Emerging Market Fluctuations: The Role of Interest Rates and Productivity Shocks

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Business cycles in emerging markets are characterized by high levels of volatility in income, investment, and net exports. Consumption is more volatile than income, and net exports are highly countercyclical (see Aguiar and Gopinath, 2007). Furthermore, the interest rates faced by these economies are highly volatile and negatively correlated with income, as described in Neumeyer and Perri (2005). In this paper, we adopt a standard stochastic business cycle model of a small open economy and allow the economy to be driven by productivity shocks that have permanent and transitory components, as well as by shocks to the interest rate process. We then estimate the role of the different processes in explaining the business cycle behavior of emerging markets.

In Aguiar and Gopinath (2007), we examine an economy driven exclusively by shocks to productivity. Productivity shocks in this context may be viewed as manifestations of deeper frictions in the economy, such as changes in monetary, fiscal, and trade policies. For instance, Restuccia and Schmitz (2004) provide evidence of a 50 percent drop in productivity in the petroleum industry in Venezuela within five years of its nationalization in 1975. Similarly, Schmitz and Teixeira (2004) document almost a doubling of productivity in the Brazilian iron ore industry following its privatization in 1991. We view such dramatic changes in productivity following reforms and the undoing of reforms as characteristic of emerging markets. Several emerging markets also experience terms-of-trade shocks that display

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a high degree of persistence. In this set-up, we provide a methodology for identifying the role of transitory versus trend shocks in explaining business cycles. The procedure relies on using the intuition behind the permanent income hypothesis.

In Aguiar and Gopinath (2007), we adopt the standard small open economy assumption and model the interest rate as an exogenous international risk-free rate, which we hold constant. The economy always repays its debt, and there is never any default. In Aguiar and Gopinath (2006), we explicitly allow for default in an Eaton and Gersovitz (1981) set-up. That paper specifies an endowment economy driven by trend and stationary shocks. We show that incorporating trend shocks is important in generating empirically plausible rates of default, as well as simultaneously matching key correlations between the interest rate, output, and the current account.

In this paper, we extend Aguiar and Gopinath (2007) to allow for a stochastic interest rate process. We consider three specifications. The first models the case of exogenous interest rate shocks that are independent of the productivity shocks. In the second specification, the interest rate responds to transitory productivity shocks in addition to independent shocks. In the third case, the interest rate also responds to trend productivity shocks. We assume a reduced-form specification for all these processes and provide intuition for the nature of the process.

We estimate the interest rate process from the Euler equations and do not use observed interest rates. This mirrors our treatment of productivity shocks, for which we do not use the Solow residual series to directly identify the underlying productivity process. We do this for two reasons. First, the observed rates are not risk-free rates given the probability of default. The promised rate observed in the data therefore may not be the relevant real rate governing behavior.[1] Second, agents may be constrained in their access to financial markets. In that case, an implicit Lagrange multiplier, rather than the observed market rate, governs the consumption/investment decision. Our estimation will pick up fluctuations in this multiplier. This approach is different from the work of Neumeyer and Perri (2005), who take the observed interest rate process and feed it into the economy. This assumes that the Euler equation with repayment is always satisfied at the observed interest rates.

We show that the model with interest rate shocks that are orthogonal to productivity shocks does poorly in matching the

1. For explicit models of default, see Aguiar and Gopinath (2006); Arellano (2006).

features of the data for emerging market countries. Movements in the interest rate affect consumption and investment by setting the price for intertemporal substitution. An increase in the interest rate reduces consumption relative to the future, as it increases the incentive to save. It also reduces investment in physical capital, since the return from the bond is higher. Because interest rate shocks are orthogonal to productivity shocks in this exercise, the induced correlations between consumption and income, and investment and income are low, which is contrary to the data. The response of output, on impact, to a rise in the interest rate will be small, as productivity has not changed and capital takes time to adjust. Moreover, when consumption and leisure are inseparable, labor supply rises in response to a drop in consumption, which generates an increase in output; this is counterfactual, given that periods of high interest rates have been associated with large declines in output. Interest rate shocks that are not associated with movements in productivity will clearly perform poorly in matching the facts for emerging markets. This point is similar in spirit to the work of Neumeyer and Perri (2005) and Chari, Kehoe, and McGrattan (2005).

We next allow the interest rate to respond to productivity shocks, including both transitory and trend shocks. The data suggest that a high level of productivity should be associated with a lower interest rate. A positive shock to productivity raises consumption, and the increase is amplified by the contemporaneous decline in interest rates. This increases the relative volatility of consumption for a given income process. Investment also increases following the rise in productivity and the decline in interest rates. This implies that net exports decrease, inducing a negative correlation between net exports and income. The precise moments of the stationary distribution will depend on the persistence in the income and interest rate processes. For reasons explained below, the model performs better when the interest rate primarily responds to the transitory income shock.

Finally, we use generalized method of moments (GMM) and data from Mexico to estimate the parameters of a model that allows for both exogenous interest rate shocks and productivity shocks and for the interest rate shock to respond to the transitory income shock. In the benchmark case, in which the model allows only for productivity shocks, the random walk component of the Solow residual is estimated at 1.02. In Aguiar and Gopinath (2007), we estimate a far lower random walk component for Canada, at 0.5. When we allow for the richer specification with interest rate shocks, we estimate the random walk component to be essentially the same, at 1.01. This supports the conclusions in Aguiar and Gopinath (2007) that emerging markets are subject to more volatile trend shocks than developed markets. We also find evidence of a small negative covariance between productivity shocks and the implied interest rate.

