to domestic absorption. Specifically, we now allow the parameter ψ, governing the debt elasticity of the country premium to be econometrically estimated. Rather than fixing it at a small number. In this way, the role of the debt elasticity of the country premium is no longer limited to simply inducing stationarity, but to potentially act as the reduced form of a financial friction shaping the model's response to aggregate disturbances. The additional sources of uncertainty include a domestic preference shock, a spending shock, which can be interpreted as government purchases shock, and a country premium shock. We interpret the shock to the country premium as possibly stemming from financial imperfections that open the door to stochastic shifts in the country premium that are uncorrelated with the state of domestic fundamentals. To distinguish it from the standard RBC model studied thus far, we will refer to the model presented in this section as a 'model with financial frictions.'

Formally, in the augmented model households seek to maximize

$$E_0 \sum_{t=0}^{\infty} \nu_t \beta^t \frac{[C_t - \theta\omega^{-1}X_{t-1}h_t^\omega]^{1-\gamma} - 1}{1 - \gamma},$$

subject to the sequential resource constraint

$$\frac{D_{t+1}}{1+r_t} = D_t - Y_t + C_t + S_t + I_t + \frac{\phi}{2} \left(\frac{K_{t+1}}{K_t} - g \right)^2 K_t, \qquad (1.4)$$

and to the no-Ponzi-game condition given above. The variables ν_t and S_t represent, respectively, an exogenous and stochastic preference shock and a domestic spending shock following the AR(1) processes

$$\ln \nu_{t+1} = \rho_\nu \ln \nu_t + \epsilon^\nu_{t+1}; \quad \epsilon^\nu_t \sim \text{i.i.d. } N(0, \sigma^2_\nu).$$

and

$$\ln(s_{t+1}/s) = \rho_s \ln(s_t/s) + \epsilon^s_{t+1}; \quad \epsilon^s_t \sim \text{i.i.d. } N(0, \sigma^2_s),$$

where $s_t \equiv S_t/X_{t-1}$. The country premium takes the form

$$r_t = r^* + \psi \left(e^{\tilde{D}_{t+1}/X_t - \bar{d}} - 1 \right) + e^{\mu_t - 1} - 1,$$

where μ_t represents an exogenous stochastic country premium shock following the AR(1) process

$$\mu_{t+1} = \rho_\mu \mu_t + \epsilon^\mu_{t+1}; \quad \epsilon^\mu_t \sim \text{i.i.d. } N(0, \sigma^2_\mu).$$

All other elements of the model, including the production technology, the evolution of the stationary and nonstationary productivity shocks, and the evolution of the capital stock are as in the baseline RBC model presented above. Note that the present model nests the baseline RBC model of section 3.2.

1.8.1 Bayesian Estimation

We estimate the model using Bayesian methods and Argentine data on output growth, consumption growth, investment growth, and the trade-balance-to-output ratio over the period 1900-2005. We estimate 13 structural parameters, σ_g, ρ_g, σ_a, ρ_a, σ_ν, ρ_ν, σ_s, ρ_s, σ_μ, ρ_μ, ϕ, ψ, and g, and 4 nonstructural parameters representing

Table 1.8: Prior and Posterior Distributions

| | | | Posterior Distribution | | | | | |
| | Prior Distribution | | Financial-Friction Model | | | RBC Model | | |
Parameter	Min	Max	Median	5%	95%	Median	5%	95 %
g	1	1.03	1.01	1.003	1.017	1.005	1.001	1.012
σ_g	0	0.2	0.0071	0.0006	0.027	0.03	0.019	0.042
ρ_g	-0.99	0.99	0.35	-0.66	0.83	0.828	0.743	0.919
σ_a	0	0.2	0.033	0.028	0.038	0.027	0.024	0.032
ρ_a	-0.99	0.99	0.87	0.79	0.93	0.765	0.621	0.888
σ_ν	0	1	0.51	0.37	0.8			
ρ_ν	-0.99	0.99	0.86	0.74	0.93			
σ_s	0	0.2	0.015	0.0014	0.05			
ρ_s	-0.99	0.99	0.29	-0.73	0.92			
σ_μ	0	0.2	0.056	0.034	0.08			
ρ_ν	-0.99	0.99	0.91	0.83	0.97			
ϕ	0	8	4.6	3	6.5	3.3	2.3	4.9
ψ	0	5	2.8	1.3	4.6			
			Measurement Errors					
σ_y^{me}	0.0001	0.013	0.0001	0.0001	0.0001	0.0001	0.0001	0.0003
σ_c^{me}	0.0001	0.019	0.0001	0.0001	0.0002	0.0011	0.0008	0.0014
σ_i^{me}	0.0001	0.051	0.001	0.0002	0.0032	0.0216	0.0169	0.0281
σ_{tby}^{me}	0.0001	0.013	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002
Log-Marginal Likelihood			600.5854			547.5925		

Note: The parameters are estimated using Argentine data from 1900 to 2005. All prior distributions are uniform. Posterior statistics based on a 2 million MCMC chain from which the first million draws were discarded. The Log-Marginal Likelihood was computed using Geweke's modified harmonic mean method.

the standard deviations of i.i.d. measurement errors on the observables, σ_y, σ_c, σ_i, and σ_{tby}. We impose uniform prior distributions to all estimated parameters. Table 1.8 presents key statistics of the prior and posterior distributions. We highlight the following features of the estimated posterior distribution. First, the distributions of the parameters σ_g and ρ_g defining the nonstationary productivity shock are quite disperse. Second, the median of σ_a is four times smaller than the corresponding point estimate in the baseline RBC model, suggesting a reduced importance of this shock

under the present specification. Third, the estimated process for the stationary productivity shock is significantly more volatile and persistent than in the baseline RBC model. Fourth, the estimated debt elasticity of the country premium, ψ is substantial. The median value of this parameter implies that if the stock of external debt increases by one percentage point of GDP then the country premium increases by over half a percentage point. Fifth, the estimated volatility of the country-premium shock is large. A one-standard-deviation innovation in μ_t raises the interest rate at which the country borrows from world financial markets by about 5 percentage points .

For comparison, we also estimate the standard RBC model using Bayesian methods. Table 1.8 shows the median and the 90-percent-probability interval of the posterior distribution. Compared to the GMM estimates, the Bayesian approach delivers much more persistent processes for both productivity shocks (i.e., higher values of ρ_g and ρ_a) and a significantly higher value for the adjustment-cost parameter ϕ. The bottom line of the table shows that the log-marginal likelihood value associated with the financial-friction model is higher than the one corresponding to the standard RBC model, indicating that the data favors the model with financial frictions.

1.8.2 Model Predictions

Figure 1.8 displays with a crossed line the autocorrelation function of the trade-balance-to-output ratio predicted by the model. In producing this autocorrelation function, the structural parameters are set at the median of their posterior distributions. The figure shows that the model augmented with financial frictions is highly successful at replicating the downward-sloping autocorrelation function of the trade-balance-to-output ratio observed in Argentina over the period 1900-2005. This success is due to the reduced-form financial friction captured by the parameter ψ, governing the sensitivity of the country premium to movements in the stock of ex-

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FIGURE 1.8: The Model with Financial Frictions: Predicted Autocorrelation Function of the Trade Balance-to-Output Ratio
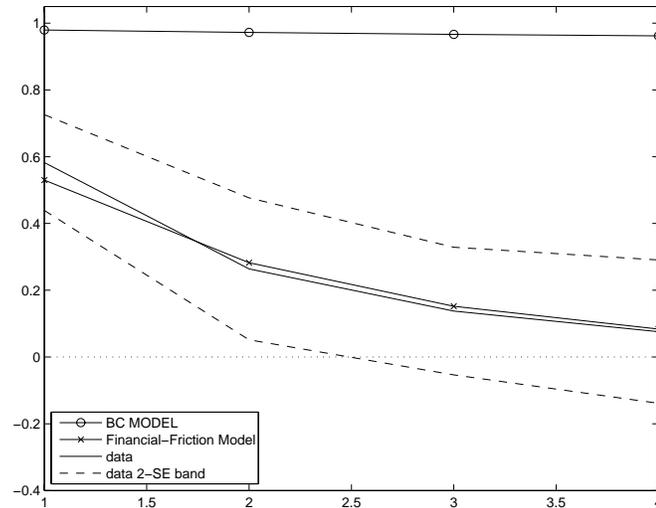
ternal debt. When ψ is relatively high, deviations of the trade-balance ratio above its long-run level cause the interest rate to increase, which curbs the growth rates of consumption and investment, thereby bringing the trade-balance ratio back down. A similar intuition applies to deviations of the trade-balance ratio below its long-run level. It follows that the larger is ψ the more trend reverting is the trade-balance ratio, and therefore the more downward-sloping is its autocorrelation function. Indeed, lowering the value of ψ from its median value of 2.8 to the small value of 0.001 imposed in the calibration of the baseline RBC model causes the autocorrelation function of the trade-balance-to-output ratio to become flat and close to unity as in the RBC model.

The other two elements of the model that are important in mimicking the observed autocorrelation function of the trade-balance-tooutput ratio are country-premium shocks and preference shocks. Shutting down these two shocks by setting $\sigma_\mu = \sigma_\nu = 0$, while keeping all other parameter values at their posterior medians, causes the autocorrelation function of the trade-balance-to-output ratio to lie entirely above

Table 1.9: Comparing Model and Data: Second Moments using Bayesian Estimates

Statistic	g^Y	g^C	g^I	tby
Standard Deviation				
– RBC Model	7.2	7.7	13.0	118.0
– Financial-Friction Model	6.2	8.2	18.0	5.0
– Data	5.3	7.5	20.4	5.2
	(0.4)	(0.6)	(1.8)	(0.6)
Correlation with g^Y				
– RBC Model		0.88	0.77	-0.01
– Financial-Friction Model		0.78	0.34	-0.024
– Data		0.72	0.67	-0.04
		(0.07)	(0.09)	(0.09)
Correlation with tby				
– RBC Model		-0.02	-0.03	
– Financial-Friction Model		-0.29	-0.25	
– Data		-0.27	-0.19	
		(0.07)	(0.08)	
Serial Correlation				
– RBC Model	0.29	0.127	0.065	0.999
– Financial-Friction Model	0.042	-0.012	-0.086	0.53
– Data	0.11	-0.005	0.32	0.58
	(0.09)	(0.08)	(0.10)	(0.07)

Note: Empirical moments are computed using Argentine data from 1900 to 2005. Standard deviations are reported in percentage points. Standard errors of sample-moment estimates are shown in parenthesis. Model moments are computed as the mean based on 400,000 draws from the posterior distribution.

the upper limit of the two-standard-error band around the empirical point estimate. On the other hand, productivity shocks are not essential for the models ability to match the autocorrelation function of the trade-balance-to-output ratio. In effect, shutting off both productivity shocks by setting $\sigma_g = \sigma_a = 0$ one obtains a predicted autocorrelation function of the trade-balance-to-output ratio that matches quite well its empirical counterpart.

Table 1.9 displays second moments predicted by the model with financial frictions. The table shows that the augmented model overcomes a number of difficulties

faced by the RBC model. First, the model with financial frictions captures the fact that in Argentina over the period 1900-2005, as in most other developing countries, consumption growth is significantly more volatile than output growth. In the model with financial frictions the bulk of the predicted excess volatility of consumption is explained not by nonstationary productivity shocks—as maintained by the hypothesis that 'the cycle is the trend'—but by domestic preference shocks. This observation will become apparent shortly when we present predicted variance decompositions. The RBC model estimated using Bayesian methods delivers a slight excess folatility of consumption but at the expense of an exorbitant volatility of the trade-balance-to-output ratio. Second, the model with financial frictions corrects the RBC model's severe overestimation of the volatility of the trade-balance-to-output ratio as well as the underestimation of the volatility of investment growth. Third, as in the data, the model with financial frictions predicts a significant negative correlation of the trade-balance ratio with consumption and investment growth. By contrast, the RBC model predicts virtually no correlation between the trade balance and the components of domestic absorption

Table 1.10 presents the variance decomposition predicted by the model with financial frictions. The most remarkable result that emerges from this exercise is that the contribution of nonstationary productivity shocks to business cycles is predicted to be virtually nil. That is, the model gives little credence to the hypothesis that 'the cycle is the trend.' By contrast, the stationary component of total factor productivity explains most of the predicted movements in output growth.

Movements in productivity, whether permanent or temporary, play virtually no role in explaining movements in investment growth or the trade balance-to-output ratio. These two variables are to a large extent driven by innovations in country interest rates. Finally, consumption growth is explained in equal parts by domestic preference shocks and stationary productivity shocks. Preference shocks are respon-

Table 1.10: Variance Decomposition Predicted by the Model with Financial Frictions

Shock	Output Growth	Consumption Growth	Investment Growth	Trade Balance to GDP Ratio
Nonstationary Tech.	7.4	4.3	1.5	0.4
	(11.1)	(6.9)	(2.7)	(0.7)
Stationary Tech.	84.2	51.3	15.9	1.3
	(11.1)	(8.2)	(4.1)	(0.7)
Preference	5.5	39.1	20.2	19.3
	(2.2)	(5.0)	(5.1)	(5.9)
Country Premium	2.9	5.2	62.4	78.9
	(0.7)	(1.8)	(5.0)	(6.3)
Government Spending	0.0	0.0	0.0	0.1
	(0.0)	(0.1)	(0.0)	(0.1)

Note: Means based on 400,000 draws from the posterior distribution. Standard deviations are in parenthesis. The estimated contribution of all four measurement errors (not shown) is negligible for all four variables.

sible for most of the excess volatility in consumption growth.

1.9   Conclusion

The present study scrutinizes the hypothesis that business cycles in developing economies are driven by permanent and/or transitory exogenous shifts in total factor productivity and transmitted through the familiar mechanism of the frictionless RBC model.

The starting point of our investigation is the notion that if permanent shocks are to play an important role in the macroeconomy, then long time series are called both for characterizing business cycles, as well as for identifying the parameters defining the stochastic process of the underlying shocks. Accordingly, we build a data set covering more than a century of aggregate data from Argentina and Mexico. We use these data to estimate a battery of statistics that provide a fairly complete picture of the Argentine and Mexican business cycles. We then formulate a standard RBC

model of the small open economy driven by permanent and transitory productivity shocks. We estimate the parameters of these productivity shock processes and other structural parameters of the model using our data from Argentina and Mexico.

Comparing the predictions of the model with the data, we arrive at the conclusion that the RBC model does a poor job at explaining business cycles in Argentina and Mexico. One dimension along which the RBC model fails to explain the data is the trade-balance-to-output ratio. In the model, the trade balance-to-output ratio follows a near random walk, with a flat autocorrelation function close to one. In the data, the autocorrelation of the trade-balance share is far below unity and converges quickly to zero. Another challenge for the RBC model is the empirical fact that in Argentina and Mexico, as in many other emerging countries, private consumption growth is more volatile than output growth. In order for the RBC model to explain this fact, permanent shocks to productivity must be sufficiently predominant. Our estimates do not assign permanent shocks this predominance. On the other hand, there is a sense in which permanent shocks are too important in the model. In effect, in the model the trade balance-to-output ratio is about four times as volatile as output growth, whereas in the data these two variables are equally volatile. This mismatch between model and data is due to the permanent component of productivity shocks. For shutting off this shock in the theoretical model causes the volatility of the trade balance-share to fall by about 75 percent.

Taken together, our findings suggest that the RBC model driven by productivity shocks does not provide an adequate explanation of business cycles in emerging countries. We further scrutinize this conclusion by estimating, using Bayesian methods and the Argentine data set, an augmented version of the RBC model that incorporates an empirically realistic debt elasticity of the country premium and three additional sources of uncertainty: country-premium shocks, preference shocks, and government spending shocks. The augmented model does a remarkable job at ex-

plaining the Argentine business cycle. In particular, the model delivers a downward-sloping autocorrelation function of the trade-balance-to-output ratio, excess volatility of consumption, a high volatility of investment, and a volatility of the trade-balance-to-output ratio similar to that of output growth. More importantly, the model predicts that permanent productivity shocks explain a negligible fraction of aggregate fluctuations, giving little support to the hypothesis that the cycle is the trend. We interpret these results as suggesting that a promising area for future research is to formulate, estimate, and quantitatively evaluate dynamic stochastic models of the emerging economy with microfounded financial imperfections.

2

What Drives the Roller Coaster?
Sources of Fluctuations in Emerging Countries

2.1 Introduction[1]

The international macroeconomics' literature has widely documented the distinctive features of business cycles in emerging countries. For instance, since World War II, fluctuations of aggregate measures of economic activity have dampened in developed economies, whereas many emerging countries display no signs of smoothing in the past fifty years. Additionally, consumption seems to be more volatile than output in emerging countries, the trade-balance is generally more countercyclical in developing economies, and the components of aggregate demand seem to be more correlated with output than in developed markets.[2]

Although there is an extensive literature analyzing different driving forces that may explain these business cycle facts, most of these studies have proposed "isolated"

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[1] I would like to thank to Carlos Bózzoli for sharing his data on interest rates.

[2] These differences, and several others, where analyzed by Basu and McLeod (1992), Mendoza (1995), Kydland and Zarazaga (1997), Basu and Taylor (1999), Aguiar and Gopinath (2007), Neumeyer and Perri (2005), Uribe (2007) and García-Cicco et al. (2009).

explanations for these phenomena.[3] There are few studies attempting to disentangle the relative importance of each of these different explanations, most of them still proposing incomplete characterizations. The goal of this paper is to provide a comprehensive analysis of the alternatives evaluated in the literature in order to asses their relevance in explaining business cycles fluctuations in emerging economies.

To achieve this goal, we present a fully-fledged real DSGE model of an emerging country encompassing the different models used in this literature. In particular, we consider a small open economy with three consumption goods: exportables, importables and non-tradeables, in the spirit of Mendoza (1995). These are produced with capital and labor, while a fixed factor (land) is also used to produce exportable goods (as in Kose (2002)). Following Uribe and Yue (2006) and Neumeyer and Perri (2005), firms are also subject to a working capital constraint. Households have access to an incomplete international asset market, where the interest rate paid is the sum of the world rate and the country premium. Ten alternative driving forces are considered: stationary shocks to the production technology in each sector, non-stationary shifts in the level of embodied and disembodied technology, disturbances to the terms of trade, world interest rate and country spread shocks, exogenous fluctuations in government purchases and trade policy changes.

In order to asses its empirical relevance, the model is estimated using a Bayesian approach. A non trivial issue in analyzing emerging countries is the limited data availability. Most existing studies choose to work with quarterly data starting around 1980 or even later. This practice has been recently criticized by García-Cicco et al. (2009), particularly due to the ability of characterizing non-stationary shocks using a short span of data. In that work, a data set containing almost a century of annual data for Argentina was constructed, which we have further expanded here to include

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[3] The word "isolated" is used to reference studies proposing a given explanation, without necessarily comparing it with other proposed alternatives. We present a review of this literature in Section 2.2.

other relevant variables in our model.

Our main motivation is the difficulty to compare and generalize the existing results due to the methodological dispersion that exists in this literature, particularly in ranking the relevance of each driving force emphasized by these papers. On one hand, one might think that probably all proposed alternatives have a role in explaining fluctuations, for all of them appear to be successful in accounting for some of the observed facts. However, the results obtained with an isolated explanation may be due to the omission of other relevant alternatives. To illustrate this point, consider the case of the variance decomposition of output in emerging countries. Aguiar and Gopinath (2007) claim that almost 80 percent of output variability is due to permanent shocks to technology. Kose (2002) computes that fluctuations in international prices are responsible for roughly 88% of output variance. Finally, Uribe and Yue (2006) conclude that nearly 30% of the volatility of output is due to shocks in the real interest rate. Clearly, it cannot be the case that all these computed numbers are correct. This is an example highlighting how to study all these driving forces simultaneously would allow to properly rank their relative importance.

In sharp contrast with previous studies, our results indicate that the predominant driving force behind fluctuations in Argentina for this sample is the stationary productivity shock in the non-traded sector, explaining more than 60% of output growth's variance. This result is robust to the inclusion of sectorial production data in the set of observables used for the estimation, a novel approach in this literature. In a second order of magnitude, terms-of-trade and country premium shocks explain close to 10% of such a variance, while the role of non-stationary technology shocks, the world interest rate, trade distortions and government expenditures seems to be negligible.

Moreover, an improvement in the productivity of non-tradeables produces a real depreciation that raises consumption and investment in this sector proportionally

more than output. Therefore, the model is able to reproduce two of the distinctive characteristics of business cycles in emerging countries: the volatility of consumption exceeding that of output and a countercyclical trade balance.

We also found a challenge in jointly accounting for the behavior of output and the real exchange rate, particularly when the model is estimated using sectorial shares. In the data, particularly in the last 30 years, recessions are generally associated with real depreciations. However, a real appreciation should be experienced if these contractions are generated by negative shocks to non-traded productivity, as implied by the estimated model. This puzzling result is important because it is a common practice in this literature to judge the goodness of fit of models without using real exchange rate data, mostly because DSGE-based studies generally use one-sector models which are not suitable to analyze the behavior of this variable.

The rest of this document is organized as follows. Section 2.2 presents a description of the previous literature. In Section 2.3, we describe our data set and compute several statistics in order to characterize the business cycles in Argentina for the period 1913-2005. Section 2.4 displays the model that will lead our analysis. The empirical strategy is described in Section 2.5 and the estimation results, particularly the variance decomposition exercise, are shown in Section 2.6; including those obtained using sectorial data. Section 2.7 concludes.

2.2 Literature Review

This section presents a brief review of the related literature. We divide the description to reflect the different types of shocks that are going to be analyzed later in this work. In particular, they are grouped in three categories: technological change, terms of trade and trade distortions, and interest rates and country premia.

We pay special attention to papers analyzing the different driving forces in the context of dynamic stochastic general equilibrium (DSGE) models, summarizing also

studies that empirically characterize the role of each driver. In addition, we describe the intuition that makes each of the possible sources of fluctuations appealing to explain the stylized facts in emerging countries.

The goal of this review is not only to place this work in the context of previous contributions, but also to highlight the lack of comprehensive studies and the dispersion in this literature that, as commented in the introduction, motivates our work.

2.2.1 Technological Change

The seminal paper by Mendoza (1991) adapted the basic real business cycle (RBC) framework to small open economies. By calibrating the model to Canadian data, he argues that a small open economy version of the RBC model driven by a total factor productivity (TFP) shock does a good job in replicating most of the empirical facts he documented. Although this was the first contribution proposing TFP shocks as a driver for small open economies, the relation with our paper is however weak, as he attempts to characterize a *developed* country.[4]

TFP disturbances have a good chance (at least theoretically) to explain the empirical facts in emerging economies if non-stationary processes are considered. In a simple RBC framework, rational agents facing a TFP shock that produces an increasing pattern in future expected output will find optimal to increase consumption by more than the current increase in output. This will be translated in a volatility for consumption greater than for output, as well as in a countercyclical trade balance.

Using this conceptual framework, Aguiar and Gopinath (2007) estimate the parameters describing the stochastic processes of both stationary and non-stationary TFP shocks in a simple small open RBC model for Canada and Mexico. Their re-

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[4] Some other examples using standard RBC models to describe fluctuations in developed small open economies are Correia et al. (1995) and Backus et al. (1992).

sults show that while in Canada the stationary technology shock seems to be more relevant, the non-stationary shock plays the key role for Mexico. In particular, they argue that nearly 80% of the output variance in Mexico can be explained by non-stationary TFP shocks. Using a similar model, Kydland and Zarazaga (2002) find that the RBC model can replicate satisfactorily the "lost decade" of the 1980s in Argentina.[5]

An important drawback of this literature is the use of short samples (around 20 years of quarterly data) in characterizing the non-stationary process. By nature, driving forces with unit roots are associated with low frequency cycles. As a result, short time series are particularly ill-suited to estimate this type of uncertainty. In a recent paper, García-Cicco et al. (2009) estimate the parameters defining the stochastic processes of permanent and temporary productivity shocks in a simple RBC framework, using almost a century of data for Argentina. Their results show that the estimated model fails to replicate most of the empirical facts characterizing the business cycles in that country, particularly the behavior of the trade balance. Moreover, they describe how the lack of fit in some aspects of the model is closely linked with the transmission mechanism imbedded in the simple RBC framework, regardless of the estimated persistence of the TFP process.

Another type of technological change that has been emphasized recently as a business cycle driver in developed economies is the investment-specific (or embodied) technology.[6] Although there are a few studies analyzing the role of this type of shock in open economies,[7] there are no papers –to our knowledge– characterizing

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[5] Bergoeing et al. (2002a) also find that TFP shocks are most important in explaining business cycles in Chile. In addition, Bergoeing et al. (2002b) argue that the differences in the recovery after the early 80's crisis in both Chile and Mexico can be mainly explained by discrepancies in Solow residuals. However, these papers do not strictly share the spirit of our work as they analyze these issues in the context of a *closed* economy model.

[6] For instance, Greenwood et al. (2000) argue that this type of shock can explain near 30 percent of output fluctuations in the U.S. post-war era.

[7] For instance, Boileau (2002) highlights the role of investment specific technology in generating

its importance for emerging countries. Theoretically, this shock can help to explain several stylized facts in these economies. For an embodied technology shock increases investment on impact whereas output is affected with a lag, which can generate a countercyclical trade balance and make investment more volatile than output.

2.2.2 Terms of Trade and Trade Distortions

Because most emerging countries are mainly exporters of a few primary commodities, it is reasonable to believe that the terms of trade (TOT hereafter) –the ratio between the *world* prices of exports and imports– can be an important source behind aggregate fluctuations in these countries. In addition, due to the assumption of small economies, TOT can be regarded as exogenous, simplifying the identification task.

Along these lines, the main theoretical reference characterizing the role of TOT in a business cycle framework for emerging countries is Mendoza (1995). He considers a three-sector economy (non-tradeables, importables and exportables) driven by sector-specific technology shocks and fluctuation in the TOT. In addition, capital used for production is assumed to be an imported good, allowing for an additional amplification channel for TOT disturbances. His model is able to qualitatively match many of the business cycle differences between emerging and developed countries. Moreover, he finds that nearly 50 percent of output and real exchange rate fluctuations can be attributed to TOT shocks.

The studies following Mendoza (1995) have delivered mixed evidence on the role of TOT as a business cycle driver. One one side, Kose and Riezman (2001) and Kose (2002) extended Mendoza's work by specifying a richer production side. Specifically, production of exportables uses labor, imported capital and a fixed production factor

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cross country output correlations and terms of trade volatility in G7 countries. Additionally, Mulraine (2006) calibrates a small open economy including embodied technological change to Canadian data. He argues that this shocks is particulary important to replicate the countercyclical behavior of external accounts.

(land). In addition, production of non-tradeables uses labor capital and imported intermediate goods. Finally, the capital adjustment costs are different across sectors.[8] These differences generate additional amplification mechanisms for the propagation of shocks to external prices. However, because there is more than one imported good (capital and intermediate inputs), the shocks to external prices they analyze are different from the TOT shock considered in Mendoza (1995). Nevertheless, their results show that between 50 and 90% of output fluctuations in emerging countries can be explained by shocks to external prices.

On the other hand, evidence from VAR analysis suggests that TOT fluctuations are less important. For instance, Hoffmaister and Roldos (1997) use a sample of 17 Asian and 17 Latin American countries, finding that TOT shocks can explain less than ten percent of the output forecast error; although they are most important in explaining trade balance fluctuations. Otto (2003) uses a similar methodology applied to 55 small open economies (15 developed and 40 emerging), focusing on the impact on the trade balance. He concludes that TOT shocks can explain nearly 20% of the variance of the trade balance in emerging countries, and about 15% in developed countries. Finally, a recent work by Lubik and Teo (2005) finds –using an estimated DSGE model for Mexico and Chile– that TOT fluctuations account for less than 5% of output variability. Their model is, however, significantly different from Mendoza's. In particular, they assume only two consumption goods (domestic and foreign), abstracting in this way from effects through the real exchange rate.

An important issue related to the role of TOT is its empirical counterpart. In principle, the small economy assumption allow us to identify TOT shocks directly from the data only if *external* TOT (i.e. prices determined in the rest of the world) are available. Several of these papers, however, use a different series: the ratio of the

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[8] There are however some differences with Mendoza (1995). In their setup, imported goods are not produced domestically and utility depends only on of non-traded consumption. They also considered world interest rate shocks.

implicit deflators for exports and imports (or *domestic* TOT).[9] Assuming that this is a strictly exogenous variable could be misleading. In fact, the ratio of domestic TOT to external TOT is frequently used as a measure of trade distortions.[10]

Although domestic TOT will in part reflect the shocks to external prices, it will also reflect any deviation from the law of one price in both goods, particularly capturing the impact of export taxes, tariffs on imports, preferred nominal exchange rates, etc. In addition, commercial policy can be designed in a way to ameliorate the impact of variations in international prices. Finally, from a theoretical point of view, a change to trade policy that moves the domestic TOT can have a different response than a change in international prices; for the former produces a differential wealth effect depending on how the revenue from trade policy is rebated to consumers.

Nevertheless, this difference between domestic and external TOT suggests that it is worth to explore whether trade policy has a role in explaining business cycles; by the end of the day, domestic TOT should be the relevant variable affecting the incentives to allocate production and consumption across different sectors. Moreover, trade policy can potentially be relevant in explaining fluctuations not only as a driving force but also as a propagation mechanism for other shocks.

2.2.3 Interest Rates and Country Premium

Emerging countries heavily rely on external borrowing. For instance, Reinhart et al. (2003) report that the average (between 1970 and 2002) debt-to-GNP ratio for a sample of 16 emerging countries lies between 20 and 60%. Given this picture, it is natural to believe that fluctuations in the cost of borrowing will significantly affect these economies. Moreover, evidence seems to indicate that the real interest rates in most emerging economies are countercyclical and lead the cycle, in sharp contrast

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[9] This is the case in Otto (2003) and Lubik and Teo (2005), among many others in this literature.

[10] See, for instance, Díaz Alejandro (1991), Mundlak et al. (1990) and Berlinski (2003) for applications to Argentina.

with developed economies.[11]

The real interest rate faced by an emerging country can be decomposed into two components: the world interest rate and the country premium. Given that emerging countries do not play a role in the determination of the world interest rate, this first component can be regarded as exogenous. This assumption has been exploited by the literature to identify fluctuations in the world interest rate as a possible business cycle driver.

The evidence documented in studies that try to account for the role of the world interest rate is, however, mixed. On one side, Blankenau et al. (2001) argue that one-third of output fluctuations in Canada can be explained by world real interest shocks. Additionally, Lubik and Teo (2005), using their estimated DSGE model for Mexico and Chile, conclude that between 35 and 45% of output variance can be explained by these shocks.

On the other hand, Kose (2002) presents a model that includes trade, productivity and world interest rate shocks. His emerging country calibration leads to the conclusion that world interest rate fluctuations can explain less than 2% of output variance. Kose and Riezman (2001) calibrate a similar model using African data and conclude that the contribution of world interest rate is almost nil. Finally, Hoffmaister and Roldos (1997) present VAR-based evidence showing that world interest rate shocks can account for nearly 20% of output forecast error for Latin American countries, but less than 6% in Asia.

The aforementioned papers share two distinct characteristics. On one hand, they only focus on world interest rate shocks, muting any effect coming from the country premium (in fact, they all assume that the country premium is zero). This omission is important for at least two reasons. First, shocks to the country premium can be an additional source of fluctuations as well. Additionally, given that the country

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[11] These stylized facts are reported by Neumeyer and Perri (2005) and Uribe and Yue (2006).

premium is endogenously determined, it can have an important role by propagating other shocks. On the other hand, regardless of the inclusion of the country premium, they do not consider any additional amplification mechanism able to enlarge the effect of interest rate fluctuations in aggregate fluctuations.

These issues were recently addressed by Neumeyer and Perri (2005) and Uribe and Yue (2006). They consider the role of country premia, both as a source of fluctuations and as a propagation mechanism. Neumeyer and Perri (2005) consider the case where the country premium is an increasing function of the productivity shocks, whereas Uribe and Yue (2006) consider a reduced form representation where the domestic interest rate reacts to current and lagged values of the world interest rate, output, investment and the trade-balance-to-output ratio. In addition, these two papers assume that firms are subject to a working capital constraint in the supply side: part of the wage bill needs to be paid in advance. This departure from the standard RBC framework induces an additional amplification mechanism, as labor supply will also be affected by a change in the cost of borrowing in this case.

Given these modifications, the model in Neumeyer and Perri (2005) calibrated to Argentine data indicates that eliminating country risk lowers output volatility by 27%, whereas the world interest rate can explain only 3% of this variance. They also show that the presence of both the endogenous country premium and the working capital constraint are key in obtaining these results, as well as in fitting other aspects of the data. On the other hand, Uribe and Yue (2006) estimate their model to match impulse responses implied by a panel VAR of seven developing countries. They conclude that about 20% of output variance can be attributed to foreign interest rate shocks and nearly 12% can be explained by country premium disturbances. In addition, they show that eliminating the endogenous country premium feedback reduces the model's predicted output variance by almost 30%.

2.2.4 Discussion

The fact that some of the previously cited studies appear in the discussion of more than one type of shocks implies that some attempts to compare the importance of alternative drivers have been made in this literature. In terms of analyses based on DSGE models, however, there is still an important dispersion. Specifically, most have omitted the role of country premia, even those analyzing the role of world interest rates. In addition, studies comparing transitory and non-stationary TFP shocks do not analyze any other possible explanation. Finally, with the exception of Mulraine (2006), the literature seems to have neglected the role of investment specific shocks.[12]

On the other hand, we have also described some studies based on VAR approaches. Under this framework, the relevance of the analysis is strictly linked with the identification assumptions. Although shocks regarded as strictly exogenous (like foreign terms of trade and the world interest rate) might be properly identified by the small economy assumption, this is not the case for other drivers. For instance, by imposing long run restrictions this literature frequently identifies supply and demand shocks. The comparison of such shocks with those usually included in DSGE models is not clear. Moreover, this framework is not informative either about the relevant transmission mechanisms that propagate these shocks.

2.3 A First Look at the Data

As explained in the introduction, the properties of our model will be tested using Argentine data from 1913 to 2005. We present a brief description of the series, while the sources' description is included in the Appendix. National account series (GDP, private and government consumption and investments per capita) are measured in

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[12] Note that we have omitted from our discussion other dimensions that contribute to the lack of comparability in this literature; namely, the estimation/calibration approach, as well as the countries and samples used for the analysis. These differences are clearly not innocuous in determining the relevance of each contribution.

terms of domestic consumption. The real exchange rate is measured as the ratio of the foreign price of imports (expressed in domestic currency trough the nominal exchange rate) to the domestic consumption price index. We choose this ratio instead of the more generally used based on foreign and domestic CPI in order to be consistent with the measure of real exchange rate produced by our model.

We construct a trade policy index based on the ratio of domestic to foreign TOT.[13] The latter is measured as the world relative price of exports in terms of imports, whereas the former is a proxy calculated as the ratio of the wholesale price indexes for agricultural and non-agricultural products.[14] Although this index can reflect many different types of quantitative and nominal restrictions imposed by the commercial policy, in order to understand its behavior it is useful to think of a situation with taxes on exports (τ_X) and tariffs on imports (τ_M). In this situation, the trade policy index will be equal to $(1 - \tau_X)/(1 + \tau_M)$. An increase in either of the tax rates will generate a decrease in the index; thus lower values will represent situations with greater trade restriction.

We will also study the importance of interest rates. Because we want to disentangle the different roles played by the world interest rate and the country premium, we analyze two series: the real interest rate in the U.S. and a series constructed by della Paolera et al. (2003) that represents the domestic cost of international borrowing.

In the rest of this section we present some business cycle properties of our sample. Table 2.1 presents a number of second moments characterizing the cycle in this sample. Many were already extensively discussed for this same period in García-Cicco et al. (2009), for which we just present here a brief summary. In line with

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[13] As discussed before, the difference between these two relative prices may reflect other types of trade distortion. For simplicity, and given the structure of our model, we choose to interpret this ratio as a trade policy index.

[14] This measure has been previously used as a meassure of trade distortions for the Argentine case by Díaz Alejandro (1991) and Berlinski (2003), among others.

many emerging economies, private consumption is significantly more volatile than output. The standard error of investments is almost three times of that for output. The trade balance-to-output ratio (tby) seems to be more volatile than output and is slightly countercyclical. While both consumption and investment display a strong positive correlation with output, they show a significantly negative correlation with tby.

The growth rate of government expenditure is almost twice as volatile as GDP and procyclical. Its correlation with tby is negative but insignificant, in contrast with what we observed for the other aggregate demand components. The real exchange rate (RER) also shows an even higher volatility (nearly nine times that for GDP growth) and it seems to be negatively correlated with both GDP growth and the trade balance.[15]

In terms of TOT and trade policy, we observe that they are much more volatile than output.[16] Both seem to be acyclical and, while TOT are positively correlated with the trade balance, the trade policy index displays a negative correlation. Additionally, the trade policy index seems to be highly persistent, although unit root tests cannot reject the stationarity hypothesis.

Both the country premium and the world interest rate seem to be less volatile than output, a result also reported in Neumeyer and Perri (2005), while both appear to be acyclical. In terms of the trade balance, however, it is positively related with the country premium but it exhibits a negative correlation with rw.

Finally, we want to further explore the cyclical behavior of the RER, as it will play a significant role in understanding the properties of the estimated model. Figure 2.1

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[15] These moments are similar using the ratio of CPI's as the measure of RER.

[16] Mendoza (1995) have reported that the volatility of TOT seems to be smaller than for GDP for most of the emerging countries he analyzed. A possible explanation could be related with the sample used. Whereas his starts after 1970, ours includes the interwar period when TOT appear to be more volatile.

displays the change in the log of the RER (a positive number is a real depreciation) along with the contraction years described in Sturzenegger and Moya (2003).[17] The RER appears to have experienced a depreciation in most of the recessions, especially in the last 30 years in which its volatility has also sharply increased. This relationship is, however, weak as we can also observe in Table 2.2. While the mean annual change in the RER is 5% in recessions and -2% in expansions, a significant variability can be observed as well. Moreover, Figure 2.2 indicates that is not clear either if the RER leads or lags the cycle.

2.4   The Model

The basic structure of the model is the decentralized version of Mendoza (1995), augmented to include the additional features highlighted in Section 2.2. We provide a brief description before specifying the details of the model in the following subsections.

The economy is populated by households, firms and a government. The supply side is composed by three productive sectors (exportables, importables and non-tradables). Capital and labor are used as inputs in these sectors, while the exportable sector also requires a fixed production factor. These firms are subject to a working capital constraint, by which they need to borrow in advance to pay part of their wage bills. The required funds are provided by households, through a competitive domestic loans' market. In addition, there are two intermediate firms (aggregators) producing both tradable and final consumption composites.

Households derive utility from final consumption goods (subject to habit formation) and from leisure. They have access to an incomplete foreign asset market and they own the stock of capital. Investment is subject to adjustment costs that differ

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[17] Their work analyze data up to 1990. We have updated this series to include a recession from 2001 to 2003.

in the type of capital used in each sector. Households' resources come from renting labor and capital services to domestic firms, foreign debt and profits from domestic firms.

The government is assumed to consume an exogenous stream of final goods. In addition, it implements a trade policy and collects lump-sum taxes.

This economy is subject to ten stochastic shocks affecting the following variables: the TFP in each of the three productive sectors, the growth rate of a labor-augmenting technology common to each sector, the growth rate of an embodied (investment-specific) level of technology, government purchases, foreign TOT, the trade policy, the world interest rate and the country premium. Finally, we choose the numeraire in the model to be the foreign price of imports.

2.4.1 Households

The economy is populated by a continuum of identical household of mass one. The representative household maximizes

$$E_0 \left\{ \sum_{t=0}^{\infty} \beta^t U \left(C_t - \eta \widetilde{C}_{t-1}, l_t \right) \right\},$$

where C_t and l_t denote final consumption and labor effort, respectively, at time t; while $\widetilde{C}_{t-1}$ represents the average level of consumption at $t-1$ (i.e., the utility function exhibits *external* habit formation) and $\eta \in [0,1)$. We use upper case letters to denote variables containing a trend in equilibrium while lower case letters represent stationary ones.

The period t budget constraint is

$$p_t^C \left(C_t + I_t \right) + \left(1 + r_{t-1} \right) D_t + T_t = W_t l_t + K I_t + D_{t+1} - \Psi \left(D_{t+1} \right) + \Pi_t^D. \quad (2.1)$$

The variables W_t and KI_t denote, respectively, the wage rate and net total capital income (described below), whereas T_t are lump-sum taxes/transfers. In addition,

the relative price of final consumption in terms of foreign imports is represented by p_t^C. The stock of international real debt outstanding at time t (in terms of foreign importables) is denoted by D_t and r_{t-1} is the associated interest rate. We assume convex adjustment costs associated with changes in the stock debt, captured by $\Psi(\cdot)$.[18] Additionally, households receive the profits generated by domestic firms, Π_t^D. Consumers are also subject to a no-Ponzi-scheme constraint of the form $\lim_{j\to\infty} E_t \left\{ \frac{D_{t+j}}{\Pi_{s=0}^j (1+r_s)} \right\} \leq 0$.

The interest rate paid for international borrowing has two components: the world interest rate (rw_t) and the country premium (cp_t). Specifically, $(1+r_t) \equiv (1+rw_t)(1+cp_t)$. While the first one is assumed to be a strictly exogenous process, we allow the country premium to depend on some endogenous observables, as well as on an exogenous disturbance. We specify these processes below.

Aggregate investment in units of domestic consumption is defined as $I_t \equiv \left(I_t^X + I_t^M + P_t^N I_t^N \right) / p_t^C$, with P_t^N being the relative price of non-tradable goods in terms of importables. While capital used in the non-traded sector is assumed to be produced with non-tradeables, capital is an imported good in both tradable sectors. This specification seems to be empirically plausible, for capital in the production of tradeable goods is mainly composed by machinery and equipment (in particular in the production of primary goods), whereas structures represent the most significant part of capital in the non-tradeable sector.[19]

In each sector $j = X, M, N$, capital evolves according to

$$K_{t+1}^j = (1-\delta) K_t^j + V_t I_t^j + \Phi^j \left(K_{t+1}^j / K_t^j \right), \tag{2.2}$$

[18] This portfolio adjustment cost is a possible way to 'close' a small open economy model. For details and alternatives see Schmitt-Grohé and Uribe (2003).

[19] As an illustrative example, according to the input-output tables constructed for Argentina in 1997, INDEC (2001), near 85% of the intermediate demand for construction goods comes from industries in the non-traded sector. On the other hand, only 20% of the intermediate demand for imported Metallic Products, Machinery and Equipment comes from non-traded industries.

where δ is a constant capital depreciation rate. The variable V_t denotes the level of investment-specific (or embodied) technology, assumed to be non-stationary. The function $\Phi^j(\cdot)$ introduces convex capital adjustment costs in sector j. In principle, we allow for this function to vary across sectors, as a way of representing lack of perfect substitutability between different types of capital. This assumption then calls for different rental rates for each sector. Therefore, total capital income is $KI_t \equiv Q_t^X K_t^X + Q_t^M K_t^M + Q_t^N P_t^N K_t^N$, where Q_t^j denotes the rental rate associated with capital of type $j = X, M, N$.

