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# Sudden Floods, Macroprudential Regulation and Stability in an Open Economy

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**Abstract**

We develop a dynamic stochastic model of a middle-income, small open economy with a two-level banking intermediation structure, a risk-sensitive regulatory capital regime, and imperfect capital mobility. Firms borrow from a domestic bank and the bank borrows on world capital markets, in both cases subject to an endogenous premium. A sudden flood in capital flows generates an expansion in credit and activity, and asset price pressures. Countercyclical regulation, in the form of a Basel III-type rule based on real credit gaps, is effective at promoting macroeconomic stability (defined in terms of the volatility of a weighted average of inflation and the output gap) and financial stability (defined in terms of the volatility of a composite index of the nominal exchange rate and house prices). However, because the gain in terms of reduced volatility may exhibit diminishing returns, a countercyclical regulatory rule may need to be supplemented by other, more targeted, macroprudential instruments.

**JEL Classification Numbers**: E44, E51, F32.

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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 caused by the expansionary monetary policies of advanced 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 macro and financial stability at home. Indeed, "sudden floods" of private capital have been a source of macroeconomic instability in many of these countries, as a result of rapid credit and monetary expansion (due to the difficulty and cost of pursuing sterilization policies), real exchange rate appreciation, and widening current account deficits. In particular, the surge in capital flows to Latin America between early 2009 and mid 2011 has induced booms in credit and equity markets in many countries and raised concerns about asset price bubbles and financial fragility.[2] Sustained growth, abundant global liquidity and large interest rate differentials have attracted substantial inflows of capital, which have led to real appreciation, rapid credit growth, an expansion in economic activity, and pressures

[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]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.

on asset prices.[3] The scope for responding to the risk of macroeconomic and financial instability through monetary policy is somewhat limited, because higher domestic interest rates vis-à-vis zero interest floors prevailing in advanced economies may exacerbate the flood of private capital. So far, other measures (such as direct taxes on fixed income and equity inflows, and foreign exchange market intervention) have 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 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, Alper, and Pereira da Silva (2011). 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 (2008)). Domestic private borrowers face an upward-sloping supply curve of funds on world capital markets, and internalize the effect of capital

[3]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.

[4]According to recent 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.

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. (2007, 2009), 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 can obtain funds—both domestically and abroad. At the same time, domestic agents (in particular, capital good producers), 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 rate induces banks to borrow more in foreign currency. This reduces their domestic borrowing from the central bank and leads to a lower real bond rate, which stimulates current consumption and the demand for housing services. In turn, this raises real estate prices, which increases the value of collateral that firms can pledge and lower the loan rate, thereby stimulating investment. Capital floods may therefore generate an economic boom that is magnified by a financial accelerator effect, through their impact on the banks' balance sheets and pricing decisions.[7]

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[5] In the existing literature, to ensure a well-defined steady-state it is common to assume that the premium on foreign bond holdings depends on the aggregate net foreign asset position of domestic households. Adolfson et al. (2008) also introduce the expected change in the exchange rate in the specification of the premium, but this is largely arbitrary. Alternatively, Kollintzas and Vassilatos (2000) 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), and Elekdag et al. (2006, 2007), Guajardo (2008), and Leblebicioglu (2009).

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

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, capital regulation takes the form of a Basel III-type countercyclical rule, similar to the rule specified in Agénor, Alper and Pereira da Silva (2011). 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 created. 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 a composite measure involving the volatility of both house prices and exchange rates.

The remainder of the paper is organized as follows. Section II presents the model. The presentation of its closed-economy ingredients is kept as brief as possible, given that they are described at length in Agénor, Alper, and Pereira da Silva (2009, 2011). 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 III and some key features of the steady state are discussed in Section IV. An illustrative calibration is presented in Section V. 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 VI. Optimal regulatory policy is discussed in Section VII. Sensitivity tests, involving 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 VIII. The last section offers concluding remarks and discusses some potentially fruitful directions for future investigation.

[8] As noted later, accounting for the last feature would simply reinforce the 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, indexed by $j \in (0,1)$, which are imperfect substitutes to a continuum of imported intermediate goods, also indexed by $j \in (0,1)$. 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 intermediate good is produced or imported 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, who 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 short-term working capital needs. Its supply of loans is perfectly elastic at the prevailing lending rate. To satisfy capital regulations, it issues domes-

[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 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.

tic nominal debt at the beginning of time $t$, in line with the level of (risky) loans in its portfolio.[11] It also borrows on world capital markets and from the central 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 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. The central bank supplies liquidity elastically to the bank and alters its policy rate in response to inflation deviations from target and the output gap, 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

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

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

[11] This is consistent with the evidence which suggests that prior to the global financial crisis banks in some countries met capital requirements by issuing "hybrid" securities that are more like debt than equity. Even though the definition of capital has been tightened under the new Basel III rules (only stocks and retained earnings can count as Tier 1 capital, see Basel Committee on Banking Supervision (2010)), there is an ongoing debate as to whether banks should be allowed to hold capital not only in the form of core (Tier 1) equity but also in the form of loss-absorbing debt, such as contingent convertible bonds, which convert into equity once a bank's capital ratio falls below a certain level.

[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 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, $\mathbb{E}_t$ is 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 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, 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 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] It also pays a lump-sum tax, whose real value is $T_t$. The household then adjusts its demand for housing.

[13]The FG firm makes zero profits.

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

$$\Delta M_t^P + D_t + (B_t^P + E_t B_t^{F,P}) + P_t^H \Delta H_t + V_t \quad (4)$$
$$= P_t^S(\omega_t N_t - T_t) - P_t^S C_t + (1 + i_{t-1}^D)D_{t-1} + (1 + i_{t-1}^B)B_{t-1}^P$$
$$+(1 + i_{t-1}^{F,P})E_t B_{t-1}^{F,P} + (1 + i_{t-1}^V)V_{t-1} + J_t^I + J_t^K + J_t^B - \Theta_V \frac{V_t^2}{2},$$

where 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

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

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

$$\theta_t^{F,P} = \frac{\theta_0^{F,P}}{2} B_t^{F,P}, \quad (6)$$

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 (borrow, with $B_t^{F,P} < 0$) more on world capital markets only at a lower (higher) rate of interest; the latter captures the existence of *individual default risk*.[15]

Our treatment differs substantially from the "country risk" specification proposed by Benigno (2009) and often adopted in the open-economy New Keynesian literature; see, for instance, Lindé et al. (2009). 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 assets, $B_t^{F,P}$; in contrast with models of "pure" country risk, our formulation implies that the representative household internalizes the effect of its borrowing decisions on $\theta_t^{F,P}$, as discussed next.

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

[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 log-linearized before solving it.

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 $P_t$, and $T_t$. Let $1+\pi_{t+1}^S = P_{t+1}^S / P_t^S$ and let $\lambda_t$ 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

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

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

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

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

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

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

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

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

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

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

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

Combining (12) and (13) yields

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

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 $B_t^{F,P}$. Condition (14) can therefore be rearranged to give holdings of foreign bonds as

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

which shows that the optimal level of household holdings of foreign bonds is a function of the difference between the expected, depreciation-adjusted world safe interest rate and the domestic bond rate. Perfect capital mobility prevails when $\theta_0^{F,P} \rightarrow 0$, 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:

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

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

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

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).

