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. The central bank accumulates reserves on the basis of both trade and financial factors. A "sudden flood" in capital flows, consistent with the post-crisis global excess liquidity conditions, generates an expansion, asset price increases, and inflationary pressures. Countercyclical capital regulation, taking the form of a Basel III-type rule based on credit growth gaps, is quite effective (up to a certain point) at promoting 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.

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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 usually play an important role in financial crises (in the form of either overvalued exchange rates, excessive short-term foreign borrowing, or growing fiscal and current account imbalances), 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 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), inflationary pressures, real exchange rate appreciation, and widening current account deficits. In particular, the surge in capital flows to Latin America since 2008 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, and pressures on asset prices and consumer prices. The scope for responding to the risk of macroeconomic and financial insta-

[1] See Agénor (2011) 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.

bility 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. 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 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.[3] 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 de-

[3] 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.

cisions 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.[4] 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.[5]

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 not only the volatility of real house prices but also the volatility of (real and nominal) 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

[4] 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).

[5] 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.

here departs from those papers, especially with respect to the financial sector and the countercyclical regulatory rule. 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 large and 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.

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.[6] 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.[7] The final good is consumed by the household and the government, used for investment (subject to additional costs) by the CG producer, or exported.

[6] 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.

[7] In Turkey for instance, during the period 2006-09, the share of intermediate goods in total imports exceeded 68 percent. 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.

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 domestic nominal debt at the beginning of time t, in line with the level of (risky) loans in its portfolio.[8] 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.[9] Finally, capital mobility is

[8] 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, there is an ongoing debate as to whether banks should be allowed to hold capital not only in the form of core (tier one) 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.

[9] 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.

2.1 Household

The objective of the representative household is to maximize

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

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 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, and real bank deposits, d_t, both at the beginning of period t:

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

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

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

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

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

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.

in $t-1$, i^D_{t-1}, principal and interest payments on maturing domestic and foreign government bonds, at rates i^B_{t-1} and $i^{F,P}_{t-1}$ respectively, and principal and interest payments on bank debt, at rate i^V_{t-1}.

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 $\omega_t = W_t/P^S_t$ 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, $J^I_t = \int_0^1 J^I_{jt}dj$, the CG producer, J^K_t, and the bank, J^B_t, which is (as noted earlier) liquidated at the end of the period.[10] It also pays a lump-sum tax, whose real value is T_t. The household then adjusts its demand for housing.

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

$$\Delta M^P_t + D_t + (B^P_t + E_t B^{F,P}_t) + P^H_t \Delta H_t + V_t \tag{4}$$

$$= P^S_t(\omega_t N_t - T_t) - P^S_t C_t + (1+i^D_{t-1})D_{t-1} + (1+i^B_{t-1})B^P_{t-1}$$

$$+(1+i^{F,P}_{t-1})E_t B^{F,P}_{t-1} + (1+i^V_{t-1})V_{t-1} + J^I_t + J^K_t + J^B_t - \Theta_V \frac{V^2_t}{2},$$

where the last term represents transactions costs associated with changes in holdings of bank debt, with $\Theta_V > 0$ denoting an adjustment cost parameter.[11] For simplicity, we assume that housing does not depreciate.

The rate of return on foreign bonds is defined as

$$1 + i^{F,P}_t = (1 + i^W_t)(1 - \theta^{F,P}_t), \tag{5}$$

where i^W_t is the risk-free world interest rate and $\theta^{F,P}_t$ an endogenous spread, defined as

$$\theta^{F,P}_t = \frac{\theta^{F,P}_0}{2} B^{F,P}_t, \tag{6}$$

where $\theta^{F,P}_0 > 0$. As discussed at length in Agénor (1997, 1998, 2006) this specification reflects the view that the household is able to lend (borrow, with $B^{F,P}_t < 0$) more on world capital markets only at a lower (higher) rate of interest; the latter captures the existence of *individual default risk*.[12]

[10] The FG firm makes zero profits.

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

[12] A more general specification would be to specify the risk premium as a convex curve, with a binding constraint when $B^{F,P}_t$ is sufficiently high. However, this does make much difference here, given that the model is log-linearized before solving it.

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.

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 λ_t denote the shadow price associated with constraint (4). Maximizing (1) subject to (2)-(6) yields the following first-order conditions

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

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

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

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

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

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

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

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

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

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

which yields the standard interest parity under perfect capital mobility, $1 + i_t^B = \mathbb{E}_t[(1+i_t^W)(E_{t+1}/E_t)]$ if $\theta_0^{F,P} \to 0$. In general, however, equation (17) shows that (deviations in) the optimal level of household holdings of foreign bonds is a function of the conventionally-measured covered interest rate differential, given by the difference between the after-tax domestic bond rate and the expected, depreciation-adjusted world safe interest rate.

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_{jt}^i 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_{jt}^D denote the price of domestic intermediate good j set by firm j, and P_{jt}^F the price of imported intermediate good j, in domestic currency. Cost minimization yields the demand functions for each variety of intermediate goods:

$$Y_{jt}^i = (\frac{P_{jt}^i}{P_t^i})^{-\theta_i} Y_t^i, \quad i = D, F \tag{20}$$

where P_t^D and P_t^F are price indices for domestic and imported intermediate goods, respectively:

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

Aggregating across firms yields the allocation of total demand between domestic and foreign goods:[13]

$$Y_t^D = \Lambda_D^\eta (\frac{P_t^D}{P_t})^{-\eta} Y_t, \quad Y_t^F = (1-\Lambda_D)^\eta (\frac{P_t^F}{P_t})^{-\eta} Y_t, \tag{22}$$

[13] Combining equations (22) yields $Y_t^D/Y_t^F = [\Lambda_D/(1-\Lambda_D)]^\eta (P_t^D/P_t^F)^{-\eta}$.

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

$$P_t = [\Lambda_D^{\eta}(P_t^D)^{1-\eta} + (1-\Lambda_D)^{\eta}(P_t^F)^{1-\eta}]^{1/(1-\eta)}. \tag{23}$$

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,

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

where WP_{jt}^F 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, $E_t W P_{jt}^F$; there is complete pass-through (that is, producer currency pricing) if and only if $\mu^F = 1$.[14] 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^N, and exports, Y_t^X, we assume the existence of a constant elasticity of transformation (CET) function, of the form[15]

$$Y_t = \left[\Gamma_Y (Y_t^N)^{1+1/\upsilon} + (1-\Gamma_Y)(Y_t^X)^{1+1/\upsilon}\right]^{\upsilon/(1+\upsilon)}, \tag{25}$$

where $\Gamma_Y \in (0,1)$, and $\upsilon > 1$ is the elasticity of transformation.

Let P_t^X denote the domestic-currency of exports of the final good; it 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.

[14] 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.

[15] 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.

The identity between the value of production and the total value of sales is[16]

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

Minimizing (25) subject to (27) yields the familiar optimal allocation rule associated with the CET specification,

$$\frac{Y_t^S}{Y_t^X} = (\frac{1-\Gamma_Y}{\Gamma_Y})^{\upsilon}(\frac{P_t^S}{P_t^X})^{\upsilon}, \tag{28}$$

which can be solved for the level of exports, Y_t^X.[17]

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:

$$Y_{jt}^D = N_{jt}^{1-\alpha} K_{jt}^{\alpha}, \tag{29}$$

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.[18] The amount borrowed is therefore such that

$$L_{jt}^W \geq P_t^S \omega_t N_{jt}. \tag{30}$$

[16] Note that this identity is often ignored, with the distribution of output between domestic sales and exports written directly in volumes; see Kollmann (2001, p. 247) for instance.

[17] Alternatively, as in Nimark (2007) for instance, it could be assumed that exports depend directly on relative prices and world output Y_t^F, so that $Y_t^X = (P_t^D/P_t^X)^{-\upsilon_1}(Y_t^F)^{\upsilon_2}$, with υ_1 and υ_2 denoting constant elasticities. In either case, (27) can be solved for $Y_t^S = (P_t Y_t - P_t^X Y_t^X)/P_t^S$.

[18] 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.

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 (30) 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

$$\frac{K_{jt}}{N_{jt}} = (\frac{\alpha}{1-\alpha})[\frac{(1+i_t^R)\omega_t}{r_t^K}]. \quad \forall j \tag{31}$$

The unit real marginal cost is thus

$$mc_{jt} = \frac{\left[(1+i_t^R)\omega_t\right]^{1-\alpha} (r_t^K)^{\alpha}}{\alpha^{\alpha}(1-\alpha)^{1-\alpha}}. \tag{32}$$

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 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:[19]

$$\{P_{jt+s}^D\}_{s=0}^{\infty} = \arg\max \mathbb{E}_t \sum_{s=0}^{\infty} \beta^s \lambda_{t+s} (\frac{J_{jt+s}^I}{P_{t+s}^D}), \tag{33}$$

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

$$J_{jt}^I = (P_{jt}^D - P_t^D mc_t) Y_{jt}^D - \frac{\phi_I}{2} (\frac{P_{jt}^D}{\tilde{\pi}^{D,G} P_{jt-1}^D} - 1)^2 Y_t^D. \tag{34}$$

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

$$(1-\theta_D)\lambda_t (\frac{P_{jt}^D}{P_t^D})^{-\theta_D} \frac{Y_t^D}{P_t^D} + \theta_D \lambda_t (\frac{P_{jt}^D}{P_t^D})^{-\theta_D - 1} \frac{mc_{jt} Y_t^D}{P_t^D} \tag{35}$$

[19]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.

$$-\lambda_t \phi_I \left\{ (\frac{P^D_{jt}}{\tilde{\pi}^{D,G} P^D_{jt-1}} - 1) \frac{Y^D_t}{\tilde{\pi}^{D,G} P^D_{jt-1}} \right\}$$

$$+\beta \phi_I \mathbb{E}_t \left\{ \lambda_{t+1} (\frac{P^D_{jt+1}}{\tilde{\pi}^{D,G} P^D_{jt}} - 1) Y^D_{t+1} (\frac{P^D_{jt+1}}{\tilde{\pi}^{D,G} (P^D_{jt})^2}) \right\} = 0,$$

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:

$$K_{t+1} = I_t + (1 - \delta_K) K_t - \frac{\Theta_K}{2} \frac{(K_{t+1} - K_t)^2}{K_t}, \tag{36}$$

where $K_t = \int_0^1 K_{jt} dj$, $\delta_K \in (0, 1)$ 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:

$$L^I_t = P^S_t I_t. \tag{37}$$

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 $(1 + i^L_t) P^S_t I_t$, where i^L_t 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:

$$\{I_{t+s}\}^\infty_{s=0} = \arg\max \mathbb{E}_t \sum_{s=0}^{\infty} \beta^s \lambda_{t+s} (\frac{J^K_{t+s}}{P^S_{t+s}}), \tag{38}$$

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

$$J^K_{t+s} = P^S_{t+s} r^K_{t+s} K_{t+s} - (1 + i^L_{t+s-1}) P^S_{t+s-1} I_{t+s-1},$$

subject to (36).[20]

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

$$\mathbb{E}_t r^K_{t+1} = \frac{(1+i^L_t)}{(1+\pi^S_{t+1})}\mathbb{E}_t\left[1+\Theta_K(\frac{K_{t+1}}{K_t}-1)\right] \tag{39}$$

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

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, which use them to buy goods for investment purposes and pay for labor in advance. Thus, total lending, L_t, is equal to, using (30) and (37),

$$L_t = \int_0^1 L^W_{jt}\,dj + L^I_t = P^S_t\omega_t N_t + P^S_t I_t, \tag{40}$$

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, $L^{F,B}_t$, the bank borrows from the central bank, $L^{C,B}_t$, to fund any shortfall. At the end of the period, it repays the central bank, at the interest rate, i^R_t. It also holds required reserves at the central bank, RR_t.[21]

The bank's balance sheet is thus

$$L_t + RR_t = D_t + E_t L^{F,B}_t + V_t + L^{C,B}_t, \tag{41}$$

where

$$V_t = V^R_t + V^E_t, \tag{42}$$

with V^R_t denoting capital requirements and V^E_t excess capital.

