

# World Interest Rate, Business Cycles, and Financial Intermediation in Small Open Economies

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## Abstract

The consensus about the ability of the standard open-economy neoclassical growth model to account for interest-rate driven business cycles has changed over time: whereas early research concluded that business cycles are neutral to interest-rate shocks, more recent investigations suggest that these shocks can explain a large extent of the business cycles of a small open economy when firms borrow to pay for their labor cost before cashing their sales. The first goal of this paper is to show that the recently found effectiveness of interest-rate shocks to cause business cycles rests more on the statistical properties of the shocks than on the working-capital constraint; in particular, recent results are only valid when the level and volatility of the interest rate are high and when the interest rate is negatively correlated with total factor productivity. The paper also shows that interest-rate shocks cannot be the sole driving force of business cycles even when the canonical model is augmented to include a working-capital constraint. The second goal of the paper is to quantitatively explore the dynamic properties of the neoclassical growth model extended to include financial intermediation. It is shown that the extended model with external effects in financial intermediation can match the negative correlation between GDP and a domestic borrowing-lending spread if the economy is subject to productivity shocks but not when it is subject to both productivity and interest-rate shocks.

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# 1 Introduction

The last decade has witnessed several episodes in which the winding path of interest-rate driven capital flows affected the economic developments of several emerging market countries, including counts of devastating consequences for some economies. After the 1994 Mexican devaluation and the Russian default and Asian crises in 1997-1998, Latin American and Asian countries experienced how the shrinking interest rates that accompanied capital inflows and fuelled economic expansions at the beginning of the 1990's, started to increase giving rise to deep recessions, unemployment, and financial turmoil before the turn of the decade. At the onset of a new upward swing in short-term rates led by the US monetary policy, renewed concerns arise upon the implications of higher world interest rates on the economic developments of emerging-market countries.

The negative correlation between interest rates and overall economic activity in emerging countries contrasts with the acyclical nature of interest rates in industrial countries as it has been documented by Agénor and Prasad (2000), and more recently by Neumeyer and Perri (2005) and Uribe and Yue (2004). These studies find that the correlation coefficient between interest rates and output is negative and may exceed (in absolute value) 0.5 in emerging countries. They also show that whereas the interest rate lags the cycle in industrial countries, it leads the cycle in developing countries.

Being the access to international borrowing-and-lending centers the distinguishing characteristic of open economies, it is not a surprise that the cost of borrowing affects the economic prosperity of emerging countries in the short run. The effect has been corroborated empirically: for instance, assessing the relative importance of internal and external factors to explain the surge of capital flows to Asian and Latin American countries during the 1990's, Calvo et al. (1996) conclude that the cyclical movement in world interest rates is the most critical element that explains those capital flows and the subsequent growth stimulus in the aforementioned countries. On theoretical grounds, however, the consensus about the ability of the open-economy neoclassical growth model to reproduce interest-rate driven business cycles when countries have access to a frictionless international capital

market has changed over time. Early open-economy business cycle theory concluded that business cycles are neutral to interest-rate disturbances: Mendoza (1991) arrives at the conclusion that “... moderate shocks to [the international interest rate]  $r^*$  have minimal effects on the equilibrium stochastic process of the model.” Recent developments which combine pure international interest-rate shocks with country spread shocks to obtain a unified definition of the country interest rates arrive at an opposite conclusion: Neumeyer and Perri (2005), for instance, indicate that eliminating both country risk and international real rate fluctuations would lower GDP volatility by 30% in Argentina.

If the wealth effect is ruled out, interest rate shocks could become the driving force of business cycles in emerging countries if they pose large substitution effects. In the basic open economy RBC model, the substitution effects of international interest rates shocks on output operate through the supply side of factor inputs. First, labor supply decisions respond to incentives for intertemporal substitution inducing households to work harder and to save more when the return on savings is high and to defer work efforts and to save less when the return on saving is low. Second, a fall in bond prices has a two fold effect on the supply of capital: it induces households to save more and it lowers the relative return to physical capital favoring a portfolio reallocation towards less capital and less debt. Early research, for instance Mendoza (1991) and Correia et al. (1995), indicate the combination of these substitution effects is not large enough to cause the type output swings observed in small open economies.

Neumeyer and Perri (2005) arrive at a different conclusion by departing from the canonical model in three respects: a) the interest rate is raised more than three times; b) a working capital constraint is imposed on the firm’s optimization problem; and c) the interest rate  $R_t$  is the product of two components: a stochastic interest rate on international risky assets,  $R_t^*$ , which is invariant across countries, and a country spread,  $D_t$ . Neumeyer and Perri propose two strategies to model the dynamics of  $D_t$ , depending on whether  $D_t$  responds to domestic economic fundamentals or is driven by an exogenous stochastic process. In both strategies, the covariance between  $R_t^*$  and  $D_t$  is non-negative guaranteeing that the

volatility of  $R_t$  exceeds the volatility of  $R_t^*$ .

The working-capital constraint, which is grounded on the assumption that firms have to pay (a fraction of) their labor cost before cashing their sales, is aimed to add an interest-induced substitution effect on the demand side of input markets. Since firms cannot rely on internal finance by assumption, they have to borrow working capital issuing international bonds. As interest expenses incurred by firms add to their total input costs, the additional mechanism through which interest-rate shocks affect business cycles is similar to the mechanism that Christiano (1991) and Christiano and Eichenbaum (1992) introduce to explain the liquidity effect induced by money inflows in a closed economy: a change in the domestic interest rate (due to a liquidity effect in one case and to an international interest-rate shock in the other) not only affects input supplies as it occurs in the standard model, but it also impacts on the labor demand through the financial cost of hiring labor.

In a related work, Uribe and Yue (2004) investigate the interplay between domestic interest rates, country risk, and business cycles in a group of seven developing countries. Uribe and Yue modify the standard small-open-economy model to include gestation lags, habit formation, and working capital. They show that that the impulse-response functions implied by their model are consistent with the dynamics of domestic macroeconomic aggregates and interest rates identified by a restricted VAR model whose restrictions are consistent with the specification of the theoretical model. Again, the working-capital constraint is introduced to create an interest-induced substitution effect on the supply side of input markets.

The first goal of this paper is to show the extent to which a working-capital constraint and the statistical properties of interest rates explain the disparate results about the interest-rate-induced macro volatility predicted by the open-economy neoclassical growth model. By isolating the determinants of interest-rate induced macro volatility, section 3.1 shows that the canonical model is neutral to interest-rate shocks and that the neutrality is robust to several specifications of the statistical process of the interest rate.

Section 3.2 shows that the inclusion of a working capital constraint in the standard

open-economy stochastic growth model is not an effective mechanism by itself to align the interest-rate macro volatility predicted by the artificial neoclassical economy with what is observed in emerging countries. In particular, under the calibration of the neoclassical model to the Canadian economy made by Mendoza (1991) and setting the world interest rate equal to 10%, when the percentage deviation of this rate is equal to 3%, a working-capital constraint that forces firms to pay one-fourth of their labor cost in advance barely affects the volatility of GDP, raising it from 3.22% to 3.26%. Although the response of output to interest-rate shocks increases lightly when the semi-annual value of the labor cost is paid in advance, still the inclusion of working capital scarcely affects the volatility of GDP and other macroeconomic aggregates. Results indicate that the world interest rate could affect the dynamics of the economy only if interest-rate shocks possess very specific attributes, namely high level and volatility and negative contemporaneous correlation with productivity shocks.

The literature studying open-economy macroeconomic fluctuations induced by world financial developments is not homogeneous at modelling the timing of interest payments nor at adopting a solution technique. Particularly, interest is assumed to be paid in advance in some models and at maturity in others; moreover, whereas in some models the interest rate is known at the borrowing time, in some other models it is unknown at the borrowing time and only known at maturity. Insofar as different assumptions about the timing of interest payments and the information set of borrowers could explain why otherwise similar models predict opposite responses of small open economies to interest-rate shocks, the effect of these alternative assumptions of interest rates is studied in section 3.4. It is shown there that the artificial economy is more responsive to interest-rate shocks when interest is known than when it is unknown in advance and that the quantitative differences grow larger when the persistence of interest-rate shocks is low than when the persistence is high. As for the solution technique, in section 3.3 the neoclassical open-economy model is solved using parameterized expectations and a log-linear solution technique to show that the log-linearization technique tends to exaggerate the volatility of macroeconomic aggregates by

around 10%.

The second goal of the paper is to explore the type of financial intermediation that can account for the business-cycle dynamics of the banking lending-borrowing spread in emerging countries, specially the correlations between these internal spread and the world interest rate and between the internal spread and GDP. Figures 1 and 2 complement the cross-country evidence of the negative correlation between interest rate and output in Neumeyer and Perri (2005) and Uribe and Yue (2004). Figure 1 depicts series of GDP and borrowing-lending spreads in eight emerging countries. All series represent percentage deviations from their Hodrick-Prescott trends and the spread is defined as the ratio of lending to borrowing rates of domestic financial institutions. For most of the countries in the figure, the GDP-spread correlation is negative and exceeds 0.4 in absolute value in three of the eight countries, revealing that financial intermediation is less costly during the expansive phase than during the recessive phase of business cycles. Figure 2 depicts time series of country interest rates and the borrowing-lending spreads for the eight countries included in Figure 1; the contemporaneous correlation between the series in each country is positive and it exceeds 0.5 in Argentina and Brazil.

The search for the type of financial intermediation that account for the aforementioned correlations is performed keeping the framework of the analysis consistent with the assumption of frictionless access to world financial markets used in other papers studying interest-induced business cycles. For this reason, it is assumed that neoclassical banks carry out the domestic intermediation of capital inflows in the artificial economy. These banks, which are the only agents in the economy with access to international financial centers, are modelled following the “production approach” in the banking literature (see Freixas and Rochet, 1997, chap. 2). In the spirit of Gurley and Shaw (1960), the role played by banks in the artificial economy is to transform the financial securities issued by domestic agents into assets attractive to world investors.

It is shown in section 3.5 that when the banking system operates under conditions of constant returns to scale, however, the internal spread is constant and cannot match the the

correlations shown in Figures 1 and 2. To break this spread acyclicity, the model allows for external technical economies by which the expansion by an individual bank spills over the banking system as it affects favorably the overall intermediation conditions. Whereas the model with external economies is able to reproduce the GDP-spread correlation when the economy is only hit by productivity shocks, it fails to do so when the model dynamics are driven by both financial and productivity shocks.

## 2 The Model

The model of this section is a standard decentralized small-open-economy model augmented to include a demand for working capital and a domestic financial sector that exploits a neoclassical technology to intermediate capital inflows. Households do not have direct access to international financial markets and their assets are physical capital and bank loans. Households own all banks and firms in the economy but perfect competition cuts down banks' and firms' profits to zero.