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 goods:[16]

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

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,

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

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, $E_t W P^F_{jt}$; there is complete pass-through (that is, producer

[16] Combining equations (22) yields $Y^D_t / Y^F_t = [\Lambda_D/(1 - \Lambda_D)]^\eta (P^D_t / P^F_t)^{-\eta}$.

currency pricing) if and only if $\mu^F = 1$.[17] In general, the domestic-currency price of imports will reflect only partially current fluctuations of the nominal exchange rate.

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 the the domestic-currency price of exports of the final good, $P_t^X$, relative to the price of goods sold on the domestic market:[18]

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

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

There is a continuum of IG producers, indexed by $j \in (0, 1)$. Each firm producing domestic intermediate goods combines labor and capital to produce a distinct, perishable good that is sold on a monopolistically competitive market:

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

[17] 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), Lindé et al. (2004), Caputo et al. (2006), Adolfson et al. (2007), Senay (2008), Pavasuthipaisit (2010), and Shi and Xu (2010). Our assumption is that all importers follow a backward-looking pricing rule. This simplifies matters, given the focus of this study.

[18] Thus, exports are (indirectly) produced by using imported goods in addition to domestically-produced intermediate goods; see Christiano et al. (2007) for an alternative approach. Note also that we abstract from external demand factors.

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 rate $r_t^K$, measured in terms of the price of intermediate goods. 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.[19] 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 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.

With (29) holding with equality, total 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

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

As in Rotemberg (1982), domestic IG producers incur a 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

[19] 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.

domestic 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:[20]

$$\{P^D_{jt+s}\}^{\infty}_{s=0} = \arg\max \mathbb{E}_t \sum_{s=0}^{\infty} \beta^s \lambda_{t+s} (\frac{J^I_{jt+s}}{P^D_{t+s}}), \tag{32}$$

where $J^I_{jt+s}$ denotes nominal profits at $t$, defined as

$$J^I_{jt} = (P^D_{jt} - P^D_t mc_t) Y^D_{jt} - \frac{\phi_I}{2} (\frac{P^D_{jt}}{\tilde{\pi}^{D,G} P^D_{jt-1}} - 1)^2 Y^D_t. \tag{33}$$

Taking $\{mc_{t+s}, P^D_{t+s}, Y^D_{t+s}\}^{\infty}_{s=0}$ as given, the first-order condition for this maximization problem is:

$$\begin{aligned} &(1-\theta_D)\lambda_t (\frac{P^D_{jt}}{P^D_t})^{-\theta_D} \frac{Y^D_t}{P^D_t} + \theta_D \lambda_t (\frac{P^D_{jt}}{P^D_t})^{-\theta_D - 1} \frac{mc_{jt} Y^D_t}{P^D_t} \\ &-\lambda_t \phi_I \left\{ (\frac{P^D_{jt}}{\tilde{\pi}^{D,G} P^D_{jt-1}} - 1) \frac{Y^D_t}{\tilde{\pi}^{D,G} P^D_{jt-1}} \right\} \\ &+\beta \phi_I \mathbb{E}_t \left\{ \lambda_{t+1} (\frac{P^D_{jt+1}}{\tilde{\pi}^{D,G} P^D_{jt}} - 1) Y^D_{t+1} (\frac{P^D_{jt+1}}{\tilde{\pi}^{D,G} (P^D_{jt})^2}) \right\} = 0, \end{aligned} \tag{34}$$

which determines the adjustment process of the nominal price $P^D_{jt}$.

## 2.4 Production of Capital

At the beginning of the period, the CG producer buys an amount $I_t$ of the final good from the FG producer and combines it with the existing capital stock to produce new capital goods that will be used in the next period, $K_{t+1}$. The existing capital stock is then rented to IG producers, at the rate $r^K_t$. Aggregate capital accumulates as follows:

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

[20] 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.

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:

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

At the end of the period, loans are repaid in full, with interest. Thus, the total (interest-inclusive) cost of buying final goods for investment purposes is given by $(1+i_t^L)P_t^S I_t$, where $i_t^L$ is the lending rate.

The CG producer chooses the level of investment (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:

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

where $J_{t+s}^K$ denotes nominal profits at the end of period $t+s$ (or beginning of $t+s+1$), defined as

$$J_{t+s}^K = P_{t+s}^S r_{t+s}^K K_{t+s} - (1+i_{t+s-1}^L) P_{t+s-1}^S I_{t+s-1},$$

subject to (35).[21]

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

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

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

## 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 IG producers,

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

which use them 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 intermediate 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, $RR_t$.[22]

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.

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

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

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

where $\theta_0^{F,B} > 0$. Thus, the premium that the bank faces on world capital markets depends on how much it borrows.[23]

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 $\sigma_t$ 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:[24]

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

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:

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

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

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

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

[23] 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.

[24] See Agénor, Alper, and Pereira da Silva (2009) for a detailed discussion of this specification. Alternatively, under the Standardized Approach, $\sigma_t$ could be taken to be a function of the output gap, if ratings are assumed to be procyclical.

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

where $\kappa \in (0,1)$, $\gamma_D$, $\gamma_L$, $\gamma_V > 0$, $\gamma_{VV} \geq 0$, $\phi_E \in (0,1)$, and $q_t \in (0,1)$ is the repayment probability of the CG producer, and $\bar{H}$ the exogenous stock of housing, which produces a proportional supply of services.[25] The third term in this expression on the right-hand side, $q_t(1+i_t^L)P_t^{S,-1}L_t^I$, represents expected repayment on loans to the CG producer if there is no default. The fourth term represents what the bank expects to earn in case of default, that is, "effective" collateral, given by a fraction $\kappa \in (0,1)$ of "raw" collateral, which consists of the marked-to-market value of the housing stock.

The fifth 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) by the bank. The term $(1+i_t^V)P_t^{S,-1}V_t/$ represents the value of bank debt redeemed at the end of the period plus interest, 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, Alper, and Pereira da Silva (2009, 2011), that maintaining a positive capital buffer generates benefits—it signals that the bank's financial position is strong, and reduces the intensity of regulatory scrutiny.

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

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

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

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

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

[25] 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.

where $\eta_D$ is the interest elasticity of the supply of deposits to the deposit rate and $\eta_F$ the interest elasticity of the CG demand for loans (or investment) to the lending rate.

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 cost of borrowing abroad 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 $\gamma_V$) reduces excess capital, whereas an increase in $\gamma_{VV}$ raises excess capital.

As in Agénor, Alper, and Pereira (2009, 2010), and given the focus of this study, we adopt a reduced-form approach to model the repayment probability.[26] 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:

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

with $\varphi_1, \varphi_2 > 0$ and $y_t^G = Y_t/\bar{Y}_t$ is the output gap, with $\bar{Y}_t$ the frictionless level of aggregate output (that is, the level corresponding to $\theta_D = 0$).[27] We also abstract from the "monitoring incentive effect" associated with bank capital, as discussed in Agénor, Alper, and Pereira da Silva (2010, 2011), given that it plays no substantive role in the present analysis.

Figure 1 summarizes the links between bank capital, the repayment probability, and the loan rate in the model.

[26] Cúrdia and Woodford (2010) also use a quasi-reduced form to define bank spreads.

[27] In Agénor and Pereira da Silva (2011), 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).

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

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

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.