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

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

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

$$RR_t = \mu^R D_t, \tag{43}$$

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

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

$$1 + i_t^{F,B} = (1 + i_t^W)(1 + \theta_t^{F,B})\mathbb{E}_t(\frac{E_{t+1}}{E_t}), \tag{44}$$

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

$$\theta_t^{F,B} = \frac{\theta_0^{F,B}}{2} L_t^{F,B}, \tag{45}$$

where $\theta_0^{F,B} > 0$. Thus, the premium that the bank faces on world capital markets depends on how much it borrows.[22]

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

$$V_t^R = \rho_t \sigma_t L_t^I, \tag{46}$$

where $\rho_t \in (0,1)$ is the "overall" capital ratio (defined later) and σ_t the risk weight. In line with the "foundation" variant of the Internal Ratings Based (IRB) approach of Basel II (which remains essentially the same under Basel III), the risk weight is assumed to depend on the repayment probability of the CG producer:[23]

$$\sigma_t = (\frac{q_t}{\tilde{q}})^{-\phi_q}, \tag{47}$$

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 liabilities to satisfy capital requirements, 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

[22] 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.

[23] See Agénor, Alper, and Pereira da Silva (2009) for a detailed discussion of this specification. Alternatively, under the Standardized Approach, σ_t could be taken to be a function of the output gap, under the assumption that ratings are procyclical.

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:

$$i_t^D, i_t^L, \frac{L_t^{F,B}}{P_t^S}, \frac{V_t^E}{P_t^S} = \arg\max \mathbb{E}_t(\frac{J_{t+1}^B}{P_{t+1}^S}), \tag{48}$$

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

$$\mathbb{E}_t(\frac{J_{t+1}^B}{P_{t+1}^S}) = (1+i_t^R)(\frac{L_t^W}{P_t^S}) + q_t(1+i_t^L)(\frac{L_t^I}{P_t^S}) + (1-q_t)\kappa(\frac{P_t^H}{P_t^S})\bar{H} \tag{49}$$

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

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

where $\kappa \in (0,1)$, γ_D, γ_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 supply of housing.[24] 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.

[24] 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.

Solving (48) subject to (37), (40) to (46), and (49) yields

$$i_t^D = (1 + \frac{1}{\eta_D})^{-1}(1 - \mu^R) i_t^R, \tag{50}$$

$$1 + i_t^L = \frac{(1 - \rho_t \sigma_t)(1 + i_t^R) + \rho_t \sigma_t \left[(1 + i_t^V) + \gamma_V \right]}{(1 + \eta_F^{-1}) q_t}, \tag{51}$$

$$L_t^{F,B} = \max \left\{ \frac{(1 + i_t^R) - \mathbb{E}_t[(1 + i_t^W)(E_{t+1}/E_t)]}{\theta_0^{F,B} \mathbb{E}_t[(1 + i_t^W)(E_{t+1}/E_t)]}, 0 \right\}, \tag{52}$$

$$\frac{V_t^E}{P_t^S} = \left\{ \frac{\gamma_{VV}}{i_t^V + \gamma_V - i_t^R} \right\}^{1/(1-\phi_E)}, \tag{53}$$

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

Equation (50) shows that the equilibrium deposit rate is a markup over the refinance rate, adjusted (downward) for the implicit cost of holding reserve requirements. Equation (51) 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 (52) 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 (53) shows that an increase in the direct or indirect cost of issuing debt (i_t^V or γ_V) reduces excess capital, whereas an increase in γ_{VV} raises excess capital.

As in Agénor, Alper, and Pereira (2009, 2010), the repayment probability q_t is taken to depend positively on the effective collateral-CG loan ratio (which mitigates moral hazard on the part of borrowers), the cyclical position of the economy (as measured by the output gap), and the bank's capital-total loan ratio, which increases incentives for the bank to screen and monitor its borrowers:

$$q_t = (\frac{\kappa P_t^H \bar{H}}{L_t^I})^{\varphi_1} (\frac{V_t}{L_t})^{\varphi_2} (y_t^G)^{\varphi_3}, \tag{54}$$

with $\varphi_i > 0$, $\forall i$ 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, corresponding to $\theta_D = 0$).[25]

[25]In Agénor and Pereira da Silva (2011), the repayment probability is endogenously

The balance sheet constraint (41), together with (43), can be used to determine residually borrowing from the central bank:

$$L_t^{C,B} = L_t - E_t L_t^{F,B} - (1 - \mu^R) D_t - V_t. \qquad (55)$$

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

$$E_t R_t^F + B_t^C + L_t^{C,B} = M_t + RR_t. \qquad (56)$$

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, $L_t^{F,B} - B_t^{F,P}$:

$$R_t^{F,T} = (\phi_1^R W P_t^F Y_t^F)^{\varphi^F} [\phi_2^R (L_t^{F,B} - B_t^{F,P})]^{1-\varphi^F}, \qquad (57)$$

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

$$R_t^F = (R_t^{F,T})^{\varphi^R} (R_{t-1}^F)^{1-\varphi^R}, \qquad (58)$$

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 to select (*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 (**??**).

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

Using (43), equation (56) yields

$$M_t^s = E_t R_t^F + B_t^C + L_t^{C,B} - \mu^R D_t. \tag{59}$$

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:

$$i_t^R = \chi i_{t-1}^R + (1-\chi)[\tilde{r} + \pi_t^S + \varepsilon_1(\pi_t^S - \pi^{S,T}) + \varepsilon_2 \ln y_t^G + \varepsilon_3 \Delta \ln E_t] + \epsilon_t, \tag{60}$$

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, ρ^D, and a cyclical component, ρ_t^C:

$$\rho_t = \rho^D + \rho_t^C. \tag{61}$$

In turn, the cyclical component is related to deviations of the growth rate of real credit to the CG producer from its steady-state value:

$$\rho_t^C = \theta^C(\Delta \ln L_t^I - \Delta \ln \tilde{L}^I), \tag{62}$$

where $\theta^C > 0$. Thus, the macroprudential rule calls for a tightening of capital requirements when credit growth exceeds its steady-state value.[26]

[26] The rule is specified with nominal, rather than real credit growth. In the numerical experiments that are conducted here, the results are qualitatively similar with either specification.

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

$$B_t = (1 + i^B_{t-1})B^P_{t-1} + B^C_{t-1} + P^S_t(G_t - T_t) \tag{63}$$
$$-i^R_{t-1}L^{C,B}_{t-1} - i^W_{t-1}E_{t-1}R^F_{t-1},$$

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:

$$G_t = \psi Y^S_t. \tag{64}$$

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:

$$Y^S_t = C_t + G_t + I_t + \frac{\Theta_K}{2}\frac{(K_{t+1} - K_t)^2}{K_t}, \tag{65}$$

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

$$P^S_t = (P_tY_t - P^X_tY^X_t)/Y^S_t. \tag{66}$$

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

$$M^s_t = M^P_t + L_t, \tag{67}$$

where M_t^s is defined in (59). Using (55) as well for $L_t^{C,B}$ implies that the equilibrium condition (67) can be rewritten as

$$M_t^P + D_t = B_t^C + E_t(R_t^F - L_t^{F,B}) - V_t, \tag{68}$$

which, after substituting (9) and (10) for M_t^P 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[27]

$$WP_t^X Y_t^X - WP_t^F Y_t^F + i_{t-1}^W NFA_{t-1} + \theta_{t-1}^{F,P} B_{t-1}^{F,P} \tag{69}$$
$$-\theta_{t-1}^{F,B} L_{t-1}^{F,B} - \Delta NFA_t = 0,$$

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

$$NFA_t = R_t^F + B_t^{F,P} - L_t^{F,B}. \tag{70}$$

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

$$\tilde{q} = (\frac{\kappa \tilde{P}^H \bar{H}}{\tilde{L}^I})^{\varphi_1} (\frac{\tilde{V}}{\tilde{L}})^{\varphi_2},$$

[27] Under a fixed exchange rate, $E_t = \bar{E}$ and condition (69) determines changes in official reserves, R_t^F. Equation (58) is thus dropped from the system. Under a flexible exchange rate, condition (69) determines implicitly the nominal exchange rate.

whereas steady-state interest rates are given by

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

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

and

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

From these equations it can be shown that $\tilde{\imath}^B > \tilde{\imath}^D$. We also have $\tilde{\imath}^V > \tilde{\imath}^B$ for $\Theta_V > 0$ (because holding bank debt is subject to a cost), and thus $\tilde{\imath}^V > \tilde{\imath}^D$. Equation (53) determines $\tilde{V}^E$, which is positive given that $\tilde{\imath}^V > \tilde{\imath}^R$. From (47), $\tilde{\sigma} = 1$ (by construction) and from (46), the steady-state required capital-risky assets ratio, $\tilde{V}^R/\tilde{L}^I$, is equal to ρ.

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 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 nominal credit growth.

Parameter values are summarized in Table 1. The discount factor β is set at 0.93, which corresponds to an annual real interest rate of 7 percent. The intertemporal elasticity of substitution, ς, is 0.6, in line with estimates for middle-income countries (see Agénor and Montiel (2008)). The preference parameters for leisure, η_N, and for composite monetary assets, η_x, are both set at 1.5. The preference parameter for housing, η_H, is set at a low value, 0.02. The share parameter in the index of money holdings, ν, which corresponds to the relative share of cash in narrow money, is set at 0.2.

The distribution parameter between domestic and imported intermediated goods in the production of the final good, Λ_D, is set at 0.7, whereas η, the elasticity of substitution between baskets of domestic and imported composite intermediate goods, is set at 0.6. 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, θ_D, and imported goods among themselves, θ_F are set equal at 10. The average pass-through elasticity is set at $\mu^F = 0.5$; this is line with the value estimated by Soto and Selaive (2003) for instance, for a group of 35 countries. The elasticity of transformation between sales on the domestic market and exports, υ, is set at 0.6; this is consistent with the range of estimates for the upper middle-income countries included in the sample considered by Devarajan et al. (1999).