### 2.1 Households and the Timing of Interest Payments

The representative household of this economy has an infinite life and seeks to maximize an Epstein's (1983) Stationary Cardinal Utility choosing a sequence of consumption, labor supply, bank loans and capital  $\{c_t, n_t, \ell_t^h, k_{t+1}\}_{t=0}^{\infty}$ :

$$\max_{\{c_t, n_t, \ell_t^h, k_{t+1}\}_{t=0}^{\infty}} E \left\{ \sum_{t=0}^{\infty} \exp \left[ - \sum_{\tau=0}^{t-1} \psi \log \left( \iota + \tilde{c}_{\tau} - \frac{\tilde{n}_{\tau}^{\omega}}{\omega} \right) \right] \frac{\left( c_t - \frac{n_t^{\omega}}{\omega} \right)^{1-\sigma}}{1-\sigma} \right\}; \quad (1)$$

where the endogenous discount factor  $\exp \left[ - \sum_{\tau=0}^{t-1} \psi \log \left( \iota + \tilde{c}_{\tau} - \frac{\tilde{n}_{\tau}^{\omega}}{\omega} \right) \right]$  introduces an impatient effect by which the rate of time preference increases with past consumption and leisure. The functional form of the lifetime utility function is chosen to overcome the technical problem that would arise if the discount factor and the interest rate are exogenous to the model. This problem, explained in detail in Arellano and Mendoza (2003) and Schmitt-

Grohé and Uribe (2003), can be shortly characterized saying that the ergodic variance of household loans diverges to infinity. As the impatient effect has shown negligible in quantitative applications (see Mendoza 1991), following Schmitt-Grohé and Uribe (2003), it is assumed that atomistic households do not internalize the effects of their consumption and labor decisions on the rate of time preference. Thus, the discount factor is shown to depend on the aggregate per-capita consumption and labor supply,  $\tilde{c}_t$  and  $\tilde{n}_t$ , which are outside the control of atomistic agents.

In the equation above,  $\sigma \neq 1$  is the inverse of the elasticity of intertemporal substitution and the coefficient of risk aversion;  $\iota \geq 1$  guarantees that the argument of the logarithmic function is nonnegative;  $\psi$  is the elasticity of the rate of time preference with respect to  $(\iota + \tilde{c}_t + \tilde{n}_t^\omega/\omega)$ ; and  $1/(1 - \omega)$  is the elasticity of the labor supply for  $\omega \neq 1$ .

Assuming that the interest on bank loans is paid in advance, the representative household's flow budget constraint at time  $t \geq 0$  is:

$$w_t n_t + r_t^k k_t + (\ell_t^h - \ell_{t-1}^h) \geq c_t + x_t + \ell_t^h r_t^\ell \quad (2)$$

where the household's source of resources includes net borrowing from banks  $(\ell_t^h - \ell_{t-1}^h)$  and labor and capital-rental income, which depend on the wage rate  $w_t$  and the rental rate of capital  $r_t^k$ . Resources are spent in consumption and investment expenditures, respectively  $c_t$  and  $x_t$ , and in interest payments which depend on the amount borrowed,  $\ell_t^h$ , and the bank lending rate,  $r_t^\ell$ . Raising the stock of capital from  $k_t$  at time  $t$  to  $k_{t+1}$  at time  $t + 1$  requires incurring in installation costs  $(\phi/2)(k_{t+1} - k_t)^2$  whose size is controlled by the value of the parameter  $\phi$ . For  $\delta$  representing the depreciation rate, the (implicit) law of motion of the capital stock can then be written as:

$$x_t = [k_{t+1} - k_t(1 - \delta)] + \frac{\phi}{2}(k_{t+1} - k_t)^2 \quad (3)$$

Initial conditions  $k_0$  and  $\ell_{-1}^h$  complete the description of the household's optimization problem. The optimality conditions are standard and include the budget constraint (2)

holding as equality and the following equations:

$$n_t^{\omega-1} = w_t \quad (4a)$$

$$(1 - r_t^\ell) (c_t - n_t^\omega/\omega)^{-\sigma} = \beta_t E \left[ (c_{t+1} - n_{t+1}^\omega/\omega)^{-\sigma} \right] \quad (4b)$$

$$(c_t - n_t^\omega/\omega)^{-\sigma} [1 + \phi(k_{t+1} - k_t)] = \beta_t E \left[ (c_{t+1} - n_{t+1}^\omega/\omega)^{-\sigma} (1 + r_{t+1}^k - \delta + \phi(k_{t+2} - k_{t+1})) \right] \quad (4c)$$

Eq. (4a) equates the marginal rate of substitution of leisure for consumption to the wage rate, and eqs. (4b) and (4c) are the dynamic efficiency conditions for bank loans and capital, respectively; there  $\beta_t \equiv \left( \iota + \tilde{c}_t - \frac{\tilde{n}_t^\omega}{\omega} \right)^{-\psi}$  has been used to shorten the exposition. The innocuous assumption that households do not internalize how its decisions affect the rate at which future utility flows are discounted implies that the household takes  $\beta_t$  as an exogenous stochastic preference parameter. A sequence  $\{c_t, n_t, \ell_t^h, k_{t+1}\}_{t=0}^\infty$  satisfying (4) is a solution to the household's problem if it does not violate the limiting condition that rules out solutions where total net assets  $k_t - \ell_t^h$  grow indefinitely as well as solutions where the household indefinitely borrows and then repays interest and principal by borrowing more. Namely,

$$\lim_{t \rightarrow \infty} E \left\{ \sum_{t=0}^{\infty} \exp \left[ - \sum_{\tau=0}^{t-1} \psi \log \left( \iota + \tilde{c}_\tau - \frac{\tilde{n}_\tau^\omega}{\omega} \right) \right] \left( c_t - \frac{n_t^\omega}{\omega} \right)^{-\sigma} (k_t - \ell_t^h) \right\} = 0 \quad (5)$$

A maintained assumption of this paper and the akin literature is that agents do not behave fraudulently so they respect their promised payments when these payments are due.

Before specifying the economic problems faced by other agents in the economy, it is worth discussing here how the household's economic decisions depend on the domestic loan rate under alternative timings of the interest payment and information sets. The discussion is relevant because none of these two elements has received an homogeneous treatment in the literature studying the macroeconomic implications of interest shocks although they could explain the lack of consensus about the quantitative effect of world liquidity shocks.

The household flow constraint (2) characterizes the case where the interest rate is known

and paid at the borrowing time. This timing, called KIPA hereafter, is adopted by Díaz-Giménez et al. (1992), from whom this paper borrows the formulation of the banking problem below.<sup>1</sup> In Mendoza (1991), the interest rate is unknown at the borrowing time and interest is paid at maturity; under this interest-payment timing, called UIPM hereafter, the last term of the household's flow constraint (2) becomes  $\ell_{t-1}^h r_t^\ell$  instead of  $\ell_t^h r_t^\ell$ . Neumeyer and Perri (2005) and Uribe and Yue (2004) adopt a third interest-payment timing in which the interest rate is known at the borrowing time but interest is paid at maturity; under this timing, called KIPM hereafter, the last term of the household's constraint (2) becomes equal to  $\ell_{t-1}^h r_{t-1}^\ell$ . Note that when the interest rate is non-stochastic, the last two formulations (but not the first one) of the budget constraint are equivalent.

The interest-payment timings above imply different dynamic efficiency conditions for bank loans. Instead of (4b), the Euler equations of the UIPM and KIPM timings are (4b') and (4b''):

$$(1 - r_t^\ell) (c_t - n_t^\omega / \omega)^{-\sigma} = \beta_t E \left[ (c_{t+1} - n_{t+1}^\omega / \omega)^{-\sigma} \right] \quad (4b)$$

$$(c_t - n_t^\omega / \omega)^{-\sigma} = \beta_t E \left[ (c_{t+1} - n_{t+1}^\omega / \omega)^{-\sigma} (1 + r_{t+1}^\ell) \right] \quad (4b')$$

$$(c_t - n_t^\omega / \omega)^{-\sigma} = (1 + r_t^\ell) \beta_t E \left[ (c_{t+1} - n_{t+1}^\omega / \omega)^{-\sigma} \right] \quad (4b'')$$

Consider the UIPM case where, at the time of borrowing, the household does not know the interest rate payable at maturity one period later. Think in the atomistic household and assume that  $r_t^\ell$  rises. Eq. (4a) shows that the labor supply is independent of  $r_t^\ell$ , and once it is noticed that  $k_t$  and  $r_t^k$  are given, it is clear that neither labor nor capital-rental income changes. If  $r_t^\ell$  were an i.i.d. random variable, eq. (4b') shows that the slope of the consumption path would also remain unchanged. Furthermore, if no change were expected in the future return to capital and if  $\ell_{t-1}^h = 0$ , household decisions would be completely independent of interest-rate shocks.

Lifting these assumptions one by one, now think that  $\ell_{t-1}^h > 0$ ; the interest-rate shock

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<sup>1</sup>The first letter of this and the next acronyms specifies whether the interest rate is known or unknown at the borrowing time (K = known; U = unknown), and the last letter specifies whether the interest is paid in advance or at maturity (A = in advance; M = at maturity).

imposes a negative wealth effect as more resources have to be diverted to repaying bank loans at  $t$ . As the wealth effect spreads over the infinite life of the household, an optimizing household finds optimal to pay for its higher financing costs mostly borrowing more; consequently, the household observes only a tiny, almost imperceptible, negative effect on consumption and the accumulation of capital from  $t$  onwards. The atomistic household knows that every other household acts this way and that the return to capital will rise in the future, but all these effects are expected to be very small except when  $\ell_{t-1}^h$  is very large.

Results are quite different when  $r_t^\ell$  is not i.i.d. but dependent of an autocorrelated random shock because intertemporal substitution effects come along. After the interest-rate hike, higher rates are expected to last for some time, raising the incentives to cut down consumption and the stock of capital, with a predictable depressing effect on output. Furthermore, every period before  $r_t^\ell$  returns to its “normal” level can be thought as delivering a negative wealth effect. Now, overall household responses to the change in incentives are significant enough to alter input prices in a perceptible way. The question is: are these effects strong enough to cause business cycles of an amplitude comparable to the amplitude of the cycles caused by productivity shocks of similar intensity? The answer is that only specific parameterizations of the shocks, as shown in the next section, will allow interest-rate shocks produce real-world type business cycles. Particularly, both large mean value and standard deviation of  $r^\ell$  are required.

When the interest rate on the household debt is known in advance, eq. (4b'') shows that even when  $r_t^\ell$  is i.i.d., any interest shock induces a substitution effect that affects current consumption and investment decisions, and consequently current output. If  $r_t^\ell$  is not i.i.d. but autocorrelated, the impact of a positive (negative) interest-rate shock on production is stronger because the household anticipates that the interest rate will be relatively high (low) for some time, rewarding even higher the effort to cut (raise) the stock of capital. As the wealth effect does not vary from the case where the interest rate is known to the case where it is unknown, the interest-induced cycles under the two considered timings become similar when the persistence of  $r_t^\ell$  is high. When the persistence is low, interest-rate shocks

should be more effective to affect domestic macroeconomic aggregates when the interest rate is known than when it is unknown in advance.