Finally, we will assume that firms need to finance part of their working capital using a competitive market for domestic loans. In line with Uribe and Yue (2006), the presence of debt adjustment costs implies that the interest rate charged to those loans (denoted by r^d) will differ from the rate paid for international debt. Therefore, a non-arbitrage condition must be imposed in order to make the marginal cost of funding (i.e. the international rate adjusted by the marginal decrease in the portfolio cost) equal to the marginal benefit of lending locally. Specifically,

$$\left(1 + r_t^d\right) = \frac{(1 + r_t)}{1 - \Psi'(D_{t+1})}. \tag{2.3}$$

2.4.2 Production and Technology

The supply side of this economy is composed of firms producing importable, exportable and non-traded goods, as well as two aggregators (or packers): one combining importables and exportables to produce traded goods, and another using tradeables and non-tradeables as inputs to produce the final consumption good. All these firms are assumed to behave competitively.

Production of Final Consumption and Traded Goods

The final consumption good is produced using a CES technology that takes traded (C_t^T) and non-traded (C_t^N) consumption goods as inputs:

$$Y_t^C = \left\{ \chi \left[\left(\frac{\Gamma_{t-1}^M}{\Gamma_{t-1}^T} \right) C_t^T \right]^{-\mu} + (1 - \chi) \left[\left(\frac{\Gamma_{t-1}^M}{\Gamma_{t-1}^N} \right) C_t^N \right]^{-\mu} \right\}^{-1/\mu}, \qquad (2.4)$$

with $\mu > -1$, and Y_t^C denoting the production of final goods.[20] Firms operate in a perfectly competitive market with profits given by $p_t^C Y_t^C - P_t^T C_t^T - P_t^N C_t^N$, where P_t^T denotes the relative price of tradeables.

On the other hand, traded consumption goods are produced by combining both importable and exportable goods, using a Cobb-Douglas technology. In particular,

$$C_t^T = \left(C_t^X \right)^\kappa \left(C_t^M \right)^{1-\kappa}, \qquad (2.5)$$

where C_t^X and C_t^M indicate the domestic consumption for exportable and importable goods,[21] and $\kappa \in (0, 1)$. Firms are competitive and aim to maximize $P_t^T C_t^T - P_t^X C_t^X - C_t^M$, where P_t^X is the price of exportables in terms of imports at time t.

Production of Importables, Exportables, and Non-Tradables

Let Y_t^X, Y_t^M and Y_t^N denote the production of exportable, importable and non-traded goods, respectively, at time t. The available technology for these sectors uses both capital and labor as inputs, denoted by K_t^j and l_t^j for $j = X, M, N$. In addition, the

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[20] The variables Γ_t^T, Γ_t^X, Γ_t^M and Γ_t^N denote the equilibrium stochastic trends in the tradable, exportable, importable and non-tradable sector, respectively; defined in the appendix. The unit root in the investment-specific shock induces differential growth rates across sectors, as well as stochastic trends in the equilibrium relative prices, due to the differences in capital shares. These trends have then to be included in the CES aggregator in order to ensure the existence of a balanced growth path in equilibrium. See García-Cicco (2007) for details.

[21] Note that we are using the term 'domestic consumption' in each sector to denote total domestic consumption of that type of good; i.e. the sum of private and government consumption. Because we are going to assume an exogenous process for *total* government expenditures (there is no disaggregate data for government consumption), it is not relevant to make a distinction here.

exportable sector uses a fixed input (F). This assumption is motivated empirically, for most developing countries are net exporters of primary products. This fixed factor may then represent the use of land or mines.[22]

The production technologies in each of these sectors are

$$Y_t^X = a_t^X \left(K_t^X\right)^{\alpha_{XK}} \left(Z_t l_t^X\right)^{\alpha_{XL}} \left(\Gamma_{t-1}^X F\right)^{1-\alpha_{XK}-\alpha_{XL}} , \qquad (2.6)$$

$$Y_t^M = a_t^M \left(K_t^M\right)^{\alpha_M} \left(Z_t l_t^M\right)^{1-\alpha_M} , \qquad (2.7)$$

and

$$Y_t^N = a_t^N \left(K_t^N\right)^{\alpha_N} \left(Z_t l_t^N\right)^{1-\alpha_N} . \qquad (2.8)$$

The variable Z_t is a labor-augmenting (disembodied) technology shock affecting all sectors, driven by a non-stationary stochastic process. On the other hand, a_t^j in sector $j = X, M, N$ is a (stationary) sector-specific technology shifter. The idea behind this specification is that changes affecting the production possibilities for the economy as a whole are captured by Z_t, whereas a_t^j will reflect shocks having a differential impact in the technology of each sector.

We additionally assume that these firms need to pay a fraction $\theta \in [0, 1]$ of their wage bill at the beginning of the period, before production takes place. Therefore, firms borrow $\theta W_t l_t$ units of importable goods (the working capital) from domestic lenders, paying the interest rate for domestic loans r^d defined in (2.3).

Firms demand input quantities to maximize profits, given by

$$\Pi_t^D = P_t^X Y_t^X + Y_t^M + P_t^N Y_t^N - \left(1 + r_t^d \theta\right) W_t l_t - \left(Q_t^X K_t^X + Q_t^M K_t^M + P_t^N Q_t^N K_t^N\right) .$$

As can be seen, the presence of working capital constraints (i.e. $\theta > 0$) increases the firms' marginal cost of hiring labor: ceteris paribus, an increase in the domestic interest rate will contract the demand for labor.

[22] This assumption is highlighted also by Kose (2002) and Kose and Riezman (2001).

2.4.3 Government and Trade Policy

The government implements a trade policy, which takes the form of a gap (tp_t) between TOT_t and P_t^X. Specifically,

$$P_t^X = tp_t TOT_t. \tag{2.9}$$

In actuality, governments use different trade policy instruments: tariffs, quotas, preferential exchange rates for some industries, subsidies, preferential interest rates, etc. We condense all these alternatives in only one instrument for at least two reasons. First, the data available in our sample is not specific enough to differentiate all these alternative policies. Our empirical counterparts is then only a proxy for the actual commercial policy. On the other hand, only relative prices are pinned down in the model. Moreover, it seems reasonable to believe that these policies will affect the economy to the extent that they produce a reallocation of resources across sectors; thus trade policy will have an impact by modifying the relative price.

Finally, the government is also assumed to consume an exogenous and stochastic stream of final goods, denoted by G_t. The difference between government purchases and the proceedings from trade policy are rebated (or taxed) to consumers via lump-sum transfers (or taxes). The government budget constraint in period t can be written as

$$p_t^C G_t = (1 - tp_t) TOT_t \left(Y_t^X - C_t^X \right) + T_t. \tag{2.10}$$

Note that, for a given G_t, the assumption that revenues from trade policy are rebated using lump-sum transfers implies that a change in tp_t will exhibit a different impact than an equal change in TOT_t, for the former will only produce a substitution effect.

2.4.4 Market Clearing

In equilibrium, the markets for labor, final consumption and non-tradeables must clear:

$$l_t = l_t^X + l_t^M + l_t^X,$$

$$Y_t^C = C_t + G_t,$$

and

$$Y_t^N = C_t^N + I_t^N.$$

Additionally, the individual level of consumption must equal the average, i.e. $C_t = \widetilde{C}_t$. [23]

We introduce some aggregate measures that are useful to confront the model with the data. In equilibrium, the trade balance is defined as

$$TB_t \equiv P_t^X \left(Y_t^X - C_t^X \right) - \left(C_t^M + I_t^M + I_t^X - Y_t^M \right), \tag{2.11}$$

In addition, the gross domestic product in terms of domestic consumption (Y_t) is defined as

$$Y_t \equiv C_t + G_t + I_t + TB_t/p_t^C = \left(P_t^X Y_t^X + Y_t^M + P_t^N Y_t^N \right)/p_t^C. \tag{2.12}$$

The trade-balance to output ratio is then $tby_t = TB_t/ \left(Y_t p_t^C \right)$. The equilibrium level of foreign debt evolves according to

$$D_{t+1} = (1 + r_{t-1}) D_t - TB_t + \Psi (D_{t+1}) + \left(P_t^X - TOT_t \right) \left(Y_t^X - C_t^X \right) + r_t^d \theta W_t l_t.$$

Finally, our measure of the real exchange rate is

$$rer_t = 1/p_t^C, \tag{2.13}$$

which represents the price of foreign imports in terms of domestic consumption.

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[23] See the Appendix for a more detailed description of the optimality conditions, the definition of stationary equilibrium and the computation of the steady state.

We assume that exogenous stochastic processes are associated with stationary variables. In terms of notation, hatted variables denote the log-deviations from their non-stochastic steady state values. Thus, for a generic variable x_t, we define $\widehat{x}_t \equiv \ln(x_t) - \ln(x)$, where x is the steady state value of x_t. Finally, all error terms ϵ_t^s are assumed to be i.i.d. $\mathcal{N}(0, \sigma_s^2)$.

The variables determined in the rest of the world (rw and tot) are assumed to follow a VAR(1) process in logs, i.e.

$$\boldsymbol{v}_{t+1} = \Pi \boldsymbol{v}_t + \boldsymbol{e}_{t+1}^v, \tag{2.14}$$

where $\boldsymbol{v}_t = \left\{ \widehat{tot}_t, \widehat{1+rw}_t \right\}'$ and $\boldsymbol{e}_t^v = \{\epsilon_t^{tot}, \epsilon_t^{rw}\}'$.

In terms of technology, let $v_t \equiv V_t/V_{t-1}$ and $z_t \equiv Z_t/Z_{t-1}$ denote the gross growth rates of V_t and Z_t, respectively. They evolve according to:

$$\widehat{v}_{t+1} = \rho_v \widehat{v}_t + \epsilon_{t+1}^v, \tag{2.15}$$

and

$$\widehat{z}_{t+1} = \rho_z \widehat{z}_t + \epsilon_{t+1}^z. \tag{2.16}$$

The sector specific technology shocks are determined as follows:

$$\widehat{a}_{t+1}^j = \rho_{a^j} \widehat{a}_t^j + \epsilon_{t+1}^j + \xi^j \widehat{tot}_{t+1}, \tag{2.17}$$

for sector $j = X, M, N$. Note that we allow for the terms of trade to have an impact on the productivity of each sector. This is a usual assumption in this literature, motivated by the apparent correlation between sectorial Solow residuals and terms of trade.[24]

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[24] See, for instance, Mendoza (1995), Kose (2002) and Kose and Riezman (2001).

The other domestic drivers are determined by a random disturbance, as well as by a linear feedback function depending on other variables. In particular,[25]

$$\widehat{g}_{t+1} = \rho_g \widehat{g}_t + \Xi_{g,y} \Delta \widehat{Y}_{t+1} + \epsilon_{t+1}^g, \tag{2.18}$$

$$\widehat{tp}_{t+1} = \rho_{tp} \widehat{tp}_t + \Xi_{tp,y} \Delta \widehat{Y}_{t+1} + \Xi_{tp,tby}(tby_{t+1} - tby) + \Xi_{tp,p^c} \widehat{p}_{t+1}^C + \Upsilon_{tp,tot} \widehat{tot}_t + \epsilon_{t+1}^{tp}, \tag{2.19}$$

$$\widehat{(1+cp_{t+1})} = \rho_{cp} \widehat{(1+cp_t)} + \Xi_{cp,y} \Delta \widehat{Y}_{t+1} + \Xi_{cp,tby}(tby_{t+1} - tby) + \Xi_{cp,p^C} \widehat{p}_{t+1}^c +$$

$$\Upsilon_{cp,rw} \widehat{(1+rw_t)} + \epsilon_{t+1}^{cp}, \tag{2.20}$$

This formulation intends to capture –at least in reduced form– the endogenous response of these variables to certain fundamentals (either by government policy functions or by how the "market sentiments" are reflected in the country premium).

2.4.6 Functional Forms

To complete the description of the model, we need to specify functional forms for preferences, as well as for adjustment costs. We use two alternative utility functions. In the GHH case,

$$U\left(C_t - \eta \widetilde{C}_{t-1}, l_t\right) = \frac{\left[C_t - \eta \widetilde{C}_{t-1} - \Gamma_{t-1}^M \nu (l_t)^\omega\right]^{1-\gamma} - 1}{1-\gamma},$$

where $\gamma > 1$, $\nu > 0$ and $\omega > 0$. On the other hand, the Cobb-Douglas specification is

$$U\left(C_t - \eta \widetilde{C}_{t-1}, l_t\right) = \frac{\left[\left(C_t - \eta \widetilde{C}_{t-1}\right)(1-l_t)^\omega\right]^{1-\gamma} - 1}{1-\gamma}.$$

The debt adjustment cost function is assumed to be

$$\Psi(D_{t+1}) = \frac{\psi}{2}\left(\frac{D_{t+1}}{\Gamma_t^M} - \overline{d}\right)^2 \Gamma_t^M.$$

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[25] The variable $\Delta \widehat{Y}_t = log(Y_t) - log(Y_{t-1}) - \gamma^M$, where γ^M is the growth rate of output along the balanced-growth path.

The parameter $\bar{d}$ will pin-down the (detrended) steady state level of debt in the stationary representation, which makes the adjustment costs nil in that situation. Finally, the capital adjustment cost is, in each sector $j = X, M, N$,

$$\Phi^j \left(K_{t+1}^j / K_t^j \right) = \frac{\phi^j}{2} \left(\frac{K_{t+1}^j}{K_t^j} - \gamma^{k,j} \right)^2 \frac{K_t^j}{V_t},$$

with $\phi^j > 0$. The parameters $\gamma^{k,j}$ are defined in the appendix and they are such that the capital adjustment costs are also zero along the balanced growth path.

2.5 Empirical Strategy

In order to evaluate the performance of the model we use a combination of calibrated and estimated parameters. We chose to calibrate some of the parameters mainly because, although we are using a large number of variables for the estimation, the data set is not rich enough to identify all of them; particularly those describing production functions and preferences. This section describes our calibration approach, presents the details regarding the main estimation procedure and describes how do we choose the preferred specification of the model.

2.5.1 Calibration

The set of calibrated parameters and ratios are listed in Table 2.3. The time unit in the model is meant to be a year. Due to data limitations, we set the technology coefficients according to previous studies. The labor shares in the importable and the non-traded sector correspond to the developing country's calibration in Mendoza (1995). The values for μ and κ are also taken from Mendoza's work. In terms of the exportable sector, we follow Kose (2002), who uses our same specification. These values imply that the non-trade sector is the most labor intensive, the production of importables is more intensive in capital goods, and the share of the fixed factor in

the production of exportable goods is 45 percent.

The steady state values of the observed driving forces are set to match their unconditional means. The averages of *tot* and *tp* in our sample are 1.32 and 1.03 respectively, which implies a steady state value for p^X of 1.36. Additionally, the world interest rate and the country premium are, on average, 0.02 and 0.04 in this period. The value of g in the steady state is set to match the observed mean for the share of government expenditures of ten percent. On the other hand, we set all the steady state values for the unobserved driving forces equal to one, except for z, which is assume to be equal to 1.01 (the average growth rate of GDP per capita in our sample).

In terms of utility parameters, β implies a 6 percent domestic interest rate in the steady state, consistent with the assigned values for *rw* and *cp*. The values for the labor exponent ω, the depreciation rate δ and the risk aversion coefficient γ are set to standard values used in the literature.

The parameters ν, F, $\bar{d}$ and χ are set to generate four steady state ratios that mimic their respective unconditional means in our sample: the trade-balance-to-output ratio (close to 0.01 in the data), a share of total trade to GDP equal to 0.32, the ratio of expenditures on tradables to expenditures on non-tradables (nearly 80 percent in our sample),[26] and a value for labor in the steady state equal to 0.2.

Finally, we calibrate two other parameters that cannot be properly identified given our data. On one hand, we set ψ equal to 0.0004, a small value commonly used to ensure that this device, introduced for technical reasons only, does not drive the results. Additionally, we set $\rho_v = 0$. A possible reason for the lack of identification of this parameter is that all non-stationary variables used for the estimation share the same stochastic trend in the model which is a function of both V_t and Z_t. Therefore,

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[26] In the model, this can be computed as $(s^T - tby)/s^N$, where s^T and s^N represent, respectively, the share of tradable and non-tradable production on GDP. The sectorial data is described in Section 2.6.2.

it is likely that the estimation procedure cannot separately identify the dynamics of these two processes given that all the observables share the same trend.

2.5.2 Bayesian Approach

The other parameters, collected for notational simplicity in the vector Θ, are estimated using a Bayesian approach (see, for instance, Ann and Schorfheide (2007)). The object of interest is the joint posterior distribution of the parameters given the data, $X^T = \{x_1, ..., x_T\}$, which is computed, using the Bayes theorem, as

$$p\left(\Theta|X^T\right) = \frac{L\left(\Theta|X^T\right)p\left(\Theta\right)}{\int L\left(\Theta|X^T\right)p\left(\Theta\right)d\Theta},$$

where $L\left(\Theta|X^T\right)$ denotes the likelihood of the parameters given the data and $p\left(\Theta\right)$ is the prior distribution of the parameters.

In order to compute the likelihood, we first solve for the log-linear approximation to the policy functions (in particular, we implement the method described in Schmitt-Grohé and Uribe (2004)). Given the linear solution and the assumption of normally distributed exogenous shocks, the Kalman filter can be used to compute $L\left(\Theta|X^T\right)$. In our baseline estimation, the vector of observable variables used for the estimation is, in terms of the model's notation,

$$x_t = \left\{\Delta\hat{Y}_t,\ \Delta\hat{C}_t,\ \Delta\hat{I}_t,\ tby_t,\ \widehat{rer}_t,\ \Delta\hat{G}_t,\ \widehat{tot}_t,\ \widehat{1+rw}_t,\ \widehat{1+cp}_t,\ \widehat{tp}_t\right\}. \qquad (2.21)$$

In addition, series were demeaned and i.i.d. measurement errors were included.

The choice of priors is described in the third and fourth column of tables 2.5 to 2.7. These assumed distributions are guided by the defining constraints in these parameters and, when available, by results obtained in previous studies. The parameter governing the habit formation belongs to the interval $[0, 1)$; however, most studies estimate it to be less than a half. The assumed Beta prior reflect these previous results. In terms of the working capital requirement, studies calibrating this parameter

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generally assign a value of .25 in annual frequency (for instance, Neumeyer and Perri (2005), and Oviedo (2005). On the other hand, Uribe and Yue (2006) estimate it to be 1.2 in quarterly frequency. Our prior distribution implies a cumulative probability close to 50% for the value obtained by Uribe and Yue (2006).

For parameters that are strictly greater than zero (the capital adjustment costs and the standard deviations of the shocks and measurement errors) we use Inverse Gamma priors. In terms of the autocorrelation of the shocks, we assume a flat prior in the interval $[0, 1)$. Finally, for the rest of the parameters defining the stochastic process we use a uniform distribution in the interval $[-1, 1]$, truncated to guarantee that these processes are stationary.

Given the likelihood and the priors, we characterize the posterior distribution in two steps. First, we maximize the posterior using the optimization algorithm developed by Chris Sims.[27] The resulting posterior mode is used as the starting value of a Random Walk Metropolis-Hastings algorithm, using $\mathcal{N}(0, c\Sigma)$ as the proposal distribution –with Σ being the inverse of the Hessian evaluated at the posterior mode computed in the first step.[28] The parameter c is calibrated to obtain an acceptance ratio close to 40% and the convergence of the chain is analyzed by checking recursive means. For each estimated alternative we generate one million draws from the posterior, eliminating the first 500K to reduce dependence from initial values.

2.5.3   Model Selection

Our main goal is to perform a variance decomposition using the estimated model. The relevance of such an excercise depends on the ability of the model to fit different aspects of the data. Therefore, we estimated several variants of the model using data from 1913 to 2005, choosing our preferred specification by a combination of two

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[27] Available at `http://sims.princeton.edu/yftp/optimize/`.

[28] This matrix is updated after the first 100K draws if a new maximizer is found.

different criteria. On one hand, given that we are concerned with explaining aggregate fluctuations, we choose the specification able to better match the business cycle facts described in Section 2.3. On the other hand, we compare different specifications using the marginal likelihood as a formal goodness-of-fit test for the model.[29]

We first proceed by estimating the full version of the model for both utility specifications. The Cobb-Douglas alternative generally fails to replicate several features of the data, the most salient being consumption growth is less volatile than output growth. In addition, it also produces excessively large volatilities for the trade-balance-to-output ratio, the real exchange rate, and the trade policy index.

A common feature of both estimated models is that the parameters ξ^X, ξ^M, ξ^N, $\Pi_{tot,rw}$, $\Pi_{rw,tot}$, $\Xi_{tp,y}$, $\Xi_{cp,tby}$, $\Upsilon_{cp,rw}$ do not seem to be significantly different from zero. This lead us to estimate a reduced model with GHH utility, setting these coefficients equal to zero. This alternative performs satisfactorily, for which it will be our preferred specification, denoted as Model I. As can be seen from Table 2.4, it is also preferred in terms of the marginal likelihood over most of the alternatives. Although imposing $\theta = \eta = 0$ (i.e. no habits and no working capital constraints) yields better posterior odds, this option does not provide such a good fit to some moments as Model I does (for instance, it implies an extremely large variance for rer).

We have additionally estimated a number of alternatives that do not perform as well as Model I. In particular, for both Model I and the specification with $\theta = \eta = 0$, we alternatively imposed no feedback in the processes for tp and g, and made g, cp and tp respond to lagged (instead of current) values of Δy and tby. We have also estimated Model I imposing $1/(1 + \mu) = 0.74$, which is the value used by Mendoza

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[29] The marginal likelihood is computed using the harmonic mean procedure proposed by Geweke (1999). To save space, we do not display the second moments implied by all the estimated alternatives, and just present in the next section the ones for the preferred specification described below.

(1995) in calibrating economies. All these alternatives fail to replicate some relevant business cycle moments and, as commented before, they have worse posterior odds relative to Model I.

2.6   Results

This section is divided in two parts. One one hand, we present results based on the original sample (1913-2005). As we commented before, the estimated model assigns a predominant role to the non-traded stationary productivity. Given the importance of this sectorial shock, in the second part of the section we re-estimate the model adding sectorial shares of production to the data set.

2.6.1   Baseline Data Set (1913-2005)

We first present the estimated posterior of the parameters and compare data and model moments. The variance decomposition exercise follows, as well as a discussion aimed at understanding the relevance of these shocks in explaining business cycle facts.

Posterior Distribution and Second Moments

Tables 2.5 and 2.7 present, in column (I), the posterior means and 95% confidence bands for our preferred specification in this sample. In general terms, it seems that the information contained in the likelihood significantly updates the assumed priors for all the parameters, as reflected in the marked differences in the statistics describing these two distributions.

As can be seen, the external habit parameter is estimated to be small. The role of the working capital requirement is somewhat mild: the posterior mean indicates that firms are required to maintain a level of working capital equivalent to less than three months of wage payments, a lower value compared with other estimates in the

literature. Additionally, the capital adjustment costs seem to differ across sectors. These results could imply that the model requires a lack of perfect capital mobility across sectors in order to better approximate the data. In terms of external driving forces, TOT shocks are much more volatile than world interest rate shocks, as well as more persistent.

Focusing on the estimated processes for the stationary technology shocks, the non-traded shock seems to be the most volatile: its standard error is two and three times larger than that for importables and exportables, respectively. In addition, the productivity in the importable and non-tradable sectors seems to be more persistent than for exportables (0.99 and 0.89, against 0.63), and more volatile as well. On the other hand, while the volatility of the non-stationary shocks is similar in magnitude to that of both traded sectors, the autocorrelation of the non-stationary TFP shock is much smaller than for stationary shocks.

Additionally, the estimated specifications for trade policy and country premium shocks are highly persistent (0.9 and 0.97 respectively), while the posterior mean of ρ_g is 0.6. The trade policy index seems to be the most volatile of these, while the standard error of the country premium shock is rather small. In terms of the feedback from other endogenous variables, the most surprising and counterintuitive result is the positive value for the coefficient $\Xi_{cp,y}$. However, as described in Section 2.3, the country premium seems to be uncorrelated with output in our sample (contrary to what others have documented in the literature for shorter and recent samples). On the other hand, government expenditure appears to be procyclical, increasing with higher output growth rates. In terms of trade policy, the rule indicates an increase in protectionism as the trade balance improves.

Table 2.8 displays the posterior means of a number of second moments for some aggregates, as well as their data counterparts for comparison. While the model overestimates the volatility of output growth and underestimates that of consumption

growth, it is still able to replicate consumption being more volatile than output. As we commented before, this feature is one of the distinctive characteristic of business cycles in emerging countries. Later we will analyze why this model can generate this feature.

The volatility of investment growth generated by the model is similar to its empirical counterpart. One of the failures of the model, however, is in terms of the volatility of the trade-balance to-output ratio: in the model, the standard deviation of tby is ten times as in the data. The standard deviation of rer is also larger in the model, almost 50% greater than in the data.

The model also matches the sign of the correlation of these variables with output. In magnitude, however, these are milder than their data counterparts. This is also true in terms of the correlation of ΔC and ΔI with tby. This pattern was also reported by García-Cicco et al. (2009) in the context of a simple RBC model. However, the correlation between rer and tby is estimated to be positive and big, while in the data it is negative but mild. Overall, while the model seems to properly replicate the behavior of output, consumption and investment, it has some difficulties matching the dynamics of tby and rer.

Variance Decomposition: the Role of the Non-Traded Sector and the RER

After establishing the extent to which the estimated model can replicate the business cycle facts, we proceed with the main goal of the paper. Table 2.9 presents the variance decomposition of the ΔY, ΔC, ΔI and rer. Note that the model accounts for almost all the variance of output growth (the measurement error only explains 2% of it), while the contribution of the measurement error is more important for the other variables, particularly for ΔC.

In terms of explaining output fluctuations, the stationary productivity shock in the non-traded sector appears to be the most important: nearly 60% of output

growth volatility can be attributed to this shock.[30] In addition, both the shocks to *tot* and to *cp* account for nearly 10% of the variance of output growth. The other drivers do not seem to play a significant role in explaining output fluctuations.

The importance of shocks to the stationary productivity in the non-traded sector is in sharp contrast with previous results in the literature, in particular, as documented in Section 2.2, with those assigning leading importance to non-stationary technology shocks, as well as those emphasizing external shocks. Moreover, while some studies in the literature use models with different sectors, none of them has analyzed the role of sectorial productivity.

This shock also plays the leading role in explaining consumption volatility. In terms of investment growth, while the trade policy shock seems to be the most important, shocks in the importable and non-traded sectors have a relevant role as well. On the other hand, the stationary shock to importables' productivity is apparently most important in explaining the variance of *rer*.

Given the estimated relevance of the non-traded shock, we need to further understand its role in explaining fluctuations. Comparing the model with the data, Panel A in Figure 2.3 displays the posterior mean of the smoothed series for a_t^N under Model I, along with the (quadratic) detrended log of GDP taken from the data.[31] As can be seen, a_t^N seems to capture most of the recessions and booms, particulary in the second part of the sample. On the other hand, as captured in Panel B of Figure 2.3, around 60% (on average) of total GDP in the data corresponds to the production of non-traded goods. Moreover, particularly in the last 30 years, movements in detrended GDP have been associated with similar movements in the share of non-tradeable production: the non-traded sector seems to experience bigger

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[30] This results seems to hold also in all the other specifications described in subsection 2.5.3.

[31] We use quadratic detrending in the figures for illustrative purposes only. Results are similar using other detrending methods, particularly when a_t^N is compared with the smoothed version of y_t (i.e. using the model's stochastic trend).

increases than total GDP in expansions, suffering also larger recessions when total GDP is below trend. Overall, these facts show why it is reasonable to obtain such an important role for a_t^N. What is somewhat surprising is the model emphasizes this sector without using sectorial data for the estimation.

It is also important to understand what are the dynamics in the model implied by this shock. Figure 2.4 presents the impulse response of selected variables to an exogenous 1% increase in a_t^N. In terms of the supply side of the economy, this change will increase the factor's demand in the non-traded sector, increasing, in particular, the wage rate. Therefore, the supply curve for non-traded goods will expand, while contracting in the other two sectors.

From the consumer's perspective, the persistence of the shock coupled with the GHH formulation will generate a big positive wealth effect increasing the demand for all goods, with that for non-tradeables increasing relatively more given the bias in the CES aggregator towards those goods (i.e. $\chi < 1/2$). Additionally, desired investment in the non-traded sector will strongly increase given the persistence of the productivity shock, while the increase in wages and the reallocation of labor will decrease the marginal product of capital in the other two sectors.

In equilibrium, these movements generate a fall in the relative price of non-traded goods (i.e. a real depreciation). As a result, non-traded consumption will increase even further, overshooting aggregate consumption relative to output. This explains why this model is able to generate a volatility of consumption bigger than for output. In fact, if we shut down all the remaining shocks, the implied standard deviation for consumption growth is 15% bigger than that of output growth. On the other hand, a similar shock in any of the traded sectors will not generate this result. Although these will expand consumption demand for all goods, given that prices in the traded sector are fixed, p^N will rise (a real appreciation), dampening the effect on non-tradeable

consumption.[32]

Additionally, aggregate investment also increases proportionally more than output (the changes in desired investment described before are reinforced by the drop in p^N). Adding these two effects, the trade-balance-to-output ratio falls in response to a stationary but persistent shock in non-traded productivity. Therefore, the non-traded shock helps to explain two of the distinctive characteristics of business cycles in emerging countries: the excessive volatility of consumption and the countercyclical trade balance.

In obtaining these results, the key channel seems to be the resulting drop in p^N. This, is however, at odds with the cyclical behavior of the real exchange rate: as we described in Section 2.3, recessions are generally associated with depreciations, while appreciations are experienced during booms. This puzzle is most evident if we consider the last two recessions. It is clear from Figure 2.3 that the model associates those recessions with large drops in a_t^N. However, it is also the case that large depreciations were experienced at the beginning of these contractions. Therefore, we may ask to what extent the model can replicate this fact.

To answer this question, in Panel A of Figure 2.5 we show the posterior mean of the smoothed series for rer along with its data counterpart. Although the model seems to capture the average behavior of this variable, it cannot replicate its sudden movements (particularly those experienced during recessions).[33] On the other hand, as indicated in Table 2.9, 75% of the volatility of rer is explained by the shock to a_t^M, which is also consistent with Panel B of Figure 2.5.

[32] Strictly speaking, in our case the price of traded goods may change due to the policy rule for tp. However, this doesn't seem to affect the results. In fact, given the negative estimated value for $\Xi_{tp,tby}$, a shock in the productivity in the X sector increases p^N even further, generating an equilibrium drop of c^N.

[33] We should note that certain lack of fit along this dimension was expected. For most of the large swings in this variable observed in the data (particularly in the last 30 years) were produced by nominal depreciations followed by different types of exchange-rate-based stabilization programs. However, our model is not constructed to account for these alternative explanations.

Overall, it seems that the estimated model uses shocks to the non-traded productivity to explain fluctuation in output, consumption, etc., while shocks to a_t^M help to explain the behavior of rer (although the goodness of fit clearly is limited in this dimension). However, because no sectorial information is included in the estimation, it might be the case that we are giving many degrees of freedom to the model to accommodate different unobserved states to match the data, clearly weakening the relevance of our results. This is what motivates the inclusion of sectorial shares in the information set.

2.6.2 Adding Sectorial Data (1935-2005)

The available data on sectorial production, in nominal terms, starts in 1935. Total GDP is decomposed in 10 industries, which we grouped as follows. We include Primary products, Mining and Energy in exportables' production. We consider Manufactures as the importable good; while Construction, Retail and tourism, Transportation and communication, Financial intermediation, Public sector and Other services are the components of non-traded production. Although we are losing 22 years of data, we are adding information that may help us to disentangle the role of sectorial productivity. In addition, to our knowledge, no other paper in this literature has used sectorial data for estimation purposes.[34]

These additional data are used in three different estimation exercises. First, we augment the set of observable variables in (2.21) to include the share of exportable and non-traded goods, estimating the same specification as in Model I (we call this Model II). Alternatively, we eliminate the observations for both rw and cp, while still keeping the sectorial shares. With this new data set we estimate two specifications, differing from Model I in the assumed process for cp. In Model III the country

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[34] Although Kose and Riezman (2001) and Kose (2002) do use sectorial data to construct Solow residuals, their results are based on calibrated models.

premium follows the same process as in Model I, while we set $\Xi_{cp,y} = 0$ in Model IV (i.e. cp follows a simple AR(1) process). In both cases, we fix rw to its steady state value.

We choose to drop interest rate data to give an additional degree of freedom to the model to assign a relevant role to a shock able, in principle, to generate the observed cyclical behavior of the rer. In addition, appropriate empirical counterparts for these variables are arguably the hardest to find. However, as we will see, results are robust to the use of this alternative data set: a_t^N still plays the leading role, while the real exchange rate is not properly approximated by the estimated model. As we did before, we first present the estimated posterior of the parameters and compare data and model moments, discussing later the variance decomposition exercise.

Posterior Distribution and Second Moments

The posterior's statistics are presented in the last three columns of Tables 2.5 to 2.7. The estimate for η varies across the three alternatives: while the habit persistence seems to be mild for models III and IV, the posterior mean is 0.53 in Model II. There is also a difference for the working capital parameter. In particular, the estimated posterior mean significantly increases when interest rate data are excluded. This is not surprising given that this is an important channel to amplify interest rate shocks. In addition, as in Model I, the adjustment cost parameters seems to differ across sectors.

In terms of world shocks, we see that both tot and rw seem to be more persistent in this shorter sample. The variance of the terms of trade shock is, however, significantly smaller than what was estimated for the full sample.

The autocorrelation of a_t^N is still estimated to be high, but there are some differences in the persistence of the other sectorial shocks. While in Model II these shocks do not seem to be as persistent, these parameters significantly increase when

we exclude interest rate data. The volatility of the non-traded shock rises slightly, while it is almost unaffected for the other two sectors. The variance of non-stationary shocks continues to be mild, as well as the persistence parameters ρ_z.

In terms of the other domestic shocks, ρ_{cp} drops considerably when we exclude the interest rates, while the persistence of tp and g increases in these cases. Surprisingly, the variance of the country premium remains practically unchanged in the three specifications, while σ_{tp} drastically decreases. The response of country premium to Δy has now the more intuitive negative sign. However, the parameters $\Xi_{g,y}$ and $\Upsilon_{tp,tot}$ change their signs relative to the estimates in the original data set.

Table 2.10 compares the performance of the model in terms of second moments. As we can see, the difference between the variance of consumption and output growth is closer to the data than before. The volatility of tby continues to be more volatile than in the data, especially in Model II. With this shorter sample, however, the model now underestimates the volatility of rer. Overall, it can be argued that the model does not provide such a good fit. However, particularly for Model II, additional lack of fit might be expected because we are requiring the model to match more dimensions of the data.

Variance Decomposition: the Role of the Non-Traded Sector and the RER

Table 2.11 displays the variance decomposition of ΔY and rer for these three cases. Adding sectorial data emphasizes even further the role of stationary shocks in the non-traded sector. This is the case even if we exclude interest rate data. Moreover, as in the previous case, the model is able to explain almost all the variability of output. The relevance of this shock can also be observed in Panel A of Figure 2.6: the smoothed series of a_t^N closely follows the evolution of detrended GDP.[35]

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[35] We don't include the series for Model III in this graphs because they are similar to those of Model II.

However, in line with our previous discussion, the increasing importance of this shock reduces the chances to properly account for the behavior of the real exchange rate. Additionally, because we are now using sectorial information, the model is not free to use the shock to a_t^M to explain this variable. It is not surprising then to see in Panel B of Figure 2.6 that the estimated model cannot match the evolution of the rer in the data. The message is also conveyed in the variance decomposition of rer: the measurement error accounts for more than 70% of this volatility.

Therefore, the tension between the importance of non-traded shocks in explaining output fluctuations and the cyclical behavior of the real exchange rate is amplified once we include sectorial data. Moreover, it is still the case that the model fails to replicate some of the moments related with the trade balance.

2.7   Conclusions

In this paper we have characterized the relative relevance of ten different driving forces that have been proposed as important business cycle drivers in emerging countries. To achieve this goal, we built a real DSGE model that includes all the features previously analyzed in this literature. The model was estimated by Bayesian methods using Argentine data, including also the available sectorial information. The results in terms of the variance decomposition of output are striking: the stationary productivity shock in the non-traded sector is by far the most important in explaining GDP fluctuations. However, the importance of this shock limits the ability of the model to properly account for the evolution of the real exchange rate.

We would like to conclude by discussing several lessons or recommendations for future research that can be extracted from our analysis. First, an important caveat is in order: we should not take literally that really "productivity" or "technological change" in the non-traded sector is behind output fluctuations. Instead, we think it is more reasonable to interpret these results as emphasizing the role of the non-traded

sector in explaining business cycles in countries like Argentina.[36]

Nevertheless, our study clearly indicates that sectorial considerations, particularly the inclusion of non-traded goods, are most important in analyzing fluctuations in emerging countries. In contrast, many studies in the literature choose to draw conclusions using single-good models. This observation also motivates the use of sectorial data to properly disentangle the role of different sectors. Surprisingly, there are only a few examples in the literature using this type of data; neither of them, however, uses it for estimation purposes.

Our analysis also highlights the need to consider the behavior of the real exchange rate. For instance, the overall goodness of fit of our model should likely improve if we omit this variable from our study, as most papers in this literature do.[37] As we discussed, however, a model driven by productivity shocks in the non-traded sector cannot properly account for the documented cyclical behavior of this variable. It seems then essential to consider fluctuations in the RER in judging models designed to account for aggregate fluctuation in emerging countries.

Finally, we have described how the largest swings in the RER are generally associated with fluctuations in the nominal exchange rate. This suggests that a real model like ours (built following the tradition in this literature) has, by definition, a limited ability to describe the dynamics of the RER. Instead, a nominal model coupled with price-setting frictions seems to be better suited for this task.

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[36] For instance, it has been argued that financial factors where behind the last recession that Argentina suffered in 2001. In particular, the role of liability dollarisation was emphasized; which most certainly would have a bigger impact in the non-traded sector. However, this is something that we cannot analyze with our model.

[37] From all the papers based on DSGE models surveyed in Section 2.2, only Mendoza (1995) attempts to match several RER second moments. His model cannot, however, properly account for these facts.

2.8 Tables and Figures

Table 2.1: Argentina 1913-2005: Summary Statistics

Variable	σ_x	ρ_{x,Δ_y}	$\rho_{x,tby}$
ΔY	5.06	1.00	-0.17
	(0.36)	—	(0.12)
ΔC	8.42	0.75	-0.37
	(1.00)	(0.18)	(0.14)
ΔI	16.77	0.78	-0.25
	(1.14)	(0.13)	(0.13)
tby	6.07	-0.17	1.00
	(0.62)	(0.12)	—
rer	46.84	-0.12	-0.17
	(3.22)	(0.09)	(0.07)
tot	15.70	0.04	0.39
	(1.13)	(0.10)	(0.13)
rw	4.50	-0.05	-0.18
	(0.46)	(0.09)	(0.14)
ΔG	11.04	0.33	-0.10
	(1.02)	(0.11)	(0.10)
cp	7.99	-0.04	0.26
	(1.13)	(0.16)	(0.15)
tp	34.82	0.00	-0.49
	(2.16)	(0.10)	(0.16)

Note: ΔY, ΔC, ΔI, ΔG, tby, rer, tp, tot, cp and rw denote the growth rates of output, private consumption, investment and government expenditures per capita, the trade balance-to-output ratio, the real exchange rate, the trade policy index, foreign terms of trade, the country premium and the world interest rate. Except for tby, all variables are measured in logs (interest rates are measured as the log of the gross interest rate). Standard deviations (the first column) are reported in percentage points. GMM standard errors are shown in parenthesis. See the text for variables' definition and the Appendix for data sources.

Table 2.2: The Real Exchange Rate in Recessions and Expansions, 1913-2005.

	Recessions	Expansions
Mean	0.05	-0.02
Median	0.01	-0.03
Std.Dev.	0.34	0.19
5% Perc.	-0.46	-0.33
95% Perc.	0.72	0.34

Note: The statistics are for the average annual change in the log RER in recession and expansion years, respectively, according to the dates described in Sturzenegger and Moya (2003).

Table 2.3: Calibrated Parameters

Parameter	Description	Value
β	Discount factor	0.926
ω	Elasticity of labor supply	1.6
γ	Risk aversion	2
$1/(1+\mu)$	Elasticity of substitution between C^T and C^N	1.279
κ	Share of C^X in C^T	0.15
α_{XK}	Share of K^X in Y^X	0.18
α_{XL}	Share of l^X in Y^X	0.37
α_M	Share of K^M in Y^M	0.698
α_N	Share of K^N in Y^T	0.62
δ	Depreciation rate	0.1
ψ	Debt adjustment cost	0.0004
tby	Trade Balance to GDP in SS	0.01
TT/Y	Total Trade to GDP in SS	0.32
E^T/E^N	Expenditure on T vs N in SS	0.80
l	Labor in SS	.2

Table 2.4: Model Selection: Marginal Likelihood, 1913-2005.

	Marginal Likelihood
Model	
GHH Full	-195.57
C-D Full	-194.92
GHH reduced (Model I)	-126.03
GHH reduced, feedback to $t-1$	-190.74
GHH reduced, no feedback	-172.95
GHH reduced, $1/(1+\mu) = 0.74$	-165.25
GHH reduced, $\theta = \eta = 0$	-122.15
GHH reduced, $\theta = \eta = 0$, no feedback	-168.10
GHH reduced, $\theta = \eta = 0$, feedback to $t-1$	-182.16

Note: The reduced model sets $\xi^X=\xi^M=\xi^N=\Pi_{tot,rw}=\Pi_{rw,tot}=\Xi_{tp,y}=\Xi_{cp,tby}=\Upsilon_{cp,rw}$ =0. In performing this comparison, the priors have been re-scaled to account for the different uniqueness regions in each specification.

Table 2.5: Estimated Parameters I

Para-meter	Description	Prior Distribution		(I)	(II)	(III)	(IV)
					Posterior		
η	External habit	B	0.31 [0.05:0.68]	0.15 [0.12:0.19]	0.53 [0.52:0.55]	0.10 [0.01:0.22]	0.05 [0.01:0.11]
θ	Working capital	G	0.60 [0.03:2.05]	0.23 [0.17:0.27]	0.12 [0.10:0.13]	0.62 [0.51:0.73]	0.46 [0.33:0.59]
ϕ^X	C.A.C. in X	IG	2.00 [0.21:9.27]	0.61 [0.52:0.69]	1.01 [1.00:1.03]	0.88 [0.78:0.96]	1.62 [1.50:1.72]
ϕ^M	C.A.C. in M	IG	2.00 [0.21:9.27]	1.37 [1.28:1.50]	1.03 [1.03:1.05]	1.40 [1.31:1.54]	1.05 [0.99:1.14]
ϕ^N	C.A.C. in N	IG	2.00 [0.21:9.27]	1.04 [0.97:1.12]	1.12 [1.11:1.13]	1.73 [1.41:2.05]	1.43 [1.38:1.48]
			World Shocks				
$\Pi_{tot,tot}$	Autocorrel. tot_t	U	0.50 [0.03:0.98]	0.77 [0.66:0.89]	0.99 [0.97:1.00]	0.97 [0.92:1.00]	0.93 [0.87:0.98]
$\Pi_{rw,rw}$	Autocorrel. rw_t	U	0.50 [0.03:0.98]	0.35 [0.07:0.58]	0.45 [0.40:0.50]		
σ^{tot}	Std. Dev. ϵ_t^{tot}	IG	0.03 [0.01:0.07]	0.11 [0.09:0.13]	0.01 [0.01:0.02]	0.03 [0.02:0.04]	0.03 [0.02:0.05]
σ^{rw}	Std. Dev. ϵ_t^{rw}	IG	0.03 [0.01:0.07]	0.01 [0.01:0.02]	0.02 [0.01:0.03]		

Note: For the priors, B, G, IG and U indicate, respectively, the Beta, Gamma, Inverse Gamma and Uniform distributions. The table presents the mean of the particular distribution, as well as its 95% confidence bands in brackets. Column (I) represents the estimation using data baseline data set (1913-2005), columns (II) to (IV) use the data set that includes the shares of exportables and non-tradeables (1935-2005).