The share of capital in domestic output of intermediate goods, α , 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, ϕ_I, is set at 74.5. The rate of depreciation of private capital, δ^K, is set equal to 0.01, corresponding to an annual rate of 4 percent. The adjustment cost for transforming the final good into investment, Θ_K, is set at 14.

For the parameters characterizing bank behavior, we assume that the effective collateral-loan ratio, κ, is 0.2. The adjustment cost parameter for holdings of bank debt, Θ_V, is set at 0.3, to capture relatively inefficient markets. The elasticity of the repayment probability with respect to collateral is set at $\varphi_1 = 0.03$, with respect to the bank capital-risky assets ratio at $\varphi_2 = 0.0$, and with respect to cyclical output at $\varphi_3 = 1.5$. Thus we abstract from the "monitoring incentive effect" of the bank capital channel. The elasticity of the risk weight with respect to the repayment probability is set at a relatively low value, $\varphi_q = 0.05$. The cost parameters γ_B, γ_V, and γ_{VV} are also set at low values, 0.05, 0.08, and 0.004, respectively. The parameter ϕ_E, which captures the benefit associated with capital buffers, is set to 0.5. Given the specification of the risk weight σ_t in (47), its steady-state value is equal to unity. The deterministic component of the capital adequacy ratio, ρ^D—and thus the overall capital ratio, given that $\rho^C = 0$ in the steady-state—is set at 0.08, which corresponds to the minimum value of the ratio of capital to risk-weighted assets under 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 (2009). 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 cost differentials, is normalized at 1. Given the initial value of the bank's foreign liabilities, this actually implies a relatively low elasticity. In order to focus the analysis on bank foreign borrowing, we assume that in the initial steady state households do not hold foreign bonds.[28]

The reserve requirement rate μ^R is set at 0.1. We abstract from persistence stemming from the central bank's policy response and set the smoothing parameter $\chi = 0$. We also set $\varepsilon_1 = 2.5$ and $\varepsilon_2 = 0.5$, which are conventional values for Taylor-type rules for middle-income countries; the value of ε_2 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, φ^R, is set at 0.5. The parameter characterizing the countercyclical regulatory rule, θ^C, is initially set at 0. Finally, the degree of persistence of the shock to the world risk-free rate, ρ_W, is set at 0.8, which implies a reasonably high degree of inertia.

6 Dynamics of a Sudden Flood

To illustrate the properties of the model in response to external shocks, we consider as a base experiment a temporary, one-period only, drop in the world risk-free interest rate by 25 basis points.[29] The results are summarized in Figure 1, for 20 of the key variables.

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

[29] 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. See also Neumeyer and Perri (2005).

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 a substantial appreciation of the nominal 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 increase in reserves tends to increase the monetary base.[30] 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 latter effect dominates, implying a fall in the supply of cash. At the initial level of consumption, the *nominal* bond rate must therefore increase to reduce the demand for cash and restore equilibrium in the currency market. At the same time, however, the expected future increase in inflation means that the *real* bond rate falls; this induces households to increase consumption today and magnifies the drop in the nominal bond rate.

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 increases the value of collateral that firms can pledge. This, combined with the increase in the output gap, tends to raise the repayment probability and to lower the loan rate, thereby stimulating investment. Thus, aggregate demand (spending on the domestic good) unambiguously increases on impact. In addition to the *level effect* on final output, there is also a *composition effect*: the appreciation of the nominal exchange rate 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. The expansion in output tends to raise immediately the policy rate; combined with the increase in the gross wage, this tends to raise the effective cost of

[30]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.

labor for IG producers. Because the rental rate of capital does not change on impact (due to the one-period lag in capital accumulation), marginal costs unambiguously increase in the first period. Inflation (in terms of the price of goods sold on the domestic market) therefore increases. However, overall inflation (measured in terms of the price of the final good) falls initially, because the nominal appreciation tends to lower significantly the domestic-currency price of imported intermediate goods. In turn, this tends to mitigate the initial upward pressure on the policy rate. Over time, the reduction in the rental rate of capital induced by the boom in investment leads to lower marginal costs and inflation in terms of domestic prices.

The increase in the bond rate tends to lower household demand for bank capital, thereby exerting upward pressure on the rate of return on bank debt. Concomitantly, the increase in the repayment probability (associated with both higher collateral values and the cyclical improvement in the output gap) lowers the risk weight attached to investment loans, thereby reducing capital requirements. This tends to reduce the rate of return on bank debt. However, because the policy rate rises by more than the cost of bank capital, the net effect on the demand for excess bank capital is unambiguously positive. The latter dominates and, as a result, *total* capital increases, which tends also to raise the rate of return on bank debt. This effect mitigates the initial downward impact on the lending rate associated with the collateral and cyclical output effects, given that the bank internalizes the effect of the cost of capital in its pricing decisions. Finally, the 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.[31]

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 balance sheet effect, in the present case, operates through changes in commercial bank borrowing: 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 (45)) falls, but by less than the risk-free rate. Put differently, im-

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

perfections on world capital markets 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 significant increases in asset prices and aggregate demand, an expansion in output and inflationary pressures—despite the fact that the nominal appreciation that accompanies these inflows may mitigate somewhat the 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 and the loan rate—thereby promoting investment. 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 repayment probabilities feed into changes in risk weights under the Basel II-type regime that we consider, which in turn affect the cost of issuing capital and bank pricing decisions. There is therefore a feedback effect on these probabilities; in this particular case, this feedback effect helps to mitigate the initial shock. 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.

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 rate of nominal exchange rate depreciation. We will consider in the next section an additional sensitivity test, which involves giving a role to countercyclical capital regulation.

7.1 Degree of Exchange-Rate Pass-through

We first consider an increase in the degree of exchange rate pass-through of nominal exchange rate changes to the domestic-currency price of imported intermediate goods, μ^F, from 0.5 to 0.8. The results of this experiment are shown in Figure 2, together with the baseline results. On impact, a higher pass-through rate magnifies the downward effect of the initial nominal appreciation on the domestic-currency price of imports induced by the capital inflow. 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 latter effect dominates, the supply of cash falls by more, and the nominal bond rate must increase by more to restore equilibrium in the currency market. Because initially prices do not change much, the real 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 in investment. Marginal costs tend to increase by more initially because of the upward pressure on wages created by the fall in labor supply (a consequence of the increase in the marginal utility of leisure, as noted earlier) and the increase in the policy rate. The initial increase in inflation is thus larger. Thus, the higher pass-through rate does not dampen the domestic effects of the shock; on the contrary, it creates more volatility, magnifying movements in initial periods.

7.2 Desired Level of Reserves

We now consider a reduction in φ^F, from 1.0 to 0.5 in the definition of the desired level of reserve given in (57). At the same time, we fix the parameter ϕ_2^R in that equation to 0.2, which implies that only a relatively small fraction of an increase in net private foreign liabilities leads to reserve accumulation by the central bank.

The results of this experiment are shown in Figure 3. Because bank foreign borrowing increases significantly initially, the assumption that the central bank now sets its desired level of reserves with equal attention to trade and private sector foreign liabilities has a marked effect on that variable; in contrast to the base case experiment, it increases gradually for a significant number of periods, following an inverted U-shape pattern. The large increase in the desired and actual reserve levels tend to expand the monetary base by more. This time around, this expansionary effect dominates the contractionary effect associated by the higher level of bank foreign borrowing, implying an increase in the money supply, which requires a larger rise in the nominal bond rate to restore equilibrium. Now, with sticky prices, the real bond rate increases less, inducing households to postpone. As a result, output expands by less (with deviations from baseline turning negative fairly quickly), thereby inducing a smaller increase in the repayment probability (a rise in the risk premium) and a fairly rapid contraction in investment. Marginal costs tend to increase 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, ε_3, from 0 to 0.5. This value is quite large 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 4. By and large, the effects are not quantitatively large, given the size of the shock that we are considering; nevertheless, it is worth going through the qualitative implications of this change in the policy rule. Because the nominal exchange rate appreciates on impact, the direct implication is that the refinance rate increases by less than before. By implication, the offsetting effect of monetary policy on the loan rate (which falls, as noted earlier, due to the drop in the risk premium) is now less significant; equivalently, the loan rate falls a bit more. The expansion in investment is therefore magnified. Because the nominal exchange rate is expected to depreciate by a bit more, the increase in bank foreign borrowing is less marked, implying eventually (based on the reasoning outlined earlier) a slightly smaller increase in the nominal bond rate. However, expected future inflation is lower, implying a higher bond rate; this tends to lower consumption by more initially. Because the increase in the policy rate is not as large, the rise in the effective cost of labor (and thus marginal costs) is now less significant. By and large, other variables are unaffected. Thus, attempts to mitigate exchange rate movements through changes in the policy change do not appear to have much of an impact.

8 Countercyclical Regulation

The foregoing discussion suggests 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 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.

First, we consider an increase in the parameter characterizing the countercyclical regulatory rule, θ^C, from 0 to 1.5. The results of this experiment are shown in Figure 5. In line with the results in Agénor, Alper, and Pereira da Silva (2011), the presence of the rule mitigates the boom. As noted earlier, the increase in housing prices that accompanies the shock to the world risk-free rate raises collateral values and tends to raise the repayment probability, which reduces the lending rate and stimulates borrowing for investment. The countercyclical rule, by imposing higher capital requirements, tends to raise directly the cost of issuing debt by the bank, thereby mitigating the initial expansionary effect on the loan rate associated with higher collateral values.

Second, and as in Agénor, Alper, and Pereira da Silva (2011), suppose that the central bank is concerned with two objectives, macroeconomic stability and financial stability, with the former defined in terms of the coefficient of variation of nominal output of the final good (thereby imposing implicitly equal weights on output and price volatility) and the latter defined in terms of the coefficient of variation of real housing prices and the nominal exchange rate, again with equal weights.[32] In addition, we define a *composite*

[32] In turn, coefficients of variations are based on the asymptotic (unconditional) variances of the relevant variable. See Bergin et al. (2007) for a discussion of the benefits associated

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.[33]

Figures 6 and 7 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 θ^C varying between 0 and 6. The figure suggests that there is no trade-off among policy objectives: a stronger response of regulatory capital to credit growth 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, up to a value of about $\theta^C = 4.5$; beyond that, there is no further gain in terms of reduced volatility. 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 and disappears for a sufficiently high value of θ^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 with respect to both objectives. However, this is true only up to a certain point; other macroprudential tools (such as loan-to-value ratios) may 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 economy with a two-level banking intermediation structure, a risk-sensitive regulatory capital regime, and imperfect capital mobility. 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 both on 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

with stabilizing the exchange rate under asymmetric international financial markets.