## 2.2 Firms and the Working Capital Constraint

Competitive firms in this economy produce final output employing capital and labor,  $k_t$  and  $n_t$  respectively, and borrowing from banks to pay a fraction  $\theta$  of their labor cost before cashing their sales. Following Neumeyer and Perri (2005), it is assumed that firms borrow to overcome a friction that prevents transferring labor income to households in the standard way. Taken output and input prices as well as the interest rate on bank loans as given, the representative firm solves the following profit maximization problem:

$$\max_{k_t, n_t} \{ \exp(z_t) k_t^\alpha n_t^{1-\alpha} - w_t n_t - r_t^k k_t - r_t^\ell \ell_t^y \mid (1 - r_t^\ell) \ell_t^y \geq \theta w_t n_t \}$$

where a Cobb-Douglas technology is perturbed with a Markovian productivity shock,  $\exp(z_t)$ , whose exogenous driving process is specified later. The firm faces labor and capital rental costs as well as financial costs for it has to borrow  $\ell_t^y$  to pay for (a fraction  $\theta$  of) the labor cost in advance. Implicit in the maximization problem above is the assumption that the firm pays interest in advance: out of a loan of size  $\ell_t^y$ , a share  $r_t^\ell$  is used to pay the financial cost and the remaining share  $(1 - r_t^\ell)$  is used to pay the fraction  $\theta$  of the labor cost. Perfect competition eliminates profits in equilibrium so when the firm sells its output, the firm exhausts its sale proceeds paying two things: the remaining fraction  $(1 - \theta)$  of its labor cost at the end of period  $t$ ; and the loan principal at the beginning of period  $t + 1$ .

At the optimum it is a waste to borrow more than what is required to finance the labor cost, so the working-capital constraint holds as an equality. The remaining optimality conditions that characterize the solution to the firms' atemporal optimization problem are apparent:

$$\alpha \exp(z_t) k_t^{\alpha-1} n_t^{1-\alpha} = r_t^k \qquad (1 - \alpha) \exp(z_t) k_t^\alpha n_t^{-\alpha} = w_t \left( 1 + \theta \frac{r_t^\ell}{1 - r_t^\ell} \right); \quad (6)$$

and show how the interest rate on bank loans affects production: a fall in  $r_t^\ell$  depresses the cost of employing labor and induces firms to raise their production and demand for labor. Since  $\theta = 0$  in the standard neoclassical open-economy model, the interest rate does not affect the demand for inputs in that model and so the only effect of interest on production comes from the supply (or household) side of input markets.

To obtain a first appraisal of the importance of the interest-rate effect on the demand side of input markets and potentially on the amplitude of business cycles, define  $\hat{r}_t^\ell \equiv [r_t^\ell / (1 - r_t^\ell)]$  and consider the logarithmic differentiation of the second equation in (6) equated to zero:

$$\frac{dw_t}{w_t} + \frac{\hat{r}_t^\ell \theta}{1 + \hat{r}_t^\ell \theta} \frac{d\hat{r}_t^\ell}{\hat{r}_t^\ell} = 0$$

From the standpoint of the atomistic firm, this expression shows the interest-rate change that makes up for a 1% increase in the market wage rate so that production plans remain unchanged. Simple algebra on the precedent equation reveals that the size of the interest-rate decline that counterbalances a 1% increase in the  $w_t$  rises when the level of the interest rate falls. Consider an example in which  $r_t^\ell = 10\%$  (which implies  $\hat{r}_t^\ell = 11.11\%$ ) and the firm pays one-fourth of its labor cost in advance, i.e.  $\theta = 0.25$ .<sup>2</sup> Under these assumptions, a 31% fall in  $r_t^\ell$  compensates the firm for a 1% increase in  $w_t$ . To gauge how large an interest-rate shock has to be to produce noticeable changes in output, note that from the standpoint of the firm, if  $dk_t = 0$ , just a 1% rise of the productivity shock is enough to compensate the 1% rise in  $w_t$ .<sup>3</sup> Therefore, both the interest-rate level and its swings must be large for the working-capital constraint to add a significant amplification mechanism to interest-rate shocks not already present in the basic open-economy neoclassical growth model. This deduction will be confirmed numerically in the next section.

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<sup>2</sup>Setting  $\theta = 0.25$  in a model calibrated at annual frequency is equivalent to setting  $\theta = 1$  in a quarterly-frequency model. In their quarterly-frequency models Neumeyer and Perri (2005) and Uribe and Yue (2004) set  $\theta = 1$ , and  $\theta = 1.25$ , respectively.

<sup>3</sup>If  $dk_t \neq 0$  one has to consider output and input-substitution effects.

## 2.3 Banks and the Borrowing-Lending Spread

Banks are modelled borrowing from Díaz-Giménez et al. (1992) who specify a financial industry that operates freely accessible deposit and lending technologies characterized by constant returns to scale. The representative bank in Díaz-Giménez et al. (1992) incurs in a cost  $\eta^b$  per unit of value of financial liabilities and it incurs in a cost  $\eta^l$  per unit of value loaned domestically. The formulation of the representative bank below retains the existence of a constant cost  $\eta^b$  per unit of financial liabilities issued by the bank, which are now interpreted as bonds  $b_t$  issued in world financial centers; it also retains the existence of a constant cost, from the standpoint of the atomistic bank, per unit of value loaned. Notwithstanding, as will be clear below, without adding further structure to the intermediation technology, spreads are acyclical. A natural extension to this framework capable of breaking the acyclicity of the domestic spread involves the inclusion of external economies: the larger the volume of loans intermediated by the financial industry, the lower the unit cost of intermediation of the individual bank.

Adding spillover effects warrants some discussion. Whereas the spillovers are not formally derived, they can be motivated by appealing to theory in the financial literature. The existence of fixed transaction costs and the consequent increasing returns lies at the root of early theoretical justification of the existence of banks (see, for example, Benston and Smith, 1976). Freixas and Rochet (1997) discuss several other sources of economies of scales in the financial industry including those related to the transformation of assets, information production, and delegated monitoring, among others.

Below, the representative bank is the only domestic agent borrowing and lending in international capital markets. It is subject to a reserve requirement and pays and charges interest in advance. The bank static optimization problem consists in maximizing its end-of-period assets:

$$\max_{\ell_t, s_t, b_t} \ell_t + s_t - b_t$$

subject to a cash-flow constraint, a reserve-requirement constraint, and nonnegative con-

straints, respectively:

$$\ell_t(1 - r_t^\ell) + s_t + \eta^b b_t + \eta_1^\ell \{2 - \exp[\eta_2^\ell(\tilde{\ell} - \tilde{\ell}_t)]\} \ell_t \leq b_t(1 - r_t); \quad \eta^b, \eta_1^\ell, \eta_2^\ell \geq 0$$

$$s_t \geq \tau b_t$$

$$\ell_t, s_t, b_t \geq 0$$

where  $\ell_t$  stands for total loans;  $s_t$  for bank reserves;  $b_t$  for bonds issued by the bank in world financial markets;  $r_t$  for the world interest rate on these bonds; and  $\tau \in [0, 1)$  for the reserve requirement coefficient. When  $\eta_2^\ell > 0$ , the unit cost of intermediation falls below  $\eta_1^\ell$  if the actual (per-capita) aggregate level of loans  $\tilde{\ell}_t$  exceeds its steady state value  $\tilde{\ell}$ .

Inasmuch as reserves are not remunerated, the bank finds optimal to set  $s_t = \tau b_t$ . The remaining optimality conditions imply that the spread is implicitly given by the following expression:

$$r_t^\ell = \eta_1^\ell \{2 - \exp[\eta_2^\ell(\tilde{\ell} - \tilde{\ell}_t)]\} + \frac{r_t + \eta^b}{1 - \tau} \quad (7)$$

This expression shows that the spread rises with the reserve requirement coefficient and the intermediation costs  $\eta^b$  and  $\eta_1^\ell$ . In the absence of spillovers, i.e. when  $\eta_2^\ell = 0$ ,  $dr_t^\ell/dr_t = 1/(1 - \tau) \geq 1$ , so the bank acts as an amplification mechanism of interest-rate shocks when  $\tau > 0$ , although neither the spread nor the domestic rate varies with the volume of intermediation. Adding spillover effects enriches the dynamics of the domestic spread because the difference between the domestic rate  $r_t^\ell$  and the international rate  $r_t$  changes with the industrywide volume of intermediation which in equilibrium can be altered by any of the two shocks hitting the economy.

Completing the description of the banking problem, note that the free access to the intermediation technology drives profits down to zero; in other words:  $\ell_t = (1 - \tau)b_t$ .

## 2.4 Model Perturbations and the Competitive Equilibrium

The model dynamics are driven by the dynamics of the productivity shock and the international interest rate, two variables considered as exogenous to the model and as been determined by the following first-order vector autoregressive process:

$$\begin{bmatrix} z_t \\ r_t \end{bmatrix} = \begin{bmatrix} (1 - \rho^z)z \\ (1 - \rho^r)r \end{bmatrix} + \begin{bmatrix} \rho^z & 0 \\ 0 & \rho^r \end{bmatrix} \begin{bmatrix} z_{t-1} \\ r_{t-1} \end{bmatrix} + \begin{bmatrix} \zeta_t^z \\ \zeta_t^r \end{bmatrix} \quad (8)$$

where  $\zeta_t = [\zeta_t^z, \zeta_t^r]'$  is Gaussian,  $E[\zeta_t] = 0_{2 \times 1}$ , and  $E[\zeta_t \zeta_s'] = \Sigma$  if  $t = s$  and it is equal to 0 otherwise.  $z$  and  $r$  are the unconditional means of  $z_t$  and  $r_t$ , and  $\rho^z$  and  $\rho^r$  are the autocorrelation coefficient of productivity and interest-rate shocks.

The competitive equilibrium of the economy is a sequence of allocations  $\{c_t, n_t, \tilde{c}_t, \tilde{n}_t, \ell_t^h, k_{t+1}, b_t, \ell_t, \tilde{\ell}_t, \ell_t^y\}_{t=0}^\infty$ , a sequence of input prices  $\{w_t, r_t^k\}_{t=0}^\infty$ , and a sequence of the domestic interest rate  $\{r_t^\ell\}_{t=0}^\infty$ , such that, for a given sequence of realizations of the exogenous variables  $\{z_t, r_t\}_{t=0}^\infty$  and initial conditions  $(k_0, \ell_{-1}^h)$ , satisfy the following: a) the conditions that guarantee that the household solves its constrained lifetime utility-maximization problem, i.e. eqns. (2) to (5) hold; b) the profit-maximizing input-combination condition of the firm for every  $t \geq 0$ , i.e. eqs. (6) hold at  $t \geq 0$  with  $(1 - r_t^\ell)\ell_t^y = w_t n_t \theta$ ; c) the bank optimal intermediation condition (7) when  $b_t(1 - \tau) = \ell_t$ ; d) the consistency between individual and per-capita aggregate decisions regarding consumption and labor supply: i.e.  $c_t = \tilde{c}_t$ , and  $n_t = \tilde{n}_t$ , and regarding the volume of loans  $\ell_t = \tilde{\ell}_t$ ; e) agents always honor their debts; and f) the loan market clears:

$$\ell_t = \ell_t^h + \ell_t^y = \ell_t^h + w_t n_t \theta (1 - r_t^\ell)^{-1}$$

In this economy the trade balance is defined as follows:

$$tb_t = \exp(z_t) k_t^\alpha n_t^{1-\alpha} - c_t - x_t - \left( \eta_1^\ell \{2 - \exp[\eta_2^\ell (\tilde{\ell} - \tilde{\ell}_t)]\} + \frac{\eta^b}{1 - \tau} \right) \ell_t$$

The artificial economy of this section nests other models used in the literature to inves-

tigate the business cycle implications of interest-rate shocks. In particular, when  $r_t^\ell = r_t$  (equivalently  $\eta^b = \eta_1^\ell = \eta_2^\ell = \tau = 0$ ) for  $t \geq 0$ , the model assumes away banks and when  $\theta = 0$  it assumes away the working-capital constraint. If both conditions are imposed, the interest rate is unknown in advance and interest is paid at maturity, the model turns to be Mendoza's (1991) model. When  $\theta > 0$ ,  $r_t^\ell = r_t$ , the interest rate is known in advance, and interest is paid at maturity, the economy essentially behaves as the economy in Neumeyer and Perri (2004).<sup>4</sup>

### 3 Quantitative Results

The goal of this section is to investigate the quantitative implications of some extensions and reparameterizations of the standard small-open-economy neoclassical growth model that have been proposed in the literature to explain the interest-rate driven business cycles observed in practice. Thus, the focus of this section is not to replicate moment conditions of macroeconomic aggregates in a specific country, but to explore the extent to which these reformulations of the canonical model could serve to study how global financial factors affect macroeconomic conditions of emerging-market countries in general.

