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Sudden Floods, Macroprudential Regulation and Stability in an Open Economy

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Abstract

A dynamic stochastic model of a small open economy with a two-level banking intermediation structure, a risk-sensitive regulatory capital regime, and imperfect capital mobility is developed. Firms borrow from a domestic bank and the bank borrows on world capital markets, in both cases subject to a premium. A sudden flood in capital flows generates an expansion in credit and activity, as well as asset price pressures. Countercyclical capital regulation, in the form of a Basel III-type rule based on credit gaps, is effective at promoting macro stability (defined in terms of the volatility of a weighted average of inflation and the output gap) and financial stability (defined in terms of three measures based on asset prices, the credit-to-GDP ratio, and the ratio of bank foreign borrowing to GDP). However, because the gain in terms of reduced economic volatility exhibit diminishing returns, in practice a countercyclical regulatory capital rule may need to be supplemented by other, more targeted macroprudential instruments when shocks are large and persistent.

JEL Classification Numbers: E44, E51, F41.

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1 Introduction

The experience of the past two decades, including most recently the global financial turmoil triggered by the collapse of the subprime mortgage market in the United States, has made painfully clear that abrupt reversals in short-term capital movements tend to exacerbate financial volatility and may lead to full-blown crises. Although misaligned domestic fundamentals (in the form of either overvalued exchange rates, excessive short-term foreign borrowing, or growing fiscal and current account imbalances) usually play an important role in financial crises, they have called attention to the inherent instability of international financial markets and the risks that cross-border financial transactions—facilitated by dramatic technological advances—can pose for countries with relatively fragile financial systems, weak regulatory and supervision structures, and policy regimes that lack flexibility.[1]

In this vein, the post-crisis global excess liquidity and large interest rate differentials caused by the expansionary monetary policies of reserve currency-issuing countries has brought to policymakers in many middle-income countries—as well as in small industrial countries like Australia, Sweden, and Switzerland—the challenge of managing large amounts of capital inflows while preserving an independent monetary policy to keep macroeconomic and financial stability at home. Indeed, between early 2009 and mid 2011 "sudden floods" of private capital to Latin America led to rapid credit growth and monetary expansion (due to the difficulty and cost of pursuing sterilization policies), an expansion in economic activity, real exchange rate appreciation and widening current account deficits, and pressures on asset prices.[2] In turn, these pressures raised concerns about asset price bubbles and financial fragility in many countries of the region.[3] The scope for responding to the risk of macroeconomic and financial instability through monetary policy proved limited, because higher domestic interest rates vis-à-vis zero interest floors prevailing in advanced economies would have exacerbated capital inflows. Other measures (such as direct taxes on fixed income and equity inflows, and foreign exchange market intervention) had some success but created other challenges related to the reaction of long-term investors vis-à-vis the overall policy stance.

A key issue therefore is, and continues to be, to identify short-term policy responses

[1] See Agénor (2012) for an overview of the evidence. Terms-of-trade fluctuations can generate sizable output and employment effects, which may increase exchange rate volatility and exacerbate movements in short-term capital flows.

[2] Episodes of large capital inflows in Latin America and elsewhere have not been systematically associated with upfront increases in inflation. A key reason is that in many cases the deflationary effect of the exchange rate appreciation associated with these inflows (especially when a large proportion of intermediate goods is imported) has been very pronounced. As discussed later, in our model this is an important aspect of the transmission channel of external shocks.

[3] Under a flexible exchange rate, growing external deficits tend to bring about a currency depreciation, which may eventually lead to a realignment of relative prices and induce self-correcting movements in trade flows. However, sharp swings in capital flows make it more difficult for the central bank to strike a balance between its different objectives; in turn, this may lead to exchange rate volatility.

that can help to mitigate the impact of external financial shocks, in an environment where the use of short-term policy rates has to balance internal and external stability objectives. This paper focuses on the role of macroprudential regulation in mitigating the macroeconomic and financial instability that may be associated with sudden floods in private capital, in particular foreign bank borrowing. We do so not because of the size of bank-related capital flows—even though these flows have accounted at times for a highly significant share of cross-border capital movements.[4] Rather, it is because our goal is to highlight the role of banks in transmitting external shocks and the risk that capital flows, intermediated directly through the banking system, may lead to the formation of credit-fueled bubbles and foster financial instability. To conduct our analysis, we dwell on the closed-economy model with credit market imperfections described in Agénor et al. (2013). A key feature of that model is a direct link between house prices and credit growth, via the impact of housing wealth on collateral and interest rate spreads. We extend it in several directions. First, we consider an open economy where capital is imperfectly mobile internationally—an assumption that accords well with the evidence for developing countries (see Agénor and Montiel (2015)). Domestic private borrowers face an upward-sloping supply curve of funds on world capital markets, and internalize the effect of capital market imperfections in making their portfolio decisions. Thus, unlike New Keynesian models of the type developed by Kollman (2001), Caputo et al. (2006), Adolfson et al. (2008, 2014), and others, the external risk premium depends on the *individual's* borrowing needs, not the economy's overall level of debt.[5] As a result of these imperfections, the domestic bond rate continues to be determined by the equilibrium condition of the money market, instead of foreign interest rates (as implied by uncovered interest rate parity under perfect capital mobility). Second, we consider a managed float and imperfect pass-through of nominal exchange rate changes to domestic prices. Both features are well supported by the evidence.

Third, banks borrow on world capital markets, and their borrowing decisions affect the terms at which they obtain funds. At the same time, domestic agents borrow only from domestic banks. These assumptions are in contrast to many contributions in the existing literature, where it is usually assumed that firms (or their owners, households) borrow directly on world capital markets subject to a binding constraint determined by their net worth.[6] Most importantly, in our setting a sudden drop in the world risk-free interest rate induces banks to borrow more in foreign currency. This reduces their domestic borrowing from the central bank. Nevertheless, the inflow of foreign exchange

[4] According to data by the Institute of International Finance for instance, in 2011 net inflows of private capital associated with commercial banks accounted for almost 26 percent of total net private inflows to Emerging Asia.

[5] The reason why the premium on foreign bond holdings is assumed to depend on the domestic households' (or the economy's) aggregate net foreign asset position is to ensure a well-defined steady-state. Alternatively, Kollintzas and Vassilatos (2000) and others introduce transactions costs in the foreign sector, but they are also treated as given in the optimization process.

[6] See for instance Céspedes et al. (2003, 2004), Cook (2004), Choi and Cook (2004), Elekdag et al. (2006, 2007), Guajardo (2008), and Leblebicioglu (2009).

is such that the monetary base expands, and this requires a lower bond rate to maintain equilibrium in the money market. The drop in the bond rate raises real estate prices, which increases the value of collateral that firms can pledge. Higher collateral values, in turn, are accompanied with a fall in the loan rate, thereby stimulating investment. Large inflows of private capital may therefore generate an economic boom that is magnified by a financial accelerator effect, through their impact on collateral values, banks' balance sheets, and loan pricing decisions.[7]

Fourth, as noted earlier, we consider the role of bank regulation as a policy to mitigate the adverse effects of sudden floods. In the model, countercyclical capital regulation takes the form of a Basel III-type rule, similar to the rule specified in Agénor et al. (2013). It has been argued that by raising capital requirements in a countercyclical way regulators could help to choke off asset price bubbles—such as the one that developed in the US housing market—before vulnerabilities take hold and a crisis is triggered. We apply this idea to external financial shocks. In a way, countercyclical regulation aims to internalize potential trade-offs between the objectives of macroeconomic stability and financial stability. To measure financial stability we consider three alternative measures, based on the volatility of asset prices (house prices and the nominal exchange rate), domestic credit, and bank foreign borrowing.

The remainder of the paper is organized as follows. Section 2 describes the model. The presentation of its closed-economy ingredients is kept as brief as possible, given that they are described at length in Agénor et al. (2012, 2013). Instead, we focus on how the model presented here departs from those papers, especially with respect to the financial sector and the countercyclical regulatory rule. In addition, in order to focus on the issue at hand, we make three strategic modeling choices—we adopt reduced-form specifications with respect to the probability of repayment and the exchange rate pass-through effect, and we abstract from the (empirically important) fact that a fraction of consumers are liquidity constrained.[8] The equilibrium is characterized in Section 3 and some key features of the steady state are discussed in Section 4. An illustrative calibration is presented in Section 5. The results of our base experiment, a temporary drop in the world (risk-free) interest rate, which translates into a sudden flood of private capital, are described in Section 6. Sensitivity tests, involving alternative assumptions about the degree of exchange-rate pass-through, the nature of the reserve accumulation rule, and the response of monetary policy to exchange rate movements, are reported in Section 7. Optimal regulatory policy is discussed in Section 8. The last section offers concluding remarks and discusses some potentially fruitful directions for future investigation.

[7]Note that, in practice, nonbank firms have also benefited extensively from global excess liquidity conditions, which pose other complex problems of financial disintermediation, supervision, balance sheet imbalances and risks to financial instability. These issues are not considered in our paper but nevertheless create critical challenges to policymakers.

[8]As noted later, accounting for the last feature would simply strengthen our main results.

2 The Economy

We consider a small open economy populated by six categories of agents: a representative household, intermediate goods-producing (IG) firms, a homogeneous final good (FG) producer, a capital good (CG) producer, a financial intermediary (a bank, for short), the government, and the central bank, which also regulates the bank.[9] The country produces a continuum of intermediate goods, which are imperfect substitutes to a continuum of imported intermediate goods. In line with the McCallum-Nelson approach, imports are not treated as finished consumer goods but rather as intermediate goods, which are used (together with domestic intermediate goods) in the production of the domestic final good. This approach is quite relevant for many middle-income countries.[10] The final good is consumed by the household and the government, used for investment (subject to additional costs) by the CG producer, or exported. There is monopolistic competition in intermediate goods markets; each domestic intermediate good is produced by a single firm.

The household owns all domestic firms. It supplies labor, consumes, and holds domestic and foreign financial assets. It deposits funds in the bank at the beginning of the period and collects them (with interest) at the end of the period, after the goods market closes. It makes its housing stock available, without any direct charge, to the CG producer, which uses it as collateral against which it borrows from the bank to buy the final good for investment purposes, produce capital, and then rent it to IG producers. IG firms use labor and capital as production inputs, and adjust prices toward equilibrium markups over marginal costs of production.

The bank supplies credit to IG producers as well, who use it to finance their labor costs prior to the sale of output. The maturity period of both categories of bank loans and the maturity period of bank deposits is the same. In each period, loans are extended prior to activity (production or investment) and paid off at the end of the period. Its supply of loans is perfectly elastic at the prevailing lending rate. To satisfy capital regulations, it issues domestic nominal debt, in line with the level of (risky) loans in its portfolio.[11] It also borrows on world capital markets and from the central

[9] The assumption of a single financial intermediary is made essentially to simplify notations. Our results would remain essentially the same if we were to assume instead monopolistic competition among a multitude of banks, and that in a symmetric equilibrium all banks behave identically.

[10] In Brazil for instance, the average share of intermediate goods (including oil) in total imports amounted to 64 percent during 2006-09; for Turkey, it exceeded 68 percent for the same period. As noted by McCallum and Nelson (2000), an advantage of this approach is that it avoids the assumption (implied by the tradable-nontradable dichotomy) that export and import goods are perfectly substitutable in production. However, here the relevant price index for produced goods is *not* the same as the consumer price index.

[11] This assumption is consistent with the evidence, which suggests that prior to the global financial crisis banks often met capital requirements by issuing "hybrid" securities that are more like debt than equity. In addition, even though the definition of capital was tightened under the new Basel III rules (only common stocks and retained earnings can count as Tier 1 capital, see Basel Committee on Banking Supervision (2011)), there has been a shift in recent years toward allowing banks to hold capital not only in the form of core (Tier 1) equity but also in the form of loss-absorbing debt, such

bank. At the end of each period, it repays with interest household deposits and the liquidity borrowed from the central bank, and redeems in full its domestic and foreign debt. All profits are then distributed, the bank is liquidated, and a new bank opens at the beginning of the next period.

The central bank supplies liquidity elastically to the commercial bank and alters its policy rate in response to changes in the output gap and inflation deviations from target, as well as deviations in the growth rate of an indicator of financial stability. It does not engage in sterilization activities but it accumulates foreign-currency reserves based on a rule that depends on the volume of imports and net foreign-currency liabilities of the private sector.[12] Finally, capital mobility is imperfect.

2.1 Households

The objective of the representative household is to maximize

$$U_t = \mathbb{E}_t \sum_{s=0}^{\infty} \beta^s \left\{ \frac{C_{t+s}^{1-\varsigma^{-1}}}{1-\varsigma^{-1}} + \eta_N \ln(1-N_{t+s}) + \eta_x \ln x_{t+s} + \eta_H \ln H_{t+s} \right\}, \tag{1}$$

where C_t is consumption, $N_t = \int_0^1 N_t^j dj$, the share of total time endowment (normalized to unity) spent working, with N_t^j denoting the number of hours of labor provided to the intermediate-good producing firm j, x_t a composite index of real monetary assets, H_t the stock of housing, $\beta \in (0,1)$ the subjective discount factor, $\varsigma > 0$ the intertemporal elasticity of substitution in consumption, $\mathbb{E}_t$ the expectation operator conditional on the information available at the beginning of period t, and $\eta_N, \eta_x, \eta_H > 0$. Housing services are taken to be proportional to their stock.

The composite monetary asset is generated by a geometric average of real cash balances, m_t^P, and real bank deposits, d_t, both at the beginning of period t:

$$x_t = (m_t^P)^{\nu} d_t^{1-\nu}, \tag{2}$$

where $\nu \in (0,1)$.

End-of-period nominal wealth, A_t, is defined as

$$A_t = M_t^P + D_t + P_t^H H_t + B_t^P + E_t B_t^{F,P} + V_t, \tag{3}$$

where, $M_t^P = P_t^S m_t^P$ is nominal cash holdings (with P_t^S denoting the price of final goods sold on the domestic market), $D_t = P_t^S d_t$ nominal bank deposits, P_t^H the price

as contingent convertible bonds, which convert into equity once a bank's capital ratio falls below a certain threshold.

[12] As documented by Aizenman and Glick (2009), even though the degree of sterilization (as measured by offset coefficients) has increased in recent years in many middle-income countries, it remains imperfect—especially in Latin America. Note also that in thin and imperfect financial markets, sterilized intervention often drives up interest rates on the securities used for intervention—and this often results in even greater capital inflows. The policy is therefore not sustainable, in addition to being costly.

of housing, V_t nominal holdings of bank debt, B_t^P ($E_t B_t^{F,P}$) nominal holdings of one-period, noncontingent domestic (foreign) government bonds, where E_t is the nominal exchange rate (expressed as the domestic-currency price of foreign currency) and $B_t^{F,P}$ the foreign-currency value of foreign assets. Domestic government bonds are held only at home.

The household enters period t with M_{t-1}^P holdings of cash balances. It also collects principal plus interest on bank deposits at the rate contracted in $t-1$, i_{t-1}^D, principal and interest payments on maturing domestic and foreign government bonds, at rates i_{t-1}^B and $i_{t-1}^{F,P}$ respectively, and principal and interest payments on bank debt, at rate i_{t-1}^V.