[33] 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 contracts.

goods, which are used (together with domestic intermediate goods) in the production of the domestic final good. Thus, only trade in raw materials was assumed.

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 was shown to be negligible beyond a certain point, suggesting that a countercyclical regulatory policy may need to be supplemented by other macroprudential instruments, such as loan-to-value 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.

An interesting 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.[34] 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

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

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 unaddressed is the extent to which they can help to improve financial stability. 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.

Another 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 issgnificantly in middle-income countries like Brazil and Turkey in recent years, partly as a result of large capital inflows. In Turkey for instance, capital inflows have been associated with a sharp expansion of domestic-currency loans. The reason for this expansion stems from the fact that foreign investors were very involved in swap aggrements 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 LİBOR on their foreign exchange positions. Thus, domestic banks can hedge the currency and interest rate risk by means of these aggrements. This allowed banks to extend credit in domestic currency at longer maturities, making mortgage loans 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.

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Table 1
Benchmark Calibration: Key Parameter Values

Parameter	Value	Description
Household		
β	0.93	Discount factor
ς	0.6	Elasticity of intertemporal substitution
η_N, η_x	1.5	Preference parameter for leisure, money holdings
η_H	0.02	Preference parameter for housing
ν	0.2	Share parameter in index of money holdings
Θ_V	0.3	Adjustment cost parameter, holdings of bank debt
Production		
Λ_D	0.7	distribution parameter, final good
η	0.6	Elasticity of substitution, baskets of IG goods
μ^F	0.5	Adjustment speed, imported Intermediate goods
υ	0.6	Elasticity of transformation
θ_D, θ_F	10.0	Elasticity of demand, intermediate goods
α	0.35	Share of capital, domestic intermediate goods
ϕ_I	74.5	Adjustment cost parameter, prices
δ	0.01	Depreciation rate of capital
Θ_K	14	Adjustment cost parameter, investment
Bank		
κ	0.2	Effective collateral-loan ratio
φ_1	0.03	Elasticity of repayment prob, collateral
φ_2	0.0	Elasticity of repayment prob, capital-assets ratio
φ_3	1.5	Elasticity of repayment prob, cyclical output
φ_q	0.05	Elasticity of risk weight, prob of repayment
γ_B	0.05	Cost of adjustment, bond holdings
γ_V	0.08	Cost of issuing bank capital
γ_{VV}	0.004	Benefit of holding excess bank capital
ρ^D	0.08	Capital adequacy ratio (deterministic component)
Central bank		
μ^R	0.1	Reserve requirement rate
χ	0.0	Degree of interest rate smoothing
ε_1	2.5	Response of refinance rate to inflation deviations
ε_2	0.5	Response of refinance rate to output gap
ε_3	0.0	Response of refinance rate to nominal depreciation
ρ_W	0.8	Persistence, shock to world risk-free rate

Appendix A
Steady-State Solution

Steady-state values of all endogenous variables (denoted by tildes) are calculated by dropping all time subscripts from the relevant equations.

From (60), with $\tilde{y}^G = 1$ and $\varepsilon_3 = 0$,

$$\tilde{\imath}^R = \tilde{r} + \tilde{\pi}^S + \varepsilon_1(\tilde{\pi}^S - \pi^{S,T}). \tag{A1}$$

In the steady state, inflation is equal to its target value:

$$\tilde{\pi}^S = \pi^{S,T}. \tag{A2}$$

Substituting this result in (A1) yields therefore the steady-state value of the refinance rate:

$$\tilde{\imath}^R = \tilde{r} + \tilde{\pi}^S. \tag{A3}$$

The focus in what follows is on the case where $\pi^{S,T} = \tilde{\pi}^S = 0$.

The steady-state value of the bond rate is determined by setting $\lambda_t = \lambda_{t+1}$ and $\tilde{\pi}^S = 0$ in (13):

$$\tilde{\imath}^B = \tilde{r} = \tilde{\imath}^R = \beta^{-1} - 1. \tag{A4}$$

In the steady state, with $K_{t+1} = K_t$, capital adjustment costs are zero:

$$\frac{\Theta}{2}(\frac{\tilde{K}}{\tilde{K}} - 1)^2 \tilde{K} = 0. \tag{A5}$$

Substituting this result in (36) yields

$$\tilde{I} = \delta \tilde{K}. \tag{A6}$$

Substituting (A5) in (39) gives the steady-state value of the rental rate of capital:

$$\tilde{r}^K = (1 + \tilde{\imath}^L)[1 - \beta(1 - \delta)]. \tag{A7}$$

From (50), the steady-state value of the deposit rate is

$$\tilde{\imath}^D = (1 + \frac{1}{\eta_D})^{-1}(1 - \mu^R)\tilde{\imath}^R. \tag{A8}$$

Setting $\tilde{y}^G = 1$ in (54), the steady-state value of the repayment probability is

$$\tilde{q} = (\frac{\kappa_H \tilde{p}^H \bar{H}}{\tilde{L}^I})^{\varphi_1}(\frac{\tilde{V}}{\tilde{L}})^{\varphi_2}. \tag{A9}$$

Using (51) and (A4), the steady-state lending rate is given by

$$1+\tilde{\imath}^L = \frac{1}{(1+\eta_F^{-1})\tilde{q}} \left\{(1-\rho)\beta^{-1} + \rho\left[(1+\tilde{\imath}^V) + \gamma_V\right]\right\}. \tag{A10}$$

From (9), (10), (11), (12), and (14), the household's demand for real cash balances, bank deposits, housing stock, bank debt and foreign bonds are

$$\tilde{m}^P = \frac{\eta_x \nu \tilde{C}^{1/\varsigma}(1+\tilde{\imath}^B)}{\tilde{\imath}^B}, \tag{A11}$$

$$\tilde{d} = \frac{\eta_x(1-\nu)\tilde{C}^{1/\varsigma}(1+\tilde{\imath}^B)}{\tilde{\imath}^B - \tilde{\imath}^D}, \tag{A12}$$

$$\frac{\tilde{V}}{P} = \frac{1}{\Theta_V}(\frac{\tilde{\imath}^V - \tilde{\imath}^B}{1+\tilde{\imath}^B}), \tag{A13}$$

$$\frac{\tilde{P}^H \tilde{H}^d}{\tilde{P}^S} = \left\{1 - (\frac{1+\tilde{\pi}^H}{1+\tilde{\imath}^B})\right\}^{-1} [\frac{\eta_H}{(\tilde{C})^{-1/\varsigma}}], \tag{A14}$$

$$\tilde{B}^{F,P} = \frac{(1+\tilde{\imath}^W) - (1+\tilde{\imath}^B)}{\theta_0^{F,P}(1+\tilde{\imath}^W)}, \tag{A15}$$

or equivalently, using (A3), (A4), (A7), (A8), and with $\tilde{\pi}^S = 0$,

$$\tilde{m}^P = \frac{\eta_x \nu \tilde{C}^{1/\varsigma}}{1-\beta}, \tag{A16}$$

$$\tilde{d} = \frac{\eta_x(1-\nu)\tilde{C}^{1/\varsigma}}{(1-\beta)\mu^R}, \tag{A17}$$

$$\frac{\tilde{V}}{\tilde{P}^S} = \frac{1}{\Theta_V}(\frac{1+\tilde{\imath}^V}{1+\tilde{\imath}^B} - 1) = \frac{\beta}{\Theta_V}(1+\tilde{\imath}^V - \beta^{-1}), \tag{A18}$$

$$\frac{\tilde{P}^H \tilde{H}^d}{\tilde{P}^S} = (1-\beta)^{-1}[\frac{\eta_H}{\tilde{C}^{-1/\varsigma}}], \tag{A19}$$

$$\tilde{B}^{F,P} = \frac{\tilde{\imath}^W - \tilde{\imath}^B}{\theta_0^{F,P}(1+\tilde{\imath}^W)}. \tag{A20}$$

The demand for bank debt equation can be solved for $\tilde{\imath}^V$, with $\tilde{V}$ given. The solution is

$$\tilde{\imath}^V = \frac{\Theta_V \tilde{V}}{\beta \tilde{P}^S} + \beta^{-1} - 1, \tag{A21}$$

which implies, given that $\tilde{V} > 0$, that $\tilde{\imath}^V > \tilde{\imath}^B$ as long as $\Theta_V > 0$, as discussed in the text.

From (8), the steady-state value of labor supply is

$$\tilde{N} = 1 - \frac{\eta_N \tilde{C}^{1/\varsigma}}{\tilde{\omega}}. \tag{A22}$$

From (18), the steady-state value of the domestic final good is given by

$$\tilde{Y} = [\Lambda_D(\tilde{Y}^D)^{(\eta-1)/\eta} + (1-\Lambda_D)(\tilde{Y}^F)^{(\eta-1)/\eta}]^{\eta/(\eta-1)}. \tag{A23}$$

Similarly, from (22), steady-state demand for domestic and foreign intermediate goods is given by

$$\tilde{Y}^D = \Lambda_D^\eta(\frac{\tilde{P}^D}{\tilde{P}})^{-\eta}\tilde{Y}, \quad \tilde{Y}^F = (1-\Lambda_D)^\eta(\frac{\tilde{P}^F}{\tilde{P}})^{-\eta}\tilde{Y}. \tag{A24}$$

From (23) the steady-state value of the price of final output is

$$\tilde{P} = [\Lambda_D^\eta(\tilde{P}^D)^{1-\eta} + (1-\Lambda_D)^\eta(\tilde{P}^F)^{1-\eta}]^{1/(1-\eta)}. \tag{A25}$$

The steady-state value of the price of foreign imported intermediate goods is obtained by dropping the adjustment term in (24):

$$\tilde{P}^F = \tilde{E} \cdot WP^F. \tag{A26}$$

In the steady state, the transformation function of final output, equation (25) takes the form

$$\tilde{Y} = \left[\Gamma_Y(\tilde{Y}^S)^{1+1/\upsilon} + (1-\Gamma_Y)(\tilde{Y}^X)^{1+1/\upsilon}\right]^{\upsilon/(1+\upsilon)}. \tag{A27}$$

The steady-state value of the export price is

$$\tilde{P}^F = \tilde{E} \cdot WP^X. \tag{A28}$$

From (28), the optimality condition for output transformation is

$$\frac{\tilde{Y}^S}{\tilde{Y}^X} = (\frac{1-\Gamma_Y}{\Gamma_Y})^\upsilon(\frac{\tilde{P}^S}{\tilde{P}^X})^\upsilon. \tag{A29}$$

From (29), steady-state output of domestic intermediate goods is given by

$$\tilde{Y}^D = \tilde{N}^{1-\alpha}\tilde{K}^\alpha. \tag{A30}$$

From (31), the steady-state condition describing the optimal utilization of production factors is

$$\frac{\tilde{K}}{\tilde{N}} = (\frac{\alpha}{1-\alpha})[\frac{(1+\tilde{\imath}^R)\tilde{\omega}}{\tilde{r}^K}]. \tag{A31}$$