#### 3.1 Neutrality of the Canonical Model to Interest-Rate Shocks

The starting point of this subsection consists in the adoption of the UIPM interest timing and a parameterization of the artificial economy that rules out banks and the working capital constraint, i.e.  $r_t^\ell = r_t$  and  $\theta = 0$ . This is the specification of the standard neoclassical growth model of the small open economy in Mendoza (1991). The following parameter values are taken from his work: capital share in output:  $\alpha = 0.32$ ; depreciation rate:  $\delta = 0.10$ ; labor elasticity parameter:  $\omega = 1.455$ ; discount-factor parameters:  $\psi = 0.11$  and  $\iota = 1$ ; inverse of intertemporal elasticity of substitution:  $\sigma = 2$ ; and world interest

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<sup>4</sup>The model is not strictly the same as the Neumeyer and Perri's model because of some technicalities; for example, they include debt-adjustment costs to induce stationarity and their capital-adjustment costs are different from the costs specified in (3). However, none of the differences between the models are critical for the results that follow.

rate:  $r = 4\%$ .

Alternative values of  $r$  will be considered below given the disparate values of  $r$  used in the literature.<sup>5</sup> The discount factor has been calibrated to avoid a consumption trend when  $r = 4\%$ ; consequently, given the discount factor parameters, any other mean value of  $r$  would introduce a consumption trend that would leave the model without a stationary long-run distribution. To make meaningful comparisons between two economies facing different interest rates, the value of  $\iota$  is set to avoid the consumption trend whereas keeping constant the household net asset position as a share of GDP. More specifically, when interest is paid in advance, the value of labor and capital in steady state arise from the following equations:<sup>6</sup>

$$n = \left[ \left( \frac{1 - \alpha}{1 + \theta \hat{r}^\ell} \right) \left( \frac{\alpha}{(1 - r^\ell)^{-1} - 1 + \delta} \right)^{\frac{\alpha}{1-\alpha}} \right]^{\frac{1}{\omega-1}} ; \quad k = \left[ \frac{(1 - r^\ell)^{-1} - 1 + \delta}{\alpha} \right]^{\frac{-1}{1-\alpha}} n$$

and when interest is paid at maturity  $(1 - r^\ell)^{-1}$  is replaced by  $1 + r^\ell$ . Then, to avoid a consumption trend while targeting a consumption ratio,  $\iota$  has to be chosen to satisfy  $(1 - r^\ell) = (\iota + \tilde{c} - \tilde{n}^\omega / \omega)^{-\psi}$  (under KIPA timing) or  $1 = (1 + r^\ell)^{-1} (\iota + \tilde{c} - \tilde{n}^\omega / \omega)^{-\psi}$ , (under KIPM or UIPM timings). For  $c = \tilde{c}$ ,  $n = \tilde{n}$ , and a given value of  $\delta$ , the household budget constraint (2) at steady state shows that targeting a consumption ratio is equivalent to targeting a household net-asset position ratio. Table 1 summarizes the parameter values and steady-state ratios implied by all parameterizations considered below.

Table 2 exhibits population moment statistics of the model variables under the described parameterization. There,  $\sigma(z)$  and  $\sigma(r)$  denote the percentage standard deviation of the productivity shock and interest rate and the  $\rho$ 's are their respective autocorrelation coefficients. Results in Table 2 are derived under the assumption of a zero contemporaneous correlation between  $z_t$  and  $r_t$ . Results in panel (a), which differ lightly from Mendoza's (1991) results because of approximation errors, show classical productivity-driven business-

<sup>5</sup>For instance: Mendoza (1991) calibrates  $r = 4\%$ ; Kanczuk (2004),  $r = 7.82\%$ ; Uribe and Yue (2004),  $r = 11\%$ ; and Neumeyer and Perri (2005),  $r = 14.9\%$ .

<sup>6</sup>The derivation of these formulas when there is no working-capital constraint and interest is paid at maturity can be found in Schmitt-Grohé and Uribe (2003).

cycle patterns:<sup>7</sup> investment is near three times as volatile as output; consumption volatility is equal to 76% of GDP volatility; aggregates are positively autocorrelated and positively correlated with GDP, except the trade balance.

Panel (b) of Table 2 depicts the business-cycles statistics driven by a volatile interest rate when  $r = 4\%$  and the productivity shock is constant (i.e. when  $\sigma(z) = 0$ ). In the first column, interest-rate shocks have the same statistical properties as the productivity shocks of the baseline calibration:  $\sigma(r) = 1.42\%$  and the autocorrelation parameter  $\rho^r$  is equal to 0.42. Results indicate that, in a model without working capital constraints and without banks, when the international interest rate is equal to 4%, interest-rate shocks are incapable of producing business cycles of a magnitude comparable to the magnitude of productivity-shock driven business cycles. The second column of panel (b) shows that this conclusion remains valid when the volatility of interest rates is raised by a factor of 10 (i.e. setting  $\sigma(r) = 14.2\%$  instead of 1.42%). The third column of panel (b) shows that this interest-neutrality result persists after raising the autocorrelation of interest rate from 0.42 to 0.9.

Empirical evidence indicates that a first-order autoregressive process with an autocorrelation coefficient  $\rho^r$  approximately equal to 0.8 describes the dynamics of the international interest rate (see Neumeier and Perri, 2005 and Uribe and Yue, 2004). For that value of  $\rho^r$ , panel (c) of Table 2 shows when interest rate shocks seem capable of producing output fluctuations of the same volatility as the fluctuations led by the productivity shocks of panel (a):  $r = 10\%$  and  $\sigma(r) = 5.79\%$ . Nevertheless, this seemingly success comes at the cost of many other implausible results: investment, capital, and the trade balance ratio are too volatile; investment becomes counter-cyclical; and the investment-saving correlation is now negative. One could think that these unappealing results are caused by the lack of tune of the investment adjustment costs. But this is not the case either: when the value of the adjustment cost parameter  $\phi$  is set to obtain an investment volatility equal to 3 times

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<sup>7</sup>The results in the table duplicate the results that Schmitt-Grohé and Uribe (2003) obtain for the same model using the same (log-linearization) solution technique. The technique, explained in detail in Oviedo (2005), is well known and consists in solving the log-linear approximation to the model around its steady state.

the volatility of GDP, the volatility of GDP more than halves.

The following sums up the findings of this subsection: in the canonical one-good open-economy neoclassical growth model without capital markets frictions, shocks to the world interest rate cannot generate business cycles that mimic the business cycles observed in actual open economies. This conclusion is robust to the specification of the world interest rate and this is important because disparate values of  $r$  have been used in the literature.

### 3.2 The Working-Capital Constraint and the Contemporaneous Correlation between Domestic and External Shocks

This subsection answers the following: are the precedent interest-neutrality results robust to the introduction of a working-capital constraint that requires firms to pay for their labor cost before cashing their sales? In other words, does the imposition of a working-capital constraint turn moderate-to-large interest-rate shocks into a plausible driving force of business cycles in a small-open-economy model?

Figure 3.a shows the relationship between the percentage standard deviation of the international interest rate,  $\sigma(r)$ , and the percentage standard deviation of GDP for two values of the international interest rate:  $r=4\%$  (solid lines) and  $r=10\%$  (dashed lines) when productivity shocks are equal to zero. To obtain the four curves in the figure, the model is solved for different values of  $\sigma(r)$ , setting the adjustment-cost parameter  $\phi$  equal to 0.028 as in the benchmark calibration. Solid lines identify the results when the working-capital constraint is set off (i.e.  $\theta = 0$ ) and dashed lines identify the simulations arising when the constraint is on (i.e.  $\theta = 0.25$ ). Regardless the value of  $\sigma(r)$ , the imposition of the working-capital constraint raises the volatility of GDP by 6.5% when  $r = 4\%$  and by 9.8% when  $r = 10\%$ .

Results in Figure 3.a confirm the back-of-the-envelope calculations carried out at studying the problem of the firm: for the working-capital constraint to enlarge the output responses to interest-rate shocks, both the level and the volatility of  $r$  should be high. This conclusion is reinforced when the adjustment-cost parameter is tuned so as to match the

relative volatility of investment of the baseline calibration because, in that case, the volatility of GDP falls by more than half for every value of  $\sigma(r)$ . Answering the question posed above, it is fair to say that the imposition of the working capital constraint does not turn interest-rate shocks into a plausible driving force of business cycles in the standard open-economy neoclassical growth model.

Figure 3.b shows the marginal contribution of interest-rate shocks to the long-run volatility of macroeconomic aggregates; the figure depicts GDP volatility against interest-rate volatility when the standard deviation of the productivity shock is equal to its baseline-calibration value of 1.42%. Except for the starred line, all other lines correspond to  $r = 10\%$ . Here, the value of the investment adjustment-cost parameter is altered so that the relative volatility of investment with respect to output volatility is equal to 2.97, as in the baseline calibration. The figure illustrates how the contemporaneous correlation coefficient between the interest rate and the productivity shock affects the sensitivity of output to interest-rate shocks. The maximum output response arises at higher levels of the interest rate and when the correlation between the domestic and external shocks is negative; that is, when a boost to productivity is accompanied by a fall in the cost of borrowing from financial centers and viceversa. On the contrary, when the shocks are positively correlated, the incentives to hire more inputs and accumulate more capital created by a productivity hike can be overturned by the incentives created by a higher interest rate that induces the firm to hire less labor and the household to lower its indebtedness by selling capital.

Focusing on the case where  $r = 10\%$  and  $\sigma(r) = 3\%$ , Table 3 shows the extent to which the working capital constraint explains the marginal contribution of interest-rate shocks to GDP fluctuations shown in Figure 3.b. In panel (a) the constraint is set off:  $\theta = 0$ ; in panel (b) two values of  $\theta$  are considered, 0.25 and 0.50, which imply that the firm borrows an amount equal to its quarterly and semiannual labor cost, respectively. All results are derived tuning investment adjustment costs such that investment is 2.97 times as volatile as output. If one compares the case where  $\theta = 0$  and the shocks are uncorrelated ( $\rho_{r,z} = 0$ ) with the case where  $\theta = 0.25$  and  $\rho_{r,z} = -0.5$ , one notes that the joint effect of negatively

correlated shocks and the working-capital constraint raises output volatility by 7.6%. By setting  $\theta = 0$  and keeping  $\rho_{r,z} = -0.5$  the last column of Table 3 shows that much of that rise (63%) is explained by the correlation of the shocks rather than by the working capital constraint.