## 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 a self-insurance motive against volatile capital flows, or a desire to stabilize the exchange rate, 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 $R_t^{F,T}$, specified as a weighted average of shares of imports of intermediate goods and foreign liabilities of the private sector, $L_t^{F,B} - B_t^{F,P}$:

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

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

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

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

Using (42), equation (55) yields

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

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 off-balance-sheet items.

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

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

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, $\chi \in (0,1)$ 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 targeting inflation, the central bank also "leans against the wind" by raising (lowering) the policy rate when the nominal exchange rate depreciates (appreciates). We will consider subsequently an alternative specification, in which the central bank responds to fluctuations in the *real* exchange rate.

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

$$\rho_t = \rho^D + \rho_t^C. \quad (60)$$

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:

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

where $\theta^C > 0$. Thus, the macroprudential rule calls for a tightening of capital requirements when real credit exceeds beyond its steady-state value. This specification captures, in our view, the main idea behind the countercyclical capital buffer rule envisaged under Basel III Basel (see Committee on Banking Supervision (2010))—with the difference that here we do not impose any constraint on the range of values that $\rho_t^C$ can take.

## 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

$$B_t = (1 + i_{t-1}^B) B_{t-1}^P + B_{t-1}^C + P_t^S (G_t - T_t) \quad (62)$$

$$-i^R_{t-1}L^{C,B}_{t-1} - i^W_{t-1}E_{t-1}R^F_{t-1},$$

where $B_t = B^C_t + B^P_t$ 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:

$$G_t = \psi Y^S_t. \tag{63}$$

# 3 Equilibrium

In a symmetric equilibrium, firms producing intermediate goods are identical. Thus, $K_{jt} = K_t$, $N_{jt} = N_t$, $Y_{jt} = Y_t$, $P^D_{jt} = P^D_t$, 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 at $\tilde{\pi}$.

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

$$Y^S_t = C_t + G_t + I_t + \frac{\Theta_K}{2}\frac{(K_{t+1} - K_t)^2}{K_t}, \tag{64}$$

with the price of sales on the domestic market determined by rewriting the identity (27):

$$P^S_t = (P_t Y_t - P^X_t Y^X_t)/Y^S_t. \tag{65}$$

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

$$M^s_t = M^P_t + L_t, \tag{66}$$

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

$$M^P_t + D_t = B^C_t + E_t(R^F_t - L^{F,B}_t) - V_t, \tag{67}$$

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

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

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[28]

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

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, Alper, and Pereira da Silva (2009, 2011), 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 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

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

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

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

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 $\rho$.

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 (2009) and Agénor, Alper and Pereira da Silva (2009, 2011). 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, the coefficient of the rate of nominal exchange rate depreciation in the monetary policy rule, and the sensitivity of countercyclical bank capital to credit gaps.

Parameter values are summarized in Table 1. The discount factor $\beta$ is set at 0.985, which corresponds to an annual real interest rate of 6 percent. The intertemporal elasticity of substitution, $\varsigma$, is 0.6, in line with estimates for middle-income countries (see Agénor and Montiel (2008)). The preference parameter for leisure, $\eta_N$, 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, $\eta_x$, and housing, $\eta_H$, are set at the same low value, 0.02. The share parameter in the index of money holdings, $\nu$, 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, $\Lambda_D$, is set at 0.7, whereas $\eta$, 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 (e.g., Brazil). The elasticities of substitution between intermediate domestic goods among themselves, $\theta_D$, and imported goods among themselves, $\theta_F$ are set equal at 10. The pass-through elasticity 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, $\alpha$ , is set at 0.35. With $\theta_D = 10$, the steady-state value of the markup rate, $\theta_D/(\theta_D-1)$, is equal to 11.1 percent. The adjustment cost parameter for prices of domestic intermediate goods, $\phi_I$, is set at 74.5. The rate of depreciation of private capital, $\delta$, is set equal to 0.03, corresponding to an annual rate of 4 percent. The adjustment cost for transforming the final good into investment, $\Theta_K$, is set at 14.

For the parameters characterizing bank behavior, we assume that the effective collateral-loan ratio, $\kappa$, is 0.2. The adjustment cost parameter for holdings of bank debt, $\Theta_V$, 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 $\gamma_V$ and $\gamma_{VV}$ are also set at low values, 0.18, and 0.001, respectively. The parameter $\phi_E$, which captures the benefit associated with capital buffers, is set to 0.5. Given the specification of the risk weight $\sigma_t$ in (46), its steady-state value is equal to unity. The deterministic component of the capital adequacy ratio, $\rho^D$—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 Pillar 1 of Basel II. 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 (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. In order to focus the analysis on capital flows associated with bank foreign borrowing, we assume zero net holdings of foreign bonds by households.[29]

The reserve requirement rate $\mu^R$ 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 $\varepsilon_2$, 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 $\varphi^F = 1$, and we 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, $\varphi^R$, is set at 0.2. The parameter characterizing the countercyclical regulatory rule, $\theta^C$, is initially set at 0. Finally, the degree of persistence of the shock to the world risk-free rate, $\rho_W$, 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, one-period only, 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.[30] The magnitude of the shock is thus large enough to illustrate the thrust of the analysis.

The results are summarized in Figure 2, for 20 of the key variables. 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

[29] As a result, we do not fix a value for the parameter $\theta_0^{F,P}$.

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

exchange rate. In turn, the nominal appreciation lowers the domestic price of imported intermediate goods and stimulates 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.[31] At the same time, the increase in foreign borrowing by the 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, thereby reducing the repayment probability. But because the output gap 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 drop in inflation (measured in terms of the price of domestic sales), itself related to the fact that the nominal appreciation tends to lower the domestic-currency price of imported intermediate goods. Thus, aggregate demand (spending on the 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 domestic production allocated to exports, and an increase in the share of production 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 real wages resulting from the increased demand for labor associated with higher output.

[31] Because both the reserve target and bank foreign borrowing increase, the net foreign asset position of the economy is in general ambiguous. Given our calibration, it deteriorates, implying that the latter effect dominates the former.

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 (in terms of the price of goods sold on the domestic market) resulting from the 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 in terms of domestic prices.

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 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.[32] 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 very 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.[33]

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 (2008)) are not present. The

[32] 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.

[33] Of course, the fact that the shock to the world risk-free rate is assumed to show some persistence matters as well.

balance sheet effect, in this model, operates through changes in commercial bank liabilities: higher foreign borrowing feeds into the risk premium that the bank faces on world capital markets and falls only slowly over time; 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—despite the fact that the nominal appreciation that accompanies these inflows may mitigate somewhat the initial impact on inflation, and the fact that higher bank borrowing abroad does not lead directly to higher 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 in turn feed into the repayment probability, the loan rate and the policy rate—thereby promoting investment.[34] The expansionary mechanism is therefore indirect and depends crucially on bank pricing behavior.

At the same time, the analysis shows that the regulatory regime matters in the transmission of external shocks. Movements in the repayment probability feeds 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.[35] Put differently, 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), the nature of the regulatory regime also matters in assessing the dynamics of sudden floods in foreign capital.

[34] With liquidity-constrained consumers, as for instance in Agénor et al. (2011), the expansion in consumption would be larger than recorded in this experiment.

[35] Note also that the Basel II-type 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, Alper, and Pereira da Siva (2010)).