At the beginning of the period, the household chooses the levels of cash, deposits, bank debt, housing services, the amounts of domestic and foreign bonds, and labor supply to IG producers, for which it receives factor payments of $\omega_t N_t$, where $\omega_t = W_t/P_t^S$ is the economy-wide real wage (with W_t denoting the nominal wage), measured in terms of the price of final goods sold domestically. At the end of the period, it receives all the profits made by the IG firms, $J_t^I = \int_0^1 J_{jt}^I dj$, the CG producer, J_t^K, and the bank, J_t^B, which is (as noted earlier) liquidated at the end of the period.[13]

The household's end-of-period budget constraint is thus

$$\Delta M_t^P + D_t + (B_t^P + E_t B_t^{F,P}) + P_t^H \Delta H_t + V_t \tag{4}$$

$$= P_t^S(\omega_t N_t - T_t) - P_t^S C_t + (1 + i_{t-1}^D)D_{t-1} + (1 + i_{t-1}^B)B_{t-1}^P$$

$$+(1 + i_{t-1}^{F,P})E_t B_{t-1}^{F,P} + (1 + i_{t-1}^V)V_{t-1} + J_t^I + J_t^K + J_t^B - \Theta_V \frac{V_t^2}{2},$$

where T_t denotes the real value of lump-sum taxes and the last term represents transactions costs associated with changes in holdings of bank debt, with $\Theta_V > 0$ denoting an adjustment cost parameter.[14] For simplicity, we assume that housing does not depreciate.

The rate of return on foreign bonds is defined as

$$1 + i_t^{F,P} = (1 + i_t^W)(1 - \theta_t^{F,P}), \tag{5}$$

where i_t^W is the risk-free world interest rate and $\theta_t^{F,P}$ an endogenous spread, defined as

$$\theta_t^{F,P} = \frac{\theta_0^{F,P}}{2} B_t^{F,P}, \tag{6}$$

where $\theta_0^{F,P} > 0$. As discussed at length in Agénor (1997, 1998, 2006) this specification reflects the view that the household is able to lend (or borrow, with $B_t^{F,P} < 0$) more on world capital markets only at a lower (higher) rate of interest; the latter captures

[13] The FG firm makes zero profits.

[14] As in Markovic (2006) for instance, the adjustment cost is taken to be a deadweight loss for society.

the existence of *individual default risk*.[15] Our treatment differs substantially from the country risk specification often adopted in the open-economy New Keynesian literature; see, for instance, Benigno (2009), Lindé et al. (2009), and Adolfson et al. (2008, 2014). In our specification, as in Benigno's, the premium is symmetric; households receive a lower (pay a higher) rate on their international savings (foreign debt). However, with country risk, the spread depends (positively) on the country's net foreign debt, or (negatively) on the economy's net foreign assets, defined as $NFA_t = R_t^F + B_t^{F,P} - L_t^{F,B}$, where R_t^F denotes central bank reserves and $L_t^{F,B}$ bank borrowing. In our specification, $\theta_t^{F,P}$ depends only on individual (net) assets, $B_t^{F,P}$. Moreover, the representative household in our setting internalizes the effect of its borrowing decisions on the premium that it faces, rather than taking it as given as in models with country risk.

The risk-free world interest rate follows a first-order autoregressive process:

$$\ln i_t^W = \rho_W \ln i_{t-1}^W + \xi_t^W,$$

where $\rho_W \in (0,1)$ and $\xi_t^W \sim N(0, \sigma_{\xi W})$.

The household maximizes lifetime utility with respect to C_t, N_t, m_{t+1}^P, d_{t+1}, B_t^P, $B_t^{F,P}$, H_t, and V_t, taking as given period-$t-1$ variables as well as P_t^H, P_t, ω_t, domestic interest rates, i_t^W, profits, and T_t. Let $1+\pi_{t+1}^S = P_{t+1}^S/P_t^S$ and let λ_t denote the shadow price associated with constraint (4), that is, the marginal value of wealth. Maximizing (1) subject to (2)-(6) yields the following first-order conditions:

$$C_t^{-1/\varsigma} = \lambda_t, \tag{7}$$

$$N_t = 1 - \frac{\eta_N C_t^{1/\varsigma}}{\omega_t}, \tag{8}$$

$$m_t^P = \frac{\eta_x \nu C_t^{1/\varsigma}(1+i_t^B)}{i_t^B}, \tag{9}$$

$$d_t = \frac{\eta_x (1-\nu) C_t^{1/\varsigma}(1+i_t^B)}{i_t^B - i_t^D}, \tag{10}$$

$$\frac{\eta_H}{H_t} = \lambda_t (\frac{P_t^H}{P_t^S}) - \beta \mathbb{E}_t[\lambda_{t+1}(\frac{P_{t+1}^H}{P_{t+1}^S})], \tag{11}$$

$$-\lambda_t + \beta \mathbb{E}_t \left\{ \lambda_{t+1} (\frac{1+i_t^V}{1+\pi_{t+1}^S}) \right\} - \Theta_V \lambda_t \frac{V_t}{P_t^S} = 0, \tag{12}$$

$$-\lambda_t + \beta \mathbb{E}_t \left\{ \lambda_{t+1} (\frac{1+i_t^B}{1+\pi_{t+1}^S}) \right\} = 0, \tag{13}$$

[15] A more general specification would be to specify the risk premium as a convex curve, with a binding constraint when $B_t^{F,P}$ is sufficiently high. However, this does not make much difference here, given that the model is solved in its log-linearized form. Adolfson et al. (2008, 2014) introduce the expected change in the exchange rate in the specification of the premium, but this is largely arbitrary.

$$(1+i_t^B)=(1-\theta_0^{F,P}B_t^{F,P})(1+i_t^W)\mathbb{E}_t(\frac{E_{t+1}}{E_t}). \quad (14)$$

These conditions are familiar except for (11), (12), and (14). Equation (11), combined with (7) and (13), yields the demand for housing as

$$\frac{P_t^H H_t}{P_t^S}=\left\{1-\mathbb{E}_t(\frac{1+\pi_{t+1}^H}{1+i_t^B})\right\}^{-1}[\frac{\eta_H}{(C_t)^{-1/\varsigma}}], \quad (15)$$

where $1+\pi_{t+1}^H=P_{t+1}^H/P_t^H$.

Combining (12) and (13) yields

$$\frac{V_t^d}{P_t^S}=\Theta_V^{-1}(\frac{i_t^V-i_t^B}{1+i_t^B}), \quad (16)$$

which shows that the demand for bank debt depends positively on its rate of return and negatively on the domestic bond rate.

Equation (14) is an arbitrage condition, which equates the expected marginal rates of return on domestic and foreign assets under the assumption of imperfect world capital markets. It reflects the fact that the marginal rate of return on foreign bonds falls with a marginal increase in $B_t^{F,P}$, or equivalently that the marginal cost of borrowing abroad rises with a marginal increase in the amount borrowed. Condition (14) can therefore be rearranged to give holdings of foreign bonds as

$$B_t^{F,P}=\frac{(1+i_t^W)\mathbb{E}_t(E_{t+1}/E_t)-(1+i_t^B)}{\theta_0^{F,P}(1+i_t^W)\mathbb{E}_t(E_{t+1}/E_t)}, \quad (17)$$

which shows that the optimal level of household holdings of foreign bonds is a function of the difference between the world safe interest rate (adjusted for expected depreciation) and the domestic bond rate. Perfect capital mobility prevails when $\theta_0^{F,P}\to 0$, in which case $1+i_t^B=(1+i_t^W)\mathbb{E}_t(E_{t+1}/E_t)$, corresponding to the standard uncovered interest parity condition.

2.2 Domestic Final Good

The final-good producer imports a continuum of differentiated intermediate goods directly (without incurring distribution costs) from the rest of the world and combines them with a similar continuum of domestically-produced intermediate goods to generate a domestic final good, which is sold both domestically (for consumption and investment) and abroad. The good is produced in quantity Y_t using a CES technology:

$$Y_t=[\Lambda_D(Y_t^D)^{(\eta-1)/\eta}+(1-\Lambda_D)(Y_t^F)^{(\eta-1)/\eta}]^{\eta/(\eta-1)}, \quad (18)$$

where $\Lambda_D\in(0,1)$, Y_t^D (Y_t^F) a quantity index of domestic (imported) intermediate goods, and $\eta>0$ is the elasticity of substitution between baskets of domestic and imported composite intermediate goods. These baskets are defined as

$$Y_t^i=\left\{\int_0^1[Y_{jt}^i]^{(\theta_i-1)/\theta_i}dj\right\}^{\theta_i/(\theta_i-1)}, \quad i=D,F \quad (19)$$

where $\theta_i > 1$ is the elasticity of substitution between intermediate domestic goods among themselves ($i = D$), and imported goods among themselves ($i = F$), and Y^i_{jt} is the quantity of type-j intermediate good of category i (domestic or imported), for $j \in (0, 1)$.[16]

The FG producer sells its output at a perfectly competitive price. Let P^D_{jt} denote the price of domestic intermediate good j set by firm j, and P^F_{jt} the price of imported intermediate good j, in domestic currency. Cost minimization yields the demand functions for each variety of intermediate goods:

$$Y^i_{jt} = (\frac{P^i_{jt}}{P^i_t})^{-\theta_i} Y^i_t, \quad i = D, F \tag{20}$$

where P^D_t and P^F_t are price indices for domestic and imported intermediate goods, respectively:

$$P^i_t = \left\{ \int_0^1 (P^i_{jt})^{1-\theta_i} dj \right\}^{1/(1-\theta_i)}, \quad i = D, F \tag{21}$$

Aggregating across firms yields the allocation of total demand between domestic and foreign intermediate goods:[17]

$$Y^D_t = \Lambda^\eta_D (\frac{P^D_t}{P_t})^{-\eta} Y_t, \quad Y^F_t = (1 - \Lambda_D)^\eta (\frac{P^F_t}{P_t})^{-\eta} Y_t, \tag{22}$$

where P_t is the implicit final output deflator (or final producer price), given by

$$P_t = [\Lambda^\eta_D (P^D_t)^{1-\eta} + (1 - \Lambda_D)^\eta (P^F_t)^{1-\eta}]^{1/(1-\eta)}. \tag{23}$$

To allow for imperfect exchange rate pass-through of import prices, we assume local currency price stickiness. Specifically, the domestic-currency price of imports of intermediate good j is taken to be determined through a simple partial adjustment mechanism,

$$P^F_{jt} = (E_t WP^F_{jt})^{\mu^F} (P^F_{jt-1})^{1-\mu^F}, \tag{24}$$

where WP^F_{jt} is the foreign-currency price of good j and $\mu^F \in (0, 1)$ measures the speed of adjustment of the domestic-currency price of imports to its "normal" value, $E_t WP^F_{jt}$; there is complete pass-through (that is, producer currency pricing) if and only if $\mu^F = 1$.[18] For $\mu^F < 1$, in the short term the domestic-currency price of imports

[16] For simplicity, the number of both domestic and imported intermediate goods is normalized to unity.

[17] Combining equations (22) yields $Y^D_t / Y^F_t = [\Lambda_D / (1 - \Lambda_D)]^\eta (P^D_t / P^F_t)^{-\eta}$, which relates relative demands for intermediate goods to relative prices.

[18] Alternatively, to account for imperfect exchange rate pass-through, we could introduce a monopolistically competitive import goods sector and assume that domestic prices of imported intermediate goods are sticky à la Calvo-Rotemberg. See for instance Smets and Wouters (2002), Caputo et al. (2006), Adolfson et al. (2008, 2014), Senay (2008), Lindé et al. (2009), Pavasuthipaisit (2010), and Shi and Xu (2010). Given the focus of this study, the assumption that all importers follow a pure backward-looking pricing rule simplifies matters.

will reflect only partially current fluctuations of the nominal exchange rate, whereas in the long term complete pass-through will occur.

To model the allocation of production of the final good between sales on the domestic market, Y_t^S, and exports, Y_t^X, we assume that the volume sold abroad depends only on the domestic-currency price of exports of the final good, P_t^X, relative to the price of goods sold on the domestic market, P_t^S:[19]

$$Y_t^X = Y_0^X (\frac{P_t^X}{P_t^S})^{\varkappa}, \tag{25}$$

where $\varkappa > 1$ is the elasticity of transformation.

The domestic-currency price of exports is given by

$$P_t^X = E_t W P_t^X, \tag{26}$$

where WP_t^X is the world price. Thus, exports are priced in the importers' currency, in line with the evidence for many developing countries.

The volume of goods sold on the domestic market is given by

$$Y_t^S = Y_t - Y_t^X. \tag{27}$$

2.3 Domestic Intermediate Goods

Each IG producers $j \in (0, 1)$ combines labor and capital to produce a distinct, perishable good that is sold on a monopolistically competitive market:

$$Y_{jt}^D = N_{jt}^{1-\alpha} K_{jt}^{\alpha}, \tag{28}$$

where N_{jt} is the supply of labor by the representative household to firm j and $\alpha \in (0, 1)$.

At the beginning of the period, each IG producer rents capital from the CG producer, at the net rate r_t^K. Capital rent is paid at the end of the period; however, wages must be paid in advance. To do so firm j borrows the amount L_{jt}^W from the bank.[20] The amount borrowed is therefore such that

$$L_{jt}^W \geq P_t^S \omega_t N_{jt}. \tag{29}$$

Loans contracted for the purpose of financing working capital (which are short-term in nature) do not carry any risk, and are therefore made at a rate that reflects only the marginal cost of borrowing from the central bank, i_t^R, which we refer to as the refinance rate. Repayment of all loans occurs at the end of the period.

[19] Thus, exports are (indirectly) produced by using imported goods in addition to domestically-produced intermediate goods; see Christiano et al. (2011) for an alternative approach. Note also that we abstract from foreign activity as a potential determinant.

[20] Firms do not have direct access to credit from foreign lenders, they borrow only from the domestic bank. This assumption is consistent with the evidence, which shows that firms in developing countries (except for the very large ones) depend predominantly on domestic banks for most of their credit needs.