The differences in the Solow residual processes between developed and emerging markets may well be a manifestation of deeper frictions in the economy. Chari, Kehoe, and McGrattan (2007), for instance, show that many frictions, including financial frictions, can be represented in reduced form as Solow residuals. From the perspective of private agents in our economy, these shocks appear as exogenous shifts in productivity. Our analysis provides support for models with frictions that are reflected in the persistence of Solow residuals, rather than frictions that distort the response of investment and consumption to underlying productivity. Guajardo (in this volume), for instance, finds that his model with financial frictions fits the data best when procyclical exogenous labor financing wedges affect hiring decisions. That is, financing working capital requirements is easier in booms than in recessions. These financing wedges behave like productivity shocks. Our analysis shows that interest rate shocks that only affect the Euler equation add little to matching the facts in the data for emerging markets. One could clearly argue that interest rate movements can interact with underlying financial frictions to generate shocks that look like productivity shocks. Our analysis is completely consistent with such a model.

We also present evidence that Chile has features similar to other emerging markets documented in Aguiar and Gopinath (2007).[2] The correlation between Hodrick-Prescott-filtered net exports as a ratio of gross domestic product (GDP) and the HP-filtered log of GDP is –0.82 for Chile. Quarterly series on private consumption are not available before 1996. For the ten years from 1996—2006, the volatility of the HP-filtered log GDP is 1.63, compared with a volatility of 1.89 for the HP-filtered log of private consumption. This is similar to other emerging markets, in which consumption volatility generally exceeds the volatility of income and net exports are highly countercyclical.

The next section describes the stochastic growth model. Section 2 then outlines the identification strategy and provides intuition through impulse responses to various shocks. Section 3 presents the results from a GMM estimation of the model.

2. We thank David Rappoport for providing us with this data.

1. Stochastic Growth Model

The model here is based on Aguiar and Gopinath (2007) and augmented to include a stochastic interest rate process. Technology is characterized by a Cobb-Douglas production function that uses capital, K_t, and labor, L_t, as inputs

$$Y_t = e^{z_t} K_t^{\alpha} (\Gamma_t L_t)^{1-\alpha}, \tag{1}$$

where $\alpha \in (0, 1)$ represents labor's share of output. The parameters z_t and Γ_t represent productivity processes. The two productivity processes are characterized by different stochastic properties. Specifically, z_t follows an AR(1) process,

$$z_t = \rho_z z_{t-1} + \varepsilon_t^z, \tag{2}$$

with $|\rho_z| < 1$, and ε_t^z represents independent and identically distributed (i.i.d.) draws from a normal distribution with zero mean and standard deviation σ_z.

The parameter Γ_t represents the cumulative product of so-called growth shocks. In particular,

$$\Gamma_t = e^{g_t} \Gamma_{t-1} = \prod_{s=0}^{t} e^{g_s} \text{ and}$$

$$g_t = (1 - \rho_g)\mu_g + \rho_g g_{t-1} + \varepsilon_t^g,$$

where $|\rho_z| < 1$, and ε_t^g represents i.i.d. draws from a normal distribution with zero mean and standard deviation σ_g. The term μ_g represents the long-run mean growth rate of productivity. We loosely refer to the realizations of g as growth shocks, as they constitute the stochastic trend of productivity. We use separate notation for shocks to the level of productivity (z_t) and the growth of productivity (g_t) to simplify exposition and calibration.

Given that a realization of g permanently influences Γ, output is nonstationary with a stochastic trend. For any variable x, we introduce a hat to denote its detrended counterpart:

$$\hat{x}_t \equiv \frac{x_t}{\Gamma_{t-1}}.$$

We normalize by trend productivity through period $t - 1$. This ensures that if xt is in the agent's information set as of time $t-1$, then so is $\hat{x}_t$. The solution to the model is invariant to the choice of normalization.

Period utility is Cobb-Douglas:

$$u_t = \frac{\left[C_t^{\gamma}(1-L_t)^{1-\gamma}\right]^{1-\sigma}}{1-\sigma}, \tag{3}$$

where $0 < \gamma < 1$. If β is the subjective intertemporal discount factor, a well-behaved steady state of the deterministic linearized model requires

$$\beta(1+r^*) = \mu_g^{1-\gamma(1-\sigma)}.$$

The equilibrium is characterized by maximizing the present discounted value of utility subject to the production function (equation 1) and the per-period resource constraint:

$$C_t + K_{t+1} = Y_t + (1-\delta)K_t - \frac{\phi}{2}\left(\frac{K_{t+1}}{K_t} - e^{\mu_g}\right)^2 K_t - B_t + q_t B_{t+1}. \tag{4}$$

Capital depreciates at the rate δ, and changes to the capital stock entail a quadratic adjustment cost of $(\phi/2)[(K_{t+1}/K_t) - e^{\mu_g}]^2 K_t$. We assume that international financial transactions are restricted to one-period, risk-free bonds. The level of debt due in period t is denoted B_t, and q_t is the time t price of debt due in period $t + 1$.