# 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, $\mu^F$, from 0.3 to 0.7. The results of this experiment are shown in Figure 3, together with the baseline results. On impact, a higher pass-through rate magnifies slightly 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 magnify 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 on world capital markets; this reduces its borrowing from the central bank, which tends to contract the monetary base. Because the former effect dominates, the supply of cash increases by more, 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, inducing households to increase consumption today by more as well. As a result, output expands by more, thereby inducing a larger increase in the repayment probability (a fall in the risk premium) and a larger positive effect on investment. 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. Thus, a higher pass-through rate magnifies the domestic effects of the shock and creates more volatility.

## 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, $\varphi^R$, 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 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 smaller 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, output expands by less. 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.

## 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, $\varepsilon_3$, 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.

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 risk premium) is now larger, and the initial expansion in investment is magnified. Because the nominal exchange rate is expected to depreciate by a bit more, the increase in bank foreign borrowing is less marked, implying now (based on the reasoning outlined earlier) a larger drop in the nominal bond rate. As a result, consumption today increases by more initially. 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 drop in the cost of short-term borrowing. 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 other variables are more volatile.

# 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 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 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 affects economic instability. We do so while keeping the interest rate rule as in the base experiment, that is, without response to exchange rate depreciation.

Consider an increase in the parameter characterizing the countercyclical regulatory rule, $\theta^C$ in (61), from an initial value of 0 to 5. The outcome of this experiment is shown in Figure 6. In line with the results in Agénor, Alper, and Pereira da Silva (2011), despite inducing higher volatility in bank capital, the presence of the rule mitigates the 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.

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. Indeed, Figure 5 shows that the cost of bank capital drops by much less than in the baseline 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.

However, 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, and inducing in the process a larger response in consumption.[36] Indeed, in the case considered here, with the initial appreciation translating into lower inflation, the presence of the countercyclical regulatory rule implies that the policy rate needs to decline by more than otherwise, and this eventually leads to a larger increase in consumption. The reason is that with a larger drop in the policy (and deposit) rate, and by implication lower bank deposits, borrowing from the central bank increases, and this would bring a larger increase in the supply of cash—requiring therefore a larger drop in the bond rate to equilibrate the currency market. This, in turn, would induce 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 value 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

[36]In principle for this effect to operate what is needed is an increase in $\sigma_t\rho_t$, not only an increase in $\rho_t$. For the shock considered here, this is indeed the case, even though $\sigma_t$ falls. Note also that, the endogeneity of $\sigma_t$ means that the impact of an increase in $\rho_t$ is mitigated, making the countercyclical rule less effective. This is again an illustration of the Basel II-type regime being more procyclical than a Basel I-type, in which the risk weight is constant.

more volatile bank capital (as can be expected) but also increased volatility in consumption and asset prices—and, by implication, other macroeconomic variables.

This volatility trade-off has important implications for the effectiveness of countercyclical regulatory rules and how aggressive these policies should be. As in Agénor, Alper, and Pereira da Silva (2011), 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.[37] The latter objective is defined in terms of the coefficient of variation of 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.[38] Thus, financial volatility is measured in real terms, as a mix of both types of asset prices.[39] In addition, we define a *composite index* of economic stability, defined with two sets of weights: first with equal weight 0.5 to each objective of stability, and second with a weight of 0.8 for macroeconomic stability and 0.2 for financial stability.[40]

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 drop in the world risk-free rate), and for values of $\theta^C$ varying between 0 and 10.[41] The figure suggests that there is no trade-off

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

[38] The results are not highly sensitive to these weights.

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

[40] 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.

[41] Of, the maximum value of 10 is rather arbitrary, but this is sufficient to illustrate our

among policy objectives: a stronger response of regulatory capital to credit gaps leads, in either case, 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 (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 coefficient, $\sigma\rho$, in the loan rate-setting equation (see (50)); but as $\theta^C$ increases, it becomes also stronger. 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.[42]

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. However, in a setting where banks must indeed meet capital requirements by issuing costly debt, as is the case here, the ability of a countercyclical regulatory rule to mitigate reduce macroeconomic and financial volatility may be limited beyond a certain point. The same conclusion would naturally hold in a "mixed" system where capital is built through both profit accumulation and capital issuance, the only difference being that decreasing marginal returns (in terms of reduce

purpose.

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

volatility) would begin to appear at a higher value of $\theta^C$.

Thus, to the extent that monetary policy has limited room for manoeuvre (given the nature of the shock), a countercyclical regulatory rule is a complementary instrument—at least with respect to the shock considered—because it helps to improve outcomes relative to both objectives. However, given 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 to mitigate macroeconomic and financial imbalances.

# 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. We 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 pressure on asset prices and an economic boom, the magnitude of which depends on bank pricing behavior and the nature of the 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. Given the nature of the shock that we consider, the reason for making that assumption is that the central bank is concerned that by raising interest rates it runs 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 policy 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 a composite index involving nominal exchange rate volatility and volatility in real house prices. However, the gain in terms of reduced volatility may exhibit diminishing returns beyond a certain point—essentially because regulatory-induced volatility in capital holdings translates into volatility in lending and other macroeconomic and financial variables, including foreign bank borrowing and the exchange rate. In the end, an aggressive countercyclical capital regulatory rule may do little to reduce the volatility of capital flows. These results suggest that a countercyclical regulatory policy may need to be supplemented by other, more targeted, macroprudential instruments, such as loan-to-value, debt-to-income, and leverage ratios. 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 expansion stems from the fact that foreign investors were very involved in swap agreements with long maturities. In these transactions, foreigners swap 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. Thus, capital inflows not only provided ample foreign exchange liquidity to banks but also the opportunity to transform these funds to longer-term domestic-currency loans. In recent years, 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 controls on capital inflows, for instance by introducing a specific tax on bank borrowing abroad. Capital controls, unlike prudential tools, typically involve discriminating between residents and non-residents. In general, the evidence on their benefits is mixed; there is no firm support to the view that they can be effective at preventing financial instability and currency crises.[43] However, several countries continue to use them (e.g., Brazil, in the form of a direct tax on fixed income and equity inflows) in the aftermath of the recent global financial crisis. Because the effectiveness of controls is likely to differ both across countries as well as over time, it would be worth exploring their use in a context where mitigating instability (rather than preventing crises) is a key policy objective. Indeed, the issue here is to which short-term capital controls can help to improve macroeconomic and financial stability. There has been a paradigm shift in institutions like the International Monetary Fund (2011), which suggests that capital controls have proved effective, at least to some extent, in improving macroeconomic stability; the question that remains unanswered is the extent to which they can help to improve financial stability, and if, under what conditions. Some types of capital controls (e.g., exposure limits on foreign-currency borrowing, or reserve requirements on foreign-currency deposits in domestic banks) are tantamount to prudential measure—which are especially important when inflows are intermediated through the regulated financial system. In the model, this could be accounted for by assuming that foreign borrowing by domestic banks is subject to a tax.

Notwithstanding these extensions, our analysis provides an important framework for investigating the dilemmas that policymakers in middle-income countries have faced in the aftermath of the global financial crisis, and options to respond to them. This has become especially relevant after the implementation of unprecedented, unconventional monetary policy measures first by the Federal Reserve Board and more recently the European Central Bank. These measures resulted *de facto* in adding to an already low inter-

[43]See Edwards and Rigobon (2009), Binici, Hutchison, and Schindler (2010), Glick and Hutchison (2011), and the overview in Agénor (2011).

est rate environment the provision of ample liquidity to the global financial system, thus exacerbating the features of our scenario of "sudden floods". In many countries the policy response involved combining standard monetary policy reaction to rising inflationary pressures with macroprudential measures (including higher bank capital requirements) to dampen the potentially destabilizing effects of large capital flows on asset prices and credit markets. These policies have been largely effective although in some cases their combination, in the context of well-established inflation targeting regimes, might have complicated the task of forecasting inflation and anchoring expectations. Our analysis has helped to shed light on the conditions under which the combination of monetary and macroprudential policies can help to address the policy challenges created by large capital inflows.

