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Emerging Economy Business Cycles: Interest Rate Shocks *vs* Trend Shocks

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Abstract

The recent literature studying the source of business cycles in emerging market economies (EMEs) has debated the relative importance of productivity trend shocks *versus* interest rate shocks coupled with financial frictions. Importantly, the papers where an important role was assigned to interest rate shocks did not force their models to match the historical paths of the world or country interest rate. This could have led to poorly identified interest rate shocks and inaccurate measures of contributions of shocks to EME business cycles. To address this issue, we estimate a small open economy model for Argentina and Mexico using Bayesian methods where world and country interest rate series are included as observables. This estimation strategy brings quantitative accuracy by imposing discipline on the estimated shocks. Although we find evidence in favour of both shocks, including interest rates as observables, shifts explanatory power away from trend shocks towards interest rate shocks.

Keywords: Business Fluctuations; Cycles ; Financial Markets and the Macroeconomy

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1 Introduction

A number of recent papers have used estimated small open economy (SOE) dynamic general equilibrium models to study the sources of business cycles in emerging market economies (EMEs). This recent literature has led to a debate on the relative importance of shocks to the productivity trend *versus* interest rate shocks coupled with financial frictions. On one side, Aguiar and Gopinath (2007) estimate a small open economy model that includes productivity shocks (trend and stationary) but no financial frictions and found that trend shocks are the primary source of fluctuations in Mexico. On the other side, García-Cicco, Pancrazi and Uribe (2010) (GCPU henceforth) and Chang and Fernandez (2013) use Argentine and Mexican data to estimate SOE models that include financial frictions and interest rate shocks (shocks to the world interest rate or to the country's interest rate premium) in addition to productivity shocks (trend and stationary).¹ These two articles find that trend shocks play an extremely limited role. Instead, it is the combination of stationary productivity shocks and interest rate shocks that explain more than 50% (often a lot more than 50%) of the variance of output growth, consumption growth, investment growth and the trade balance-output ratio (tb/y) in their models with financial frictions. More recently, Drechsel and Tenreyro (2018) extended the GCPU model by adding a commodity sector and making the country premium a function of commodity prices. They estimate their model using Argentine data and also find an important role for stationary productivity shocks, interest rate shocks and financial frictions.² Neumeyer and Perri (2005) and Uribe and Yue (2006) also argue in favour of country premium shocks and financial frictions but their model do not incorporate trend shocks so they do not directly contribute to the debate.

Importantly, the papers where a major role was assigned to interest rate shocks and financial frictions did not force their models to match the historical paths of the world interest rate or country rate.³ This could have resulted in poorly identified interest rate shocks. Since these shocks are not tied down by interest rate data they could have picked up the explanatory power of other shocks. Also, since the models are not forced to match interest rate data, the interest rate paths they imply may not resemble historical interest rate time series. In such cases, the contributions of shocks to the EME business cycles (as measured by variance

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¹GCPU also includes preference shocks and spending shocks.

²Interestingly, productivity trend shocks are more important than in GCPU. They explain about 20% of the variance of output growth and 10% of the variance of consumption growth.

³One of the robustness testing exercise in Chang and Fernandez (2013) is an exception. As discussed in more detail below, our model differs from theirs and we use nine more years of data in estimating our model.

decompositions) would be inaccurate. Accordingly, the main contribution of this paper is to provide quantitative accuracy to the estimation of country premium shocks and world interest rate shocks as well as verify their ability to explain the business cycle fluctuations of EME when the model and shocks are constrained to match observed interest rate time series, taking into account different forms of financial frictions.⁴ To achieve this, we do two things. First, we work with quarterly data for a period where country interest rates for Argentina and Mexico are available (1994-2012). Second, we estimate our SOE model using Bayesian methods where a world interest rate series and a country interest rate series are included in the set of observables. This estimation strategy forces the model and estimated shocks to match the time paths of the world and country interest rates which puts a great deal of discipline on the estimated shocks. It also has the advantage of allowing us to separately identify shocks to the world interest rate and shocks to the country premium and to measure their respective abilities to explain the business cycles variation in output growth, consumption growth, investment growth and tb/y .

Our quantitative analysis builds on GCPU. Our model has one sector, GHH preferences, one-period debt, a debt-elastic country premium,⁵ a working capital constraint and five shocks: preferences, stationary productivity, trend productivity, world interest rate and country-premium. Therefore, our benchmark model specification differs from GCPU in the following ways. First, we include a second financial friction in the form of a working capital constraint as suggested by the influential work of Neumeyer and Perri (2005) and Uribe and Yue (2006).⁶ Second, we include a shock to the world interest rate since our estimation strategy allows us to separately identify country-premium shocks and world interest rate shocks. Third, we discard spending shocks since the variance decomposition in GCPU shows that these shocks do not explain the variance of the observables and that is also what we find. Contrary to GCPU and the other papers cited above, our estimation method uses a world interest rate series (proxied by the US real interest rate) and a country interest rate series as observables in our Bayesian estimation. The other four “core” observables are those used by

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⁴There are different forms of financial frictions that previous studies have found important. For example, while Neumeyer and Perri (2005) emphasized the role of working capital constraints and “induced country risk” specification, GCPU emphasize the role of debt-elastic country interest rate. We consider all of them either in the benchmark specification or as a robustness check.

⁵This is a common assumption in the literature. Ortiz Bolaños and Wishart (2012) find that a financial friction of that form improves the fit of their model for all of the emerging countries they look at.

⁶Both of these papers adopt theoretical models where the effects of interest rate shocks are amplified by a financial friction taking the form of a working capital constraint. We thank a referee for suggesting adding financial frictions to the GCPU setup.

GCPU: growth rate of output, growth rate of consumption, growth rate of investment, and tb/y . Like GCPU, we estimate the persistence and variance of shocks, the capital adjustment costs parameter as well as the debt elasticity of the country interest rate premium. We also estimate the parameter appearing in the working capital constraint⁷ to test if that constraint is empirically relevant.

While most would agree that using interest rate data to identify interest rate shocks is a natural thing to do, it is also natural to wonder if doing so actually changes the model's implications. To answer this question we also estimate our model without including (i) the world interest rate as an observable; (ii) the country rate as an observable; (iii) world interest rate shocks.⁸ Then we use the estimated interest rate shocks and the model to calculate the time series of the country interest rate implied by the model. In the case of Mexico, the correlation between the model implied country rate and its Mexican counterpart is -0.06! For Argentina, the correlation between the model implied series and its counterpart in the data is 0.63. However, the standard deviation of the simulated series is only about half of the standard deviation of its counterpart in Argentine data. Comparing variance decompositions for the cases with and without interest rate data in the set of observables reveals a pattern: the addition of interest rate data dramatically reduces the fraction of the variance of investment growth and tb/y explained by productivity trend shocks while the fraction explained by interest rate shocks increases. In Argentina, productivity trend shocks are more important drivers of investment growth and tb/y than interest rate shocks when interest rate data are not used as observables. However, that ranking is reversed when we estimate the model using interest rate data. In Mexico, when interest rate data are not used as observables the fraction of the variance of investment growth and tb/y explained by interest rate shocks is only 2%. However, when interest rate data are included as observables the fraction of the variance of Mexican investment growth and tb/y explained by interest rate shocks (country premium shocks and world interest rate shocks) rise to 32% and 23% respectively. Conversely, the fraction of investment growth and tb/y explained by productivity trend shocks fall by 35 and 23 percentage points, respectively. Therefore, the better identification of interest rate shocks brought by the addition of interest rate data to the set of observables has important implications for the assessment of those shocks (and of productivity trend shocks) as sources

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⁷Representing the fraction of the wage bill that firms must borrow.

⁸Since the world interest shocks and premium shocks enter the model additively, we cannot separately identify them once we have dropped the interest rate data from the list of observables. Hence, the interest rate shock remaining in the model can be interpreted as a shock to the world interest rate (as in Chang and Fernandez) or as a premium shock (as in GCPU).

of business cycle fluctuations in Argentina and Mexico.

We believe our work is relevant for both sides of the aforementioned debate. Like Aguiar and Gopinath, we find that trend shocks represent the dominant source of business cycle fluctuations in Mexico when interest rate data are not used in the estimation of the model. However, when we do use such data, the role of trend shocks diminishes significantly and they become only one of the main sources of business cycle fluctuations in Mexico and Argentina. What about the relevance of interest rate shocks? We find that forcing estimated models to match the historical paths of the world interest rate and country rate actually improves the ability of interest rate shocks to explain the variance of investment growth and tb/y in Mexico and Argentina. Therefore, our work supports the findings of GCPU and others about the importance of interest rate shocks for explaining the variance of investment growth and tb/y in Argentina.

