Explaining Business Cycle Facts in Mexico*

by

Arturo Antón, Josué Cortés and Emilio Fernández-Corugedo

Banco de México

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Abstract

As it is well known, business cycle stylized facts in developing countries exhibit notable differences with respect to those in developed countries. Two of these differences are the strongly negative correlation between net exports and output observed in developing countries, and the relatively large volatility of consumption with respect to output. This paper presents two alternative dynamic, stochastic general equilibrium models that may account for these facts. The first model is a relatively standard real business cycle model with working capital and shocks to risk premium and to the transitory and permanent components of technology. The second model is a monetary model with working capital, flexible prices and shocks to the growth rate of money and to the transitory and permanent components of technology. Taking Mexico as a representative developing country, first we show that each model is capable of generating a strongly countercyclical trade balance and a relatively large volatility of consumption. Second, contrary to what is found in Aguiar and Gopinath (2007), the transitory component of technology is relatively more important than its permanent counterpart for explaining business cycle facts.

*The views expressed herein are those of the authors and not necessarily those of Banco de México.
1 Introduction

As it is well known, business cycles stylized facts in developing countries exhibit notable differences with respect to those in developed countries (see, for example, Neumeyer and Perri, 2005; Aguiar and Gopinath, 2007). One of these differences is the strongly negative correlation between net exports and output observed in developing countries. Another difference is the relatively large volatility of consumption with respect to output. The goal of this paper is to present two alternative dynamic, stochastic general equilibrium models that may account for these facts. The first model is a relatively standard real business cycle model with working capital, preferences of the type first considered by Greenwood, Hercowitz and Huffman (1988, henceforth GHH) and shocks to technology and risk premium. The second model is a monetary model with working capital, GHH preferences, flexible prices and shocks to technology and the growth rate of money. The motivation behind these models is the idea that developing countries are subject to risk premium and monetary shocks that are substantially different in nature to those observed in developed countries. Taking Mexico as a representative developing country, we show that each model is capable of generating a strongly countercyclical trade balance and a relatively large volatility of consumption.

In a paper closely related to ours, Aguiar and Gopinath (2007) report that a standard real business cycle model with shocks to trend growth is capable of generating a strongly negative correlation between net exports and output as well as a large ratio of consumption-to-output volatility. Furthermore, they find that shocks to trend growth (rather than transitory productivity shocks) are the main source of fluctuations in developing countries. The mechanism driving this result is that a shock to the growth rate induces an increase in current output, but an even further increase in future output. From the permanent income hypothesis, consumption exhibits a larger increase than income, thus reducing savings and deteriorating the trade balance. To acknowledge for this effect, each of the two models presented in this paper decompose productivity in two terms: a transitory and a permanent component. Therefore, this decomposition allows to evaluate the importance of trend shocks to productivity relative to monetary and transitory technology shocks along the business cycle.

The two models presented in this paper are roughly similar in the sense that they share the same transmission mechanism of primitive shocks via interest rates. The mechanism whereby these models are able to account for business cycle facts in developing countries is as follows. First, a change in interest rates has a direct and an indirect effect on consumption
growth. The direct effect is that an increase in the interest rate induces savings to increase and consumption to fall (through the standard Euler equation for consumption). The indirect effect works through its impact on employment. As firms must finance their wage bill through working capital, the demand for labor is a function of the interest rate. Given an increase in the interest rate, the labor cost for firms increases which reduces labor demand for any given real wage. As the preference specification in the model is such that the labor supply is not affected by changes in interest rates, the decline in labor demand leads to a fall in equilibrium employment. Since the capital stock is relatively stable at business cycle frequencies, the fall in employment translates into a fall in output and consumption, thus exacerbating the initial fall in consumption induced by the direct effect. If such effect is large, it may yield a large volatility of consumption relative to output. Simultaneously, a higher interest rate leads to an increase in savings and a decrease in investment, so net exports increase. Therefore, changes in interest rates are able to generate countercyclical net exports. The transmission mechanism just described is similar to the one presented by Neumeyer and Perri (2005). However, since trend shocks to productivity are included in our model this allows us to quantify the importance of such shocks relative to transitory technology shocks in order to explain business cycle facts in developing countries, an aspect not considered by Neumeyer and Perri (2005).

Notwithstanding their similarities, these two models are essentially different in one key aspect: the source of primitive shocks directly affecting interest rates. In the real model, the risk premium is assumed to be negatively related to a trend shock (cf. Aguiar and Gopinath (2006)). Thus a negative shock to the permanent technology component leads to a higher risk premium and, consequently, to a higher real interest rate. This allows the trend shock to have an additional transmission mechanism for explaining business cycle facts. In the monetary model, a positive shock to the growth rate of money leads to a higher nominal interest rate and thus to a lower level of employment (cf. Carlstrom and Fuerst (1995)). In such model, risk premium shocks are not included so that interest rates are only directly affected by monetary shocks.