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Table 1
Benchmark Calibration: Key Parameter Values

| Parameter | Value | Description |
|---|---|---|
| *Household* | | |
| $\beta$ | 0.985 | Discount factor |
| $\varsigma$ | 0.6 | Elasticity of intertemporal substitution |
| $\eta_N$ | 4.5 | Preference parameter for leisure |
| $\eta_x$ | 0.02 | Preference parameter for money holdings |
| $\eta_H$ | 0.02 | Preference parameter for housing |
| $\nu$ | 0.35 | Share parameter in index of money holdings |
| $\Theta_V$ | 1.0 | Adjustment cost parameter, holdings of bank debt |
| *Production* | | |
| $\Lambda_D$ | 0.7 | distribution parameter, final good |
| $\eta$ | 0.8 | Elasticity of substitution, baskets of IG goods |
| $\mu^F$ | 0.3 | Adjustment speed, imported intermediate goods |
| $\varkappa$ | 0.7 | Price elasticity of exports |
| $\theta_D, \theta_F$ | 10.0 | Elasticity of demand, intermediate goods |
| $\alpha$ | 0.35 | Share of capital, domestic intermediate goods |
| $\phi_I$ | 74.5 | Adjustment cost parameter, IG prices |
| $\delta$ | 0.03 | Depreciation rate of capital |
| $\Theta_K$ | 14 | Adjustment cost parameter, investment |
| *Commercial Bank* | | |
| $\kappa$ | 0.2 | Effective collateral-loan ratio |
| $\varphi_1$ | 0.03 | Elasticity of repayment prob, collateral |
| $\varphi_2$ | 1.5 | Elasticity of repayment prob, cyclical output |
| $\varphi_q$ | 1.25 | Elasticity of risk weight, prob of repayment |
| $\gamma_V$ | 0.18 | Cost of issuing bank capital |
| $\gamma_{VV}$ | 0.001 | Benefit of holding excess bank capital |
| $\rho^D$ | 0.08 | Capital adequacy ratio (deterministic component) |
| *Central bank* | | |
| $\mu^R$ | 0.1 | Reserve requirement rate |
| $\chi$ | 0.0 | Degree of interest rate smoothing |
| $\varphi^R$ | 0.2 | Speed of adjustment to reserve target |
| $\varepsilon_1$ | 2.5 | Response of refinance rate to inflation deviations |
| $\varepsilon_2$ | 0.2 | Response of refinance rate to output gap |
| $\varepsilon_3$ | 0.0 | Response of refinance rate to nominal depreciation |
| $\rho_W$ | 0.8 | Persistence, shock to world risk-free rate |

**Figure 1**
**Bank Capital, Repayment Probability and the Lending Rate**

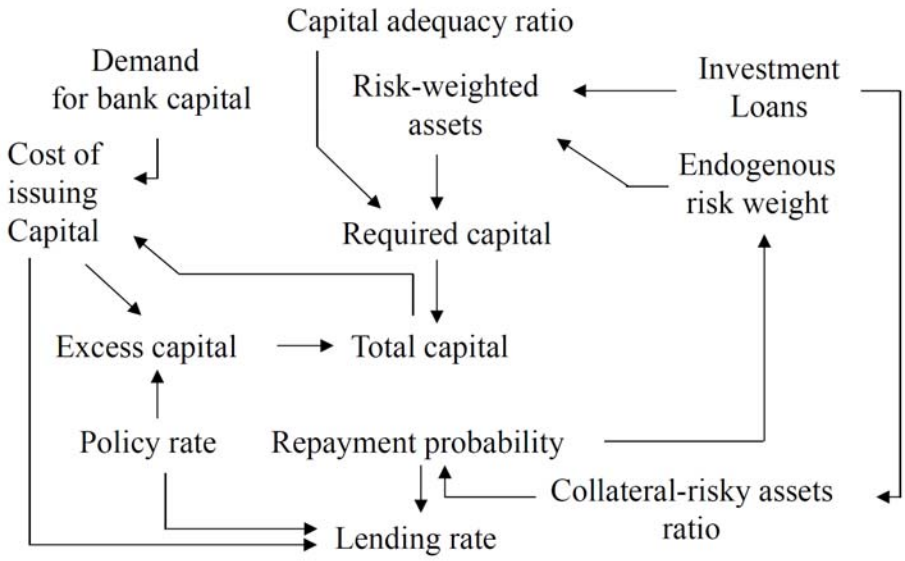
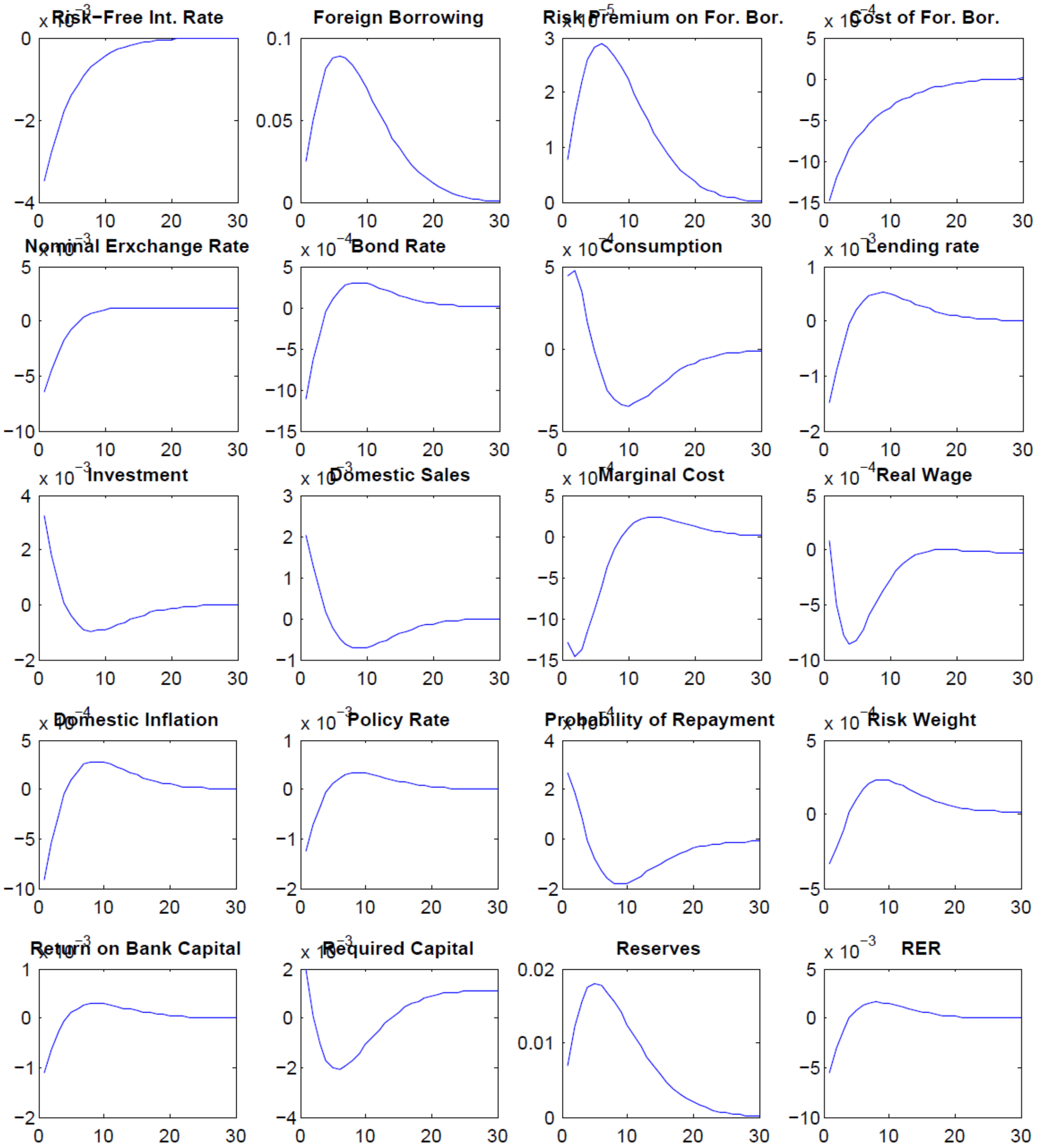