We extend our model in a few directions to check the robustness of our findings. First, we introduce an anticipated component to stationary and trend productivity shocks. This opens up an additional channel through which trend productivity shocks could influence business cycle fluctuations. It could also affect the role of interest rate shocks which appears to be especially important for investment growth. Since investment in physical capital is influenced by expectations about future productivity of capital (which depends on expectations about future TFP) we want to verify whether interest rate shocks are still relevant when agents can better forecast the future productivity of capital. We find that anticipated productivity shocks do not improve the model's ability to fit Mexican data (in terms of log data density). They do improve the fit to Argentine data. For that country, we find that country-premium shocks and shocks to the world interest rate remain important when news shocks are added to the model. Trend productivity shocks (anticipated plus unanticipated) do not become a more important source of variation in output growth, consumption growth and investment growth.

Second, we make the country interest rate premium a function of expectations about future productivity as in Neumeyer and Perri's induced country risk specification and in Chang and Fernandez (2013). In this specification, there are three factors determining the country premium: (i) the country's net external debt (as in the benchmark specification), (ii) a shock (as in the benchmark specification), and (iii) expectations about future productivity. If some of the variation in country premium data reflects anticipated changes in future fundamentals (represented here by future productivity) then the role of interest rate shocks should be less

important than what we found in the benchmark specification. To some limited degree, that is what we find. For Mexico, the country interest rate and world interest rate shocks now each explain about 10% of the variance of investment growth and tb/y . The explanatory power of stationary productivity shocks increases while that of trend shocks does not change much. In a somewhat comparable specification (but without preference shocks and with a tiny debt elasticity) Chang and Fernandez (2013) find that country-premium shocks and world interest rate shocks each explain 6%-9% of the variance of investment growth and 14%-22% of the variance of the trade balance-output ratio in Mexico. This extension of the benchmark specification does not improve the fit of the model to Argentine data (in terms of log data density).

Those robustness tests support our conclusions that interest rate shocks are a relevant source of fluctuations in key macro aggregates (primarily investment growth and trade balance-output ratio) and that, while they are not irrelevant, trend productivity shocks are just one of the important sources of fluctuations in EME.

The rest of the paper is organized as follows. Section 2 describes the model environment. Section 3 explains how we estimate our model. Section 4 presents results for Argentina and Section 5 for Mexico. Section 6 concludes.

2 Model

2.1 Representative Firm

There is a large number of identical firms producing a single homogenous good. The representative firm rents physical capital K_t at rate r_t^K and hires labour h_t at rate W_t to produce output, Y_t , according to the aggregate production function⁹

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

Exogenous variables a_t and X_t represent stationary and non-stationary productivity shocks respectively. As GCPU argue, these two sources of aggregate volatility do not only capture variations in technology, they include other disturbances which may cause variations in total

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⁹Our notation convention is to use lowercase to denote stationary variables while uppercase are used to denote variables that grow stochastically. Two exceptions are the country gross interest rate R and world gross interest rate R^* which are both stationary.

factor productivity such as terms of trade shocks. The stationary productivity shock follows a first-order auto regressive process in logs given by

$$\log(a_{t+1}) = \rho_a \log(a_t) + \varepsilon_{a,t+1} \quad (2)$$

where $0 < \rho_a < 1$. Innovation $\varepsilon_{a,t+1}$ is an $iid(0, \sigma_{\varepsilon_a})$ random variable.

The growth rate of X_t is $g_t = \frac{X_t}{X_{t-1}}$ where the logarithm of g_t follows an AR(1) process of the form

$$\log\left(\frac{g_{t+1}}{\bar{g}}\right) = \rho_g \log\left(\frac{g_t}{\bar{g}}\right) + \varepsilon_{g,t+1} \quad (3)$$

where $0 < \rho_g < 1$ and $\bar{g}$ is the average gross growth rate of X_t . Innovation $\varepsilon_{g,t+1}$ is an $iid(0, \sigma_{\varepsilon_g})$ random variable.

We follow Neumeyer and Perri (2005) and Uribe and Yue (2006) in assuming that firms must borrow a fraction τ of their wage bill in advance. More specifically, during period t , the representative firm borrows $\tau W_t h_t$ at net rate $R_{t-1} - 1$. Hence, the firm's profits are given by

$$Y_t - W_t h_t - r_t^k K_t - (R_{t-1} - 1)\tau W_t h_t. \quad (4)$$

Profit maximization yields

$$r_t^k = \alpha \frac{Y_t}{K_t} \quad (5)$$

$$W_t = \frac{(1 - \alpha)Y_t/h_t}{1 + \tau(R_{t-1} - 1)} \quad (6)$$

2.2 Representative Household

The representative household supplies labour and rents out capital in competitive labour and capital markets. The representative household derives utility from consumption (C) and disutility from working. Its preferences are represented by the expected utility function

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \nu_t \frac{[C_t - \theta \omega^{-1} X_{t-1} h_t^\omega]^{1-\gamma} - 1}{1 - \gamma} \quad (7)$$

where ν_t denotes a preference shock which evolves as

$$\log(\nu_{t+1}) = \rho_\nu \log(\nu_t) + \varepsilon_{\nu,t+1} \quad (8)$$

where $0 < \rho_\nu < 1$. Innovation $\varepsilon_{\nu,t+1}$ is an $iid(0, \sigma_{\varepsilon_\nu})$ random variable. As argued in Correia, Neves and Rebelo (1995) GHH utility helps produce a countercyclical trade balance.

The period-by-period budget constraint is

$$W_t h_t + r_t^k K_t + \frac{D_{t+1}}{R_t} = D_t + C_t + S_t + I_t + \frac{\phi}{2} K_t \left(\frac{K_{t+1}}{K_t} - \bar{g} \right)^2 \quad (9)$$

where D_t represents the country's debt with the rest of the world at the beginning of period t . This debt must be repaid in period t . The country accumulates new debt in period t by issuing and selling D_{t+1} units of bonds to the rest of the world. Each bond issued in t pays one unit of consumption in period $t+1$. The gross rate of return (or interest rate) on bonds issued in period t is denoted R_t which implies that the price of a bond is given by $\frac{1}{R_t}$. The left side of the budget constraint represents the resources available in period t while the right side shows how these resources are used. I_t denotes investment in physical capital. We limit the variance of investment by imposing capital adjustment costs. Exogenous variable S_t represents domestic spending. It is simply given by $S_t = sX_{t-1}$ where s is a constant.¹⁰

The stock of capital evolves according to

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

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

The representative household chooses sequences for C , h , D , I , and K to maximize (7) subject to budget constraint (9), accumulation equation (10), and the no-Ponzi game condition

$$\lim_{j \rightarrow \infty} \mathbb{E}_t \left(\frac{D_{t+j}}{\Pi_{s=0}^j} R_s \right) \leq 0 \quad (11)$$

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¹⁰In our estimation work, we have systematically found that spending shocks explain nothing (also the case in GCPU, see their Table 5). Therefore, we discarded spending shocks.

2.3 Interest Rate Process

There are many different ways to model the interest rate faced by the small open economy in the literature.¹¹ The country interest rate R_t has three components

$$R_t = R_t^* + \psi \left(e^{\frac{\tilde{D}_{t+1}}{X_t} - \bar{d}} - 1 \right) + e^{(\mu_t - 1)} - 1, \quad \psi > 0 \quad (12)$$

First, following GCPU, the country interest rate is a function of a debt elastic risk premium (second term on the right side of the equation). The variable $\tilde{D}_t$ denotes the aggregate level of external debt per capita. Individual agents do not take into account of the effect of $\tilde{D}$ on R when deciding on the amount they wish to borrow or lend. In equilibrium we impose $\tilde{D}_t = D_t$. The debt elastic term takes into account that a country's borrowing rates tend to increase as its net foreign debt increases. This is a reduced form way of capturing the effect of indebtedness on a country's default risk. To close the SOE model (see Schmitt-Grohé and Uribe (2003)) it has been common for researchers to adopt a debt elastic interest rate setup where the debt elasticity parameter ψ is set to a very small number.¹² GCPU deviated from that approach and interpreted the premium term as a reduced form financial friction and estimated ψ . They estimated ψ using a Bayesian inference method and Argentine annual data from 1900-2005. They found the estimated value to be 2.8. We follow GCPU and estimate ψ .