Some parameters for both models are calibrated to replicate some features of Mexican data, which we take as our prototype of a developing country. The remaining parameters are estimated using the generalized method of moments (GMM).¹ Such method chooses

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¹ See, for example, Burnside (1999).
parameter values to minimize the squared difference between some theoretical moments of the model and their corresponding empirical moments. Remarkably, each model is able to match the relatively large volatility of consumption and the strong countercyclical trade balance observed in developing countries. The models are also able to replicate other moments of interest. Furthermore, it is found that the relative importance of the permanent component of technology for explaining business cycle facts decreases significantly in each model relative to what is found in Aguiar and Gopinath (2007). In fact, two alternative statistical measures suggest that the transitory component of technology is more important than its permanent counterpart at business cycle frequencies. This last result implies that slight modifications to a canonical real business cycle model are able to reverse the results reported by Aguiar and Gopinath (2007). In fact, these authors conjecture that differences in the technology process between developed and developing economies may be a result of deeper frictions in the economy. To the extent that emerging economies are subject to risk premium and/or monetary shocks substantially different to those observed in developed economies, our results are consistent with such conjecture.

The remaining of the paper is as follows. Section 2 presents the two models already described. Section 3 discusses the estimation technique and presents the results. Section 4 concludes.

2 The models

In this section we present two alternative small open economy models with transitory and permanent technology components in order to explain key business cycle facts in developing countries. Both models are similar in the sense that firms must borrow working capital and households have preferences of the type first proposed by Greenwood et al. (1988). However, the first of them is a real model with shocks to the interest rate risk premium. In particular, the risk premium is assumed to be a function of shocks to trend growth, as in Aguiar and Gopinath (2006): a positive shock to trend growth translates into a lower risk premium and thus to a lower real interest rate. The second model, in contrast, is essentially a monetary model with flexible prices and shocks to the growth rate of money. In such model, working capital is financed at the nominal interest rate as in Carlstrom and Fuerst (1995). Thus a monetary shock has an effect on the nominal interest rate and, consequently, on labor. Overall, these two models have the same transmission mechanism even though the primitive
shocks are different in nature.

2.1 A real model with shocks to risk premium

The real model with shocks to risk premium of this section is roughly a version of the model of Neumeyer and Perri (2005). Namely, it is a relatively standard small open economy model with working capital modified to allow for transitory and trend shocks to productivity as in Aguiar and Gopinath (2007). In particular, technology is represented by a Cobb-Douglas production function of the form

\[ Y_t = e^{\alpha} K_t^{1-\alpha} (\Gamma_t L_t)^{\alpha}, \]

(1)

where \( K_t \) and \( L_t \) denote capital and labor, respectively, and \( \alpha \) is the elasticity of output with respect to labor. The productivity process is captured by parameters \( z_t \) and \( \Gamma_t \). The term \( z_t \) represents the transitory component of productivity, which is given by a standard first-order autoregressive process of the form

\[ z_t = \rho_z z_{t-1} + \varepsilon^z_t, \]

(2)

with \( |\rho_z| < 1 \). Here, \( \varepsilon^z_t \) is an i.i.d. technology shock drawn from a normal distribution with zero mean and standard deviation \( \sigma_{\varepsilon^z} \).

The permanent component of productivity is represented by \( \Gamma_t \), where

\[ \Gamma_t = e^{\theta_t} \Gamma_{t-1} = \prod_{s=0}^{t} e^{\theta_s}. \]

The term \( \theta_t \) is subject to a stochastic first-order autoregressive process denoted by

\[ \theta_t = (1 - \rho_\theta) \mu_\theta + \rho_\theta \theta_{t-1} + \varepsilon^\theta_t, \]

(3)

with \( |\rho_\theta| < 1 \) and \( \varepsilon^\theta_t \) is an i.i.d. shock drawn from a normal distribution with zero mean and standard deviation \( \sigma_{\varepsilon^\theta} \). The expression \( \mu_\theta \) is the productivity’s long-run mean growth rate.

As in Neumeyer and Perri (2005), firms need to borrow working capital to pay the households that provide labor services. In particular, before production takes place workers receive a wage bill \( w_t L_t \) that must be borrowed by firms. Repayment occurs at the end of period \( t \) at the gross interest rate \( r_t \).² In contrast, the market for services of capital is not

² In Neumeyer and Perri (2005), the interest rate paid by firms is set before the state of nature is revealed.
subject to this friction so firms make payments $r_t^k K_t$ to the owners of capital at the end of period $t$ when production is realized. Accordingly, firm’s profits are given by the expression

$$Y_t - r_t w_t L_t - r_t^k K_t.$$  

To make the model stationary, non-stationary variables are scaled by the permanent component of productivity $\Gamma_{t-1}$, as in Aguiar and Gopinath (2007). Thus for any non-stationary variable $x_t$, its detrended counterpart $x_t^*$ is given by

$$x_t^* \equiv \frac{x_t}{\Gamma_{t-1}}.$$  

In the stationary version of the model, the firm’s problem is to choose labor $L_t$ and capital $K_t$ to maximize stationary profits $\tilde{Y}_t - r_t \tilde{w}_t L_t - r_t^k \tilde{K}_t$ subject to the stationary version of the technology constraint (1) and taking prices $\tilde{w}_t$, $r_t^k$ and $r_t$ as given.