With (29) holding with equality, nominal production costs of firm j in period t, TC_{jt}, are given by

$$TC_{jt} = (1 + i_t^R) P_t^S \omega_t N_{jt} + P_t^S r_t^K K_{jt}.$$

IG producers are competitive in factor markets. In standard fashion, cost minimization yields the optimal capital-labor ratio as

$$\frac{K_{jt}}{N_{jt}} = (\frac{\alpha}{1-\alpha})[\frac{(1+i_t^R)\omega_t}{r_t^K}]. \quad \forall j \tag{30}$$

The unit real marginal cost is thus, $\forall j$,

$$mc_t = \frac{\left[(1+i_t^R)\omega_t\right]^{1-\alpha} (r_t^K)^{\alpha}}{\alpha^{\alpha}(1-\alpha)^{1-\alpha}}. \tag{31}$$

As in Rotemberg (1982), domestic IG producers incur a real cost in adjusting prices, of the form $(\phi_I/2)[P_{jt}^D/(\tilde{\pi}^{D,G} P_{jt-1}^D) - 1]^2 Y_t^D$, where $\phi_I \geq 0$ is the adjustment cost parameter (or, equivalently, the degree of price stickiness) and $\tilde{\pi}^{D,G} = 1 + \tilde{\pi}^D$ is the gross steady-state inflation rate in the price of domestic intermediate goods. Each firm j chooses a sequence of prices so as to maximize the discounted real value of all its current and future real profits:[21]

$$\{P_{jt+s}^D\}_{s=0}^{\infty} = \arg\max \mathbb{E}_t \sum_{s=0}^{\infty} \beta^s \lambda_{t+s} (\frac{J_{jt+s}^I}{P_{t+s}^D}), \tag{32}$$

where J_{jt+s}^I denotes nominal profits at t, defined as

$$J_{jt}^I = (P_{jt}^D - P_t^D mc_t) Y_{jt}^D - \frac{\phi_I}{2} (\frac{P_{jt}^D}{\tilde{\pi}^{D,G} P_{jt-1}^D} - 1)^2 P_t^D Y_t^D. \tag{33}$$

Taking $\{mc_{t+s}, P_{t+s}^D, Y_{t+s}^D\}_{s=0}^{\infty}$ as given, and using (20) with $i = D$, the first-order condition for this maximization problem is:

$$\begin{aligned} &(1-\theta_D)\lambda_t (\frac{P_{jt}^D}{P_t^D})^{-\theta_D} \frac{1}{P_t^D} + \theta_D \lambda_t (\frac{P_{jt}^D}{P_t^D})^{-\theta_D - 1} \frac{mc_t}{P_t^D} \\ &-\lambda_t \phi_I \left\{ (\frac{P_{jt}^D}{\tilde{\pi}^{D,G} P_{jt-1}^D} - 1) \frac{1}{\tilde{\pi}^{D,G} P_{jt-1}^D} \right\} \\ &+\beta \phi_I \mathbb{E}_t \left\{ \lambda_{t+1} (\frac{P_{jt+1}^D}{\tilde{\pi}^{D,G} P_{jt}^D} - 1)(\frac{P_{jt+1}^D}{\tilde{\pi}^{D,G} (P_{jt}^D)^2}) \frac{Y_{t+1}^D}{Y_t^D} \right\} = 0, \end{aligned} \tag{34}$$

which determines the adjustment process of the nominal price P_{jt}^D.

[21] In standard fashion, IG firms (which are owned by households) are assumed to value future profits according to the household's intertemporal marginal rate of substitution in consumption.

2.4 Production of Capital

At the beginning of the period, the CG producer buys a gross amount I_t of the final good from the FG producer and combines it with the existing capital stock to produce new capital goods. Aggregate capital accumulates therefore as follows:

$$K_{t+1} = I_t + (1-\delta)K_t - \frac{\Theta_K}{2}(\frac{K_{t+1}}{K_t} - 1)^2 K_t, \tag{35}$$

where $K_t = \int_0^1 K_{jt}dj$, $\delta \in (0,1)$ is a constant rate of depreciation, and $\Theta_K > 0$ is a parameter that measures the magnitude of adjustment costs.

Investment goods must be paid in advance; the CG producer must therefore borrow from the bank:

$$L_t^I = P_t^S I_t. \tag{36}$$

Repayment is uncertain and occurs with probability $q_t \in (0,1)$. If loans are repaid in full, the total (interest-inclusive) cost of buying final goods for investment purposes is $(1+i_t^L)P_t^S I_t$, where i_t^L is the lending rate. If there is default, which occurs with probability $1-q_t$, the CG producer loses the collateral that it pledges to secure the loan; collateral is given by $\kappa P_t^H \bar{H}$, where $\kappa \in (0,1)$ is defined as a share of the value of the housing stock, with $\bar{H}$ the exogenous stock of housing, which produces a proportional supply of services.[22] Thus, expected repayment (at the end of the period) is $q_t(1+i_t^L)P_t^S I_t + (1-q_t)\kappa P_t^H \bar{H}$.

At the beginning of each period, the existing capital stock is then rented to IG producers, at the rate r_t^K. Subject to (35), the CG producer chooses the level of the capital stock K_{t+1} (taking the rental rate, the lending rate, the price of the final good, and the existing capital stock, as given) so as to maximize the value of the discounted stream of dividend payments to the household:[23]

$$\{K_{t+s+1}\}_{s=0}^{\infty} = \arg\max \sum_{s=0}^{\infty} \mathbb{E}_t[\beta^s \lambda_{t+s}(\frac{J_{t+s+1}^K}{P_{t+s}^S})], \tag{37}$$

where $\mathbb{E}_t[\beta^s \lambda_{t+s}(J_{t+s+1}^K / P_{t+s}^S)]$ denotes expected real profits at the end of period $t+s$ (or beginning of period $t+s+1$), defined as

$$\mathbb{E}_t[\beta^s \lambda_{t+s}(\frac{J_{t+s+1}^K}{P_{t+s}^S})] = \beta^s \mathbb{E}_t \left\{ \lambda_{t+s} \left[r_{t+s}^K K_{t+s} - [q_{t+s}(1+i_{t+s}^L)I_{t+s} + (1-q_{t+s})\kappa(\frac{P_{t+s}^H}{P_{t+s}^S})\bar{H}] \right] \right\}.$$

[22] An alternative assumption, as in Agénor et al. (2013), would be to assume that in case of default the capital seized by the bank is returned immediately and in its entirety to the household, who turns it back instantly to the CG-producing firm. As a result, the CG producer would not internalize the risk of default, that is, the possibility that it could lose the fraction of the housing stock that it used to secure bank loans.

[23] Again, the CG producer is assumed to value future profits according to the household's intertemporal marginal rate of substitution in consumption.

Using (13), the first-order condition for maximization yields

$$\mathbb{E}_t r_{t+1}^K = q_t(1+i_t^L)\mathbb{E}_t\left\{\left[1+\Theta_K(\frac{K_{t+1}}{K_t}-1)\right](\frac{1+i_t^B}{1+\pi_{t+1}^S})\right\} \tag{38}$$

$$-\mathbb{E}_t\left\{q_{t+1}(1+i_{t+1}^L)\left\{1-\delta+\frac{\Theta_K}{2}\left[(\frac{K_{t+2}}{K_{t+1}})^2-1\right]\right\}\right\},$$

which shows that the repayment probability affects the expected rate of return to capital, through its effect on expected repayment in both period t and period $t+1$.[24]

2.5 Commercial Bank

At the beginning of each period t, the bank receives deposits D_t from the household. Funds are used for loans to the CG producer and domestic IG producers, which use them (as discussed earlier) to buy goods for investment purposes and pay for labor in advance. Thus, total lending, L_t, is equal to, using (29) and (36),

$$L_t = \int_0^1 L_{jt}^W dj + L_t^I = P_t^S \omega_t N_t + P_t^S I_t, \tag{39}$$

where $N_t = \int_0^1 N_{jt} dj$ is aggregate demand for labor by IG producers.

The maturity period of loans to IG firms coincides with the maturity period of household deposits. Upon receiving these deposits, and given its capital requirements (which determines how much debt it issues, V_t), total loans, L_t, and its foreign borrowing, $L_t^{F,B}$, the bank borrows from the central bank, $L_t^{C,B}$, to fund any shortfall. At the end of the period, it repays the central bank, at the interest rate, i_t^R. It also holds required reserves at the central bank, RR_t.[25]

The bank's balance sheet is thus

$$L_t + RR_t = D_t + E_t L_t^{F,B} + V_t + L_t^{C,B}, \tag{40}$$

where

$$V_t = V_t^R + V_t^E, \tag{41}$$

with V_t^R denoting capital requirements and V_t^E excess capital.

[24] The model is part of a class of models in which collateral constraints ensure that borrowers repay their debts and which rule out, by design, the possibility of firm default in equilibrium. Equivalently, given collateral requirements, shocks are never "bad enough" to induce the CG producer to actually default—even though *ex ante* both the CG producer and the bank factor it in choosing the optimal level of capital and in setting the loan rate, respectively. For an explicit analysis of the risk of default, in which idiosyncratic shocks affect productivity rather than the return on capital (as in Bernanke et al. (2000)), see Pesaran and Xu (2013).

[25] The bank holds no domestic bonds. As discussed in the next section, in equilibrium it has no incentive to do so.

Reserves held at the central bank do not pay interest. They are determined by:

$$RR_t = \mu^R D_t, \tag{42}$$

where $\mu^R \in (0,1)$ is the reserve requirement ratio.

Let $i_t^{F,B}$ denote the cost of foreign borrowing, defined as

$$1 + i_t^{F,B} = (1 + i_t^W)(1 + \theta_t^{F,B})\mathbb{E}_t(\frac{E_{t+1}}{E_t}), \tag{43}$$

where i_t^W is again the risk-free world interest rate and $\theta_t^{F,B}$ a risk premium, defined as

$$\theta_t^{F,B} = \frac{\theta_0^{F,B}}{2} L_t^{F,B}, \tag{44}$$

where $\theta_0^{F,B} > 0$. Thus, the premium that the bank faces on world capital markets depends on how much it borrows.[26]

Capital requirements are imposed only on risky loans to the CG producer:

$$V_t^R = \rho_t \sigma_t L_t^I, \tag{45}$$

where $\rho_t \in (0,1)$ is the overall capital ratio (defined later) and σ_t the risk weight. In line with the foundation variant of the Internal Ratings Based (IRB) approach of Basel II (which remains essentially the same under Basel III), the risk weight is assumed to depend on the repayment probability of the CG producer:[27]

$$\sigma_t = (\frac{q_t}{\tilde{q}})^{-\phi_q}, \tag{46}$$

where $\phi_q > 0$. Thus, in the steady state, the risk weight is normalized to unity.

The bank sets the deposit and lending rates, issues capital (in the form of one-period debt) to satisfy prudential rules, and determines foreign borrowing and excess capital so as to maximize the present discounted value of its profits, while internalizing the effect of its borrowing decisions on the risk premium that it faces on world capital markets. Because the bank is liquidated and debt is redeemed at the end of each period, this maximization problem boils down to a static problem:

$$i_t^D, i_t^L, \frac{L_t^{F,B}}{P_t^S}, \frac{V_t^E}{P_t^S} = \arg\max \mathbb{E}_t(\frac{J_{t+1}^B}{P_t^S}), \tag{47}$$

[26] Alternatively, the premium could be specified as a function of the ratio of foreign borrowing to bank capital, $L_t^{F,B}/V_t$. In practice, many middle-income countries impose maximum limits on a bank's foreign currency liabilities in terms of its core capital or net worth.

[27] See Agénor et al. (2012) for a detailed discussion of this specification. Alternatively, under the Standardized approach, σ_t could be taken to be a function of the output gap, if ratings are assumed to be procyclical.

where expected profits at the end of period t (or beginning of $t+1$) are defined as

$$\mathbb{E}_t(\frac{J_{t+1}^B}{P_t^S}) = (1+i_t^R)(\frac{L_t^W}{P_t^S}) + q_t(1+i_t^L)(\frac{L_t^I}{P_t^S}) + (1-q_t)\kappa(\frac{P_t^H}{P_t^S})\bar{H} \tag{48}$$

$$+\mu^R d_t - (1+i_t^D)d_t - (1+i_t^R)(\frac{L_t^{C,B}}{P_t^S}) - (1+i_t^V)(\frac{V_t}{P_t^S})$$

$$-(1+i_t^{F,B})(\frac{E_t L_t^{F,B}}{P_t^S}) - \gamma_V(\frac{V_t}{P_t^S}) + \frac{\gamma_{VV}}{\phi_E}(\frac{V_t^E}{P_t^S})^{\phi_E},$$

where γ_D, γ_L, $\gamma_V > 0$, $\gamma_{VV} \geq 0$, $\phi_E \in (0,1)$.[28] As noted earlier, the second term on the right-hand side of this expression, $q_t(1+i_t^L)L_t^I/P_t^S$, represents expected repayment on loans to the CG producer if there is no default, whereas the third term represents what the bank expects to earn in case of default, that is, "effective" collateral, defined as a fraction of the marked-to-market value of the housing stock.

The fourth term, $\mu^R d_t$, represents the reserve requirements held at the central bank and returned to the bank at the end of the period, prior to its closure. The term $(1+i_t^D)d_t$ represents the value of deposits (principal and interest) redeemed at the end of the period. Similarly, the term $(1+i_t^V)P_t^{S,-1}V_t$ represents the gross value of bank debt repaid at the end of the period, whereas $(1+i_t^{F,B})E_t P_t^{S,-1}L_t^{F,B}$ is the domestic-currency value of the bank's repayment on foreign loans.

The linear term $\gamma_V P_t^{S,-1}V_t$ captures the cost associated with issuing bank debt, whereas the last term, $\phi_E^{-1}\gamma_{VV}(P_t^{S,-1}V_t^E)^{\phi_E}$, captures the view, discussed in Agénor et al. (2012, 2013), that maintaining a positive capital buffer generates benefits—by signaling for instance that the bank's financial position is strong and thereby reducing the intensity of regulatory scrutiny.

Solving (47) subject to (36), (39) to (45), and (48) yields

$$i_t^D = (1+\frac{1}{\eta_D})^{-1}(1-\mu^R)i_t^R, \tag{49}$$

$$1+i_t^L = \frac{(1-\rho_t\sigma_t)(1+i_t^R) + \rho_t\sigma_t\left[(1+i_t^V)+\gamma_V\right]}{(1+\eta_F^{-1})q_t}, \tag{50}$$

$$L_t^{F,B} = \max[\frac{(1+i_t^R)-(1+i_t^W)\mathbb{E}_t(E_{t+1}/E_t)}{\theta_0^{F,B}(1+i_t^W)\mathbb{E}_t(E_{t+1}/E_t)}, 0], \tag{51}$$

$$\frac{V_t^E}{P_t^S} = \left\{\frac{\gamma_{VV}}{i_t^V+\gamma_V-i_t^R}\right\}^{1/(1-\phi_E)}, \tag{52}$$

where η_D is the interest elasticity of the supply of deposits by households to the deposit rate and η_F the interest elasticity of the CG producer demand for loans (or investment) to the lending rate.

[28] The expectation $\mathbb{E}_t$ is taken with respect to an implicit idiosyncratic shock to output of capital goods, which is unknown at the time the bank makes its pricing decisions.

Equation (49) shows that the equilibrium deposit rate is a markup over the refinance rate, adjusted (downward) for the implicit cost of holding reserve requirements. Equation (50) indicates that the lending rate depends negatively on the repayment probability, and positively on a weighted average of the marginal cost of borrowing from the central bank and the total cost of issuing debt for capital requirement purposes. Equation (51) states that foreign borrowing is decreasing in the premium-exclusive cost of borrowing abroad (adjusted for expected depreciation) and increasing in the cost of borrowing domestically from the central bank; there is no borrowing if the former increases the latter. Equation (52) shows that an increase in the direct or indirect cost of issuing debt (i_t^V or γ_V) reduces excess capital, whereas an increase in γ_{VV} raises the excess capital that the bank is willing to hold.