Second, the country interest rate depends on the stochastic world interest rate R_t^* . In reality, the world interest rate is determined by the borrowing and lending behaviour of large open economies. We do not model those countries. Instead, we assume that R^* follows the AR(1) process

$$\log(R_t^*) = (1 - \rho_r^*)R^* + \rho_r^* \log(R_{t-1}^*) + \varepsilon_{r,t}^* \quad (13)$$

where $0 < \rho_r^* < 1$, $R^* > 1$ and $\varepsilon_{r,t}^* \sim iid(0, \sigma_{r^*}^2)$. We are using the US real interest rate as a proxy for the world interest rate and use that time series as an observable in our Bayesian estimation. In practice, this means that the innovations $\varepsilon_{r,t}^*$ that are identified from the data must be such that the time series of R^* produced by (13) must match the US interest rate (a small measurement error is included).

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¹¹See for example Neumeyer and Perri (2005), Uribe and Yue (2006), GCPU, Alvarez-Parra, Brandao-Marques and Toledo (2013).

¹²For example, the value of ψ assumed by Aguiar and Gopinath (2007) and Schmitt-Grohé and Uribe (2003) is 0.001.

Finally, the country premium $R_t - R_t^*$ has an exogenous stochastic component (μ_t) interpreted as a country-premium shock. This shock also appears in the “independent country risk” specification in Neumeyer and Perri (2005). It reflects factors beyond the country’s external debt position that could affect the rate at which the small country borrows and lends. Those factors could be internal (like political factors) or external (like the fear of contagion or commodity prices as in Drechsel and Tenreyro (2018)). The country-premium shock evolves according to

$$\log(\mu_t) = \rho_\mu \log(\mu_{t-1}) + \varepsilon_{\mu,t} \quad (14)$$

where $0 < \rho_\mu < 1$ and $\varepsilon_\mu \sim iid(0, \sigma_\mu^2)$. In our Bayesian estimation, we are using a time series of real interest rate for Argentina or Mexico as an observable.

3 Model Solution and Estimation

The model described above does not allow an analytical solution for commonly used parameter values. Hence numerical solution methods will be used. Before solving the model numerically we make it stationary. The deterministic version of our model implies a balanced growth path where h and r^k are constant while Y , K , I , C and D and W grow at rate $\bar{g}$. We detrend variables as follows: $c_t = C_t/X_{t-1}$, $y_t = Y_t/X_{t-1}$, $i_t = I_t/X_{t-1}$, $d_t = D_t/X_{t-1}$, $w_t = W_t/X_{t-1}$, and $k_t = K_t/X_{t-1}$. The stationary version of the model is presented in Appendix A. It is solved using a first-order linear approximation method as implemented in Dynare.

Our parameter assignment strategy largely borrows from GCPU’s work. We cut down on the number of parameters to estimate by calibrating technology and preference parameters γ , δ , α , ω , θ , β and steady-state debt $\bar{d}$. Unless otherwise indicated the values of calibrated parameters we employ are taken from GCPU¹³ and are reported in Table 1. For Argentina, we set $\bar{d} = 2$ to have a steady state value of tb/y of about 0.03 which is the average value of the trade balance output ratio in our quarterly data set. For Mexico, the same calibration strategy implies $\bar{d} = 1.39$.

Table 1: Calibrated Parameters

Parameter	γ	δ	α	ω	θ	β
Values	2	0.03	0.32	1.6	2.24	0.98

¹³We convert the values of β and δ to a quarterly frequency: $\beta = 0.98$ and $\delta = 0.03$.

All remaining parameters are estimated using Bayesian estimation methods (as implemented in Dynare) and quarterly data for Argentina or Mexico over the period 1994Q2-2012Q4. The set of observables includes six variables. Four of them are common with GCPU: the level of the trade balance-output ratio as well as the growth rates of output, consumption and investment.¹⁴ See Appendix B for more details about the data.

As explained in the previous section, we use a world interest rate series (proxied by the real US interest rate) and a country interest rate series as observables to help with the identification of shocks to R^* and μ . Let R^{US} be the real US quarterly interest rate. Let R^i be country i 's quarterly real interest rate (where i =Argentina or Mexico).¹⁵ Let $g_{y,t}^i$, $g_{c,t}^i$ and $g_{i,t}^i$ denote the growth rate of GDP, consumption and investment respectively. Let tby^i denote the trade balance-output ratio. We use the following measurement equations

$$g_{y,t}^i = \log \left(\frac{y_t}{y_{t-1}} g_{t-1} \right) \quad (15)$$

$$g_{c,t}^i = \log \left(\frac{c_t}{c_{t-1}} g_{t-1} \right) \quad (16)$$

$$g_{i,t}^i = \log \left(\frac{i_t}{i_{t-1}} g_{t-1} \right) \quad (17)$$

$$tby^i = \frac{tb_t}{y_t} \quad (18)$$

$$R_t^i = R_t \quad (19)$$

$$R_t^{US} = R_t^* \quad (20)$$

In our benchmark specification (labeled M1), we estimate the parameters governing the stochastic process of productivity ($\rho_g, \sigma_{\varepsilon_g}, \rho_a, \sigma_{\varepsilon_a}$), interest rates ($\rho_\mu, \sigma_{\varepsilon_\mu}, \rho_r, \sigma_{\varepsilon_{r^*}}$), preference ($\rho_\nu, \sigma_{\varepsilon_\nu}$) as well as the parameters governing the degree of capital adjustment costs (ϕ), the debt elasticity of interest rate (ψ) and the fraction of wage bill borrowed by firms (τ). We also estimate six non-structural parameters which represent the standard deviations of i.i.d. measurement errors on the observables.

¹⁴First differences of logged data. The growth rates of consumption, investment and output differ markedly in our data set. This is not consistent with our model so we demeaned all three growth rates series.

¹⁵The country interest rate data we use are from Uribe and Yue (2006) and is the sum of J.P. Morgan's EMBI+ stripped spread and the US real interest rate.

GCPU assume uniform prior distributions for all the parameters they estimate. For each measurement error standard deviation, the prior's upper bound is set at 25% of the standard deviation of the corresponding observable. We use the same prior for the standard deviations of all shocks except preference shocks. When we used the same prior for all shocks, we found that the density of the posterior distribution of σ_ν was concentrated at the arbitrary upper bound 0.2. Hence, we widened its prior.

Since it is difficult to have a sense of the range we should use for the prior of the capital adjustment cost parameter ϕ , we use a normal distribution instead of a uniform since the former does not impose an upper bound. We follow Chang and Fernandez (2013) and use a Beta distribution for the prior of the working capital parameter τ . Our default prior for ψ is a uniform prior over the range $[0, 1]$. In some instances, the density of the posterior distribution is concentrated at the arbitrary upper bound. In those cases, we use a normal prior with mean 1 and standard deviation 0.3.

To show the importance of using interest rate data as observables we also estimate our model *without* including data on the world interest rate and on the country rate as observables. That is, we drop measurement equations (19) and (20). Since the world interest shocks and premium shocks enter the model additively in equation (12) we cannot separately identify them once we have dropped the interest rate data from the list of observables. Therefore, we drop stochastic process (13) and make R^* constant. Hence, in this “basic” specification labeled M0 the interest rate shock remaining in the model (μ) can be interpreted as a shock to the world interest rate (as in Chang and Fernandez) or as a premium shock (as in GCPU).

In our estimation, the number of replications for the Metropolis-Hastings algorithm is set to two millions and the number of chains is set to two. Tables 2 and 5 present the prior distributions, the means of the posterior distributions as well as confidence intervals (for the benchmark specification) for Argentina and Mexico respectively. Figures displaying the prior and posterior distributions as well as estimated shocks for the benchmark specification (for both countries) are included in Appendix C.

Our discussion of results is organized by countries, starting with Argentina.