Substituting (A4) and (A7) in this expression, and solving for $\tilde{\omega}$ with $\tilde{\pi} = 0$, yields the steady-state real wage as

$$\tilde{\omega} = (\frac{1-\alpha}{\alpha})\frac{\tilde{K}(\beta^{-1} - 1 + \delta)}{\tilde{N}(1+\tilde{\imath}^R)}. \tag{A32}$$

The steady-state level of borrowing from the bank is thus

$$\tilde{L}^W = \tilde{P}^S\tilde{\omega}\tilde{N}. \tag{A33}$$

With $\tilde{\pi}^D = 0$ (so that $\tilde{\pi}^{D,G} = 1$), price adjustment costs are zero in the steady state. The price adjustment equation (35) yields

$$(1-\theta_D) + \theta_D\widetilde{mc} - \phi_I(\frac{\tilde{\pi}^D}{\tilde{\pi}^{D,G}} - 1)(\frac{\tilde{\pi}^D}{\tilde{\pi}^{D,G}}) + \beta\phi_I(\frac{\tilde{\pi}^D}{\tilde{\pi}^{D,G}} - 1)(\frac{\tilde{\pi}^D}{\tilde{\pi}^{D,G}}) = 0,$$

which can be solved for the steady-state value of the marginal cost:

$$\widetilde{mc} = \frac{\theta_D - 1}{\theta_D}. \tag{A34}$$

From (37), the amount of loans demanded by the capital good producer is

$$\tilde{L}^I = \tilde{P}^S\tilde{I}. \tag{A35}$$

From (53), and using (A4), the steady-state value of the bank's demand for excess capital is

$$\frac{\tilde{V}^E}{\tilde{P}^S} = \left\{\frac{\gamma_{VV}}{\tilde{\imath}^V + \gamma_V - \beta^{-1} + 1}\right\}^{1/(1-\phi_E)}, \tag{A36}$$

where, from (46) and (47),

$$\tilde{V}^R = \rho\tilde{L}^I. \tag{A37}$$

From (A36) and(A37), total capital is

$$\tilde{V} = \tilde{V}^R + \tilde{V}^E. \tag{A38}$$

From (55), the steady-state level of the bank's borrowing from the central bank is

$$\tilde{L}^{C,B} = \tilde{L}^{W} + \tilde{L}^{I} - \tilde{E} \cdot \tilde{L}^{F,B} - (1-\mu^{R})\tilde{d} \cdot \tilde{P}^{S} - \tilde{V}. \tag{A39}$$

From (52), the steady-state level of the bank's foreign borrowing is

$$\tilde{L}^{F,B} = \frac{\beta^{-1} - (1+\tilde{\imath}^{W})}{\theta_0^{F,B}(1+\tilde{\imath}^{W})}. \tag{A40}$$

From (57), the steady-state level of the central bank's foreign reserves is

$$\tilde{R}^{F} = \tilde{R}^{F,T} = (\phi_1^{R} W P^{F} \tilde{Y}^{F})^{\varphi^{F}} [\phi_2^{R}(\tilde{L}^{F,B} - \tilde{B}^{F,P})]^{1-\varphi^{F}}.$$

The equilibrium condition of the goods market, equation (65), yields the steady-state condition $\tilde{Y}^{S} = \tilde{C} + \tilde{G} + \tilde{I}$, which can be rearranged, using (A6) and (64), to give

$$(1-\psi)\tilde{Y}^{S} = \tilde{C} + \delta\tilde{K}. \tag{A41}$$

The steady-state price of sales on the domestic market is, from (66):

$$\tilde{P}^{S} = (\tilde{P}\tilde{Y} - \tilde{P}^{X}\tilde{Y}^{X})/\tilde{Y}^{S}. \tag{A42}$$

From (68), the equilibrium condition of the market for cash yields

$$\frac{\bar{B}^{C}}{\tilde{P}^{S}} = \frac{\tilde{V}}{\tilde{P}^{S}} + \eta_X \tilde{C}^{1/\varsigma}(1+\tilde{\imath}^{B})(\frac{\nu}{\tilde{\imath}^{B}} + \frac{1-\nu}{\tilde{\imath}^{B} - \tilde{\imath}^{D}}),$$

which can rearranged as, using (A3), (A4), (A7), and (A8), and with $\tilde{\pi}^{S} = 0$,

$$\frac{\bar{B}^{C}}{\tilde{P}^{S}} = \frac{\tilde{V}}{\tilde{P}^{S}} + \frac{\eta_X \tilde{C}^{1/\varsigma}}{1-\beta}(\nu + \frac{1-\nu}{\mu^{R}}). \tag{A43}$$

This equation can be solved for $\tilde{P}^{S}$. Given that the overall stock of bonds $\bar{B}$ is also constant, household holdings of government bonds are given by

$$\bar{B}^{P} = \bar{B} - \bar{B}^{C}. \tag{A44}$$

From (63) and (64), the steady-state value of lump-sum taxes is thus

$$\tilde{T} = \psi\tilde{P}^{S}\tilde{Y}^{S} + \tilde{\imath}^{B}\bar{B}^{P} - \tilde{\imath}^{R}\tilde{L}^{B} - i^{W}\tilde{E}\tilde{R}^{F}. \tag{A45}$$

The steady-state equilibrium condition of the market for foreign exchange, equation (69), yields

$$WP^{X}\tilde{Y}^{X} - WP^{F}\tilde{Y}^{F} + i^{W}NF\tilde{A} + \tilde{\theta}^{F,P}\tilde{B}^{F,P} - \tilde{\theta}^{F,B}\tilde{L}^{F,B} = 0, \tag{A46}$$

whereas the economy's net foreign asset position is

$$\widetilde{NFA} = \tilde{R}^{F} + \tilde{B}^{F,P} - \tilde{L}^{F,B}. \tag{A47}$$

Appendix B
Log-Linearized System

Based on the results of Appendix A, the log-linearized equations of the model are presented below. Variables with a hat denote percentage point deviations of the related variables for interest rates and inflation, and log-deviations for the others, from steady-state levels.[35]

From the first-order conditions from household optimization, equations (7) and (13), private consumption is driven by

$$E_t\hat{C}_{t+1} = \hat{C}_t + \varsigma(\hat{\imath}_t^B - E_t\pi_{t+1}^S), \tag{B1}$$

where π_{t+1}^S is defined as, given that $\tilde{\pi}^S = 0$,

$$E_t\pi_{t+1}^S = E_t\hat{P}_{t+1}^S - \hat{P}_t^S. \tag{B2}$$

From (9) the demand for cash is

$$\hat{m}_t^P\tilde{m}^P = \frac{\eta_x\nu(\tilde{C})^{1/\varsigma}}{1-\beta}[\frac{\hat{C}_t}{\varsigma} - (\frac{\beta}{1-\beta})\hat{\imath}_t^B]. \tag{B3}$$

By using the steady-state value of cash balances from (A16), equation (B3) can be written as

$$\hat{m}_t^P = \frac{\hat{C}_t}{\varsigma} - (\frac{\beta}{1-\beta})\hat{\imath}_t^B. \tag{B4}$$

From (10) and (A17), the demand for deposits is

$$\hat{d}_t = \frac{\hat{C}_t}{\varsigma} + \left[\frac{1-\mu^R+\mu^R\beta}{\mu^R(1-\beta)}\right](\hat{\imath}_t^D - \hat{\imath}_t^B). \tag{B5}$$

From (16) and (A18), the demand for bank debt is

$$\hat{V}_t^d - \hat{P}_t^S = (\frac{\tilde{\imath}^V}{\tilde{\imath}^V - \tilde{\imath}^B})\left(\hat{\imath}_t^V - \hat{\imath}_t^B\right). \tag{B6}$$

From equation (15) demand for housing in real terms is

$$\hat{H}_t^d = \hat{P}_t^S - \hat{P}_t^H + \frac{\tilde{\pi}^H(\hat{\pi}_{t+1}^H - \hat{\imath}_t^B)}{\tilde{\imath}^B - \tilde{\pi}^H} + \frac{\hat{C}_t}{\varsigma} \tag{B7}$$

[35] Net interest rates are thus used as approximations of the log gross interest rates.

From (8), labor supply is

$$\tilde{N}\hat{N}_t = \frac{\eta_N \tilde{C}^{1/\varsigma}}{\tilde{\omega}}\hat{\omega}_t - \frac{\eta_N \tilde{C}^{1/\varsigma}\hat{C}_t}{\varsigma\tilde{\omega}},$$

that is, using (A22),

$$\hat{N}_t = (\frac{\eta_N \tilde{C}^{1/\varsigma}}{\tilde{\omega} - \eta_N \tilde{C}^{1/\varsigma}})(\hat{\omega}_t - \frac{\hat{C}_t}{\varsigma}). \tag{B8}$$

The linearized version of final good production from (18), can be written as

$$\hat{Y}_t = [\Lambda_D(\frac{\tilde{Y}^D}{\tilde{Y}})^{(\eta-1)/\eta}]\hat{Y}_t^D + ((1-\Lambda_D)[(\frac{\tilde{Y}^F}{\tilde{Y}})^{(\eta-1)/\eta}]\hat{Y}_t^F. \tag{B9}$$

From (22) the linearized demand for domestic and foreign intermediate goods can be derived as

$$\hat{Y}_t^D = \eta(\hat{P}_t - \hat{P}_t^D) + \hat{Y}_t, \quad \hat{Y}_t^F = \eta(\hat{P}_t - \hat{P}_t^F) + \hat{Y}_t,$$

respectively, whereas from (23) the linearized price of final good as a linear function of $\hat{P}_t^D$ and $\hat{P}_t^F$ can be derived as

$$\hat{P}_t = [\Lambda_D^{\eta}(\frac{\tilde{P}^D}{\tilde{P}})^{1-\eta}]\hat{P}_t^D + [(1-\Lambda_D)^{\eta}(\frac{\tilde{P}^F}{\tilde{P}})^{1-\eta}]\hat{P}_t^F. \tag{B10}$$

From (24) the linearized adjustment function of foreign intermediate good prices is

$$\hat{P}_t^F = \mu^F(\hat{E}_t + W\hat{P}_t^F) + (1-\mu^F)\hat{P}_{t-1}^F. \tag{B11}$$

The linearized equation for transformation of the final good can be derived from (25) as

$$\hat{Y}_t = \Gamma_Y(\frac{\widetilde{Y}^S}{\widetilde{Y}})^{(1+\upsilon)/\upsilon}\widehat{Y}_t^S + (1-\Gamma_Y)(\frac{\widetilde{Y}^X}{\widetilde{Y}})^{(1+\upsilon)/\upsilon}\widehat{Y}_t^X. \tag{B12}$$