We focus on fluctuations in the price of debt, q_t. We assume that the interest rate is potentially driven by an exogenous process, r_t, as well as the domestic total factor productivity (TFP) shocks. Specifically, the price of debt, q, is given by the following expression:

$$\frac{1}{q_t} = 1 + r^* + e^{\left[r_t + a_z z_t + a_g(g_t - \mu_g)\right]} + \psi\left[e^{(B_{t+1}/\Gamma_t)-b} - 1\right], \tag{5}$$

where

$$r_t = \rho_r r_{t-1} + \varepsilon_t^r. \tag{6}$$

The world interest rate is held constant at r^*. The country-specific shock to the interest rate is given by ε_t^r, which is orthogonal to z and g. The induced process, r_t, has an autocorrelation coefficient of ρ_r and a long-run mean of zero. The parameters a_z and a_g capture the sensitivity of the interest rate to the transitory productivity shock and the trend productivity shock, respectively. Correlation between the interest rate and productivity does not imply a direction of causation between the two, however. Aguiar and Gopinath (2006) describe a model in which exogenous domestic productivity shocks drive an endogenous interest rate, while Neumeyer and Perri (2005) present a model in which exogenous (foreign) interest rate shocks drive domestic TFP. The variable b represents the steady-state level of debt, and $\psi > 0$ governs the elasticity of the interest rate to changes in indebtedness. This sensitivity to the level of outstanding debt takes the form used in Schmitt-Grohé and Uribe (2003).[3] When choosing the optimal amount of debt, the representative agent does not internalize the fact that he or she faces an upward-sloping supply of loans.

In normalized form, the representative agent's problem can be stated recursively:

$$V\left(\hat{K},\hat{B},z,g,r\right)=\max_{\left\{\hat{C},L,\hat{K}',\hat{B}'\right\}}\left\{\begin{array}{l}\dfrac{\left[\hat{C}_t^{\gamma}\left(1-L_t\right)^{1-\gamma}\right]^{1-\sigma}}{1-\sigma}\\ +\beta e^{g_{\gamma}(1-\sigma)}EV\left(\hat{K}',\hat{B}',z',g',r'\right)\end{array}\right\}, \tag{7}$$

such that

$$\hat{C}+e^{g}\hat{K}'=\hat{Y}+(1-\delta)\hat{K}-\frac{\phi}{2}\left(e^{g}\frac{\hat{K}'}{\hat{K}}-e^{\mu_g}\right)^2\hat{K}-\hat{B}+e^{g}q\hat{B}'. \tag{8}$$

The evolution of the capital stock is given by

$$e^{g}\hat{K}'=(1-\delta)\hat{K}+\hat{X}-\frac{\phi}{2}\left(\frac{\hat{K}'}{\hat{K}}e^{g}-e^{\mu_g}\right)^2\hat{K}\,. \tag{9}$$

3. This adjustment is typically motivated by the need to make assets stationary in the linearized model. An alternative is to recognize that we are linearly approximating a nonlinear economy for which a stationary distribution exists (for example, as a result of borrowing constraints and a world equilibrium interest rate that is lower than the discount rate, as in Aiyagari, 1994). Quantitatively, since the elasticity of the interest rate to changes in indebtedness is set close to 0 (0.001 to be exact), there is a negligible difference between the two approaches in terms of the HP-filtered or first-differenced moments of the model.

Given an initial capital stock, $\hat{K}_0$, and debt level, $\hat{B}_0$, the behavior of the economy is characterized by the first-order conditions of the problem (equation 7), the technology and budget constraints (equations 1 and 8, respectively), and the transversality conditions.

We solve the normalized model numerically by log-linearizing the first-order conditions and resource constraints around the deterministic steady state. Given a solution to the normalized equations, we can recover the path of the nonnormalized equilibrium by multiplying through by Γ_{t-1}. We also compute the theoretical moments of the model from the coefficients of the linearized solution.

2. Identification

The primary goal of this paper is to assess the relative importance of interest rate shocks, transitory productivity shocks, and permanent shocks to productivity in explaining the behavior of emerging markets. In Aguiar and Gopinath (2007), we describe the methodology of exploiting decisions by informed, optimizing agents for identifying the underlying shock process. This paper extends that methodology to accommodate a richer process for the interest rate.

The methodology we employ selects parameters of the model to match key moments of the data. Below, we discuss which moments are particularly useful in identifying the parameters of interest. We do not use market interest rates on sovereign debt, however, because those interest rates represent the price of a defaultable bond. This is a different asset than that modeled above. To see this, consider the Euler equation for bonds from the above model:

$$\frac{\beta}{q} E \frac{u_c'}{u_c} = 1 . \tag{10}$$

While consumption is stochastic, the interest rate paid (conditional on information at the time of borrowing) is deterministic. In a model with defaultable debt, the consumer pays the interest rate conditional on no default and pays zero (or some fraction) if default occurs. Therefore, the observed market interest rate cannot be used directly in a simple Euler equation, but must be combined with a full specification of the states in which default occurs and the payments to be made conditional on default.