Table 2.6: Estimated Parameters II

Para-meter	Description	Prior Distribution	Posterior (I)	(II)	(III)	(IV)
		Technology Shocks				
ρ_z	Autocorrel. z_t	U	0.22	0.25	0.25	0.11	0.39
			[0.03:0.53]	[0.04:0.58]	[0.04:0.50]	[0.02:0.26]	[0.31:0.47]
ρ_{a^X}	Autocorrel. a_t^X	U	0.50	0.63	0.37	0.96	1.00
			[0.03:0.98]	[0.22:0.99]	[0.32:0.43]	[0.88:1.00]	[0.99:1.00]
ρ_{a^M}	Autocorrel. a_t^M	U	0.50	0.99	0.44	0.86	0.71
			[0.03:0.98]	[0.98:1.00]	[0.39:0.48]	[0.82:0.90]	[0.59:0.80]
ρ_{a^N}	Autocorrel. a_t^N	U	0.50	0.89	0.93	0.92	0.98
			[0.03:0.98]	[0.82:0.95]	[0.91:0.94]	[0.90:0.94]	[0.96:0.99]
σ^v	Std. Dev. ϵ_t^v	IG	0.02	0.03	0.01	0.01	0.01
			[0.01:0.05]	[0.02:0.05]	[0.01:0.01]	[0.01:0.01]	[0.01:0.02]
σ^z	Std. Dev. ϵ_t^z	IG	0.02	0.02	0.03	0.02	0.02
			[0.01:0.05]	[0.01:0.04]	[0.01:0.04]	[0.01:0.04]	[0.01:0.05]
σ^{a^X}	Std. Dev. $\epsilon_t^{a^X}$	IG	0.02	0.02	0.01	0.02	0.02
			[0.01:0.05]	[0.01:0.05]	[0.01:0.02]	[0.01:0.03]	[0.01:0.03]
σ^{a^M}	Std. Dev. $\epsilon_t^{a^M}$	IG	0.02	0.04	0.02	0.04	0.04
			[0.01:0.05]	[0.03:0.07]	[0.01:0.03]	[0.03:0.06]	[0.03:0.06]
σ^{a^N}	Std. Dev. $\epsilon_t^{a^N}$	IG	0.02	0.07	0.08	0.08	0.06
			[0.01:0.05]	[0.06:0.08]	[0.07:0.10]	[0.06:0.09]	[0.05:0.08]

Note: See Table 2.5.

Table 2.7: Estimated Parameters III

Para-meter	Description	Prior Distribution	Posterior			
			(I)	(II)	(III)	(IV)
		Other Domestic Shocks				
ρ_g	Autocorrel. g_t	U	0.65	0.69	0.96	0.74
		0.50	[0.59:0.75]	[0.67:0.71]	[0.90:1.00]	[0.64:0.82]
		[0.03:0.98]				
ρ_{tp}	Autocorrel. tp_t	U	0.90	0.61	0.92	0.91
		0.50	[0.85:0.96]	[0.58:0.63]	[0.86:0.98]	[0.87:0.96]
		[0.03:0.98]				
ρ_{cp}	Autocorrel. cp_t	U	0.97	0.81	0.19	0.34
		0.50	[0.94:1.00]	[0.80:0.83]	[0.04:0.39]	[0.18:0.51]
		[0.03:0.98]				
$\Xi_{g,y}$	Feedback Δy_t on g_t	U	0.18	-0.05	-0.15	-0.02
		0.00	[0.06:0.29]	[-0.07:-0.03]	[-0.44:0.07]	[-0.07:0.03]
		[-0.95:0.95]				
$\Xi_{tp,tby}$	Feedback tby_t on tp_t	U	-0.21	-0.04	-0.03	-0.03
		0.00	[-0.34:-0.02]	[-0.07:-0.03]	[-0.07:0.01]	[-0.14:0.12]
		[-0.95:0.95]				
$\Upsilon_{tp,tot}$	Feedback tot_t on tp_t	U	-0.02	0.26	-0.03	0.11
		0.00	[-0.20:0.14]	[0.22:0.31]	[-0.12:0.04]	[0.09:0.14]
		[-0.95:0.95]				
$\Xi_{cp,y}$	Feedback Δy_t on cp_t	U	0.28	-0.25	-0.94	
		0.00	[0.20:0.36]	[-0.26:-0.24]	[-1.00:-0.84]	
		[-0.95:0.95]				
σ^g	Std. Dev. ϵ_t^g	IG	0.06	0.10	0.11	0.04
		0.03	[0.02:0.09]	[0.08:0.12]	[0.09:0.13]	[0.03:0.05]
		[0.01:0.07]				
σ^{tp}	Std. Dev. ϵ_t^{tp}	IG	0.11	0.01	0.03	0.01
		0.03	[0.07:0.14]	[0.01:0.02]	[0.02:0.04]	[0.01:0.01]
		[0.01:0.07]				
σ^{cp}	Std. Dev. ϵ_t^{cp}	IG	0.01	0.01	0.01	0.01
		0.03	[0.01:0.01]	[0.01:0.01]	[0.01:0.02]	[0.01:0.02]
		[0.01:0.07]				

Note: See Table 2.5.

Table 2.8: Implied Second Moments, Model I, 1913-2005.

Variable	σ_x Data	(I)	$\rho_{x,\Delta Y}$ Data	(I)	$\rho_{x,tby}$ Data	(I)
ΔY	5.06	6.22	1.00		-0.17	-0.08
	(0.36)		—		(0.12)	
ΔC	8.42	6.40	0.75	0.62	-0.37	-0.07
	(1.00)		(0.18)		(0.14)	
ΔI	16.77	18.63	0.78	0.52	-0.25	-0.08
	(1.14)		(0.13)		(0.13)	
tby	6.07	61.59	-0.17	-0.08	1.00	
	(0.62)		(0.12)		—	
rer	46.84	69.79	-0.12	-0.04	-0.17	0.52
	(3.22)		(0.09)		(0.07)	

Note: Standard Deviations (σ_x) in percentage points. The contribution of measurement errors are not included. GMM standard errors in parenthesis.

Table 2.9: Variance Decomposition , Model I, 1913-2005.

Shock	ΔY	ΔC	ΔI	rer
v	4	5	3	1
	[1:6]	[2:8]	[1:4]	[0:4]
z	3	0	2	0
	[0:8]	[0:1]	[0:4]	[0:0]
a^x	1	0	0	0
	[0:3]	[0:0]	[0:1]	[0:0]
a^m	7	3	13	75
	[3:11]	[1:5]	[5:20]	[40:94]
a^n	57	33	18	4
	[45:66]	[22:42]	[9:27]	[0:8]
tot	11	2	1	0
	[8:15]	[1:2]	[1:2]	[0:1]
rw	0	0	12	0
	[0:1]	[0:1]	[5:19]	[0:0]
g	0	0	0	0
	[0:0]	[0:0]	[0:0]	[0:0]
cp	11	2	1	1
	[6:15]	[1:3]	[0:1]	[0:1]
tp	3	2	26	0
	[2:5]	[1:4]	[15:34]	[0:1]
m.e.	2	53	24	18
	[0:5]	[39:61]	[16:31]	[2:36]

Note: Each entry denotes the posterior means of the variance decomposition, as well as its 95% confidence bands in brackets.

Table 2.10: Implied Second Moments, 1935-2005.

Variable	σ_x				$\rho_{x,\Delta Y}$				$\rho_{x,tby}$			
	Data	(II)	(III)	(IV)	Data	(II)	(III)	(IV)	Data	(II)	(III)	(IV)
ΔY	4.95	6.80	5.80	5.13	1.00				-0.12	-0.25	-0.10	-0.12
	(0.4)				—				(0.2)			
ΔC	6.84	7.47	7.03	6.53	0.85	0.79	0.93	0.92	-0.33	-0.08	-0.04	-0.12
	(0.8)				(0.2)				(0.2)			
ΔI	14.8	30.0	15.6	12.1	0.79	0.41	0.72	0.75	-0.06	-0.24	-0.16	-0.14
	(1.1)				(0.1)				(0.2)			
tby	3.75	31.6	18.0	17.9	-0.12	-0.25	-0.10	-0.12	1.00			
	(0.4)				(0.2)				—			
rer	50.8	22.7	19.9	32.7	-0.14	-0.15	-0.01	0.03	-0.05	0.19	0.09	0.26
	(3.8)				(0.1)				(0.1)			

Note: See Table 2.8.

Table 2.11: Variance Decomposition, 1935-2005.

Shock	ΔY			rer		
	(II)	(III)	(IV)	(II)	(III)	(IV)
v	4	2	2	0	0	0
	[2:6]	[1:3]	[1:3]	[0:0]	[0:0]	[0:0]
z	5	4	6	0	0	0
	[1:10]	[1:7]	[1:13]	[0:0]	[0:0]	[0:0]
a^x	0	1	1	0	0	0
	[0:1]	[0:2]	[0:2]	[0:0]	[0:0]	[0:0]
a^m	1	6	6	0	1	0
	[0:2]	[3:9]	[3:10]	[0:0]	[0:1]	[0:0]
a^n	71	83	75	21	17	29
	[60:79]	[75:89]	[62:83]	[13:27]	[8:24]	[19:37]
tot	0	1	2	0	0	0
	[0:1]	[0:2]	[1:3]	[0:0]	[0:0]	[0:0]
rw	4			0		
	[2:5]			[0:0]		
g	0	0	2	0	0	0
	[0:0]	[0:0]	[1:3]	[0:0]	[0:0]	[0:0]
cp	0	1	0	0	0	0
	[0:1]	[0:2]	[0:1]	[0:0]	[0:0]	[0:0]
tp	11	0	0	0	0	0
	[5:16]	[0:1]	[0:0]	[0:1]	[0:0]	[0:0]
m.e.	2	2	6	78	82	71
	[0:4]	[0:3]	[2:10]	[68:84]	[73:89]	[59:78]

Note: See Table 2.9.

FIGURE 2.1: Real Exchange Rate and Recessions, 1913-2005.
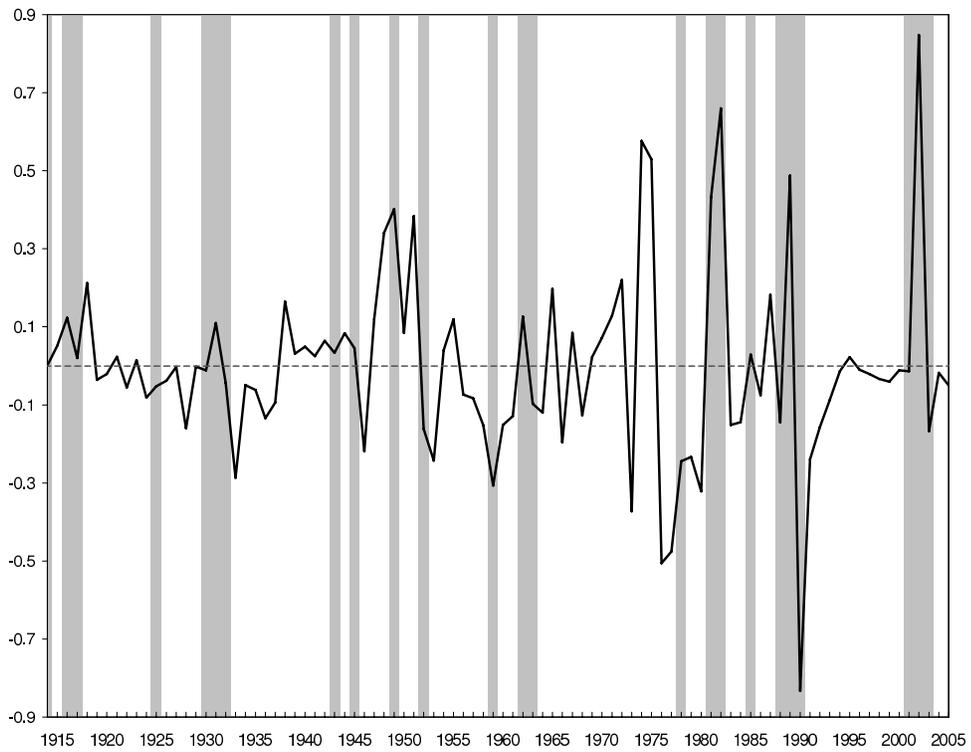
Note: The solid line is the change in the log of RER from the data (a positive number is a depreciation). The gray bars indicate the recession dates described in Sturzenegger and Moya (2003).

FIGURE 2.2: Real Exchange Rate and GDP, Leads and Lags Correlation, 1913-2005.
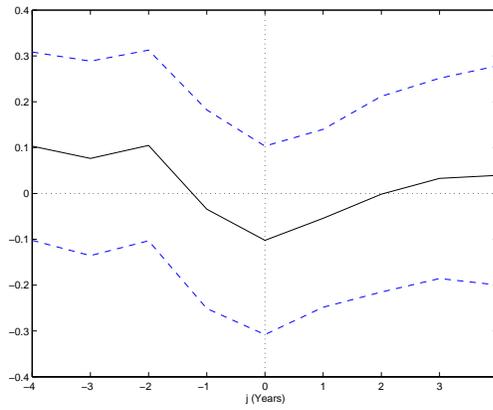
Note: The solid line is the correlation between Δy_t and rer_{t+j}, and the dashed lines are GMM 2-S.E. bands.

FIGURE 2.3: Explaining GDP, 1913-2005.

A. Non–Traded Productivity vs. Detrended GDP

B. Sectorial Shares of GDP
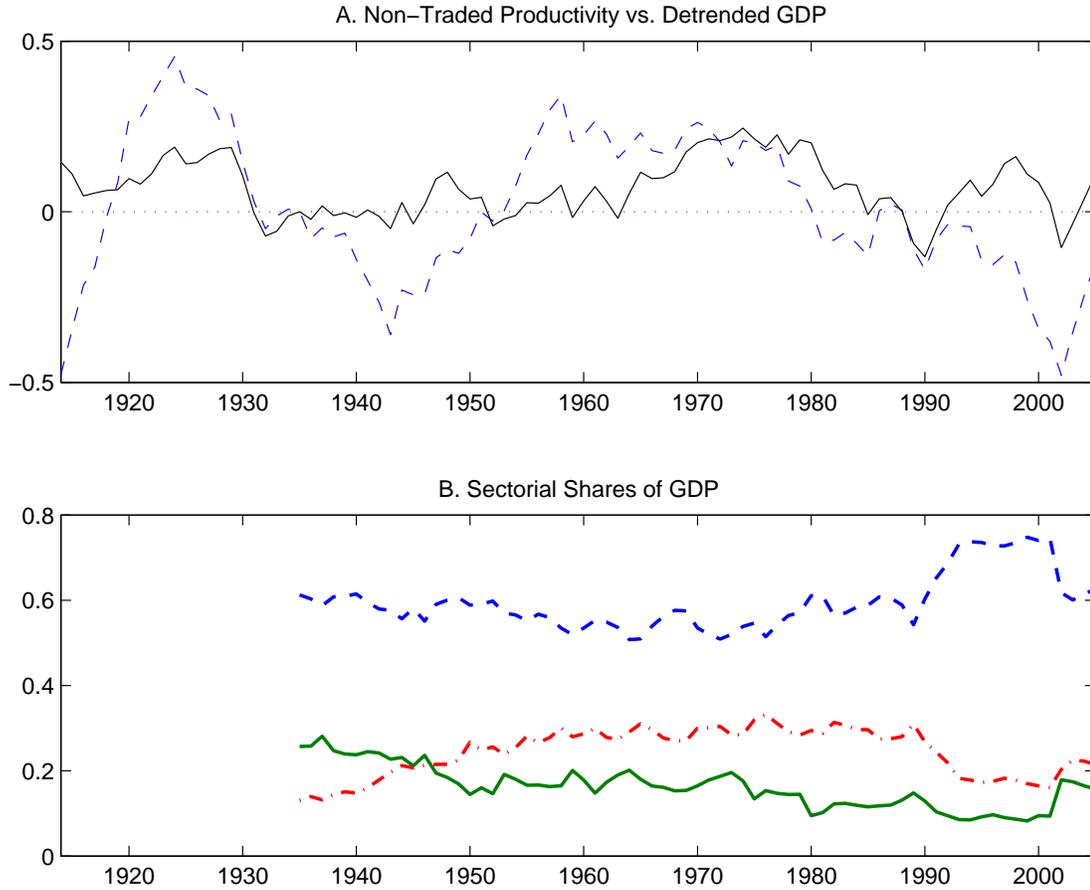
Note: In the upper graph, the dashed line is the posterior mean of the smoothed a_t^N from Model I, while the solid line is the (quadratic) de-trended log of GDP from the data. Series are re-scaled. In the lower graph, the dashed, solid and dashed-dotted lines are, respectively, the shares of non-tradeables, exportables and importables from the data.

FIGURE 2.4: Impulse Response to a 1% increase in a_t^N, Model I, 1913-2005.
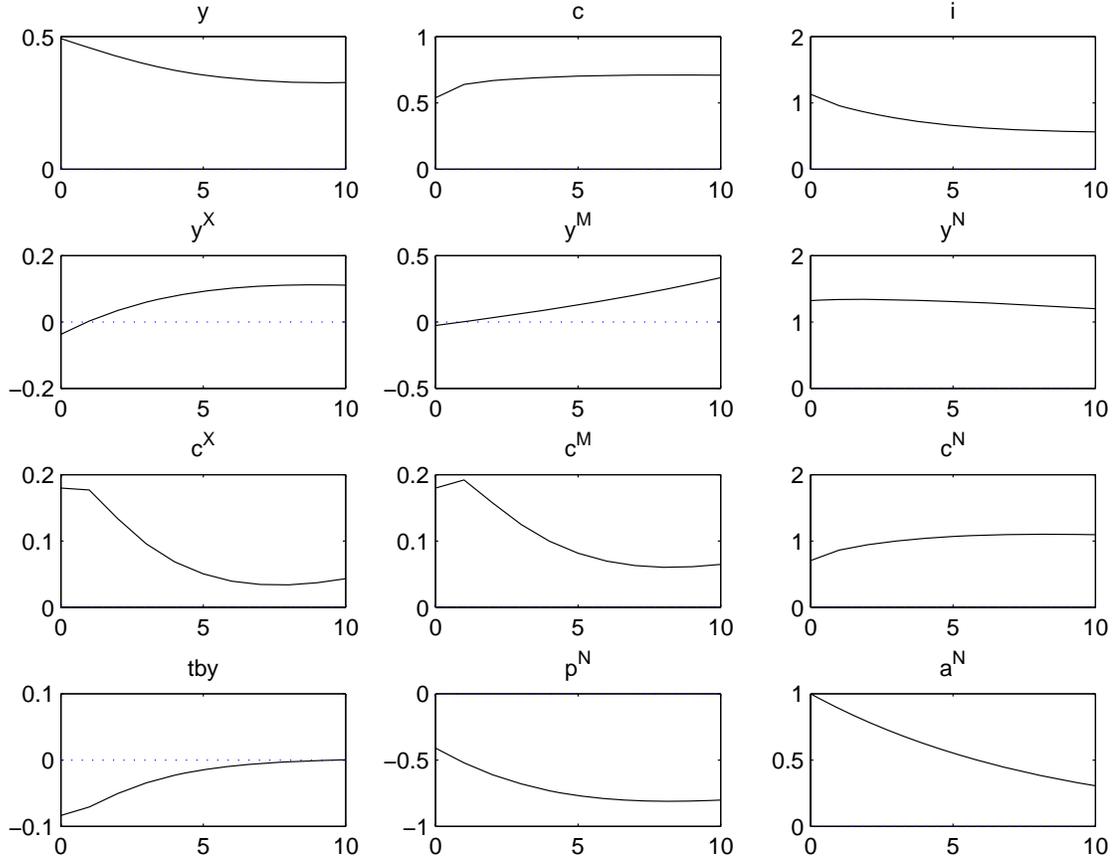
A. RER: Model vs. Data

B. Importable Productivity and RER
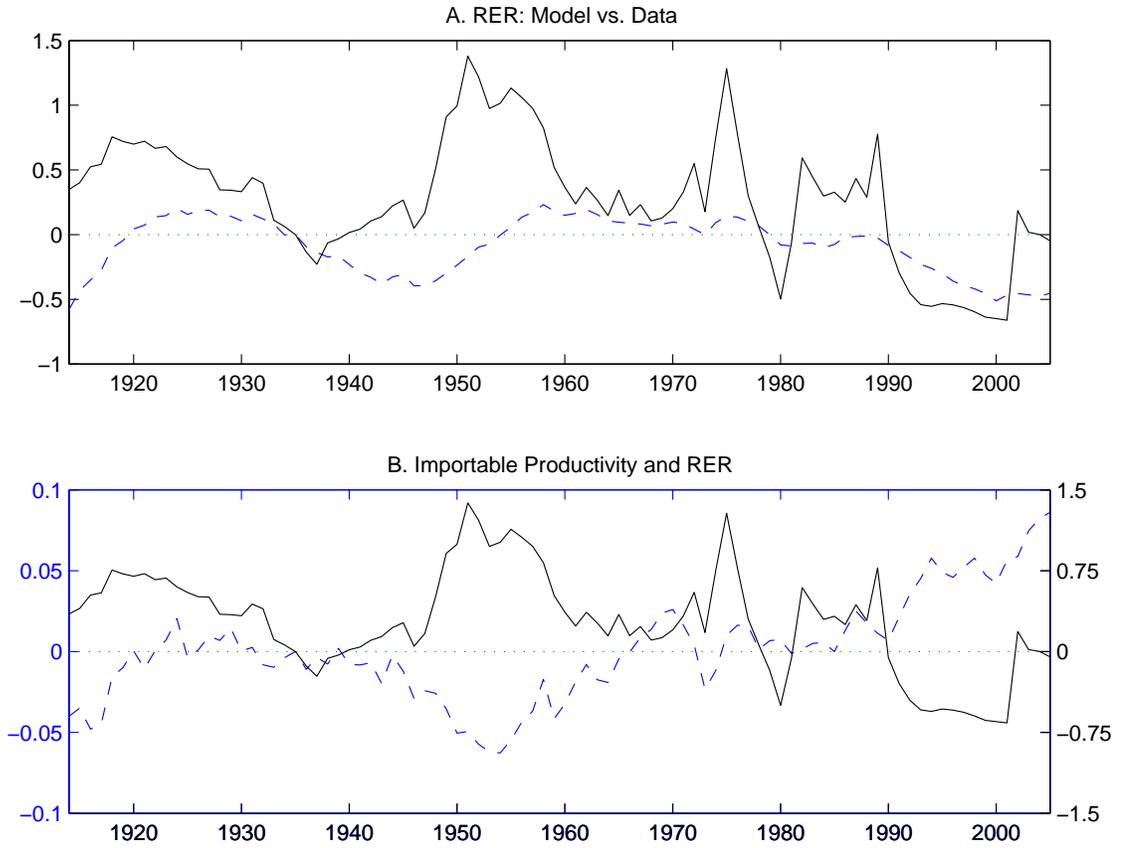
Note: In the upper graph, the dashed line is the posterior mean of the smoothed rer_t from Model I; while the solid line is the log of RER from the data. In the lower graph, the dashed line (right scale) is the posterior mean of the smoothed a_t^M from Model I; while the solid line (left scale) is the log of RER from the data. Series are re-scaled.

FIGURE 2.6: Explaining GDP and the Real Exchange Rate, 1935-2005.
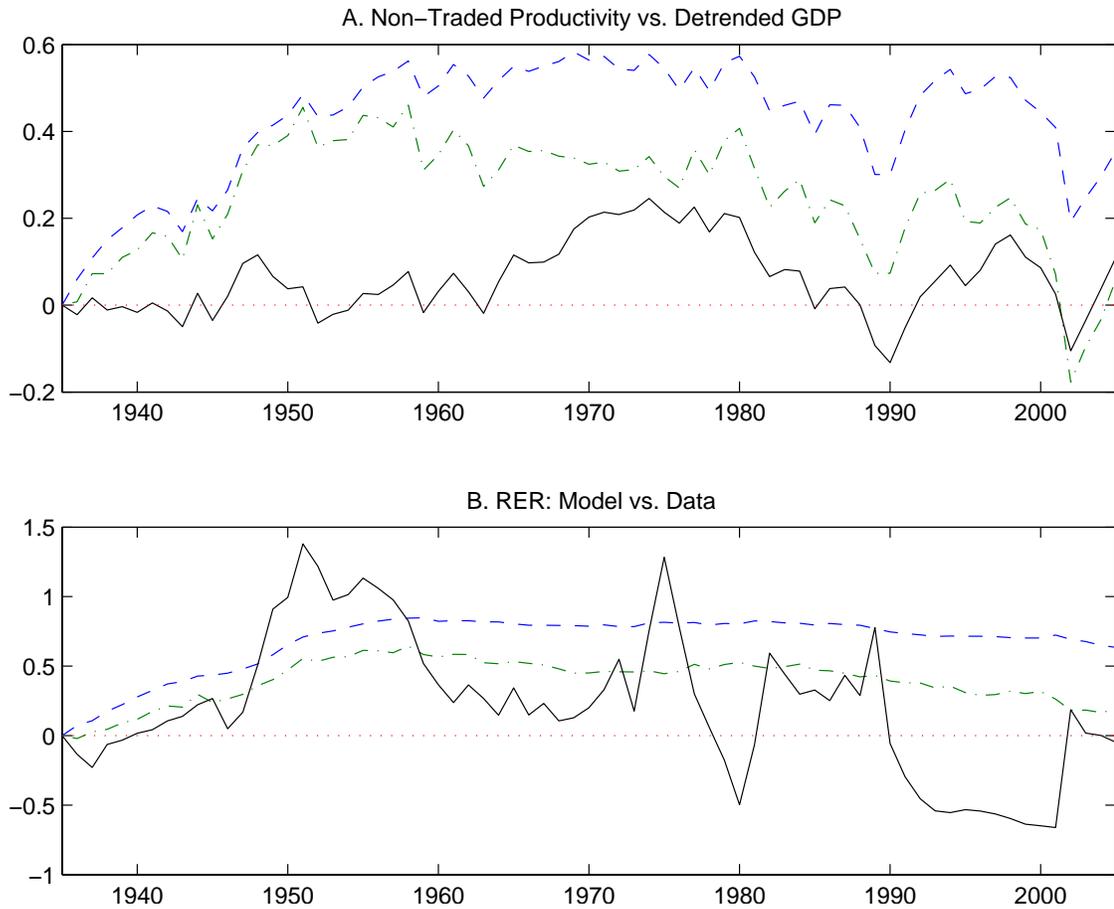
A. Non–Traded Productivity vs. Detrended GDP

B. RER: Model vs. Data

Note: In the upper graph, the dashed and dashed-dotted lines are the posterior means of the smoothed a_t^N from models II and IV, respectively; while the solid line is the (quadratic) detrended log of GDP from the data. In the lower graph, the dashed and dashed-dotted lines are the posterior means of the smoothed rer_t from models II and IV, respectively; while the solid line is the log of RER from the data. Series are re-scaled.

3

Estimating Models for Monetary Policy Analysis in Emerging Countries

3.1   Introduction[1]

What makes the job of the monetary authority in an emerging country different from that in a more developed economy? The literature has analyzed many distinctive characteristics of these markets that are relevant for policy analysis.[2] For instance, emerging economies are subject to shocks to international interest rates and prices, for they heavily rely on foreign trade and/or financing but they are generally price takers in the rest of the world. Additionally, financial frictions are usually in place, generating countercyclical costs of financing which tend to amplify business cycles fluctuations. Moreover, if an important part of their debt is denominated in foreign currency, they might face a liability dollarization problem that can exacerbate any

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[1] I would like to thank seminar participants at Universidad de San Andrés, Universidad T. Di Tella, Universidad del CEMA, Banco Central de la República Argentina, Banco Central de Chile, Universidad de Montevideo, University of Virginia, University of Illinois, Federal Reserve Board, Kansas City Fed, I.M.F. and Pontificia Universidad Católica de Chile for helpful comments.

[2] Calvo (2005), for example, provides an excellent book-length treatment of many of these distinctive features of emerging economies and how they have played a role in explaining their experience in the last two decades.

financial constraint. Another feature of these countries is the coexistence of both domestic and foreign currency (currency substitution). All these impose non-trivial restrictions on policy-related decisions like exchange-rate regimes, stabilization policies and inflation management.

Part of the literature that has emerged after the series of emerging-markets crises since the mid-90's has re-evaluated the design of monetary policy in these countries by explicitly acknowledging these characteristics mentioned above.[3] In terms of financial frictions and liability dollarization, for instance, Cespedes et al. (2004) and Cook (2004) have studied the optimal exchange-rate regime by adapting the financial accelerator framework of Bernanke et al. (1999) to a small open economy with dollar-denominated debt.[4] Additionally, the link between currency substitution and monetary policy, despite its long tradition,[5] has been recently revisited in the context of DSGE models by Felices and Tuesta (2007) and Batini et al. (2007, 2008). On the other hand, in terms of the domestic propagation of international prices, Calvo et al. (2008) have highlighted the importance of accounting for the use of intermediate inputs (particularly those imported) in analyzing exchange-rate regimes, while the study by Devereux et al. (2006) also addresses this issue by considering the role of delayed pass-through for monetary policy.

While this recent literature has significantly improved our understanding of why these features are important for monetary policy, the relevance of any policy-related study strongly depends on whether the specific model (and its parameterization) used to draw recommendations is empirically sound or not. This is of particular

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[3] Another feature distinguishing this new wave of research from the older related literature is methodological, for they have been able to exploit the recent developments in the so-called New-Open-Economy Macroeconomics (NOEM), as well as the progress in tools for policy analysis for dynamic stochastic general equilibrium (DSGE) models. See García-Cicco (2008) for a survey of this literature.

[4] See also Devereux et al. (2006), Elekdag and Tchakarov (2007) and Gertler et al. (2007).

[5] See, for instance, the survey by Calvo and Végh (1992).

importance for the aforementioned papers for at least two reasons. First, this line of research usually applies calibration techniques to assign values for the relevant parameters, many times using as reference studies from developed countries. Second, in spite of how the model is parameterized, these papers do not analyze if the model can adequately fit the data. Moreover, given this methodological approach, the question of which of the emerging-countries' frictions are empirically more relevant is not addressed, even though it is of great interest for policy design.

Given these empirical concerns, our contribution is to set up and estimate a comprehensive DSGE model that takes into account these defining characteristics of emerging countries. In particular, our framework features a sectorial decomposition of the productive sector, the use of intermediate inputs, imperfect pass-through, endogenous premium to finance capital accumulation, balance sheets effects due to liability dollarization, currency substitution, as well as price and wage rigidities. Additionally, eleven driving forces, both of domestic and international origin, are considered. We follow a Bayesian approach to estimate the model using a quarterly data set from Mexico –from 1980 to 2007– that includes a large number of observables.

Our goal is to address three main quantitative questions. First, can the estimated model fit the data? Our answer is generally yes, but with some caveats (for instance, the fit of real wages is not satisfactory). Second, are the estimated parameters similar to those calibrated in policy-related studies? The results show many significant differences, particularly for those describing financial frictions, price stickiness and money demand. Finally, which of the emerging-markets' frictions are more relevant in fitting the data? We found that including intermediate inputs is most relevant, while currency substitution does not seem to play a relevant role. Moreover, the financial accelerator mechanism and liability dollarization are also important.

Additionally, we use our preferred specifications to study which of the included

driving forces are more important in explaining the data. We found that, while foreign shocks play a non-negligible role (especially export prices), the most important sources of fluctuations have a domestic origin. In particular, sectorial (stationary) technology shocks account for more than 40% of the variance of most domestic observables. Country premium disturbances are also relevant to explain real variables, while shocks related with monetary policy are helpful in describing the dynamics of inflation.

From a methodological perspective, we depart from the usual implementation of the Bayesian estimation of DSGE models in two aspects. First, our approach to assign priors for the estimated parameters modifies the methodology proposed by Del Negro and Schorfheide (2006), which provides a more transparent procedure (particularly for parameters describing driving forces) to translate our *a priori* beliefs into a probability density. Second, in addition to the usual model comparison according to the marginal likelihood, we perform a more thorough analysis by applying the loss function-based approach developed by Schorfheide (2000), which allows ranking models according to their ability to fit the data in many different dimensions.

This paper is also related to studies estimating DSGE models in emerging countries. For instance, NOEM models featuring frictions like sticky prices and wages are estimated by Caputo et al. (2006) and Medina and Soto (2005) for Chile and da Silveira (2006) for Brazil. In terms of the financial frictions and liability dollarization, Elekdag et al. (2005) and Tovar (2006b) estimate a simplified version of the financial accelerator using data from Korea, while Tovar (2006a) does it for Chile, Colombia and Mexico. Additionally, the work by Castillo et al. (2006) estimates a model featuring currency substitution for Peru.

Our approach differs, however, from these empirical studies in several relevant aspects. All these papers use models with a single domestically-produced good that is fully tradable, while our framework displays a richer production structure that

also includes non-traded goods. In addition, with the exception of Castillo et al. (2006), cash-less economies are generally considered. Finally, only a few number of observables are frequently used for estimation. In particularly, although foreign prices and interest rates are usually considered as driving forces in these models, they are generally not included in the data set. On the other hand, we match the likelihood of 14 variables, both domestic and foreign.

The rest of the paper is organized as follows. Section 3.2 describes the model, while Section 3.3 presents the details of the estimation procedure. The results under the Baseline model are studied in Section 3.4, in which we analyze the posterior of the parameters, as well as the extent to which the model can fit the data. Section 3.5 evaluates the role of several emerging-countries frictions in replicating the data, comparing also the estimation results of the preferred specifications in terms of posterior distributions and variance decompositions. Finally, Section 3.6 summarizes the findings and discusses directions for future research.

3.2 The Model

This section presents the Baseline model. We start with a brief overview, describing then the problems faced by all agents, as well as the driving forces affecting the economy. The Technical Appendix provides the details regarding optimality conditions, definition of the stationary equilibrium and computation of the non-stochastic steady state.

The small open economy is populated by households, firms, entrepreneurs and a consolidated government. There are three consumption goods: exportables (x, sold both domestically and in the rest of the world), non-tradeables (n) and imported goods (f). The first two are produced domestically, while the latter is produced abroad and sold domestically trough import agents. The production of x and n uses labor, capital, and other consumption goods as inputs, taking their prices as

given. While exportable firms sell at a price determined in the rest of the world, both non-traded firms and import agents have market power and face price adjustment costs.

Capital goods are produced in three steps. First, competitive firms combine entrepreneurs labor with both non-traded and foreign goods to produce final investment goods. In a second stage, a group of competitive firms produce unfinished capital goods for each sector combining final investment goods and used capital, which they buy from entrepreneurs. Finally, entrepreneurs transform these into finished capital goods using a linear technology. This production process is subject to an idiosyncratic productivity shock, revealed privately to entrepreneurs ex-post. Because they have to borrow to produce, this informational asymmetry introduces an endogenous finance premium. In addition, they are subject to balance-sheet effects originated by movements in the nominal exchange rate, for they borrow in foreign currency but their income is denominated in local currency.

Households derive utility from consumption (subject to habit formation), leisure and holdings of real balances of domestic (pesos) and foreign currency (dollars). The demand for both types of currency reflects a non-trivial degree of substitutability, and real balances are partially complements of consumption. In terms of other financial assets, they have access to both domestic and foreign non-contingent nominal bonds. Additionally, households are assumed to have monopoly power in setting wages, facing adjustment costs.

The government consumes an exogenous stream of final goods and collects lump sum taxes. They also print domestic currency and set the interest rate on domestic bonds according to a Taylor-type rule with time-varying targets (inflation and output).

This economy is subject to a multitude (11) of shocks affecting the following variables: non-stationary labor augmenting productivity, stationary TFP (sector

specific), domestic nominal interest rate, targets in the Taylor rule, government purchases, country premium, world interest rate and international prices (exports and imports).

3.2.1 Households

The economy is populated by a continuum of households in the unit interval, indexed by h, seeking to maximize $E_0 \left\{ \sum_{t=0}^{\infty} \beta^t \frac{\left[V_t^h (1-l_t^h)^\phi \right]^{1-\sigma}}{(1-\sigma)} \right\}$, with $\phi > 0$ and $\sigma > 0$, where

$$ V_t^h \equiv \left[b(X_t^h)^{1-1/\zeta} + (1-b)(Z_t^h)^{1-1/\zeta} \right]^{\frac{\zeta}{\zeta-1}}, $$

with $b \in [0,1]$ and $\zeta > 0$. $X_t^h \equiv \left(C_t^h - \rho_c C_{t-1} \right)$ is habit adjusted consumption, where C_t^h is final consumption by household h, $C_t = \int_0^1 C_t^h dh$ is aggregate household consumption (i.e. the utility function exhibits *external* habit formation), and $\rho_c \in [0,1)$. Labor effort is denoted by l_t^h. We follow the notation that lower case letters represent stationary variables while those in capital letters contain a stochastic trend in equilibrium.

The variable Z_t^h is a liquidity-service index, defined as

$$ Z_t^h \equiv \left[\nu \left(\frac{M_{t+1}^h}{P_t} \right)^{1-1/\chi} + (1-\nu) \left(\frac{D_{t+1}^h S_t}{P_t} \right)^{1-1/\chi} \right]^{\frac{\chi}{\chi-1}}, $$

with $\nu \in [0,1]$ and $\chi > 0$. The holdings of pesos and dollars (decided at t) are denoted by, respectively, M_{t+1}^h and D_{t+1}^h, S_t is the nominal exchange rate (measured as pesos per dollar) and P_t is the price of final consumption goods (with $\pi_t \equiv P_t/P_{t-1}$ denoting inflation). This particular way of introducing currency substitution is due to Felices and Tuesta (2007). The parameter ν governs the importance of the liquidity services provided by domestic currency: if $\nu = 1$ dollars are not useful for transaction purposes while $\nu = 0$ represents the case of full transaction dollarization. Notice also

that we allow for non-trivial complementarities between habit-adjusted consumption and liquidity services (governed by ζ). This interaction, as emphasized by Felices and Tuesta (2007), is particularly important for the design of monetary policy, for it introduces an endogenous tradeoff between output and inflation stabilization as the marginal utility of consumption depends on money holdings.

Each household h sells labor services in a monopolistically competitive market, charging a nominal wage denoted by W_t^h (in pesos), and facing a demand given by $(W_t^h/W_t)^{-\theta_w} l_t^d$, with $\theta_w > 1$. The variable l_t^d denotes aggregate labor demand and $W_t \equiv [\int_0^1 (W_t^h)^{1-\theta_w} dh]^{1/(1-\theta_w)}$ is the aggregate nominal wage index. Given that workers supply labor in order to meet their demand, we have $l_t^h = l_t^d(W_t^h/W_t)^{-\theta_w}$. Additionally, changing wages is costly, with adjustment costs given by (in pesos)

$$AC_t^{w,h} \equiv W_t \frac{\psi_w}{2} \left(\frac{W_t^h}{\hat{\pi}_t W_{t-1}^h} - 1 \right)^2,$$

where $\psi_w > 0$. $\hat{\pi}_t$ (defined below) is the inflation target, to which nominal wages are indexed.[6]

Additionally, households have access to two types of non-contingent one-period debt: one denominated in pesos (B_t^h), with nominal rate given by i_t, and the other is dollar denominated (B_t^{*h}), with a rate of $i_t^* \xi_t$. The variable ξ_t denotes the country premium and is defined as

$$\xi_t = \psi_d \left[\exp\left(\frac{S_t B_{t+1}^*}{P_t GDP_t} - \bar{b} \right) - 1 \right] + \xi_t^*, \tag{3.1}$$

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[6] This target will be used for price indexation as well (see below). Emerging countries have many times implemented inflation-stabilization programs. Most of these attempts have been successful, at least in the short-run, in the sense that inflation was indeed reduced after their implementation (see, for instance, Mendoza and Uribe, 2000, for an analysis of the Mexican case). To the extent that these policies will be reflected in changes in the inflation target, it seems appropriate to use it as the indexation variable. If, alternatively, prices and wages were indexed to past inflation, they will not adjust after the policy is implemented as in the data. Moreover, we have estimated the Baseline Model allowing the indexation variable to be a combination of the target and past inflation. The results in terms of the parameter governing this combination strongly suggest to use only the target.

with $\psi_d > 0$.[7] As can be seen, this premium is determined by an endogenous component that depends on the aggregate level of households international debt ($B^*_{t+1} = \int_0^1 B^{*h}_{t+1} dh$) relative to aggregate output (GDP_t, to be defined), and by a stochastic component (ξ^*_t).

Overall, each household h faces, at period t, the following nominal budget constraint

$$P_t C^h_t + AC^{w,h}_t + M^h_{t+1} + S_t D^h_{t+1} - B^h_{t+1} - S_t B^{*h}_{t+1} =$$

$$W^h_t l^h_t - B^h_t i_{t-1} - S_t B^{*h}_t i^*_{t-1} \xi_{t-1} + M^h_t + S_t D^h_t + \Pi^h_t + T^h_t. \quad (3.2)$$

As households own the monopolistic firms, part of their income comes from aggregate profits $\Pi_t \equiv \sum_j \Pi^j_t$ for $j = n, f$ (defined below), with $\Pi_t = \int_0^1 \Pi^h_t dh$. Finally, each household receives a lump-sum transfer from the government in the amount of T^h_t pesos.

3.2.2 Supply of Consumption Goods

Firms operating in each consumption-goods market x, n and f differ across sectors along two dimensions: available technology and price setting ability. We describe first the production in each sector, discussing then the pricing problem in the different markets. In addition, there are two packer sectors, combining different consumption goods into a final consumption basket.

Production

The technology available for the domestic production of goods x and n uses as inputs labor and capital rented from households, as well as intermediate inputs from other sectors. Firms are price takers in input markets. The typical firm, indexed by i, in

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[7] This is as a possible way to "close" this small open economy model. See Schmitt-Grohé and Uribe (2003) for details and alternatives.

sector j uses the following production function

$$Y_t^{j,i} = A_j z_t^j \left(K_t^{j,i}\right)^{\alpha_j^k} \left(\Gamma_t l_t^{j,i}\right)^{\alpha_j^l} \left(IC_t^{x,j,i}\right)^{\alpha_j^x} \left(IC_t^{n,j,i}\right)^{\alpha_j^n} \left(IC_t^{f,j,i}\right)^{\alpha_j^f}, \qquad (3.3)$$

with $A_j \equiv \prod_\iota (\alpha_j^\iota)^{-\alpha_j^\iota}$ and $\sum_\iota \alpha_j^\iota = 1$ for $\iota = k, l, x, n, f$ and $j = x, n$. In addition, we assume $\alpha_j^j = 0$. Intermediate consumption of good $\iota = x, n, f$ by a firm i in sector $j = x, n$ is given by $IC_t^{\iota,j,i}$. The variable z_t^j denotes a sector-specific technology shifter, assumed to be stationary. On the other hand, Γ_t is a labor-augmenting technology shock common to all sectors, driven by a non-stationary process. The idea behind this specification is that changes affecting the production possibilities of the economy as a whole are captured by Γ_t, whereas z_t^j will reflect shocks having a differential impact in the technology of each sector.

Given the constant-return-to-scale technology and the price-taking assumption in factor's markets, each firm in sector j will face the same nominal marginal cost given by

$$MC_t^j = \left(z_t^j\right)^{-1} \left(R_t^j\right)^{\alpha_j^k} \left(\frac{W_t}{\Gamma_t}\right)^{\alpha_j^l} (P_t^x)^{\alpha_j^x} (P_t^n)^{\alpha_j^n} \left(P_t^f\right)^{\alpha_j^f},$$

for $j = x, n$, where P_t^ι is the domestic price of good $\iota = x, n, f$ and R_t^j is the rental rate of capital.