Households derive life-time expected utility from consumption $C_t$ and disutility from labor $L_t$ according to the preferences postulated by Greenwood et al. (1988), which are extensively used in the small open economy literature:

$$E_0 \sum_{t=0}^{\infty} \beta^t \left( C_t - \tau \Gamma_{t-1} L_t^\nu \right)^{1-\sigma} \left( 1 - \sigma \right),$$

where the subjective discount factor satisfies $\beta \in (0, 1)$, the intertemporal elasticity of substitution is $1/\sigma$, and $\sigma, \tau > 0, \nu > 1$. The corresponding labor supply elasticity is given by $1/(\nu - 1)$.

Households’ budget constraint is given by

$$C_t + I_t + r_t B_t = w_t L_t + r_t^k K_t + B_{t+1},$$

where $B_t$ is the stock of real foreign debt that pays an interest rate $r_t$ at the beginning of period $t$. Investment $I_t$ is subject to quadratic adjustment costs of the type

$$I_t = K_{t+1} - (1 - \delta) K_t + \frac{\phi}{2} \left( \frac{K_{t+1}}{K_t} - e^{\rho t} \right)^2 K_t,$$

with $\delta \in (0, 1)$ denoting the depreciation rate. As usual, adjustment costs are introduced in order to avoid excessive volatility of investment (Mendoza, 1991).

In stationary form, lifetime expected utility is given by

$$E_0 \sum_{t=0}^{\infty} \beta^t \left( \tilde{C}_t - \tau L_t^\nu \right)^{1-\sigma} \left( 1 - \sigma \right),$$  

(4)
whereas the budget constraint and the investment equation are respectively given by
\[ C_t + I_t + r_t B_{t+1} = \tilde{w}_t L_t + r_t^{\delta} \tilde{K}_t + e^{\theta_t} \tilde{B}_{t+1} \]  
and
\[ \tilde{I}_t = e^{\theta_t} \tilde{K}_{t+1} - (1 - \delta) \tilde{K}_t + \phi \left( \frac{e^{\theta_t} \tilde{K}_{t+1}}{\tilde{K}_t} - e^{\mu_o} \right) \tilde{K}_t, \]

with \( \tilde{\beta} \equiv \beta e^{(1-\sigma)\theta_t} \). To guarantee that utility is well defined, it is assumed that \( \beta e^{(1-\sigma)\mu_o} < 1 \).

If \( r \) denotes the steady state interest rate, it is also required that \( r \beta = e^{\sigma \mu_o} \) so that steady-state detrended consumption is well behaved.

Given prices \( \tilde{w}_t, r_f^t \) and \( r_t \), and initial conditions \( \tilde{K}_0 \) and \( \tilde{B}_0 \) for the capital stock and foreign debt, respectively, the household’s problem is to choose consumption \( \tilde{C}_t \), labor \( L_t \), foreign debt \( \tilde{B}_{t+1} \) and next period’s capital stock \( \tilde{K}_{t+1} \) to maximize life-time expected utility \( (4) \) subject to the budget constraint \( (5) \), the law of motion for capital \( (6) \) and a no-Ponzi game condition for foreign debt.

To close the model (cf. Schmitt-Grohe and Uribe, 2003), the interest rate \( r_t \) faced by domestic agents is assumed to be an increasing function of the ratio of foreign indebtedness to GDP, \( b_{t+1} \):
\[ r_t = r^* + \psi \left[ \exp \left( b_{t+1} - b \right) - 1 \right] + \kappa_t, \]
where \( r^* \) and \( b \equiv B \gamma \) denote the world interest rate and the steady-state ratio of foreign debt to GDP, respectively. The last two terms in expression \( (7) \) may be interpreted respectively as the deterministic and stochastic component of the country-specific risk premium.\(^3\) The first term implies that the risk premium increases as the ratio of foreign indebtedness to GDP is larger than its long-run value \( b \). The second term \( \kappa_t \) captures the stochastic component of risk premium.

To model the stochastic risk premium, we follow Aguiar and Gopinath (2006). Using a small open economy model of debt and endogenous default, the authors report that the presence of trend shocks in the default rate and thus on the interest rate allows their model to better match some empirical regularities of the data at business cycle frequencies in developing countries. Following this idea, a reduced form specification for the stochastic risk premium is given by the expression
\[ \kappa_t = 1 - \exp \left[ \eta \left( \theta_t - \mu_{\theta} \right) \right], \]

\(^3\) A similar specification may be found in Murchison and Rennison (2006) and Adolfson et al. (2007).
where the parameter $\eta > 0$ reflects how much country risk premium responds to deviations of trend shocks with respect to its long-run mean growth rate $\mu_0$. The expression (8) implies that a positive trend shock causes the country risk premium and thus the interest rate to fall. Therefore, this specification potentially allows for an additional channel - the country risk premium channel - for trend shocks to explain business cycles facts. At the steady state, the country risk premium component $\kappa_t$ is equal to zero.

Given initial conditions $\hat{K}_0$ and $\hat{B}_0$, a sequence of transitory and trend components of productivity denoted respectively by $z_t$ and $\theta_t$, and a sequence of stochastic risk premium $\kappa_t$, an equilibrium for this economy is a sequence of allocations $\{C_t, L_t, \hat{K}_{t+1}, \hat{B}_{t+1}, {\hat{I}_t}, {\hat{Y}_t}\}$ and prices $\{\hat{w}_t, r^k_t, r_t\}$ such that (i) the allocations solve the firm’s and the household’s problem at the equilibrium prices, and (ii) markets clear.