Table 2: Prior and Posterior Distributions-Argentina

Param.	Prior Distribution	Mean of Posterior Distribution					
		M0	M1	M1 5%	M1 95%	M2	M3
ρ_g	U(0, 0.99)	0.672	0.895	0.846	0.946	0.875	0.680
ρ_a	U(0, 0.99)	0.945	0.942	0.904	0.984	0.962	0.981
ρ_ν	U(0, 0.99)	0.934	0.953	0.907	0.990	0.821	0.968
ρ_μ	U(0, 0.99)	0.802	0.717	0.651	0.785	0.677	0.694
ρ_{r^*}	U(0, 0.99)	n/a	0.958	0.929	0.990	0.974	0.932
σ_{ε_g}	U(0, 0.2)	0.011	0.009	0.007	0.012	0.005	0.016
$\tilde{\sigma}_{\varepsilon_g}$	U(0, 0.2)	n/a	n/a	n/a	n/a	0.010	n/a
σ_{ε_a}	U(0, 0.2)	0.010	0.011	0.009	0.013	0.013	0.004
$\tilde{\sigma}_{\varepsilon_a}$	U(0, 0.2)	n/a	n/a	n/a	n/a	0.002	n/a
σ_{ε_ν}	U(0, 1)	0.220	0.297	0.155	0.476	0.163	0.327
σ_{ε_μ}	U(0, 0.2)	0.006	0.018	0.015	0.021	0.011	0.021
$\sigma_{\varepsilon_{r^*}}$	U(0, 0.2)	n/a	0.004	0.004	0.005	0.004	0.004
ψ	U(0,1) or N(1,0.3)	0.186	0.041	0.007	0.076	1.033	0.0099
ϕ	Normal(20,3)	18.368	26.556	22.832	30.188	26.065	26.847
τ	Beta(0.5, 0.224)	0.198	0.128	0.021	0.228	0.086	0.185
η_1	U(0, 1.4)	n/a	n/a	n/a	n/a	n/a	1.206
η_2	U(0, 1.4)	n/a	n/a	n/a	n/a	n/a	0.582
Measurement errors							
σ_y^{me}	U(0.0001, 0.0051)	0.0022	0.0033	0.0012	0.0051	0.0045	0.0021
σ_c^{me}	U(0.0001, 0.0066)	0.0033	0.0036	0.0010	0.0066	0.0044	0.0049
σ_i^{me}	U(0.0001, 0.0243)	0.0160	0.0206	0.0164	0.0243	0.0182	0.0191
σ_{tby}^{me}	U(0.0001, 0.0119)	0.0041	0.0039	0.0027	0.0051	0.0039	0.0043
σ_r^{me}	U(0.0001, 0.0114)	n/a	0.0109	0.0104	0.0114	0.0108	0.0109
$\sigma_{r^*}^{me}$	U(0.0001, 0.0051)	n/a	0.0005	0.0001	0.0010	0.0005	0.0006
LDD		709	1132			1142	1124

Notes: LDD: log data density; M0: Basic=Benchmark w/o interest rate data as observables; M1: Benchmark; M2: Anticipated productivity shocks; M3: Country premium as a function of $E[a_{t+4}]$ and $E[g_{t+4}/\bar{g}]$

4 Results-Argentina

We begin with a few remarks about the organization of Table 2 and of our discussion of results. Specification M1, our benchmark specification, corresponds to the model described in Section 2 and estimated as explained in Section 3. This is our principal specification so Table 2 also includes the lower bound (M1 5%) and upper bound (M1 95%) of 90% interval estimates. The posterior means reported in column M0 are for our “basic” specification (corresponding to the benchmark model specification estimated *without* using interest rate data). M2 corresponds to the specification with anticipated productivity shocks (covered in Section 4.2). M3 corresponds to the “induced country risk” specification (covered in Section 4.3). The last row of the table reports the log data density (LDD) of each specification. We use the LDD to measure the fit of the model.¹⁶

4.1 Benchmark and Basic Specifications

4.1.1 Parameter Estimates

The estimated parameters for our basic specifications (M0 in Table 2) show that all shocks are persistent and that trend productivity shocks are the least persistent ($\rho_g = 0.67$). The estimated standard deviations of trend productivity shocks, stationary productivity shocks and interest rate shocks are around 0.01 while the standard deviation of preference shocks is estimated at 0.22. All of the frictions included in the theoretical model are in operation in the basic specification. The debt elasticity of the interest rate (ψ) and the share of the wage bill that needs to be paid in advance (τ) are about 20%. The capital adjustment cost parameter is approximately 18.

The addition of the world interest rate and the country rate to the set of observables changes the estimated values of many parameters. The autocorrelation and standard deviation of preference shocks are a little higher in M1 than M0. The standard deviation of innovations in trend productivity shocks is slightly lower in M1 than M0 (0.009 vs 0.011) but their autocorrelation is significantly higher in M1 ($\rho_g = 0.895$ vs 0.672). As a result, the unconditional variance of trend shocks is higher in M1. Recall that M1 includes a world interest rate shock and a country-premium shock while M0 includes only one kind of interest rate shocks (which we labelled μ). The estimated standard deviation of innovations to μ shocks is three times

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¹⁶Notice that since M0 is estimated with a different data set than other specifications, its LDD is not comparable with the other LDD numbers in Table 2.

higher in M1 than M0 but the stochastic process for μ is less persistent. The estimated standard deviations and autocorrelations imply that μ has higher unconditional variance in M1 than M0. Finally, to match all six observables, the benchmark specification relies on higher adjustment costs and smaller financial frictions than in M0. The fraction of the wage bill that is paid in advance (τ) is a little smaller (13% vs 20%) and the estimated value of the debt elasticity parameter $\psi = 0.041$ is more than four times smaller than in M0. The value $\psi = 0.041$ implies that, starting in steady state, an 11% increase in the country's external debt raises the country rate by one percentage point. Hence, both financial frictions are in operation.

4.1.2 Variance Decomposition Results

4.1.2a Importance of Using Interest Rate Data as Observables

We begin this section by comparing the implications of the basic and benchmark specifications. Recall that when interest rate series are part of the set of observables (as in M1), the estimated model and shocks must match those time series almost exactly (we allow for some measurement errors) while there is no such restrictions in the basic specification M0. Figure 1 shows the Argentine country rate as well as the country rate implied by specifications M0 and M1 (all series demeaned). Clearly, the series implied by M1 is much closer to the data. The correlation of the Argentine interest rate with R in specification M1 is 0.97 while its correlation with R in M0 is 0.63. It makes intuitive sense to expect that, everything else equal, less variable shocks will explain smaller fractions of the variance in the observables. Let's now turn to the variance decomposition results in Table 3 (M1 on the left and M0 on the right). This comparison will enable us to find out whether using interest rate data to identify interest rate shocks actually changes the model's implications.

Figure 1: Historical and Smoothed rates - Argentina

Table 3: Variance Decomposition—Argentina (1994Q2 - 2012Q4)

Benchmark Specification (M1)							Basic Specification (M0)			
shock	g_y	g_c	g_i	tb/y	r	r^*	g_y	g_c	g_i	tb/y
ε_a	60.39	20.17	3.83	1.71	0.93	0	62.52	27.53	8.35	3.58
ε_g	35.82	26.89	14.15	27.92	4.11	0	34.66	28.14	31.83	43.89
ε_ν	2.37	36.75	19.11	27.89	19.54	0	2.47	42.09	40.47	35.02
ε_μ	1.13	13.21	52.44	30.49	66.93	0	0.35	2.55	19.35	17.51
ε_r^*	0.28	2.98	10.47	11.99	8.50	100	n/a	n/a	n/a	n/a

Comparing variance decomposition in the left panel of Table 3 (interest rate data in the set of observables) and in the right panel (no interest rate data in the set of observables) shows that the addition of interest rate data dramatically reduces the fraction of the variance of investment growth and tb/y explained by the productivity trend shocks while the fraction explained by interest rate shocks increases importantly. More specifically, the share of investment growth explained by trend shocks falls from 32% to 14% while the share of tb/y falls from 44% to 28%. Conversely, the share of investment growth explained by premium shocks and world rate shocks increases from 19% to 63% while the share of tb/y increases from 18% to 42%. Therefore, productivity trend shocks are a more important driver of investment growth and tb/y than interest rate shocks in specification M0 while that ranking is the opposite in M1.

Therefore, the better identification of interest rate shocks brought by the use of interest rate data in the set of observables has important implications for the assessment of those shocks and of productivity trend shocks as sources of business cycle fluctuations in Argentina. Using interest rate data as observables shifts explanatory power to interest rate shocks from trend shocks. Section 4.1.2b discusses the variance decomposition for our benchmark specification in more detail.