As in Agénor et al. (2012, 2013), we adopt a reduced-form approach to model the repayment probability.[29] Specifically, q_t is taken to depend positively on the effective collateral-CG loan ratio (which mitigates moral hazard on the part of borrowers) and the cyclical position of the economy:

$$q_t = (\frac{\kappa P_t^H \bar{H}}{L_t^I})^{\varphi_1}(\frac{Y_t}{\tilde{Y}})^{\varphi_2}, \tag{53}$$

with $\varphi_1, \varphi_2 > 0$ and $\tilde{Y}$ is the steady-state level of aggregate output.[30,31] Figure 1 summarizes the links between bank capital, the repayment probability, and the loan rate in the model.

The balance sheet constraint (40), together with (42), can be used to determine residually borrowing from the central bank:

$$L_t^{C,B} = \max[L_t - E_t L_t^{F,B} - (1 - \mu^R)D_t - V_t, 0]. \tag{54}$$

Finally, at the end of the period, the bank pays interest on deposits, and repays with interest loans received from the central bank and the debt that it issued. Because the bank closes down, there are no retained earnings; all profits are rebated lump-sum to the household.[32]

[29] Cúrdia and Woodford (2010) also rely on a reduced-form intermediation technology to define bank spreads.

[30] In Agénor and Pereira da Silva (2014), the repayment probability is endogenously determined as part of the bank's optimization process. Specifically, they assume that the bank can affect the repayment probability on its loans by expending effort on selecting (*ex ante*) its borrowers; the higher the effort, the safer the loan. Assuming that the cost of screening depends (inversely) not only on the collateral-investment loan ratio but also on the cyclical position of the economy and the capital-loan ratio yields a specification similar to (53).

[31] Note that we abstract from the monitoring incentive effect associated with bank capital, as discussed in Agénor et al. (2012, 2013), given that it plays no substantive role in the present analysis.

[32] Recall that there is no default in equilibrium; the actual profits that are rebated to the household are obtained by setting the repayment probability equal to one on the right-hand side of (48). Note also that these profits are essentially rents for owning the bank, without putting any equity. This is consistent with our assumption that capital consists of debt rather than common stocks.

2.6 Central Bank

The central bank's assets consists of international reserves, $E_t R_t^F$, holdings of government bonds, B_t^C, and loans to commercial banks, $L_t^{C,B}$. Its liabilities consists of cash, M_t, and required reserves, RR_t. The balance sheet of the central bank is thus given by

$$E_t R_t^F + B_t^C + L_t^{C,B} = M_t + RR_t. \tag{55}$$

Although the exchange rate is flexible, we assume that, as a result of standard trade considerations and a self-insurance motive against volatile capital flows, the central bank intervenes in the foreign exchange market to adjust the actual foreign-currency value of its reserves so as to achieve a desired value $R_t^{F,T}$. This desired value is thus specified as a weighted average of imports of intermediate goods and foreign liabilities of the private sector, $L_t^{F,B} - B_t^{F,P}$:

$$R_t^{F,T} = (\phi_1^R W P_t^F Y_t^F)^{\varphi^F} [\phi_2^R (L_t^{F,B} - B_t^{F,P})]^{1-\varphi^F}, \tag{56}$$

where $\varphi^F \in (0,1)$ and $\phi_1^R, \phi_2^R > 0$. Thus, in the particular case where $\varphi^F = 0$ and $\phi_2^R = 1$, the central bank's objective is to maintain a zero stock of net foreign assets.

Actual reserves adjust according to a simple partial adjustment mechanism,

$$R_t^F = (R_t^{F,T})^{\varphi^R} (R_{t-1}^F)^{1-\varphi^R}, \tag{57}$$

where $\varphi^R \in (0,1)$ is the speed of adjustment.

Using (42), equation (55) yields the supply of base money as

$$M_t^s = E_t R_t^F + B_t^C + L_t^{C,B} - \mu^R D_t. \tag{58}$$

Any income made by the central bank on its foreign reserves and from its loans to the commercial bank is transferred to the government at the end of each period. The effect of exchange rate fluctuations, however, are taken to be an off-balance-sheet item.

The central bank sets its policy rate, i_t^R, on the basis of an augmented Taylor-type policy rule:

$$i_t^R = \chi i_{t-1}^R + (1-\chi)[\tilde{r} + \pi_t^S + \varepsilon_1(\pi_t^S - \pi^{S,T}) + \varepsilon_2 \ln(\frac{Y_t}{\tilde{Y}}) + \varepsilon_3 \Delta \ln E_t] + \epsilon_t, \tag{59}$$

where $\tilde{r}$ is the steady-state value of the real interest rate on bonds, $\pi^{S,T} \geq 0$ the central bank's headline inflation target (in terms of the price of goods sold domestically), $\chi \in (0,1)$ a coefficient measuring the degree of interest rate smoothing, and $\varepsilon_1, \varepsilon_2, \varepsilon_3 > 0$, and $\ln \epsilon_t$ is a serially uncorrelated random shock with zero mean. Thus, in addition to reacting to output and inflation, the central bank also "leans against the wind" by raising (lowering) the policy rate when the nominal exchange rate depreciates (appreciates).

The overall capital ratio set by the central bank-cum-regulator consists of a minimum, deterministic component, ρ^D, and a cyclical component, ρ_t^C:

$$\rho_t = \rho^D + \rho_t^C. \tag{60}$$

In turn, the cyclical component is related to deviations of real credit for investment, $l_t^I = L_t^I/P_t^S$, from its steady-state value:

$$\rho_t^C = \theta^C(\frac{l_t^I}{\tilde{l}^I} - 1), \tag{61}$$

where $\theta^C > 0$. Thus, in line with the countercyclical capital buffer rule envisaged under Basel III (see Committee on Banking Supervision (2011)), the macroprudential rule considered here calls for a tightening of capital requirements when real credit exceeds its steady-state value.[33]

2.7 Government

The government purchases the final good and issues nominal riskless one-period bonds to finance its deficit; it does not borrow abroad. Its budget constraint is given by

$$B_t = (1 + i_{t-1}^B)B_{t-1}^P + B_{t-1}^C + P_t^S(G_t - T_t) \tag{62}$$
$$-i_{t-1}^R L_{t-1}^{C,B} - i_{t-1}^W E_t R_{t-1}^F,$$

where $B_t = B_t^C + B_t^P$ is the outstanding stock of government bonds, G_t real government spending, and T_t real lump-sum tax revenues. The last two terms represent the interest income transferred by the central bank to the government.

Government purchases represent a fraction $\psi \in (0,1)$ of domestic sales of the final good:

$$G_t = \psi Y_t^S. \tag{63}$$

3 Equilibrium

In a symmetric equilibrium, firms producing intermediate goods are identical. Thus, $K_{jt} = K_t$, $N_{jt} = N_t$, $Y_{jt}^D = Y_t^D$, $P_{jt}^D = P_t^D$, for all $j \in (0,1)$. All firms also produce the same output and prices are the same across firms. In the steady state, inflation is constant.

Equilibrium in the goods markets requires that sales on the domestic market be equal to aggregate demand, inclusive of price adjustment costs:

$$Y_t^S = C_t + G_t + I_t + \frac{\phi_I}{2}(\frac{1+\pi_t^D}{1+\tilde{\pi}^D} - 1)^2(\frac{P_t^D}{P_t^S})Y_t^D, \tag{64}$$

[33] All experiments reported later on were also conducted with an alternative rule in which countercyclical regulatory requirements depend on deviations of the investment credit-to-GDP ratio from its steady-state values; results are qualitatively similar to those discussed later and are omitted to save space.

with the price of sales on the domestic market determined by rewriting the identity linking the value of output and the value of domestic sales and exports, $P_tY_t = P_t^SY_t^S + P_t^XY_t^X$, that is, using (27),

$$P_t^S = \frac{P_tY_t - P_t^XY_t^X}{Y_t - Y_t^X}. \tag{65}$$

Suppose that bank loans to IG firms and the capital producer are made only in the form of cash, and let M_t^E denote total cash holdings by these agents; thus, $L_t = M_t^E$. The equilibrium condition of the market for cash is then given by

$$M_t^s = M_t^P + L_t, \tag{66}$$

where M_t^s is defined in (58). Using (54) as well for $L_t^{C,B}$ implies that the equilibrium condition (66) can be rewritten as

$$M_t^P + D_t = B_t^C + E_t(R_t^F - L_t^{F,B}) - V_t, \tag{67}$$

which, after substituting (9) and (10) for M_t^P and D_t, can be solved for the equilibrium bond rate.

The government balances its budget by adjusting lump-sum taxes, while keeping the overall stock of bonds constant at $\bar{B}$ and the central bank also keeps its stock of bonds constant at $\bar{B}^C$. Private holdings of domestic government bonds are thus constant at $B^P = \bar{B} - \bar{B}^C$.

Finally, the external budget constraint of the economy (or equivalently the equilibrium condition of the market for foreign exchange), measured in foreign-currency terms, is given by[34]

$$WP_t^XY_t^X - WP_t^FY_t^F + i_{t-1}^WNFA_{t-1} + \theta_{t-1}^{F,P}B_{t-1}^{F,P} \tag{68}$$
$$-\theta_{t-1}^{F,B}L_{t-1}^{F,B} - \Delta NFA_t = 0,$$

where NFA_t is the net foreign asset position of the economy, defined as

$$NFA_t = R_t^F + B_t^{F,P} - L_t^{F,B}. \tag{69}$$

4 Steady State

The steady-state solution of the model is derived in Appendix A. Several of its key features are similar to those of the closed-economy models described in Agénor et al. (2012, 2013), so we refer to those papers for a more detailed discussion.

In brief, with a headline inflation target $\pi^{S,T}$ equal to zero, the steady-state inflation rate $\tilde{\pi}^S$ is also zero. In addition to standard results (the steady-state value of the

[34] Under a fixed exchange rate, $E_t = \bar{E}$ and condition (68) determines changes in official reserves, R_t^F. Equation (57) must therefore be dropped from the system. Under a flexible exchange rate, condition (68) determines implicitly the nominal exchange rate.

marginal cost, for instance, is given by $(\theta_D - 1)/\theta_D)$, the steady-state value of the repayment probability is

$$\tilde{q} = (\frac{\kappa \tilde{P}^H \bar{H}}{\tilde{L}^I})^{\varphi_1},$$

whereas steady-state interest rates are given by

$$\tilde{\imath}^B = \tilde{\imath}^R = \frac{1}{\beta} - 1 = \tilde{r},$$

$$\tilde{\imath}^D = (1 + \frac{1}{\eta_D})^{-1}(1 - \mu^R)\tilde{\imath}^R,$$

and

$$\tilde{\imath}^L = \frac{(1-\rho)\beta^{-1} + \rho\left[(1 + \tilde{\imath}^V) + \gamma_V\right]}{(1 + \eta_F^{-1})\tilde{q}} - 1.$$

From these equations it can be shown that $\tilde{\imath}^B > \tilde{\imath}^D$. We also have $\tilde{\imath}^V > \tilde{\imath}^B$ for $\Theta_V > 0$ (because holding bank debt is subject to a cost), and thus $\tilde{\imath}^V > \tilde{\imath}^D$. Equation (52) determines $\tilde{V}^E$, which is positive given that $\tilde{\imath}^V > \tilde{\imath}^R$. From (46), $\tilde{\sigma} = 1$ (by construction) and from (45), the steady-state required capital-risky assets ratio, $\tilde{V}^R/\tilde{L}^I$, is equal to $\tilde{\rho} = \rho^D$, given that from (61) $\tilde{\rho}^C = 0$.

To analyze the response of the economy to shocks, we log-linearize the model around a nonstochastic, zero-inflation steady state. The log-linearized equations are summarized in Appendix B.

5 Illustrative Calibration

To calibrate the model we dwell extensively on Agénor and Alper (2012) and Agénor et al. (2012, 2013). We therefore refer to those studies for a detailed discussion of some of our choices. In addition, for some of the parameters that are "new" or specific to this study, we consider alternative values in sensitivity tests. This is the case, in particular, for the degree of exchange rate pass-through, the weight attached to net private sector foreign liabilities in the reserve accumulation equation (56), the coefficient of the rate of nominal exchange rate depreciation in the monetary policy rule (59), and the sensitivity of countercyclical bank capital to credit gaps in (61).

Parameter values are summarized in Table 1. The discount factor β is set at 0.985, which corresponds to an annual real interest rate of 6 percent. The intertemporal elasticity of substitution, ς, is 0.6, in line with estimates for middle-income countries (see Agénor and Montiel (2015)). The preference parameter for leisure, η_N, is set at 4.5. This value is consistent with a share of time allocated to market work equal to 0.33 (corresponding to 8 hours a day). The preference parameters for composite monetary assets, η_x, and housing, η_H, are set at the same low value, 0.02. The share parameter in the index of money holdings, ν, which corresponds to the relative share of cash in narrow money, is set at 0.35.

The distribution parameter between domestic and imported intermediated goods in the production of the final good, Λ_D, is set at 0.7, whereas η, the elasticity of substitution between baskets of domestic and imported composite intermediate goods, is set at 0.8. The first parameter, which can be approximated in practice by the share of nontraded goods in total GDP, reflects the fact that we consider an economy that is still relatively closed. The elasticities of substitution between intermediate domestic goods among themselves, θ_D, and imported goods among themselves, θ_F, are set equal to the same value, 10. The pass-through parameter is set at $\mu^F = 0.3$; this is line with the average value estimated by Soto and Selaive (2003) for instance, for a group of 35 countries, and consistent with the recent evidence suggesting a decline in the strength of the pass-through effect in both industrial and developing countries. The price elasticity of exports, $\varkappa$, is set equal to 0.7, a value consistent with a range of estimates for middle-income countries.

The share of capital in domestic output of intermediate goods, α, is set at 0.35. The adjustment cost parameter for prices of domestic intermediate goods, ϕ_I, is set at 74.5. The rate of depreciation of private capital, δ, is set equal to 0.03. The adjustment cost for transforming the final good into investment, Θ_K, is set at 14. With $\theta_D = 10$, the steady-state value of the markup rate in the intermediate goods sector, $\theta_D/(\theta_D - 1)$, is equal to 11.1 percent.

For the parameters characterizing bank behavior, we assume that the effective collateral-loan ratio, κ, is 0.2. The adjustment cost parameter for holdings of bank debt, Θ_V, is set at 1.0, to capture relatively inefficient markets. The elasticity of the repayment probability is set at $\varphi_1 = 0.03$ with respect to collateral and $\varphi_2 = 1.5$ with respect to the output gap. The elasticity of the risk weight with respect to the repayment probability is set at $\varphi_q = 1.25$. The cost parameters γ_V and γ_{VV} are set at low values, 0.18, and 0.001, respectively. The parameter ϕ_E, which captures the benefit associated with capital buffers, is set to 0.5. Given the specification of the risk weight σ_t in (46), its steady-state value is equal to unity. The deterministic component of the capital adequacy ratio, ρ^D—and thus the overall capital ratio, given that $\rho^C = 0$ in the steady-state—is set at 0.08, which corresponds to the minimum value of the ratio of capital to risk-weighted assets under the recent Basel agreements. We also calibrate the excess capital-risky assets ratio to be equal to 0.04. This implies that the steady-state ratio of total bank capital to risky loans is set at about 12 percent (so that $\tilde{V}^E/\tilde{V}^R = 0.53$), in line with the evidence reported in Agénor and Pereira da Silva (2010, 2012). Our calibration implies a total (corporate) credit-to-output ratio of about 60 percent, which is consistent with data for several middle-income countries. Parameter $\theta_0^{F,B}$, which determines how the bank's foreign borrowing responds to the differential in the cost of domestic and foreign borrowing, is set at 0.16; this number implies that bank foreign liabilities represent about 10 percent (a reasonable number for many middle-income countries) of their total liabilities.