### 2.2 A monetary model

The monetary model of this section shares many of the characteristics of the real model described above. Namely, it is a small open economy model with working capital and productivity subject to transitory and trend shocks. However, this model abstracts from country risk premium shocks and introduces instead both financial intermediaries and money under flexible prices. Alternatively, the model below may be roughly seen as a small open economy version of Carlstrom and Fuerst (1995) augmented to disentangle technology shocks into a transitory and a permanent component.

Technology in the monetary model is described as before, namely by equations (1) - (3). As in the real model of the previous section, firms need to borrow working capital to pay for labor services. In nominal terms, the corresponding firm’s profits may be expressed as $P_tY_t - R_tW_tL_t - R^k_tK_t$. This expression is similar as in the model with risk premium shocks, with the exception that now $R_t$ denotes the nominal interest rate that must be paid by firms on the amount of working capital, where $W_t$ represents the nominal wage paid by firms.

As before, the stationary version of the model requires real non-stationary variables to be divided by the productivity term $\Gamma_{t-1}$. As for nominal variables, it is useful to define

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5 We acknowledge this is a reduced-form approach to endogenous default subject to the usual critiques. Our interest here is rather to show that changes in risk premium induced by a permanent technology shock can be a powerful transmission mechanism.
\( \hat{P}_t \equiv \frac{P_{t-1}^{\Gamma_t}}{\hat{M}_t}, \hat{W}_t \equiv \frac{W_t}{\hat{M}_t} \) and \( \hat{R}_t^k \equiv \frac{R_{t-1}^{\Gamma_t}}{\hat{M}_t} \). Thus the stationary version of the firm’s problem is to choose labor \( L_t \) and capital \( \hat{K}_t \) to maximize \( \hat{P}_t \hat{Y}_t - \hat{R}_t \hat{W}_t L_t - \hat{R}_t^k \hat{K}_t \) subject to the stationary version of (1) and taking prices \( \hat{W}_t, \hat{R}_t^k \), and \( R_t \) as given.

The monetary authority in this model issues money at the stochastic growth rate \( \mu_t \) so that

\[ M_{t+1} = \mu_t M_t, \tag{9} \]

where \( \mu_t \) follows an autoregressive process of the form

\[ \mu_t = \rho \mu \mu_{t-1} + \varepsilon_t^\mu, \]

with \( |\rho| < 1 \) and \( \varepsilon_t^\mu \) represents an i.i.d. monetary shock drawn from a normal distribution with zero mean and standard deviation \( \sigma_{\varepsilon_t^\mu} \).

The representative household begins period \( t \) with nominal money holdings \( m_t \). The amount of money \( q_t < m_t \) provides utility services to the household. The remaining money, \( m_t - q_t \), is deposited by the household in the financial intermediary at the beginning of period \( t \) that pays an interest rate \( R_t \).

The household derives utility from consumption \( C_t \) and real money holdings \( \frac{q_t}{P_t} \), and disutility from labor \( L_t \). In particular, the household maximize life-time expected utility according to

\[
E_0 \sum_{t=0}^{\infty} \beta^t \left[ \frac{(C_t - \sigma \Gamma_{t-1} L_t^{\mu})^{1-\sigma}}{1-\sigma} + \chi \left( \frac{q_t}{P_t} \right)^{1-\sigma} \frac{1}{1-\sigma} \right]
\]

with \( \chi > 0 \) and subject to the budget constraint

\[
P_t (C_t + I_t) + m_{t+1} + R_t^s S_t B_t = W_t L_t + R_t (m_t - q_t) + q_t + R_t^k K_t + S_t B_{t+1} + \Pi_t^f + \Pi_t^i.
\]

In the expression above, the representative household derives resources from wage income, \( W_t L_t \), the interest on the amount of money not held as cash, \( R_t (m_t - q_t) \), the rental of capital, the issuance of foreign debt denominated in domestic currency \( S_t B_{t+1} \) (where \( S_t \) is the nominal exchange rate), and nominal benefits from firms and financial intermediaries denoted respectively by \( \Pi_t^f \) and \( \Pi_t^i \). These resources are devoted to consumption, investment \( I_t \), the acquisition of real money holdings \( m_{t+1} \), and the payment of interest on foreign debt, \( R_t^s S_t B_t \). Gross investment \( I_t \) is subject to the same quadratic adjustment costs in capital as in the real model with shocks to risk premium.
To state the household’s problem in stationary form, it is useful to define \( \hat{m}_t \equiv \frac{m_t}{M_t} \), \( \hat{q}_t \equiv \frac{q_t}{M_t} \), and \( \hat{S}_t \equiv \frac{S_{t+1}}{M_t} \). The corresponding lifetime expected utility is written as

\[
E_0 \sum_{t=0}^{\infty} \beta^t \left[ \left( \hat{C}_t - \frac{\tau L_t}{1 - \sigma} \right)^{1-\sigma} + \frac{\chi \left( \frac{\hat{q}_t}{P_t} \right)^{1-\sigma}}{1 - \sigma} \right]
\]

and the budget constraint is expressed as

\[
P_t \left( \hat{C}_t + \hat{I}_t \right) + \mu_t \hat{m}_{t+1} + e^\theta \hat{S}_t \hat{B}_{t+1} = \hat{W}_t L_t + R_t \left( \hat{m}_t - \hat{q}_t \right) + \hat{q}_t + \hat{R}_t^k \hat{K}_t + R_t^* \hat{S}_t \hat{B}_t + \hat{\Pi}_t^f + \hat{\Pi}_t^i. \tag{11}
\]

The investment equation in stationary form is exactly the same as before (see equation (6)).