**Figure 2**

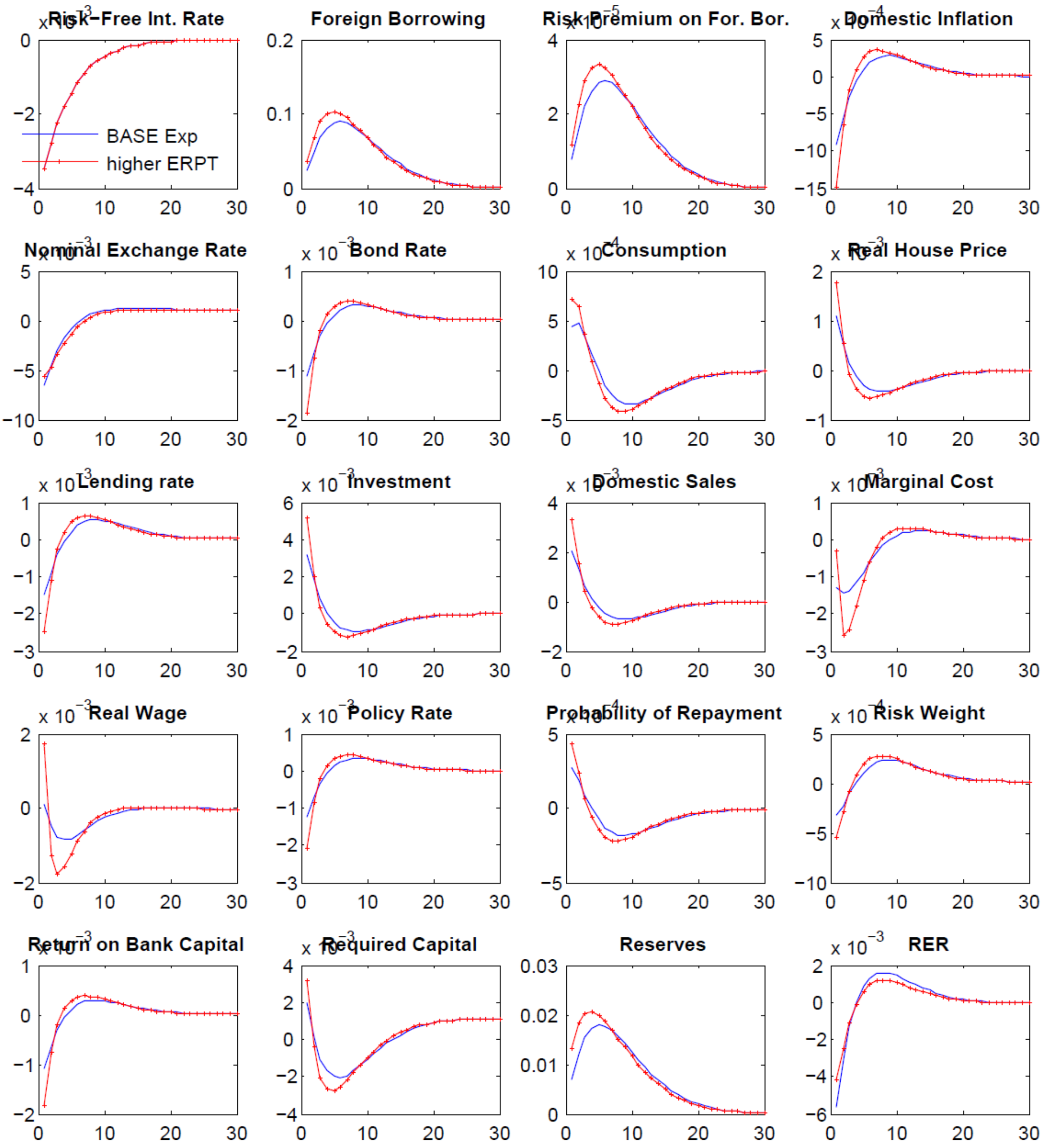
**Base Experiment: Temporary Drop in World Risk-Free Interest Rate**

(Deviations from Steady State)