If as pointed out by Calvo et al. (1996), external factors are the most important cause of declining interest rates and surging capital inflows, results above indicate that the standard open-economy neoclassical growth model, even when it is augmented to include a working capital constraint, is not the most appropriate model to predict the domestic macroeconomic consequences of global financial factors: for the model to deliver interest-rate driven business cycles, it is necessary that favorably external winds be accompanied by favorable domestic winds, something that is not guaranteed when the interest rate is determined independently of the domestic macroeconomic conditions of the small open economy.

Comparing the results of Table 3 with the results in Table 2 reveals that at a high level of the interest rate, consumption volatility exceeds output volatility. On the other hand, whereas savings are less volatile than investment at low levels of the interest rate, they are more volatile than investment at a high level of the interest rate. As noticed before, the investment-savings correlation falls with the introduction of interest-rate shocks although it falls less when these shocks are negatively correlated with productivity shocks.

The findings of this subsection are the following: a) in the small-open-economy neoclassical growth model extended to include a working-capital constraint, interest-rate shocks are unable to produce the type of business cycles observed in practice; b) when both interest-rate and productivity shocks are the driving force of the artificial economy, the marginal impact of interest-rate shocks on business cycles increases with the level and the volatility of the interest rate; and c) the negative correlation between domestic and external shocks is more important than the working-capital constraint to account for interest-induced fluctuations in the artificial economy.

### 3.3 Accuracy of the Log-Linear Approximation to the Open Economy Neoclassical Growth Model

Studying the dynamics of a non-linear economic model focusing on the dynamics of its log-linear approximation has proven misleading in cases where model perturbations place the artificial economy significantly away from its steady state. In the context of the standard *closed-economy* neoclassical growth model, it is known that the solution to the log-linear model approximates very well the solution to the true non-linear model when the variance of the productivity shock is small (see for example Danthine and Mehra, 1989 and Dotsey and Mao, 1992). Heretofore, the accuracy of this technique, when it is applied to the open-economy neoclassical growth model, has not received the same attention it receives when it is applied to solve the closed-economy version of the model. The accuracy inquiry is pertinent because this open-economy model is the workhorse model to study several business-cycle phenomena in emerging countries and, inasmuch as emerging countries suffer from high macroeconomic volatility, their economies will likely operate significantly away from their steady states.

To gauge how the log-linear solution technique could affect the quantitative business-cycle implications of internal and external shocks when they are applied to solve the small-open-economy neoclassical growth model, the version of the basic model analyzed in sections 3.1 and 3.2 is solved here by parameterized expectations. The parameterized expectation algorithm detailed in Den Haan and Marcet (1990) and Marcet and Marshall (1994) consists in approximating the conditional expectation embedded in the Euler equations with a parameterized function whose arguments are the state variables of the model and whose parameter values are found in the solution process. This algorithm has been shown to deliver very accurate solutions in a number of cases (see the discussion and references in Christiano and Fisher, 2000).

The version of the parameterized-expectations algorithm used here is based on the collocation strategy explained by Miranda and Fackler (2002, chap. 6) in which the parametric function is represented by multivariate chebyshev polynomials in  $(z_t, r_t, k_t, b_t)$ . 10 collocation

tion nodes are used for each endogenous state ( $k_t$  and  $\ell_t^h$ ) and 3 collocation nodes are used for each exogenous state ( $z_t$  and  $r_t$ ). Innovations to the (exogenous) shocks are model using three-point Markov chains. The ergodic distribution of the model variables is computed defining a grid of 200 points for each of the two endogenous state variables and then using the policy function implied by the parameterized expectations to compute the transition probability of all state variables.

Panels (a) and (b) of Table 4 show two sets of solutions to the basic open-economy model when banks and working capital are assumed away. Business-cycle statistics in panel (a) correspond to the log-linear approximation to the model; statistics in panel (b) arise when the model is solved by parameterized expectations. Whereas approximating the model with a log-linear technique does not affect much the autocorrelations nor the comovements between GDP and the other variables in the table, panel (c) shows that the log-linear technique exaggerates the volatility of macroeconomic aggregates by around 10%. At higher levels of the interest rate, the discrepancy between the population moments arising from the parameterized-expectation solution and the log-linearized solution remains in the range of 10%.

A challenge faced by a log-linearization solution technique when it is used to solve the open-economy neoclassical growth model is that the net asset position of the country can deviate considerably from its non-stochastic steady-state value. Large deviation can occur even when the model perturbations have small variances. This happens because the access to frictionless world financial markets allows the economy to completely separate savings from investment decisions. The case where the open economy is only hit by productivity shocks illustrates this point. Assume that the economy's initial net asset position is equal to the asset position at the non-stochastic steady state. Whereas a few periods later it is likely that the asset position does not depart much from its steady-state value, in the long run, there are several sequences of realizations of the productivity shock with non-zero probabilities that are capable of bringing the net asset position significantly away from the steady state. For instance, a relatively long-sequence of low productivity shocks might turn

a net creditor country into a net debtor country as the household borrows to dissociate its consumption stream from the fortuitous sequence of low productivity shocks.

Figure 4.a shows the marginal bi-variate ergodic distribution of capital and household debt when productivity and interest rate are stochastic variables with standard deviations equal to 1.42% and 3%, respectively. As can be seen in the figure, the probability that the stock of capital be lower than 3.35 or higher than 3.45 is insignificant; as the non-stochastic value of capital is 3.40, this means that the probability that the capital stock deviates by more than 1.5% from that value is nil. Things are different when it comes to consider the household's debt position; the marginal distribution of this debt is shown in Figure 3.b. In the non-stochastic steady state  $\ell^h=0.59$ , but in the long-run, the probability that the household debt be lower (higher) than 0.39 (0.76) is equal to 10%. Thus, the stock of household debt can deviate 29% above its non-stochastic value or 48% below that value with significant probabilities.

This difficulty created by the separation of investment and savings decisions on the log-linear techniques can be alternatively characterized noting the following: the marginal ergodic distribution of  $\ell_t^h$  shown in Figure 4.b implies that the economy spends 70% of its time in points of the state space that are more than 10% away from the non-stochastic steady state.

In brief, this subsection has shown that solving the small-open-economy neoclassical model using a log-linear technique does not affect the comovement nor the autocorrelation of the variables, but that it does overestimate the volatility of macroeconomic aggregates by 10%. Furthermore, it has been shown that the economy spends most of its time in points of the state space that are far from the stationary point around which the model is log-linearized. Due to the proven inaccuracy of the results obtained employing log-linear techniques to solve the model, all results hereafter are derived solving the model with parameterized expectations.

### 3.4 Timing of Interest Payment and the Information Set of the Household

Two aspects of the model of section 2 are considered here, the timing of interest payments and the information set of the household. As for the interest timing, what matters is whether interest is paid in advance or at maturity; for the information set, specifications differ depending on whether or not the household knows at time  $t$  the interest rate applicable to the debt incurred at that time. From the standpoint of the firm, however, neither aspect is relevant since the firm's optimization problem essentially is an atemporal problem.

Table 5 compares business cycle statistics of the three specifications of the interest timing in the small open economy neoclassical growth model augmented to incorporate the firm's working capital constraint when  $\sigma(r) = 3\%$ . Panel (a) corresponds to the case where the interest rate is unknown at the borrowing time and interest is paid at maturity (UIPM); panel (b) shows what happens when the interest rate is known in advance although paid at maturity (KIPM); and panel (c) corresponds to the case where the interest rate is known in advance and paid at the borrowing time (KIPA). For the UIPM and KIPM cases  $r = 10\%$  and for the KIPA case  $r = 9.09\%$ . The lower value of  $r$  in the KIPA case accounts for the time value of resources from the standpoint of the household: a 10% rate discounted one period at the intertemporal discount rate implicit in the discount factor, is equal to 9.09%. The same value of the adjustment cost parameter is used in the three specifications:  $\phi$  is set equal to 6.75 times its value in the baseline calibration, so that investment is three times as volatile as output under the UIPM specification. In all cases, to activate the firm's constraint,  $\theta = 0.25$ .

Results in Table 5 reveal that the ergodic moments of the model variables do not change much across the considered interest timings. The ergodic means of the variables are the same across the two specifications in which the interest is paid at maturity (UIPM and KIPM). The standard deviations of the variables are higher when the interest rate is known than when it is unknown; the largest differences are in investment (14.8%), capital (19.8%) and the trade balance ratio (9.4%) while the lowest differences are in consumption

and savings (1.8% and 2.8%). Although not shown in the table, all variables are lightly more persistent under the KIPM timing than under the UIPM timing.

When the interest is paid in advance (KIPA), the volatility of all variables except consumption is higher than when the interest is known in advance and paid at maturity (KIPM). Here the largest differences correspond to investment and (8.3 and 8%) and the minimum to GDP and consumption (2.3 and 1.2%). A difference to remark is that consumption is more volatile than output only under the UIPM case; more in general, the relative volatility of consumption rises with higher levels of the interest rate, regardless the interest timing.

Results between parenthesis in Table 5 are obtained solving the alternative formulations of the model under the assumption that the autocorrelation of the interest rate is equal to 0.42 instead of 0.8. As discussed in subsection 2.1, the business-cycle implications of interest shocks show more discrepancies across interest-payment timings when the autocorrelation of the international interest rate is low than when it is high. Note for example that when  $\rho^r=0.42$ , investment and capital are more than 51% more volatile when the interest is known than when it unknown in advance.

### 3.5 Domestic Financial Intermediation

When accessing international financial markets is costly because real resources have to be used by domestic financial institutions to borrow abroad and lend domestically, the intermediation spread is different from zero, fluctuates with business cycles, and is capable of becoming a dampening mechanism. The quantitative importance of this mechanism is illustrated in Table 6; results in the table are derived assuming the existence of a working-capital constraint ( $\theta = 0.25$ ) and tuning the adjustment cost parameter to obtain an investment volatility equal to 2.97 times the volatility of GDP when the model is solved without the external effects of financial intermediation.

The values of the intermediation costs parameters are set preserving the ratio of lending to borrowing costs equal to 4.74 specified by Díaz-Giménez et al. (1992), assuming that

the reserve requirement coefficient  $\tau$  is equal to 1%, and that the internal spread is equal to the difference between the two values of the interest rates considered above, 4 and 10%. According to this setting,  $\eta_1^\ell = 0.049$   $\eta^b = 0.010$ . Allowing for external effects also requires specifying the value of  $\eta_2^\ell$ , which is a free parameter. Its value is set equal to 0.135 to help the model match the correlation between GDP and the domestic spread when the economy is hit by productivity shocks.