The household’s problem in stationary form is to choose consumption \( \hat{C}_t \), labor \( \hat{L}_t \), nominal cash balances \( \hat{q}_t \), and next period’s stock of money \( \hat{m}_{t+1} \), foreign debt \( \hat{B}_{t+1} \) and the capital stock \( \hat{K}_{t+1} \) to maximize life-time expected utility (10) subject to the budget constraint (11), the law of motion for capital (6) and a no-Ponzi game condition for foreign debt, given prices \( \hat{P}_t, \hat{W}_t, \hat{R}_t^k, R_t^* \) and \( R_t \), and initial conditions for the capital stock \( \hat{K}_0 \), the stock of money \( \hat{M}_0 \) and foreign debt \( \hat{B}_0 \), respectively.

In nominal terms, the financial intermediary receives deposits \( m_t - q_t \) from the representative household plus a transfer, \( (\mu_t - 1) M_t \), from the monetary authority. These resources are lent to finance the working capital of firms. The clearing condition in the loan market is thus \( W_t L_t = (\mu_t - 1) M_t + m_t - q_t \). In stationary form, such condition is given by

\[
\hat{W}_t L_t = \mu_t - 1 + \hat{m}_t - \hat{q}_t. \tag{12}
\]

To close the model, the interest rate on foreign bonds \( R_t^* \) is assumed to be increasing in the aggregate level of foreign debt in terms of GDP, \( b_{t+1} \), as follows:

\[
R_t^* = R^* + \psi \left[ \exp \left( b_{t+1} - b \right) - 1 \right]. \tag{13}
\]

Thus the monetary model abstracts from risk premium shocks.

Given initial conditions \( \hat{K}_0, \hat{M}_0 \) and \( \hat{B}_0 \), a sequence of transitory and trend components of productivity denoted respectively by \( z_t \) and \( \theta_t \), and a sequence of money growth rates \( \mu_t \), an equilibrium for this economy is a sequence of allocations \( \left\{ \hat{C}_t, L_t, \hat{M}_{t+1}, \hat{m}_{t+1}, \hat{q}_t, \hat{B}_{t+1}, \hat{K}_{t+1}, \hat{I}_t, \hat{Y}_t \right\} \) and prices \( \left\{ \hat{P}_t, \hat{W}_t, \hat{R}_t^k, R_t^*, R_t \right\} \) such that (i) the allocations solve the firm’s and the household’s problem at the equilibrium prices, and (ii) markets clear.
3 Estimation and results

This section is devoted to the estimation and discussion of results for each of the two models presented above. Of particular interest is the evaluation of the relative importance of the trend and transitory shocks to productivity for explaining stylized facts of the business cycle in Mexico. In this regard, there are a number of alternative measures when trying to establish the importance of permanent versus transitory components. In this paper we present results under two commonly used measures. The first one, advocated by Cochrane (1988) and used by Aguiar and Gopinath (2007), seeks to determine the importance of the permanent component of the technology shock in explaining the Solow residual. If this residual is expressed as the sum of a random walk component and a transitory component, under some conditions such importance is given by the following equation:

\[
\frac{\sigma^2_P}{\sigma^2_{\Delta SR}} = \frac{\alpha^2 \sigma^2_{\epsilon z} / (1 - \rho^2_\theta)}{[2/(1 + \rho_z)] \sigma^2_{\epsilon z} + \alpha^2 \sigma^2_{\epsilon \theta} / (1 - \rho^2_\theta)},
\]

(14)

where \( \sigma^2_P \) and \( \sigma^2_{\Delta SR} \) denote the variances of the random walk component and the Solow residual, respectively.

We also present a more traditional form of determining the relative importance of permanent versus transitory components by reporting the ratio of the variance of the permanent component to the variance of the transitory technology shock, a measure closer in spirit to the one used by Aguiar and Gopinath (2004) and Boz et al. (2008):

\[
\frac{\sigma^2_{\epsilon \theta}}{\sigma^2_{\epsilon z}} = \frac{\sigma^2_{\epsilon \theta} / (1 - \rho^2_\theta)}{\sigma^2_{\epsilon z} / (1 - \rho^2_\theta)},
\]

(15)

where a ratio greater than one denotes that the permanent component is more volatile than the transitory component.