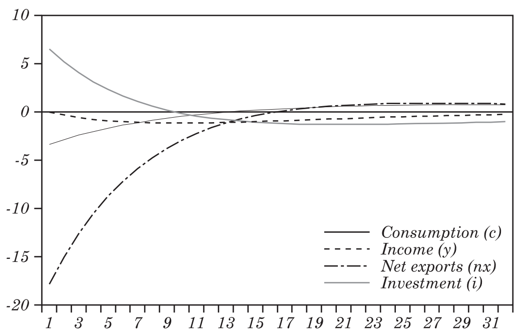
Our interest rate process, q, can be viewed as a wedge in the Euler equations for consumption and investment. Our estimation will then back out the parameters governing the stochastic process of this wedge, similar to the exercise of Chari, Kehoe, and McGrattan (2007). It also captures unobserved frictions (to a linear approximation) such as additional borrowing costs or constraints beyond the market interest rate.

2.1 Interest Rate Shocks Orthogonal to Productivity Shocks

We begin with an exploration of uncorrelated interest rate shocks—that is, shocks to the interest rate that are orthogonal to total factor productivity. Changes in the interest rate induce changes in consumption and investment for a given path of income owing to intertemporal substitution. This will raise the relative volatility of consumption and investment. Such shocks therefore have the potential to explain the relatively high volatility of consumption in emerging markets. However, introducing shocks that move consumption and investment independently of income reduces the covariance of consumption and investment with income. This generates counterfactual implications for the cyclicality of net exports.

Figure 1 plots the impulse responses of consumption, investment, net exports, and income to a one percent shock to ε^r. We set $\rho_r = 0.9$. As expected, an increase in the interest rate leads to a drop in consumption, with an initial decline of roughly 3 percent. Investment declines even more dramatically. Output remains steady, declining slightly over time as a result of the lagged declines in investment. This leads to a jump in net exports.

Figure 1. Impulse Response to Interest Rate Shock[a]



Source: Authors' computations.

a. Impulse response of consumption, investment, net exports, and income to a one percent shock to ε^r; we set $\rho_r = 0.9$.

To explore how orthogonal interest rate shocks affect key moments of the simulated model, we set $a_z = a_g = 0$, but set $\sigma_r \equiv$ standard deviation $(\varepsilon^r) > 0$. To be precise, we consider models with various values of σ_r, ranging from zero to one percent. For each environment, we compute key moments of the simulated economy and plot them in figure 2. We fix all other parameters. We also set $\gamma = 1$, so that labor supply is fixed. All moments refer to HP-filtered variables. Panel A of figure 2 illustrates how the relative (to income) variance of consumption, investment, and net exports increases as we increase σ_r. This corresponds to the above intuition. Panel B shows that net exports become more procyclical as σr increases. This takes us further from the data. At the same time, consumption and investment become less correlated with income, because a positive interest rate shock lowers consumption and investment. Since TFP has not changed, this reduces the correlation with income. When consumption and leisure are inseparable, the decreased consumption is associated with higher labor and therefore higher income, inducing a negative correlation between consumption and income. In this set-up, a crisis associated with a large increase in interest rates will reduce consumption but raise output, which is completely counterfactual.

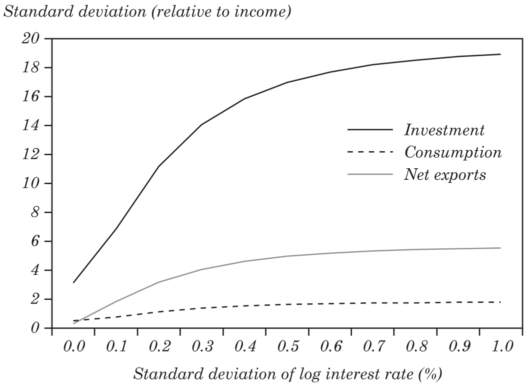
Exogenous interest rate shocks clearly do poorly in explaining the behavior of emerging markets. Such a model is unable to generate the large countercyclicality in the current accounts and the much larger responsiveness of consumption relative to income. This argument is in line with the results in Neumeyer and Perri (2005) and Chari, Kehoe, and McGrattan (2005). A model in which the interest rate process does not affect productivity has little hope of matching moments of the business cycle.

2.2 Interest Rates that Covary with Productivity Shocks

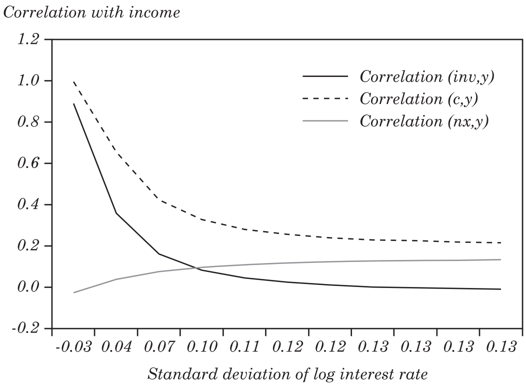
The previous section confirms that we need to interact the interest rate shock with the productivity shock. Since we have two productivity processes, we can link the interest rate and productivity along two dimensions. We begin by setting $a_g = 0$ and considering the link between transitory productivity shocks and the interest rate. We then set $a_z = 0$ and assume the interest rate responds only to the permanent shock, g.