Results in panels (a) and (b) of Table 6, which are derived assuming that productivity shocks are the only driving force of the model, show how the financial spillovers help to align the GDP-spread correlation of the artificial economy with the statistics shown in Figure 1. In panel (a) spillovers are assumed away (i.e.  $\eta_2^\ell = 0$ ) and the spread is acyclical because intermediation costs do not respond to the volume of intermediation (see eq. (7)). To obtain the countercyclical spread shown in panel (b), whose correlation with GDP is approximately equal to the average correlation of the countries in Figure 1,  $\eta_2^\ell$  is set equal to 0.135. Comparing the results of the first two panels of the table indicates that whereas the introduction of financial spillovers barely affects output volatility, it raises the investment-saving correlation and it lowers considerably the relative volatility of consumption, savings, household loans (not shown in the table), and the trade-balance ratio.

To understand the effects arising from external economies in the financial industry note that, absence these economies, the supply of loans is infinitely elastic at the level of the domestic rate  $r_t^\ell$  at which the interest-rate spread exactly compensates the unitary cost of intermediating a unit of value. A productivity hike induces firms to produce more and, provided productivity is autocorrelated, the productivity hike raises household's incentives to increase the stock of capital. Household savings decisions, which are governed by eq. (4b), are separated from investment decisions and respond to the incentive to equate the intertemporal rate of substitution to the the cost of borrowing. The procyclicality of the trade balance in panel (a) indicates that the pro-saving effect dominates the pro-borrowing effect; the former is induced by the incentive to raise consumption not only during the period where productivity is higher but during a longer horizon; the latter is induced by

the incentive to increase the stock of capital.

Allowing for financial spillovers breaks this Fisher separation; when firms produce more and households borrow to increase the stock of capital, the domestic interest rate falls as the financial system intermediates more. The interest-rate fall encourages household to substitute present for future consumption which lowers the volatility of savings relative to the case without external effects. This explains why the cross correlation between capital and household debt (not shown in the table) goes from -0.07 to -0.57 when spillovers are added to the model. Moreover, the trade balance becomes countercyclical because the pro-borrowing effect is now reinforced by the incentive created by the higher interest rate to advance consumption.

Panels (c) and (d) of Table 6 show population moment conditions of macroeconomic aggregates when the intermediated economy is subject to interest and productivity shocks; having both shocks driving the dynamics of the artificial economy permits studying the extent to which the economy reproduces the correlation between the domestic spread and the international interest shown in Figure 2. Results in panel (c) assume away the spillovers which are then reintroduced to obtain results in panel (d).

Financial intermediation mitigates the effect of international liquidity shocks on domestic business cycles as the interest rate relevant for domestic decisions, namely the domestic interest rate, does not change as much as the international interest rate. The standard deviation of the domestic rate in panel (c) of Table 6 is less than half the standard deviation of the international rate. The lending rate of a costly-operated banking system depends on two different costs: a financial cost which is given by the international interest rate, and a non-financial cost represented by the opportunity cost of the real resources used for financial intermediation. Inasmuch as the non-financial costs are nontrivial, an international liquidity shock does not impact one-by-one on the domestic interest rate. Thus, when a costly operated banking system is added to the open-economy neoclassical growth model, interest-rate shocks are even less likely to generate the type of business cycles observed in emerging countries.

As for the comovements, when the intermediated economy without external effects is hit by interest-rate as well as productivity shocks and these shocks are uncorrelated, the correlation between the spread and the international rate is equal to -1 as it is implied by eq. (7); likewise, the correlation between the domestic rate and the spread is equal to 1. Although reintroducing the external effects sensibly affects the correlation between  $r^\ell$  and the spread, it barely raises the correlation between the spread and the international interest rate. On the other hand, world interest-rate shocks brings on procyclical spreads even after introducing the banking external effects. Thus, the neoclassical growth model with financial intermediation subject to uncorrelated internal and external shocks seems to be incapable of reproducing the GDP-spread correlation and the correlation between the spread and the world interest rate. Future research should focus on the correlation between interest rate and productivity shocks as well in alternative forms of financial intermediation that could provide the foundations to reproduce the interest-rate correlations that the neoclassical growth model with financial intermediation cannot reproduce.

## 4 Concluding Remarks

Whereas empirical investigations are conclusive about the role of the world interest rate on the macroeconomic developments in emerging-market countries, the consensus about the ability of the standard open-economy neoclassical growth model to account for interest-driven business cycles has been less persuasive. Early research (Mendoza, 1991) concluded that with frictionless access to incomplete world financial markets, interest-rate shocks have minimal effects on business cycles. After adding a working-capital constraint to the canonical model, more recent studies (for example Neumeyer and Perri, 2005 and Uribe and Yue (2004)) find that these shocks might explain a great extent of the business cycles in small open economies. The working-capital constraint restricts firms to borrow a value equal to a fraction of their labor cost from financial markets. Consequently, interest expenses become part of the firms' total cost and interest-rate shocks add a substitution effect that is not present in the canonical model. The added substitution effect could capture the reasons

why world financial conditions affect domestic macroeconomic aggregates.

This paper has revised the relative importance of the working-capital constraint and the statistical properties of financial shocks to induce business cycles and found out the following. First, only when the mean value of the world interest rate is high, interest-rate swings have the potential to affect macroeconomic conditions in the standard small-open-economy model. However, interest-rate shocks cannot be the sole driving force of business cycles. Second, when the canonical model is perturbed with productivity and interest-rate shocks, the marginal impact of interest-rate shocks on business cycles relies more on the negative contemporaneous correlation between the shocks than on the working-capital constraint. Third, by comparing the interest-payment timing in earlier open-economy business-cycle research with the timing in more recent theoretical developments, it can be seen that the interest rate becomes a more powerful driving force of the model when households know the interest rate at the borrowing time than when they do not know that rate until maturity. The timing of interest payments becomes more critical when the autocorrelation of financial shocks is low than when it is high.

The paper has also documented the difficulties arising when the open-economy version of the neoclassical growth model is solved using a local log-linearization technique instead of a global non-linear technique. The log-linear solution to the model exaggerates the volatility of macroeconomic aggregates by around 10%. Furthermore, it has been shown that the artificial economy spends most of its time (around 70%) in points of the state space that are (more than 10%) distant from the stationary point around which the model is log-linearized.

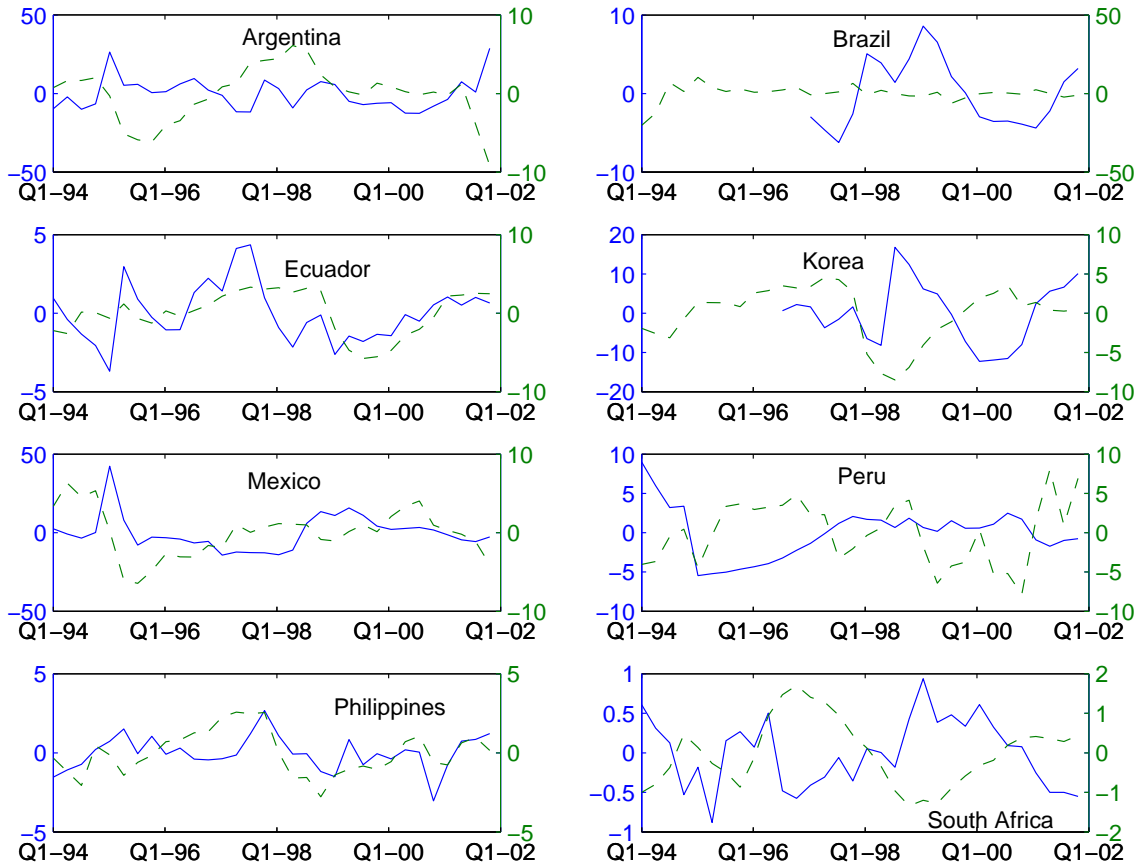
When financial intermediation is introduced in the canonical model, banks mitigate the effect of world liquidity shocks because the shocks only affect the financial cost of lending but not the real cost of intermediation. It has been shown that a model with financial intermediation can generate counter-cyclical spreads only when the economy is subject to productivity shocks but not when it is also affected by interest-rate shocks.

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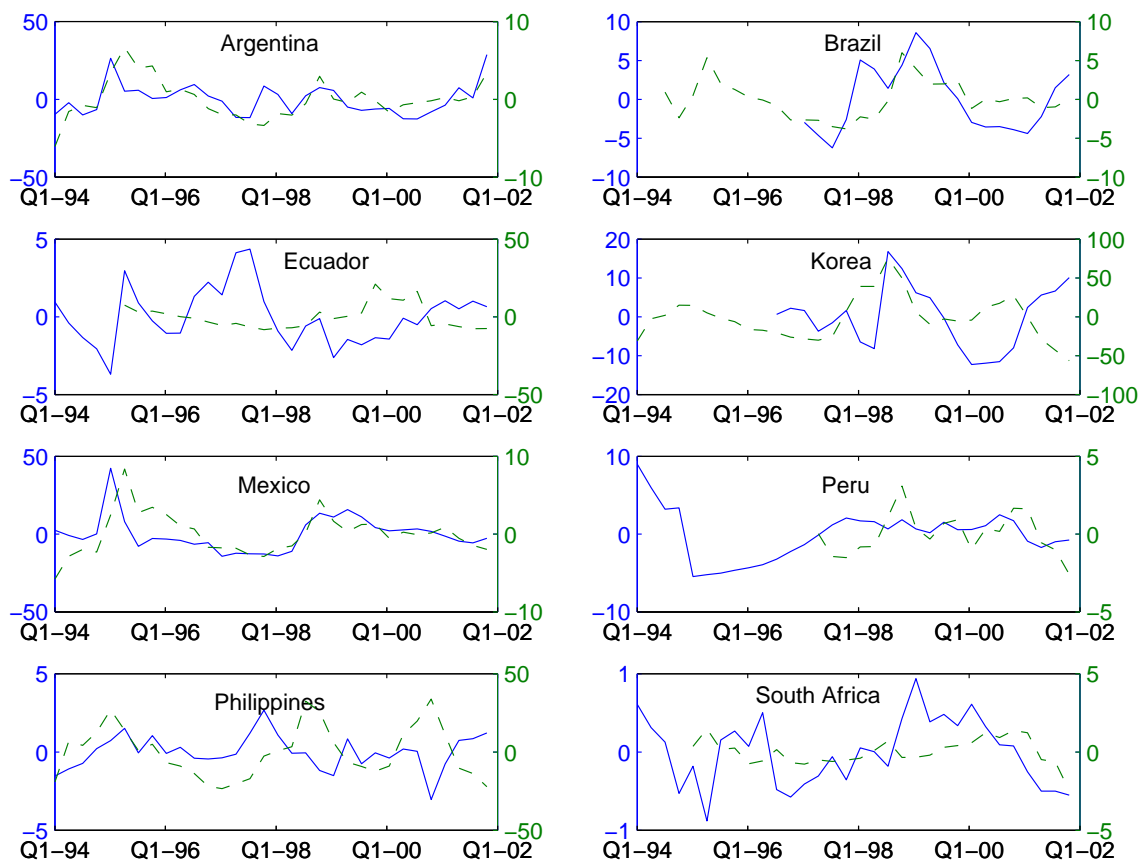
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Figure 1: Borrowing-Lending Spreads and Output in Emerging Market Countries