Production allocated for domestic sales is linearized from (28):

$$\hat{Y}_t^S = \hat{Y}_t^X + \upsilon(\hat{P}_t^S - \hat{P}_t^X). \tag{B13}$$

The linearized equation domestic-currency price of exported goods is the sum of deviations of the nominal exchange rate and the world price of exported goods:

$$\hat{P}_t^X = \hat{E}_t + W\hat{P}_t^X \tag{B14}$$

From the production function (29), output of intermediate goods is

$$\hat{Y}_t^D = (1-\alpha)\hat{N}_t + \alpha\hat{K}_t. \tag{B15}$$

From (31), labor demand by IG producers can be derived as

$$\hat{N}_t = \hat{K}_t - \hat{\imath}_t^R - \hat{\omega}_t + \frac{(1+\tilde{r}^K)}{\tilde{r}^K}\hat{r}_t^K. \tag{B16}$$

A log-linear approximation around the steady state of the price adjustment equation (35) yields

$$\hat{\pi}_t^D = (\frac{\theta_D - 1}{\phi_I})\widehat{mc}_t + \beta E_t\hat{\pi}_{t+1}^D, \tag{B17}$$

where, using (32),

$$\widehat{mc}_t = (1-\alpha)(\hat{\imath}_t^R + \hat{\omega}_t) + \alpha(\frac{\tilde{r}^K}{\tilde{r}^K - 1})\hat{r}_t^K. \tag{B18}$$

From 36 investment can be linearized as

$$\hat{I}_t = (1/\delta_K)[\hat{K}_{t+1} - (1-\delta_K)\hat{K}_t]. \tag{B19}$$

The linearized law of motion for the rate of return of capital is

$$\mathbb{E}_t r_{t+1}^K = \frac{(1+\tilde{\imath}^L)}{(1+\tilde{r}^K)}\left[(\hat{\imath}_t^L - \hat{\pi}_{t+1}^N) + \Theta_K(\hat{K}_{t+1} - \hat{K}_t)\right] \tag{B20}$$

$$-\frac{\beta(1+\tilde{\imath}^L)}{(1+\tilde{r}^K)}\left[(1-\delta)(\hat{\imath}_{t+1}^L - \hat{\imath}_{t+1}^B) + \Theta_K(\hat{K}_{t+2} - \hat{K}_{t+1})\right].$$

From (50) and (A8), the deposit rate is given by

$$\hat{\imath}_t^D = \frac{(1-\mu^R)}{1-(1-\beta)\mu^R}\hat{\imath}_t^R. \tag{B21}$$

From (51), the linearized equation for the lending rate is given by

$$\hat{\imath}_t^L = \frac{1}{(1+\tilde{\imath}^L)\tilde{q}} \left\{ \frac{(1-\rho^D)}{\beta}\hat{\imath}_t^R + \rho^D(1+\tilde{\imath}^V)\hat{\imath}_t^V \right. \tag{B22}$$

$$\left. -(1+\rho^D)(1+\tilde{\imath}^V+\gamma_V-\frac{1}{\beta})\hat{\rho}_t^C + \rho^D[(1+\tilde{\imath}^V)+\gamma_V-\frac{1}{\beta}]\hat{\sigma}_t \right\} - \hat{q}_t.$$

The linearized equation for the cost of foreign borrowing in domestic currency can be derived from (44) and (45):

$$\hat{\imath}_t^{FB} = \hat{\imath}_t^W + \hat{E}_{t+1} - \hat{E}_t + \frac{(1+\widetilde{\imath}^W)(\theta_0^{F,B}/2)\tilde{L}^{F,B}}{(1+\widetilde{\imath}^W)(1+(\theta_0^{F,B}/2)\tilde{L}^{F,B})}\widehat{L}_t^{F,B}$$

From (54), the linearized equation for the probability of repayment is

$$\hat{q}_t = \varphi_1(\hat{P}_t^H - \hat{L}_t^I) + \varphi_2\hat{\sigma}_t + \varphi_3\hat{Y}_t. \tag{B23}$$

From (60), with $\varepsilon_3 = 0$, the central bank policy rate is determined by

$$\hat{\imath}_t^R = \chi\hat{\imath}_{t-1}^R + (1-\chi)[\varepsilon_1\hat{\pi}_t^S + \varepsilon_2(\hat{Y}_t - \hat{\bar{Y}}_t)]. \tag{B24}$$

From 58 accumulation of central bank reserves determined by

$$\hat{R}_t^{F,T} = \varphi^F(W\hat{P}_t^F + \hat{Y}_t^F) + (1-\varphi^F)\frac{\tilde{L}^{F,B}\hat{L}_t^{F,B} - \tilde{B}^{F,P}\hat{B}_t^{F,P}}{\tilde{L}^{F,B} - \tilde{B}^{F,P}}. \tag{B25}$$

Intermediate good producer firms' demand for credit is, from (30),

$$\hat{L}_t^W = \hat{N}_t + \hat{\omega}_t + \hat{P}_t^S. \tag{B26}$$

Capital good producer firms' demand for credit is, from (37),

$$\hat{L}_t^I = \hat{P}_t^S + \hat{I}_t. \tag{B27}$$

The sum of total credit demanded by firms is

$$\hat{L}_t^W = (\frac{1}{\tilde{L}_t^F})\tilde{L}_t^W\hat{L}_t^W + \tilde{L}_t^I\hat{L}_t^I.$$

From (53), the bank's demand for excess capital is given by

$$\hat{V}_t^E - \hat{P}_t^S = \frac{1}{1-\phi_E}\frac{\beta^{-1}\hat{\imath}_t^R - (1+\tilde{\imath}^V)\hat{\imath}_t^V}{1+\tilde{\imath}^V+\gamma_V-\beta^{-1}}, \tag{B28}$$

whereas from (46),

$$\hat{V}_t^R = (\frac{1+\rho^D}{\rho^D})\hat{\rho}_t^C + \hat{\sigma}_t + \hat{L}_t^I. \tag{B29}$$

For the risk weight, linearization of (47) yields

$$\hat{\sigma}_t = -\phi_q \hat{q}_t. \tag{B30}$$

From (62), the countercyclical component of the capital adequacy ratio is

$$\hat{\rho}_t^C = \theta^C(\hat{L}_t^I - \hat{L}_{t-1}^I).$$

Equations (B28) and (B29) can be used to calculate $\hat{V}_t$ as

$$\hat{V}_t = (\frac{\widetilde{V}^R}{\widetilde{V}})\hat{V}_t^R + (\frac{\widetilde{V}^E}{\widetilde{V}})\hat{V}_t^E,$$

which can then be substituted in (B6), the bank debt demand equation, to determine $\hat{i}_t^V$.

From (55), the bank's borrowing from the central bank is

$$\hat{L}_t^{C,B} = \frac{1}{\tilde{L}^{C,B}}\left[\tilde{L}\hat{L}_t - \widetilde{E}\widetilde{L}^{FB}(\widehat{E}_t + \widehat{L}^{FB}) - (1-\mu^R)\tilde{P}^S\tilde{d}(\hat{d}_t + \hat{P}_t^S) - \tilde{V}\hat{V}_t\right]. \tag{B31}$$

and foreign borrowing by the domestic bank is

$$\widehat{L}_t^{F,B} = \frac{(1+\widetilde{i}^R)}{(\widetilde{i}^R - \widetilde{i}^W)}(\hat{i}_t^R - \widehat{i}^W - \widehat{E}_{t+1} + \widehat{E}_t). \tag{B32}$$

The equilibrium condition of the market for cash, (68), yields

$$(\tilde{m}^P\tilde{P}^S)(\hat{m}_t^P + \hat{P}_t^S) + (\tilde{d}\tilde{P}^S)(\hat{d}_t + \hat{P}_t^S) = \tilde{E}\tilde{R}^F(\hat{R}_t^F + \hat{E}_t) - \tilde{E}\tilde{L}^{F,B}(\hat{L}_t^{F,B} + \hat{E}_t) - \tilde{V}\hat{V}_t \tag{B33}$$

The equilibrium condition of the goods market, equation (65), is, using (64):

$$(1-\psi)(\frac{\tilde{Y}}{\tilde{C}})\hat{Y}_t^N = \hat{C}_t + \frac{\tilde{K}}{\tilde{C}}(\mathbb{E}_t\hat{K}_{t+1} - \hat{K}_t) + \delta\frac{\tilde{K}}{\tilde{C}}\hat{K}_t. \tag{B34}$$

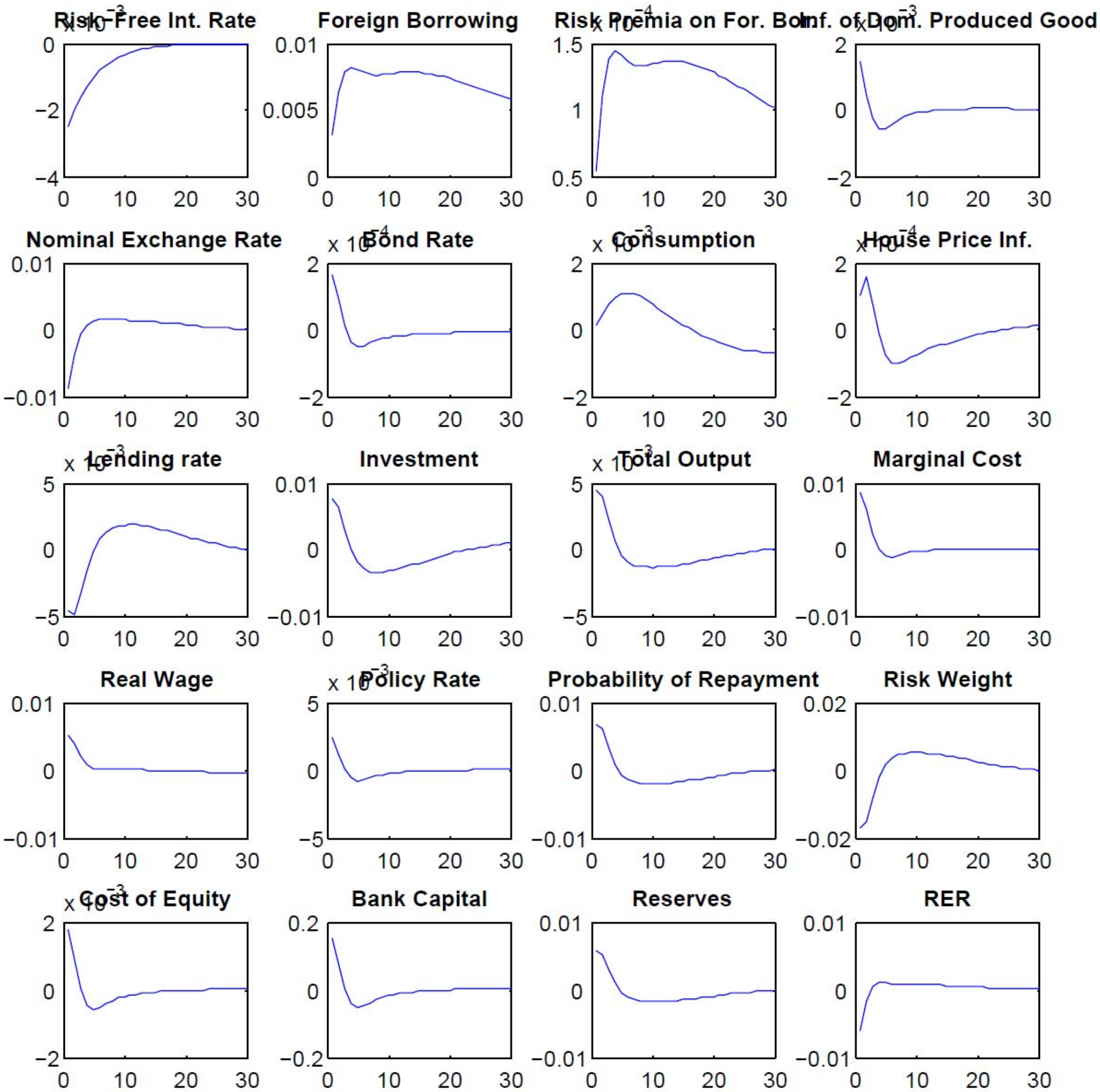
The equilibrium condition for housing market could be stated by simply equating the real demand for housing, given by equation (B7), to zero:

$$\hat{H}_t^d = 0. \tag{B35}$$

Finally, the linearized form of the equilibrium condition of the market for foreign exchange is given by