3.1 Estimation

For the two models presented in Section 2 (labeled “Model 1” and “Model 2” henceforth), some parameters are calibrated and others are estimated using Mexican data. In terms of calibrated parameters, the subjective discount factor, \( \beta \), the risk aversion parameter, \( \sigma \), and the depreciation rate, \( \delta \), are set to 0.99, 2 and 0.03, respectively. These parameter values are relatively standard in the literature. The parameter \( \nu \) is fixed at 1.6, implying a labor supply elasticity of \( 1/(\nu - 1) = 1.67 \). This parameter value is used by Neumeyer and Perri
(2005), and it is between the value of 1.5 used by Mendoza (1991) and the value of 1.7 used by Correia et al. (1995). The parameter $\tau$ is set so that the representative household allocates about one third of its time to working activities, an observation consistent with data reported by the National Employment Survey and the National Survey of Occupation and Employment. The coefficient on the country-specific, deterministic risk premium $\psi$ is set at 0.001, a parameter value typically used in the literature (cf. Schmitt-Grohé and Uribe, 2003; Aguiar and Gopinath, 2007). For the monetary version of the model, the parameters $\mu$ and $\chi$ are calibrated so that for the case of $\mu$ the quarterly growth rate of M2 in Mexico is equal to that one of the data (7 per cent), and $\chi$ is calibrated in order to match the average ratio of M1 to M2 money balances in Mexico (22 percent).

To calibrate the share of debt to GDP, $b$, note that the absence of financial intermediaries in the model with shocks to risk premium implies that the net foreign asset position in terms of output at the steady state is given by the expression $\frac{WL}{Y} - \frac{B}{Y}$. According to García-Verdú (2005), the labor share in Mexican data is about 0.68. Similarly, the net foreign asset position in terms of output is set at 0.43, which is consistent with the historical average for Mexico as reported by Lane and Milesi-Ferreti (2001). These two numbers imply a debt-to-GDP ratio of 0.25 at the steady state. To calibrate $\alpha$, notice that the labor share at the steady state is given by $\frac{WL}{Y} = \frac{\alpha}{r}$ in Model 1. This yields a value for $\alpha$ of 0.695, given the parametrization of the model. The calibration of these two parameters in the monetary model is slightly different. First, the debt-to-GDP ratio is simply fixed at 0.43, given the presence of financial intermediaries in such model. Second, $\alpha$ is calibrated to satisfy the steady-state equilibrium condition $\frac{WL}{Y} = \frac{\alpha}{R}$.

The parameters calibrated for each model are summarized in Table 1. For convenience, we also report the parameters used by Aguiar and Gopinath (2004) when estimating their model with GHH preferences. As it may be noticed, that other than the time preference rate $\beta$, the elasticity parameter $\alpha$, and the steady-state debt to GDP ratio $b$, there are no differences between the parameters of Model 1 and Model 2 with those used by Aguiar and Gopinath (2004). The differences in those parameters arise because those values are better able to capture the characteristics of Mexican data.$^6$

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$^6$ Changing our parameter values to be equal to those of Aguiar and Gopinath (2004) does not change our results in a significant manner.
The parameters estimated are those governing productivity and capital adjustment costs. Namely, we seek to estimate \( \rho_\theta, \rho_\varepsilon, \sigma_{\varepsilon \theta}, \sigma_{\varepsilon \varepsilon} \) and \( \phi \). We also estimate other parameters depending on the version of the model considered: \( \eta \) when estimating the model with real interest rate shocks, and \( \rho_\mu, \sigma_{\varepsilon \mu} \) when estimating the model with monetary shocks. We use the same data and the same period of analysis as in Aguiar and Gopinath (2007) so that if there are any substantial differences in the results, they cannot be attributed to the data or the time period used.\(^7\) When estimating the model with money growth, we also use data on M2. In the model, a period corresponds to a quarter.

As in Aguiar and Gopinath (2007), parameters are estimated using GMM (see, for example, Burnside (1999)). GMM finds parameter estimates that minimize the squared difference between the moments from the model and those from data. For such purpose, we use Mexican data for the period 1980Q1 - 2003Q1. The empirical moments used for the estimation of parameters in Model 1 are given by the following: the standard deviations of log (filtered) output, consumption, investment, and net exports to GDP; the correlation of log (filtered) output with lagged output, consumption, investment, and net exports to GDP; and the standard deviation and autocorrelation of (unfiltered) output growth. When estimating Model 2, we also augment our moments with the following: the standard deviation and autocorrelation of money growth, and the correlation of money growth with output, consumption, investment, and net exports to GDP. Given that the number of empirical moments is greater than the number of parameters to be estimated in both Models 1 and 2, the optimal weighting matrix suggested by Hansen (1982) is used.

Table 2 reports the results for the estimated parameter values associated with Models 1 and 2 together with their standard errors. It also reports the importance of the trend/permanent component of technology implied by equations (14) and (15).

[TABLE 2 HERE]

Table 2 presents three sets of results for Mexico using the empirical moments mentioned earlier. The second and third columns present the results obtained from estimating Model 1 and Model 2, respectively. In the last column, the results of Aguiar and Gopinath (2004)
are reported.\textsuperscript{8} For Model 1, the estimation suggests a value for the standard deviation of the permanent component, $\sigma_{\tilde{\theta}}$, of 0.10, which is insignificant at the 10 percent level. The corresponding value for the standard deviation of the transitory component, $\sigma_{\tilde{z}}$, is 0.69 and significant at the 10 percent level. These values, along with their corresponding estimates for persistence imply a value of 0.03 for the random walk component and of 0.005 for our measure of relative variances. As for the monetary model, the point estimate for $\sigma_{\tilde{\theta}}$ is roughly twice as large as compared to the model with shocks to risk premium, and the point estimate for $\sigma_{\tilde{z}}$ now decreases to 0.55. Similar to the estimate for Model 1, $\sigma_{\tilde{\theta}}$ is insignificant at the 10 percent level and $\sigma_{\tilde{z}}$ it is not. Now the random walk component estimate increases to 0.50 and the measure of relative variances increases to 0.23. In both cases, the estimation cannot be rejected at standard significance levels, as suggested by the p-value of the model.