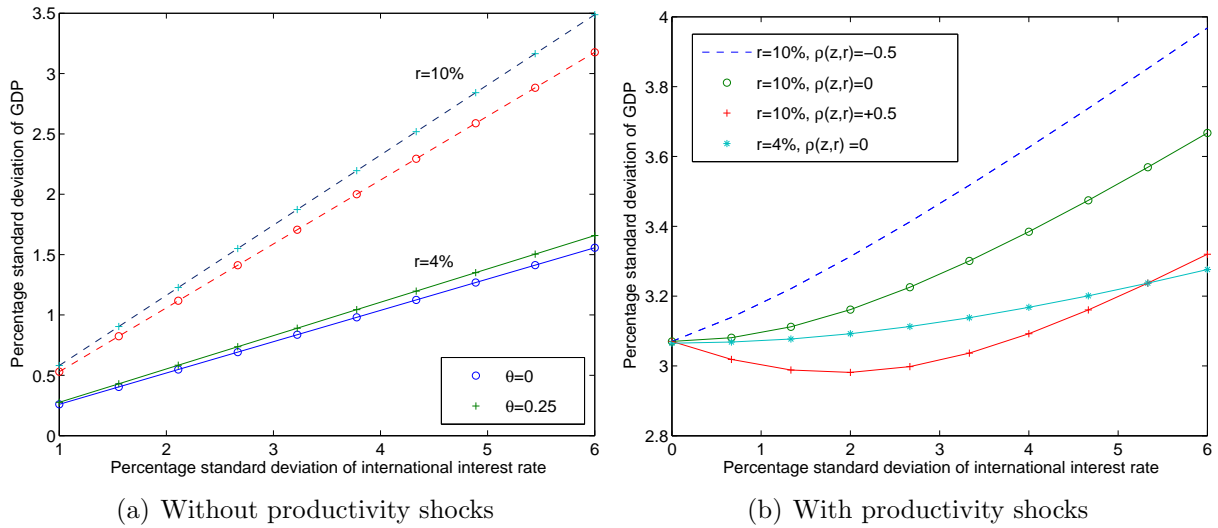
Notes: Time series in the figure are percentage deviations from Hodrick-Prescott filtered data. Country interest rates (dashed lines) are measured on the right-hand-side y-axes and interest-rate spreads (solid lines) are measured on the left-hand-side y-axes. Data sources: GDP series are from Uribe and Yue (2004). Interest-rate spreads are equal to the ratio between the lending and borrowing rates reported in the International Financial Statistics of the International Monetary Fund. The correlation coefficients between the two series are the following: Argentina: -0.43; Brazil: -0.33; Ecuador: 0.47; Korea: -0.39; Mexico: 0.08; Peru: -0.44; Philippines: 0.39; South Africa: -0.64.

Figure 2: Country Interest Rates and Borrowing-Lending Spreads in Emerging Countries



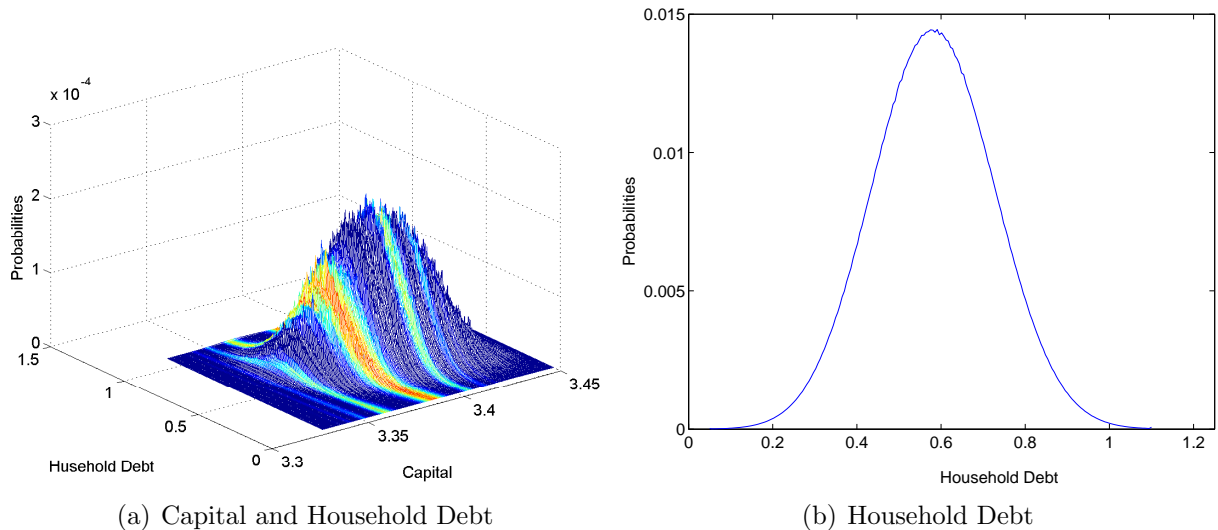
Notes: Time series in the figure are percentage deviations from Hodrick-Prescott filtered data. Country interest rates (dashed lines) are measured on the right-hand-side y-axes and interest-rate spreads (solid lines) are measured on the left-hand-side y-axes. Data sources: interest rates for all countries except for Philippines are from Uribe and Yue (2004); Philippines interest-rate is from Neumeyer and Perri (2004). The interest-rate spread is equal to the ratio between the lending and borrowing rates as reported in the International Financial Statistics of the International Monetary Fund. The correlation coefficient between country interest rates and the lending-borrowing spread are the following: Argentina: 0.54; Brazil: 0.55; Ecuador: -0.28; Korea: -0.02; Mexico: 0.44; Peru: 0.22; Philippines: -0.23; South Africa: 0.16.

Figure 3: Working Capital Constraint as a Business-Cycles Amplification Mechanism without Banks



Notes: Both panels show the effect of raising the percentage standard deviation (volatility) of the international interest-rate on the percentage standard deviation of GDP when banks are assumed away. The autocorrelation coefficient of interest-rate shocks  $\rho^r$  is equal to 0.8. In panel (a), innovations to the productivity shock were set equal to zero (i.e.  $\sigma(z)=0$ ); solid lines show the result of simulations when  $r = 4\%$  and dashed lines the result of simulations when  $r = 10\%$ . When  $\theta = 0$  the working-capital constraint is set off and when  $\theta = 0.25$ , one fourth of the annual labor cost is paid in advance. In panel (b),  $\rho^r = 0.8$  and, except for the starred line where  $r = 4\%$ , all other lines correspond to  $r = 10\%$ ; the volatility of the innovations to productivity shocks is equal to 1.29% as in the baseline calibration;  $\rho(z, r)$  refers to the contemporaneous correlation between the productivity and the interest rate shocks.

Figure 4: Marginal Ergodic Distributions of Capital and Household Debt



Notes: Figure 1.a shows the ergodic distribution of the endogenous state variables of the model and Figure 1.b shows the marginal ergodic distribution of household debt when the canonical model is solved setting  $r = 10\%$  and  $\sigma(r) = 3\%$ . For all other parameter values, see Table 1.

Table 1: Parameter Values and Implied Steady-State Macroeconomic Aggregates Across Different Parameterizations of the Model

		Common to all parameterizations									
		$\alpha$	$\delta$	$\omega$	$\sigma$	$\psi$					
		0.32	0.10	1.455	2.00	0.11					
		Specific parameter values and macroeconomic ratios									
		$\iota$	$\theta$	$r$	$h$	$k$	$\frac{c}{GDP}$	$\frac{x}{GDP}$	$\frac{\ell^y}{GDP}$	$\frac{\ell^h}{GDP}$	$\frac{\ell}{GDP}$
Baseline Calibration (subsection 3.1)											
	-Low $r$	1.00	0.00	<b>4.00%</b>	1.01	3.40	0.75	0.23	0.00	0.40	0.40
	-High $r$	2.09	0.00	<b>10.0%</b>	0.70	1.39	0.80	0.16	0.00	0.40	0.40
Working Capital (subsection 3.2)											
	-Low $r$	1.01	<b>0.25</b>	<b>4.00%</b>	0.98	3.32	0.75	0.23	0.17	0.40	0.56
	-High $r$	2.11	<b>0.25</b>	<b>10.0%</b>	0.66	1.31	0.78	0.16	0.16	0.40	0.40
Timing of Interest payments (subsection 3.4)											
	-UIPM	2.11	<b>0.25</b>	<b>10.0%</b>	0.66	1.31	0.78	0.16	0.16	0.40	0.40
	-KIPM	2.11	<b>0.25</b>	<b>10.0%</b>	0.66	1.31	0.78	0.16	0.16	0.40	0.40
	-KIPA	2.11	<b>0.25</b>	<b>9.09%</b>	0.66	1.32	0.78	0.16	0.17	0.43	0.59
Financial Intermediation (subsection 3.5)											
		2.35	<b>0.25</b>	<b>4.00%</b>	0.62	1.14	0.79	0.15	0.16	0.43	0.59

Notes: The nomenclature used in the table follows:  $\alpha$ : capital share in output;  $\delta$ : depreciation rate;  $\omega$ : labor elasticity parameter;  $\sigma$ : inverse of intertemporal elasticity of substitution;  $\psi$  and  $\iota$ : discount-factor parameters;  $\theta$ : fraction of annual labor cost paid in advance;  $r$ : international interest rate;  $k$ : stock of capital;  $c$ : consumption;  $l^y$ : stock of working-capital loans;  $l^h$ : stock of household loans;  $l$ : stock of total loans; UIPM: household interest-payment timing in which the interest rate is unknown at the borrowing time and interest is payed at maturity; KIPM: known interest rate and interest payed at maturity; KIPA known interest rate and interest paid in advance. References to subsections in the table indicate the section of the paper where the corresponding parameterization has been used.