Figure 2. Business Cycle Moments and σ_r[a]

A. Standard deviation of investment, consumption, and net exports



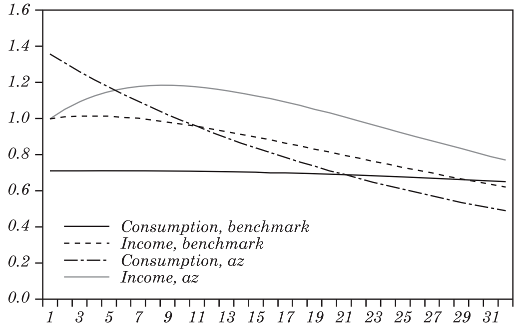
B. Cyclicality of investment, consumption, and net exports



Source: Authors' computations.
a. Panel A shows the standard deviation of (HP-filtered, log) consumption, investment, and net exports relative to income as a function of σ_r. Panel B shows the correlation of (HP-filtered, log) consumption, investment, and net exports with income as a function of σ_r.

Figure 3 plots the impulse response functions of consumption and income to a shock to ε^z when $a_z = 0$ and when $a_z = -0.1$. The latter case generates a fall in the interest rate when productivity increases. This could be an implication of an Eaton-Gersovitz model of default, in which default occurs during low income realizations (see Aguiar and Gopinath, 2006; Arellano, 2006). With persistent shocks, a high shock today implies, on average, high shocks tomorrow and a correspondingly low probability of default, resulting in a negative relationship between productivity and the interest rate.

Figure 3. Impulse Response to *z* Shock[a]

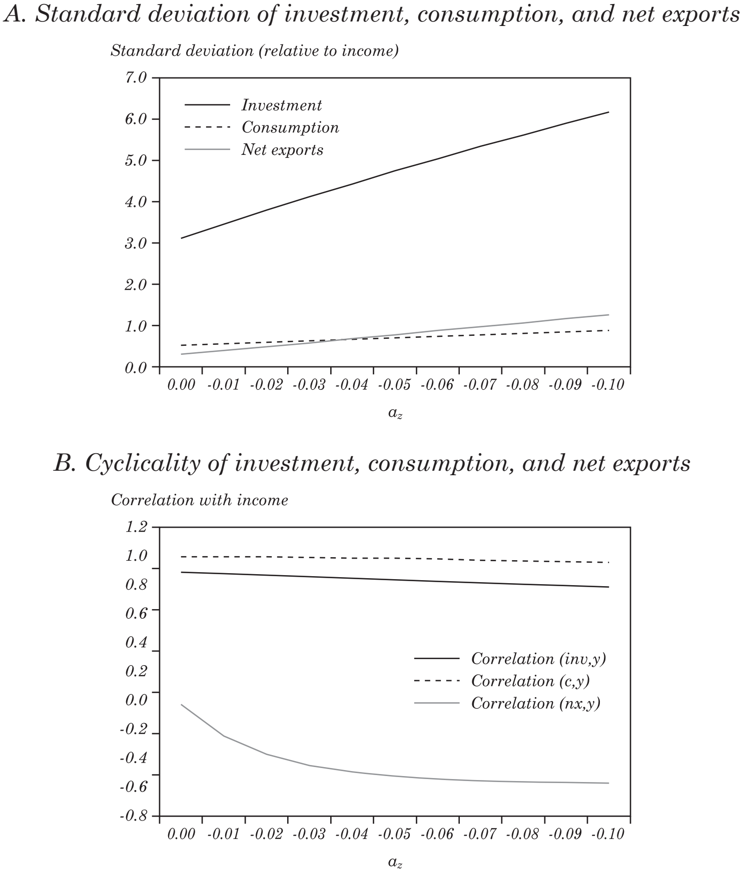


Source: Authors' computations.
a. Impulse response of consumption, investment, net exports, and income to a one percent shock to ε^z. Benchmark model sets $a_z = 0$; *az* model sets $a_z = -0.1$.

For the benchmark case of $a_z = 0$, we find the standard consumption-smoothing result: consumption increases, but income increases much more. The case of $a_z < 0$ combines the income response with a substitution response that favors initial consumption. This generates a larger initial jump in consumption and a subsequent decline. Given the transitory nature of the shock, the net effect is that consumption tracks the shape of the income impulse response. The response of investment (not depicted) has a similar intuition as consumption.

The impulse responses indicate that allowing the interest rate and productivity to comove overcomes some of the limitations of transitory productivity. Namely, consumption and investment respond more strongly to income and in a way that makes net exports negatively associated with income. To illustrate how this extension affects business cycle moments, we plot the key moments as a function of a_z in figure 4. As a_z becomes increasingly negative, the volatility of consumption rises relative to income. A positive productivity shock lowers interest rates, generating an increase in consumption above and beyond the income effect. In contrast with the orthogonal interest rate process of figure 2, the additional consumption volatility increases the correlation of consumption and income. This effect is driven by the fact that the interest rate moves one-for-one with productivity. A similar story holds for investment. These effects make net exports countercyclical, a key feature of the data for emerging markets.

Figure 4. Business Cycle Moments and a_z[a]

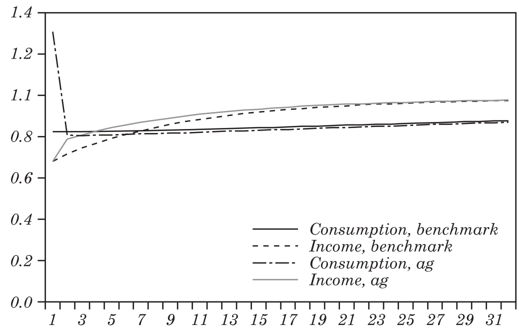


Source: Authors' computations.

a. Panel A shows the standard deviation of (HP-filtered, log) consumption, investment, and net exports relative to income as a function of a_z. Panel B shows the correlation of (HP-filtered, log) consumption, investment, and net exports with income as a function of a_z.