4.1.2b Variance Decomposition Results—Benchmark Specification

Recall that GCPU find that country-premium shocks are the single most important source of variation in investment growth and tb/y in Argentina (annual data, 1900-2005), explaining more than 60% of those two observables. They find that shocks to trend productivity explain less than 8% of the variance of core observables. More recently, Drechsel and Tenreyro (2018) extended the GCPU model by adding a commodity sector and making the country premium a function of commodity prices. They estimate their model using Argentine data covering 1900-2015 and also find an important role for interest rate shocks. In their baseline case, interest rate shocks explain about 25% of the variance of investment growth and 65% of the variance of tb/y . Productivity trend shocks are more important than what GCPU found, explaining 10-20% of the variance of output growth and consumption growth. Before turning to our own variance decomposition results we note that one should keep in mind that GCPU and Drechsel and Tenreyro use data covering a much longer period than us (and at a different frequency). Therefore, our results are not fully comparable to theirs.

The left panel of Table 3 displays the variance decomposition results for our benchmark specification. It is worth reiterating that our estimation strategy differs from the one used by GCPU and many others along one important dimension: we have a world interest rate series and a country interest rate series in the set of observables. This means that the model and estimated shocks must reproduce the times series of the world rate and country rate (with some allowance for measurement errors). Figure 2 shows that this is indeed the case.

Figure 2: Benchmark Specification - Historical and Smoothed Variables

Dashed line: Historical   Solid line: Smoothed variables

Coming back to the left panel of Table 3, the second last row shows that country-premium shocks (μ) explain around 50% of the variance of investment growth, about 30% of the variance of tb/y and two-thirds of the variance of the Argentine interest rate. Therefore, we confirm the results of GCPU and Drechsel and Tenreyro (2018) regarding the importance of

interest rate shocks using quarterly data covering a different time span and an estimation strategy that puts a lot more discipline on estimated interest rate shocks. Note that we should not expect country premium shocks to explain all of the country interest rate since the country-premium is also a function of the country's debt which is driven by other shocks. Hence, productivity and preference shocks will cause some endogenous movements in the country rate.¹⁷

As expected, the world interest rate observable is entirely explained by world interest rate shocks (recall that R^* is entirely exogenous). Those shocks also explain around 10% of the variance of investment growth and tb/y . Adding up the shares explained by country-premium shocks and those explained by world interest rate shocks we find that interest rate shocks explain more than 60% of the variance of investment growth and more than 40% of the variance of tb/y . Therefore, interest rate shocks represent the main driver of investment growth and tb/y .

As explained in Neumeyer and Perri (2005), interest rate shocks have a significant effect on the volatility of output when firms need to borrow a large percentage of the wage bill (*i.e.* when τ is near 1). That percentage is estimated at 12.8% which might explain why interest rate shocks explain very little of the variance of output growth.

Preference shocks explain some of the variance of all the observables except output growth and the world interest rate.

Stationary productivity shocks explain 60% of the variance of output growth and 20% of the variance of consumption growth. Shocks to the productivity trend explain about 30% of the variance of output growth, consumption growth and tb/y .

In summary, the variance decomposition results presented in this section contribute the following two points to the debate on the importance of trend productivity shocks and interest rate shocks: (i) interest rate shocks are the main drivers of investment growth and tb/y ; (ii) trend productivity shocks are relevant but they are not the primary driver of output growth, consumption growth, investment growth and tb/y .

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¹⁷When we force $\psi = 0.001$ instead of estimating it, 83% of the variance of the country rate is explained by country-premium shocks.

4.1.3 Business Cycle Statistics

We complete our discussion of the implications of the benchmark specification by looking at some business cycle statistics to complement the information conveyed by Figure 2. Figure 3 presents the autocorrelation of trade balance-output ratio obtained from quarterly Argentine data and the model.

Figure 3: Benchmark Specification - Autocorrelation Function of TB/Y

Despite the fact that the model does not produce autocorrelations that are quite as large as those in the data, the model is able to capture the overall downward slopping pattern of the autocorrelation function of trade balance-output ratio. Recall that GCPU showed that the SOE RBC model cannot produce such a downward sloping function.

Finally, the model produces negative correlations of the trade balance-output ratio and country interest rate with output. The benchmark specification produces $\text{correl}(\log(y), tby) = -0.44$ and $\text{correl}(\log(y), R) = -0.39$. To calculate the equivalent moments in the data we needed to detrend the variables. We did that using the HP filter. The correlations are -0.8 and -0.64 respectively.

4.2 Anticipated Productivity Shocks (M2)

In this first extension we add anticipated (or news) shocks about stationary and trend productivity.¹⁸ This opens up an additional channel through which trend productivity shocks could influence business cycle fluctuations. It could also affect the role of interest rate shocks which, according to the results presented above, are especially important for investment growth. Since investment in physical capital is influenced by expectations about future productivity of capital (which depends on expectations about future TFP) we want to verify whether interest rate shocks are still relevant when agents can better forecast the future productivity of capital.

To illustrate our modelling of anticipated shocks, consider the stochastic process for stationary productivity shock a

$$\log(a_t) = \rho_a \log(a_{t-1}) + \varepsilon_{a,t} + \varepsilon_{a,t-J}^J \quad (21)$$

where as before $0 < \rho_a < 1$. The unanticipated component of a_t is represented by $\varepsilon_{a,t}$ which is an $iid(0, \sigma_{\varepsilon_a})$ random variable while the anticipated component is represented by $\varepsilon_{a,t-J}^J$ which is $iid(0, \tilde{\sigma}_{\varepsilon_a})$. Therefore in period t agents learn the value of $\varepsilon_{a,t}$ which allows them to calculate a_t and they also learn the value of $\varepsilon_{a,t}^J$ which helps them forecast the value of a_{t+J}

$$\mathbb{E}_t \log(a_{t+J}) = \rho_a^J \log(a_t) + \varepsilon_{a,t}^J. \quad (22)$$

The prior and posterior distributions are in Table 2 (column M2). The variance decomposition results for a specification with $J = 8$ are in Table 4. We should note that the prior distribution we use for ψ here is not the same as in the benchmark specification. When using prior $U(0, 1)$ most of the density of the posterior distribution for ψ is concentrated at the upper bound. We then tried a wider uniform prior $U(0, 2)$ and a normal prior $N(1, 0.3)$. The log data density values are similar in both cases (1141 for the former and 1142 for the latter), the mean of the posterior distribution for ψ is similar (1.15 vs 1.03) and the variance decomposition results are nearly identical. Since the Markov chains converge a lot quicker when using a normal prior we decided to work with that.

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¹⁸Jaimovich and Rebelo (2008) were the first to study the effects of anticipated changes in TFP in a small open economy DGE model. A few early examples of papers studying news shocks in closed-economy DGE models are Beaudry and Portier (2006), Barsky and Sims (2011), Schmitt-Grohé and Uribe (2012).

Table 4: Variance Decomposition—M2—Argentina
Anticipated Productivity Shocks (M2)

shock	g_y	g_c	g_i	tb/y	r	r^*
ε_a	65.02	45.42	11.65	5.38	1.88	0
ε_a^{news}	2.11	0.52	0.09	0.58	0.55	0
ε_g	7.31	10.78	8.92	18.06	1.54	0
ε_g^{news}	24.60	9.32	6.17	21.82	38.88	0
ε_ν	0.64	26.05	33.98	20.81	20.22	0
ε_μ	0.26	6.69	33.24	27.82	31.72	0
ε_r^*	0.05	1.22	5.95	5.53	5.2	100

Variance decomposition results show that, while they play a less prominent role, interest rate shocks are still central to explaining the variance of investment growth and of tb/y despite the presence of anticipated productivity shocks. Country-premium shocks explain about 30% of the variance of investment growth, tb/y and country interest rate. We also looked at 4-quarters ahead anticipated shocks (*i.e.* $J = 4$) and obtained the same value for the log data density and a similar variance decomposition.

Of the four types of productivity shocks included in this model specification, only the anticipated stationary productivity explain very little of the variance of the observables. The anticipated productivity trend shock explains 20%-25% of the variance of output growth and tb/y . It also explains about 40% of the variance of the country rate. Notice that the value of ψ is twenty-five times larger here than in the baseline model and that the anticipated trend productivity shock explains around 40% of the variance of the country's external debt. Hence, it is not surprising to see that it explains a significant share of the variance of the country interest rate because of the presence of the debt elastic term in (12).¹⁹ Adding together the contributions of anticipated and unanticipated trend productivity shocks reveals that those shocks are only the dominant source of variation for one of the observables, namely tb/y .

We noticed that the significance of anticipated productivity shocks in Argentina appears to come from the positive correlation of output growth, consumption growth, investment growth with the country rate during the four years following the debt default of 2001Q4.