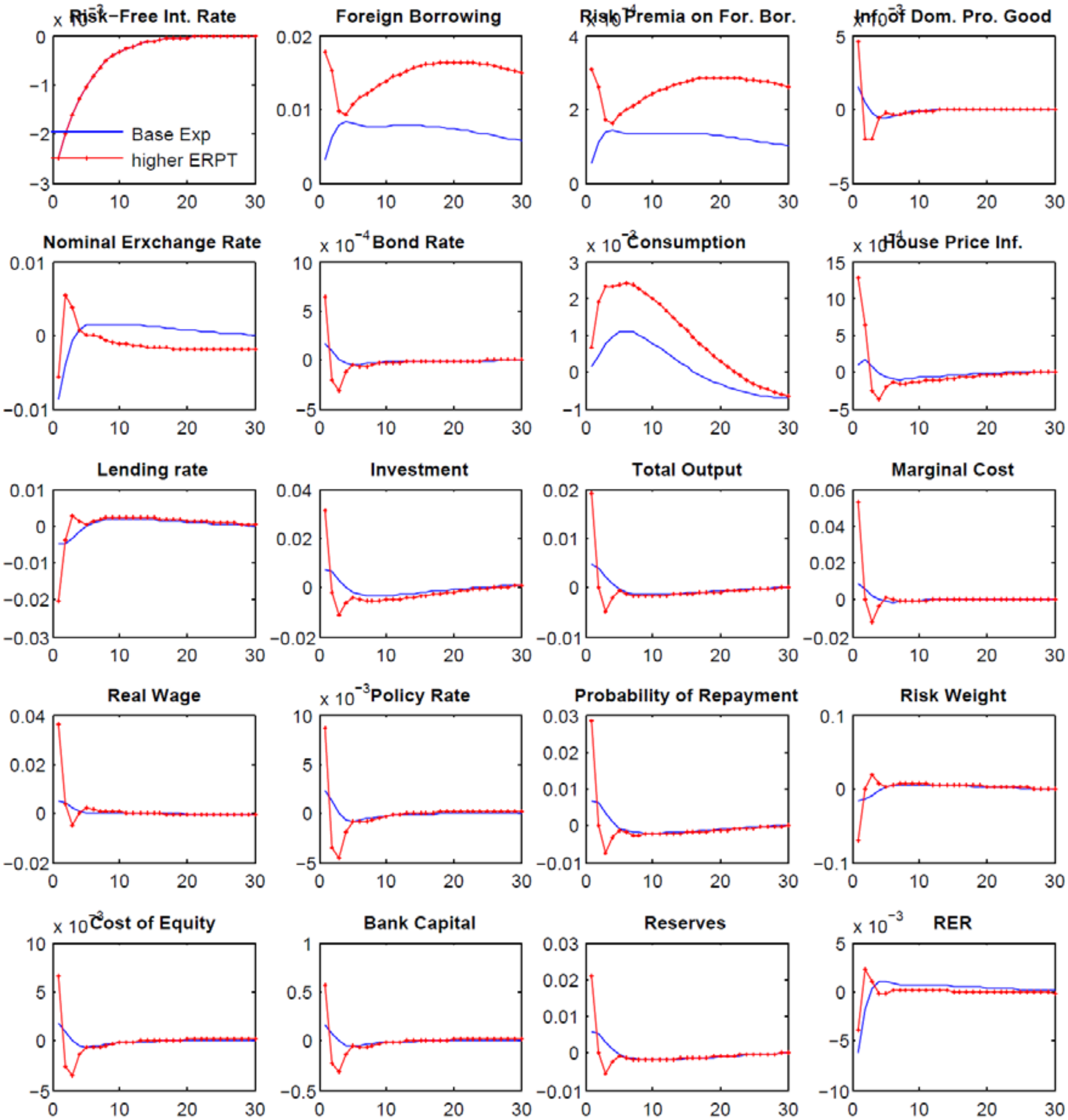
$$\begin{aligned}&\widetilde{WP}^X \widetilde{Y}^X(\widehat{WP}_t^X + \widehat{Y}_t^X) - \widetilde{WP}^F \widetilde{Y}^F(\widehat{WP}_t^F + \widehat{Y}_t^F)\\ &+\widetilde{NFA}\widetilde{i}^W \widehat{i}_{t-1}^W + \widetilde{NFA}(\widetilde{i}^W - 1)\widehat{NFA}_{t-1} = \widetilde{\theta}^{F,B}\widetilde{L}^{F,B}\theta_{t-1}^{F,B}\\ &+(\widetilde{\theta}^{F,B} - 1)\widetilde{L}^{F,B}\widehat{L}_{t-1}^{F,B} + \widetilde{NFA}(\widehat{NFA}_t - NFA_{t-1}).\end{aligned} \tag{B36}$$

Figure 1
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 2
Increase in the Degree of Exchange Rate Pass-through
(Deviations from Steady State)

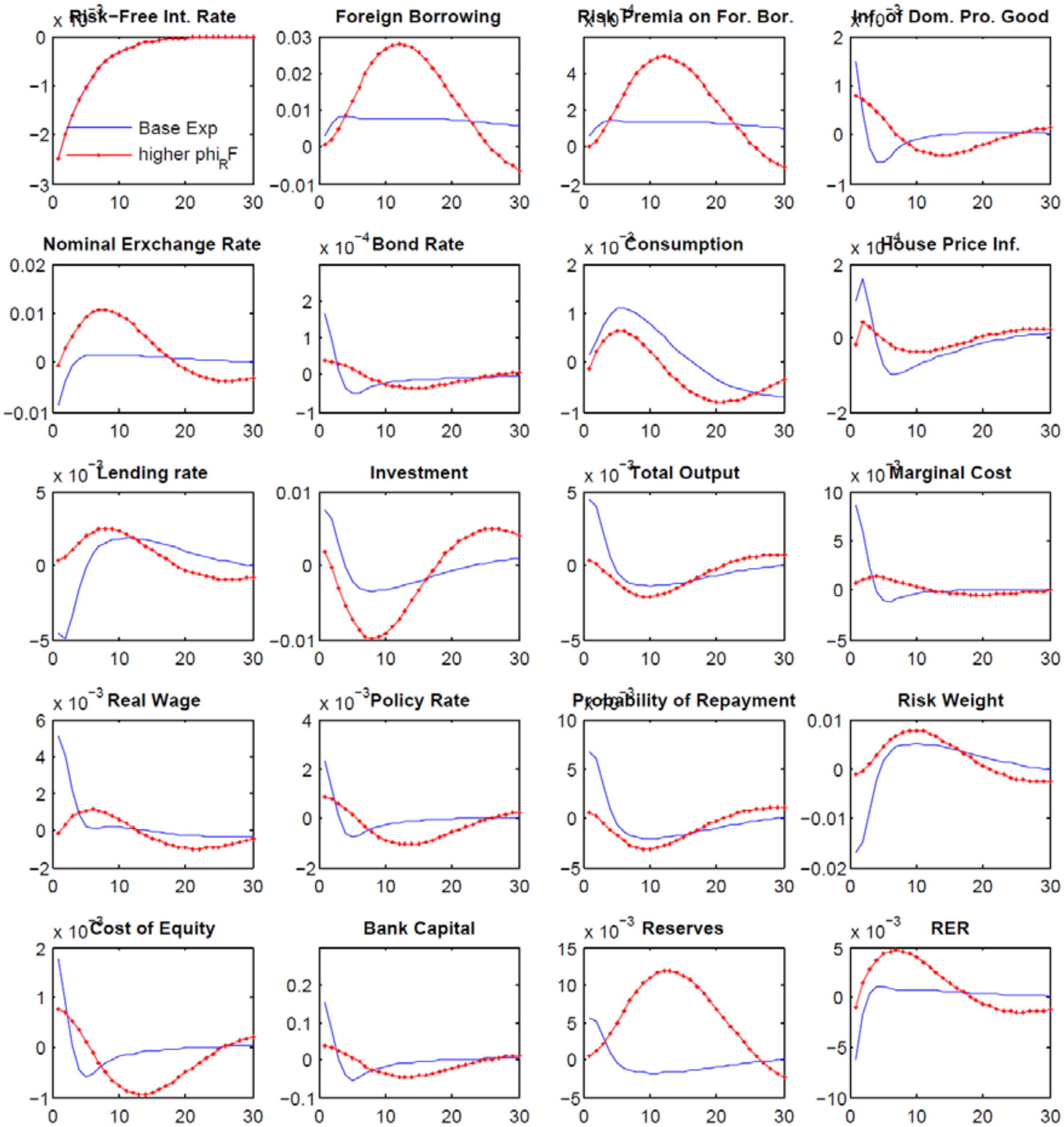


Note: See note to Figure 1.