The fourth column of Table 2 presents the estimates for the parameters of interest reported in Aguiar and Gopinath (2004). In contrast to the previous results, the permanent component is relatively more volatile than the transitory component, and is significant at the 10 percent level. As suggested by the measures for the random walk component and the relative variances ratio, the results clearly show that the permanent technology shock component is crucial in explaining the business cycle in Mexico in such model: both measures are greater than one.

The results in Table 2 suggest that slight modifications to a canonical real business cycle model are able to reverse the results obtained by Aguiar and Gopinath (2004, 2007) that stochastic trends are the most important determinant of the business cycle in emerging market economies.\textsuperscript{9} In particular, it suggests that introducing an alternative transmission mechanism channel (ie, a perturbation transmitted through interest rates in a model with working capital and GHH preferences) may substantially decrease the importance of the permanent technology shock component. In this regard, Aguiar and Gopinath (2007) discusses the possibility that differences in the Solow residual processes between developed and emerg-

\textsuperscript{8} In Aguiar and Gopinath (2007), preferences are of the Cobb-Douglas class only. Here we refer to their NBER Working Paper version (Aguiar and Gopinath, 2004) where results under GHH preferences are also presented.

\textsuperscript{9} A similar finding is reported in Boz et al. (2008), where agents are subject to imperfect information in the sense that they cannot perfectly distinguish between the permanent and transitory components of TFP shocks.
ing markets may be a manifestation of deeper frictions in the economy, including changes in monetary, fiscal and trade policies. Indeed, our analysis is consistent with this observation. Our first model takes inspiration from the debt default literature and shows that the incorporation of risk premium shocks affecting the probability of default, is important. Indeed, this shock incorporates, together with working capital, an additional channel whereby permanent technology shocks can affect the variables of the model via their effect on real interest rates. This result is interesting because in the 1980s and early 1990s recessions in Mexico were mainly driven by financial crises.

Our second model incorporates money in a flexible price economy under the premise that monetary policy shocks might be partially responsible for business cycle fluctuations, specially in the case of Mexico where inflation was above 100% and money growth was rapid in the mid 1980s. Our results suggest that money growth shocks may be an important determinant of the business cycle in Mexico, and perhaps, their omission from the canonical real business cycle model used by Aguiar and Gopinath (2004, 2007) implies that the permanent technology shock might have been picking up the monetary shocks. This is not to say that monetary shocks are able to affect the long-run growth rate. It rather says that, if monetary shocks are incorporated into the model, the permanent technology shock seems to loose relevance in explaining key features of the data.

3.2 Theoretical and empirical moments

In this section we report a number of theoretical moments using the parameter estimates obtained from Table 2 as a way to evaluate the performance of each model. We show that the estimated models match many of the key business cycle features of the Mexican economy. We pay particular attention to the most telling moments, namely the relative variance of consumption to output and the correlation between net exports and output, which as we have mentioned above, exhibit the most notable differences in emerging versus developed economies. Table 3 presents the moments associated with the parameter estimates presented in Table 2.

[TABLE 3 HERE]

The models are able to match a number of business cycle features. More importantly, all estimates show that for the case of Mexico, consumption is more volatile than output
and the correlation between net exports and output is strongly negative. Moreover, when considering other moments, other than those associated with the variance of output growth and the correlation of output growth, Models 1 and 2 do at least as good a job or better at replicating the data moments, as the model of Aguiar and Gopinath (2004).

4 Conclusions

We have presented two examples of small open economy models with transitory and permanent technology shocks consistent with some business cycle stylized facts observed in developing countries. Both models are similar in the sense that firms must finance its working capital and households have preferences of the type postulated by Greenwood et al. (1988). However, the first of them is a real money with shocks to risk premium whereas the second is a monetary model with flexible prices. Each model features a strongly countercyclical trade balance as well as a relatively large volatility of consumption, which are two of the business cycle facts that typically differentiate developed from developing countries. Interestingly, it is found that neither model requires a relatively large volatility of the permanent technology shock, as reported by Aguiar and Gopinath (2007). In fact, the transitory component of technology is relatively more volatile than its permanent component. This finding thus suggests that shocks to the trend growth rate in the model of Aguiar and Gopinath (2007) may be a reduced-form device capturing deeper frictions in the economy. In the present paper, such frictions are manifested in terms of large changes in interest rates that distort the labor-leisure choice of households.

In future work, we are planning to estimate each model using data for a developed country such as Canada, in order to evaluate the relative importance of the permanent component in such case.