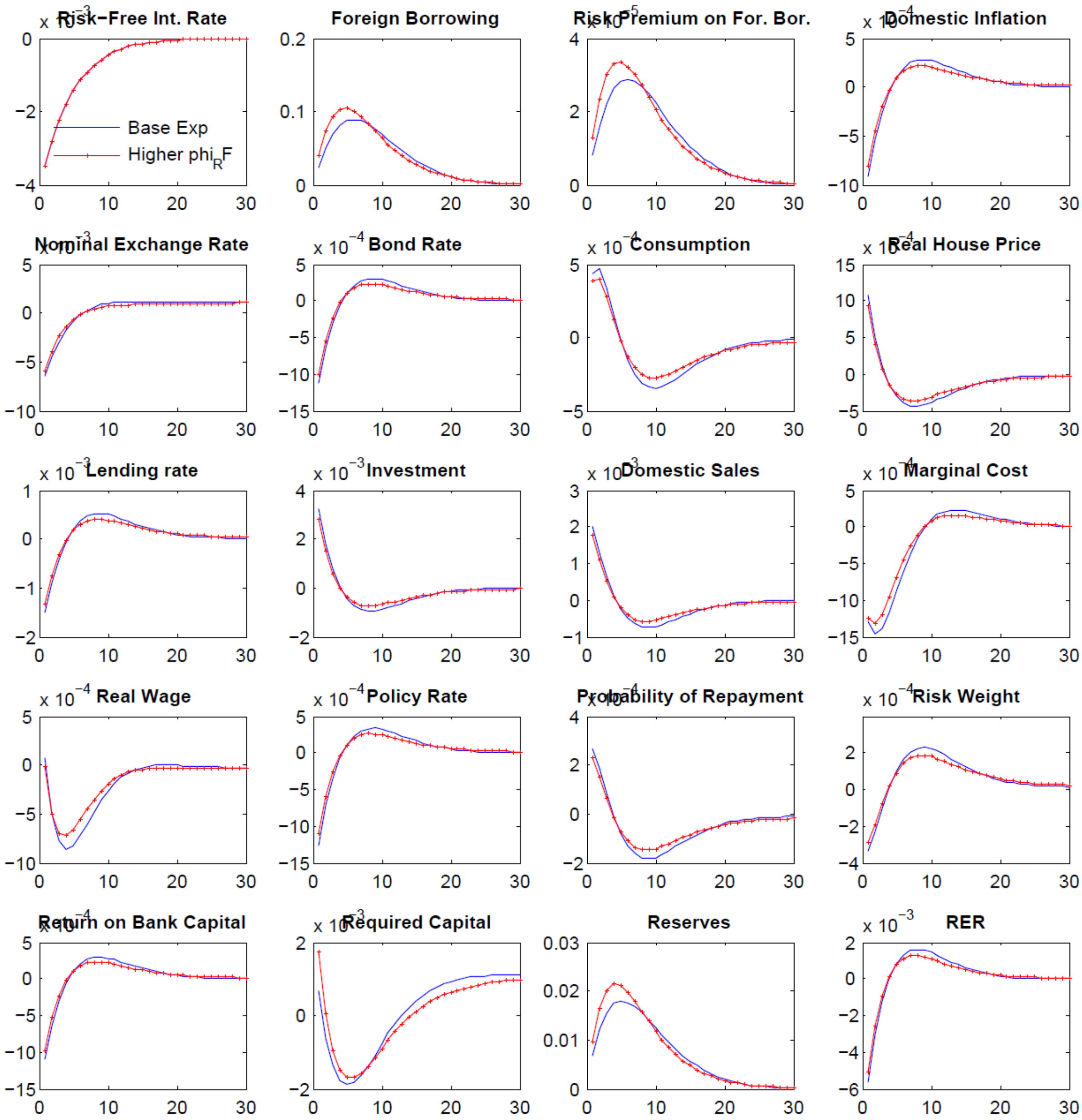

Note: Interest rates, inflation rate and the repayment probability are measured in absolute deviations, that is, in the relevant graphs a value of 0.05 for these variables corresponds to a 5 percentage point deviation in absolute terms. RER denotes the real exchange rate, defined in terms of the prices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

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



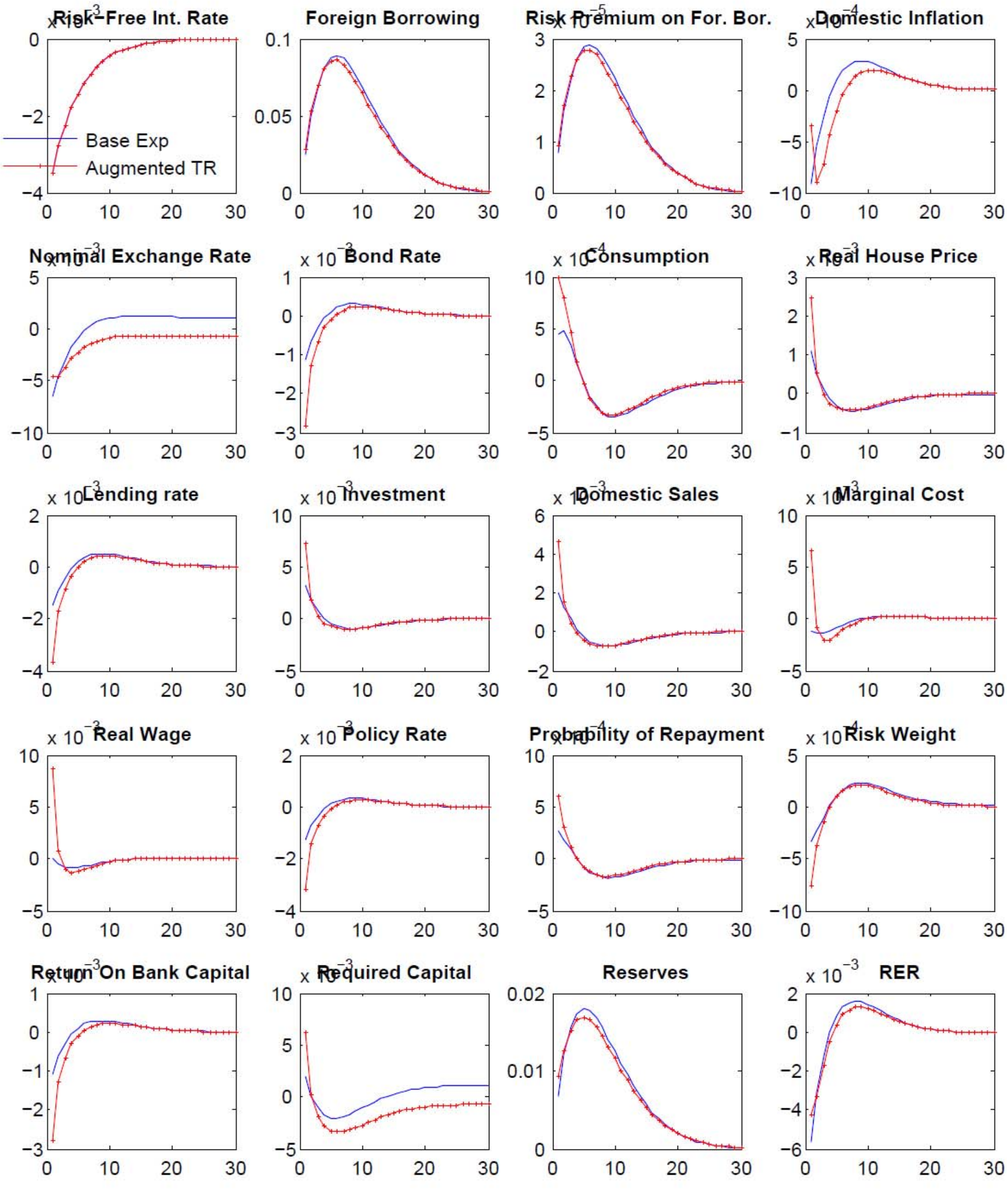

Note: See note to Figure 1.