Finally, consumption goods of type f are produced in the rest of the world and sold domestically by import agents. The nominal marginal cost in pesos (MC_t^f, common to all firms in this sector) is simply the international dollar price of these goods (P_t^{*f}, determined by an exogenous process) adjusted by the nominal exchange rate. Thus, $MC_t^f = P_t^{*f} S_t$.

Price Setting and Profits

Firms also differ across markets in terms of price setting ability and the demand they face. On one hand, firms producing exportable goods x are assumed to behave

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competitively, taking the international price as given. This implies that $P_t^x = S_t P_t^{*x}$, with P_t^{*x} being the (exogenous) international dollar price of exports.[8]

On the other hand, firms selling only domestically do have price setting power. We assume that all buyers of goods n demand part of an homogeneous aggregate defined as

$$Y_t^{d,n} \equiv \left[\int_0^1 \left(Y_t^{d,n,i} \right)^{\frac{\theta_n - 1}{\theta_n}} di \right]^{\frac{\theta_n}{\theta_n - 1}},$$

with $\theta_n > 1$. Therefore, a firm i in sector n, charging a price $P_t^{n,i}$, will face a demand given by $Y_t^{d,n,i} = Y_t^{d,n}(P_t^{n,i}/P_t^n)^{-\theta_n}$, where $P_t^n = [\int_0^1 (P_t^{n,i})^{1-\theta_n} di]^{1/(1-\theta_n)}$. As we assumed for wages, changing prices is costly due to quadratic adjustment costs given by (in pesos)

$$AC_t^{n,i} \equiv \frac{\psi_n}{2} \left(\frac{P_t^{n,i}}{\hat{\pi}_t P_{t-1}^{n,i}} - 1 \right)^2 P_t^n \Gamma_t,$$

where $\psi_p > 0$. Additionally, these firms incur in fixed operational costs, in terms of their own output, given by $\Gamma_t \kappa^n y^n$, where y^n denotes output of sector n in the non-stochastic (stationary) steady state.[9] Therefore, the profits of a firm i in sector n are given by

$$\Pi_t^{n,i} = \left[P_t^{n,i} - MC_t^n \right] Y_t^{d,n,i} - P_t^n \Gamma_t \kappa^n y^n - AC_t^{n,i}.$$

Finally, import agents (sector f) face a similar situation than firms in sector n, differing only in terms of parameter values for the elasticity of substitution, adjustment costs and fixed costs. Thus, a firm i in sector f faces a demand given by

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[8] Here we are departing from many studies estimating DSGE models in emerging economies, which usually assume that exporters face a negatively-sloped demand curve and have enough market power internationally to set prices (either in pesos or dollars). See, for instance, Elekdag et al. (2005), da Silveira (2006), Tovar (2006a,b), Caputo et al. (2006) and Castillo et al. (2006). It is not clear, however, that this is an appropriate assumption for these countries, for most of them are mainly exporters of some commodities for which they are clearly price takers (e.g. oil in Mexico, copper in Chile, agricultural goods in Argentina, etc.).

[9] Variables without time subscript represent steady state values

$Y_t^{d,f,i} = Y_t^{d,f}(P_t^{f,i}/P_t^f)^{-\theta_f}$, with $\theta_f > 1$ and $P_t^f = [\int_0^1 (P_t^{f,i})^{1-\theta_f} di]^{1/(1-\theta_f)}$. The cost associated with price changes is

$$AC_t^{f,i} \equiv \frac{\psi_f}{2} \left(\frac{P_t^{f,i}}{\hat{\pi}_t P_{t-1}^{f,i}} - 1 \right)^2 P_t^f \Gamma_t,$$

and profits are $\Pi_t^{f,i} = \left[P_t^{f,i} - MC_t^f \right] Y_t^{d,f,i} - P_t^f \Gamma_t \kappa^f y^f - AC_t^{f,i}$.

Final Consumption Goods

Final consumption goods are a combination of non-traded (n) and traded $(x$ and $f)$ goods. The later are produced competitively according to

$$C_t^T = A_T (C_t^x)^{\eta_x} \left(C_t^f \right)^{1-\eta_x}, \tag{3.4}$$

where $A_T \equiv (\eta_x)^{-\eta_x} (1 - \eta_x)^{-(1-\eta_x)}$. Aggregate final consumption of each type is denoted by C_t^j for $j = x, n, f$.[10] In equilibrium, the price for this aggregate will be $P_t^T = (P_t^x)^{\eta_x} (P_t^f)^{1-\eta_x}$.

On the other hand, the production of final consumption goods is given by

$$Y_t^C = \left[a^{1/\varphi} \left(C_t^N \right)^{1-1/\varphi} + (1-a)^{1/\varphi} \left(C_t^T \right)^{1-1/\varphi} \right]^{\frac{\varphi}{\varphi-1}}. \tag{3.5}$$

and thus the domestic price index is $P_t = \left[a \left(P_t^N \right)^{1-\varphi} + (1-a) \left(P_t^T \right)^{1-\varphi} \right]^{\frac{1}{1-\varphi}}$.

3.2.3 Capital Goods and Financial Frictions

The stock of capital that will be available for next period's production is accumulated in three steps. First, competitive firms produce final investment goods, Y_t^k,

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[10] Because we assume that households and the government share the same preference for different goods and varieties, C_t^j is the aggregate consumption of good j. The other part of the demand for these goods is given by intermediate demand by firms (and exports for good x).

combining non-traded $(IC_t^{k,n})$ and foreign goods $(IC_t^{k,f})$,[11] as well as entrepreneurial labor $(L_t^e$, supplied inelastically). In particular, the production function in this sector is

$$Y_t^k = A_k \left(IC_t^{n,k} \right)^{\alpha_k^n} \left(IC_t^{f,k} \right)^{\alpha_k^f} (\Gamma_t l_t^e)^{\alpha_k^e}, \qquad (3.6)$$

where $A_k \equiv \prod_\iota (\alpha_k^\iota)^{-\alpha_k^\iota}$ and $\sum_\iota \alpha_k^\iota = 1$ for $\iota = n, f, e$. Letting W_t^e denote entrepreneurial wage, perfect competition implies that the equilibrium price of these goods is $P_t^k = (P_t^n)^{\alpha_k^n} (P_t^f)^{\alpha_k^f} (W_t^e/\Gamma_t)^{\alpha_k^e}$.

In a second stage, after the production of consumption and final investment goods is finished, a group of competitive firms produce unfinished capital goods for each sector (selling at a price Q_t^j) combining final investment goods and used capital, which they buy from entrepreneurs (paying $Q_t^{old,j}$ per unit). Specifically, for each sector $j = x, n$ they operate the following technology

$$K_{t+1}^j = (1 - \delta) K_t^j + I_t^j - \frac{\psi_k^j}{2} \left[\frac{I_t^j}{K_t^j} - (\gamma - 1 + \delta) \right]^2 K_t^j, \qquad (3.7)$$

where δ represents the depreciation rate. Prices of unfinished and old capital are determined by the optimality conditions of these firms.

Finally, a continuum of risk-neutral entrepreneurs buy unfinished capital goods for all sectors, transforming them into final capital goods using a linear technology.[12] In particular, given K_{t+1}^j units of unfinished capital of sector $j = x, n$, they produce $\omega_{t+1} K_{t+1}^j$ units of finished capital; where $\ln(\omega_t) \sim \mathcal{N}(-.5\sigma_\omega^2, \sigma_\omega^2)$. This idiosyncratic

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[11] Calvo et al. (2008) highlight the importance for monetary policy design of considering that the production of capital goods uses imported goods as inputs.

[12] This specification is similar to Bernanke et al. (1999), adapted to an open economy and a multi-sector framework. Cespedes et al. (2004), Cook (2004) and Gertler et al. (2007) pioneered the used of this framework to analyze monetary policy in a one-sector small open economy model, while Devereux et al. (2006) use it in a two-sector model closer to ours. The details of the entrepreneurs problem and the financial contract, as well as the differences with these previous papers, are presented in the Technical Appendix.

productivity shock is revealed to entrepreneurs ex-post (i.e. after paying the cost of production), and it might be also observed by a third party paying a fraction μ of the total value of production (monitoring cost).

The total cost of this operation ($KC_t \equiv \sum_{j=x,n} Q_t^j K_{t+1}^j$) is financed in part by entrepreneurs net worth (NW_t, defined below) and by borrowing from foreign lenders in dollars (B_{t+1}^{*e}). On the other hand, in the following period they obtain a payoff given by $KI_{t+1} \equiv \sum_{j=x,n} (R_{t+1}^j + Q_{t+1}^{old,j}) K_{t+1}^j$, i.e. the sum of the rental income from firms and the proceeding from selling used capital to unfinished capital producers. Because entrepreneurs income is denominated in pesos but they borrow in dollars, they are exposed to a balance-sheet effect generated by movements in the nominal exchange rate.

Given the informational asymmetry, foreign lenders will charge a premium (rp_t, a.k.a. external finance premium) for these loans, satisfying

$$E_t \left\{ rp_{t+1} \left(R_{t+1}^j + Q_{t+1}^{old,j} \right) / Q_t^j \right\} = i_t^* \xi_t, \tag{3.8}$$

for $j = n, x$. As can be seen, this premium –which will be an increasing function of the leverage ratio KC_t/NW_t under the optimal contract– represents a wedge between the opportunity cost for foreign lenders (i.e. return on households lending) and the expected return of entrepreneurs operation.

At the beginning of each period, a fraction ϑ of surviving entrepreneurs collect the returns on capital and repay their debt. Therefore, as shown in the Technical Appendix, the net worth available to finance a project in period t is given by

$$NW_t = \vartheta \left[KI_t(1 - \upsilon_t) - i_{t-1}^* \xi_{t-1} S_t B_t^{*e} \right] + W_t^e, \tag{3.9}$$

where υ_t (defined in the Technical Appendix) represents monitoring costs. Therefore, an unexpected nominal depreciation will reduce entrepreneurs net worth, which will

in turn increase the external finance premium generating the aforementioned balance-sheet effect.

3.2.4 Government

We assume that government bonds remain in zero net supply at all time (i.e. $B_t = 0$, $\forall t$). The period t government budget constraint is then given by

$$P_t G_t + \int_0^1 T_t^h dh = M_{t+1} - M_t, \tag{3.10}$$

where government consumption of final goods (G_t) is exogenously given.

Monetary policy is carried by Taylor-type rule for the nominal interest rate in pesos, with time varying targets. In particular,

$$\frac{i_t}{i} = \left(\frac{i_{t-1}}{i}\right)^{\alpha_i} \left[\left(\frac{\pi_t}{\hat{\pi}_t}\right)^{\alpha_\pi} \left(\frac{g_t^y}{\hat{g}_t^y}\right)^{\alpha_y}\right]^{1-\alpha_i} \hat{i}_t, \tag{3.11}$$

with $\alpha_i \in [0, 1)$ and $\alpha_\pi, \alpha_y > 0$.[13] The growth rate of GDP is denoted by $g_t^y \equiv GDP_t/GDP_{t-1}$ and $\hat{i}_t$ is a policy disturbance. $\hat{\pi}_t$ and $\hat{g}_t^y$ denote, respectively, the policy targets for aggregate inflation and output growth, which are assumed be stochastic. In particular,

$$\ln(\hat{\pi}_t/\pi) = \rho_\pi \ln(\hat{\pi}_{t-1}/\pi) + \epsilon_t^\pi, \tag{3.12}$$

$$\ln(\hat{g}_t^y/g^y) = \rho_y \ln(\hat{g}_{t-1}^y/g^y) + \epsilon_t^y, \tag{3.13}$$

where $\rho_\pi, \rho_\pi \in [0, 1)$.

It might seem odd that we have not included the nominal exchange rate in this rule, for many emerging countries have (particularly in the 80's and 90's) explicitly targeted this variables in implementing monetary policy. Moreover, many times they have experienced some abrupt (sometimes dramatic) changes in their exchange-rate regime. To properly model these policy fluctuations, however, it would require

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[13] These parameters are further constrained by the requirement of equilibrium determinacy.

not only to include the nominal depreciation rate in the rule but to additionally consider a time-varying coefficient describing how the interest rate adjusts to changes in the exchange rate. For instance, under fixed exchange rates, the coefficient will be extremely high, while different levels of softs pegs or pre-announced devaluations should be represented by lower values for this parameter. However, dealing with a model with such a rule is computationally more difficult.[14] Moreover, it is important to highlight that none of the previous papers estimating DSGE models for emerging countries has dealt with these issues, for they constrain themselves to floating periods (which clearly limits the size of the sample and, thus, the inference power).

Our approach to deal with this situation is to replace the exchange rate regime represented with a time-varying coefficient with a time-varying target for inflation; which can instead be solved up to first order. The motivation behind this alternative is based on observing that, for most emerging countries, policy changes associated with exchange rates have generally led to similar changes in inflation. Therefore, we might be able capture policy changes that were actually implemented targeting the exchange rate trough changes in the inflation target, as if they were observationally equivalent. While this is certainly not the most accurate representation of the actual policy, it will be enough if we obtain a good fit for policy-related variables using this alternative, which we will analyze after estimating the model. Therefore, although we acknowledge the potential limitations, we choose this approach that is computationally simpler, and leave the alternative based on higher-order-perturbation methods

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[14] First, it is easy to show that this additional variable (i.e. the time-varying coefficient) will not appear in the first-order approximation of the rule. Unfortunately, relaying on a higher order of approximation, while feasible, is computational more intensive, both to solve the model and to compute its likelihood. Second, we could consider discrete changes of regimes (i.e. the exponent in the rule following a discrete Markov process). However, perturbation methods would not be appropriate under this alternative and other solution techniques (such as value function iterations, parameterized expectations or collocations methods) are almost impractical given the dimension of our model.

for future research.[15]

3.2.5 Driving Forces

The model includes 11 driving forces: eight domestic and three determined in the rest of the world. In terms of technology, define $\gamma_t \equiv \Gamma_t/\Gamma_{t-1}$ to be the growth rate of labor-augmenting technology. We assume

$$\ln(\gamma_t/\gamma) = \rho_\gamma \ln(\gamma_{t-1}/\gamma) + \epsilon_t^\gamma. \tag{3.14}$$

All error terms are assumed to be i.i.d. normal with mean zero and variance to be estimated. The sector-specific technology follows

$$\ln(z_t^j) = \rho_{z^j} \ln(z_t^j) + \epsilon_t^{z^j}, \quad \text{for} \quad j = x, n. \tag{3.15}$$

We include three monetary policy shocks. Those associated with the time-varying targets were already described in (3.12) and (3.13). Additionally, the residuals in the Taylor rule are determined by

$$\ln(\hat{i}_t/i) = \rho_i \ln(\hat{i}_{t-1}/i) + \epsilon_t^i. \tag{3.16}$$

Government expenditures also follow an exogenous process given by

$$\ln(g_t/g) = \rho_g \ln(g_{t-1}/g) + \rho_{g,gdp} \ln(gdp_{t-1}/gdp) + \epsilon_t^g, \tag{3.17}$$

where $g_t \equiv G_t/\Gamma_{t-1}$ and $gdp_t \equiv GDP_t/\Gamma_{t-1}$ are the detrended versions of government expenditures and GDP, respectively. We allow government purchases to react to the level of economic activity, for it is generally argued that fiscal policy is procyclical in emerging countries (see, for instance, Talvi and Végh, 2005). The final domestic driver is the shock to the country premium, for which we assume

$$\ln(\xi_t^*) = \rho_{\xi^*} \ln(\xi_{t-1}^*) + \epsilon_t^{\xi^*}, \tag{3.18}$$

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[15] Moreover, given the lack of such a comprehensive study tackling this issue, we consider that this simpler approach is still a clear step forward.

The world variables are jointly determined by an exogenous stochastic process. Alternatively, some papers in the literature explicitly model the rest of the world, generally using a simplified version of the small economy model.[16] In principle, it is not clear which of the two approaches should be preferred. The advantage of modeling the rest of the world is that we can "name" the foreign shocks (for instance, technology or monetary policy). However, it is not clear how the particular model choice will impact the estimation of the small open economy model. Therefore, we choose a more agnostic approach given that our main goal is to characterize the parameters describing the emerging country. Moreover, it is likely that a reduced form specification will provide a better fit to the behavior of the international variables that a highly stylized model of the rest of the world.

Let the vector $x_t^* \equiv [\pi_t^{*f}, \pi_t^{*x}, i_t^*]'$ collect the stationary rest-of-the-world variables, where $\pi_t^{*f} \equiv P_t^{*f}/P_{t-1}^{*f}$ and $\pi_t^{*x} \equiv P_t^{*x}/P_{t-1}^{*f}$ are, respectively, the foreign inflation of imported and exported goods. Notice that we cannot simply model them as a VAR process, for the terms of trade ($tot_t \equiv P_t^{*x}/P_t^{*f}$) have to be stationary.[17] An error-correction representation is then appropriate for these foreign variables, in which lagged values of terms of trade are included as regressors. In particular,

$$A_0 \ln(x_t^*/x^*) = B \ln(tot_{t-1}/tot) + A(L) \ln(x_{t-1}^*/x^*) + \epsilon_t^{rw},$$

where A_0 is a 3x3 matrix, B is 3x1 and $A(L)$ is a matrix in the lag operator.[18] The vector $\epsilon_t^{rw} \equiv [\epsilon_t^{f^*}, \epsilon_t^{x^*}, \epsilon_t^{i^*}]'$ is i.i.d. normal with mean zero and diagonal variance-

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[16] For instance, see Elekdag et al. (2005), Castillo et al. (2006), Tovar (2006a,b), Caputo et al. (2006) and da Silveira (2006)

[17] This restriction needs to hold in the model for the equilibrium's stationary representation to exist. Additionally, unit root tests reject the hypothesis that terms of trade are I(1) in the data.

[18] The optimal lag length is selected by Bayesian and Hannan-Quinn information criteria; both suggesting for Mexico to include only one lag.

covariance matrix. In order to identify these three shocks we impose

$$
A_0 = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ a_i^f & a_i^x & 1 \end{bmatrix}.
$$

In particular, this assumption implies that the nominal interest rate may react to contemporaneous shocks to prices, but prices will not react contemporaneously to changes in the interest rate; an assumption in line with the literature identifying monetary shocks in the U.S. (see, for instance, Christiano et al., 1999).[19] This error-correction process is estimated by maximum likelihood, ahead of estimating the other parameters in the model.[20] Results are presented in Table 3.1. It is relevant to highlight that the identified shock to export prices is significantly more volatile than the other two, which mainly reflects the observed path of oil prices in our sample.

3.2.6 Aggregation and Market Clearing

Given that adjustments costs parameters for both prices and wages are the same across firms of each type and households, and that marginal cost are also equal across firms in each sector, the equilibrium will be symmetric. Therefore, we can drop the indices i and h from allocations and prices of different firms and households. In equilibrium, the following market clearing conditions must hold:

- Labor market for households and entrepreneurs: $l_t = l_t^d = l_t^x + l_t^n$ and $l_t^e = 1$.

- Exportables: $Y_t^x = C_t^x + IC_t^{x,n} + EXP_t$, with EXP_t denoting exports.

- Non-tradeables: $Y_t^n = C_t^n + \sum_{j=x,k} IC_t^{j,n} + \Gamma_t \kappa^n y^n + AC_t^n/P_t^n$.

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[19] Using Likelihood Ratio tests, this specification cannot be rejected against others, particularly a triangular representations for A_0.

[20] This helps to reduce the dimensionality of the estimation procedure for the DSGE model. As a robustness check, we have estimated the Baseline specification including all the parameters in one step, but the results are not significantly different from this alternative two-steps approach.

- Imported: $IMP_t \equiv Y_t^f = C_t^f + \sum_{j=x,n,k} IC_t^{j,f} + \Gamma_t \kappa^f y^f + AC_t^f / P_t^f$, where IMP_t are imports.

- Investment: $Y_t^k = \sum_{j=x,n} I_t^j$.

- Final consumption: $Y_t^c = C_t + G_t$.

Finally we introduce several helpful measures to confront the model with the data. The trade balance, in terms of domestic consumption, is given by $TB_t \equiv \frac{P_t^x}{P_t} EXP_t - \frac{P_t^f}{P_t} IMP_t$, while gross domestic product at domestic prices is defined as $GDP_t \equiv C_t + G_t + \frac{P_t^k}{P_t} I_t + TB_t$.[21] and $TBY_t = TB_t / GDP_t$. The inflation rate in the non-traded sector is $\pi_t^n \equiv P_t^n / P_{t-1}^n$, the share of non-traded value added is $s_t^n \equiv \left(P_t^n Y_t^n - P_t^x IC_t^{n,x} - P_t^f IC_t^{n,f} - P_t^n \Gamma_t \kappa^n y^n - AC_t^n \right) / (P_t GDP_t)$, and $M1_t \equiv M_{t+1} + S_t D_{t+1}$ is the money aggregate outstanding at the end of period t.

3.3 Empirical Strategy

In order to evaluate the performance of the model we use a combination of calibrated and estimated parameters. We chose to calibrate some of them mainly because, although we are using a large number of variables for the estimation, the data set is not rich enough to identify all of them; particularly those from production functions. This section first describes our calibration approach, presenting then the details regarding the estimation procedure.

3.3.1 Calibrated Parameters

The parameters describing the production function for sectors n, x and k are calibrated, following Calvo et al. (2008), using the input-output matrix. We present the values in Table 3.2, while a detailed explanation of the criteria used is included in

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[21] Given the market clearing conditions, GDP_t is also equal to real value added.

Appendix C.1. Comparing the exportable and non-traded sectors, we can see that the later is more labor intensive, while the use of capital is similar in both. Also, a significant share of inputs in the exportable sector are non-traded goods. On the other hand, while most of the inputs used for investment-goods production come from the non-traded sector, the share of imported inputs is around 16%.

The time unit is meant to be a quarter. We set the steady state inflation to be equal to 6%, which is the average for the quarterly GDP deflator inflation in our sample. Also, the steady state values for the foreign and domestic interest rate, as well as the terms of trade, are equal to their sample mean (i.e. $i^* = 1.01$, $i = 1.08$ and $tot = 0.6$). In addition, the steady state value for the trend of TFP is $\gamma = 1.007$, equal to the average (quarterly) growth rate of GDP. These will determine the value for the discount factor β. It is important to highlight that we are departing here from the common strategy in previous studies estimating models for emerging countries, which generally assumes zero steady state inflation. Given that, up to first order, the steady state represent the unconditional mean of the variables, our approach has the advantage of "centering" the model closer to the unconditional mean in the data.

Four parameters are calibrated to standard values, for preliminary estimations indicate that they are weakly identified given our data set. We set the depreciation rate $\delta = 0.025$, a common value used in the literature. In addition, we follow Tovar (2006a,b), Caputo et al. (2006) and Castillo et al. (2006) to assign values for the elasticities of substitution between variates of labor and goods: $\theta_w = 2$ and $\theta_n = \theta_f = 6$. Given these, the values for κ^n and κ^f are chosen to make the steady state profits equal to zero. Also, we set the risk aversion coefficient $\sigma = 2$.

Finally, the parameters ϕ, η^x, a, $\bar{b}$ and g (the steady state value of government expenditures) are set to match the following steady state values: a share of time devotes to work equal to 20%, a 10% of the total labor supply working in the exportable

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sector,[22] and shares of exports, imports and government expenditures over GDP to match their sample averages (22, 23 and 10%, respectevely).

3.3.2 Bayesian Approach

The other parameters, collected in the vector Θ, are estimated using a Bayesian approach (see, for instance, Ann and Schorfheide, 2007). Given the sample $X^T = \{x_1, ..., x_T\}$, the object of interest is the joint posterior distribution of the parameters given the data,

$$p\left(\Theta|X^T\right) = \frac{L\left(X^T|\Theta\right)p\left(\Theta\right)}{\int L\left(X^T|\Theta\right)p\left(\Theta\right)d\Theta},$$

where $L\left(X^T|\Theta\right)$ denotes the likelihood function, $p\left(\Theta\right)$ is the prior distribution, and the denominator is known as the marginal likelihood of the data.

In order to compute the likelihood, we first solve for the log-linear approximation to the policy functions around the non-stochastic steady state (in particular, we implement the method described in Schmitt-Grohé and Uribe, 2004). Given the linear solution, and the assumption of normally-distributed shocks, the Kalman filter can be used to compute $L\left(X^T|\Theta\right)$.

The vector of observables used for estimation includes the growth rates of output, consumption and government expenditures per capita, the trade-balance-to-output ratio, the overall and non-traded inflation rates, the share of traded value-added in total GDP, the growth rate of the real wage and of M1, the nominal depreciation, the domestic nominal interest rate, foreign inflation of imported and exported goods, and the foreign nominal interest rate (see Appendix C.1 for data sources and definitions).

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[22] This value is infered from the fact that, according to the 2003 Input-Output Matrix, 10% of total wage payments correspond to the exportable sector. If wages are the same across sectors, as assumed in the model, this share is also the fraction of total labor in the sector. Additionally, this value implies that the share of non-traded value added on total value added is equal to 92%, close to the mean of this variable in the data (96%).

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Thus, in terms of the model's notation,

$$x_t = \{\Delta \ln(GDP_t),\ \Delta \ln(C_t),\ \Delta \ln(G_t),\ TBY_t,\ \ln(\pi_t),\ \ln(\pi_t^n),\ \ln(s_t^n),$$
$$\Delta \ln(W_t/P_t),\ \Delta \ln(M1_t),\ \Delta \ln(S_t),\ \ln(i_t),\ \ln(\pi_t^{*f}),\ \ln(\pi_t^{*x}),\ \ln(i_t^*)\},$$

where Δ denotes the first-difference operator. In addition, we include i.i.d. measurement errors for domestic variables. The data is quarterly, from 1980:I to 2007:IV.[23]

It is relevant to notice that our set of observables includes more variables than most previous DSGE estimations for emerging countries. On one hand, we consider series that are of general interest for policy analysis –such as output, consumption, the trade balance, inflation, real wages, the exchange rate and the nominal interest rate– which are those generally used in the literature. On the other hand, our data set also includes variables that may *a priori* help us identify several features of the model. Clearly, government expenditures and the three variables in the foreign block will be useful in characterizing their associated stochastic processes and disturbances. Additionally, our measure of the stock of money includes the holdings of both domestic and foreign currency, which contains information that may improve the identification of the parameters associated with the preference for liquidity and currency substitution.[24] The price of non-tradeables is included to help the model tell apart the price-adjustment parameters in both sectors. Finally, we use the share of non-tradeables value added on GDP, for it may contain relevant information to

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[23] Series are demeaned and the X-12 filter was applied to those showing significant seasonal behavior. Additionally, we have performed unit-root tests for these variables, generally rejecting the hypothesis of non-stationarity for these variables. Moreover, for those measured in differences these tests do not reject the null of unit root in levels.

[24] Two comments are in order here. First, while Castillo et al. (2006) estimate a model with currency substitution, they do not use a measure of money as an observable. Second, it would be preferable to also include the peso/dollar decomposition of the total stock of money, which may in principle contain additional information to describe the currency-substitution block of the model. Unfortunately, a long series of such a decomposition is not available, either because central banks started to produce these series only recently, or because there have been significant methodological changes in computing this decomposition that makes the construction of such a long series a difficult task.

separately identify the parameters describing the sectorial technology shocks.

Given the likelihood and the prior (described below), we characterize the posterior distribution in two steps. First, the posterior is maximized[25] and the resulting mode is used as the starting value of a Random Walk Metropolis-Hastings algorithm, using a $\mathcal{N}(0, c\Sigma)$ as the proposal distribution.[26] The parameter c is calibrated to obtain an acceptance ratio close to 30% and the convergence of the chain is analyzed by checking recursive means. For each estimated alternative we generate two million draws from the posterior, eliminating the first million to reduce the dependence from initial values.

Priors

Our approach to assign the prior distribution for the parameters modifies the one proposed by Del Negro and Schorfheide (2006). While a detailed explanation of our method (as well as the differences with the original) is included in Appendix C.2, we describe here the general idea of the procedure and its implementation.

The advantage of using priors is to take our *a priori* beliefs into account in estimating the parameters of the model. However, it is not always clear how we should elicit these beliefs, expressing them in terms of statistical distributions. For some parameters, we can use information coming from previous studies (e.g. from micro-evidence, studies related with other countries or samples, or estimations performed using a different approach). This is the case, for instance, for those describing preferences, technology, frictions or policy rules. But this task is less straight forward for some other parameters, particularly those describing the driving forces of the model,

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[25] This was implemented by combining two optimization algorithms: `csminwel` developed by Chris Sims (available at http://sims.princeton.edu/yftp/optimize/) and `CMAES-DSGE` by Martin Andreasen (available at http://www.econ.au.dk/DCSC/DCSC_mma2.htm).

[26] Σ is the inverse of the posterior's Hessian evaluated at the mode computed in the first step. This matrix is computed numerically, and it is updated after the first 500K draws if a new maximizer is found by the Metropolis-Hastings.

for our beliefs are generally expressed in terms of certain stylized facts (moments). For instance, given that is well known that consumption is more volatile than output and that the trade balance tends to be countercyclical in emerging countries, *a priori* we may conjecture that shocks able to generate those features (such as interest rate fluctuations or shocks to the trend of technology) are likely to be more important. The method proposed by Del Negro and Schorfheide (2006), and the modifications included here, gives us a way to translate those beliefs collected in a set of moments into a distribution for the parameters.

Formally, let the vector of parameters Θ be decomposed in two groups, i.e. $\Theta = [\Theta'_1, \Theta'_2]'$. The subset Θ_1 contains parameters for which we can assign standard distributions as priors based on parameter constraints and on previous studies (preferences, technology, policy, etc), while Θ_2 collects the ones for which this task is not easy to implement (in our case, those describing the evolution of the driving forces and measurement errors). Our prior distribution takes the following form

$$p\left(\Theta|\Omega^*\right) \equiv c_1\left(\Omega^*\right) L(\Theta_1, \Theta_2|\Omega^*)\pi(\Theta_2)p(\Theta_1).$$

The distribution $p(\Theta_1)$ is the prior that we choose based on previous studies, while $\pi(\Theta_2)$ is an initial prior for Θ_2, which might be uninformative (i.e. flat). The sufficient statistics of interest are collected in Ω^* and the function $L(\theta_1, \Theta_2|\Omega^*)$ can be interpreted as a measure of how well can the model replicate, *a priori*, the target moments collected in Ω^*. In particular, we specify this as a transformation of a minimum-distance objective function that seeks to match a collection of data moments (specified below) with those generated by the model, in the spirit of the Laplace-type estimator suggested by Chernozhukov and Hong (2003). Finally, the constant $c_1\left(\Omega^*\right)$ is chosen to make the prior $p\left(\Theta|\Omega^*\right)$ proper (see Appendix C.2 for details).

It is important to notice that under this approach the parameters will generally

not be independent (although according to $p(\Theta_1)$ and $\pi(\Theta_2)$ they might be). The usual practice in estimating DSGE models is to specify independent priors, which is generally assumed for simplicity. However, our goal is to choose a distribution that makes our model as close to the moments that represent our beliefs as possible; which may perfectly require a distribution in which parameters are dependent. Moreover, while the targeted moments Ω^* and the functions $p(\Theta_1)$ and $\pi(\Theta_2)$ are the same regardless of the particular model, the distribution $p(\Theta|\Omega^*)$ will change as we estimate different versions of the model. Therefore, for each estimated model we will report the final implied prior.

Columns three to five in Table 3.3 describe the initial prior distributions $p(\Theta_1)$ and $\pi(\Theta_2)$. In terms of the preference parameters for both types of currency, our main reference is the estimation for Peru in Castillo et al. (2006). They calibrate $\zeta = 2$, $\chi = 1$ and $b = 0.83$, while estimating values for ν between 0.6 and 0.7. On the other hand, Batini et al. (2007) calibrate $\chi = 4$, while Felices and Tuesta (2007) set $b = .83$, $\zeta = 4.1$, $\nu = .5$ and $\chi = \{0.9, 2\}$. Therefore, we center the priors for these parameters around the values from Castillo et al. (2006) and set the dispersion according to the calibrations used in these other studies.

In terms of habit persistence, previous studies show mixed evidence for ρ_c. While Castillo et al. (2006) estimate it to be large (in the range of $[0.7, 0.9]$ for Peru), Medina and Soto (2005) found a value close to 0.3 for Chile and the results in Uribe and Yue (2006) indicate $\rho_c = 0.2$ for a panel emerging countries. Thus, we chose a Beta distribution with mean similar to that from Castillo et al. (2006), given that their utility specifications is closer to ours.

The wage adjustment cost coefficient, ψ_w, is estimated by Tovar (2006a) to be between 0.24 and 0.86 for three Latin American countries, while Tovar (2006b) obtains a value of 1.35 for Korea. Our prior includes these values in the 95% confidence band. In terms of price adjustment costs, we are not aware of emerging-countries

studies estimating a model with pricing parameters that differ across sectors. Using a one-sector model, Tovar (2006a) estimates values between 4.6 and 7.13 for his sample of Latin American countries and 5.7 for Korea in Tovar (2006b). Therefore, we assign the same prior for both ψ_n and ψ_f, with a mean of 5.25.[27]

The coefficient in the country premium faced by households ψ_d is a parameter usually calibrated to low values ranging from 0.001 to 0.1, and the evidence from estimated exercises is mixed: while Castillo et al. (2006) find it to be almost zero in Peru, Caputo et al. (2006) obtain values between 0.1 and 0.9 for Chile. Conservatively, our initial prior assigns most of the probability mass to low values. The capital adjustment cost is also generally calibrated, an exception being Castillo et al. (2006) that obtains a values between 0.34 and 0.98 for Peru. Additionally, the previous literature do not make a sectorial distinction for capital adjustment costs. Thus, we assign the same prior for both parameters, with a 95% confidence region wider then the estimated values mentioned before.

In terms of the elasticity of substitution between traded and non-traded good, φ, Mendoza (1995) uses a value close to 1.3 for emerging countries, while Gonzalez-Rozada and Neumeyer (2003) estimate it to be around 0.4 for Argentina. Other studies assuming that all goods are tradeables use a related measure: the elasticity of substitution between domestic and foreign goods. Medina and Soto (2005) estimate a value of 0.6, while Castillo et al. (2006) obtain values between 1.07 and 2.5. Given this dispersion in the literature, we assign an Inverse Gamma distribution with a wide confidence region.

The estimated parameters describing the entrepreneurs problem are the external finance premium in steady-state (rp), the variance of the idiosyncratic shock (σ_ω)

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[27] Other studies estimating models with price and/or wage rigidities for emerging countries generally use staggering *a la* Calvo, making their results difficult to interpret in our framework. See, for instance, Medina and Soto (2005), Elekdag et al. (2005), Castillo et al. (2006), Caputo et al. (2006) and da Silveira (2006).

and the monitoring cost (μ).[28] Choosing priors for these based on previous research is however difficult. As mentioned before, there are few studies estimating models that include these type of financial frictions (e.g. Tovar, 2006a, 2006b, and Elekdag et al., 2005). However, they use a simpler version of the financial accelerator, making their results hard to interpret under the more general framework.[29] Therefore, our prior is based on emerging-countries papers that calibrate models of the financial accelerator compatible with ours, even though these values are generally chosen based on U.S.-related studies. Cook (2004) and Gertler et al. (2007) use $rp = 1.035$, $\sigma_\omega = 0.28$ and $\mu = 0.12$, while Devereux et al. (2006) set them to be, respectively, 1.02, 0.2 and 0.5. Additionally, from Elekdag et al. (2005) we can infer an estimate for rp for Korea in a range between 1.02 and 1.05. The chosen distributions include these values within the 95% confidence band.

Previous estimates of the smoothing coefficient in the Taylor rule (α_i) show mixed results. According to Tovar (2006a,b), it ranges from 0.03 to 0.71 for his sample, Medina and Soto (2005) found values around 0.3 for Chile, Elekdag et al. (2005) estimates a value of 0.68 for Korea and Castillo et al. (2006) found it to be small for Peru (around 0.04). We then choose a uniform prior for this parameter. Additionally, the evidence in terms of the response to inflation and to output growth is also disperse: α_π ranges from 1.27 in Castillo et al. (2006) to 2.6 in Tovar (2006b), while α_y is almost zero in Castillo et al. (2006) and Elekdag et al. (2005) but Tovar (2006b) found a value of 1.4 for Korea. We thus choose a normal prior centered in the average of these previous estimates and with enough variance to include this previous results with significant mass.

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[28] In steady-state, these three will determine the survival rate ϑ.

[29] These studies generally estimate two parameters: the steady state leverage ratio and the elasticity of the premium with respect to this ratio. However, these two "reduced form" coefficients are a complicated function of the three parameters describing the financial accelerator, and thus the later cannot be computed from the former.

For the parameters describing the exogenous stochastic processes in the model (i.e. the driving forces and measurement errors) we assign uninformative initial priors. The autocorrelation of the shocks have a uniform prior between zero and one, with the exception of ρ_γ for which we use a Beta distribution with mean of 0.3, for it is generally estimated to be small. The feedback of GDP to government expenditures $\rho_{g,gdp}$ has a uniform prior in the range [-1,1]. The standard errors of shocks also have a uniform prior: for driving forces is in the [0,0.15] range, while for measurement errors it is limited by 25% of the standard deviation of the particular variable in the data.

After setting the initial priors $p(\Theta_1)$ and $\pi(\Theta_2)$, we continue by describing the minimum-distance function that determines $L(\Theta_1, \Theta_2|\Omega^*)$. In particular, this function measures the difference between the following data and model moments related with the 11 domestic observables: the standard deviations, the correlations of all variables with output growth, the trade-balance-to-output ratio and inflation, as well as all the first order autocorrelations; obtaining a total of 49 distinct moments. In addition, the weighting matrix that completes this function is set to the optimal one (see Appendix C.2 for further details).[30]

Columns six and seven on Table 3.3 report the mean and the 95% confidence band from the final prior under the Baseline model. Draws from this distribution are obtained with a Metropolis-Hastings algorithm analogous to the one specified before. As we can see, the information contained in the selected moments significantly updates the initial prior. In some cases, this additional information helps to narrow the prior's confidence bands (e.g. the smoothing and output-growth coefficients in the Taylor rule, or the risk premium in steady state), while for others it also significantly

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[30] These moments are computed from the same sample used for the estimation. Alternatively, Del Negro and Schorfheide (2006) use a pre-sample to compute their sufficient statistics. This approach will be unfortunately too costly in our case because we only have a short sample available. As a robustness check, we have re-estimated the baseline model using only data up to 1990 to compute the moments in the prior, and results are in line with those obtained using the full sample.

changes the center of the distribution.

To conclude, the final prior allow us to have an *a priori* rank of the variances of the shocks: in order to replicate the targeted moments, the model requires a relatively large variance for the inflation target shock, followed by, in order of importance, the country premium shock and by disturbances to government expenditures, the non-stationary productivity and the TFP in the exportable sector. Of course, this order might change under the posterior (and indeed it will), for the likelihood may contain additional information allowing a better characterization of the parameters' distribution.

3.4   The Fit of the Baseline Model

In this section we first describe the estimated posterior distribution, paying particular attention to those parameters describing the frictions that are characteristic of emerging countries. We then perform a posterior predictive analysis to establish the extent to which the Baseline model can fit the data.

3.4.1   Posterior Distribution

The last two columns of Table 3.3 describe the estimated posterior distribution. In terms of the demand for money, we can see that b is estimated to be close to one, with a tight confidence band, and that the elasticity of substitution ζ has a posterior mean of 0.08. Putting this result in the context of the related literature, the key channel relating currency substitution with monetary policy according to Felices and Tuesta (2007) (i.e. the marginal utility of consumption depending on money holdings) is estimated to be irrelevant for Mexico. Moreover, the estimation exercise in Castillo et al. (2006) calibrates $b = 0.83$. While results are not comparable as they use Peruvian data, this finding at least suggests that it might be important to estimate

this parameter as well.[31]

While the role of currency substitution is reduced given the value of b, the parameters ν and χ might still play a role (as long as $b < 1$) in determining the demand of pesos relative to dollars. The elasticity of substitution has a wide confidence region, with values from 1.4 to 6.9, while the confidence band for the share of dollars in the liquidity index indicates a significance range between almost zero and 0.2. The last parameter in the utility function, ρ_c, indicates a strong degree of habit persistence.

The wage adjustment cost, ψ_w, has a posterior mean of 0.4, which is somehow bigger than the value of 0.24 estimated for Mexico by Tovar (2006a). Looking at price adjustment costs, the estimation indicates that this friction is significantly more severe for imported goods. This is not surprising given that the correlation between aggregate and non-traded inflation is extremely high in the data (see Table 3.4): the model requires prices in the f sector to be more sticky in order to obtain such a strong correlation. In addition, this distinction puts a warning sign in interpreting the estimation of price stickiness in the literature. As commented before, previous studies do not allow for sectorial decomposition of inflation and all goods are assumed to be tradables. The case of Mexico thus shows that these assumptions are likely inappropriate.[32]

The posterior mean for the country premium coefficient implies an elasticity with respect to the debt-to-GDP ratio (equal to $\psi_d \bar{b}$)[33] of around 0.08 and significantly greater than zero (the implied lower bound is 0.05). Additionally, capital adjustment costs seem to be similar in both sectors, although the confidence band for these parameters includes a wide range of values. Finally, the estimated elastic-

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[31] Particularly in terms of currency substitution, Mexico and Peru seem to be really different. For instance, Levy-Yeyati (2006) documents that the annual share of dollar-denominated deposits was, on average, 67% for Peru between 1991 and 2004 but only 7.3% for Mexico in that same period.

[32] While Devereux et al. (2006) use a model with a sectorial decomposition similar to ours, they calibrate the price stickiness parameter to be the same across sectors.

[33] At the posterior mean, the debt-to-GDP ratio in steady state, $\bar{b}$, is 0.04.

ity of substitution between traded and non-traded good is high (between 2.6 and 3.4), which is significantly bigger than the values usually calibrated in the literature –generally based in reduced-form estimations.

Turning to the parameters describing financial frictions, it is relevant to compare the initial prior and the posterior. Recall, from the discussion above, that the initial prior was set to reflect the calibrated values used in policy exercises which, as discussed, are generally drawn from U.S.-related studies. As we can see, the estimated parameters are completely different, particularly indicating that financial frictions are more severe that what is generally assumed. Moreover, the posterior confidence band does not even include the initial prior mean. This represents a significant drawback for the related literature, and gives additional support to our original motivation about the empirical relevance of these studies.

The estimated Taylor rule displays a mild smoothing coefficient, while the responses to inflation and output growth (with posterior means of 2.08 and 0.46, respectively) are in the range of previous studies. In terms of the three monetary-related disturbance, the shocks to GDP-growth target seems to be more volatile and persistent. On the other hand, σ_i and σ_π display similar posterior means, while the inflation target seems to be more persistent than $\hat{i}$.

The volatility of the country premium shock is comparable with that of the GDP target and it is also significantly persistent. The disturbances to government purchases display high volatility as well and the posterior confidence bands for its persistence indicate values from 0.2 to 0.7. Additionally, government expenditures display a significant procyclical response to lagged output.

Finally, in terms of technology, the shock to the stationary productivity in the exportables sector is the most volatile, with a posterior mean of 0.08, which is even higher than that estimated for the foreign price of exports (around 0.06). Both stationary TFP shocks display high persistence (the posterior means for ρ_{z^x} and

ρ_{z^n} are, respectively, near 0.8 and 0.9). A more illustrative analysis of the relative importance of each driving force will be presented in the next section, when we perform the variance decomposition exercise.