Table 2: Business-Cycles Statistics: Basic Neoclassical Model with Productivity and Interest-Rate Shocks in the Absence of Banks and Working Capital

Variable $x$	(a)			(b)			(c)		
	Benchmark Calibration $\sigma(z) = 1.42$ ; $\sigma(r) = 0$ $\rho^z = 0.42$			$\sigma(z) = 0$ ; $\sigma(r) =$ $=1.42\%$ $=14.2\%$ $=1.42\%$ $\rho^r = 0.42$ $\rho^r = 0.9$			$r = 10\%$ $\sigma(z) = 0$ ; $\sigma(r) = 5.79\%$ $\rho^r = 0.8$		
	$\sigma(x)$	$\rho_{x',x}$	$\rho_{x,GDP}$	$\sigma(x)$	$\sigma(x)$	$\sigma(x)$	$\sigma(x)$	$\rho_{x',x}$	$\rho_{x,GDP}$
<i>Intl. int. rate</i>	0.000	0.420	0.310	1.421	14.21	2.959	5.792	0.800	-0.788
GDP	3.066	0.612	1.000	0.123	1.232	0.990	3.066	0.883	1.000
Consumption	2.335	0.938	0.699	0.084	0.839	0.714	2.074	0.913	0.983
Investment	9.100	0.070	0.658	1.385	13.85	4.496	23.92	0.189	-0.035
Savings	6.287	0.625	0.918	0.251	2.508	1.943	7.343	0.835	0.978
Capital	1.347	0.752	0.591	0.205	1.665	1.648	5.104	0.883	1.000
Hours	2.107	0.612	1.000	0.085	0.687	0.680	2.107	0.883	1.000
TB/GDP	1.546	0.331	-0.005	0.340	2.764	1.090	4.258	0.172	0.338
$\rho_{S,I}$		0.67		-0.32	-0.32	0.090		-0.017	

Notes:  $\sigma(x)$  states for the percentage standard deviation of  $x$ ,  $\rho_{x',x}$  for the first autocorrelation coefficient and  $\rho_{x,y}$  for the contemporaneous correlation coefficient between  $x$  and  $y$ .  $z$  = productivity shock;  $r$  = international interest rate. The baseline calibration to obtain results in (a) is taken from Mendoza (1991) and business cycles are only driven by productivity shocks. In panels (b) and (c) only interest-rate shocks drive business cycles.

Table 3: Working Capital Constraint and Interest-Rate Shocks

Variable $x$	(a)			(b)								
	No Working Capital: $\theta = 0$ $r = 10\%$ ; $\rho^r = 0.8$ $\sigma(r) = 3\%$ ; $\sigma(z) = 1.42\%$			Active Working Capital Constraint $r = 10\%$ ; $\rho^r = 0.8$ ; $\sigma(r) = 3\%$ ; $\sigma(z) = 1.42\%$								
	$\sigma(x)$	$\rho_{x',x}$	$\rho_{x,GDP}$	$\theta = 0.25$ $\rho_{r,z}=0$	$\theta = 0.50$ $\rho_{r,z}=0$	$\theta = 0.25$ $\rho_{r,z}=-0.5$	$\theta = 0$ $\rho_{r,z}=-0.5$	$\sigma(x)$	$\rho_{x,GDP}$	$\sigma(x)$	$\rho_{x,GDP}$	$\sigma(x)$
<i>Intl. int. rate</i>	3.000	0.80	-0.284	3.000	-0.317	3.000	-0.347	3.000	-0.743	3.000		3.000
GDP	3.219	0.633	1.000	3.262	1.000	3.307	1.000	3.465	1.000	3.374		
Consumption	3.199	0.935	0.741	3.299	0.735	3.409	0.728	3.577	0.791	3.379		
Investment	9.554	0.319	0.513	9.631	0.512	9.814	0.511	10.28	0.693	10.01		
Savings	10.85	0.820	0.610	10.21	0.615	9.722	0.618	9.751	0.589	10.12		
Capital	2.352	0.914	0.577	2.433	0.592	2.511	0.608	2.687	0.650	2.591		
Hours	2.212	0.633	1.000	2.262	1.000	2.317	0.999	2.428	1.000	2.319		
TB/GDP	2.165	0.786	0.189	2.212	0.174	2.263	0.158	1.955	-0.046	1.853		
$\rho_{S,I}$	0.336			0.327		0.320		0.484		0.496		

Notes:  $\sigma(x)$  states for the percentage standard deviation of  $x$ ,  $\rho_{x',x}$  for the first autocorrelation coefficient and  $\rho_{x,y}$  for the contemporaneous correlation coefficient between  $x$  and  $y$ .  $z =$  productivity shock;  $r =$  international interest rate.

Table 4: Basic Neoclassical Model: Business Cycles Discrepancies Due to Log-Linear Approximations

Variable $x$	(a)				(b)				(c)	
	Benchmark Calibration Solution Method: Log-Linearization $\sigma(\zeta^z) = 1.29$ ; $\rho^z = 0.42$ $\sigma(r) = 0$				Benchmark Calibration Solution Method: Parameterized Expectations $\sigma(\zeta^z) = 1.29$ ; $\rho^z = 0.42$ $\sigma(\zeta^r) = 0$					Compari- son of Volatilities (a) / (b) (%)
	$E[x]$	$\sigma(x)$	$\rho_{x',x}$	$\rho_{x,GDP}$	$E[x]$	$\sigma(x)$	$\rho_{x',x}$	$\rho_{x,GDP}$		
<i>Intl. int. rate</i>	0.040	0.000	0.420	0.310	0.040	0.000	0.420	0.310	-	
GDP	1.486	3.066	0.612	1.000	1.487	2.782	0.612	1.000	11.88	
Consumption	1.123	2.335	0.938	0.699	1.123	2.133	0.961	0.933	9.47	
Investment	0.340	9.100	0.658	0.070	0.340	8.259	0.335	0.070	10.18	
Savings	0.363	6.287	0.625	0.918	0.364	5.734	0.616	0.911	9.64	
Capital	3.398	1.347	0.752	0.591	3.398	1.223	0.752	0.590	10.14	
Hours	1.007	2.107	0.612	1.000	1.007	1.912	0.612	1.000	10.20	
TB/GDP	0.016	1.546	0.331	-0.005	0.016	1.414	0.339	-0.006	9.34	
$\rho_{S,I}$	0.67				0.67					

Notes:  $\sigma(x)$  states for the percentage standard deviation of  $x$ ,  $\rho_{x',x}$  for the first autocorrelation coefficient and  $\rho_{x,y}$  for the contemporaneous correlation coefficient between  $x$  and  $y$ .  $z =$  productivity shock;  $r =$  international interest rate. The baseline calibration follows Mendoza (1991).

Table 5: Interest-Payment Timing and the Information Set of the Household

Variable $x$	Interest Payment Timing and the Information Set of the Household					
	UIPM		KIPM		KIPA	
	$\sigma(x)$	$\rho_{x,GDP}$	$\sigma(x)$	$\rho_{x,GDP}$	$\sigma(x)$	$\rho_{x,GDP}$
GDP	3.001 (2.771)	1.000 (1.000)	3.148 (2.918)	1.000 (1.000)	3.221 (2.949)	1.000 (1.000)
Consumption	3.042 (2.923)	0.732 (0.706)	3.096 (2.970)	0.743 (0.721)	3.133 (2.975)	0.746 (0.724)
Investment	8.903 (8.223)	0.496 (0.587)	10.22 (12.45)	0.436 (0.338)	10.85 (13.24)	0.411 (0.304)
Savings	9.544 (9.247)	0.609 (0.578)	9.803 (9.461)	0.636 (0.608)	10.08 (9.600)	0.643 (0.613)
Capital	2.350 (1.315)	0.604 (0.555)	2.816 (1.989)	0.647 (0.584)	3.041 (2.118)	0.665 (0.593)
Hours	2.084 (1.911)	0.998 (0.999)	2.188 (2.016)	0.998 (0.999)	2.237 (2.037)	0.999 (0.999)
TB/GDP	2.078 (1.880)	0.183 (0.120)	2.274 (2.516)	0.200 (0.161)	2.383 (2.644)	0.208 (0.171)
$\rho_{S,I}$	0.304 (0.396)		0.256 (0.202)		0.234 (0.175)	

Notes: UIPM: specification of the model in which the interest rate is unknown at the borrowing time and interest is paid at maturity; KIPM: known interest rate and interest paid at maturity; KIPA: known interest rate and interest paid in advance.  $\sigma(x)$  states for the percentage deviation of  $x$  and  $\rho_{x,y}$  for the contemporaneous correlation between  $x$  and  $y$ . Figures between parenthesis are obtained setting  $\rho^r = 0.42$  and all other results are derived setting  $\rho^r = 0.8$ . The mean value of  $r$  is equal to 10% and  $\sigma(r) = 3\%$ .

Table 6: Financial Intermediation and Components of the Domestic Spread

Variable $x$	(a)		(b)		(c)		(d)	
	Productivity Shocks				Productivity and Interest-Rate Shocks			
	$\eta_2^\ell = 0$		$\eta_2^\ell = 0.135$		$\eta_2^\ell = 0$		$\eta_2^\ell = 0.135$	
	$\sigma(x)$	$\rho_{x,GDP}$	$\sigma(x)$	$\rho_{x,GDP}$	$\sigma(x)$	$\rho_{x,GDP}$	$\sigma(x)$	$\rho_{x,GDP}$
GDP	2.800	1.000	2.852	1.000	2.873	1.000	2.904	1.000
Internac. int. rate	0.000	-	0.000	-	3.000	-0.221	3.000	-0.196
Domestic int. rate	0.000	-	0.496	-0.175	1.212	-0.223	1.213	-0.252
Spread	0.000	-	0.497	-0.174	1.790	0.217	1.958	0.144
Consumption	3.133	0.671	2.877	0.661	3.156	0.680	2.897	0.843
Investment	8.310	0.660	8.135	0.585	8.536	0.585	8.280	0.626
Savings	10.20	0.529	7.289	0.525	10.23	0.543	7.382	0.623
Capital	1.268	0.599	1.527	0.594	1.761	0.575	1.869	0.586
Hours	1.925	1.000	1.962	1.000	1.981	0.998	2.002	0.999
TB/GDP	1.950	0.073	1.329	-0.065	2.047	0.121	1.453	0.010
$\rho_{S,I}$	0.436		0.564		0.371		0.479	
$\rho_{r,spread}$	-		-0.149		-1.000		-0.968	
$\rho_{r^\ell,spread}$	-		0.991		-1.000		-0.783	
$\rho_{r,r^\ell}$	-		-0.089		1.000		0.911	

Notes:  $\sigma(x)$  states for the percentage deviation of  $x$  and  $\rho_{x,y}$  for the contemporaneous correlation between  $x$  and  $y$ . The level of the international (domestic) interest rate is equal to 4% (10%). The autocorrelation of interest-rate shocks  $\rho^r = 0.8$ , the autocorrelation of productivity shocks is  $\rho^z = 0.42$ , and  $\sigma(r) = 3\%$ . The reserve-requirement coefficient  $\tau = 0.01$ . the non-financial cost of borrowing per unit of value  $\eta^b = 0.010$ ; the cost of lending a unit of value in the absence of spillovers  $\eta_1^\ell = 0.049$ ; and the size of the external effect in lending,  $\eta_2^\ell$ , is equal to 0 and (columns (a) and (c)) and is equal to 0.135 (columns (b) and (d)).