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



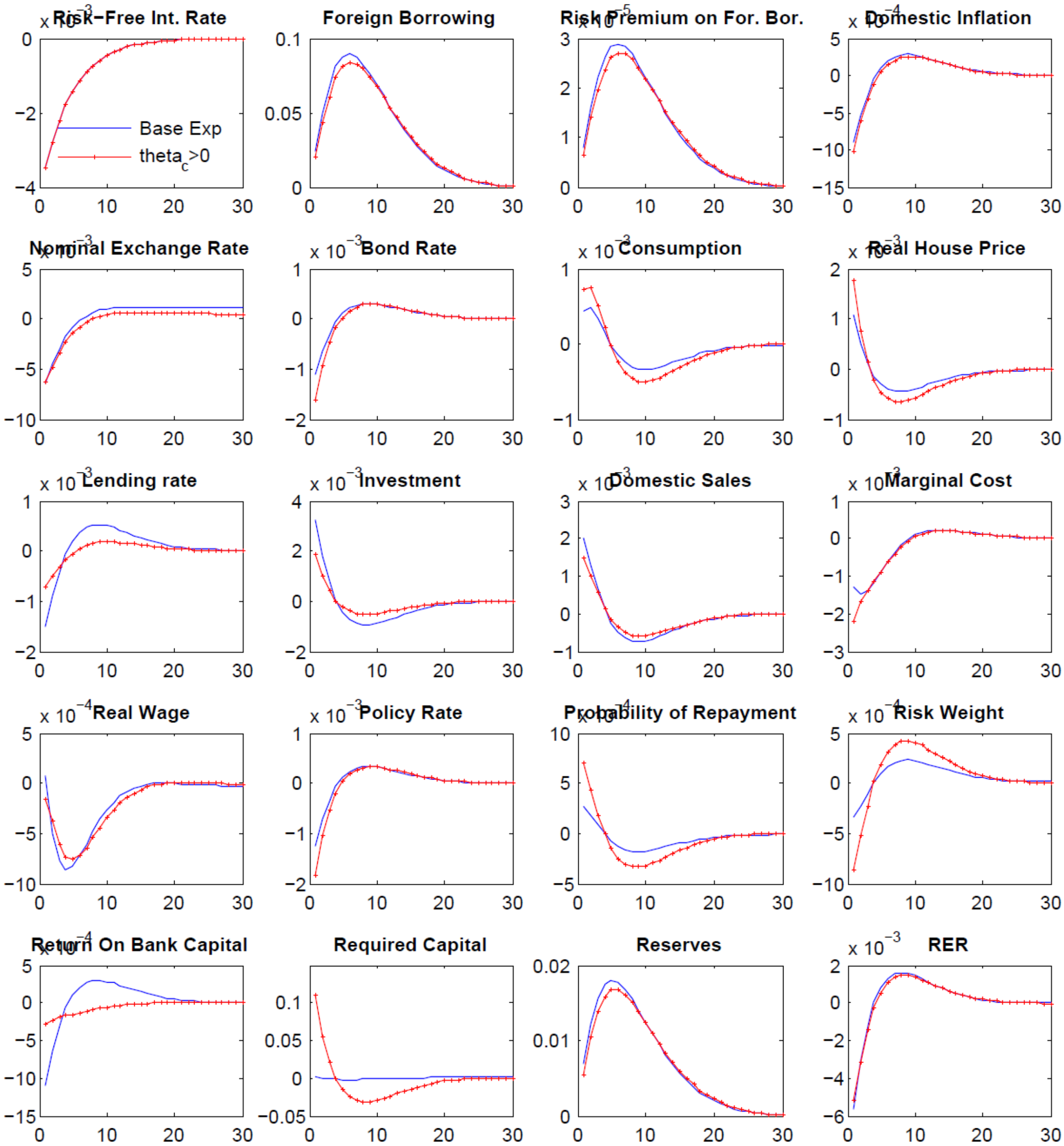

Note: See note to Figure 1.

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



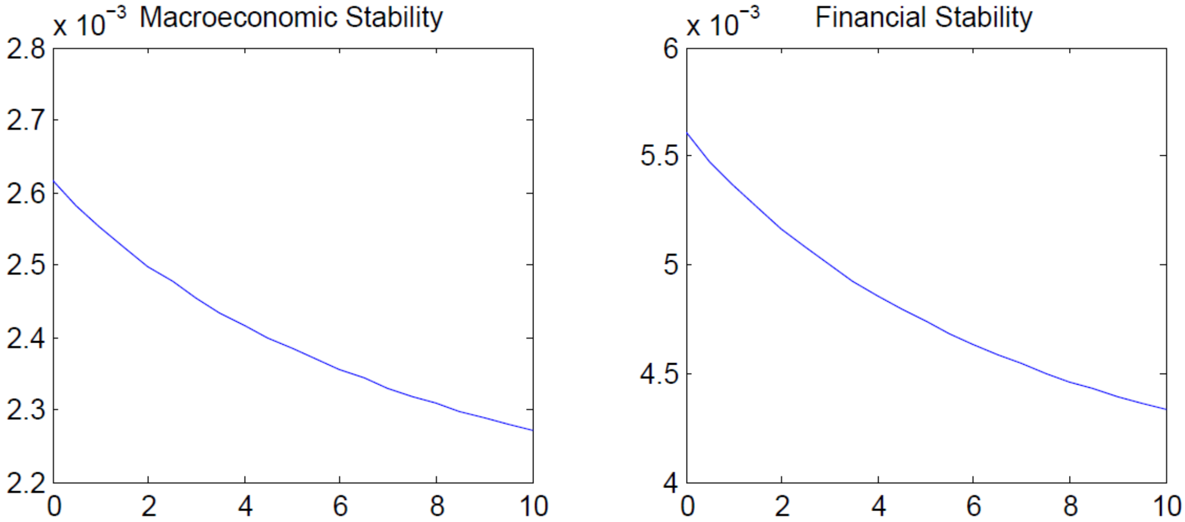

Note: See note to Figure 1.

# Figure 6
# Positive Response in Countercyclical Regulatory Capital Rule



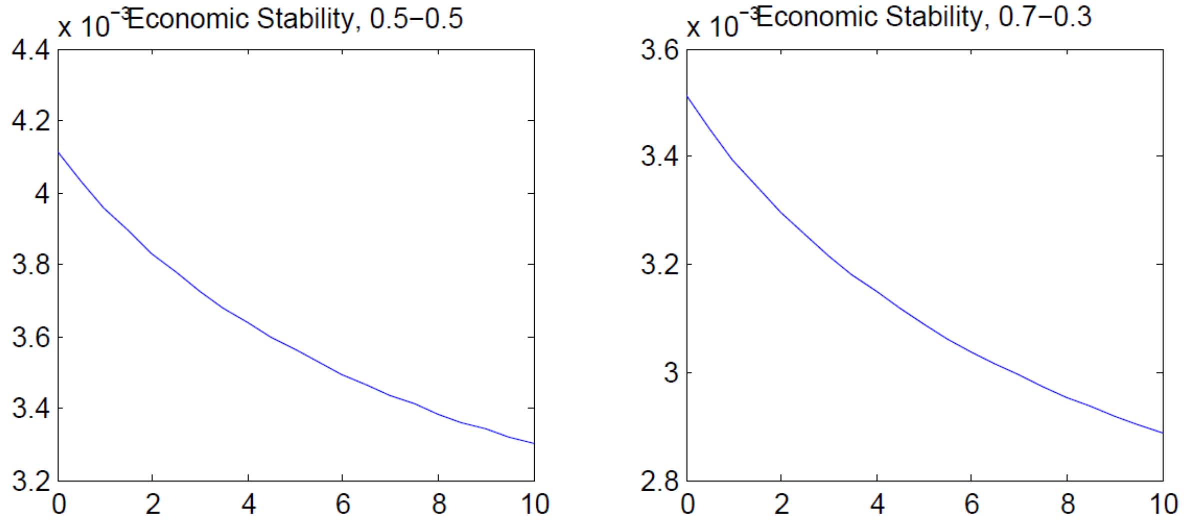

Note: See note to Figure 1.

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




Note: The horizontal axis shows values of $\theta^C$, and the vertical axis the coefficient of variation of the relevant variable. Macroeconomic stability is measured in terms of nominal income stability, defined in terms of output and price of the final good, with equal weights. Financial stability is defined in terms of real house price volatility and nominal exchange rate volatility, with equal weights.

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




Note: The horizontal axis shows values of $\theta^C$, and the vertical axis the coefficient of variation of the relevant variable. Economic stability is defined in terms of nominal income stability and financial stability.