Figure 3

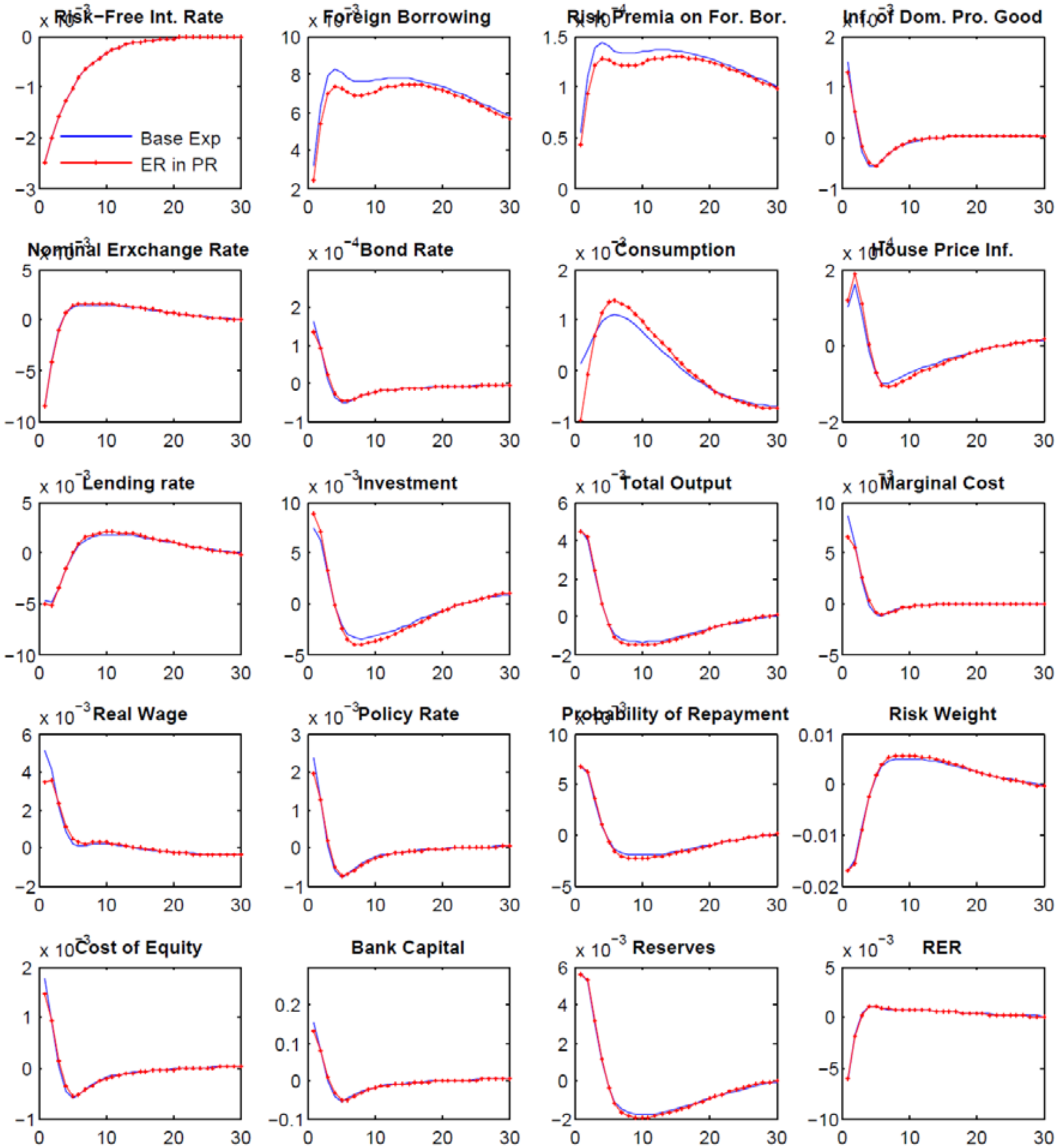
Change in Reserve Accumulation Target

(Deviations from Steady State)



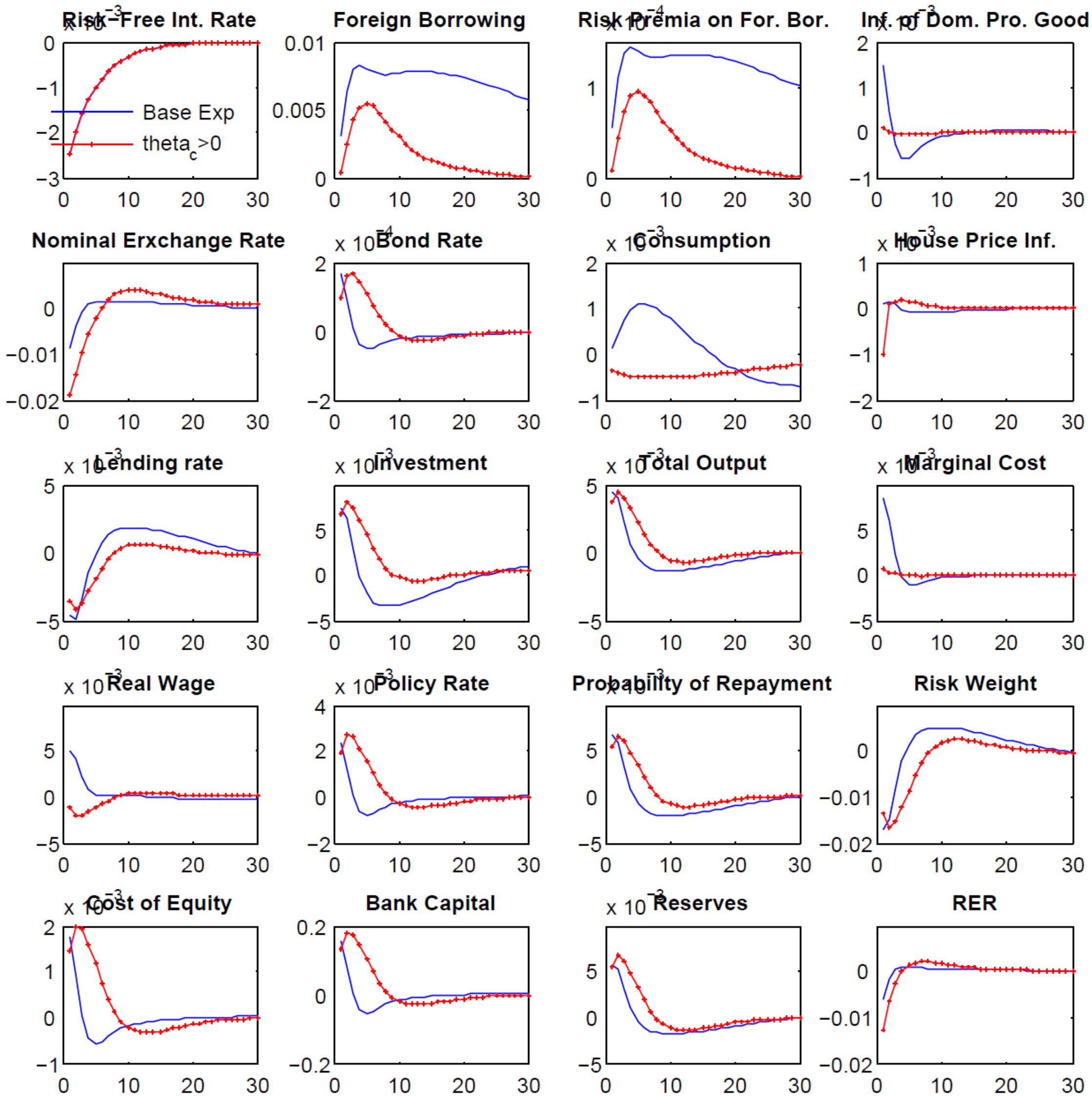
Note: See note to Figure 1.

Figure 4
Positive Response of Policy Rate to Exchange Rate Depreciation
(Deviations from Steady State)



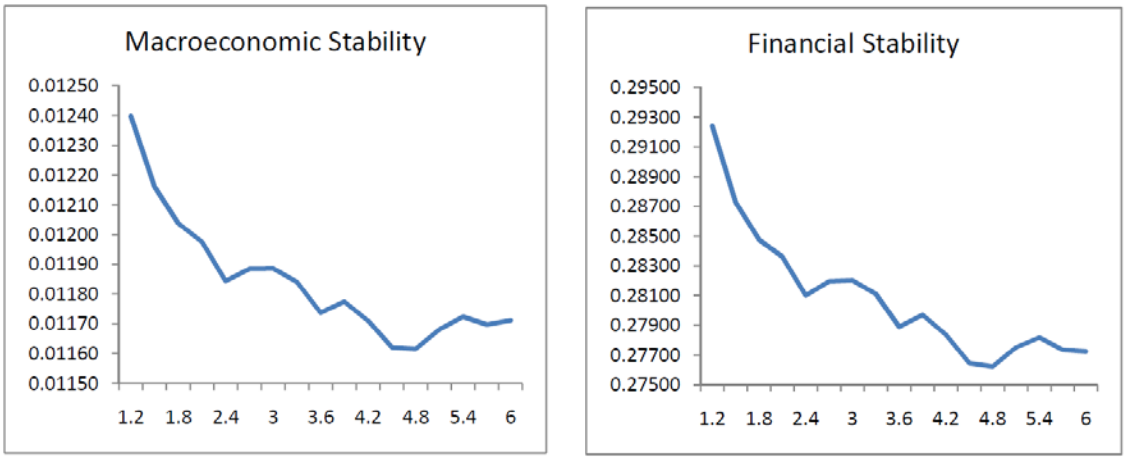
Note: See note to Figure 1.

Figure 5
Positive Response in Countercyclical Regulatory Capital Rule



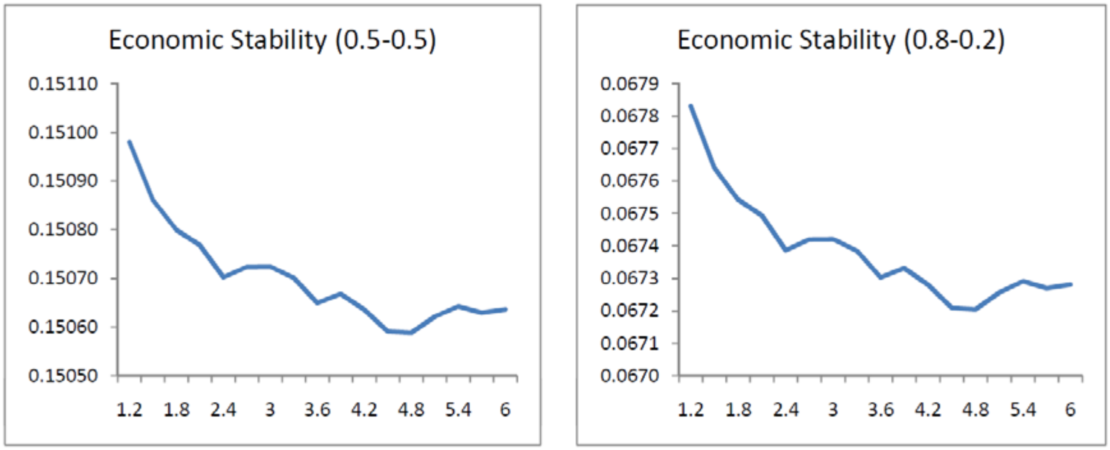
Note: See note to Figure 1.

Figure 6
Countercyclical Regulatory Capital Rule:
Impact on Macroeconomic Stability and Financial Stability



Note: The horizontal axis shows values of θ^C, and the vertical axis the coefficient of variation of the relevant variable. Macroeconomic stability is measured in terms of 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 7
Countercyclical Regulatory Capital Rule:
Impact on Composite Index of Economic Stability



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