As noted earlier, the focus of our analysis in this paper is on capital flows associated with bank foreign borrowing, rather than portfolio flows associated with household asset allocation. To illustrate our results in the most transparent way, we assume that the intensity of credit market imperfections that domestic households face on world capital markets are such that the marginal effect of higher private foreign borrowing on the risk premium, as measured by the parameter $\theta_0^{F,P}$, is high—so high, in fact, that private holdings of foreign bonds are effectively zero. Formally, as can be inferred from (17), this implies setting $\theta_0^{F,P} \to \infty$.[35]

The reserve requirement rate μ^R is set at 0.1. We abstract from persistence stemming from the central bank's policy response and set the smoothing parameter $\chi = 0$. We also set $\varepsilon_1 = 2.5$ and $\varepsilon_2 = 0.2$, which are conventional values for Taylor-type rules for middle-income countries; the value of ε_2, in particular, is consistent with the evidence reported for Chile by Caputo et al. (2006) and for several countries in Latin America by Moura and Carvalho (2010). We initially assume that the central bank does not respond to fluctuations in the nominal exchange rate, and set therefore $\varepsilon_3 = 0$. We also assume initially that the central bank's foreign reserve target is set only in terms of trade considerations, so that $\varphi^F = 1$, and set $\phi_1^R = 2$, to capture the view that the central bank targets a stock of reserves equal to 6 months of (intermediate) imports. The speed of adjustment of actual reserves to its target level, φ^R, is set at 0.2. The parameter characterizing the countercyclical regulatory rule, θ^C, is initially set at 0. Finally, the degree of persistence of the shock to the world risk-free rate, ρ_W, is set at 0.8, which implies a reasonably high degree of inertia.

6 Dynamics of a Sudden Flood

To illustrate the properties of the model in response to external shocks, we consider as a base experiment (with $\theta^C = 0$) a temporary drop in the world risk-free interest rate by 35 basis points at a quarterly rate, or about 141 basis points at an annual rate.[36] The magnitude of the shock is thus large enough to illustrate the consequences of a sudden flood.

The results are summarized in Figure 2, for 20 of the key variables of the model. The immediate effect of the shock is to lower the cost of borrowing abroad for the domestic bank. The bank's foreign liabilities therefore increase, with a matching inflow of capital, which leads to an appreciation of the nominal exchange rate. In turn, the nominal appreciation lowers the domestic price of imported intermediate goods and stimulates their demand as well as final good production, while at the same time raising the central bank's desired level—and thus the actual stock, given partial adjustment—of foreign reserves. In turn, the accumulation of foreign reserves tends to increase the monetary base.[37] At the same time, the increase in foreign borrowing by the

[35] This assumption is also consistent with a policy environment where the central bank imposes capital controls—after households have solved their optimization problem—and the cost of avoiding these controls is prohibitive.

[36] See Neumeyer and Perri (2005) and Maćkowiak (2007) for evidence on the impact of monetary shocks in the United States on middle-income countries in East Asia and Latin America.

[37] Because both the reserve target and bank foreign borrowing increase, the change in the net foreign asset position of the economy is in general ambiguous. Given our calibration, the increase in the latter

commercial bank reduces its domestic borrowing from the central bank, which tends to reduce the monetary base. The former effect dominates, implying an increase in the supply of cash. At the initial level of consumption, the *nominal* bond rate must therefore fall to increase the demand for cash and restore equilibrium in the currency market. At the same time, the expected future increase in inflation means that the *real* bond rate also falls; this induces households to increase consumption today.

In addition to an intertemporal effect on consumption, the fall in the real bond rate also leads to an increase in the demand for housing, which tends to raise real estate prices. This raises the value of collateral that firms can pledge. Because the real loan rate falls initially, the demand for investment loans increases—so much so that the collateral-loan ratio falls, which tends to reduce the repayment probability. But because output (relative to potential) increases, the net effect on the probability of repayment is positive. The nominal loan rate therefore falls. This effect is compounded by the drop in the policy rate, which reflects an initial fall in inflation (measured in terms of the price of domestic sales), itself related to the fact that, as noted earlier, the nominal appreciation tends to lower the domestic-currency price of imported intermediate goods. Thus, aggregate demand (spending on goods sold domestically) unambiguously increases on impact. In addition to the *level effect* on final output, there is also a *composition effect*: the appreciation of the nominal and real exchange rates translates into a drop in the share of final output allocated to exports, and an increase in the share sold domestically.

Over time, the increase in investment raises the capital stock, which tends to lower the rental rate of capital and to raise the marginal product of labor and therefore *gross* wages. The increase in current consumption raises the marginal utility of leisure and induces households to reduce their supply of labor, thereby magnifying the initial upward pressure on wages resulting from higher output and the increased demand for labor. However, the downward movement in the policy rate (the rate at which intermediate goods producers borrow to finance their working capital needs) is large enough to ensure that the *effective* wage rate falls. Indeed, as noted earlier the initial fall in domestic inflation tends to lower immediately the policy rate, despite the expansion in output. Because the rental rate of capital does not change on impact (due to the one-period lag in capital accumulation), marginal costs unambiguously fall in the first period. This tends to compound the downward effect on inflation (again, in terms of the price of goods sold on the domestic market) resulting from exchange rate appreciation, and thus the drop in the policy and loan rates. Over time, the reduction in the rental rate of capital induced by the boom in investment leads in a first phase to lower marginal costs, but the increase in the effective wage leads to higher inflation.

The fall in the bond rate tends to increase household demand for bank capital, thereby exerting downward pressure on the rate of return on bank debt. At the same time, there are two opposing forces on the supply of bank capital. On the one hand, the increase in risky investment loans increases capital requirements; on the other, the

dominates the increase in the former, implying that net foreign assets fall.

increase in the repayment probability lowers the risk weight attached to investment loans, which tends (together with an initial fall in prices) to lower capital requirements. The latter dominates and, as shown in Figure 2, the net effect is an increase in required capital, which tends to increase the rate of return on bank capital. The net effect on the latter is thus in general ambiguous. In the case shown in the figure, the rate of return on bank capital falls.[38] In turn, the reduction in the cost at which the bank issues capital magnifies the initial downward impact on the lending rate. The regulatory regime is thus procyclical. Finally, the gradual increase in the policy rate (the marginal cost of domestic borrowing for the bank) explains why foreign borrowing continues to increase beyond the first period and falls only gradually afterward (keeping the external risk premium high in the process), despite the fact that the drop in the world risk-free rate is only temporary.[39]

It is worth noting that because firms do not borrow directly abroad, the type of balance sheet effects often discussed in the literature on devaluations and financial crises (see Agénor and Montiel (2015)) are not present. The balance sheet effect, in this model, operates solely through changes in commercial bank liabilities: higher foreign borrowing feeds into the risk premium that the bank faces on world capital markets. As a result, the premium-inclusive cost of foreign borrowing (as defined in equation (44)) falls, but by less than the risk-free rate. Put differently, the fact that imperfections on world capital markets are internalized actually mitigate incentives to borrow abroad; they therefore play a stabilizing role.

The results of this experiment illustrate fairly well the fact that a sudden flood of foreign capital, induced by a drop in the risk-free rate of return on external assets, may generate a domestic boom characterized by increases in asset prices and aggregate demand, an expansion in output, and (over time) inflationary pressures. This occurs despite the fact that the nominal appreciation that accompanies capital inflows may mitigate the initial impact on inflation, and the fact that higher bank borrowing abroad does not lead directly to more credit, as in some models where credit is supply-driven. Indeed, at the initial levels of credit and deposits, higher bank borrowing abroad leads simply to less borrowing from the central bank. In turn, this affects the determination of the bond rate (through the equilibrium condition of the currency market), consumption, housing demand, and collateral values, which then feed into the repayment probability, the loan rate and the policy rate, thereby promoting investment.[40] The expansionary mechanism is therefore indirect and depends crucially on bank pricing behavior.

At the same time, the analysis shows that the regulatory regime—in addition to the stance of monetary policy, which in the present case includes not only the interest rate rule but also the reserve accumulation rule—also matters in assessing the dynam-

[38] The policy rate drops by about the same amount as the cost of bank capital, implying that the net effect on excess bank capital is relatively small.

[39] Of course, the fact that the shock to the world risk-free rate displays persistence matters as well.

[40] With liquidity-constrained consumers, as for instance in Agénor et al. (2013), the expansion in consumption would be larger than recorded in this experiment.

ics of sudden floods. Movements in the repayment probability feed into changes in risk weights, which in turn affect the cost of issuing capital and bank pricing decisions. Given our calibration, this feedback effect helps to magnify the initial shock; the regulatory regime is thus procyclical.[41]

7 Sensitivity Analysis

To assess the sensitivity of the previous results, we consider several additional experiments: an increase in the degree of exchange rate pass-through, a greater weight attached to net private sector foreign liabilities in the reserve accumulation equation, and a monetary policy that "leans against the wind" by responding to changes in the nominal exchange rate. We will consider in the next section an additional sensitivity test, which involves giving a role to countercyclical capital regulation.

7.1 Degree of Exchange-Rate Pass-through

We first consider an increase in the degree of exchange rate pass-through of nominal exchange rate changes to the domestic-currency price of imported intermediate goods, μ^F, from 0.3 to 0.7. The results of this experiment are shown in Figure 3, together with the results of the benchmark experiment. On impact, a higher pass-through rate magnifies the downward effect of the initial nominal appreciation on the domestic-currency price of imports induced by capital inflows. As a result, the shift in demand toward imported intermediate goods is larger. This tends to amplify the increase in the desired and actual reserve levels, which in turn tends to expand the monetary base. However, the appreciation induces the bank to borrow more (compared to the benchmark case) on world capital markets; this reduces its borrowing from the central bank by more, which induces a larger contraction of the monetary base. The supply of cash therefore increases by more than before, and the nominal bond rate must fall by more to restore equilibrium in the currency market. Because initially prices do not change much, the bond rate falls by more than in the benchmark experiment, generating a larger increase in current household consumption as well. As a result, the expansion in final output is larger, thereby inducing a larger increase in the repayment probability and a larger drop in the loan rate, and thus a stronger positive effect on investment than in the benchmark case. Marginal costs fall by more because of the larger drop in the policy rate. The initial drop in inflation (measured in terms of the price of goods sold domestically) is thus larger than in the benchmark experiment. Overall, a higher pass-through rate magnifies the domestic effects of the shock and creates more volatility.

[41] Note also that the regulatory regime that we consider is (because of the endogeneity of the risk weight) more procyclical than a Basel I-type regime with a fixed risk weight, due to its direct link with the repayment probability. This is consistent with the conventional view, although we have discussed elsewhere a counterintuitive case (see Agénor et al. (2012)).

7.2 Speed of Adjustment to Foreign Reserve Target

We now consider an increase in the speed of adjustment of foreign-currency reserves to their target level, φ^R, from the initial value 0.2 to 0.7. The results of this experiment are shown in Figure 4. Because bank foreign borrowing increases significantly initially, the assumption that the central bank adjusts its desired level of reserves to its target value at a faster rate implies its net foreign assets increase by more than in the benchmark case in the initial periods. The increase in the desired and actual reserve levels tend to expand the monetary base by more. The larger increase in money supply requires a larger drop in the nominal bond rate to restore equilibrium on the currency market. Consequently, the real bond rate increases by less, dampening the shift in household consumption across periods and mitigating the initial boom in private expenditure. As a result, final output expands by less than in the benchmark experiment. The drop in the loan rate is also dampened, implying that investment expands by less. Marginal costs tend to fall by less initially because the upward pressure on wages is now weaker and the central bank eases its policy stance. The initial increase in inflation is thus dampened compared to the benchmark case.

7.3 Response to Exchange Rate Movements

Finally, we consider an increase in the parameter that captures the extent to which the central bank responds to nominal depreciation in setting its policy rate, ε_3, from 0 to 0.5. This value is quite large compared to some of the estimates in the literature for middle-income countries; Caputo et al. (2006), for instance, estimated a value of about 0.15 for Chile. However, this is a useful case for illustrative purposes.

The results of this experiment are shown in Figure 5. Because the nominal exchange rate appreciates on impact, the direct implication is that the refinance rate falls by more than before. This, naturally enough, smoothes out the path of the exchange rate. But the drop in the loan rate (initially related to the drop in the policy rate) is now larger, and the initial expansion in investment is magnified. The larger initial fall in the policy rate implies that the increase in bank foreign borrowing is less significant, implying now (based on the reasoning outlined earlier) a larger drop in the nominal bond rate. As a result, consumption today increases initially by more than in the benchmark case. Because this also raises the marginal utility of leisure by more, the drop in labor supply is magnified, implying that the initial upward pressure on real wages is larger. As a result, the initial rise in the effective cost of labor (and thus marginal costs) is now more significant, despite the larger reduction in the cost of short-term borrowing for intermediate goods producers. By and large, attempts to mitigate exchange rate movements through changes in the policy rate create a trade-off: the nominal exchange rate is less volatile, but most of the other variables are more volatile initially.

8 Countercyclical Regulation

As discussed in the introduction, a dilemma that policymakers in middle-income countries have faced in recent years is related to the that, if a central bank responds to a sudden flood in foreign capital by raising interest rates to dampen credit expansion and counter inflationary pressures, it runs the risk of exacerbating inflows (because banks would borrow more abroad), which in turn would translate into more lending, higher domestic demand, and possibly higher inflation—despite the initial benefit of nominal appreciation on the domestic-currency price of imported goods. The question then is whether, in such conditions, other instruments can help to maintain economic stability. Specifically, we now turn to an examination of the potential role of countercyclical bank capital regulation in response to sudden floods. We begin by considering how a countercyclical regulatory rule affects the transmission process; we then consider how it can promote economic stability. We do so while keeping the interest rate rule the same as in the benchmark experiment, that is, without any response to exchange rate depreciation.