¹⁹When we fix τ and ψ to the values estimated in the benchmark calibration the anticipated trend productivity shocks explains about 10% of the variance of the country rate. It still explains more than a quarter of the variance of output growth.

These positive correlations contrast with the negative ones observed in the subsamples 1994Q2-2001Q3 and 2005Q3-2012Q4 for Argentina and in our full sample of Mexican data. Since anticipated productivity shocks are the only shocks in the model generating positively correlated responses of output growth, consumption growth, investment growth and country rate it is perhaps not surprising to find that they are relevant to match the observables in the full sample. Evidently, Argentina's limited access to the international bond markets following its default triggered adjustments that an open-economy model like ours will not capture well. When we re-estimate the model using the admittedly very short sample 1994Q2-2001Q3, country-premium shocks and world interest rate shocks still each explain somewhere between 11% and 14% of the variance of investment growth and trade balance-output ratio while anticipated productivity shocks are negligible.

To summarize, the variance decomposition results in this section imply the following two points related to the debate on the importance of trend productivity shocks and interest rate shocks: (i) interest rate shocks are an important driver of investment growth and tb/y ; (ii) trend productivity shocks are relevant but they are not the primary driver of output growth, consumption growth, and investment growth.²⁰

4.3 Expected Productivity in Country Premium (M3)

In this section we introduce a different financial friction to our benchmark specification. It captures, in a reduced-form manner, the sensitivity of the country rate to expected future country fundamentals. One can think of international investors changing the premium they charge to the small country in response to changes in their expectations about the small-country's fundamentals. Better expected future fundamentals reduce the probability of default which leads to a smaller country premium. We follow Neumeyer and Perri (2005) "induced country risk" specification and add terms that directly relate the country premium to expected future productivity as follows

$$R_t = R_t^* + \psi \left(e^{\frac{\bar{D}_{t+1}}{\bar{X}_t} - \bar{d}} - 1 \right) + (e^{(\mu_t - 1)} - 1) - \eta_1 \mathbb{E}_t[\ln a_{t+i}] - \eta_2 \mathbb{E}_t[\ln g_{t+i}/\bar{g}] \quad (23)$$

Using (2) and (3) we can write

$$R_t = R_t^* + \psi \left(e^{\frac{\bar{D}_{t+1}}{\bar{X}_t} - \bar{d}} - 1 \right) + (e^{(\mu_t - 1)} - 1) - \eta_1 \rho_a^i \ln a_t - \eta_2 \rho_g^i \ln(g_t/\bar{g}) \quad (24)$$

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²⁰They are the primary driver of tb/y .

where i denotes the expectation horizon.

To choose a prior distribution for η_1 and η_2 we turn to Neumeyer and Perri (2005) and Chang and Fernandez (2013) for some guidance. The former authors' calibrated $\eta_1 = 1.04$ (there is no trend shock in their model so no η_2) while the latter authors estimated a value of 0.73 (using Mexican data) for a parameter multiplying $E_t \ln(a_t g_t^{1-\alpha})$. The prior they use is a Gamma distribution with a mean of one. Those two cases do not exactly map into our specification so we tried a few priors. First, we worked with a Gamma distribution with a mean of one and standard deviation of 0.3 for both η_1 and η_2 . We experimented with $i = 1$ and $i = 4$ and obtained a log data density value of 1123 in both cases and similar variance decomposition results. When $i = 1$, the mean of the posterior distributions are $\eta_1 = 1.15$ and $\eta_2 = 0.76$ whereas they are $\eta_1 = 1.34$ and $\eta_2 = 0.91$ when $i = 4$. Recall that the benchmark specification has an LDD of 1132 while the specification with anticipated productivity shocks has an LDD of 1142.

Then we tried a uniform prior with lower bound zero and upper bound 1.4 for both η_1 and η_2 for the case $i = 4$.²¹ The posterior mean obtained are $\eta_1 = 1.21$ and $\eta_2 = 0.58$ and the LDD is 1124. Finally, we estimated the model under the assumptions $\eta_1 = 0.1$ and $\eta_2 = 0.1$. Again, the LDD is lower than in the benchmark specification. We conclude that the “induced country risk” extension does not help the model fit the Argentine data.

In all three specifications where we estimated η_1 and η_2 , the country-premium shock explains more than one-third of the variance of investment growth, more than 15% of the variance of tb/y , and more than half of the variation of the country interest rate. Shocks to the world interest rate explain about 10% of the variance of investment growth and tb/y . Clearly, making the country premium a function of the expectations of future productivity does not alter our conclusion regarding the importance of interest rate shocks for explaining the variance of investment growth and tb/y . Finally, trend productivity shocks explain most of the variance of output growth but are not the primary driver of the fluctuations in the other observables.

In conclusion, the results presented in sections 4.1, 4.2 and 4.3 point to two robust findings: (i) interest rate shocks are an important driver of investment growth and tb/y in Argentina; (ii) trend productivity shocks are relevant but they are not the primary driver of all the core observables (output growth, consumption growth, investment growth and tb/y) in Argentina.²²

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²¹See last column Table 2 for estimates.

²²They are the primary driver of tb/y in the specification with news shocks and of output growth in induced

5 Results-Mexico

5.1 Benchmark and Basic Specifications

5.1.1 Parameter Estimates

We now use quarterly data for Mexico for the period 1994Q2 to 2012Q4 to further investigate into the contribution of interest rate and trend productivity shocks to the business cycles of EMEs. The values of the calibrated parameters are given in Table 1 except for the steady-state external debt $\bar{d}$ that is set to 1.39 to match the average debt to GDP ratio over this period. The prior distributions and the mean of the posterior distributions of the estimated parameters are in Table 5 (see Appendix C for the corresponding graphs). We use the same prior as for Argentina except for ψ and the upper bounds of the measurement errors. When using a uniform prior with lower bound 0 and upper bound 1 the density of the posterior distribution of ψ is concentrated near the arbitrary upper bound. Hence, as explained previously, we switch to prior $N(1, 0.3)$. In our benchmark specification, we also experimented with a Beta distribution defined over the range $[0, 2]$ for ψ . The log data density is the same with both priors and the variance decompositions are nearly identical.

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country risk specification.

Table 5: Prior and Posterior Distributions-Mexico

Param.	Prior Distribution	Mean of Posterior Distribution				
		M0	M1	M1 5%	M1 95%	M3
ρ_g	U(0, 0.99)	0.696	0.866	0.819	0.914	0.788
ρ_a	U(0, 0.99)	0.922	0.950	0.917	0.984	0.968
ρ_ν	U(0, 0.99)	0.880	0.945	0.890	0.990	0.935
ρ_μ	U(0, 0.99)	0.520	0.802	0.636	0.990	0.762
ρ_{r^*}	U(0, 0.99)	n/a	0.968	0.948	0.990	0.965
σ_{ε_g}	U(0, 0.2)	0.009	0.007	0.006	0.008	0.007
σ_{ε_a}	U(0, 0.2)	0.006	0.007	0.006	0.009	0.008
σ_{ε_ν}	U(0, 1)	0.061	0.085	0.042	0.141	0.078
σ_{ε_μ}	U(0, 0.2)	0.002	0.005	0.004	0.006	0.004
$\sigma_{\varepsilon_{r^*}}$	U(0, 0.2)	n/a	0.004	0.004	0.005	0.004
ψ	N(1,0.3)	1.066	1.025	0.562	1.463	1.025*
ϕ	Normal(20,3)	21.470	19.373	15.708	23.067	20.068
τ	Beta(0.5, 0.224)	0.370	0.153	0.008	0.292	0.193
η_1	Gamma(1, 0.3)	n/a	n/a	n/a	n/a	0.461
η_2	Gamma(1, 0.3)	n/a	n/a	n/a	n/a	0.411
Measurement errors						
σ_y^{me}	U(0.0001, 0.0034)	0.0033	0.0033	0.0032	0.0034	0.0033
σ_c^{me}	U(0.0001, 0.0048)	0.0046	0.0046	0.0044	0.0047	0.0046
σ_i^{me}	U(0.0001, 0.0122)	0.0104	0.0108	0.0091	0.0122	0.0106
σ_{tby}^{me}	U(0.0001, 0.0029)	0.0026	0.0028	0.0025	0.0029	0.0027
σ_r^{me}	U(0.0001, 0.0011)	n/a	0.0005	0.0001	0.0009	0.0005
$\sigma_{r^*}^{me}$	U(0.0001, 0.0051)	n/a	0.0007	0.0001	0.0013	0.0007
LDD		841	1416			1418