3.4.2   Posterior Predictive Analysis

In order to asses the goodness of fit of the model, we start with a visual inspection of the estimated path of the observables. Figures 3.1 and 3.2 display the actual series for the domestic variables, as well as the posterior mean of their smooth version according to the Baseline model.[34] As can be seen, the fit in terms output and consumption growth, as well as for both inflations, is almost perfect. The model does a good job also for the trade balance, the share of non-tradables and M1. The fit seems also appropriate for the nominal depreciation, although the model seems to overestimate its volatility for relatively stable periods. Overall, the model seems able to replicate the reduction in volatility that can be observed from most of the variables after the Tequila crisis.

The predicted path for the nominal interest rate is also close to the actual series, with some minor caveats. First, the model seems to underestimate it for the first year of the sample, while it implies higher-than-observed values from 1983 to 1985. Additionally, the interest rate in the last five years of the sample is somehow more volatile than in the data. On the other hand, the variable for which the model clearly provides a very limited fit is the real wage.

Table 3.4 compares a number of moments computed from the data and those (unconditional) implied by the model. The Baseline specification closely replicates

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[34] In general, the goal of a posterior predictive analysis is to characterize a vector of interest z (in this case, the smoothed series of observables) which is a function of the parameters of the model (i.e. $z = h(\Theta)$). Given draws from the posterior of the parameters, $p\left(\Theta|X^T\right)$, we can easily characterize moments associated with the posterior of the vector of interest $p\left(z|X^T\right)$. For instance, if we have M random draws from the posterior of parameters Θ_i for $i = 1, ..., M$, an estimate of $E\left(z|X^T\right)$ can be computed as $M^{-1}\sum_{i=1}^{M} h(\Theta_i)$.

the standard deviation of the real variables as well as that of both inflations and the nominal interest rate, although it mildly overestimate those of output and consumption. In particular, the model predicts consumption being more volatile than output, a feature that is characteristic of most emerging countries. Also, in line with the evidence presented before, while the volatility of the monetary aggregate and the exchange rate is over estimated (especially for the former), the implied standard error of real wages is predicted to be smaller in the model.

In terms of the cyclical behavior of the variables –measured by their correlation with GDP growth– the model provides an adequate approximation to the data. While the posterior mean of these moments is somehow smaller (in absolute value) to their empirical counterpart, most of the posterior confidence regions generally overlap with the error bands computed from the data. In particular, the model is able to replicate the countercyclicality of the trade balance, inflations, interest rates and nominal depreciation. Important mismatches can be observed, however, in terms of the correlation of the share of non-tradables and real wages with GDP (the later was expected given the poor fit in this dimension described before).

On the other hand, the fit is significantly better in terms of the correlation of the variables with aggregate inflation. Two minor exemptions are the correlations with GDP and consumption growth: in the model, the first is smaller while the latter is somehow bigger. The fit is good also in terms of of the autocorrelation of the variables. While, as expected, the match is not good for real wages, most of the posterior means and point estimates in the data are similar. Additionally, the confidence bands in the data and in the model tend to overlap.

We conclude the section by summarizing the findings. Overall, the model seems to provide a good fit to the data, particularly in terms of output, inflations and the nominal exchange rate. A major exception is the ability of the model to account for the dynamics of the real wage. Additionally, the fit in terms of the nominal

interest rate seems appropriate, with some minor limitations. Given these results, in the next section we investigate the role of the frictions that are characteristic of emerging countries in obtaining these results.

3.5 On the Importance of Emerging-Countries Frictions

We now turn to study which features of the model are more relevant in explaining the data. While the Baseline model contains many nominal and real frictions, we are particularly interested in assessing the role of those that are characteristic of emerging countries. In particular, four different versions of the Baseline model are estimated. First, we will shut down the currency substitution channel, keeping the demand for real balances. This specification (denoted as No C.S.) is obtained by setting $\nu = 1$.[35] Given the estimated value of b close to one for the Baseline model, it is likely that this alternative will improve the overall fit of the model.

A second variant eliminates the liability dollarization friction (No L.D.), while still maintaining the financial accelerator mechanism. In this case, entrepreneurs borrow in pesos using the domestic bond market, making the domestic interest rate the relevant opportunity cost for lenders. Therefore, surprises in the nominal exchange rate will have no first-order effect on entrepreneurs net worth, although they may have an indirect impact.

In addition, a version without the financial accelerator is estimated (No F.A.). Under this alternative, entrepreneurs are no longer part of the economy and capital is instead owned (and accumulated) by households. While the endogenous country premium in equation (3.1) is maintained, changes in the cost of borrowing will produce no direct effects in the supply side of the economy.

The final specification eliminates the use of intermediate inputs for production (No I.I.). In particular, we set $\alpha_x^n = \alpha_x^f = \alpha_n^x = \alpha_n^f = \alpha_k^f = 0$ and adjust the other

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[35] Under this restriction, the parameter χ becomes irrelevant.

coefficients to maintain the homogeneity of degree one in the production functions. Given the calibrated values for these parameters presented in Table 3.2, this alternative will most likely have an impact by eliminating the transmission of import price shocks to the price of investment goods.

In the rest of the section, we first address the goodness of fit of these specifications by means of both informal and formal model comparison tools. After determining which of them are more useful in explaining the data, we compare the results in terms of the estimated posterior of the parameters for these preferred specifications and perform a variance decomposition exercise.

3.5.1 Model Comparison

As we did before, we start by comparing the smoothed series of observables implied by each alternatives with the actual data, presented in figures 3.3 and 3.4. For most of the variables, this visual inspection does not help to tell models apart. The only noticeable difference seems to be in terms of the nominal interest rate. While the model that excludes currency substitution generates a similar path for this variables as in the Baseline, albeit somehow less volatile than in the data, the fit of this variables in the other three alternatives is less satisfactory. Additionally, neither of them seems to produce an improvement in terms of the real wage.

In order to quantify the differences across models, we begin by comparing them according to same set of moments previously analyzed. Tables 3.5 and 3.6 shows the posterior mean and confidence regions for the selected moments, reproducing also those from the Baseline and their data counterparts to facilitate the comparison. In terms of standard deviations, the fit of the No C.S. alternative is similar to that of the Baseline. The only significant difference seems to be in the volatility of the interest rate, which is estimated to be smaller. On the other hand, the performance of the other three alternatives is less satisfactory. In particular, neither of these is

able to generate more volatility for consumption compared to GDP. Additionally, these three specifications imply even smoother interest rates and real wages.

While the Baseline and No C.S. models have similar predictions in terms of volatility, the latter does not perform as well in terms of correlations with GDP growth. Counterfactually, inflation and the nominal interest rate are estimated to be procyclical. Additionally, the negative correlation of trade balance with output is milder under this specification. On the other hand, while most of these correlations under the other alternatives have the correct sign, they are not as close to the data as the Baseline model. The only apparent improvement is in terms of the cyclical behavior of consumption.

Regarding the correlation with inflation, none of the alternatives produce a significant improvement relative to the Baseline. For instance, the No L.D., No F.A. and No I.I. specifications generate a comovement between inflation and the nominal devaluation that is closer to the data. However, these three produce a significantly smaller correlation with money growth. Additionally, the correlation of both consumption growth and the trade-balance-to-output ratio with inflation are underestimated by No C.S., No L.D. and No I.I.. Finally, a similar pattern can be observed in terms of the first order autocorrelations.

The next step is to compare the alternatives using formal tools. One of the most widely used methods under a Bayesian framework is the marginal likelihood, which allows to compare models in terms of their relative one-step-ahead forecasting ability (see, for instance, Geweke, 1999). Table 3.7 present the log marginal likelihood of the four alternatives relative to that of the Baseline. As can be seen, according to this criteria eliminating the demand for dollars from the utility function produces the most significant improvement to the overall fit of the model. The No L.D. alternative also seems to adjust the data better that the Baseline, but it is worst than the No C.S. model. On the other hand, eliminating either the financial accelerator mechanism

and the intermediate demand for consumption goods provides a worst fit to the data, particularly the No I.I. alternative.

While the marginal likelihood is a useful tool to compare models in terms of their overall fit, it is also of interest to determine in which particular dimensions different models can perform better. To this end, we implement the loss function-based evaluation proposed by Schorfheide (2000), who provides a formal way to compare models in terms of their ability to match certain data features of interest. A detailed description of this procedure, as well as our implementation, is presented in Appendix C.3.[36] The general idea is, for a given set of targeted moments, to compare the performance of each DSGE relative to a reference model that is more densely parameterized and that provides a good fit to the data (in our case, Bayesian VAR with a Minnesota prior). In addition, a loss function that penalizes deviations of the DSGE model prediction in terms of the moments of interest relative to the reference model is specified (we use a quadratic loss). The alternative DSGE models are then ranked in terms of their posterior risk, defined as the expected loss incured in using the particular model.

We compare the different specifications based on their ability to match several covariances functions: the autocovariance of each domestic variable and their contemporaneous and lagged covariance with output growth and aggregate inflation, all of them up to eight quarters. Table 3.8 displays the ratio of the risk of the particular set of moments for each model, relative to the Baseline (if the ratio is bigger than one, the Baseline is preferred).[37] The first general conclusion that can be drawn is that, in line with the marginal-likelihood-based results, the specification that exclude intermediate inputs generally provides the worst fit relative to all other

[36] As described in the Appendix C.3, this method is more general and flexible that our particular application.

[37] Real wages are omitted from the table as we already saw that the fit is not good.

specifications. Such a clear difference cannot be found in the other alternatives, for which we analyze each set of moments separately.

In terms of autocovariances, the Baseline model clearly outperforms the others for output growth and, to a less extent, the nominal interest rate. It also better approximates the autocovariance of the nominal exchange rate compared with No C.S., although it seems inferior in this dimension relative to No L.D. and No F.A.. On the other hand, these three alternatives seem to outperform the Baseline for the other variables. Additionally, among these specifications, shutting down the currency substitution channel improves the fit in terms of the autcovariances of trade balance, both inflations and the share of non-tradables, while the No F.A. alternative seems more appropriate in terms of consumption and the No L.D. better accounts for the dynamics of the nominal depreciation.

Looking at the lagged covariances of the variables with respect to output growth, the Baseline model generally provides a better fit. Two exceptions are the covariance with TBY, in which the No I.I. and No C.S. are preferred, and with $M1$, where No C.S. seems to be preferable. Finally, either the Baseline or the No C.S. specification appear superior in terms of the lagged covariances with inflation.

After this detailed model comparison exercise, we can draw the following conclusions. First, of the four evaluated frictions that are of special relevance for policy analysis in emerging countries, the inclusion of intermediate inputs is the one that appears more important. On the other hand, currency substitution does not seems to be consequential, although eliminating this channel counterfactually induces a procyclical inflation. Additionally, the No L.D. and No F.A. specifications, while improving the fit along a few dimensions, are generally inferior relative to either the Baseline or the No C.S. specification, which seems to indicate that both play a relevant role as well.

Given the results from the previous analysis, we now present the parameter's posterior for the No C.S. specification. The goal is to see if the estimated parameters are similar to those from the Baseline model. Table 3.9 displays the posterior mean and confidence for the parameters under this alternative and the Baseline.[38] In terms of utility-related coefficients, b is estimated to be close to one as in the Baseline. Thus, in spite of its denomination, money appears to have no significant influence in the marginal utility of consumption. Additionally, while the estimate of ζ is bigger in the No C.S. specification, this value is still significantly smaller than in previous studies.

While the posterior mean for wage and price adjustment-costs parameters are somehow smaller if we exclude the currency substitution channel, the confidence bands significantly overlap for both specifications. In particular, it is still the case that prices of imported goods appear to be more sticky than for non-tradeables.

The elasticity the country premium is smaller in this case, around 0.03, but still significantly positive (the implied lower bound is near 0.02). On the other hand, the estimated elasticity of substitution between traded and non-traded goods is similar under No C.S., while the capital adjustment costs are estimated to be less important.

In terms of the financial accelerator mechanism, the absence of currency substitution preserves the previous findings: while the posterior means are somehow different, the confidence bands are similar for both specifications. Moreover, it is still the case that financial frictions are estimated to be more severe than what is usually calibrated in policy-related studies. Results are also similar in terms of the coefficients in the Taylor rule.

Finally, there are some discrepancies in terms of the parameters describing the

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[38] For completeness, the table also includes those for the other three specifications, even though we regard them as inferior. Additionally, the final prior for each alternative can be found in Table C.1 in Appendix C.2.

evolution of the driving forces. However, it is more illustrative to study how different are the exogenous processes by analyzing how they propagate to the rest of the economy, which we analyze in what follows.

3.5.3 Variance Decomposition

Table 3.10 presents the decomposition of the unconditional variance for the domestic variables under the Baseline model. In line with the previous discussion, the model provides a good overall fit: the contribution of measurement errors in explaining the variability of the observables is generally small. The exception is, as before, the real wages (the measurement error explains almost 80% of the variances).

A second general observation is that the (stationary) sectorial technology shocks play an important role in explaining the behavior of all variables, in particular that for exportables. Regarding real variables, each of them account for near 30% of output fluctuations and they togheter generate around 40% of the variance of consumption and the trade balance. In addition, the shock in the exportable sector accounts for near 30% of the variance of both inflations and between 35 and 45% of policy-related variables, while the shock in the other sector only have a minor contribution for these. On the other hand, the non-stationary productivity shock seems to play no significant role, with the exception of consumption for which it explains around 35% of the variance.

Among the foreign driving forces, the price of exportables appears to have the biggest impact, although it is of second order relative to the sectorial technology disturbances. Around 10% of the variability of inflation, consumption and the nominal interest rate is explained by this shocks, and it seems even more important for the trade balance, the nominal exchange rate and the stock of money.

Another driver with a relevant contribution is the shock to the country premium, explaining around 40% of the variance of the non-traded share and close to 20% of

the variance of GDP, the trade balance and M1. Additionally, it has a smaller impact in terms of inflation, the nominal interest rate and depreciation, contributing to at most 10% of their variability.

In terms of policy-related shocks, unexpected changes in both targets together explain almost 40% of the fluctuations in inflation, but only around 10% of money, nominal depreciation and the interest rate. On the contrary, shocks to government expenditure and the Taylor-rule residuals have a negligible impact.

Turning to Table 3.11, which presents the variance decomposition for the No C.S. specification, we can see that many of the previous conclusion are maintained, with some important caveats. While both sectorial shocks still have an important role, their influence in both inflations is significantly smaller. External shocks, country premium disturbances and non-stationary TFP appear to be of similar importance compared with the Baseline model. Moreover, measurement errors for the interest rate are more relevant for this alternative.

The main difference across these two specifications is in terms of monetary policy shocks. First, the residual of the Taylor rule seems to be more important under No C.S.: it explains almost 20% of output fluctuations and near 10% of inflation volatility. Additionally, shocks to both targets play significantly bigger role in explaining prices, for combined they now account for almost 70% of the variance of both inflations.

As a final exercise, Figure 3.5 present a historical decomposition of aggregate inflation, the nominal depreciation and the domestic interest rate in both preferred specifications. While the variance decomposition give us an idea of the average contribution of each shock, this approach is useful to understand if the impact of the driving forces has changed over time. To facilitate the exposition, we have clustered the sources of fluctuations in three groups: monetary policy shocks are those appearing in the Taylor rule, other domestic shocks include the three technology

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disturbances, government expenditure and country premium shocks, and the rest are international shocks.

In terms of inflation, it seems that monetary shocks have been an important determinant of the two major peaks experienced in the 80's. Nevertheless, other domestic shocks appear to have played an additional relevant role in the first of these episodes, while international disturbances (particularly the drop in oil prices in 1986) have also contributed to the second.[39] On the other hand, non-policy domestic shocks are estimated to be the main factor during the Tequila crisis. This can partially be explained by the fact that the estimated model seems to assign an important part of the sudden stop to a negative productivity shock in the exportable sector. Lastly, the observed stabilization in the level of inflation experienced since 1996 appears to be mostly explained by the evolution of international variables.

On the other hand, regarding the fluctuations in the nominal depreciation rate, the historical decomposition is less clear, for it seems complicated to attribute the episodes of large fluctuations in this variable to a particular set of shocks. Finally, in line with the variance decomposition exercise, most nominal interest rate movements were mainly originated by the endogenous response to other real and international shocks. Moreover, it seems that these two groups of shocks have historically pushed this variable in opposite directions.

3.6   Conclusions and Future Research

This work presents a quantitative evaluation of the empirical relevance of several frictions that, as has been argued, constrain the design of monetary policy in emerging countries. We were motivated by the fact that the recent literature does not provide a satisfactory assessment of the goodness of fit of models used to draw policy

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[39] In the model, a drop in the price exportables generates inflation through the implied nominal depreciation.

recommendations, which might potentially limit the relevance of their conclusions.

Our framework included a sectorial decomposition of the productive sector, the use of intermediate inputs, imperfect pass-through, endogenous premium to finance capital accumulation, balance sheets effects due to liability dollarization, currency substitution, price and wage rigidities, as well as eleven driving forces. The model was estimated using a Bayesian approach with a quarterly data set from Mexico, including more observables than what is typically used in estimations of emerging-market models.

Our findings carry both good and bad news. On one hand, a model that includes these distinctive characteristics of emerging economies can indeed provide a good approximation to the data, which makes its use for policy analysis appealing. Moreover, we have been able to identify which of these frictions appear to be more important in fitting Mexican data. In particular, accounting for intermediate inputs seems to be most relevant, while the currency substitution channel has a negligible estimated role.

On the other hand, however, our results also suggest that many of the parameterizations chosen in the policy literature are significantly different from what arises after a meticulous estimation exercise, placing a warning sign in interpreting these previous conclusions. This seems to be the case particularly for financial frictions, prices stickiness and money demand. Additionally, many of these policy-related papers exclusively consider foreign shocks as driving forces. Nonetheless, according to our findings these appear to be relatively less important compared with domestic sources of fluctuations for the Mexican case.

We conclude by suggesting several potential venues for future research. First, while results based on up-to-first-order solutions are encouraging, it seems relevant to also estimate the model using a higher order of approximation. As discussed before, this solution technique will allow a better characterization of changes in

exchange-rate regimes. Additionally, given that the degree of uncertainty (measured, for instance, by the volatility of variables like GDP, inflation, etc.) in these countries has been considerable, a higher order of approximation might be more appropriate to account for endogenous responses to uncertainty (e.g. precautionary savings cannot be captured with a first-order approximation).

A second relevant study would be an international comparison, for evidence suggests that the role of these emerging-countries frictions is significantly different across countries. For instance, Levy-Yeyati (2006) documents that, for a sample of 15 Latin American countries in 2000, while the mean of the share of dollar-denominated deposits was close to 32%, the observed values ranged from 1.5% to around 90%. He also reports ratios of total dollar liabilities over GDP for these countries from near 20% to almost 150%; with mean and median of, respectively, 63% and 50%. Clearly, the role of both currency substitution and liability dollarization is expected to vary for different emerging countries, which will provide an additional empirical test for the model.

Additionally, in this paper we have just evaluated the in-sample goodness of fit of the model. It could be of interest to also investigate the out-of-sample performance of the model, by comparing its forecasting ability with BVAR models or by using a DSGE-VAR approach. Finally, given that our findings indicate that the parameter values of models previously used for policy analysis are not in line with estimated results, it seems important to re-evaluate issues like exchange-rate regimes and optimal stabilization policies using a model that is more empirically sound.

3.7 Tables and Figures

Table 3.1: Estimated VECM(1) for the rest-of-the-world variables.

Equation	π_t^{*f}	π_t^{*x}	π_{t-1}^{*f}	π_{t-1}^{*x}	i_{t-1}^*	tot_{t-1}	Std. Dev. σ_j
	Coefficients						Std. Dev.
π_t^{*f}	–	–	0.397	0.031	0.007	-0.021	0.008
			(0.09)	(0.02)	(0.03)	(0.01)	(0.00)
π_t^{*x}	–	–	0.597	0.085	-0.156	-0.347	0.057
			(0.67)	(0.09)	(0.25)	(0.08)	(0.01)
i_t^*	0.065	-0.009	0.063	-0.003	0.925	0.002	0.002
	(0.03)	(0.00)	(0.03)	(0.00)	(0.04)	(0.00)	(0.00)

Note: The table shows the MLE estimates and their respective standard errors in parenthesis (computed by Boostrap, based on randomly drawing 5000 series of reduced-form errors).

Table 3.2: Calibrated values for α_j^i, Mexico.

Input (i)	Sector (j)		
	x	n	k
x	—	0.039	—
n	0.310	—	0.835
f	0.056	0.072	0.162
l	0.116	0.302	0.001
k	0.519	0.587	—

Note: Based on the 2003 Input-Output Matrix, according to the methodology described in Appendix C.1.

Table 3.3: Prior and Posterior Distributions, Baseline Model.

Para-meter	Description	Dist.	Initial Prior Mean	Initial Prior 95% CB	Final Prior Mean	Final Prior 95% C.B.	Posterior Mean	Posterior 95% CB
b	Share of X in V	B	0.71	[0.4,1]	0.51	[0.4,0.6]	0.99	[0.99,1]
ζ	E.o.S. X and Z	IG	2	[0.2,9.3]	1	[0.9,1.2]	0.08	[0.06,0.1]
ρ_c	Habit	B	0.6	[0.2,0.9]	0.44	[0.2,0.6]	0.83	[0.81,0.86]
ν	Share of M in Z	B	0.67	[0.3,0.9]	0.44	[0.4,0.5]	0.1	[0.03,0.21]
χ	E.o.S. M and D	IG	2	[0.2,9.3]	2.84	[2.4,3.6]	3.9	[1.38,6.86]
ψ_w	Wage A.C.	G	1	[0.1,2.8]	0.02	[0,0.05]	0.44	[0.12,0.79]
ψ_d	Country premium	IG	0.01	[0,0.01]	0.07	[0,0.1]	1.91	[1.19,2.79]
φ	E.o.S. n and T	IG	2	[0.4,8.3]	0.75	[0.3,1.3]	2.96	[2.59,3.44]
ψ_n	Price A.C. in n	G	5.25	[1.1,13]	5.32	[4.5,5.8]	1.07	[0.2,2.88]
ψ_f	Price A.C. in f	G	5.25	[1.1,13]	8.62	[8,9.2]	14.2	[10.1,18.5]
ψ_k^n	Cap. A.C. in n	IG	0.5	[0.1,1.6]	0.42	[0.2,0.8]	1.92	[0.66,4.11]
ψ_k^x	Cap. A.C. in x	IG	0.5	[0.1,1.6]	3.16	[2.7,3.5]	1.86	[0.39,6]
rp-1	Risk Premium SS	G	0.01	[0,0.05]	0.01	[0,0.02]	0.06	[0.05,0.1]
σ_ω	Std.Dev. of $\ln(\omega)$	IG	0.43	[0.2,0.9]	1.7	[1.4,1.9]	2.37	[1.93,2.81]
μ	monitoring cost	B	0.25	[0,0.6]	0.6	[0.3,0.8]	0.54	[0.45,0.68]
α_i	Coef. of i_{t-1}	U	0.5	[0,1]	0.56	[0.5,0.7]	0.08	[0,0.24]
α_π	Coef. of π	N	2	[1.6,2.4]	1.35	[1.2,1.5]	2.08	[1.91,2.29]
α_y	Coef. of g^y	N	0.5	[0.3,0.7]	0.54	[0.4,0.7]	0.46	[0.27,0.66]
ρ_i	Autocorr. of $\hat{i}$	U	0.5	[0,1]	0.37	[0,0.9]	0.34	[0.02,0.89]
ρ_π	Autocorr. of $\hat{\pi}$	U	0.5	[0,1]	0.26	[0.1,0.4]	0.69	[0.52,0.85]
ρ_y	Autocorr. of $\hat{g^y}$	U	0.5	[0,1]	0.44	[0,0.9]	0.94	[0.9,0.98]
ρ_{ξ^*}	Autocorr. of ξ^*	U	0.5	[0,1]	0.35	[0,0.6]	0.97	[0.96,0.99]
ρ_g	Autocorr. of g	U	0.5	[0,1]	0.66	[0.4,0.9]	0.43	[0.18,0.71]
$\rho_{g,gdp}$	Corr. g_t to gdp_{t-1}	U	0	[-1,1]	0.55	[0.3,0.7]	0.17	[0.02,0.34]
ρ_γ	Autocorr. of γ	B	0.33	[0.1,0.7]	0.5	[0.3,0.7]	0.07	[0.02,0.16]
ρ_{z^x}	Autocorr. of z^x	U	0.5	[0,1]	0.24	[0,0.7]	0.79	[0.74,0.82]
ρ_{z^n}	Autocorr. of z^x	U	0.5	[0,1]	0.56	[0,0.98]	0.89	[0.84,0.95]
σ_i	Std.Dev. of $\hat{i}$	U	0.08	[0,0.1]	0.00	[0,0.01]	0.01	[0,0.02]
σ_π	Std.Dev. of $\hat{\pi}$	U	0.08	[0,0.1]	0.04	[0.03,0.05]	0.01	[0.01,0.02]
σ_y	Std.Dev. of $\hat{g^y}$	U	0.08	[0,0.1]	0.00	[0,0.01]	0.02	[0.01,0.04]
σ_{ξ^*}	Std.Dev. of ξ^*	U	0.08	[0,0.1]	0.02	[0.01,0.04]	0.02	[0.02,0.03]
σ_g	Std.Dev. of g	U	0.08	[0,0.1]	0.01	[0,0.03]	0.03	[0.03,0.04]
σ_γ	Std.Dev. of γ	U	0.08	[0,0.1]	0.01	[0,0.01]	0.01	[0.01,0.01]
σ_{z^x}	Std.Dev. of z^x	U	0.08	[0,0.1]	0.01	[0,0.02]	0.08	[0.07,0.09]
σ_{z^n}	Std.Dev. of z^x	U	0.08	[0,0.1]	0.00	[0,0.01]	0.01	[0.01,0.01]

Note: B, U, G, IG and N denote, respectively, Beta, Uniform, Gamma, Inverse Gamma and Normal distributions. Priors are truncated at the boundary of the determinacy region. C.B. denotes confidence band.

Table 3.4: Selected Moments, Baseline Model.

Variable	σ_x Data	σ_x Model	$\rho_{x,\Delta\ln(GDP)}$ Data	$\rho_{x,\Delta\ln(GDP)}$ Model	$\rho_{x,\ln(\pi)}$ Data	$\rho_{x,\ln(\pi)}$ Model	$\rho_{x_t,x_{t-1}}$ Data	$\rho_{x_t,x_{t-1}}$ Model
$\Delta\ln(GDP)$	1.5	1.6	—		-0.32	-0.16	0.11	0.02
	(0.2)	[1.5,1.7]			(0.1)	[-0.24,-0.07]	(0.15)	[-0.06,0.11]
$\Delta\ln(C)$	1.8	2	0.77	0.43	-0.35	-0.42	0.15	0.47
	(0.2)	[1.9,2.2]	(0.19)	[0.36,0.49]	(0.1)	[-0.49,-0.35]	(0.15)	[0.39,0.53]
TBY	3.8	3.2	-0.24	-0.14	0.67	0.73	0.94	0.77
	(0.2)	[3,3.4]	(0.11)	[-0.24,-0.04]	(0.1)	[0.67,0.79]	(0.1)	[0.74,0.8]
$\ln(\pi)$	6.1	5.9	-0.32	-0.16	—		0.88	0.83
	(0.5)	[5.8,6]	(0.1)	[-0.24,-0.07]			(0.16)	[0.8,0.86]
$\ln(\pi^n)$	6.1	6	-0.29	-0.13	0.98	0.99	0.9	0.83
	(0.6)	[5.9,6.1]	(0.1)	[-0.22,-0.04]	(0.18)	[0.99,0.99]	(0.17)	[0.8,0.86]
$\ln(s^n)$	1.5	1.5	0.13	-0.04	-0.71	-0.7	0.93	0.74
	(0.2)	[1.4,1.6]	(0.09)	[-0.13,0.06]	(0.11)	[-0.75,-0.63]	(0.19)	[0.7,0.78]
$\Delta\ln(W/P)$	5	2.2	0.16	0.57	-0.24	-0.21	-0.1	0.41
	(0.7)	[1.9,2.6]	(0.14)	[0.44,0.67]	(0.12)	[-0.36,-0.04]	(0.15)	[0.23,0.53]
$\Delta\ln(M1)$	6.5	11.1	0.02	0.22	0.54	0.37	0.57	0.49
	(0.7)	[10.1,12]	(0.12)	[0.09,0.32]	(0.14)	[0.3,0.44]	(0.14)	[0.42,0.59]
$\Delta\ln(S)$	10.5	11.5	-0.29	-0.35	0.61	0.49	0.41	0.16
	(1.4)	[10.6,12.4]	(0.13)	[-0.45,-0.25]	(0.13)	[0.42,0.55]	(0.11)	[0.13,0.2]
$\ln(i)$	4.5	4.2	-0.26	-0.19	0.9	0.92	0.92	0.87
	(0.3)	[3.9,4.5]	(0.09)	[-0.29,-0.1]	(0.15)	[0.9,0.94]	(0.13)	[0.85,0.89]

Note: For each moment, the table shows the one from the data (GMM standard errors in parenthesis) and the corresponding posterior mean (computed using 50,000 draws from the posterior) of the unconditional moment using the Baseline Model (95% confidence bands in brackets). Standard Deviations (σ_x) in percentage points. The contribution of measurement errors to the variance is not included.

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Table 3.5: Model Comparison, Moments.

Variable	Data	Baseline		No C.S.		No L.D.		No F.A.		No I.I.	
σ_x											
$\Delta\ln(GDP)$	1.5	1.6	[1.5,1.7]	1.8	[1.7,2]	2.2	[2.1,2.3]	2.3	[2.2,2.4]	2.1	[1.9,2.2]
$\Delta\ln(C)$	1.8	2	[1.9,2.2]	2	[1.9,2.2]	2.1	[1.9,2.3]	1.9	[1.7,2.1]	2.1	[1.9,2.2]
TBY	3.8	3.2	[3,3.4]	3.1	[2.8,3.3]	2.9	[2.7,3.1]	3	[2.9,3.2]	3	[2.7,3.2]
$\ln(\pi)$	6.1	5.9	[5.8,6]	5.9	[5.8,6]	6.2	[6.1,6.3]	6.3	[6.2,6.4]	6.3	[6.2,6.5]
$\ln(\pi^n)$	6.1	6	[5.9,6.1]	6	[5.9,6.1]	6.2	[6.1,6.3]	6.2	[6.1,6.3]	6.1	[6,6.2]
$\ln(s^n)$	1.5	1.5	[1.4,1.6]	1.5	[1.4,1.6]	1.5	[1.4,1.6]	1.4	[1.3,1.5]	1.7	[1.6,1.8]
$\Delta\ln(W/P)$	5	2.2	[1.9,2.6]	2.1	[1.8,2.5]	1.9	[1.8,2.2]	1.6	[1.4,1.8]	1.8	[1.4,2.2]
$\Delta\ln(M1)$	6.5	11.1	[10,12]	10	[9,11]	9.6	[9,11]	8.9	[8,10]	8.2	[7,10]
$\Delta\ln(S)$	10	11.5	[11,12]	12.1	[11,13]	9.9	[9,10]	10.6	[10,11]	11.1	[10,12]
$\ln(i)$	4.5	4.2	[3.9,4.5]	2.8	[2.5,3.2]	1.9	[1.7,2.3]	1.7	[1.6,2]	1.8	[1.6,2]
$\rho_{x,\Delta\ln(GDP)}$											
$\Delta\ln(C)$	0.77	0.43	[0.4,0.5]	0.48	[0.4,0.5]	0.73	[0.6,0.8]	0.8	[0.7,0.9]	0.64	[0.5,0.7]
TBY	-0.24	-0.14	[-0.2,0]	-0.04	[-0.1,0]	-0.04	[-0.1,0]	-0.09	[-0.2,0]	-0.01	[-0.1,0.1]
$\ln(\pi)$	-0.32	-0.16	[-0.2,-0.1]	0.08	[0,0.2]	-0.09	[-0.2,0]	-0.09	[-0.2,0]	-0.02	[-0.1,0.1]
$\ln(\pi^n)$	-0.29	-0.13	[-0.2,0]	0.12	[0,0.2]	-0.02	[-0.1,0.1]	-0.03	[-0.1,0]	0.1	[0,0.2]
$\ln(s^n)$	0.13	-0.04	[-0.1,0.1]	-0.18	[-0.2,-0.1]	-0.13	[-0.2,-0.1]	-0.11	[-0.2,0]	-0.19	[-0.3,-0.1]
$\Delta\ln(W/P)$	0.16	0.57	[0.4,0.7]	0.54	[0.4,0.6]	0.81	[0.6,0.9]	0.65	[0.4,0.8]	0.68	[0.5,0.8]
$\Delta\ln(M1)$	0.02	0.22	[0.1,0.3]	0.25	[0.1,0.3]	0	[-0.1,0.1]	0.02	[-0.1,0.1]	0.27	[-0.1,0.4]
$\Delta\ln(S)$	-0.29	-0.35	[-0.4,-0.3]	-0.26	[-0.4,-0.2]	-0.57	[-0.6,-0.5]	-0.55	[-0.6,-0.5]	-0.33	[-0.4,-0.2]
$\ln(i)$	-0.26	-0.19	[-0.3,-0.1]	0.06	[0,0.1]	0.03	[0,0.1]	-0.02	[-0.1,0]	-0.03	[-0.1,0]

Note: See Table 3.4

Table 3.6: Model Comparison, Moments, Cont.

Variable	Data	Baseline		No C.S.		No L.D.		No F.A.		No I.I.	
$\rho_{x,\ln(\pi)}$											
$\Delta\ln(C)$	-0.35	-0.42	[-0.5,-0.3]	-0.11	[-0.2,0]	-0.07	[-0.1,0]	-0.11	[-0.2,0]	-0.35	[-0.4,-0.2]
TBY	0.67	0.73	[0.7,0.8]	0.47	[0.4,0.6]	0.26	[0.2,0.4]	0.25	[0.2,0.3]	0.59	[0.5,0.7]
$\ln(\pi^n)$	0.98	1	[1,1]	1	[1,1]	0.99	[1,1]	1	[1,1]	0.97	[1,1]
$\ln(s^n)$	-0.71	-0.7	[-0.8,-0.6]	-0.56	[-0.6,-0.5]	-0.26	[-0.4,-0.2]	-0.22	[-0.3,-0.2]	-0.43	[-0.5,-0.4]
$\Delta\ln(W/P)$	-0.24	-0.21	[-0.4,0]	-0.09	[-0.2,0]	-0.07	[-0.3,0.1]	-0.24	[-0.3,-0.1]	-0.31	[-0.5,-0.1]
$\Delta\ln(M1)$	0.54	0.37	[0.3,0.4]	0.51	[0.4,0.6]	0.22	[0,0.4]	0.31	[0.2,0.4]	0.11	[-0.1,0.3]
$\Delta\ln(S)$	0.61	0.49	[0.4,0.5]	0.45	[0.4,0.5]	0.69	[0.7,0.7]	0.69	[0.7,0.7]	0.74	[0.7,0.8]
$\ln(i)$	0.9	0.92	[0.9,0.9]	0.74	[0.7,0.8]	0.7	[0.6,0.8]	0.72	[0.7,0.8]	0.58	[0.5,0.7]
$\rho_{x_t,x_{t-1}}$											
$\Delta\ln(GDP)$	0.11	0.02	[-0.1,0.1]	0.03	[0,0.1]	-0.05	[-0.1,0]	-0.01	[0,0]	-0.15	[-0.2,-0.1]
$\Delta\ln(C)$	0.15	0.47	[0.4,0.5]	0.46	[0.4,0.5]	0.13	[0,0.2]	0.06	[0,0.1]	0.23	[0.1,0.3]
TBY	0.94	0.77	[0.7,0.8]	0.83	[0.8,0.9]	0.74	[0.7,0.8]	0.78	[0.8,0.8]	0.83	[0.8,0.8]
$\ln(\pi)$	0.88	0.83	[0.8,0.9]	0.58	[0.5,0.7]	0.41	[0.3,0.5]	0.42	[0.4,0.5]	0.57	[0.5,0.6]
$\ln(\pi^n)$	0.9	0.83	[0.8,0.9]	0.58	[0.5,0.7]	0.42	[0.4,0.5]	0.43	[0.4,0.5]	0.53	[0.4,0.6]
$\ln(s^n)$	0.93	0.74	[0.7,0.8]	0.8	[0.7,0.8]	0.7	[0.7,0.7]	0.69	[0.7,0.7]	0.7	[0.7,0.7]
$\Delta\ln(W/P)$	-0.1	0.41	[0.2,0.5]	0.39	[0.3,0.5]	0.07	[0,0.1]	0.05	[0,0.1]	0.11	[0,0.2]
$\Delta\ln(M1)$	0.57	0.49	[0.4,0.6]	0.38	[0.3,0.5]	0.16	[0.1,0.2]	0.17	[0.1,0.2]	0.34	[0.3,0.4]
$\Delta\ln(S)$	0.41	0.16	[0.1,0.2]	0.02	[0,0.1]	0.09	[0.1,0.1]	0.08	[0.1,0.1]	0.26	[0.2,0.3]
$\ln(i)$	0.92	0.87	[0.9,0.9]	0.9	[0.9,0.9]	0.93	[0.9,1]	0.92	[0.9,0.9]	0.96	[0.9,1]

Note: See Table 3.4

Table 3.7: Model Comparison, Marginal Likelihood.

Model	Difference with Baseline
No Currency Substitution (No C.S.)	112
No Liability dollarization (No L.D.)	64.4
No Financial Accelerator (No F.A.)	-19.5
No Intermediate Inputs (No I.I.)	-187.2

Note: The table shows the log Marginal Likelihood for each model minus that for the Baseline model. These were computed using the modified harmonic mean proposed by Geweke (1999). In performing this comparison, the priors have been re-scaled to account for the possibly different uniqueness regions in each specification.

Table 3.8: Model Comparison based on Loss-Function.

Variable	No C.S.	No L.D.	No. F.A.	No I.I.
$cov(x_t, x_{t-h}), h = 0, .., 8$				
$\Delta \ln(GDP)$	3.58	11.79	15.02	248.62
$\Delta \ln(C)$	0.97	0.56	0.23	17.51
TBY	0.63	0.75	0.62	0.89
$\ln(\pi)$	0.75	0.87	0.83	9.44
$\ln(\pi^n)$	0.74	0.85	0.82	1.79
$\ln(s^n)$	0.61	0.87	0.96	52.38
$\Delta \ln(M1)$	0.36	0.29	0.19	2.77
$\Delta \ln(S)$	1.31	0.78	0.84	8.99
$\ln(i)$	1.06	1.1	1.13	1.07
$cov(\Delta \ln(GDP_t), x_{t-h}), h = 0, .., 8$				
$\Delta \ln(C)$	1.94	4.79	6.06	191.19
TBY	0.5	15.21	22.11	0.16
$\ln(\pi)$	3.77	2.54	1.7	350.63
$\ln(\pi^n)$	4.11	2.94	2.02	93.4
$\ln(s^n)$	1.78	1.95	1.11	345.65
$\Delta \ln(M1)$	0.87	0.13	0.1	37.04
$\Delta \ln(S)$	1.59	2.73	3.37	50.32
$\ln(i)$	2.89	3.86	3.3	0.4
$cov(\ln(\pi_t), x_{t-h}), h = 0, .., 8$				
$\Delta \ln(GDP)$	1.39	0.81	0.48	62.86
$\Delta \ln(C)$	0.77	0.28	0.2	14.99
TBY	0.83	1.27	1.38	1.07
$\ln(\pi^n)$	0.75	0.87	0.83	9.44
$\ln(s^n)$	0.59	1.29	1.64	10.3
$\Delta \ln(M1)$	0.1	0.33	0.26	19.44
$\Delta \ln(S)$	0.71	0.64	0.65	6.4
$\ln(i)$	1.06	1.11	1.16	0.8

Note: The table shows the ratio of the Risk factor of each model relative to the Baseline (if the ratio is bigger than 1, the Baseline is preferred). See the Appendix for details.

Table 3.9: Model Comparison, Posterior Distribution.

Para-meter	No C.S. mean	95% C.B.	No L.D. mean	95% C.B.	No F.A. mean	95% C.B.	No I.I. mean	95% C.B.
b	0.99	[0.99,1]	0.29	[0.1,0.5]	0.38	[0.2,0.5]	0.27	[0.2,0.4]
ζ	0.25	[0.2,0.3]	0.76	[0.6,0.9]	0.67	[0.6,0.7]	0.85	[0.6,0.9]
ρ_c	0.7	[0.6,0.8]	0.19	[0,0.4]	0.13	[0,0.3]	0.38	[0.2,0.5]
ν			0.91	[0.8,1]	0.89	[0.8,0.9]	0.81	[0.8,0.8]
χ			2.93	[1.7,4.4]	2.98	[2.1,4]	7.04	[6.2,8.1]
ψ_w	0.34	[0.2,0.7]	0.08	[0,0.2]	0.45	[0.1,0.9]	0.07	[0,0.1]
ψ_d	0.72	[0.5,1]	0.94	[0.8,1.1]	1.12	[0.7,2]	1.04	[0.7,1.4]
φ	2.9	[2.5,3.3]	2.79	[2.5,3.2]	2.92	[2.6,3.3]	2.13	[2,2.3]
ψ_n	0.63	[0.1,1.8]	7.3	[5.9,8.8]	3.36	[0.8,5.4]	4.01	[1,7.4]
ψ_f	13.4	[9,19]	6.5	[6,7]	25	[20,30]	25	[23,27]
ψ_k^n	0.85	[0.3,1.7]	1.08	[0.2,3.6]	6.87	[4.3,9.8]	36	[38,40]
ψ_k^x	0.74	[0.2,1.7]	1.14	[0.2,5]	2.49	[1.5,3.3]	37	[34,40]
rp-1	0.07	[0.05,0.1]	0	[0,0]			0.02	[0,0.05]
σ_ω	2.1	[1.7,2.5]	1.48	[1.2,1.8]			0.41	[0.4,0.4]
μ	0.68	[0.5,0.8]	0.29	[0.1,0.6]			0.73	[0.4,0.9]
α_i	0.06	[0,0.2]	0.46	[0,0.7]	0.47	[0.3,0.6]	0.84	[0.7,0.9]
α_π	2.12	[1.8,2.5]	1.8	[1.5,2.1]	1.57	[1.3,1.9]	1.57	[1.4,1.8]
α_y	0.55	[0.4,0.7]	0.73	[0.6,0.9]	0.75	[0.6,0.9]	0.59	[0.4,0.9]
ρ_i	0.13	[0,0.3]	0.11	[0,0.2]	0.96	[0.9,1]	0.99	[1,1]
ρ_π	0.06	[0,0.2]	0.13	[0,0.3]	0.15	[0,0.2]	0.12	[0,0.5]
ρ_y	0.95	[0.9,1]	0.94	[0.9,1]	0.1	[0,0.4]	0.02	[0,0.1]
ρ_{ξ^*}	0.97	[0.9,1]	0.98	[1,1]	0.98	[1,1]	0.72	[0.3,1]
ρ_g	0.46	[0.2,0.7]	0.26	[0,0.6]	0.33	[0.1,0.6]	0.52	[0.3,0.7]
$\rho_{g,gdp}$	0.11	[-0.1,0.3]	0.18	[-0.1,0.5]	0.29	[0.1,0.5]	-0.03	[-0.2,0.2]
ρ_γ	0.07	[0,0.1]	0.1	[0,0.3]	0.11	[0,0.2]	0.08	[0,0.1]
ρ_{z^x}	0.73	[0.7,0.8]	0.8	[0.8,0.9]	0.78	[0.7,0.8]	0.74	[0.7,0.8]
ρ_{z^n}	0.92	[0.8,1]	0.96	[0.9,1]	0.97	[0.9,1]	0.97	[1,1]
σ_i	0.03	[0,0.04]	0.03	[0,0.07]	0.00	[0,0.01]	0.00	[0,0.0]
σ_π	0.03	[0,0.04]	0.03	[0,0.04]	0.04	[0,0.04]	0.02	[0,0.04]
σ_y	0.03	[0,0.03]	0.01	[0,0.02]	0.04	[0,0.07]	0.1	[0,0.14]
σ_{ξ^*}	0.01	[0,0.02]	0.03	[0,0.04]	0.03	[0,0.05]	0.05	[0,0.14]
σ_g	0.03	[0,0.04]	0.03	[0,0.03]	0.03	[0,0.03]	0.03	[0,0.03]
σ_γ	0.01	[0,0.01]	0.01	[0,0.01]	0.01	[0,0.01]	0.01	[0,0.01]
σ_{z^x}	0.09	[0.1,0.1]	0.05	[0,0.05]	0.05	[0,0.06]	0.06	[0.05,0.07]
σ_{z^n}	0.01	[0,0.01]	0.01	[0,0.01]	0.01	[0,0.01]	0.01	[0,0.01]

Table 3.10: Variance Decomposition, Baseline Model.