Consider an increase in the parameter characterizing the countercyclical regulatory rule, θ^C in (61), from an initial value of 0 to an arbitrary value of 5, for illustrative purposes. The outcome of this experiment is shown in Figure 6. In line with the results in Agénor et al. (2013), despite inducing higher volatility in bank capital, the presence of the rule mitigates the investment boom. As noted earlier, the initial expansion in output and the increase in housing prices that accompanies the shock to the world risk-free rate tend to raise the repayment probability, which reduces the lending rate and stimulates borrowing for investment. However, the countercyclical rule, by imposing higher capital requirements, mitigates the initial drop in the cost of issuing debt by the bank, thereby dampening the initial expansionary effect on the loan rate associated with higher collateral values and a higher repayment probability. Indeed, Figure 6 shows that the cost of bank capital drops by much less than in the benchmark case. Although bank capital is naturally more volatile, the loan rate and investment are less volatile. In that sense, therefore, the policy works as intended. Nevertheless, the figure also shows that the policy rate drops by more than in the baseline experiment, and that consumption and real house prices increase by more as well.

Intuitively, these results can be explained as follows. In the absence of the countercyclical regulatory rule, investment responds quite significantly to a change in the policy rate, through its effect on the loan rate. Thus, as aggregate demand (consumption and investment) responds relatively strongly to the policy rate, changes in that variable induced by any given inflation-inducing shock would not need to be very large. However, in the presence of a regulatory rule, and to the extent that the shock requires a higher capital adequacy ratio, the link between the policy rate and the loan rate is weakened. The reason is that the higher capital adequacy ratio raises the weight attached to the cost of issuing bank capital in the price-setting equation for the loan rate. As a result, investment (and therefore aggregate demand) becomes less reactive to changes in the policy rate—which would need now to react more significantly to an inflationary shock, inducing in the process a larger response in consumption.[42] Indeed, in the case considered here, with the initial appreciation translating initially into lower inflation, the presence of the countercyclical regulatory rule implies that the policy rate needs to decline on impact by more than otherwise, and this eventually leads to a larger increase in consumption. This is because with a larger drop in the policy (and deposit) rate, and by implication lower bank deposits, borrowing from the central bank increases, and this brings a larger increase in the supply of cash—requiring therefore a larger drop in the bond rate to equilibrate the currency market. In turn, this drop induces households to spend more today. By implication, the demand for housing services, and real house prices, would also increase. The rise in house prices (through its effect on the value of collateral) magnifies the increase in the repayment probability, thereby compounding the downward effect on the loan rate and offsetting somewhat the benefit associated with the countercyclical rule. The important point, however, is that the countercyclical regulatory rule, while making the loan rate and investment less volatile, may be associated not only with more volatile bank capital (as can be expected) but also increased volatility in consumption and asset prices—and, by implication, other macroeconomic variables. So the net effect on *aggregate* volatility is in general indeterminate and depends on how it is measured.

This potential dynamic volatility trade-off has important implications for the effectiveness of countercyclical regulatory rules and how aggressive these policies should be. As in Agénor et al. (2013), suppose that the central bank is concerned with two objectives, macroeconomic stability and financial stability. The former is defined in terms of the weighted average of the coefficient of variation of the output gap (measured in terms of sales on the domestic market) and of inflation (also in terms of the price of sales on the domestic market), with weights of 0.3 and 0.7; thus, we consider a central bank more concerned with inflation than output.[43] The latter objective is defined in terms of the coefficient of variation of three alternative indicators: a weighted average of nominal house prices and the nominal exchange rate, with equal weights of 0.5, divided by the price of goods sold on the domestic market; the credit-to-GDP ratio; and the ratio of bank foreign borrowing to GDP.[44] Thus, the first measure involves a mix of both types of asset prices.[45] In addition, we define a *composite index* of economic

[42] In principle for this effect to operate what is needed is an increase in $\sigma_t \rho_t$, not only an increase in ρ_t. For the shock considered here, this is indeed the case, even though σ_t falls. Note also that, the endogeneity of σ_t means that the impact of an increase in ρ_t is mitigated, making the countercyclical rule less effective.

[43] In turn, coefficients of variations are based on the asymptotic (unconditional) variances of the relevant variable.

[44] We also used bank foreign borrowing scaled by exports, and the growth rate of bank foreign borrowing; results were similar to those reported here. Note also that the measures could be combined to yield a single indicator, although in that case the issue of which weighting scheme to adopt would arise. To avoid this issue, and to show that all three indicators behave in the same way, we have kept them separate.

[45] In general, there are three main channels through exchange rate volatility could undermine financial stability. First, large currency movements could destabilize exchange rate expectations, causing

stability, calculated with two sets of weights: first with equal weight 0.5 to each objective of stability, and second with a weight of 0.7 for macroeconomic stability and 0.3 for financial stability.[46]

Figures 7 and 8 shows the behavior of our measures of (in)stability separately, and the index of economic stability, when the underlying shock is the same as described earlier (a temporary drop in the world risk-free rate), and for values of θ^C varying between 0 and 10.[47] The figure suggests that, given our calibration, there is actually no trade-off among policy objectives, regardless of the way financial stability is measured: a stronger response of regulatory capital to credit gaps leads to a reduction in *both* indicators of volatility—at least up to a certain value. Indeed, the curves have a convex shape, which indicates that the marginal benefit of countercyclical capital regulation diminishes as it becomes more aggressive (roughly above $\theta^C = 4$ in the figure). A similar result holds for the index of economic stability; given our base calibration, the marginal contribution of the regulatory capital rule to economic stability is positive but decreases as the policy becomes more aggressive.

Intuitively, the reason for the convex relationship between volatility and the strength with which the countercyclical capital rule responds to real credit growth is as follows. As noted earlier, the countercyclical rule mitigates the drop in the loan rate, which tends to reduce volatility in that variable. At first, this effect is not large, because the cost of issuing capital enters with a relatively low composite coefficient, $\sigma\rho$, in the loan rate-setting equation (see (50)). As θ^C increases, this coefficient also increases, thereby reducing volatility in the loan rate and investment. However, as the policy becomes more aggressive, it also generates more volatility in bank capital requirements, which then translate into higher volatility in the cost of issuing capital. At the same time, higher volatility in bank capital increases (as indicated earlier) volatility in the marginal value of wealth, consumption, and real house prices—which, through higher volatility in the repayment probability, raises volatility in the loan rate. In turn, this leads to higher volatility in investment, aggregate demand, the policy rate, inflation (through marginal costs) and other other macroeconomic variables, including foreign bank borrowing and the exchange rate.[48] Put differently, in a setting where banks must

abrupt changes in capital flows and inducing high volatility in local currency debt and equity markets. Second, currency depreciation could exacerbate currency mismatches (and thus undermine the creditworthiness) of domestic (bank and nonbank) borrowers with large foreign-currency debts. Third, large depreciations could be associated with a deterioration in external funding conditions during a crisis. In the present setting, the first two channels are the more relevant ones—although, in practice, the actual degree of currency mismatch depends on how far balance sheet exposures are hedged (through off-balance sheet positions) in derivatives markets.

[46] We experimented with other weighting schemes as well but they did not make much difference in terms of the results; we do not report them to save space.

[47] The maximum value of 10 is rather arbitrary, but this is sufficient to illustrate our purpose.

[48] Because increases in i_t^V reduce the demand for excess capital, when θ^C is low changes in that variable absorb some of the fluctuations in capital requirements, thereby imparting greater inertia to total capital. However, as θ^C increases, and movements in the cost of issuing capital are magnified, this mitigating role of excess capital becomes weaker.

indeed meet capital requirements by issuing costly debt, as is the case here, the ability of a countercyclical regulatory rule to mitigate macroeconomic and financial volatility may be limited beyond a certain point.

Of course, if bank capital was accumulated exclusively through retained earnings, rather than by issuing capital, the volatility induced by the "cost channel" of capital regulation would not operate. Nevertheless, The conclusion regarding the effectiveness of countercyclical regulatory rules would continue to hold in a "mixed" system where capital is built through both retained profits and capital issuance—the only difference being that decreasing marginal returns (in terms of reduced volatility) would begin to appear at a higher value of θ^C.

The thrust of the analysis, therefore, is that to the extent that monetary policy has limited room for manoeuvre (given the nature of the shock that the economy faces), a countercyclical regulatory rule is a complementary instrument because it helps to improve outcomes relative to both macroeconomic and financial stability objectives. However, because the policy entails diminishing marginal returns, other, more targeted macroprudential tools (such as loan-to-value ratios, debt-to-income limits, and reserve requirements) may well be needed in practice to mitigate macroeconomic and financial imbalances when external shocks are large and persistent.

9 Concluding Remarks

The purpose of this paper has been to develop a dynamic stochastic model of a small open middle-income economy with a two-level banking intermediation structure, a risk-sensitive regulatory capital regime, and imperfect capital mobility, to study the role of countercyclical regulatory policy in response to capital flows associated with foreign bank borrowing. In the model firms borrow from domestic banks and banks borrow on world capital markets, in both cases subject to an endogenous premium. The central bank pursues a policy of reserve accumulation that depends on both trade and financial factors. In line with the approach proposed by McCallum and Nelson (2000), imports are not treated as finished consumer goods but rather as intermediate goods, which are used (together with domestic intermediate goods) in the production of the domestic final good. It was argued that this approach is particularly relevant for middle-income countries, where trade in raw materials accounts for a very large share of imports.

A sudden flood in foreign capital, induced by a drop in the world risk-free interest rate, was shown to generate asset price pressures and an economic boom, the magnitude of which depends on bank pricing behavior and the nature of the prudential regulatory regime. We also considered the role of countercyclical capital regulation, taking the form of a Basel III-type rule, under the assumption that monetary policy is constrained by the nature of the shock, that is, the possibility that raising interest rates too aggressively entails the risk of exacerbating capital inflows. As noted in the introduction, this is a policy dilemma that many central banks in middle-income countries have confronted in recent years. The countercyclical regulatory rule was shown to be quite effective—at least for the shock considered—at promoting both macroeconomic and financial stability, with the latter defined in terms of three alternative indicators based on volatility in asset prices (house prices and the nominal exchange rate), the credit-to-GDP ratio, and the ratio of bank foreign borrowing to GDP. However, the marginal gain in terms of reduced volatility may exhibit diminishing returns beyond a certain point—essentially because regulatory-induced volatility in capital requirements translates into volatility in lending and other macroeconomic and financial variables, including foreign bank borrowing and the exchange rate. In the end, an countercyclical capital regulatory rule that is too aggressive may do little to reduce the volatility of capital flows. These results suggest that in practice countercyclical capital buffers may need to be supplemented by other, more targeted, macroprudential instruments, such as loan-to-value and debt-to-income ratios, when external shocks are large and persistent. More generally, our experiments illustrate well how the regulatory regime matters, given the monetary policy stance, in the transmission of sudden floods. Movements in repayment probabilities feed into changes in risk weights under the Basel II-type regime that we considered, thereby affecting the cost of issuing capital and bank pricing decisions.

A useful extension of the model would be to account for household borrowing from banks. Even though it remains low (in proportion of GDP) compared to industrial countries, this component of lending has increased significantly in middle-income countries like Brazil and Turkey in recent years—partly as a result of domestic factors (notably the expansion of the middle class in Brazil) but also partly as a result of large capital inflows. In Turkey for instance, the expansion of domestic-currency loans has been closely associated with capital inflows. The reason for this is because foreign investors were very involved in swap agreements with long maturities. In these transactions, foreigners swapped their domestic currency holdings (bought in the first place from domestic residents) with foreign exchange held by domestic banks. Foreigners get a fixed rate of return on domestic-currency assets during the duration of the agreement, with domestic banks earning LIBOR on their foreign exchange positions. Thus, domestic banks can hedge the currency and interest rate risk by means of these agreements. This allowed banks to extend credit in domestic currency at longer maturities, making mortgage loans more affordable for households. Capital inflows not only provided ample foreign exchange liquidity to banks but also the opportunity to transform these funds into longer-term domestic-currency loans. In addition, capital inflows also had an indirect effect on credit to households, through their effect on expected interest rates. Because of the perception that lower interest rates abroad and strong capital inflows would persist, domestic banks became convinced that domestic interest rates would not increase substantially over time. This prompted them to take more interest rate risk and resulted in a lengthening of loan maturities—thereby stimulating household demand for mortgages and magnifying the boom in credit and output.

Another useful extension of our analysis would be to analyze the role of restrictions on capital inflows, which continue to be used by several countries in Latin America and Asia. Capital controls, unlike prudential tools, typically involve discriminating between residents and non-residents. In general, the evidence on their benefits (especially for direct taxes on fixed income and equity inflows) is mixed and differs both across countries and over time. However, some empirical studies do suggest that capital controls can be effective, at least in the short term.[49] A worthwhile exercise would therefore be to study in a full-blown DSGE model like ours how controls operate in a context where mitigating financial instability is also a key policy objective. Indeed, an important issue in this context is to identify which *type* of capital controls can be most effective to promote economic stability, and if so, under what conditions. Some types of controls (such as exposure limits on foreign-currency borrowing, reserve requirements on foreign-currency deposits in domestic banks, and so on) are tantamount to prudential measures—which are especially important when inflows are intermediated through the regulated financial system. In the model, this could be accounted for by introducing a tax on foreign borrowing by domestic banks. We intend to pursue this line of investigation in the near future.

[49] See Edwards and Rigobon (2009), Binici et al. (2010), Glick and Hutchison (2011), and the overview in Agénor (2012) and Agénor and Pereira da Silva (2013). The paradigm shift in institutions like the International Monetary Fund (2012) is also worth noting.