As noted above, an alternative approach is to allow the interest rate to respond to permanent productivity shocks, that is, to set $a_g < 0$. Figure 5 plots the impulse response functions to a shock to ε^g in the benchmark case and in the case of $a_g = -1$. Given that g has a permanent effect on income, consumption responds strongly to the initial shock in the benchmark case, exceeding the initial response of income. Allowing the interest rate to respond as well heightens the initial response of consumption. The interest rate falls back quickly to its initial level, however, as *g* is nearly i.i.d. This generates a sharp fall in consumption and then a leveling out, but income jumps and then continues to rise in response to a growth shock. Allowing $a_g < 0$ thus lowers the correlation of consumption with income, taking us further from the data. This effect is clearly demonstrated in figure 6. As we increase a_g (in absolute value), the variance of consumption and investment increase, while the correlations with income at business cycle frequencies fall. This reduces the cyclicality of net exports, drawing us further from the data.

Figure 5. Impulse Response to *g* Shock[a]



Source: Authors' computations.
a. Impulse response of consumption, investment, net exports, and income to a one percent shock to ε^g. Benchmark model sets $a_g = 0$; ag model sets $a_g = -0.1$.

Figure 6. Business Cycle Moments and a_g[a]

A. Standard deviation of investment, consumption, and net exports

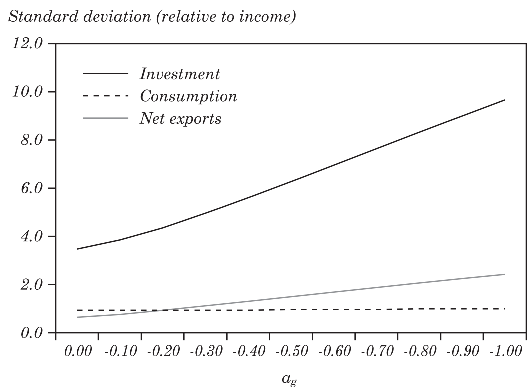
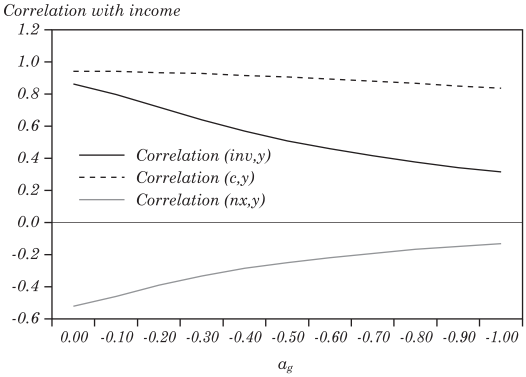


Figure 6. (continued)

B. Cyclicality of investment, consumption, and net exports



Source: Authors' computations.
a. Panel A shows the standard deviation of (HP-filtered, log) consumption, investment, and net exports relative to income as a function of a_g. Panel B shows the correlation of (HP-filtered, log) consumption, investment, and net exports with income as a function of a_g.

The poor performance of the model with $a_g < 0$ is due to the fact that growth rates are not very persistent, generating interest rates that similarly fluctuate. Alternatively, interest rates could be a function of the level of the stochastic trend, Γ, but this would imply a nonstationary interest rate.

2.3 Productivity Shocks Alone

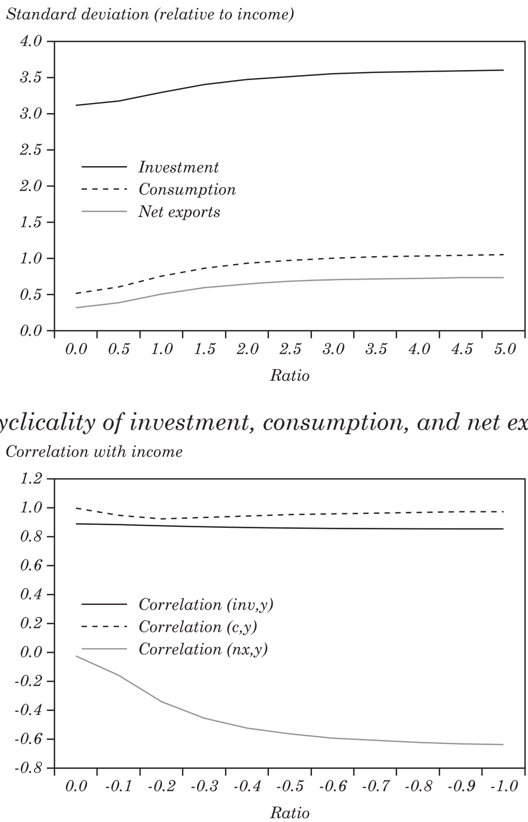
Aguiar and Gopinath (2007) consider a model in which $a_z = a_g = 0$. Here, we briefly summarize the intuition behind the identification of the relative variance, σ_g/σ_z. In response to a transitory shock to productivity, agents increase consumption by less than the increase in income, since they expect income to fall in the future and therefore save to smooth future consumption. On the other hand, if the economy is hit by a growth shock that implies permanently higher income and (depending on the persistence of the growth shock) an upward-sloping profile of income, the agents will increase consumption by at least as much as the increase in income. Therefore consumption is more volatile relative to income under permanent shocks than under transitory shocks. This difference in the response of $\sigma(c)$is shown in figure 7.