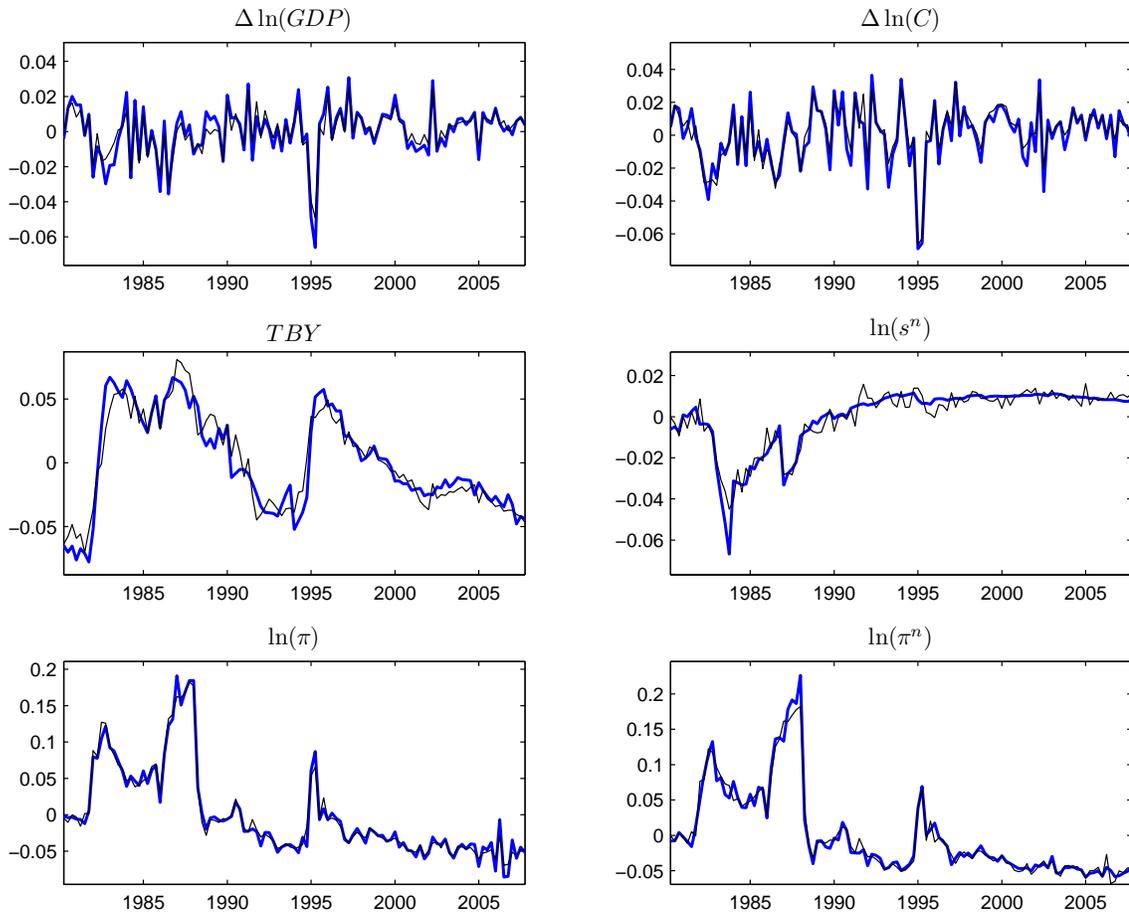| Variable						Shock						m.e.
	$\hat{i}$	$\hat{\pi}$	$\hat{g}^y$	ξ^*	g	γ	z^x	z^n	π^{*f}	π^{*x}	i^*	m.e.
$\Delta\ln(GDP)$	3 [0,10]	1 [0,2]	1 [0,2]	17 [13,21]	1 [1,2]	4 [2,5]	30 [22,37]	28 [21,34]	2 [1,2]	5 [3,7]	3 [2,5]	7 [5,8]
$\Delta\ln(C)$	0 [0,0]	0 [0,0]	0 [0,0]	4 [2,6]	0 [0,1]	36 [29,45]	35 [28,42]	7 [5,10]	0 [0,0]	11 [9,14]	0 [0,1]	6 [5,8]
TBY	0 [0,0]	0 [0,0]	1 [0,1]	22 [17,28]	0 [0,0]	0 [0,0]	40 [34,48]	0 [0,1]	2 [1,2]	20 [17,23]	3 [2,5]	11 [9,12]
$\ln(\pi)$	2 [0,1]	20 [12,30]	22 [8,35]	8 [5,11]	1 [1,2]	1 [1,1]	29 [22,39]	4 [3,7]	0 [0,1]	9 [6,12]	1 [0,2]	2 [1,4]
$\ln(\pi^n)$	2 [0,6]	19 [11,30]	22 [8,34]	8 [5,11]	1 [1,2]	1 [1,1]	29 [22,38]	5 [3,7]	0 [0,1]	10 [7,13]	1 [0,2]	3 [2,4]
$\ln(s^n)$	2 [0,6]	3 [1,5]	7 [2,14]	40 [32,47]	1 [0,2]	0 [0,0]	14 [10,19]	3 [2,6]	3 [2,3]	13 [10,17]	6 [3,9]	8 [7,10]
$\Delta\ln(W/P)$	2 [0,7]	0 [0,0]	0 [0,0]	1 [0,1]	0 [0,0]	1 [1,2]	12 [8,18]	5 [3,8]	0 [0,0]	2 [1,3]	0 [0,0]	79 [71,84]
$\Delta\ln(M1)$	1 [0,1]	6 [4,10]	7 [2,10]	17 [12,22]	1 [1,2]	0 [0,1]	40 [33,49]	6 [4,9]	1 [1,1]	16 [13,19]	2 [1,3]	3 [3,4]
$\Delta\ln(S)$	1 [0,2]	5 [3,9]	6 [2,9]	6 [4,8]	0 [0,1]	0 [0,0]	48 [41,57]	1 [1,2]	0 [0,0]	24 [21,28]	1 [1,1]	7 [6,8]
$\ln(i)$	0 [0,1]	4 [1,9]	9 [2,14]	12 [7,16]	1 [1,2]	1 [0,1]	43 [36,54]	6 [4,10]	1 [0,1]	14 [11,17]	1 [1,2]	8 [7,9]

Note: Each entry denotes the posterior means of the unconditional variance decomposition (in percentage) under the Baseline Model (computed using 50,000 draws from the posterior), as well as its 95% confidence bands in brackets. m.e. denotes measurement error.

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Table 3.11: Variance Decomposition, No C.S. Model.

| Variable						Shock						
	$\hat{i}$	$\hat{\pi}$	$\hat{g}^y$	ξ^*	g	γ	z^x	z^n	π^{*f}	π^{*x}	i^*	m.e.
$\Delta\ln(GDP)$	17	0	1	10	0	2	33	25	1	3	4	4
	[9,25]	[0,0]	[0,1]	[6,14]	[0,0]	[2,3]	[26,40]	[19,32]	[1,2]	[2,4]	[3,6]	[2,6]
$\Delta\ln(C)$	1	0	0	5	0	27	40	9	0	9	2	6
	[0,2]	[0,0]	[0,0]	[3,8]	[0,1]	[20,33]	[34,48]	[7,12]	[0,0]	[7,11]	[1,2]	[3,8]
TBY	2	0	2	21	0	0	39	0	2	16	7	10
	[1,3]	[0,0]	[1,4]	[15,28]	[0,0]	[0,0]	[31,46]	[0,0]	[1,3]	[14,19]	[5,9]	[7,13]
$\ln(\pi)$	8	33	40	4	0	1	9	1	0	3	1	0
	[4,11]	[23,43]	[31,55]	[2,7]	[0,0]	[0,1]	[3,15]	[1,2]	[0,0]	[1,4]	[1,2]	[0,0]
$\ln(\pi^n)$	8	31	37	4	0	1	9	1	0	3	1	5
	[5,11]	[22,40]	[29,51]	[2,6]	[0,0]	[1,1]	[3,15]	[1,2]	[0,0]	[1,4]	[1,2]	[4,6]
$\ln(s^n)$	10	0	16	37	0	0	5	2	3	7	13	7
	[5,16]	[0,0]	[8,27]	[28,46]	[0,1]	[0,1]	[2,9]	[1,3]	[2,4]	[4,10]	[9,17]	[4,9]
$\ln(W/P)$	1	0	0	1	0	1	11	4	0	2	0	79
	[0,3]	[0,0]	[0,0]	[1,2]	[0,0]	[1,2]	[6,16]	[2,6]	[0,0]	[1,3]	[0,1]	[72,86]
$\Delta\ln(M1)$	5	9	17	20	1	1	22	5	1	6	8	4
	[2,8]	[6,13]	[12,24]	[15,27]	[1,2]	[1,3]	[13,33]	[3,7]	[1,2]	[5,7]	[5,10]	[3,4]
$\Delta\ln(S)$	3	8	9	3	0	0	46	0	0	23	1	6
	[2,5]	[5,10]	[7,13]	[2,5]	[0,0]	[0,0]	[39,52]	[0,0]	[0,0]	[20,26]	[1,2]	[5,7]
$\ln(i)$	0	0	30	13	0	1	25	1	0	7	4	16
	[0,0]	[0,1]	[21,43]	[9,18]	[0,1]	[1,1]	[13,37]	[1,3]	[0,1]	[6,10]	[3,6]	[14,18]

Note: See table 3.10.
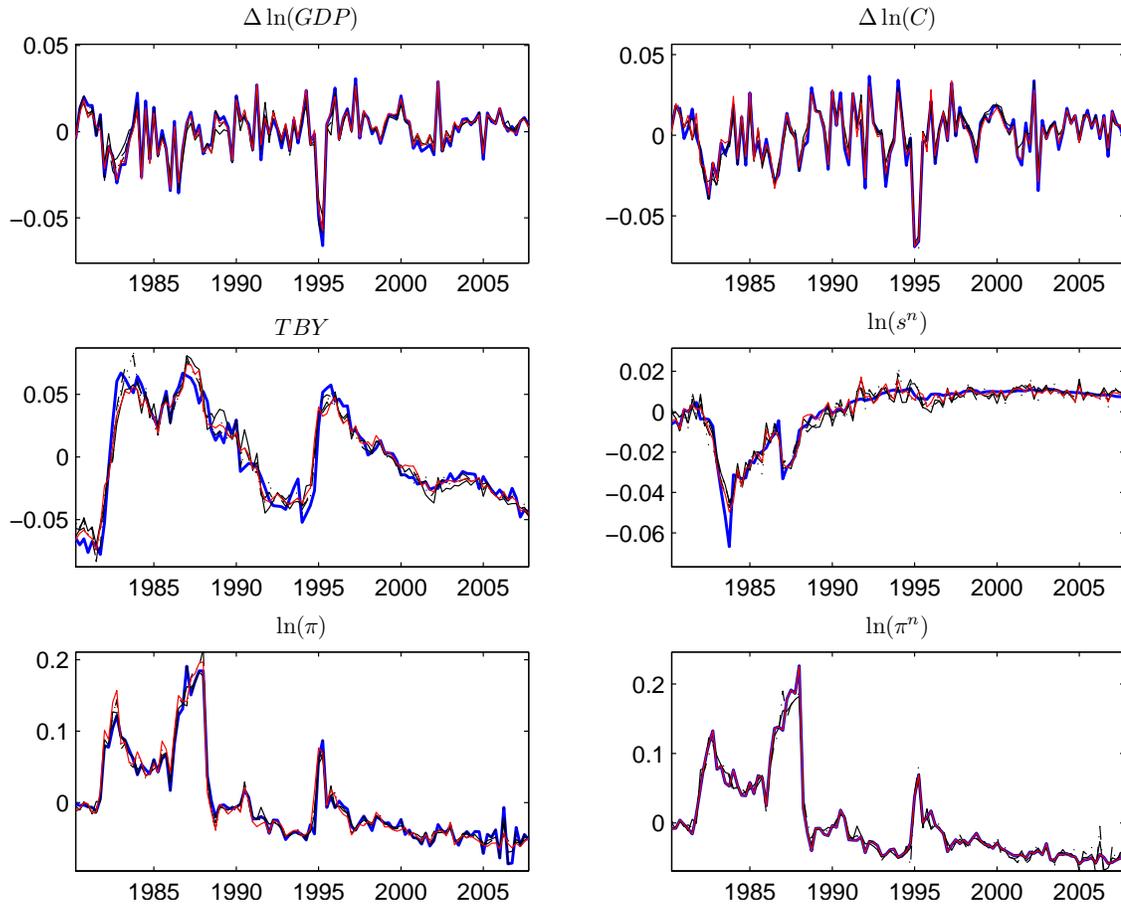
FIGURE 3.1: Data vs. Baseline Model

Note: The blue thick line is the data (measured as deviations from the mean) and the black line posterior mean of the smooth version of the same series form the Baseline Model (computed using 50,000 draws from the posterior).

FIGURE 3.2: Data vs. Baseline Model, cont.

$\Delta \ln(W/P)$

$\Delta \ln(M1)$

$\Delta \ln(S)$

$\ln(i)$
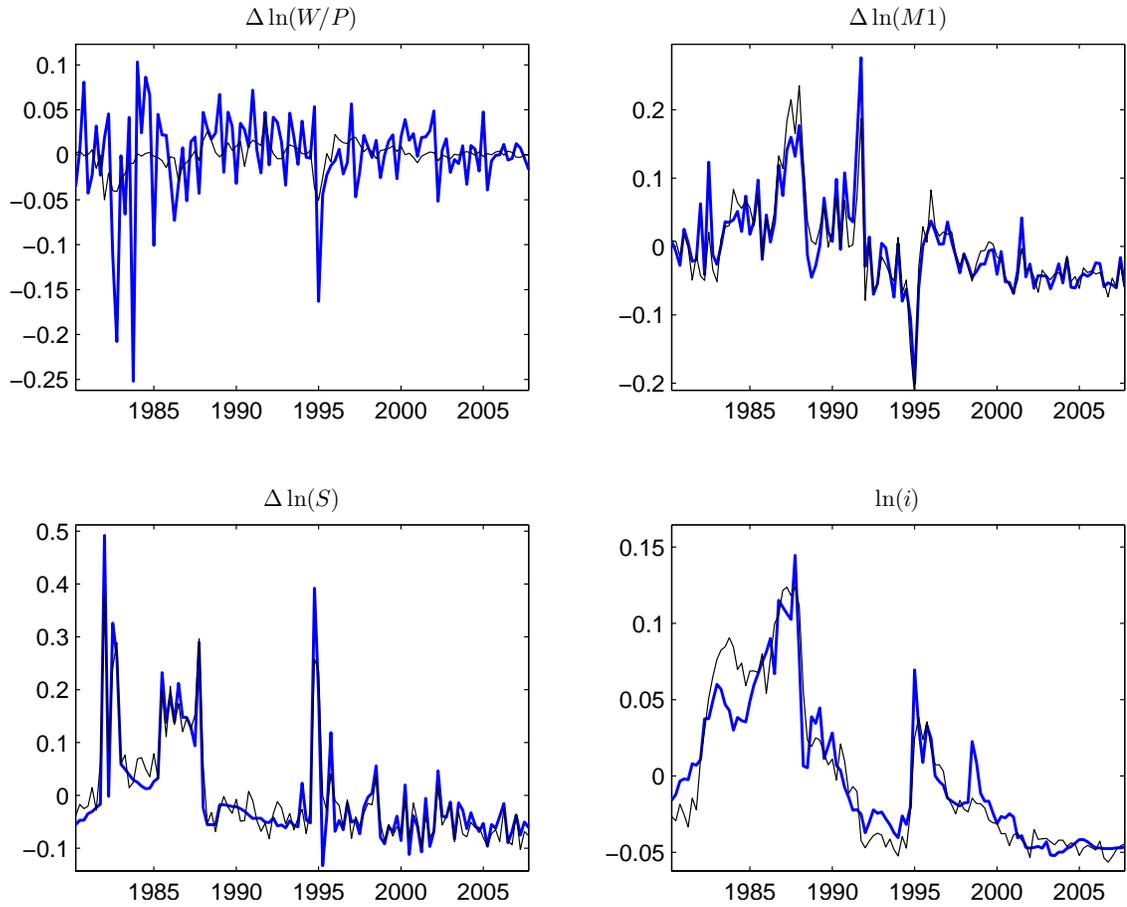
Note: See Figure 3.1.

FIGURE 3.3: Data vs. Different Models

Note: The blue thick line is the data (measured as deviations from the mean), the black line is the Baseline Model, the black dashed-doted line is the model without Currency Substitution, the black doted line is the model without Liability dollarization, the black dashed line is the model without Financial Accelerator, and the red line is the model without Intermediate Inputs.

FIGURE 3.4: Data vs. Different Models, cont.

$\Delta \ln(W/P)$

$\Delta \ln(M1)$

$\Delta \ln(S)$

$\ln(i)$
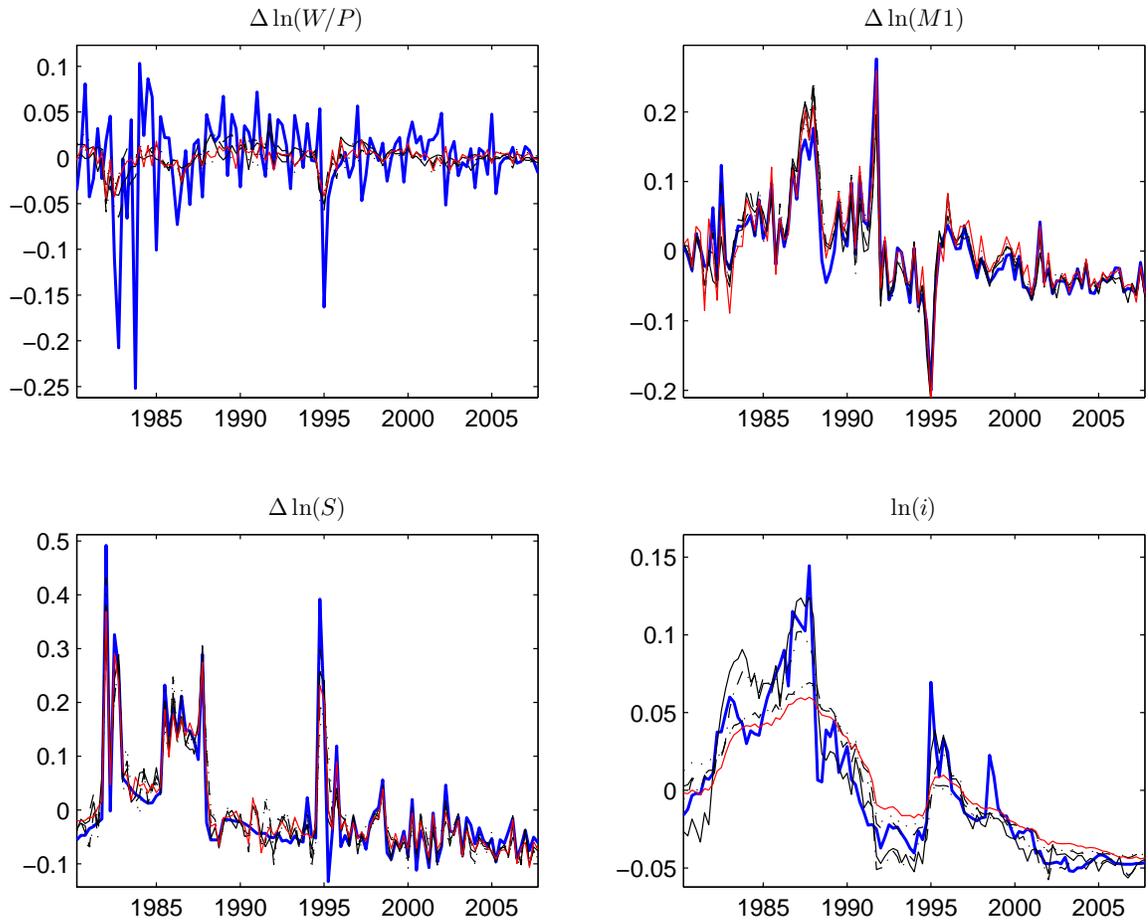
Note: See Figure 3.3.

FIGURE 3.5: Historical Decomposition, Selected variables.
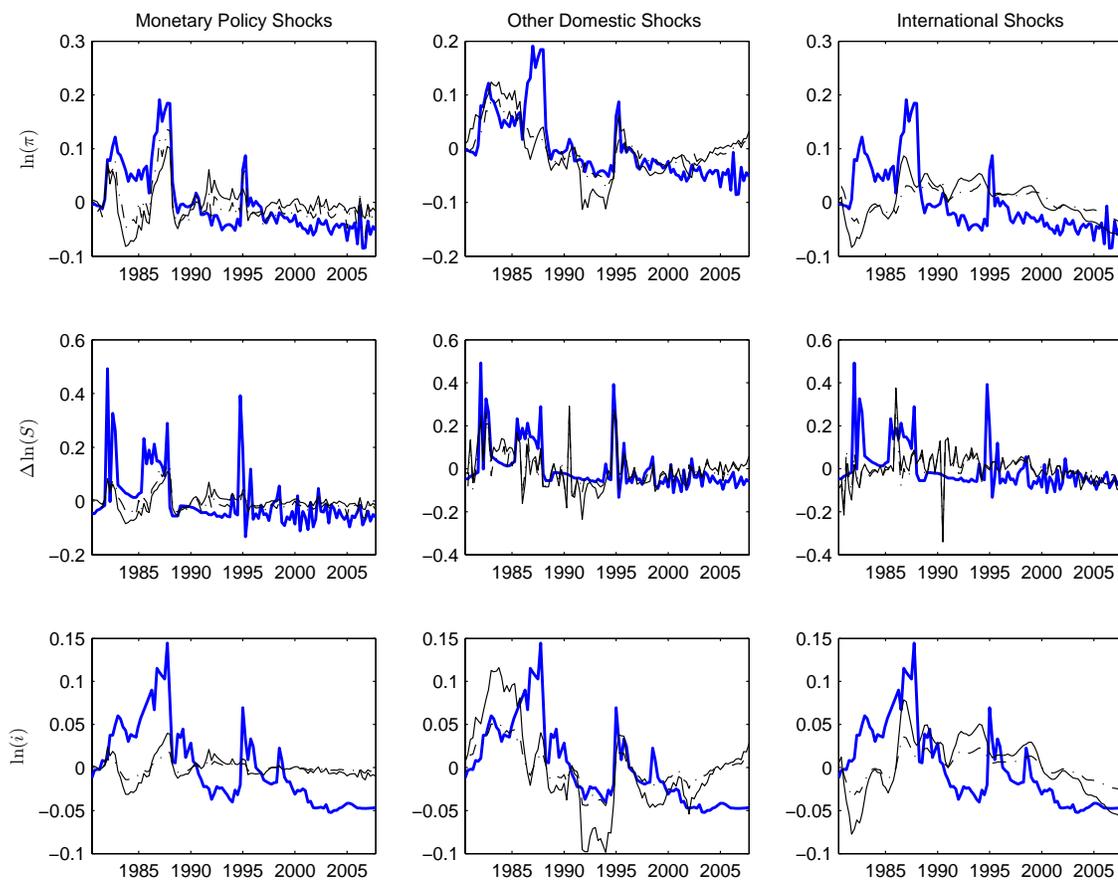
Note: The thick blue line is the data (measured as deviations from the mean), the thin black line shows the model series if only the shocks in the particular group are active under the Baseline (measured as deviations from the steady state) and the dashed-dotted line is the analogous for the No C.S. model. The values for each shock are computed from the smooth Kalman filter evaluated at the posterior mean.

Appendix A

Appendix to Chapter 1

A.1   Data Sources

A.1.1   Argentina

GDP, Investment, Exports, and Imports

1900-1912: Ferreres (2005).

1913 - 1980: IEERAL (1986), table 2.

1981 - 1992: Dirección Nacional de Cuentas Nacionales (1996). Available at

`http://www.mecon.gov.ar/secpro/dir_cn/ant/contenido.htm`.

1993 - 2005: Secretearía de Política Económica (2006). Available at

`http://www.mecon.gov.ar/peconomica/informe/indice.htm`.

Private Consumption:

1900-1912: Ferreres (2005).

1913 - 1980: IEERAL (1986), table 2.

1980 - 1992: Ministerio de Economía y Obras y Servicios Públicos (1994).

1993 - 2005: Secretearía de Política Económica (2006). Available at

`http://www.mecon.gov.ar/peconomica/informe/indice.htm`.

Population:

1900-1912: Ferreres (2005).

1913 - 1949: IEERAL (1986), table 4.

1950 - 2005: CEPAL and INDEC (2004). Available at

`http://www.indec.gov.ar/principal.asp?id_tema=165`.

A.1.2   United States:

GDP

1900 - 1928: Romer (1989).

1929 - 2005: Bureau of Economic Analysis. Available at

`www.bea.gov`.

Population

1900 - 2005: U.S. Census, Statistical Abstract of the United States. Available at

`http://www.census.gov/compendia/statab/population/`.

A.1.3   Mexico

GDP and Private Consumption per capita

1900 - 2005: Data base compiled by R. Barro and J. Ursúa, available at:

`http://www.economics.harvard.edu/faculty/barro/data_sets_barro`.

Investment

1900 - 2000: Oxford Latin American Economic History Database (OxLAD), University of Oxford, available at: `http://oxlad.qeh.ox.ac.uk/index.php`.

2001 - 2005: Instituto Nacional de Estadıistica, Geografıia e Informática (INEGI), available at: `http://dgcnesyp.inegi.org.mx/bdiesi/bdie.html`.

Trade Balance

1900 - 2000: INEGI, Estadıisticas Históricas de México, available at:

`http://biblioteca.itam.mx/recursos/ehm.html`.

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A.2   Optimality Conditions of the Household's Problem

Letting $\lambda_t X_{t-1}^{-\gamma}$ denote the Lagrange multiplier associated with the sequential budget constraint, the optimality conditions associated with this problem are (1.1), (1.4), the no-Ponzi-game constraint holding with equality, and

$$\left[C_t/X_{t-1} - \theta\omega^{-1}h_t^\omega\right]^{-\gamma} = \lambda_t$$

$$\left[C_t/X_{t-1} - \theta\omega^{-1}h_t^\omega\right]^{-\gamma}\theta h_t^{\omega-1} = (1-\alpha)a_t\left(\frac{K_t}{X_{t-1}h_t}\right)^\alpha\left(\frac{X_t}{X_{t-1}}\right)^{1-\alpha}\lambda_t$$

$$\lambda_t = \beta\frac{1+r_t}{g_t^\gamma}E_t\lambda_{t+1}$$

$$\left[1+\phi\left(\frac{K_{t+1}}{K_t}-g\right)\right]\lambda_t = \frac{\beta}{g_t^\gamma}E_t\lambda_{t+1}\left[1-\delta+\alpha a_{t+1}\left(\frac{X_{t+1}h_{t+1}}{K_{t+1}}\right)^{1-\alpha}\right.$$

$$\left. +\phi\left(\frac{K_{t+2}}{K_{t+1}}\right)\left(\frac{K_{t+2}}{K_{t+1}}-g\right) - \frac{\phi}{2}\left(\frac{K_{t+2}}{K_{t+1}}-g\right)^2\right]$$

A.3   Equilibrium Conditions

Define $y_t = Y_t/X_{t-1}$, $c_t = C_t/X_{t-1}$, $d_t = D_t/X_{t-1}$, and $k_t = K_t/X_{t-1}$. Then, a stationary competitive equilibrium is give by a set of processes stationary solution to the following equations:

$$[c_t - \theta\omega^{-1}h_t^\omega]^{-\gamma} = \lambda_t$$

$$\theta h_t^{\omega-1} = (1-\alpha)a_t g_t^{1-\alpha}\left(\frac{k_t}{h_t}\right)^\alpha$$

$$\lambda_t = \frac{\beta}{g_t^\gamma}\left[1+r^* + \psi\left(e^{d_t-\bar{d}}-1\right)\right]E_t\lambda_{t+1}$$

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$$\left[1 + \phi\left(\frac{k_{t+1}}{k_t}g_t - g\right)\right]\lambda_t \;=\; \frac{\beta}{g_t^\gamma}E_t\lambda_{t+1}\left[1 - \delta + \alpha a_{t+1}\left(\frac{g_{t+1}h_{t+1}}{k_{t+1}}\right)^{1-\alpha}\right.$$

$$\left. + \phi\frac{k_{t+2}}{k_{t+1}}g_{t+1}\left(\frac{k_{t+2}}{k_{t+1}}g_{t+1} - g\right) - \frac{\phi}{2}\left(\frac{k_{t+2}}{k_{t+1}}g_{t+1} - g\right)^2\right]$$

$$\frac{d_{t+1}}{1 + r_t}g_t = d_t - y_t + c_t + i_t + \frac{\phi}{2}\left(\frac{k_{t+1}}{k_t}g_t - g\right)^2 k_t,$$

$$r_t = r^* + \psi\left(e^{d_t - \bar{d}} - 1\right),$$

$$k_{t+1}g_t = (1 - \delta)k_t + i_t$$

$$y_t = a_t k_t^\alpha (g_t h_t)^{1-\alpha}$$

A.4   GMM Estimation Procedure

Let $b \equiv [g\,\sigma_g\,\rho_g\,\sigma_a\,\rho_a\,\phi]'$ be the 6×1 vector of structural parameters to be estimated. We write the moment conditions as:[1]

$$
u_t(b) = \begin{bmatrix}
E_{gy}(b) - g_t^Y \\
\sigma_{gy}^2(b) - (g_t^Y - \bar{g}^Y)^2 \\
\sigma_{gc}^2(b) - (g_t^C - \bar{g}^C)^2 \\
\sigma_{gi}^2(b) - (g_t^I - \bar{g}^I)^2 \\
\sigma_{tby}^2(b) - (tby_t - \overline{tby})^2 \\
\rho_{gy,gc} - \frac{(g_t^Y - \bar{g}^Y)(g_t^C - \bar{g}^C)}{\sigma_{gy}(b)\sigma_{gc}(b)} \\
\rho_{gy,gi} - \frac{(g_t^Y - \bar{g}^Y)(g_t^I - \bar{g}^I)}{\sigma_{gy}(b)\sigma_{gi}(b)} \\
\rho_{gy,tby} - \frac{(g_t^Y - \bar{g}^Y)(tby_t - \overline{tby})}{\sigma_{gy}(b)\sigma_{tby}(b)} \\
\rho_{gy1}(b) - \frac{(g_t^Y - \bar{g}^Y)(g_{t-1}^Y - \bar{g}^Y)}{\sigma_{gy}^2(b)} \\
\rho_{gy2}(b) - \frac{(g_t^Y - \bar{g}^Y)(g_{t-2}^Y - \bar{g}^Y)}{\sigma_{gy}^2(b)} \\
\rho_{gc1}(b) - \frac{(g_t^C - \bar{g}^C)(g_{t-1}^C - \bar{g}^C)}{\sigma_{gc}^2(b)} \\
\rho_{gc2}(b) - \frac{(g_t^C - \bar{g}^C)(g_{t-2}^C - \bar{g}^C)}{\sigma_{gc}^2(b)} \\
\rho_{gi1}(b) - \frac{(g_t^I - \bar{g}^I)(g_{t-1}^I - \bar{g}^I)}{\sigma_{gi}^2(b)} \\
\rho_{gi2}(b) - \frac{(g_t^I - \bar{g}^I)(g_{t-2}^I - \bar{g}^I)}{\sigma_{gi}^2(b)} \\
\rho_{tby1}(b) - \frac{(tby_t - \overline{tby})(tby_{t-1} - \overline{tby})}{\sigma_{tby}^2(b)} \\
\rho_{tby2}(b) - \frac{(tby_t - \overline{tby})(tby_{t-2} - \overline{tby})}{\sigma_{tby}^2(b)}
\end{bmatrix},
$$

where $Ex(b)$ denotes the expected value of the variable x_t implied by the theoretical model, $\sigma_x(b)$ denotes the standard deviation of x_t implied by the theoretical model, $\rho_{xy}(b)$ denotes the correlation between x_t and y_t implied by the theoretical model,

---

[1] The estimation results are little changed if in writing the moment conditions we replace the empirical moments $\bar{g}^Y$, $\bar{g}^C$, and $\bar{g}^I$ by their theoretical counterpart $E_{gy}(b)$, and the empirical moment $\overline{tby}$ by its theoretical counterpart $E_{tby}(b)$. In this case, the parameter estimates using Argentine data from 1900 to 2005 are

Parameter	Point Estimate	Standard Deviations
g	1.001	0.0046
σ_g	0.029	0.0041
ρ_g	0.412	0.0496
σ_a	0.021	0.0022
ρ_a	0.027	0.0753
ϕ	0.555	0.1610

We thank Masao Ogaki for suggesting to us to carry out this robustness exercise.

and ρ_{xj} denotes the autocorrelation of order j of x_t implied by the theoretical model. All of these statistics are functions of the vector b of structural parameters. We denote by $\bar{x} \equiv T^{-1} \sum_{t=1}^{T} x_t$ the sample mean of x_t, where T is the sample size. We compute moments implied by the theoretical model by solving a linearized version of the system of equilibrium conditions with respect to the logarithm of all variables except the trade-balance share in GDP, which we keep in levels.

Define $J(b, W) = \bar{u}' W \bar{u}$, where $\bar{u}(b)$ denotes the sample mean of $u_t(b)$ and W is a symmetric positive definite matrix compatible with $\bar{u}(b)$. The GMM estimate of b, denoted $\hat{b}$, is given by

$$\hat{b} = \underset{b}{\operatorname{argmin}} J(b, W).$$

The matrix W is estimated in two steps. For more details see Burnside (1999).

Appendix B

Appendix to Chapter 2

B.1   Data Sources

B.1.1   National Accounting

National accounts series (GDP, private and government consumption, investments, exports and imports) in nominal terms, and their respective deflators are taken from: 1913-1934, Domenech (1986); 1935-2004, Ferreres (2005); and 2005, Secretearía de Política Económica (2006). The nominal sectorial shares of production are from: 1935-2004, Ferreres (2005); and 2005, Secretearía de Política Económica (2006).

B.1.2   Exchange Rates and Price Indexes

The series for domestic wholesale price of agricultural and non-agricultural goods, foreign prices of exports and imports, CPI for Argentina and the U.S., and nominal exchange rates (against U.S. dollars) are from Ferreres (2005) for the period 1913-2004; and for 2005 from Secretearía de Política Económica (2006).

To construct the world real interest series, we use a short run nominal rate for U.S. from Ferreres (2005). This series represents, for the period 1913-1930, Commercial Papers and for 1930-2005 is the three months T-bill. The real interest rate is this nominal rate minus the expected CPI inflation in the U.S. (computed assuming the inflation follows a random walk).

The series of the domestic real interest rate for the period 1913-2000 was constructed by della Paolera *et al.* (2003). For 2001-2005 we take the EMBI-ARG from Secretearía de Política Económica (2006).

B.2   Technical Appendix

Trough this technical appendix, the model is shown under the GHH specification. The Cobb-Douglas case is a straightforward modification.

B.2.1   Household and Firms' Optimality

Let $\lambda_t \left(\Gamma_{t-1}^M \right)^{-\gamma}$ be the Lagrange multiplier associated with the household's budget constraint. The optimality conditions for the household's problem are $(1) - (3)$ in the paper , the non-Ponzi game condition holding with equality and

$$\left[\frac{C_t}{\Gamma_{t-1}^M} - \eta \frac{\widetilde{C}_{t-1}}{\Gamma_{t-1}^M} - \nu \left(l_t \right)^{\omega} \right]^{-\gamma} = \lambda_t p_t^C,$$

$$\nu \omega l_t^{\omega-1} = \frac{W_t}{p_t^C} \frac{1}{\Gamma_{t-1}^M},$$

$$\lambda_t \left[1 - \psi \left(\frac{D_{t+1}}{\Gamma_t^M} - \overline{d} \right) \right] = \beta \left(\gamma_t^M \right)^{-\gamma} \left(1 + r_t \right) E_t \left\{ \lambda_{t+1} \right\},$$

$$\lambda_t \left[1 + \phi^X \left(\frac{K_{t+1}^X}{K_t^X} - \gamma^{X,k} \right) \right] = \beta \left(\gamma_t^M \right)^{-\gamma} E_t \left\{ \frac{\lambda_{t+1}}{v_{t+1}} \left[Q_{t+1}^X V_{t+1} + (1 - \delta) + ... \right. \right.$$

$$\left. \left. ... + \phi^X \left(\frac{K_{t+2}^X}{K_{t+1}^X} - \gamma^{X,k} \right) \frac{K_{t+2}^X}{K_{t+1}^X} - \frac{\phi^X}{2} \left(\frac{K_{t+2}^X}{K_{t+1}^X} - \gamma^{X,k} \right)^2 \right] \right\},$$

$$\lambda_t \left[1 + \phi^M \left(\frac{K_{t+1}^M}{K_t^M} - \gamma^{M,k} \right) \right] = \beta \left(\gamma_t^M \right)^{-\gamma} E_t \left\{ \frac{\lambda_{t+1}}{v_{t+1}} \left[Q_{t+1}^M V_{t+1} + (1 - \delta) + ... \right. \right.$$

$$\left. \left. ... + \phi^M \left(\frac{K_{t+2}^M}{K_{t+1}^M} - \gamma^{M,k} \right) \frac{K_{t+2}^M}{K_{t+1}^M} - \frac{\phi^M}{2} \left(\frac{K_{t+2}^M}{K_{t+1}^M} - \gamma^{M,k} \right)^2 \right] \right\},$$

$$\lambda_t \left[1 + \phi^N \left(\frac{K_{t+1}^N}{K_t^N} - \gamma^{N,k} \right) \right] = \beta \left(\gamma_t^M \right)^{-\gamma} E_t \left\{ \frac{\lambda_{t+1}}{v_{t+1}} \frac{P_{t+1}^N}{P_t^N} \left[Q_{t+1}^N V_{t+1} + (1 - \delta) + ... \right. \right.$$

$$\left. \left. ... + \phi^N \left(\frac{K_{t+2}^N}{K_{t+1}^N} - \gamma^{N,k} \right) \frac{K_{t+2}^N}{K_{t+1}^N} - \frac{\phi^N}{2} \left(\frac{K_{t+2}^N}{K_{t+1}^N} - \gamma^{N,k} \right)^2 \right] \right\},$$

The optimality conditions associated with the production of exportable, importable and non-traded goods are $(6) - (8)$ in the paper and

$$P_t^X \alpha_{XK} Y_t^X \left(K_t^X \right)^{-1} = Q_t^X,$$

$$\alpha_M Y_t^M \left(K_t^M \right)^{-1} = Q_t^M,$$

$$\alpha_N Y_t^N \left(K_t^N \right)^{-1} = Q_t^N,$$

$$P_t^X \alpha_{XL} Y_t^X \left(l_t^X \right)^{-1} = \left(1 + r_t^d \theta \right) W_t,$$

$$(1 - \alpha_M) Y_t^M \left(l_t^M \right)^{-1} = \left(1 + r_t^d \theta \right) W_t,$$

$$P_t^N (1 - \alpha_N) Y_t^N \left(l_t^N \right)^{-1} = \left(1 + r_t^d \theta \right) W_t.$$

Finally, the optimality conditions for tradables and final consumption sectors are $(4), (5)$ in the paper and

$$P_t^T \kappa C_t^T \left(C_t^X \right)^{-1} = P_t^X,$$

$$P_t^T (1 - \kappa) C_t^T (C_t^M)^{-1} = 1.$$

$$p_t^C (Y_t^C)^{\mu+1} \chi \left(\frac{\Gamma_{t-1}^M}{\Gamma_{t-1}^T} \right)^{-\mu} (C_t^T)^{-\mu-1} = P_t^T,$$

$$p_t^C (Y_t^C)^{\mu+1} (1 - \chi) \left(\frac{\Gamma_{t-1}^M}{\Gamma_{t-1}^N} \right)^{-\mu} (C_t^N)^{-\mu-1} = P_t^N.$$

B.2.2 Equilibrium Conditions

The model has a stochastic trend in equilibrium due to the presence of Z_t and V_t. We shall then transform the model in order to reach a stationary representation. This is not straight forward due to the difference in capital shares across sectors. To see why, consider an permanent increase in V_t, which will make investment in capital more attractive. Because capital is substitutable between sectors, the production in the sector with higher capital share will experience faster growth. That will additionally imply that the equilibrium relative price of that good should decrease. Therefore, it is necessary to consider different stochastic trends for different sectors and relative prices. A detailed discussion of the required transformations is presented in García-Cicco (2007), including the assumptions about utility needed for the model to exhibit a balanced growth path.