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Table 1
Benchmark Calibration: Key Parameter Values

Parameter	Value	Description
Household		
β	0.985	Discount factor
ς	0.6	Elasticity of intertemporal substitution
η_N	4.5	Preference parameter for leisure
η_x	0.02	Preference parameter for money holdings
η_H	0.02	Preference parameter for housing
ν	0.35	Share parameter in index of money holdings
Θ_V	1.0	Adjustment cost parameter, holdings of bank debt
Production		
Λ_D	0.7	distribution parameter, final good
η	0.8	Elasticity of substitution, baskets of IG goods
μ^F	0.3	Adjustment speed, imported intermediate goods
$\varkappa$	0.7	Price elasticity of exports
θ_D, θ_F	10.0	Elasticity of demand, intermediate goods
α	0.35	Share of capital, domestic intermediate goods
ϕ_I	74.5	Adjustment cost parameter, IG prices
δ	0.03	Depreciation rate of capital
Θ_K	14	Adjustment cost parameter, investment
Commercial Bank		
κ	0.2	Effective collateral-loan ratio
φ_1	0.03	Elasticity of repayment prob, collateral
φ_2	1.5	Elasticity of repayment prob, cyclical output
φ_q	1.25	Elasticity of risk weight, prob of repayment
γ_V	0.18	Cost of issuing bank capital
γ_{VV}	0.001	Benefit of holding excess bank capital
ρ^D	0.08	Capital adequacy ratio (deterministic component)
Central bank		
μ^R	0.1	Reserve requirement rate
χ	0.0	Degree of interest rate smoothing
φ^R	0.2	Speed of adjustment to reserve target
ε_1	2.5	Response of refinance rate to inflation deviations
ε_2	0.2	Response of refinance rate to cyclical output
ε_3	0.0	Response of refinance rate to nominal depreciation
ρ_W	0.8	Degree of persistence, shock to world risk-free rate

Figure 1
Bank Capital, Repayment Probability and the Lending Rate

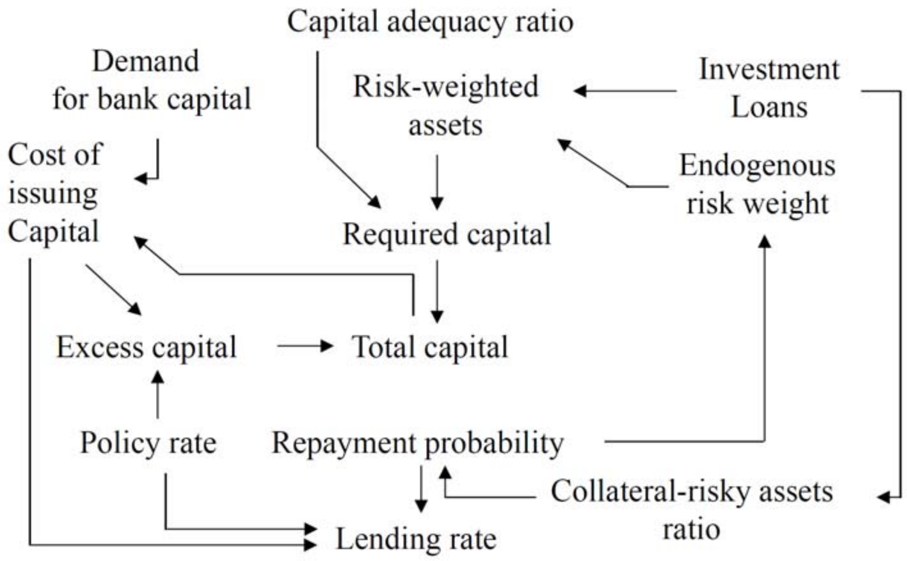
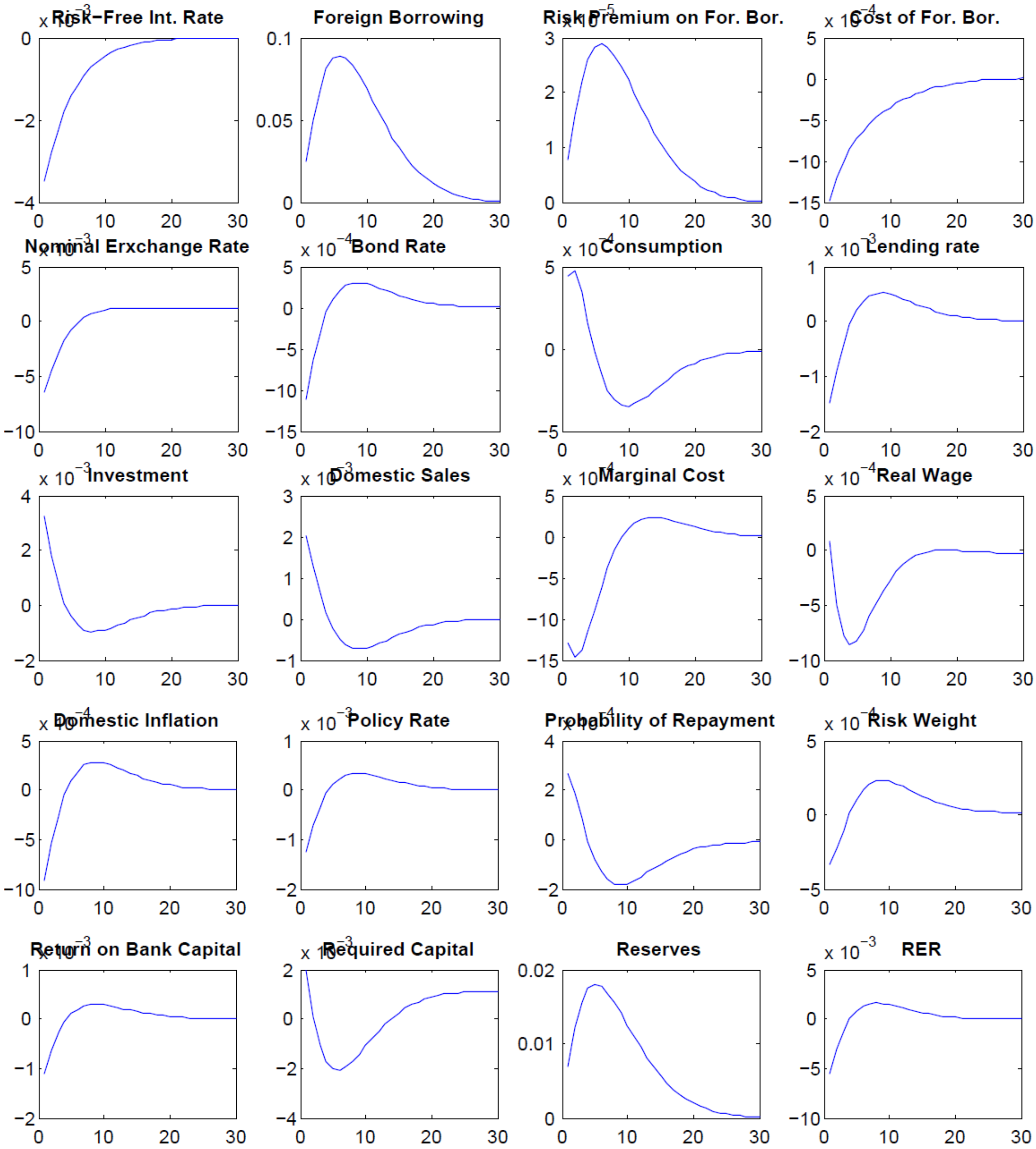
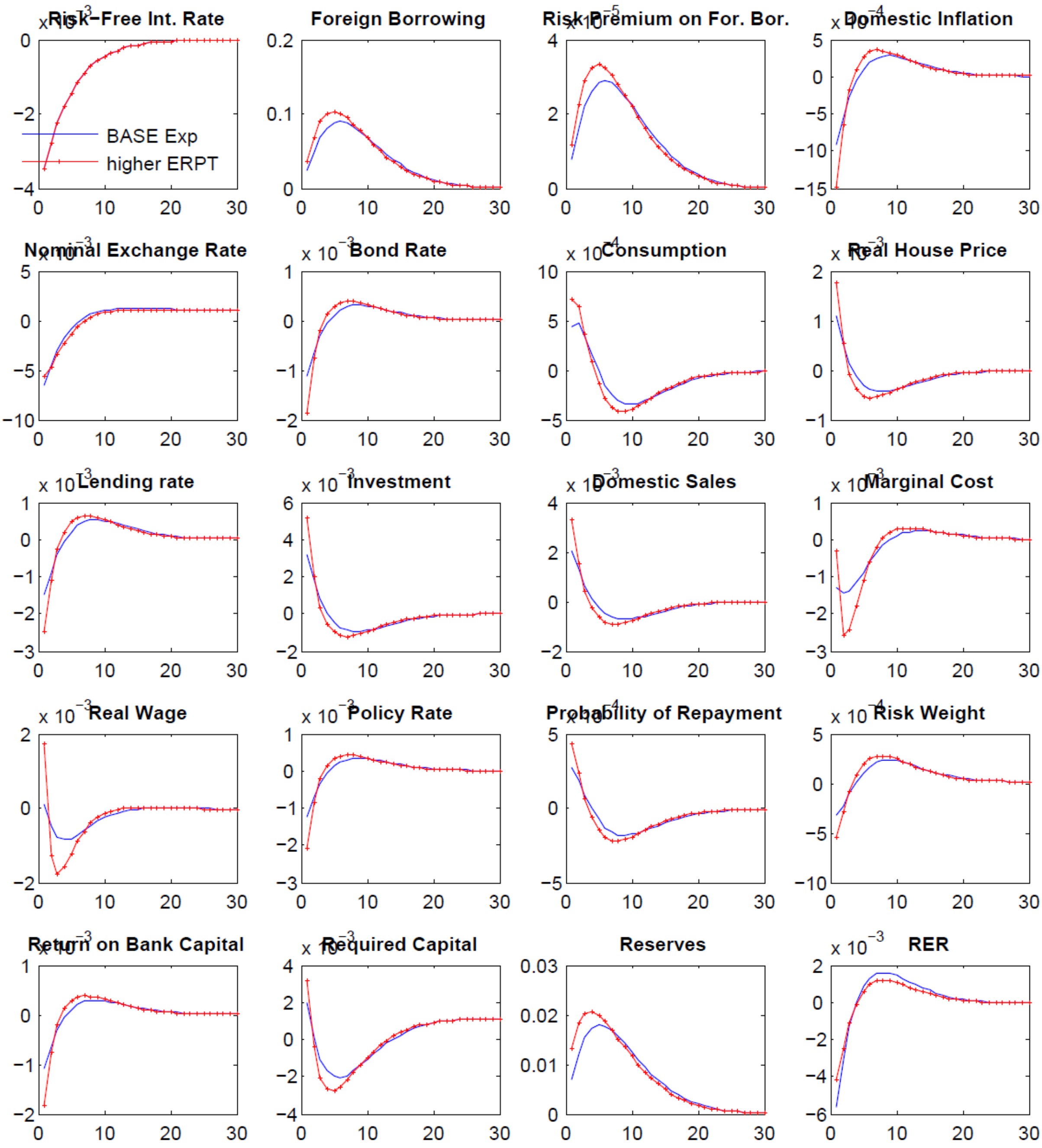


Figure 2
Base Experiment: Temporary Drop in World Risk-Free Interest Rate
(Deviations from Steady State)



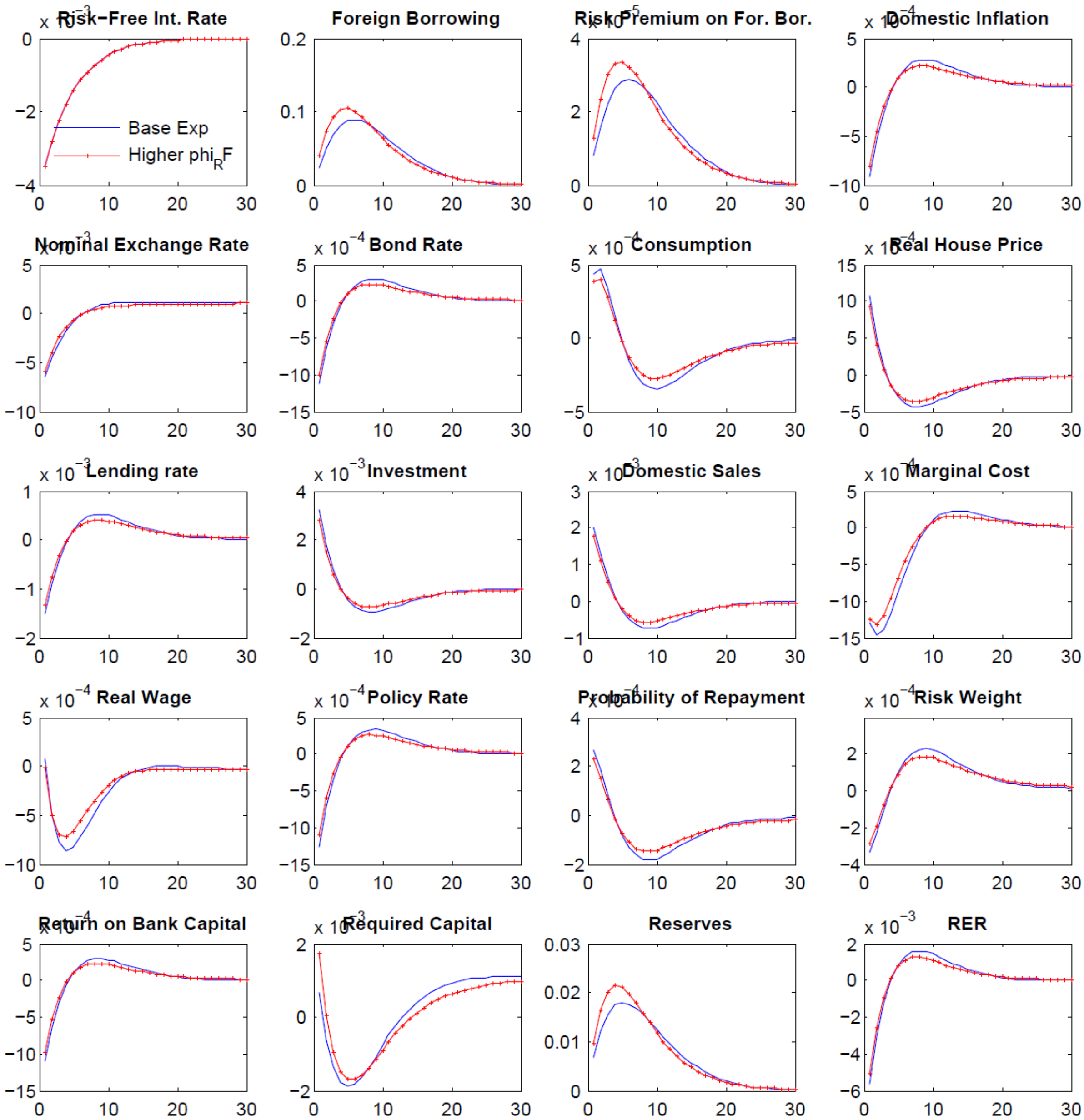
Note: Interest rates, inflation rate and the repayment probability are measured in absolute deviations, that is, in the relevant graphs a value of 0.05 for these variables corresponds to a 5 percentage point deviation in absolute terms. RER denotes the real exchange rate, defined in terms of the prices domestic and imported intermediate goods.