By observing the behavior of consumption, we can infer the relative importance of trend versus transitory shocks. It follows that given the response of consumption and income, we should expect net exports to

Figure 7. Business Cycle Moments and σ_g / σ_z [a]

A. Standard deviation of investment, consumption, and net exports

B. Cyclicality of investment, consumption, and net exports



Source: Authors' computations.

a. Panel A shows the standard deviation of (HP-filtered, log) consumption, investment, and net exports relative to income as a function of σ_g / σ_z. Panel B shows the correlation of (HP-filtered, log) consumption, investment, and net exports with income as a function of σ_g / σ_z.

be far more countercyclical for the economy with trend shocks, and the moment on net exports can be used to identify the underlying productivity shock.

2.4 Identification Strategy

Given the above results, we restrict $\sigma_r = a_g = 0$. That is, we consider a model in which the interest rate covaries with transitory productivity shocks, and we allow for both transitory and trend shocks to productivity. The patterns depicted in figures 4 and 7 indicate how we can identify the key parameters. Increases in the magnitude of a_z and σ_g/σ_z have a similar impact on the cyclicality of the current account. However, while both raise the relative volatility of consumption, net exports, and investment, the relationships differ. Figure 4 indicates that a_z has an almost linear effect on the relative variances, while figure 7 shows that the impact of σ_g/σ_z eventually dies out. In particular, for a large enough a_z, the relative volatility of net exports exceeds that of consumption. This reflects the differential sensitivity of investment and consumption to interest rate shocks. Therefore, the empirical moments of $\sigma(c)$ and $\sigma(nx)$, combined with the empirical covariance of net exports with output, pin down the relative magnitudes of a_z and σ_g/σ_g. Given the relative variance of trend and transitory shocks, the level of income volatility then identifies the level of σ_z and σ_g.

3. Estimates

In this section, we follow the above identification strategy to estimate σ_g, σ_z, and a_z by matching the following (HP-filtered) moments of the data: the standard deviations of income, consumption, and net exports; and the covariance of net exports with income. We use data from Mexico as a representative emerging market and Canada as a representative developed open economy. We fix other parameters at the values listed in table 1.

Table 1. Benchmark Parameter Values

Parameter	*Symbol*	*Value*
Time preference rate	β	0.98
Coefficient of relative risk aversion	σ	2
Cobb-Douglas utility parameter	γ	1, 0.36
Ratio of steady-state debt to GDP	b	0.10
Coefficient on interest rate premium	ψ	0.001
Labor exponent (production)	α	0.68
Depreciation rate	δ	0.05
Capital adjustment cost	ϕ	1.5
Persistence in z process	ρ_z	0.95
Persistence in g process	ρ_g	0.01

Source: Authors' estimations.

For each set of estimates, we report the relative importance of the random walk component of productivity. Beveridge and Nelson (1981) show that any I(1) series can be decomposed into a random walk component (denoted τ) and a stationary component. A natural measure of the importance of the random walk component is the ratio of the variance of the growth rate of the trend component to the growth rate of total TFP:

$$\frac{\sigma^2_{\Delta\tau}}{\sigma^2_{\Delta TFP}} = \frac{\alpha^2\sigma^2_g}{\left(1-\rho_g\right)^2\sigma^2_{\Delta TFP}} = \frac{\alpha^2\sigma^2_g \Big/ \left(1-\rho_g\right)^2}{\left\{\left(2\sigma^2_z/1+\rho_z\right)+\left[\alpha^2\sigma^2_g/1-\rho^2_g\right]\right\}}. \tag{11}$$

We report the estimates for σ_g, σ_z, and a_z in table 2. In the columns labeled benchmark, we restrict $a_z = 0$. This corresponds to the benchmark model of Aguiar and Gopinath (2007). The remaining columns estimate a_z. The first two columns consider a model for Mexico in which labor is supplied exogenously. This corresponds to setting the Cobb-Douglas preference parameter on consumption (γ) to one, so that leisure does not enter utility. The next two columns allow labor supply to vary endogenously, setting $\gamma = 0.36$. The final two columns estimate the model using Canadian data and assuming endogenous labor supply.

For the benchmark model using Mexican data (column 1), σ_g is larger than σ_z, and the relative contribution of the random walk component to TFP is 1.02. This is similar to the results reported in Aguiar and Gopinath (2007). In the second column, we estimate a_z along with σ_z and σ_g. We find that $a_z < 0$, although we cannot reject $a_z = 0$ at standard significance levels. Even allowing for interest rate shocks, we estimate a relatively large σ_g, with an estimated contribution of the random walk component of 1.01.

Allowing labor supply to vary endogenously does not overturn this pattern. In both specifications, the random walk component of productivity is estimated to be roughly 1.0. The coefficient a_z is estimated to be small.

The case of Canada indicates a relatively small random walk component. In both specifications, the estimated relative random walk component is 0.4. The estimated coefficient a_z is also small and not significantly different from zero.