In order to characterize the stationary equilibrium, we first define the following equilibrium stochastic trends

$$\Gamma_t^M \equiv Z_t (V_t)^{\alpha_M/(1-\alpha_M)},$$

$$\Gamma_t^X \equiv \Gamma_t^M (V_t)^{(\alpha_{XK}/(\alpha_{XK}+\alpha_{XL})-\alpha_M)/(1-\alpha_M)},$$

$$\Gamma_t^N \equiv \Gamma_t^M (V_t)^{\alpha_N/(1-\alpha_N)-\alpha_M/(1-\alpha_M)},$$

$$\Gamma_t^T \equiv (\Gamma_t^M)^{1-\kappa} (\Gamma_t^X)^{\kappa}.$$

In addition, let $\gamma_t^j = \Gamma_t^j/\Gamma_{t-1}^j$ for $j = X, M, N, T$. Intuitively, allocations measured in terms of j will have an equilibrium stochastic trend given by Γ_t^j, and the stochastic

trend for relative prices will be determined by the (inverse) of the respective relative growth rates. Formally, define the following transformed variables

$$
\begin{array}{lll}
c_t = C_t/\Gamma_{t-1}^M & c_t^X = C_t^X/\Gamma_{t-1}^X & c_t^M = C_t^M/\Gamma_{t-1}^M \\
c_t^N = C_t^N/\Gamma_{t-1}^N & c_t^T = C_t^T/\Gamma_{t-1}^T & y_t^C = Y_t^C/\Gamma_{t-1}^M \\
y_t^X = Y_t^X/\Gamma_{t-1}^X & y_t^M = Y_t^M/\Gamma_{t-1}^M & y_t^N = Y_t^N/\Gamma_{t-1}^N \\
y_t^T = Y_t^T/\Gamma_{t-1}^T & y_t = Y_t/\Gamma_{t-1}^M & i_t = I_t/\Gamma_{t-1}^M \\
i_t^X = I_t^X/\Gamma_{t-1}^M & i_t^M = I_t^M/\Gamma_{t-1}^M & i_t^N = I_t^N/\Gamma_{t-1}^N \\
g_t = G_t/\Gamma_{t-1}^M & k_t = K_t/\left(\Gamma_{t-1}^M V_{t-1}\right) & k_t^X = K_t^X/\left(\Gamma_{t-1}^M V_{t-1}\right) \\
k_t^M = K_t^M/\left(\Gamma_{t-1}^M V_{t-1}\right) & k_t^N = K_t^N/\left(\Gamma_{t-1}^N V_{t-1}\right) & p_t^X = P_t^X\Gamma_{t-1}^X/\Gamma_{t-1}^M \\
p_t^N = P_t^N\Gamma_{t-1}^N/\Gamma_{t-1}^M & p_t^T = P_t^T\Gamma_{t-1}^T/\Gamma_{t-1}^M & tot_t = TOT_t\Gamma_{t-1}^X/\Gamma_{t-1}^M \\
w_t = W_t/\Gamma_{t-1}^M & tr_t = T_t/\Gamma_{t-1}^M & q_t^X = Q_t^X V_{t-1} \\
q_t^M = Q_t^M V_{t-1} & q_t^N = Q_t^N V_{t-1} & tb_t = TB_t/\Gamma_{t-1}^M \\
d_t = D_t/\Gamma_{t-1}^M & &
\end{array}
$$

Finally, let $\gamma^{X,k} = \gamma^{M,k} = v\gamma^M$ and $\gamma^{N,k} = v\gamma^N$, where variables without time subscripts denote non-stochastic steady state values.

With these definitions at hand, we can now specify the complete set of stationary equilibrium conditions:

$$
\left[c_t - \eta\frac{c_{t-1}}{\gamma_{t-1}^M} - \nu\left(l_t\right)^\omega\right]^{-\gamma} = \lambda_t p_t^C, \tag{B.1}
$$

$$
\nu\omega l_t^{\omega-1} = \frac{w_t}{p_t^C}, \tag{B.2}
$$

$$
\lambda_t\left[1 - \psi\left(d_{t+1} - \overline{d}\right)\right] = \beta\left(\gamma_t^M\right)^{-\gamma}\left(1 + r_t\right)E_t\left\{\lambda_{t+1}\right\}, \tag{B.3}
$$

$$
\lambda_t\left[1 + \phi^X\left(\frac{k_{t+1}^X}{k_t^X}\gamma_t^M v_t - \gamma^M v\right)\right] = \beta\left(\gamma_t^M\right)^{-\gamma}E_t\left\{\frac{\lambda_{t+1}}{v_{t+1}}\left[q_{t+1}^X v_{t+1} + (1-\delta) + ...\right.\right.
$$

$$
\left.\left. ... + \phi^X\left(\frac{k_{t+2}^X}{k_{t+1}^X}\gamma_{t+1}^M v_{t+1} - \gamma^M v\right)\frac{k_{t+2}^X}{k_{t+1}^X}\gamma_{t+1}^M v_{t+1} - \frac{\phi^X}{2}\left(\frac{k_{t+2}^X}{k_{t+1}^X}\gamma_{t+1}^M v_{t+1} - \gamma^M v\right)^2\right]\right\}, \tag{B.4}
$$

$$\lambda_t \left[1 + \phi^M \left(\frac{k_{t+1}^M}{k_t^M} \gamma_t^M v_t - \gamma^M v \right) \right] = \beta \left(\gamma_t^M \right)^{-\gamma} E_t \left\{ \frac{\lambda_{t+1}}{v_{t+1}} \left[q_{t+1}^M v_{t+1} + (1-\delta) + \ldots \right. \right.$$

$$\left. \left. \ldots + \phi^M \left(\frac{k_{t+2}^M}{k_{t+1}^M} \gamma_{t+1}^M v_{t+1} - \gamma^M v \right) \frac{k_{t+2}^M}{k_{t+1}^M} \gamma_{t+1}^M v_{t+1} - \frac{\phi^M}{2} \left(\frac{k_{t+2}^M}{k_{t+1}^M} \gamma_{t+1}^M v_{t+1} - \gamma^M v \right)^2 \right] \right\},$$

$$\text{(B.5)}$$

$$\lambda_t \left[1 + \phi^N \left(\frac{k_{t+1}^N}{k_t^N} \gamma_t^N v_t - \gamma^N v \right) \right] = \beta \left(\gamma_t^M \right)^{-\gamma} E_t \left\{ \frac{\lambda_{t+1}}{v_{t+1}} \frac{p_{t+1}^N}{p_t^N} \frac{\gamma_t^M}{\gamma_t^N} \left[q_{t+1}^N v_{t+1} + 1 - \delta + \right. \right.$$

$$\left. \left. \ldots + \phi^N \left(\frac{k_{t+2}^N}{k_{t+1}^N} \gamma_{t+1}^N v_{t+1} - \gamma^N v \right) \frac{k_{t+2}^N}{k_{t+1}^N} \gamma_{t+1}^N v_{t+1} - \frac{\phi^N}{2} \left(\frac{k_{t+2}^N}{k_{t+1}^N} \gamma_{t+1}^N v_{t+1} - \gamma^N v \right)^2 \right] \right\},$$

$$\text{(B.6)}$$

$$k_{t+1}^X \gamma_t^M = (1-\delta) k_t^X / v_t + i_t^X, \tag{B.7}$$

$$k_{t+1}^M \gamma_t^M = (1-\delta) k_t^M / v_t + i_t^M, \tag{B.8}$$

$$k_{t+1}^N \gamma_t^N = (1-\delta) k_t^N / v_t + i_t^N, \tag{B.9}$$

$$i_t = i_t^X + i_t^M + p_t^N i_t^N, \tag{B.10}$$

$$k_t = k_t^X + k_t^M + p_t^N k_t^N, \tag{B.11}$$

$$\left(1 + r_t^d \right) = \frac{(1 + r_t)}{1 - \psi \left(d_{t+1} - \overline{d} \right)}, \tag{B.12}$$

$$y_t^X = a_t^X \left(k_t^X \right)^{\alpha_{XK}} \left(z_t l_t^X \right)^{\alpha_{XL}} (F)^{1 - \alpha_{XK} - \alpha_{XL}}, \tag{B.13}$$

$$y_t^M = a_t^M \left(k_t^M \right)^{\alpha_M} \left(z_t l_t^M \right)^{1 - \alpha_M}, \tag{B.14}$$

$$y_t^N = a_t^N \left(k_t^N \right)^{\alpha_N} \left(z_t l_t^N \right)^{1 - \alpha_N}, \tag{B.15}$$

$$p_t^X \alpha_{XK} y_t^X \left(k_t^X \right)^{-1} = q_t^X, \tag{B.16}$$

$$\alpha_M y_t^M \left(k_t^M \right)^{-1} = q_t^M, \tag{B.17}$$

$$\alpha_N y_t^N \left(k_t^N \right)^{-1} = q_t^N, \tag{B.18}$$

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$$p_t^X \alpha_{XL} y_t^X \left(l_t^X\right)^{-1} = \left(1 + r_t^d \theta\right) w_t, \tag{B.19}$$

$$\left(1 - \alpha_M\right) y_t^M \left(l_t^M\right)^{-1} = \left(1 + r_t^d \theta\right) w_t, \tag{B.20}$$

$$p_t^N \left(1 - \alpha_N\right) y_t^N \left(l_t^N\right)^{-1} = \left(1 + r_t^d \theta\right) w_t, \tag{B.21}$$

$$c_t^T = \left(c_t^X\right)^\kappa \left(c_t^M\right)^{1-\kappa}, \tag{B.22}$$

$$p_t^T \kappa c_t^T \left(c_t^X\right)^{-1} = p_t^X, \tag{B.23}$$

$$p_t^T \left(1 - \kappa\right) c_t^T \left(c_t^M\right)^{-1} = 1, \tag{B.24}$$

$$y_t^C = \left\{ \chi \left[c_t^T\right]^{-\mu} + \left(1 - \chi\right) \left[c_t^N\right]^{-\mu} \right\}^{-1/\mu}, \tag{B.25}$$

$$p_t^C \left(y_t^C\right)^{\mu+1} \chi \left(c_t^T\right)^{-\mu-1} = p_t^T, \tag{B.26}$$

$$p_t^C \left(y_t^C\right)^{\mu+1} \left(1 - \chi\right) \left(c_t^N\right)^{-\mu-1} = p_t^N, \tag{B.27}$$

$$p_t^X = t p_t tot_t, \tag{B.28}$$

$$p_t^C g_t = \left(1 - t p_t\right) tot_t \left(y_t^X - c_t^X\right) + tr_t, \tag{B.29}$$

$$l_t = l_t^X + l_t^M + l_t^N, \tag{B.30}$$

$$y_t^C = c_t + g_t, \tag{B.31}$$

$$y_t^N = c_t^N + i_t^N, \tag{B.32}$$

$$\left(1 + r_t\right) = \left(1 + r w_t\right) \left(1 + c p_t\right), \tag{B.33}$$

$$tb_t = p_t^X \left(y_t^X - c_t^X\right) - \left(c_t^M + i_t^M + i_t^X - y_t^M\right), \tag{B.34}$$

$$y_t = p_t^C \left(c_t + g_t\right) + i_t + tb_t, \tag{B.35}$$

$$d_{t+1} \gamma_t^M = \left(1 + r_{t-1}\right) d_t - tb_t + \frac{\psi}{2} \left(d_{t+1} - \overline{d}\right)^2 \gamma_t^M + \frac{\phi^X}{2} \left(\frac{k_{t+1}^X}{k_t^X} \gamma_t^M v_t - \gamma^M v\right)^2 k_t^X / v_t +$$

$$\tag{B.36}$$

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$$+\frac{\phi^M}{2}\left(\frac{k_{t+1}^M}{k_t^M}\gamma_t^M v_t - \gamma^M v\right)^2 k_t^M/v_t + p^N\frac{\phi^N}{2}\left(\frac{k_{t+1}^N}{k_t^N}\gamma_t^N v_t - \gamma^N v\right)^2 k_t^N/v_t+$$

$$+\left(p_t^X - tot_t\right)\left(y_t^X - c_t^X\right) + r_t^d\theta w_t l_t.$$

In addition, we have the ten equations defining the exogenous stochastic processes $(14)-(20)$ in the paper; which add up to a total of 46 equations.

Therefore, a stationary competitive equilibrium for this economy is a set of stationary processes for 26 allocations $\{c_t,\ y_t,\ y_t^X,\ y_t^M,\ y_t^N,\ y_t^C,\ c_t^X,\ c_t^M,\ c_t^N,\ c_t^T,\ i_t^X,\ i_t^M,\ i_t^N,\ i_t,\ k_{t+1}^X,\ k_{t+1}^M,\ k_{t+1}^N,\ k_{t+1},\ d_{t+1},\ l_t^X,\ l_t^M,\ l_t^N,\ l_t,\ tb_t,\ tr_t,\ \lambda_t\}_{t=0}^\infty$ and 10 endogenous prices $\{p_t^X,\ p_t^N,\ p_t^T,\ p_t^C,\ q_t^X,\ q_t^M,\ q_t^N,\ w_t,\ r_t^d,\ r_t\}_{t=0}^\infty$ satisfying $(B.3)$-$(B.36)$; given initial conditions $k_0^M,\ k_0^X,\ k_0^N,\ d_0$ and given the defining processes for the 10 exogenous variables $\{a_t^X,\ a_t^M,\ a_t^N,\ z_t,\ v_t,\ g_t,\ rw_t,\ cp_t,\ tp_t,\ tot_t\}_{t=0}^\infty$ presented in $(14)-(20)$ in the paper.

B.2.3 Steady State

Let variables without time subscripts denote non-stochastic steady sate values. We show how to compute the steady state for given values of all parameters (expect for $\overline{d}$, β and ν which are determined endogenously), for given steady state values of the stochastic shocks (with the exception of g which is set to match s^g), and for given values for l, tby, s^g and F.

In order to compute the remaining values in steady state, first,

$$\gamma^M = zv^{\alpha_M/(1-\alpha_M)}, \tag{B.37}$$

$$\gamma^X \equiv \gamma^M v^{(\alpha_{XK}/(\alpha_{XK}+\alpha_{XL})-\alpha_M)/(1-\alpha_M)}, \tag{B.38}$$

$$\gamma^N = \gamma^M v^{\alpha_N/(1-\alpha_N)-\alpha_M/(1-\alpha_M)}, \tag{B.39}$$

$$\gamma^T = \left(\gamma^M\right)^{1-\kappa}\left(\gamma^X\right)^\kappa. \tag{B.40}$$

Also, using (B.28)

$$\boxed{p^X = tp \cdot tot.} \tag{B.41}$$

Using (B.33),

$$(1 + r) = (1 + rw)(1 + cp). \tag{B.42}$$

Using (B.12),

$$r^d = r. \tag{B.43}$$

Using (B.3),

$$\beta = (1 + r)^{-1} \left(\gamma^M\right)^\gamma. \tag{B.44}$$

Using (B.4),

$$q^X = \frac{(1+r)v - 1 + \delta}{v}. \tag{B.45}$$

Using (B.4) and (B.5),

$$q^M = q^X. \tag{B.46}$$

Using (B.6),

$$q^N = \frac{(1+r)v\gamma^N/\gamma^M - 1 + \delta}{v}. \tag{B.47}$$

Using (B.13)-(B.14) and (B.16)-(B.17),

$$\left(l^M/k^M\right) = \left[\frac{q^M}{\alpha_M a^M z^{(1-\alpha_M)}}\right]^{1/(1-\alpha_M)}, \tag{B.48}$$

$$\left(l^X/k^X\right) = \left[\frac{q^X}{\alpha_{XK} a^X z^{(\alpha_{XL})}(F/l_X)^{1-\alpha_{XK}-\alpha_{XL}}}\right]^{1/(1-\alpha_{XK})}. \tag{B.49}$$

Then, using (B.19) and (B.20) we have that,

$$\left(l^X/k^X\right) = \left(l^M/k^M\right)\frac{\alpha_M}{(1-\alpha_M)}\frac{\alpha_{XL}}{\alpha_{XK}}. \tag{B.50}$$

This expression can be used to find l^X as a function of parameters, in particular F. Note that this is only possible under the assumption of a fixed factor (i.e. $\alpha_{XK} +$

$\alpha_{XL} < 1$). If the production function is h.d.1. in labor and capital for both sectors X and M, the steady state will generally exhibit a corner solution.

Then, using also (B.7)

$$k^X = \left(l^X/k^X\right)/l^X, \qquad i^X = \left(\gamma^M - 1 + \delta\right) k^X. \tag{B.51}$$

Using (B.13),

$$y^X = a^X \left(k^X\right)^{\alpha_{XK}} \left(zl^X\right)^{\alpha_{XL}} (F)^{1-\alpha_{XK}-\alpha_{XL}}, \tag{B.52}$$

Using (B.18),

$$\left(l^N/k^N\right) = \left[\frac{q^N}{\alpha_N a^N z^{(1-\alpha_N)}}\right]^{1/(1-\alpha_N)}. \tag{B.53}$$

Using (B.19),

$$w = \frac{p^X \alpha_{XL} y^X / l^X}{(1 + r^d \theta)}. \tag{B.54}$$

Using (B.20) and (B.21),

$$p^N = \frac{(1-\alpha_M) y^M / l^M}{(1-\alpha_N) y^N / l^N}. \tag{B.55}$$

where y^M/l^M and y^N/l^N are known given l^M/k^M and l^N/k^N, due to the h.d.1. technology in these sectors. From (B.22)-(B.24),

$$p^T = (1 - \kappa)^{-(1-\kappa)}(\kappa)^{-\kappa} \left(p^X\right)^{\kappa}. \tag{B.56}$$

Using (B.32),

$$\left(c^N/l^N\right) = \left(y^N/l^N\right) - \left(\gamma^N - 1 + \delta\right) \left(l^N/k^N\right)^{-1}. \tag{B.57}$$

Using (B.26) and (B.27),

$$\left(c^T/l^N\right) = \left[\left(\frac{\chi}{1-\chi}\right) \frac{p^N}{p^T}\right]^{1/(1+\mu)} \left(c^N/l^N\right). \tag{B.58}$$

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Using (B.34), for a given values for l and tby, we can show that,

$$l^N = A^N/B^N, \tag{B.59}$$

where

$$A^N \equiv p^X y^X (1 - tby) - i^X + \left(l - l^X\right) \left[(1 - tby) \left(y^M/l^M\right) - \left(i^M/l^M\right)\right], \tag{B.60}$$

and

$$B^N \equiv (1 - tby) \left(y^M/l^M\right) - \left(i^M/l^M\right) + tby \left(y^N/l^N\right) p^N + \left(c^T/l^N\right) p^T. \tag{B.61}$$

Then, using (B.30),

$$l^M = l - l^N - l^X. \tag{B.62}$$

Also, using (B.8)-(B.11),

$$k^N = \left(l^N/k^N\right)/l^N, \qquad k^M = \left(l^M/k^M\right)/l^M, \tag{B.63}$$

$$i^M = \left(\gamma^M - 1 + \delta\right) k^M, \qquad i^N = \left(\gamma^N - 1 + \delta\right) k^N, \tag{B.64}$$

$$k = k^X + k^M + p^N k^N, \tag{B.65}$$

$$i = i^X + i^M + p^N i^N. \tag{B.66}$$

Using (B.14) and(B.15)

$$y^M = a^M \left(k^M\right)^{\alpha_M} \left(z l^M\right)^{1-\alpha_M}, \tag{B.67}$$

$$y^N = a^N \left(k^N\right)^{\alpha_N} \left(z l^N\right)^{1-\alpha_N}. \tag{B.68}$$

Using (B.32),

$$c^N = y^N - i^N. \tag{B.69}$$

Using (B.26) and (B.27),

$$c^T = \left(c^T/l^N\right) l^N.$$

(B.70)

Using (B.24),

$$c^M = c^T(1 - \kappa)p^T.$$

(B.71)

Using (B.23) and (B.24) ,

$$c^X = \left(\frac{\kappa}{1-\kappa}\right) \frac{c^M}{p^X}.$$

(B.72)

Using (B.34) ,

$$tb = p^X \left(y^X - c^X\right) - \left(c^M + i^M + i^X - y^M\right).$$

(B.73)

From (B.25)-(B.27),

$$p^C = \left[\chi^{\frac{1}{1+\mu}} \left(p^T\right)^{\frac{\mu}{1+\mu}} + (1 - \chi)^{\frac{1}{1+\mu}} \left(p^N\right)^{\frac{\mu}{1+\mu}}\right]^{\frac{1+\mu}{\mu}}.$$

(B.74)

Using (B.25) ,

$$y^C = \left[\chi \left(c^T\right)^{-\mu} + (1 - \chi) \left(c^N\right)^{-\mu}\right]^{-1/\mu}.$$

(B.75)

Using (B.35),

$$y = p^C y^C + i + tb.$$

(B.76)

Using (B.36),

$$d = \bar{d} = (1 + r - \gamma^M)^{-1} \left[tb - \left(p^X - tot\right) \left(y^X - c^X\right) - \theta r^d wl\right].$$

(B.77)

In addition,

$$g = s^g y.$$

(B.78)

Using (B.31)

$$c = y^C - g.$$

(B.79)

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Using (B.29)

$$tr = p^C g - (1 - tp)tot\left(y^X - c^X\right).$$

(B.80)

Using (B.2)

$$\nu = wl^{1-\omega}\left(p^C\omega\right)^{-1}.$$

(B.81)

Finally, using (B.1)

$$\lambda = \left[c\left(1 - \eta/\gamma^M\right) - \nu l^\omega\right]^{-\gamma}/p^C.$$

(B.82)

Appendix C

Appendix to Chapter 3

C.1 Data Sources and Definitions

Real GDP, private and public consumption and the trade balance are from Banco de Mexico.[1] These were transformed in per-capita terms using an annual population series from ECLAC,[2] transformed to quarterly using linear interpolation. On the other hand, the series of sectorial value added and total GDP (both nominal and real) are from INEGI.[3] Our measure of aggregate inflation is the change in the GDP deflator. Inflation in the non-traded sector is a weighted average of the deflators of the industries included in the non-trade sector (see next subsection), were the weights are the nominal share of each sector in total nominal value added. Finally, the sum of these shares is equal to the share of non-tradeables in total value added.

The real wage is an index from the Manufacturing sector, computed by INEGI. The nominal exchange rate is also from INEGI. The series from M1 is from Banco de Mexico from 1986, extended backwards using the series from INEGI. The nominal

[1] Their statistical website is http://www.banxico.org.mx/tipo/estadisticas/index.html.

[2] Available at http://www.eclac.cl/celade/proyecciones/basedatos_BD.htm.

[3] Their statistical website is http://dgcnesyp.inegi.org.mx/bdiesi/bdie.html.

interest rate is the CETES91.

In terms of international variables, the foreign inflation of exportables and importables is computed from the indices of foreign price of exports and imports from INEGI. Finally, the world nominal interest rate is the 3-month T-bill from FRED.[4]

C.1.1 Calibrating the Production Function

The parameters describing the production function for sectors n, x and k are calibrated, following Calvo et al. (2008), using the input-output matrix from 2003, constructed by INEGI. First, the 18 industries are collected in two groups: exportable and non-traded.[5] An industry is considered to be exportable if the share of exports in the gross value of production is at least 20%. In the case of Mexico, the Mining sector (which includes oil production) is the only industry satisfying this condition;[6] the rest are grouped in the non-traded sector.

Given this distinction, a reduced input-output matrix of two sectors is constructed, allowing to compute to the coefficient characterizing the demand for intermediate goods in each of these two sectors, including the use of imported inputs. The share of labor is computed from the share of wage payments, and the rest of value added (minus taxes and subsidies) is attributed to capital.

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[4] Available at http://research.stlouisfed.org/fred2/.

[5] Calvo et al. (2008) collect industries at a more disaggregated level. However, because we wanted to construct a time series of sectorial production, we choose to work with a higher level of aggregation in order to be consistent with the available sectorial time series.

[6] While it is possible to distinguish from the 2003 Mexican input-output matrix the part of the manufacturing production attributed to the Maquila industries (which in 2003 constitutes almost 50% of total exports), such a decomposition is not available in the NIPA time series of sectorial production that we use for estimation (this data starts in 1993). Therefore, we do not include the Maquila industry in the exportable sector. While this is clearly a limitation, two comments are in order. First, the implied coefficients for the non-tradeables production function are almost identical regardless of the inclusion of the Maquila. On the other hand, the coefficients for the exportable sector do change depending on the treatment of the Maquila, for these Manufacturing industries are more labor intensive. However, due to the structure of the Maquila industry, they will be less dependent on fluctuations of international prices relative to the Mining sector; a point that supports our choice given the data limitation.

On the other hand, the shares of imported and non-traded intermediate goods in the production of capital are calibrated from the total demand devoted to gross capital formation. Finally, we set the share of entrepreneur labor is set to a low value, 0.1%, given that this is just introduced for technical reasons.

C.2 Forming Priors

Our approach to assign priors for the parameters modifies the procedure proposed by Del Negro and Schorfheide (2006). The vector of parameters θ is decomposed in two groups, i.e. $\theta = [\theta_1', \theta_2']'$. The subset θ_1 contains parameters for which we can assign standard distribution as prior based on parameter constraints and on previous studies (preferences, technology, policy, etc), while θ_2 collects the ones for which this task is more complicated (for instance, those describing the evolution of the driving forces). The general idea of this procedure is to choose a distribution for θ_2 capable to generate several characteristics (moments) that we observe in the data. Here, we describe the general approach and the implementation suggested by Del Negro and Schorfheide (2006), as well as the modifications we introduced relative to their work.

The general structure proposed by Del Negro and Schorfheide (2006) is

$$ p\left(\theta|\Omega^*\right) = c_1\left(\theta_1|\Omega^*\right) L(\theta_1, \theta_2|\Omega^*)\pi(\theta_2)p(\theta_1), $$

where $p(\theta_1)$ is the prior that we choose based on previous studies and $\pi(\theta_2)$ is an initial prior for θ_2, which might be uninformative (i.e. flat). The sufficient statistics of interest are collected in Ω^* and the function $L(\theta_1, \theta_2|\Omega^*)$ (to be specified) measures the probability that the model can accurately replicate the characteristics collected in Ω^*. Additionally, the normalization constant $c_1\left(\theta_1|\Omega^*\right)$ is set such that

$$ \frac{1}{c_1\left(\theta_1|\Omega^*\right)} = \int L(\theta_1, \theta_2|\Omega^*)\pi(\theta_2)d\theta_2. $$

In this way, we can interpret $p(\theta_2|\theta_1, \Omega^*) \equiv c_1(\theta_1|\Omega^*) L(\theta_1, \theta_2|\Omega^*)\pi(\theta_2)$ as the conditional probability of θ_2 given θ_1, implying that we are factorizing the overall prior using the Bayes Theorem. Moreover, the normalization constant ensure that $p(\theta_2|\theta_1, \Omega^*)$ is proper and thus, if $p(\theta_1)$ also integrates to one, $p(\theta|\Omega^*)$ will be proper as well; the later being a most relevant requirement for model comparison porpoises.

Del Negro and Schorfheide (2006) suggest to implement this approach as follows. First, recognizing that to calculate the constant is computationally cumbersome, they propose to evaluate $p(\theta_2|\theta_1, \Omega^*)$ at a given value $\bar{\theta}_1$. Therefore, the actual prior they use is

$$p(\theta|\Omega^*) = c_1(\bar{\theta}_1|\Omega^*) L(\bar{\theta}_1, \theta_2|\Omega^*)\pi(\theta_2)p(\theta_1).$$

Under this simplification, the prior for θ_2 is independent from $p(\theta_1)$. In order to compute the constant $c_1(\bar{\theta}_1|\Omega^*)$, the Metropolis-Hastings algorithm can be used to randomly draw from $L(\bar{\theta}_1, \theta_2|\Omega^*)\pi(\theta_2)$, calculating then the constant using the modified harmonic mean proposed by Geweke (1999).

On the other hand, their choice for $L(\bar{\theta}_1, \theta_2|\Omega^*)$ works as follows. In general, a VAR of order p with Gaussian errors can be written in compact form as $y_t' = x_t'\Phi + u_t'$, where the relevant parameters are collected in the matrices Φ and Σ, the latter being the variance-covariance matrix of the error term. Let $\Phi(\theta)$ and $\Sigma(\theta)$ be the analogous matrices coming from the VAR approximation of the model.[7] Additionally, suppose that we have T^* observations and we compute the associated sufficient statistics, i.e. $\sum y_t^* y_t^{*'} = T^*\Gamma_{yy}^*$, $\sum y_t^* x_t^{*'} = T^*\Gamma_{yx}^*$ and $\sum x_t^* x_t^{*'} = T^*\Gamma_{xx}^*$. Then, the quasi-likelihood

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[7] These are related with the population covariances under the model ($\Gamma_{yy}(\theta) \equiv E_\theta(y_t y_t')$, $\Gamma_{yx}(\theta) \equiv E_\theta(y_t x_t')$ and $\Gamma_{xx}(\theta) \equiv E_\theta(x_t x_t')$) by the least-square population regression $\Phi(\theta) = [\Gamma_{xx}(\theta)]^{-1} [\Gamma_{yx}(\theta)]'$ and $\Sigma(\theta) = \Gamma_{yy}(\theta) - \Gamma_{yx}(\theta)\Phi(\theta)$.

of the parameters (premultiplied by $|\Sigma(\theta)|^{-(n+1)/2}$) is given by

$$L(\theta|\Omega^*) = |\Sigma(\theta)|^{-(T^*+n+1)/2} \times$$

$$\times \exp\left\{-\frac{T^*}{2}tr\left[\Sigma(\theta)^{-1}\left(\Gamma_{yy}^* - \Phi(\theta)'\Gamma_{yx}^{*'} - \Gamma_{yx}^*\Phi(\theta) + \Phi(\theta)'\Gamma_{xx}^*\Phi(\theta)\right)\right]\right\},$$

where $\Omega^* = \left\{\Gamma_{yy}^*, \Gamma_{yx}^*, \Gamma_{xx}^*, T^*\right\}$. Thus, using this quasi-likelihood as a component of the prior would imply that we are "centering" our beliefs around the moments collected in the sufficient statistics. The lag length p in the VAR will determine which moments to match: for instance, if $p = 1$ we are matching *all* the covariances and first auto-covariances. Additionally, the parameter T^* will govern the precision of the quasi-likelihood, for it determines how concentrated $L(\theta|\Omega^*)$ is around the targeted moments.

Our approach differs from Del Negro and Schorfheide (2006) in two aspects: the treatment of the normalizing constant and the choice of $L(\theta|\Omega^*)$. First, while fixing a value $\bar{\theta}_1$ solves the computational problem, it is not clear what value should be chosen or how it will affect the results.[8] Moreover, "bad" choices for $\bar{\theta}_1$ may result in the model not being able to match the targeted moments. Therefore, we propose to replace $c_1\left(\bar{\theta}_1|\Omega^*\right)$ with $\tilde{c}_1\left(\Omega^*\right)$, where

$$\frac{1}{\tilde{c}_1\left(\Omega^*\right)} = \int L(\theta_1, \theta_2|\Omega^*)\pi(\theta_2)p(\theta_1)d\theta.$$

Several comments are in order. First, notice that instead of fixing an arbitrary value we are setting the constant equal to the unconditional expectation of the (inverse of the) constant ideally suggested by Del Negro and Schorfheide (2006) –i.e. $\tilde{c}_1\left(\Omega^*\right) = E_{\theta_1}[c_1\left(\theta_1|\Omega^*\right)^{-1}]$, where expectations are taken with respect to $p(\theta_1)$. Additionally, $\tilde{c}_1\left(\Omega^*\right)L(\theta_1, \theta_2|\Omega^*)\pi(\theta_2)$ is not the conditional probability of

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[8] Del Negro and Schorfheide (2006) set it to the mean under $p(\theta_1)$, although they don't report the robustness with respect to this choice.

θ_2 given θ_1 either and it might not be proper. Nevertheless, the final prior $\tilde{p}(\theta|\Omega^*) \equiv \tilde{c}_1(\Omega^*) L(\theta_1, \theta_2|\Omega^*)\pi(\theta_2)p(\theta_1)$ is indeed proper, what is the relevant requirement for model comparison. Finally, this constant can also be computed with the procedure outlined before, the only difference being that we should now use the Metropolis-Hastings algorithm to draw from $L(\theta_1, \theta_2|\Omega^*)\pi(\theta_2)p(\theta_1)$.[9]

In terms of the choice of $L(\theta|\Omega^*)$, using the quasi-likelihood has two limitations. First, the only degree of freedom that we have available in selecting which moments to match is the parameter p, and given this value we ask the model to match *all* the auto-covariances up to order p. However, this might be to restrictive and we may want to choose fewer moments to match. Second, even if we want to match all the moments for a given p, the procedure proposed by Del Negro and Schorfheide (2006) will weight which moments are more important according to the model, through the matrix $\Sigma(\theta)$. Alternatively, we may want to assign more weight to certain moments, or to let the data tell us which moments should be weighted more. Thus, we replace the quasi-likelihood $L(\theta|\Omega^*)$ with the minimum-distance objective function

$$\tilde{L}(\theta|\Omega^*) = \exp\left\{-\left[m^* - m(\theta)\right]' W^* \left[m^* - m(\theta)\right]\right\},$$

where m^* is the vector of moments that we want to match, $m(\theta)$ are those same moments generated by the model for a given parameterization θ, W^* is a positive-definite weighting matrix,[10] and $\Omega^* = \{m^*, W^*\}$. Additionally, in the same way that T^* was a measure of concentration of the prior around the targeted moments, we can always multiply the matrix W^* by an arbitrary constant which will serve the same goal as T^*. Finally, notice that, although $\tilde{L}$ is not a likelihood function, $\tilde{p}(\theta|\Omega^*)$ is

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[9] This alternative has an additional computational advantage. In the original, for each draw from the posterior we need to solve the model twice: for parameters $\left[\bar{\theta}'_1, \theta'_2\right]'$ to compute the prior and for $\left[\theta'_1, \theta'_2\right]'$ to compute the likelihood. Under the alternative, we only need to solve the model once for each draw.

[10] A possible choice for W^* is the optimal weighting matrix (i.e. $W^* = (S^*)^{-1}$ where S^* is an estimate of the spectral density of m^*).

indeed a probability distribution. In fact, it is a particular case of a quasi-posterior distribution as defined by Chernozhukov and Hong (2003).

C.3   Comparing Models Using a Loss-Function

In this section be briefly describe the implementation of the procedure developed by Schorfheide (2000). The goal is to compare a collection of DSGE models $\mathcal{M}_i$ for $i = 1, ..., N$ (in our case, all the variants of the Baseline Model) based on their ability to match certain population characteristics collected in the vector z (moments in our case) of size n_z. Let $\mathcal{M}_0$ be a reference model (in our case, the BVAR). For each model, we can compute z as a function of its parameters. Therefore, given random draws from the parameters' posterior distribution of model i, $p\left(\theta_i | X^T, \mathcal{M}_i\right)$, we can easily obtain draws from the moments' posterior $p\left(z | X^T, \mathcal{M}_i\right)$.

The choice of models is based on a loss function $L\left(z, \hat{z}\right)$ that penalizes deviations of the DSGE model prediction $\hat{z}$ from the population characteristics z. Based on a general loss function, the optimal predictor under model i, denoted by $\hat{z}_i$, is defined as

$$\hat{z}_i \equiv \arg\min_{\tilde{z} \in R^{n_z}} \int L\left(z, \tilde{z}\right) p\left(z | X^T, \mathcal{M}_i\right) dz.$$

Given this prediction, the DSGE models are judged according to the risk (expected loss) of $\hat{z}_i$ under the posterior distribution $p\left(z | X^T, \mathcal{M}_0\right)$,[11] defined as

$$R\left(\hat{z}_i | X^T\right) \equiv \int L\left(z, \hat{z}_i\right) p\left(z | X^T, \mathcal{M}_0\right) dz.$$

This posterior risk provides an absolute measure of how well model i predicts the population characteristics z, and it the can be used to compare models: model i is

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[11] In the more general framework, this expectation is computed with respect to the overall posterior $p\left(z | X^T\right) = \sum_{i=0}^{N} \pi_{i,T} p\left(z | X^T, \mathcal{M}_i\right)$, where $\pi_{i,T}$ is the posterior probability of model i. However, as indicated by Schorfheide (2000), if the DSGE has less structural shocks than observables (as it is the case here) these probabilities are equal to zero (i.e. $\pi_{i,T} = 0$ for $i = 1, ..., N$) and therefore $p\left(z | X^T\right) = p\left(z | X^T, \mathcal{M}_0\right)$.

preferred to j if $R\left(\hat{z}_i|X^T\right) < R\left(\hat{z}_j|X^T\right)$.

If the loss function is quadratic (i.e. $L\left(z, \hat{z}\right) = \left(z - \hat{z}\right)' W\left(z - \hat{z}\right)$, with W being a $n_z \times n_z$ positive definite weighting matrix), the risk function simplifies to

$$R\left(\hat{z}_i|X^T\right) = \left[\hat{z}_i - E\left(z|X^T, \mathcal{M}_0\right)\right]' W\left[\hat{z}_i - E\left(z|X^T, \mathcal{M}_0\right)\right],$$

and the optimal predictor under model i is the posterior mean $\hat{z}_i = E\left(z|X^T, \mathcal{M}_i\right)$. These expectations can be computed from the random draws from the posterior.

In our case, we use as the reference model a BVAR(1) with a Minnesota prior, with tightness and weight coefficients equal to 0.2 and 0.5 respectively (see, for instance Kadiyala and Karlson, 1997).[12] The posterior is then normal and we can draw from it using a simple random number generator. Additionally, we set the weighting matrix to be diagonal, with elements equal to the inverse of the variance of each moment under the BVAR (also computed from the random draws).

C.4   Technical Appendix

This section presents the details of the Baseline model in terms of the optimality conditions, the stationary equilibrium and the computation of the non-stochastic steady state.

C.4.1   Households Optimality

Let $\lambda_t\left(\Gamma_{t-1}\right)^{-\sigma}$ be the Lagrange multiplier associated with the budget constraint (2) in the text and $\frac{\lambda_t(\Gamma_{t-1})^{-\sigma} W_t}{P_t \mu_t}$ the one for the constraint $l_t^h = l_t^d (W_t^h/W_t)^{-\theta_w}$. Imposing symmetry and defining $\pi_t^w \equiv W_t/W_{t-1}$ and $\pi_t^s \equiv S_t/S_{t-1}$, the optimality conditions for the household's problem are the two constraints holding with equality, a non-Ponzi game condition holding with equality and

$$\lambda_t\left(\Gamma_{t-1}\right)^{-\sigma} = \left(1 - l_t\right)^{\phi(1-\sigma)} \left(V_t\right)^{-\sigma+1/\zeta} b\left(X_t\right)^{-1/\zeta},$$

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[12] The lag length was chosen according to both Bayesian and Hannan-Quinn information criterion.

Table C.1: Model Comparison, Prior Distribution.

Para-meter	No C.S. mean	No C.S. 95% C.B.	No L.D. mean	No L.D. 95% C.B.	No F.A. mean	No F.A. 95% C.B.	No I.I. mean	No I.I. 95% C.B.
b	0.62	[0.62,0.62]	0.62	[0.56,0.66]	0.67	[0.5,0.83]	0.79	[0.74,0.83]
ζ	0.26	[0.26,0.26]	0.66	[0.65,0.67]	1.17	[0.89,1.49]	2.53	[2.19,2.93]
ρ_c	0.997	[0.995,0.998]	0.48	[0.46,0.51]	0.76	[0.64,0.86]	0.61	[0.5,0.74]
ν			0.83	[0.82,0.84]	0.83	[0.76,0.87]	0.26	[0.08,0.44]
χ			2.19	[2.17,2.22]	1.86	[1.75,1.97]	5.6	[2.26,11.01]
ψ_w	0.01	[0.008,0.01]	1.22	[1.09,1.3]	0.07	[0.01,0.2]	0.04	[0.01,0.12]
ψ_d	0.18	[0.17,0.18]	0.49	[0.45,0.53]	0.55	[0.43,0.67]	0.29	[0.18,0.51]
φ	1.25	[1.24,1.25]	0.95	[0.91,0.99]	1.07	[0.93,1.14]	1.21	[0.84,1.62]
ψ_n	8.02	[8.02,8.02]	5.39	[5.37,5.42]	7.15	[6.79,7.75]	5.36	[2.09,11.9]
ψ_f	2.47	[2.46,2.47]	5.26	[5.21,5.31]	7.03	[6.85,7.18]	13.71	[8.84,19.1]
ψ_k^n	0.73	[0.73,0.73]	0.93	[0.91,0.95]	1.59	[1.49,1.71]	0.39	[0.15,0.86]
ψ_k^x	1.34	[1.34,1.34]	0.42	[0.37,0.46]	0.61	[0.46,0.7]	0.39	[0.16,0.69]
rp-1	0.1	[0.1,0.11]	0	[0,0]			0.26	[0.17,0.4]
σ_ω	1.25	[1.25,1.25]	0.52	[0.49,0.57]			3.21	[2.09,4.1]
μ	0.76	[0.76,0.76]	0.18	[0.16,0.2]			0.67	[0.5,0.84]
α_i	0.13	[0.1,0.17]	0.28	[0.25,0.31]	0.37	[0.07,0.61]	0.51	[0.29,0.69]
α_π	3.08	[2.97,3.24]	1.85	[1.8,1.89]	1.48	[1.27,1.64]	2.06	[1.69,2.49]
α_y	0.46	[0.3,0.63]	0.38	[0.35,0.41]	0.54	[0.37,0.68]	0.42	[0.27,0.59]
ρ_i	0.34	[0.02,0.87]	0.3	[0.23,0.35]	0.74	[0.57,0.89]	0.43	[0.02,0.93]
ρ_π	0.36	[0.01,0.86]	0.47	[0.44,0.52]	0.13	[0.06,0.22]	0.32	[0.03,0.59]
ρ_y	0.36	[0.01,0.89]	0.79	[0.77,0.81]	0.33	[0.01,0.83]	0.96	[0.94,1]
ρ_{ξ^*}	0.47	[0.02,0.95]	0.5	[0.11,0.88]	0.4	[0.04,0.82]	0.38	[0.01,0.91]
ρ_g	0.83	[0.83,0.83]	0.45	[0.4,0.5]	0.76	[0.61,0.94]	0.89	[0.83,0.94]
$\rho_{g,gdp}$	0.17	[0.17,0.17]	0.56	[0.52,0.6]	-0.25	[-0.36,-0.15]	0.5	[0.26,0.69]
ρ_γ	0.34	[0.15,0.53]	0.33	[0.2,0.41]	0.24	[0.05,0.55]	0.28	[0.07,0.58]
ρ_{z^x}	0.98	[0.98,0.99]	0.07	[0,0.2]	0.2	[0.01,0.75]	0.07	[0,0.23]
ρ_{z^n}	0.97	[0.93,1]	0.53	[0.07,0.97]	1	[1,1]	0.22	[0.01,0.83]
σ_i	0.02	[0,0.05]	0.02	[0.02,0.02]	0.01	[0,0.01]	0.01	[0,0.01]
σ_π	0.01	[0,0.02]	0.04	[0.03,0.04]	0.05	[0.03,0.06]	0.04	[0.03,0.05]
σ_y	0.05	[0,0.11]	0.04	[0.03,0.04]	0.02	[0,0.07]	0.02	[0.01,0.03]
σ_{ξ^*}	0	[0,0.01]	0.02	[0,0.03]	0.01	[0,0.02]	0.01	[0,0.02]
σ_g	0.02	[0.01,0.03]	0.02	[0.02,0.03]	0.04	[0.03,0.06]	0	[0,0.01]
σ_γ	0.01	[0.01,0.01]	0.01	[0.01,0.01]	0	[0,0.01]	0	[0,0]
σ_{z^x}	0.05	[0.05,0.06]	0.02	[0.02,0.02]	0.03	[0.01,0.04]	0.03	[0.02,0.04]
σ_{z^n}	0.01	[0,0.01]	0	[0,0]	0.01	[0.01,0.02]	0.01	[0,0.01]

Note: C.B. denotes confidence band.

$$\frac{W_t}{P_t \mu_t} = \frac{\phi \, (V_t)^{1-1/\zeta} \, (X_t)^{1/\zeta}}{b(1 - l_t)},$$

$$\left(\frac{(\theta_w - 1)}{\theta_w} - \frac{1}{\mu_t^w}\right) l_t \theta_w = -\psi_w \left(\frac{W_t}{W_{t-1}\tilde{\pi}_t^w} - 1\right) \frac{W_t}{W_{t-1}\tilde{\pi}_t^w} +$$

$$\psi_w \beta (\gamma_t)^{-\sigma} E_t \left\{\frac{\lambda_{t+1}}{\pi_{t+1}\lambda_t} \left(\frac{W_{t+1}}{W_t \tilde{\pi}_{t+1}^w} - 1\right) \left(\frac{W_{t+1}}{W_t}\right)^2 \frac{1}{\tilde{\pi}_{t+1}^w}\right\},$$

$$i_t E_t \left\{\frac{\lambda_{t+1}}{\pi_{t+1}}\right\} = i_t^* \xi_t E_t \left\{\frac{\lambda_{t+1}\pi_{t+1}^s}{\pi_{t+1}}\right\},$$

$$\frac{i_t^* \xi_t (1 - i_t)}{(1 - i_t^* \xi_t) i_t} = \frac{\nu}{1 - \nu} \left(\frac{M_{t+1}}{D_{t+1} S_t}\right)^{-1/\chi}.$$

C.4.2 Production of Consumption Goods Optimality

Imposing symmetry in each sector and defining $\pi_t^j \equiv P_t^j/P_{t-1}^j$, The optimality conditions in terms of production and demand for inputs for firms in sector $j = x, n$ are (3) in the text and

$$W_t = MC_t^j \alpha_j^l \frac{Y_t^j}{l_t^j}, \quad R_t^j = MC_t^j \alpha_j^k \frac{Y_t^j}{k_t^j},$$

$$P_t^\iota = MC_t^j \alpha_j^\iota \frac{Y_t^j}{IC_t^{j,\iota}}, \quad \text{for} \quad \iota = x, n, f, \quad \iota \neq j.$$

with $MC_t^x = P_t^x$. For sector f the optimality condition for the allocations is

$$MC_t^f = P_t^{*f} S_t.$$

In terms of pricing, for sector x we have

$$P_t^x = P_t^{*x} S_t.$$

Given that monopolistic firms are owned by households, they discount future profits by $\beta^t \lambda_t (\Gamma_{t-1})^{-\sigma} / P_t$. Thus, for sector n we have

$$\left(\frac{(\theta_n - 1)}{\theta_n} - \frac{MC_t^n}{P_t^n} \right) \frac{Y_t^n}{\Gamma_{t-1}} \theta_n (\gamma_t)^{-1} = -\psi_n \left(\frac{\pi_t^n}{\tilde{\pi}_t} - 1 \right) \frac{\pi_t^n}{\tilde{\pi}_t} +$$

$$\psi_n \beta (\gamma_t)^{-\sigma} E_t \left\{ \frac{\lambda_{t+1} \gamma_{t+1}}{\lambda_t \pi_{t+1}} \left(\frac{\pi_{t+1}^n}{\tilde{\pi}_{t+1}} - 1 \right) \frac{(\pi_{t+1}^n)^2}{\tilde{\pi}_{t+1}} \right\},$$

For sector f,

$$\left(\frac{(\theta_f - 1)}{\theta_f} - \frac{MC_t^f}{P_t^f} \right) \frac{Y_t^f}{\Gamma_{t-1}} \theta_f (\gamma_t)^{-1} = -\psi_f \left(\frac{\pi_t^f}{\tilde{\pi}_t} - 1 \right) \frac{\pi_t^f}{\tilde{\pi}_t} +$$

$$\psi_f \beta (\gamma_t)^{-\sigma} E_t \left\{ \frac{\lambda_{t+1} \gamma_{t+1}}{\lambda_t \pi_{t+1}} \left(\frac{\pi_{t+1}^f}{\tilde{\pi}_{t+1}} - 1 \right) \frac{(\pi_{t+1}^f)^2}{\tilde{\pi}_{t+1}} \right\},$$

In terms of the production of the aggregates, the optimality conditions are (4) and (5) in the text and

$$C_t^j = \eta_j \left(\frac{P_t^T}{P_t^j} \right) C_t^T, \quad \text{for} \quad j = x, f,$$

$$C_t^n = a \left(\frac{P_t^n}{P_t} \right)^{-\varphi} Y_t^C,$$

$$C_t^T = (1 - a) \left(\frac{P_t^T}{P_t} \right)^{-\varphi} Y_t^C.$$

C.4.3   Unfinished Capital

The optimality condition in the final investment goods sector are (6) in the text and the demand for inputs

$$W_t^e = P_t^k \alpha_k^e \frac{Y_t^k}{l_t^e},$$

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$$P_t^\iota = P_t^k \alpha_k^\iota \frac{Y_t^k}{IC_t^{k,\iota}}, \quad \text{for} \quad \iota = n, f.$$

The optimality conditions for the unfinished capital sector are (7) in the text and

$$Q_t^j = \left\{ 1 - \psi_k^j \left[\frac{I_t^j}{K_t^j} - (\gamma - 1 + \delta) \right] \right\}^{-1} P_t^k,$$

$$Q_t^{old,j} = Q_t^j \left\{ 1 - \delta + \psi_k^j \left[\frac{I_t^j}{K_t^j} - (\gamma - 1 + \delta) \right] \frac{I_t^j}{K_t^j} - \frac{\psi_k^j}{2} \left[\frac{I_t^j}{K_t^j} - (\gamma - 1 + \delta) \right]^2 \right\},$$

for $j = x, n$.