Figure 3
Increase in the Degree of Exchange Rate Pass-through
(Deviations from Steady State)



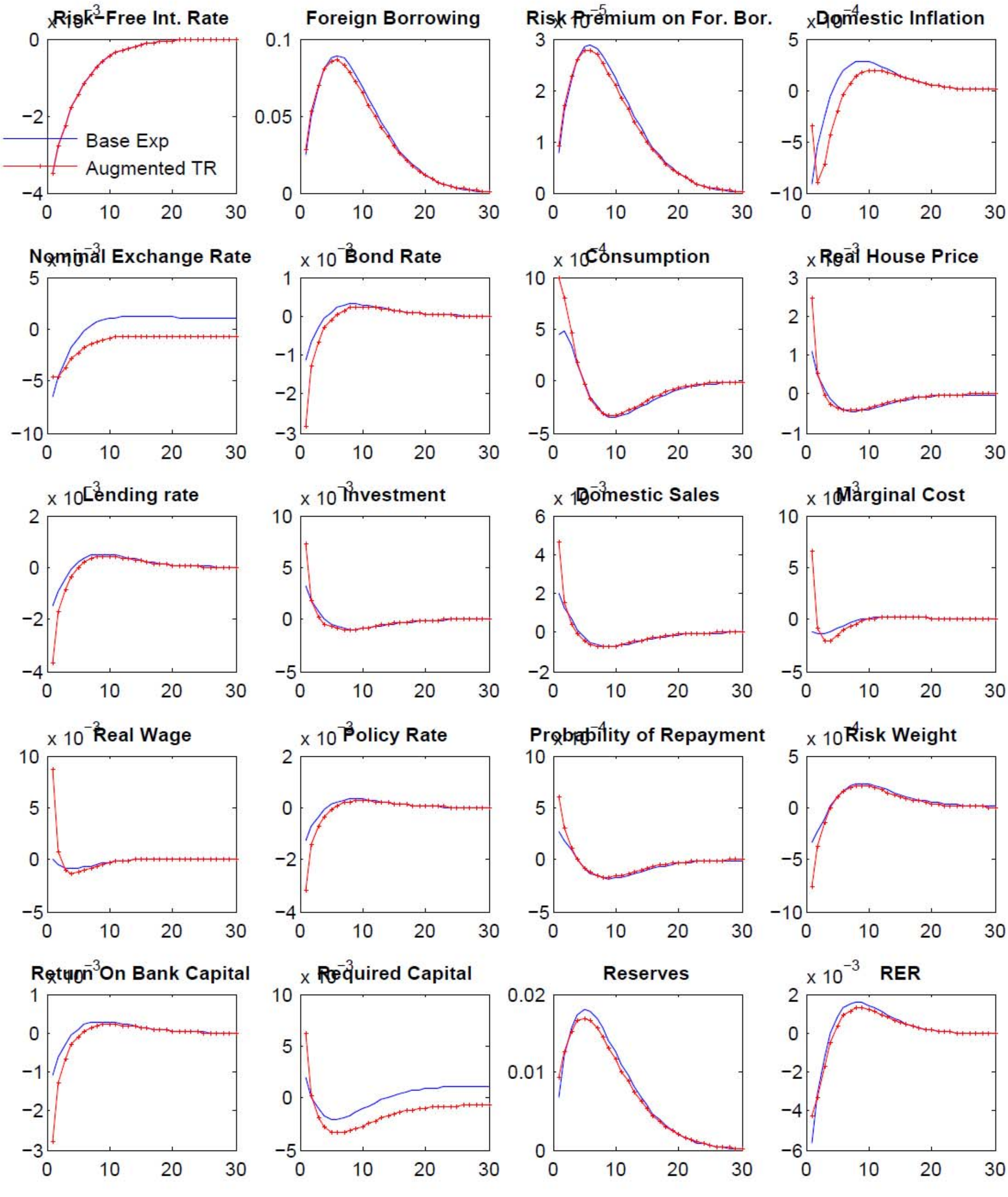
Note: See note to Figure 1.

Figure 4
Change in Speed of Adjustment to Reserve Target
(Deviations from Steady State)



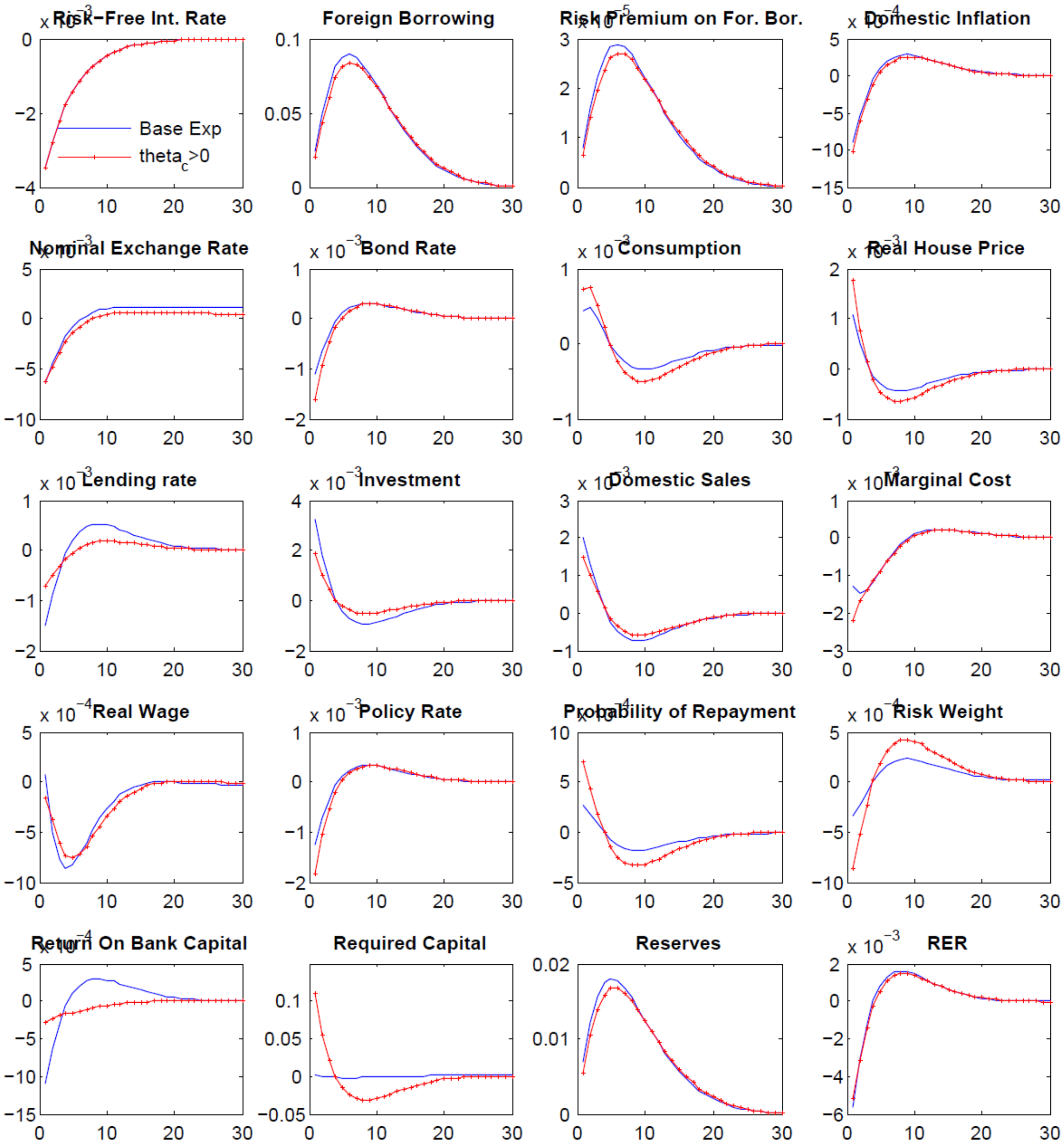
Note: See note to Figure 1.

Figure 5
Positive Response of Policy Rate to Exchange Rate Depreciation
(Deviations from Steady State)



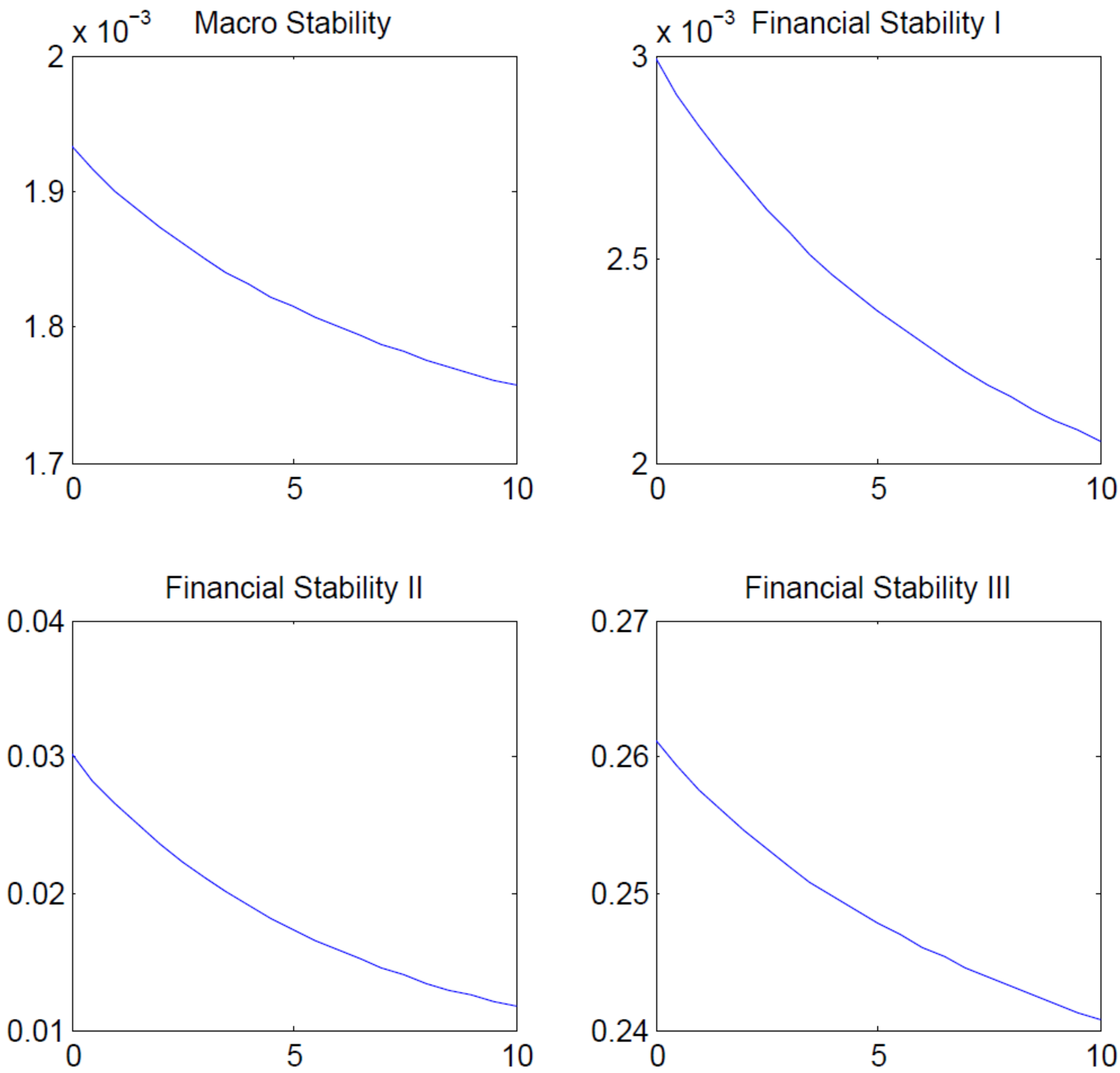
Note: See note to Figure 1.

Figure 6
Positive Response in Countercyclical Regulatory Capital Rule



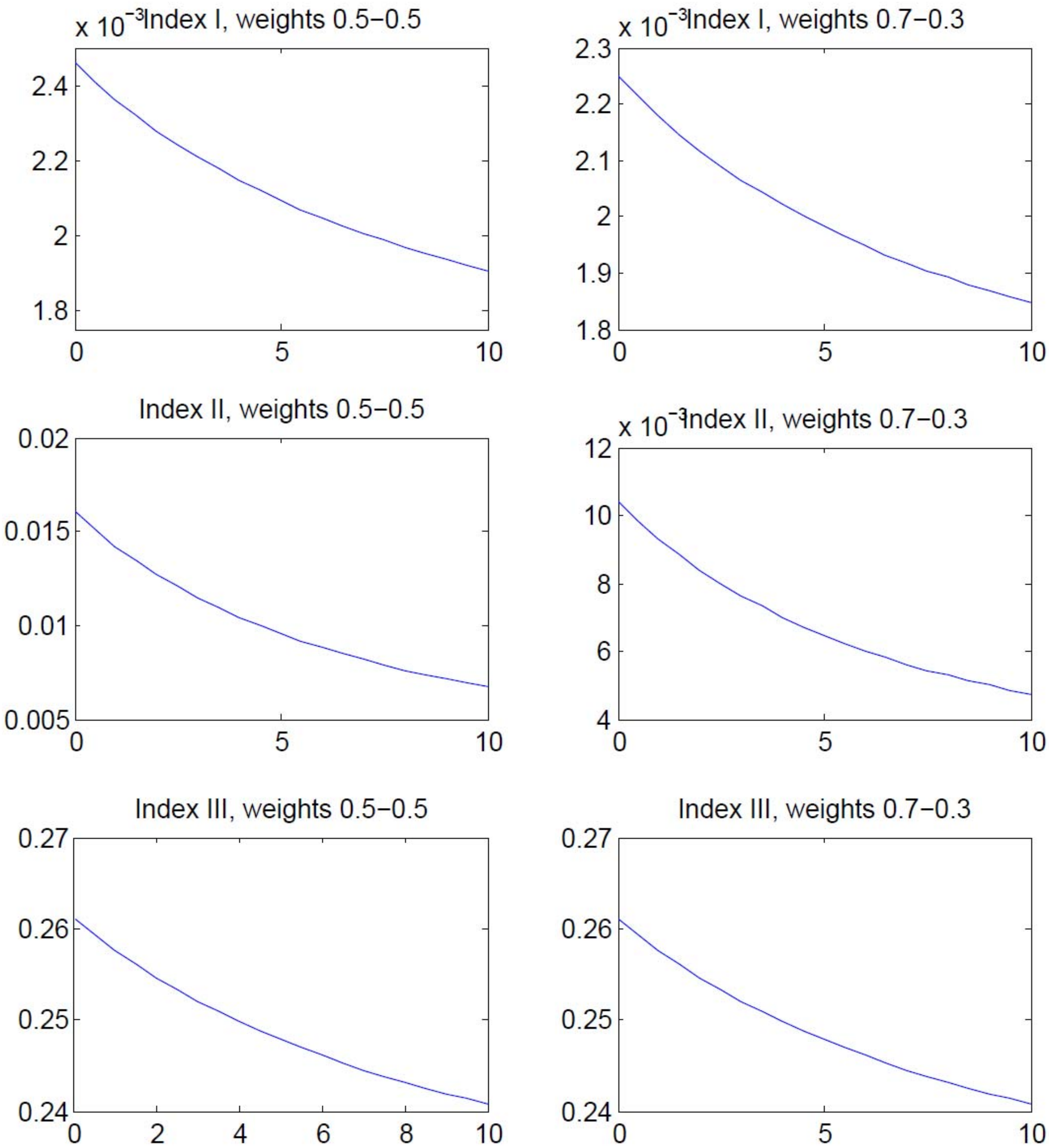
Note: See note to Figure 1.

Figure 7
Countercyclical Regulatory Capital Rule:
Impact on Macroeconomic Stability and Financial Stability



Note: The horizontal axis shows values of θ^C, and the vertical axis the coefficient of variation of the relevant variable. Macroeconomic stability is measured in terms of a weighted average of output volatility and inflation volatility, with weights of 0.3 and 0.7, respectively. Financial Stability I is defined in terms of real house price volatility and nominal exchange rate volatility, with equal weights. Financial Stability II is defined in terms of volatility of the ratio of total credit to GDP, and Financial Stability III is defined in terms of the volatility of the ratio of bank foreign borrowing (measured in domestic currency) to GDP.

Figure 8
Countercyclical Regulatory Capital Rule:
Impact on Composite Index of Economic Stability



Note: The horizontal axis shows values of θ^C, and the vertical axis the coefficient of variation of the relevant variable. Economic stability is defined in terms of a weighted average of the measure of macroeconomic stability and the three alternative measures of financial stability defined in the Note of Figure 7.