Table 2. Estimates for σ_z, σ_g, and a_z[a]

	Mexico				Canada	
	Exogenous labor		Endogenous labor		Endogenous labor	
Parameter	*Benchmark*	*With a_z*	*Benchmark*	*With a_z*	*Benchmark*	*With a_z*
σ_z	0.13	0.16	0.13	0.24	0.72	0.69
	(2.42)	(0.79)	(0.66)	(1.06)	(0.09)	(0.16)
σ_g	2.78	2.70	2.69	2.68	0.84	0.89
	(0.44)	(0.33)	(0.00)	(0.31)	(0.15)	(0.09)
a_z	–	–0.40	–	–0.01	–	0.01
	–	(1.85)	–	(0.55)	–	(0.02)
Random walk component	1.02	1.01	1.01	1.00	0.39	0.44
	(0.18)	(0.08)	(0.05)	(0.15)	(0.07)	(0.13)

Source: Authors' estimations.

a. Estimates were obtained from matching empirical moments of Mexico and Canada for respective columns. The moments used were the standard deviation of the HP-filtered log of income, the log of consumption, and net exports/GDP, as well as the covariance of HP-filtered net exports/GDP and the log of income. Exogenous labor model sets $\gamma = 1$; endogenous labor model sets $\gamma = 0.36$. In the columns labeled benchmark, we restrict $a_z = 0$; the remaining columns estimate a_z. Standard errors are in parentheses

Table 3 reports the implied business cycle moments from the estimated models, together with the corresponding empirical moments from Mexico and Canada. In the case of Mexico, both models perform well in matching key features of the data. The empirical relative volatility of consumption is 1.3, while the models with and without interest rate shocks both generate relative variances of 1.1. The cyclicality of net exports is –0.8 in the data and–0.7 and –0.6 in the models without and with interest rate shocks, respectively. In general, allowing for interest rate shocks does not markedly improve the fit of the model. A similar story holds for Canada, as reported in the final three columns of table 3.

The specification with interest rate shocks reveals that interest rates are countercyclical in Mexico and procyclical in Canada. The variance of the implied interest rates is negligible, however. This reflects the fact that while consumption is volatile in emerging markets, it is driven not by intertemporal substitution, but rather by income shocks.

4. Discussion and Conclusion

Emerging markets are characterized by large volatility in their income and consumption and large countercyclicality in net exports relative to developed small open economies. They also face a volatile interest rate process that is negatively correlated with their GDP level. A large literature attempts to explain these features of the data and infer the importance of productivity and interest rate shocks in explaining the patterns observed in the data. In this paper, we have performed a similar exercise by extending the framework in Aguiar and Gopinath (2007), which only allows for productivity shocks, to allow for both, a richer specification of interest rate shocks and interaction between productivity and interest rate shocks.

One finding, which supports other evidence in the literature, is that interest rate shocks that do not effect productivity cannot be the main explanation for business cycles in emerging markets. These markets are characterized by large movements in output at business cycle frequencies, which are associated with large movements in the Solow residual. Interest rate shocks alone do little to explain these large movements in output. It is important to uncover channels through which interest rate shocks affect productivity.

If interest rates are negatively correlated with the productivity shock, they can explain, at least qualitatively, both countercyclical net

Table 3. Implied Moments of the Business Cycle[a]

	Mexico			Canada		
Parameter	*Data*	*Model I*	*Model II*	*Data*	*Model I*	*Model II*
$\sigma(y)$	2.40	2.69	2.63	1.55	1.56	1.55
$\sigma(c)$ / $\sigma(y)$	1.26	1.09	1.10	0.74	0.71	0.72
$\sigma(nx)$ / $\sigma(y)$	0.90	0.74	0.84	0.57	0.59	0.60
$\sigma(\mathrm{i})$ / $\sigma(\mathrm{y})$	4.15	3.52	3.81	2.67	3.23	3.13
$\sigma(r)$		n.a.	0.08		n.a.	0.01
$\rho(y_t, y_{t-1})$	0.82	0.78	0.78	0.90	0.79	0.79
$\rho(c, y)$	0.92	0.98	0.98	0.87	0.87	0.85
$\rho(nx, y)$	–0.75	–0.68	–0.61	–0.12	–0.17	–0.13
$\rho(i, y)$	0.91	0.86	0.82	0.74	0.85	0.84
$\rho(r, y)$		n.a.	–0.01		n.a.	0.90

Source: Authors' estimations.
n.a. Not applicable.
a. Empirical moments and implied moments are from alternative models. Model I and model II for Mexico correspond, respectively, to the first two columns of estimates of table 2 (that is, the exogenous labor supply model). For Canada, model I and model II correspond to the respective columns of estimates for Canada in table 2.

exports and a consumption process that is more volatile than income. When we estimate the model to allow for the interaction between interest rates and productivity, we find a small negative correlation between productivity and interest rates. We also find that, even in this framework, trend shocks play a large role, which supports the main result in Aguiar and Gopinath (2007)—namely, that an important characteristic of emerging markets is that shocks to trend productivity are a predominant factor in explaining movements at business cycle frequencies, in contrast to developed markets.

In this paper, we have taken a reduced-form approach to modeling both the interest rate process and productivity shocks. Future work should examine the structural features of emerging markets that give rise to the particular form of these processes. In Aguiar and Gopinath (2006), we explore a model with Eaton-Gersovitz-style endogenous default. While this approach does generate default in equilibrium and can generate a countercyclical interest rate process, it fails to generate sufficient volatility in the market interest rate process. Further research is required to uncover the source of volatility in the interest rate process.

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