C.4.4   Entrepreneurs Problem

Entrepreneurs transform unfinished into final capital goods using the linear technology $\omega_{t+1} K_{t+1}^j$ for $j = x, n$, where ω_t is i.i.d. with c.d.f. and p.d.f. given, respectively, by $F(\omega_t)$ and $f(\omega_t)$, satisfying $E(\omega_t) = 1$. This productivity is observed only by entrepreneurs ex-post (i.e. after paying the cost of production), and may be observed by a third party paying a fraction μ of the total value of production.

The timing for entrepreneurs is as follows. At the beginning of period t they collect the the capital revenues and repay the debt contracted at $t - 1$ (buying dollars at the rate S_t); after which they work in the final investment sector. Latter, they buy unfinished capital goods using unconsumed profits, wage earnings and borrowed funds. All financial markets close short after (including the foreign currency market).[13] Finally they produce and accumulate capital for next period.

The amount of dollars they need to borrow (B_{t+1}^{*e}) satisfies $S_t B_{t+1}^{*e} = KC_t - NW_t$. Because ω_{t+1} is private information, foreign lenders will charge a premium for these loans. As shown by Bernanke et al. (1999), the optimal contract specifies a cutoff value $\bar{\omega}_{t+1}$ such that if $\omega_{t+1} \geq \bar{\omega}_{t+1}$ the borrower pays to the lender $\bar{\omega}_{t+1} K I_{t+1}$

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[13] Notice that this timing in terms of the foreign currency market is also implicity assumed in others papers using the financial accelerator framework to model balance-sheets effects.

pesos and keeps $(\omega_{t+1} - \bar{\omega}_{t+1})KI_{t+1}$. Alternatively, if $\omega_{t+1} < \bar{\omega}_{t+1}$ the borrower receives nothing (defaults) while the lender pays the monitoring cost and obtains $(1 - \mu)\omega_{t+1}KI_{t+1}$ pesos. The opportunity cost for lenders is the international rate $i_t^* \xi_t$ and we assume that entrepreneurs repay the loan at $t+1$, for which the relevant exchange rate is S_{t+1}. The lender participation constraint is then

$$B_{t+1}^{*e} i_t^* \xi_t \le KI_{t+1}g(\bar{\omega}_{t+1})/S_{t+1}, \tag{C.1}$$

where

$$g(\bar{\omega}) \equiv \bar{\omega}[1 - F(\bar{\omega})] + (1 - \mu)\int_0^{\bar{\omega}} \omega f(\omega)d\omega.$$

The right hand side in (C.1) is the lender's profits (in dollars). Notice that this equation holds for all possible states in $t + 1$; which reflects the assumption that entrepreneurs bear the aggregate risk (in terms of exchange rates and return on capital).[14] On the other hand, the entrepreneur's expected return is given by

$$E_t\left\{KI_{t+1}h(\bar{\omega}_{t+1})\right\}. \tag{C.2}$$

with

$$h(\bar{\omega}) \equiv \int_{\bar{\omega}}^{\infty} \omega f(\omega)d\omega - \bar{\omega}[1 - F(\bar{\omega})].$$

It is clear then that $g(\bar{\omega}_t) + h(\bar{\omega}_t) = 1 - \upsilon_t$, where $\upsilon_t \equiv \mu \int_0^{\bar{\omega}_t} \omega f(\omega)d\omega$.[15] The optimal contract specifies a value for K_{t+1}^j for $j = x, n$ and a state contingent $\bar{\omega}_{t+1}$ that

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[14] This assumption is in principle arbitrary, for both entrepreneurs and foreign lenders are risk neutral. Some papers, explicitly or not, assume that the aggregate risk is bore by foreign lenders; for instance, Elekdag et al. (2005), Elekdag and Tchakarov (2007), Tovar (2006a,b) and the technical appendix in Cespedes et al. (2004). In such a case, (C.1) should hold with expectations. However, as shown below, this alternative assumption imply that only expected changes in the nominal exchange rate have an impact on net worth; a results at odds with the general liability-dollarisation argument. This issue has however been neglected in these papers.

[15] Note that if $\ln(\omega) \sim N(-.5\sigma_\omega^2, \sigma_\omega^2)$, which satisfies $E(\omega) = 1$, and defining $z \equiv \frac{ln(\bar{\omega}) + .5\sigma_\omega}{\sigma_\omega^2}$ we have

$$g(\bar{\omega}) = \bar{\omega}[1 - \Phi(z)] + (1 - \mu)\Phi(z - \sigma_\omega), \quad h(\bar{\omega}) = 1 - \Phi(z - \sigma_\omega) - \bar{\omega}[1 - \Phi(z)], \quad \upsilon = \mu\Phi(z - \sigma_\omega),$$

where $\Phi(\cdot)$ is the standard Normal c.d.f.

maximizes (C.2) subject to (C.1). The optimality conditions for this problem can be written as

$$(KC_{t-1} - NW_{t-1}) \frac{S_t}{S_{t-1}} i^*_{t-1} \xi_{t-1} = KI_t g(\bar{\omega}_t),$$

$$E_t \left\{ \frac{(R^j_{t+1} + Q^{old,j}_{t+1})}{Q^j_t} \left[\frac{h'(\bar{\omega}_{t+1})g(\bar{\omega}_{t+1})}{g'(\bar{\omega}_{t+1})} - h(\bar{\omega}_{t+1}) \right] \right\} = i^*_t \xi_t E_t \left\{ \frac{S_{t+1}}{S_t} \frac{h'(\bar{\omega}_{t+1})}{g'(\bar{\omega}_{t+1})} \right\} \quad \text{for} \quad j = x, n.$$

Thus, the external finance premium in equation (8) in the text is defined as

$$rp_{t+1} \equiv \left[\frac{h'(\bar{\omega}_{t+1})g(\bar{\omega}_{t+1})}{g'(\bar{\omega}_{t+1})} - h(\bar{\omega}_{t+1}) \right] \left\{ E_t \left[\frac{S_{t+1}}{S_t} \frac{h'(\bar{\omega}_{t+1})}{g'(\bar{\omega}_{t+1})} \right] \right\}^{-1}.$$

Combining the two optimality conditions, we can see that the external finance premium is in general a function of the leverage ratio KC_t/NW_t, which Bernanke et al. (1999) showed to be increasing.

Entrepreneurs profits are given by $KI_{t+1}h(\bar{\omega}_{t+1})$ which, using the participation constraint and the definition of $h(\cdot)$, can be written as

$$\Pi^e_{t+1} = KI_{t+1}(1 - \upsilon_{t+1}) - i^*_t \xi_t S_{t+1} B^{*e}_{t+1}.$$

Therefore $NW_t = \vartheta \Pi^e_t + W^e_t$, which yields the expression in (9) in the text.[16]

C.4.5 Stationary Equilibrium Conditions

The model has a stochastic trend in equilibrium due to the presence of Γ_t. We shall then transform the model in order to reach a stationary representation. Transformed

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[16] Notice that if (C.1) holds only in expectations, we have $\Pi^e_{t+1} = KI_{t+1}(1 - \upsilon_{t+1}) - i^*_t \xi_t E_t \{S_{t+1}\} B^{*e}_{t+1} \frac{KI_{t+1}}{E_t\{KI_{t+1}\}}$. Thus, in such a case unexpected changes in the nominal exchange rate will not a have a first order effect on net worth, weakening the liability-dollarisation mechanism.

allocations (35)

$$\gamma_t = \frac{\Gamma_t}{\Gamma_{t-1}}, \qquad v_t = \frac{V_t}{\Gamma_{t-1}}, \qquad x_t = \frac{X_t}{\Gamma_{t-1}}, \qquad z_t = \frac{Z_t}{\Gamma_{t-1}}, \qquad c_t = \frac{C_t}{\Gamma_{t-1}},$$

$$m_t = \frac{M_t}{P_{t-1}\Gamma_{t-1}}, \quad d_t = \frac{S_{t-1}D_t}{P_{t-1}\Gamma_{t-1}}, \quad y_t^c = \frac{Y_t^c}{\Gamma_{t-1}}, \quad y_t^x = \frac{Y_t^X}{\Gamma_{t-1}}, \quad y_t^n = \frac{Y_t^n}{\Gamma_{t-1}},$$

$$y_t^f = \frac{Y_t^f}{\Gamma_{t-1}}, \qquad c_t^T = \frac{C_t^T}{\Gamma_{t-1}}, \qquad c_t^x = \frac{C_t^X}{\Gamma_{t-1}}, \qquad c_t^n = \frac{C_t^n}{\Gamma_{t-1}}, \qquad c_t^f = \frac{C_t^f}{\Gamma_{t-1}},$$

$$k_t^x = \frac{K_t^X}{\Gamma_{t-1}}, \qquad k_t^n = \frac{K_t^n}{\Gamma_{t-1}}, \qquad i_t^x = \frac{I_t^X}{\Gamma_{t-1}}, \qquad i_t^n = \frac{I_t^n}{\Gamma_{t-1}}, \qquad ic_t^{x,n} = \frac{IC_t^{x,n}}{\Gamma_{t-1}},$$

$$ic_t^{n,x} = \frac{IC_t^{n,x}}{\Gamma_{t-1}}, \quad ic_t^{k,n} = \frac{IC_t^{k,n}}{\Gamma_{t-1}}, \quad ic_t^{x,f} = \frac{IC_t^{x,f}}{\Gamma_{t-1}}, \quad ic_t^{n,f} = \frac{IC_t^{n,f}}{\Gamma_{t-1}}, \quad ic_t^{k,f} = \frac{IC_t^{k,f}}{\Gamma_{t-1}},$$

$$y_t^k = \frac{Y_t^k}{\Gamma_{t-1}}, \qquad tb_t = \frac{TB_t}{\Gamma_{t-1}}, \qquad gdp_t = \frac{GDP_t}{\Gamma_{t-1}}, \qquad g_t = \frac{G_t}{\Gamma_{t-1}}, \qquad exp_t = \frac{EXP_t}{\Gamma_{t-1}},$$

$$b_t^* = \frac{S_{t-1}B_t^*}{P_{t-1}\Gamma_{t-1}}, \quad nw_t = \frac{NW_t}{P_t\Gamma_{t-1}}, \quad b_t^{e*} = \frac{S_{t-1}B_t^{e*}}{P_{t-1}\Gamma_{t-1}}, \quad kc_t = \frac{KC_t}{P_t\Gamma_{t-1}}, \quad ki_t = \frac{KI_t}{P_t\Gamma_{t-1}},$$

Inflations and relative prices (21):

$$\pi_t = \frac{P_t}{P_{t-1}}, \qquad \pi_t^s = \frac{S_t}{S_{t-1}} \qquad tot_t = \frac{P_t^{*x}}{P_t^{*f}}, \quad p_t^x = \frac{P_t^x}{P_t}, \quad p_t^n = \frac{P_t^n}{P_t}, \qquad p_t^f = \frac{P_t^f}{P_t},$$

$$p_t^k = \frac{P_t^k}{P_t}, \qquad w_t = \frac{W_t}{P_t\Gamma_{t-1}}, \qquad w_t^e = \frac{W_t^e}{P_t\Gamma_{t-1}}, \quad r_t^x = \frac{R_t^x}{P_t}, \quad r_t^n = \frac{R_t^n}{P_t}, \quad mc_t^x = \frac{MC_t^x}{P_t},$$

$$mc_t^n = \frac{MC_t^n}{P_t}, \quad rer_t = \frac{S_t P_t^{*f}}{P_t}, \quad p_t^T = \frac{P_t^T}{P_t}, \quad q_t^x = \frac{Q_t^x}{P_t}, \quad q_t^n = \frac{Q_t^n}{P_t}, \quad q_t^{old,x} = \frac{Q_t^{old,x}}{P_t},$$

$$q_t^{old,n} = \frac{Q_t^{old,n}}{P_t}, \quad \pi_t^{*f} = \frac{P_t^{*f}}{P_{t-1}^{*f}} \qquad \pi_t^{*x} = \frac{P_t^{*x}}{P_{t-1}^{*x}}$$

Variables without transformations (16): $l_t, l_t^x, l_t^n, \lambda_t, \mu_t^w, \bar{\omega}_t, \upsilon_t, z_t^x, z_t^n, i_t, i_t^*, \xi_t, \xi_t^*, \hat{\pi}_t, \hat{g}_t^y,$ $\hat{i}_t$.

Given these transformed variables, and imposing symmetry, we have the following equilibrium conditions.

Households (10):

$$v_t = \left[b(x_t)^{1-1/\zeta} + (1-b)(z_t)^{1-1/\zeta} \right]^{\frac{\zeta}{\zeta-1}}, \tag{E.1}$$

$$x_t = c_t - \rho_c c_{t-1}/\gamma_{t-1}, \tag{E.2}$$

$$z_t = \left[\nu \left(m_{t+1}\gamma_t \right)^{1-1/\chi} + (1-\nu) \left(d_{t+1}\gamma_t \right)^{1-1/\chi} \right]^{\frac{\chi}{\chi-1}}, \tag{E.3}$$

$$\lambda_t = (1-l_t)^{\phi(1-\sigma)} (v_t)^{-\sigma+1/\zeta} b (x_t)^{-1/\zeta}, \tag{E.4}$$

$$\frac{w_t}{\mu_t^w} = \frac{\phi\left(v_t\right)^{1-1/\zeta}\left(x_t\right)^{1/\zeta}}{b(1-l_t)}, \qquad \text{(E.5)}$$

$$\left(\frac{(\theta_w - 1)}{\theta_w} - \frac{1}{\mu_t^w}\right) l_t \theta_w = -\psi_w \left(\frac{w_t \pi_t}{w_{t-1}\hat{\pi}_t} - 1\right)\frac{w_t \pi_t}{w_{t-1}\hat{\pi}_t} +$$

$$\psi_w \beta(\gamma_t)^{-\sigma} E_t \left\{ \frac{\lambda_{t+1}}{\lambda_t} \left(\frac{w_{t+1}\pi_{t+1}}{w_t \hat{\pi}_{t+1}} - 1\right)\left(\frac{w_{t+1}}{w_t}\right)^2 \frac{\pi_{t+1}}{\hat{\pi}_{t+1}} \right\}, \quad \text{(E.6)}$$

$$\lambda_t = \beta(\gamma_t)^{-\sigma} i_t E_t \left\{ \frac{\lambda_{t+1}}{\pi_{t+1}} \right\} \qquad \text{(E.7)}$$

$$\lambda_t = \beta(\gamma_t)^{-\sigma} i_t^* \xi_t E_t \left\{ \frac{\lambda_{t+1}\pi_{t+1}^s}{\pi_{t+1}} \right\}, \qquad \text{(E.8)}$$

$$(1 - l_t)^{\phi(1-\sigma)}\left(v_t\right)^{-\sigma+1/\zeta}(1-b)\left(z_t\right)^{-1/\zeta+1/\chi}\nu\left(m_{t+1}\gamma_t\right)^{-1/\chi} = \lambda_t - \beta(\gamma_t)^{-\sigma} E_t \left\{ \frac{\lambda_{t+1}}{\pi_{t+1}} \right\}$$

$$\text{(E.9)}$$

$$\frac{i_t^* \xi_t(1 - i_t)}{(1 - i_t^* \xi_t)i_t} = \frac{\nu}{1 - \nu}\left(\frac{m_{t+1}}{d_{t+1}}\right)^{-1/\chi}, \qquad \text{(E.10)}$$

Firms-Production (17):

$$y_t^j = A_j z_t^j \left(k_t^j\right)^{\alpha_j^k}\left(\gamma_t l_t^j\right)^{\alpha_j^l}\left(ic_t^{j,x}\right)^{\alpha_j^x}\left(ic_t^{j,n}\right)^{\alpha_j^n}\left(ic_t^{j,f}\right)^{\alpha_j^f}, \quad \text{for} \quad j = x, n, \qquad \text{(E.11)}$$

$$w_t = mc_t^j \alpha_j^l \frac{y_t^j}{l_t^j}, \quad \text{for} \quad j = x, n, \qquad \text{(E.12)}$$

$$r_t^j = mc_t^j \alpha_j^k \frac{y_t^j}{k_t^j}, \quad \text{for} \quad j = x, n, \qquad \text{(E.13)}$$

$$p_t^\iota = mc_t^j \alpha_j^\iota \frac{y_t^j}{ic_t^{\iota,j}}, \quad \text{for} \quad j = x, n \quad \iota = x, n, f, \quad \iota \neq j. \qquad \text{(E.14)}$$

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$$mc_t^x = p_t^x, \tag{E.15}$$

$$c_t^T = A_T \left(c_t^x \right)^{\eta_x} \left(c_t^f \right)^{\eta_f}, \tag{E.16}$$

$$c_t^j = \eta_j \left(\frac{p_t^T}{p_t^j} \right) c_t^T, \quad \text{for} \quad j = x, f, \tag{E.17}$$

$$c_t^n = a \left(p_t^n \right)^{-\varphi} y_t^C, \tag{E.18}$$

$$c_t^T = (1 - a) \left(p_t^T \right)^{-\varphi} y_t^C, \tag{E.19}$$

$$y_t^C = \left[a^{1/\varphi} \left(c_t^n \right)^{1-1/\varphi} + (1-a)^{1/\varphi} \left(c_t^T \right)^{1-1/\varphi} \right]^{\frac{\varphi}{\varphi-1}}, \tag{E.20}$$

Firms-Pricing (3):

$$p_t^x = tot_t rer_t, \tag{E.21}$$

$$\left(\frac{(\theta_n - 1)}{\theta_n} - \frac{mc_t^n}{p_t^n} \right) y_t^n \theta_n (\gamma_t)^{-1} = -\psi_n \left(\frac{p_t^n \pi_t}{p_{t-1}^n \hat{\pi}_t} - 1 \right) \frac{p_t^n \pi_t}{p_{t-1}^n \hat{\pi}_t} +$$

$$\psi_n \beta (\gamma_t)^{-\sigma} E_t \left\{ \frac{\lambda_{t+1} \gamma_{t+1}}{\lambda_t} \left(\frac{p_{t+1}^n \pi_{t+1}}{p_t^n \hat{\pi}_{t+1}} - 1 \right) \left(\frac{p_{t+1}^n}{p_t^n} \right)^2 \frac{\pi_{t+1}}{\hat{\pi}_{t+1}} \right\}, \tag{E.22}$$

$$\left(\frac{(\theta_f - 1)}{\theta_f} - \frac{rer_t}{p_t^f} \right) y_t^f \theta_f (\gamma_t)^{-1} = -\psi_f \left(\frac{p_t^f \pi_t}{p_{t-1}^f \hat{\pi}_t} - 1 \right) \frac{p_t^f \pi_t}{p_{t-1}^f \hat{\pi}_t} +$$

$$\psi_f \beta (\gamma_t)^{-\sigma} E_t \left\{ \frac{\lambda_{t+1} \gamma_{t+1}}{\lambda_t} \left(\frac{p_{t+1}^f \pi_{t+1}}{p_t^f \hat{\pi}_{t+1}} - 1 \right) \left(\frac{p_{t+1}^f}{p_t^f} \right)^2 \frac{\pi_{t+1}}{\hat{\pi}_{t+1}} \right\}, \tag{E.23}$$

Capital Accumulation (10):

$$y_t^k = A_k \left(ic_t^{k,n} \right)^{\alpha_k^n} \left(ic_t^{k,f} \right)^{\alpha_k^f} (\gamma_t)^{\alpha_k^e}. \tag{E.24}$$

$$w_t^e = p_t^k \alpha_k^e y_t^k, \tag{E.25}$$

$$p_t^\iota = p_t^k \alpha_k^\iota \frac{y_t^k}{ic_t^{k,\iota}}, \quad \text{for} \quad \iota = n, f. \tag{E.26}$$

$$k_{t+1}^j \gamma_t = (1 - \delta) k_t^j + i_t^j - \frac{\psi_k^j}{2} \left[\frac{i_t^j}{k_t^j} - (\gamma - 1 + \delta) \right]^2 k_t^j, \quad j = x, n, \tag{E.27}$$

$$q_t^j = \left\{ 1 - \psi_k^j \left[\frac{i_t^j}{k_t^j} - (\gamma - 1 + \delta) \right] \right\}^{-1} p_t^k, \quad j = x, n, \tag{E.28}$$

$$q_t^{old,j} = q_t^j \left\{ 1 - \delta + \psi_k^j \left[\frac{i_t^j}{k_t^j} - (\gamma - 1 + \delta) \right] \frac{i_t^j}{k_t^j} - \frac{\psi_k^j}{2} \left[\frac{i_t^j}{k_t^j} - (\gamma - 1 + \delta) \right]^2 \right\}, \quad j = x, n, \tag{E.29}$$

Entrepreneurs (8):

$$kc_t = \sum_{j=x,n} q_t^j k_{t+1}^j \gamma_t, \tag{E.30}$$

$$ki_t = \sum_{j=x,n} \left(r_t^j + q_t^{old,j} \right) k_t^j, \tag{E.31}$$

$$(kc_{t-1} - nw_{t-1}) \pi_t^s i_{t-1}^* \xi_{t-1} = ki_t \pi_t \gamma_{t-1} g(\bar{\omega}_t), \tag{E.32}$$

$$E_t \left\{ \left(\frac{q_{t+1}^{old,j} + r_{t+1}^j}{q_t^j} \right) \pi_{t+1} \left[\frac{h'(\bar{\omega}_{t+1}) g(\bar{\omega}_{t+1})}{g'(\bar{\omega}_{t+1})} - h(\bar{\omega}_{t+1}) \right] \right\} = i_t^* \xi_t E_t \left\{ \pi_{t+1}^s \frac{h'(\bar{\omega}_{t+1})}{g'(\bar{\omega}_{t+1})} \right\} \quad j = x, n, \tag{E.33}$$

$$nw_t = \vartheta \left[ki_t (1 - \upsilon_t) - i_{t-1}^* \xi_{t-1} \frac{\pi_t^s}{\pi_t \gamma_{t-1}} (kc_{t-1} - nw_{t-1}) \right] + w_t^e, \tag{E.34}$$

$$\upsilon_t = \mu \int_0^{\bar{\omega}_t} \omega f(\omega) d\omega, \tag{E.35}$$

$$\gamma_t b_{t+1}^{*e} = kc_t - nw_t, \tag{E.36}$$

Market clearing (12):

$$l_t = \sum_{j=x,n} l_t^j, \tag{E.37}$$

$$y_t^x = c_t^x + ic_t^{n,x} + exp_t, \tag{E.38}$$

$$y_t^n = c_t^n + \sum_{j=x,k} ic_t^{j,n} + \kappa^n y^n \gamma_t + \frac{\psi_n}{2} \left(\frac{p_t^n \pi_t}{p_{t-1}^n \tilde{\pi}_t} - 1 \right)^2 \gamma_t, \tag{E.39}$$

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$$y_t^f = c_t^f + \sum_{j=x,n,k} ic_t^{j,f} + \kappa^f y^f \gamma_t + \frac{\psi_f}{2} \left(\frac{p_t^f \pi_t}{p_{t-1}^f \tilde{\pi}_t} - 1 \right)^2 \gamma_t, \tag{E.40}$$

$$y_t^k = \sum_{j=x,n} i_t^j. \tag{E.41}$$

$$y_t^c = c + g_t. \tag{E.42}$$

$$tb_t = p_t^x exp_t - p_t^f y_t^f. \tag{E.43}$$

$$gdp_t = c + g_t + p_t^k y_t^k + tb_t, \tag{E.44}$$

$$rer_t = \frac{\pi_t^s \pi_t^{*f}}{\pi_t} rer_{t-1}, \tag{E.45}$$

$$\gamma_t \left(d_{t+1} - b_{t+1}^* - b_{t+1}^{*e} \right) + \frac{\psi_w}{2} \left(\frac{\pi_t^w w_t}{\tilde{\pi}_t^w w_{t-1}} - 1 \right)^2 w_t + \upsilon_t ki_t + \frac{(1-\vartheta)}{\vartheta}(nw_t - w_t^e) =$$

$$\frac{\pi_t^s}{\pi_t} \left[d_t - (b_t^* + b_t^{*e}) i_{t-1}^* \xi_{t-1} \right] + p_t^x exp_t - rer_t y_t^f, \tag{E.46}$$

$$\xi_t = \psi_d \left(e^{\gamma_t b_{t+1}^*/gdp_t - \bar{b}} - 1 \right) + \xi_t^*, \tag{E.47}$$

$$tot_t = \frac{\pi_t^{*x}}{\pi_t^{*x}} tot_{t-1}, \tag{E.48}$$

Taylor Rule (1)

$$\frac{i_t}{i} = \left(\frac{i_{t-1}}{i} \right)^{\alpha_i} \left(\frac{E_t\{\pi_{t+k}\}}{\hat{\pi}_t} \right)^{\alpha_\pi} \left(\frac{\gamma_{t-1} gdp_t/gdp_{t-1}}{\hat{g}_t^y} \right)^{\alpha_y} \hat{i}_t, \tag{E.49}$$

Driving Forces (11):

$$\ln(\hat{i}_t/i) = \rho_i \ln(\hat{i}_{t-1}/i) + \epsilon_t^i, \tag{E.50}$$

$$\ln(\hat{\pi}_t/\pi) = \rho_\pi \ln(\hat{\pi}_{t-1}/\pi) + \epsilon_t^\pi, \tag{E.51}$$

$$\ln(\hat{g}_t^y/g^Y) = \rho_y \ln(\hat{g}_{t-1}^y/g^Y) + \epsilon_t^{gy}, \tag{E.52}$$

$$A_0 \ln(x_t^*/x^*) = B \ln(tot_{t-1}/tot) + A(L) \ln(x_{t-1}^*/x^*) + \epsilon_t^{rw}, \tag{E.53}$$

$$\ln(\xi_t^*) = \rho_{\xi^*} \ln(\xi_{t-1}^*) + \epsilon_t^{\xi^*},\tag{E.54}$$

$$\ln(g_t/g) = \rho_g \ln(g_{t-1}/g) + \epsilon_t^g,\tag{E.55}$$

$$\ln(\gamma_t/\gamma) = \rho_\gamma \ln(\gamma_{t-1}/\gamma) + \epsilon_t^\gamma,\tag{E.56}$$

$$\ln(z_t^j) = \rho_{z^j} \ln(z_{t-1}^j) + \epsilon_t^{z^j}, \quad \text{for} \quad j = x, n.\tag{E.57}$$

Therefore, we have a total of 72 variables and 72 equations.

C.4.6 Steady State

We show how to compute the non-stochastic steady state in the stationary model for given values for $\boxed{l}$, $\boxed{l^x}$, $s^x \equiv \frac{p^x \, exp}{gdp}$, $s^f \equiv \frac{p^f y^f}{gdp}$, $\boxed{i^*}$, $\boxed{i}$, $\boxed{\pi}$, $\boxed{tot}$, $s^g \equiv \frac{g}{gdp}$, $\boxed{\gamma}$, $\boxed{z^x = 1}$, $\boxed{z^n = 1}$, ,rp (risk premium for entrepreneurs) and $\kappa \equiv \frac{nw}{kc}$ (leverage ratio). The free parameters are ϕ, η_x, a, $\bar{b}$, β, κ^n, κ^f, σ_ω and ϑ.

First, from (E.51), (E.52) and (E.54) we have

$$\boxed{\hat{\pi} = \pi,} \qquad \boxed{\hat{g}^y = \gamma,} \qquad \boxed{\hat{(i)} = i} \qquad \boxed{\xi^* = 1.}$$

From (E.8) and (E.7)

$$\boxed{\pi^s = i/i^*,} \qquad \boxed{\beta = \frac{\pi\gamma}{\pi^s i^* \xi^*}.}$$

From (E.45) and (E.48)

$$\boxed{\pi^{*f} = \pi/\pi^s,} \qquad \boxed{\pi^{*f} = \pi^{*x}.}$$

From (E.27) we have $(\gamma - 1 + \delta) = i^x/k^x = i^n/k^n$. Also, from (E.28) $q^x = q^n = p^k$ and from from (E.29) $q^{old,x} = q^{old,n} = p^k(1 - \delta)$; which combined by with (E.33) yields $r^x = r^n \equiv r$.

From (E.30)-(E.32) and (E.33)

$$1 - \kappa = g(\bar{\omega})rp, \qquad rp = \frac{h'(\bar{\omega})}{h'(\bar{\omega})g(\bar{\omega}) - g'(\bar{\omega})h(\bar{\omega})},$$

where $rp \equiv (r/p^k + 1 - \delta)\pi/(\pi^s i^* \xi^*)$. We can use these two conditions to solve for $\boxed{\bar{\omega}}$ and $\boxed{\sigma_\omega}$. Using (E.35)

$$\boxed{\upsilon = \mu \int_0^{\bar{\omega}} \omega f(\omega) d\omega.}$$

In addition, we can use (E.25), (E.27), (E.34) and (E.41) to obtain

$$\frac{w^e}{kc} = \frac{w^e}{p^k y^k \gamma}(\gamma - 1 + \delta) = \alpha_k^e(\gamma - 1 + \delta)/\gamma = \kappa - \vartheta \frac{\pi^s i^* \xi^*}{\pi \gamma}\left[rp(1 - \upsilon) - 1 + \kappa\right],$$

which we can use to get

$$\boxed{\vartheta = \frac{\kappa - \alpha_k^e(\gamma - 1 + \delta)/\gamma}{\frac{\pi^s i^* \xi^*}{\pi \gamma}[rp(1 - \upsilon) - 1 + \kappa]}.}$$

The next step is to compute the relative prices. Let $\tilde{x} \equiv x/p^k$ for a generic variable x. From the definition of rp we have

$$\tilde{r} = \pi^s i^* \xi^* rp/\pi - 1 + \delta. \tag{SS.1}$$

From (E.37) we have $\boxed{l^n = l - l^x}$. Combining (E.12), (E.13),(E.25) and (E.27), summing for both goods, we get

$$\tilde{w}^e = \tilde{w}\frac{\alpha_k^e(\gamma - 1 + \delta)}{\tilde{r}}\left(\frac{\alpha_x^k}{\alpha_x^l}l^x + \frac{\alpha_n^k}{\alpha_n^l}l^n\right) \tag{SS.2}$$

From the definitions of marginal costs and using (E.22) we get

$$1 = (\tilde{p}^n)^{\alpha_k^n}\left(\tilde{p}^f\right)^{\alpha_k^f}\left(\tilde{w}^e/\gamma\right)^{\alpha_k^e}, \tag{SS.3}$$

$$\tilde{p}^x = (\tilde{r})^{\alpha_x^k}\left(\tilde{w}/\gamma\right)^{\alpha_x^l}(\tilde{p}^n)^{\alpha_x^n}\left(\tilde{p}^f\right)^{\alpha_x^f}, \tag{SS.4}$$

$$\tilde{p}^n = \left(\frac{\theta_n}{\theta_n - 1}\right)(\tilde{r})^{\alpha_n^k}\left(\tilde{w}/\gamma\right)^{\alpha_n^l}(\tilde{p}^x)^{\alpha_n^x}\left(\tilde{p}^f\right)^{\alpha_n^f}. \tag{SS.5}$$

From (E.21) and (E.23)

$$\tilde{p}^f = \tilde{p}^x\left(\frac{\theta_f}{\theta_f - 1}\right)\frac{1}{tot}. \tag{SS.6}$$

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Thus, we can use the six equations (SS.1)-(SS.6) to find the six variables $\tilde{r}$, $\tilde{w}^e$, $\tilde{w}$, $\tilde{p}^x$, $\tilde{p}^n$ and $\tilde{p}^f$.[17] With these values, from (E.25)-(E.26)

$$y^k = \frac{\tilde{w}^e}{\alpha_k^e}, \qquad ic^{k,n} = \frac{\alpha_k^n}{\tilde{p}^n}y^k, \qquad ic^{k,f} = \frac{\alpha_k^f}{\tilde{p}^f}y^k.$$

From (E.12)-(E.14)

$$y^n = \frac{\tilde{w}}{\tilde{p}^n}\frac{(\theta_n-1)}{\theta_n}\frac{l^n}{\alpha_n^l}, \qquad ic^{n,x} = \frac{\tilde{w}}{\tilde{p}^x}\frac{\alpha_n^x}{\alpha_n^l}l^n, \qquad ic^{n,f} = \frac{\tilde{w}}{\tilde{p}^f}\frac{\alpha_n^f}{\alpha_n^l}l^n, \qquad k^n = \frac{\tilde{w}}{\tilde{r}}\frac{\alpha_n^k}{\alpha_n^l}l^n,$$

$$y^x = \frac{\tilde{w}}{\tilde{p}^x}\frac{l^x}{\alpha_x^l}, \qquad ic^{x,n} = \frac{\tilde{w}}{\tilde{p}^n}\frac{\alpha_x^n}{\alpha_x^l}l^x, \qquad ic^{x,f} = \frac{\tilde{w}}{\tilde{p}^f}\frac{\alpha_x^f}{\alpha_x^l}l^x, \qquad k^x = \frac{\tilde{w}}{\tilde{r}}\frac{\alpha_x^k}{\alpha_x^l}l^x.$$

From (E.27)

$$i^x = (\gamma - 1 + \delta)k^x, \qquad i^n = (\gamma - 1 + \delta)k^n,$$

Notice that if the fixed costs parameters are set to make profits zero in steady state we have $\kappa^n\gamma = (\theta_n - 1)^{-1}$ and $\kappa^f\gamma = (\theta_f - 1)^{-1}$. Then, from (E.39)

$$c^n = y^n(1 - \kappa^n\gamma) - ic^{x,n} - ic^{k,n},$$

From (E.38), (E.40) and (E.44) we have

$$\tilde{p}^x y^x = \tilde{p}^x c^x + \tilde{p}^x ic^{n,x} + s^x(gdp/p^k),$$

$$s^f(gdp/p^k)(1 - \kappa^f\gamma) = \tilde{p}^f c^f + \tilde{p}^f\left(ic^{n,f} + ic^{x,f} + ic^{k,f}\right),$$

$$(1 - s^x + s^f)(gdp/p^k) = \tilde{p}^n c^n + \tilde{p}^x c^x + \tilde{p}^f c^f + y^k,$$

Combining these 3 we have

$$(gdp/p^k) = \frac{\tilde{p}^n c^n + y^k + \tilde{p}^x\left(y^x - ic^{n,x}\right) - \tilde{p}^f\left(ic^{n,f} + ic^{x,f} + ic^{k,f}\right)}{1 + s^f\kappa^f\gamma},$$

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[17] Notice that this is a linear system in the log of the variables.

$$c^x = \frac{\tilde{p}^x(y^x - ic^{n,x}) - s^x(gdp/p^k)}{\tilde{p}^x},$$

$$c^f = \frac{s^f(gdp/p^k)(1-\kappa^f\gamma) - \tilde{p}^f\left(ic^{n,f} + ic^{x,f} + ic^{k,f}\right)}{\tilde{p}^f}.$$

Then, from (E.38) and (E.40)

$$exp = y^x - c^x - ic^{n,x},$$

$$y^f = \frac{c^f + ic^{n,f} + ic^{x,f} + ic^{k,f}}{1 - \kappa^f\gamma}.$$

Combining (E.16)-(E.17)

$$\eta_x = \left(\frac{\tilde{p}^f c^f}{\tilde{p}^x c^x} + 1\right)^{-1},$$

$$\tilde{p}^T = (\tilde{p}^x)^{\eta_x}\left(\tilde{p}^f\right)^{1-\eta_x},$$

$$c^T = \frac{\tilde{p}^f c^f + \tilde{p}^x c^x}{\tilde{p}^T}.$$

Combining (E.18)-(E.20)

$$a = \left[\frac{c^T}{c^n}\left(\frac{\tilde{p}^T}{\tilde{p}^n}\right)^\varphi + 1\right]^{-1},$$

$$p^n = \left[a + (1-a)\left(\frac{\tilde{p}^T}{\tilde{p}^n}\right)^{1-\varphi}\right]^{1/(\varphi-1)}.$$

Thus

$$p^k = \frac{p^n}{\tilde{p}^n},$$

$$p^x = p^k\tilde{p}^x,$$

$$p^f = p^k\tilde{p}^f,$$

$$p^T = p^k\tilde{p}^T,$$

$$r^x = p^k\tilde{r}, = r^n,$$

$$w = p^k\tilde{w},$$

$$w^e = p^k\tilde{w}^e,$$

$$rer = \frac{p^x}{tot}.$$

$$q^x = p^k, = q^n,$$

$$q^{old,x} = p^k(1-\delta), = q^{old,n},$$

$$mc^x = p^x,$$

$$mc^n = p^n\frac{(\theta_n - 1)}{\theta_n(1+\tau^n)^{-1}}.$$

Also

$$kc = p^k(k^x + k^n)\gamma,$$

$$nw = \kappa \cdot kc,$$

$$b^{*e} = \frac{kc - nw}{\gamma},$$

$$y^C = p^T c^T + p^n c^n,$$

$$gdp = (gdp/p^k)p^k,$$

$$g = s^g gdp,$$

$$c = y^c - c^e - g,$$

$$tb = p^x exp - p^f y^f,$$

$$ki = [r + p^k(1-\delta)](k^x + k^n).$$

From (E.2) and (E.6)

$$x = c(1 - \rho_c/\gamma),$$

$$\mu^w = \frac{\theta_w(1+\tau^w)^{-1}}{\theta_w - 1}.$$

From (E.10) and (E.3)

$$\left(\tfrac{d}{m}\right) = \left[\tfrac{i^*\xi^*(1-i)}{(1-i^*\xi^*)i}\left(\tfrac{1-\nu}{\nu}\right)\right]^\chi, \qquad \left(\tfrac{z}{m\gamma}\right) = \left[\nu + (1-\nu)\left(\tfrac{d}{m}\right)^{1-1/\chi}\right]^{\frac{\chi}{\chi-1}},$$

From (E.4), (E.7) and (E.9)

$$m = \tfrac{1}{\gamma}\left[\tfrac{(1-b)}{b}\tfrac{x^{1/\zeta}\left(\tfrac{z}{m\gamma}\right)^{-1/\zeta+1/\chi}\nu}{1-i^{-1}}\right]^\zeta, \qquad d = m\left(\tfrac{d}{m}\right), \qquad z = \left(\tfrac{z}{m\gamma}\right)\gamma m,$$

From (E.1), (E.4) and (E.5)

$$v = \left[b(x)^{1-1/\zeta} + (1-b)(z)^{1-1/\zeta}\right]^{\frac{\zeta}{\zeta-1}}, \qquad \phi = \tfrac{b(1-l)w}{(v)^{1-1/\zeta}(x)^{1/\zeta}\mu^w},$$

$$\lambda = (1-l)^{\phi(1-\sigma)}\,(v)^{-\sigma+1/\zeta}\,b\,(x)^{-1/\zeta}.$$

Finally, from (E.46)

$$b^* = -\left[b^{*e}(\gamma - i^*\xi^*/\pi^{*f}) - d(\gamma - 1/\pi^{*f}) + p^x exp - y^f rer - \upsilon \cdot ki\right]/(\gamma - i^*\xi^*/\pi^{*f}),$$

which, from (E.47) give us $\bar{b} = \gamma b^*/gdp$ and also yields $\xi = \xi^*$.

Overall, we have 81 boxes representing the steady state values for the 72 variables and 9 free parameters.

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Biography

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