Notes: *Not estimated; LDD: log data density; M0: Basic=benchmark w/o interest rate data as observables; M1: Benchmark; M3: Country premium as a function of $E[a_{t+1}]$ and $E[g_{t+1}/\bar{g}]$

Before going into variance decomposition results, we compare the estimates for our benchmark specifications M1-Mexico (see Table 5) and M1-Argentina (see Table 2). We first highlight

similarities between M1-Mexico and M1-Argentina. In both cases, stationary productivity shocks, world interest rate shocks and preference shocks are more persistent (autocorrelation greater than 0.94) than trend productivity shocks and country-premium shocks μ (autocorrelation less than 0.9). The estimated values of ρ_g , ρ_a , ρ_v and ρ_{r*} are very similar in both countries. The standard deviations of the innovations to trend and stationary productivity are the same in M1-Mexico (0.007). Those standard deviations are also very similar in M1-Argentina ($\sigma_{\epsilon_g} = 0.009$ and $\sigma_{\epsilon_a} = 0.011$). As expected, world interest rate shocks have the same estimated standard deviations in both countries. The share of the wage bill that needs to be paid in advance is $\tau = 15\%$ in M1-Mexico which is close to what we find in M1-Argentina (13%).

In terms of differences between estimates in M1-Mexico and M1-Argentina, we note that the model does not need preference shocks of the same magnitude in Mexico as in Argentina ($\sigma_{\epsilon_v} = 0.085$ in Mexico vs 0.3 in Argentina). Country premium shocks have different persistence and variance in the two countries. They are more persistent ($\rho_\mu = 0.802$) in Mexico than in Argentina (0.717) but are a great deal less variable ($\sigma_{\epsilon_\mu} = 0.005$ in Mexico vs 0.018 in Argentina). Finally, we note that the capital adjustment cost parameter $\phi = 19.4$ is lower in Mexico than in Argentina (26.6) while the interest rate debt elasticity $\psi = 1$ is a lot larger than in Argentina (0.04). We now turn to variance decomposition results.

5.1.2 Variance Decomposition Results

5.1.2a Importance of Using Interest Rate Data as Observables

We begin this section by comparing the implications of the basic and benchmark specifications. Recall that when interest rate series are part of the set of observables (as in M1), the estimated model and shocks must match those time series almost exactly (we allow for some measurement errors) while there is no such restrictions in the basic specification M0. Figure 4 shows the Mexican country rate as well as the country rate implied by specifications M0 and M1 (all series demeaned). The series implied by M1 almost perfectly tracks the Mexican rate (correlation=0.99) while the series implied by M0 is not even positively correlated with it (correlation=-0.06). Given that the series r-M0 and r-M1 greatly differ, we should expect the explanatory power of interest shocks to be quite different in M0 vs M1. Let's now turn to the variance decomposition results in Table 3 (M1 on the left and M0 on the right). Again, the purpose of this comparison is to find out whether using interest rate data to identify

Figure 4: Historical and Smoothed rates - Mexico

interest rate shocks actually changes the model's implications. The variance decompositions are included in Table 6 (M1 on the left and M0 on the right).

When interest rate data are not used as observables the fraction of the variance of investment growth and tb/y explained by interest rate shocks is only 2% (right panel of Table 6). However, when they are included as observables the fraction of the variance of Mexican investment growth and tb/y explained by interest rate shocks (country premium plus world rate) rise to 32% and 24% respectively while the fraction of investment growth and tb/y explained by productivity trend shocks fall by 35 and 23 percentage points, respectively. Therefore Mexican results confirm that the better identification of interest rate shocks brought by the use of interest rate data in the set of observables leads to very different results regarding the role of those shocks as sources of business cycle fluctuations in Mexico. Section 5.1.2b discusses the variance decomposition for our benchmark specification in more detail.

Table 6: Variance Decomposition - Mexico

	Benchmark Specification (M1)						Basic specification (M0)			
shock	g_y	g_c	g_i	tb/y	r	r^*	g_y	g_c	g_i	tb/y
ε_a	62.87	40.82	14.46	3.29	3.69	0	50.86	30.68	12.42	3.30
ε_g	36.09	42.27	32.69	64.59	17.48	0	48.64	57.24	68.47	88.10
ε_ν	0.70	13.44	20.82	8.53	19.58	0	0.40	11.75	16.79	6.86
ε_μ	0.19	1.87	17.45	12.22	33.58	0	0.10	0.34	2.31	1.73
ε_r^*	0.15	1.60	14.57	11.37	25.67	100	n/a	n/a	n/a	n/a

5.1.2b Variance Decomposition Results—Benchmark Specification

The left panel of Table 6 shows that the shock having the greatest explanatory power for the variance of the country interest rate is the country-premium shock. As expected, the world interest rate observable is entirely explained by world interest rate shocks. Country-premium shocks as well as world interest rate shocks each explain around 15% of the variance of investment growth and about 10% of the variance of the tb/y . This similarity in the explanatory power of the two types of interest rate shocks was not observed in Argentina where country-premium shocks are significantly more important potentially because of the atypical period following the sovereign debt default at the end of 2001. As discussed at the end of Section 4.2, both shocks have similar explanatory power for investment growth and tb/y in Argentina in the shorter sample 1994Q2-2001Q3 preceding the debt default.

Shocks to the productivity trend explain a sizeable fraction of the variance of all of the core observables. They explain 36% of the variance of output growth, second only to stationary productivity shocks who explain 63%. They explain 33% of the variance of investment growth which is essentially equal to the share explained by the two types of interest rate shocks combined. Both types of productivity shocks each explain a similar share of the variance of consumption growth (about 40% each). Finally, trend shocks are by far the most important source of fluctuations in tb/y (65%).

In summary, the results above contribute the following two points to the debate on the importance of trend productivity shocks and interest rate shocks: (i) interest rate shocks are an important source of fluctuations in investment growth and tb/y ; (ii) trend productivity shocks are important drivers of business cycles in Mexico, explaining at least one third of the

variance of all of the core observables.

Figure 5 shows the time paths for Mexico and those produced by the model and estimated shocks. Finally, the model produces negative correlations of the trade balance-output ratio and country interest rate with output. The benchmark specification produces $\text{correl}(\log(y), tby) = -0.39$ and $\text{correl}(\log(y), R) = -0.52$.

Figure 5: Benchmark Specification - Historical and Smoothed Variables

Dashed line: Historical   Solid line: Smoothed variables

5.2 Anticipated Productivity Shocks (M2)

We add anticipated productivity shocks as in Section 4.2. We look at four-quarter and eight-quarter ahead shocks to stationary and trend productivity. We do not report variance decomposition results since they do not differ markedly from those in the left panel of Table 6. Also, anticipated shocks explain almost none of the variance of the observables and the log data density is not higher than the one in the benchmark specification.

5.3 Expected Productivity in Country Premium (M3)

Finally, we change the interest rate equation as explained in Section 4.3. When we add expected productivity to the interest rate equation the estimation of parameter ψ with Mexican data becomes problematic.²³ Hence we set $\psi = 1.025$, its value in the benchmark specification, instead of estimating it. The log data density increases modestly (1418 *versus* 1416 in the benchmark specification). The posterior means of the estimated parameters are reported in Table 5 (rightmost column) and the variance decomposition results are in Table 7.

Table 7: Variance Decomposition—M3—Mexico

shock	g_y	g_c	g_i	tb/y	r	r^*
ε_a	66.49	49.99	27.97	11.22	18.13	0
ε_g	32.56	37.42	42.60	65.49	24.64	0
ε_ν	0.58	10.06	12.30	6.29	14.89	0
ε_μ	0.18	1.16	8.01	7.43	20.88	0
ε_r^*	0.19	1.36	9.11	9.57	21.46	100

As was the case for Argentina, the country-premium shock and world interest rate shock lose some of their explanatory power when the premium is a function of expected productivity. They still each explain about 10% of the variance of investment growth and tb/y . We conclude that shocks to the country premium and to the world interest rate explain a non-trivial part of the variance of those two observables in Mexico. This conclusion is consistent with the implications of Chang and Fernandez’ “two spread elasticities” specification. This is one of the two specifications where they use interest rate data as observables and the only one where the country interest rate depends separately on expectations of future a and future g as in our equation (23). Several differences remain between their work and ours. Specifically, they estimate their model using data covering the period 1991Q1-2003Q2 (nine less years than us), they do not estimate ψ , our model includes preference shocks while theirs do not and they use the first difference of the trade balance-output ratio as observable while we use the level of tb/y .²⁴

²³It’s posterior distribution is not smooth and the diagnostic graphs computed by dynare show a lack of converge.