References


## Appendix

<table>
<thead>
<tr>
<th></th>
<th>Model 1</th>
<th>Model 2</th>
<th>AG</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta$</td>
<td>0.99</td>
<td>0.99</td>
<td>0.98</td>
</tr>
<tr>
<td>$\nu$</td>
<td>1.6</td>
<td>1.6</td>
<td>1.6</td>
</tr>
<tr>
<td>$\tau$</td>
<td>varies*</td>
<td>varies*</td>
<td>1.4</td>
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<tr>
<td>$b/y$</td>
<td>0.25</td>
<td>0.43</td>
<td>0.10</td>
</tr>
<tr>
<td>$\psi$</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>0.695</td>
<td>0.74</td>
<td>0.68</td>
</tr>
<tr>
<td>$\sigma$</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>$\delta$</td>
<td>0.03</td>
<td>0.03</td>
<td>0.03</td>
</tr>
<tr>
<td>$g$</td>
<td>1.006</td>
<td>1.006</td>
<td>1.006</td>
</tr>
<tr>
<td>$\mu$</td>
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<td>1.07</td>
<td>NA</td>
</tr>
<tr>
<td>$\chi$</td>
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<td>0.02</td>
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*Note: $\tau$ varies to ensure that the labor share is 1/3.

Table 1: Calibrated Parameters
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Model 1</th>
<th>Model 2</th>
<th>AG</th>
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<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>$\sigma_{\varepsilon\theta}$</td>
<td>0.1</td>
<td>0.23</td>
<td>1.09*</td>
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<tr>
<td></td>
<td>(0.32)</td>
<td>(0.28)</td>
<td>(0.37)</td>
</tr>
<tr>
<td>$\sigma_{\varepsilon z}$</td>
<td>0.69*</td>
<td>0.55*</td>
<td>0.41</td>
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<tr>
<td></td>
<td>(0.11)</td>
<td>(0.07)</td>
<td>(0.42)</td>
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<tr>
<td>$\rho_\theta$</td>
<td>0.43*</td>
<td>0.66*</td>
<td>0.72*</td>
</tr>
<tr>
<td></td>
<td>(0.08)</td>
<td>(0.38)</td>
<td>(0.08)</td>
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<tr>
<td>$\rho_z$</td>
<td>0.90*</td>
<td>0.50*</td>
<td>0.94*</td>
</tr>
<tr>
<td></td>
<td>(0.18)</td>
<td>(0.19)</td>
<td>(0.29)</td>
</tr>
<tr>
<td>$\phi$</td>
<td>4.03*</td>
<td>0.49*</td>
<td>3.79*</td>
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<tr>
<td></td>
<td>(1.41)</td>
<td>(0.02)</td>
<td>(0.96)</td>
</tr>
<tr>
<td>$\eta$</td>
<td>3.68*</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>(1.56)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>$\sigma_{\varepsilon \mu}$</td>
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<td>5.65*</td>
<td>-</td>
</tr>
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<td></td>
<td>-</td>
<td>(0.62)</td>
<td>-</td>
</tr>
<tr>
<td>$\rho_{\mu}$</td>
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<td>0.67*</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>(0.02)</td>
<td>-</td>
</tr>
<tr>
<td>Random walk comp.</td>
<td>0.03</td>
<td>0.50</td>
<td>5.33</td>
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<tr>
<td>Relative variances</td>
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<td>1.71</td>
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<td>p-value of model</td>
<td>0.17</td>
<td>0.37</td>
<td>0.12</td>
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</table>

Note: GMM estimates with standard errors in parentheses. Standard deviations are reported in percentage terms.

* denotes significance at the 10 per cent level.

Table 2: Estimated Parameters

<table>
<thead>
<tr>
<th>Moments</th>
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<th>Model 2</th>
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<tr>
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<td>3</td>
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<td>Key Moments</td>
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<td></td>
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<tr>
<td>$\sigma (c)/\sigma (y)$</td>
<td>1.24</td>
<td>1.10</td>
<td>1.10</td>
<td>1.10</td>
</tr>
<tr>
<td>$\rho (NX, y)$</td>
<td>-0.74</td>
<td>-0.63</td>
<td>-0.62</td>
<td>-0.62</td>
</tr>
<tr>
<td>Other Moments</td>
<td></td>
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</tr>
<tr>
<td>$\sigma (y)$</td>
<td>2.48</td>
<td>2.26</td>
<td>2.34</td>
<td>2.33</td>
</tr>
<tr>
<td>$\sigma (\Delta y)$</td>
<td>1.52</td>
<td>2.19</td>
<td>2.19</td>
<td>1.57</td>
</tr>
<tr>
<td>$\sigma (I)/\sigma (y)$</td>
<td>4.06</td>
<td>3.94</td>
<td>3.39</td>
<td>3.92</td>
</tr>
<tr>
<td>$\sigma (NX)/\sigma (y)$</td>
<td>0.88</td>
<td>0.86</td>
<td>0.71</td>
<td>0.78</td>
</tr>
<tr>
<td>$\rho (y)$</td>
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<td>0.54</td>
<td>0.57</td>
<td>0.82</td>
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<tr>
<td>$\rho (\Delta y)$</td>
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<td>-0.18</td>
<td>-0.14</td>
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<tr>
<td>$\rho (y, c)$</td>
<td>0.92</td>
<td>0.95</td>
<td>0.96</td>
<td>0.96</td>
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<tr>
<td>$\rho (y, I)$</td>
<td>0.91</td>
<td>0.87</td>
<td>0.82</td>
<td>0.85</td>
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Table 3: Empirical and Theoretical Moments