²⁴We explored how these differences affect our results. Setting $\psi = 0.001$ (as in CF), dropping taste shocks

In summary, the results presented in sections 5.1, 5.2 and 5.3 for Mexico points to two robust findings that relate to the debate on the importance of trend productivity shocks and interest rate shocks: (i) interest rate shocks are a relevant source of fluctuations in investment growth and tb/y ; (ii) trend productivity shocks are important drivers of business cycles in Mexico, explaining at least one third of the variance of all of the core observables.

6 Conclusion

A number of recent papers (*e.g.* Aguiar and Gopinath (2007), García-Cicco, Pancrazi and Uribe (2010), Chang and Fernandez (2013), Drechsel and Tenreyro (2018)) have used estimated small open economy dynamic general equilibrium models to study the sources of business cycles in emerging-market economies. Those papers generally do not use interest rate data in the estimation of their model. This raises the issue of identification of interest rate shocks. To address this issue, we do two things. First, we work with a sample period where country interest rates for Argentina and Mexico are available (1994-2012). Second, we estimate a small open economy model using Bayesian methods where a world interest rate series and a country interest rate series are included in the set of observables. This estimation strategy forces the model and estimated shocks to match the time paths of the world and country interest rates which puts a great deal of discipline on the estimated shocks.

We build on the model by GCPU, adding a working capital constraint and a shock to the world interest rate. We show that using interest rate data in the estimation of our SOE model using Argentine and Mexican data enhances the role of interest rate shocks and diminishes the role of trend productivity shocks in business cycle fluctuations. Having established that the use of interest rate data as observables changes the contributions of interest rate shocks and trend shocks to business cycle fluctuations, we revisit the aforementioned debate in a number of versions of our SOE model.

We find that interest rate shocks (shocks to country premium plus shocks to world interest rates) explain roughly 20% to 30% of the variance of investment growth and trade balance-

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and re-estimating the model leads to a different variance decomposition where stationary productivity shocks, world rate shocks and premium shocks have larger roles while trend shocks have a much smaller role (they now explain only approximately 10% of the of investment growth, tb/y and country rate). Importantly, the LDD drops from 1418 to 1340 when we make those two changes. Hence, specification M3 fits the data better when preference shocks are included and ψ is not forced to take a tiny value. Using the first-difference of tb/y as observable instead of its level actually increases the role of both types of interest rate shocks while it reduces the role of trend shocks. Here we cannot compare LDDs because we changed one of the observables.

output ratio in Mexico while they explain between 33% and 63% in Argentina. Clearly, interest rate shocks are relevant drivers of key macro aggregates in Argentina and Mexico.

We find that, while shocks to trend productivity are clearly important drivers of business cycle fluctuations, we cannot go as far as claiming that the “cycle is the trend.” Firstly, those shocks are not the primary driver of business cycle fluctuations in output growth, consumption growth and investment growth in Argentina.²⁵ Secondly, trend productivity shocks are not even close to be the main source of fluctuations in output growth in the specifications we estimated using Mexican data.

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²⁵We do not take into account of the induced country risk specification since it does not fit Argentine data as well as our benchmark specification (in terms of log data density).

7 Appendix A: Detrended Model and Optimality Conditions

The detrended period utility function is

$$\frac{[c_t - \theta\omega^{-1}h_t^\omega]^{1-\gamma} - 1}{1-\gamma} \quad (25)$$

The firm's profit maximization problem implies

$$r_t^k = \alpha \frac{y_t}{k_t} \quad (26)$$

$$w_t = \frac{(1-\alpha)y_t/h_t}{1+\tau(R_{t-1}-1)} \quad (27)$$

where aggregate output is given by the detrended aggregate production function

$$y_t = a_t k_t^\alpha (g_t h_t)^{1-\alpha}. \quad (28)$$

Using those factor prices in the period-by-period budget constraint implies

$$\left(\alpha + \frac{1-\alpha}{1+\tau(R_{t-1}-1)} \right) y_t + \frac{g_t d_{t+1}}{R_t} = d_t + c_t + s + i_t + \frac{\phi}{2} k_t \left(\frac{g_t k_{t+1}}{k_t} - \bar{g} \right)^2 \quad (29)$$

Let λ_t be the Lagrange multiplier associated with the constraint above. The representative household's optimality conditions with respect to c_t , h_t , d_{t+1} , and k_{t+1} are

$$\lambda_t = \nu_t \left(c_t - \frac{\theta}{\omega} h_t^\omega \right)^{(-\gamma)} \quad (30)$$

$$\theta h_t^{\omega-1} = \left(\alpha + \frac{1-\alpha}{1+\tau(R_{t-1}-1)} \right) (1-\alpha) a_t g_t^{1-\alpha} \left(\frac{k_t}{h_t} \right)^\alpha \quad (31)$$

$$\lambda_t = \frac{\beta}{g_t} \mathbb{E}_t R_t \lambda_{t+1} \quad (32)$$

$$\begin{aligned}
& \lambda_t \left(1 + \phi \left(\frac{g_t k_{t+1}}{k_t} - \bar{g} \right) \right) = \\
& \beta \frac{1}{g_t} \mathbb{E}_t \lambda_{t+1} \left[\left(\alpha + \frac{1 - \alpha}{1 + \tau(R_t - 1)} \right) \alpha \frac{y_{t+1}}{k_{t+1}} + 1 - \delta - \frac{\phi}{2} \left(\frac{g_{t+1} k_{t+2}}{k_{t+1}} - \bar{g} \right)^2 \right] \\
& + \beta \frac{1}{g_t} \mathbb{E}_t \lambda_{t+1} \left[\phi \frac{g_{t+1} k_{t+2}}{k_{t+1}} \left(\frac{g_{t+1} k_{t+2}}{k_{t+1}} - \bar{g} \right) \right] \quad (33)
\end{aligned}$$

The system has six equations (28)-(33) and six endogenous variables c , h , y , k , d and λ .

8 Appendix B: Data

We obtained the quarterly Argentine and Mexican data for output, consumption, investment and net exports from Martin Uribe's website

<http://www.columbia.edu/~mu2166/book/empirics/>

World interest rate:

US 3-month T bill rate is from Federal Reserve Board via Haver Analytics and US GDP deflator is from Bureau of Economic Analysis via Haver Analytics.

Country Interest rate for both Argentina and Mexico:

<http://www.columbia.edu/~mu2166/book/irs>

Argentina

GDP : INDEC (<http://www.indec.gov.ar/>)

Investment (gross capital formation): INDEC for base 1993 (<http://www.indec.gov.ar/>); FIEL for base 1986 (<http://www.fiel.org/>)

Imports of goods and services as percentage of GDP :

INDEC for base 1993 (<http://www.indec.gov.ar/>); FIEL for base 1986 (<http://www.fiel.org/>)

Exports of goods and services as percentage of GDP :

INDEC for base 1993 (<http://www.indec.gov.ar/>); FIEL for base 1986 (<http://www.fiel.org/>)

Consumption (household final consumption expenditure as percentage of GDP): INDEC (<http://www.indec.gov.ar/>)

Mexico

The Mexican data series (other than interest rate series) is from OECD as mentioned at Martin Uribe's website, <http://www.columbia.edu/~mu2166/book/empirics/>

9 Appendix C: Prior Distributions, Posterior Distributions, and Shocks— Benchmark Specification

Figure 6: Prior and Posterior Distributions graph 1 of 3-Argentina

Figure 7: Prior and Posterior Distributions graph 2 of 3-Argentina

Figure 8: Prior and Posterior Distributions graph 3 of 3-Arentina

Notes for Figures 6-8:

Vertical dashed line represent the mode of the posterior distribution.

SE_OBS_X denotes the standard errors of observable variable X.

Figure 9: Smoothed Shocks-Argentina

Figure 11: Prior and Posterior Distributions graph 2 of 3-Mexico

Figure 12: Prior and Posterior Distributions graph 3 of 3-Mexico

Notes for Figures 10-12:

Vertical dashed line represent the mode of the posterior distribution.

SE_OBS_X denotes the standard errors of observable variable X.

Figure 13: Smoothed Shocks-Mexico

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