Monetary and Macroprudential Policies to Manage Capital Flows*

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We study interactions between monetary and macroprudential policies in a model with nominal and financial frictions. The latter derive from a financial sector that provides credit and liquidity services that lead to a financial accelerator-cum-fire-sales amplification mechanism. In response to fluctuations in world interest rates, inflation targeting neutralizes nominal distortions but leads to increased volatility in credit and asset prices. Taylor rules do better, but the use of a countercyclical macroprudential instrument in addition to the policy rate improves welfare and has important implications for the conduct of monetary policy. "Leaning against the wind" or augmenting a Taylor rule with an argument on credit growth is not an optimal policy response.

JEL Codes: E44, E52, E61, F41.

1. Introduction

One of the legacies of the recent financial crisis has been a shift toward a systemwide or macroprudential approach to financial supervision and regulation (Bernanke 2008; Blanchard, Dell' Ariccia, and Mauro 2010). By their own nature, macroprudential policies that have a systemic and cyclical approach are bound to affect macroeconomic variables beyond the financial sector and interact with other macro policies, especially monetary policy (Caruana 2011; International Monetary Fund 2013a). In this paper, we study

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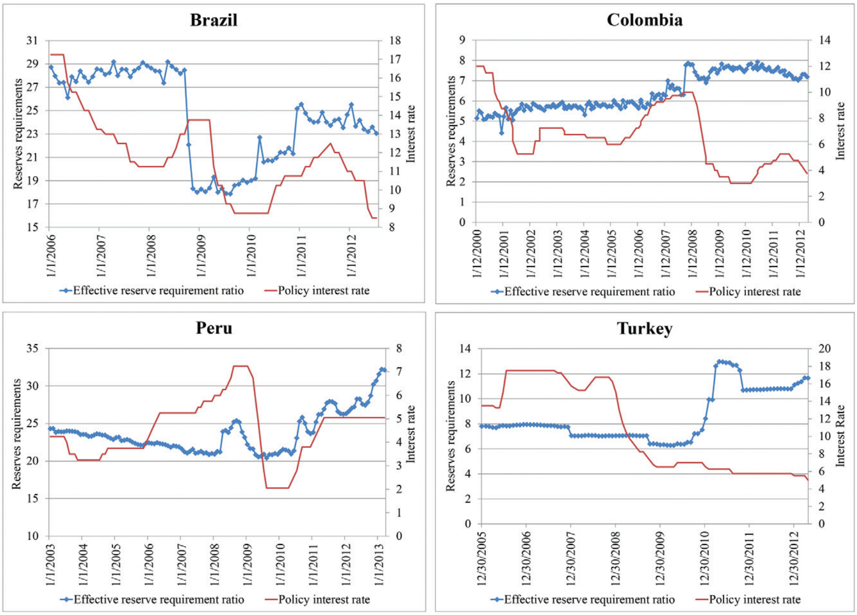
Figure 1. Interest Rates and Reserve Requirements in Selected Emerging Markets



these interactions, focusing on the distortions that these policies attempt to mitigate, especially in the management of swings in capital flows (Ostry et al. 2011).

A number of emerging market economies have recently used macroprudential instruments countercyclically to deal with swings in capital flows. Lim et al. (2011) document this for a number of macroprudential instruments, and Federico, Vegh, and Vuletin (2014) do it for reserve requirements.[1] Figure 1 shows the countercyclical use of reserve requirements for four emerging markets around Lehman's bankruptcy (see also IMF 2012). All four countries slashed policy rates in the immediate aftermath of Lehman's bankruptcy, but Brazil and Peru reduced reserve requirements dramatically even

[1]Elliot, Feldberg, and Lehnert (2013) provide a comprehensive survey of the historical evidence on the use of cyclical macroprudential instruments in the United States, including underwriting standards, reserve requirements, credit growth limits, deposit rate ceilings, and supervisory pressure.

before cutting rates. As capital inflows surged following the adoption of unconventional monetary policies in the major reserve-currency-issuing countries, all four countries raised reserve requirements to curb credit growth, and they increased policy rates—with the exception of Turkey.[2]

These policy responses and the crisis itself have opened an intense debate about objectives, targets, and instruments of both monetary and macroprudential policies. Most papers addressing these issues assume that the government's objective is to minimize a loss function that adds credit growth volatility to that of output and inflation, and rank policies accordingly (see, for instance, Glocker and Towbin 2012; Mimir, Sunel, and Taskin 2013; Suh 2014). They usually find that macroprudential instruments contribute to price and financial stability, especially when dealing with financial shocks, but that there are tradeoffs between monetary and macroprudential instruments with respect to demand or productivity shocks. Kannan, Rabanal, and Scott (2012) and Unsal (2013) also rank these policies according to the volatility of inflation and the output gap, and do not derive the impact of the macroprudential measures from financial frictions but rather postulate that the measures lead to an additional cost for financial intermediaries. Quint and Rabanal (2014) and Bailliu, Meh, and Zhang (2015) do welfare analysis (rather than postulate an arbitrary loss function), but still their financial frictions are postulated in an ad hoc way (without fully modeling the incentive problems behind the frictions).

In this paper we study interactions between monetary and macroprudential policies and we innovate on three fronts. First, we model explicitly and with *microfoundations* the nominal and financial frictions that monetary and macroprudential policies attempt to mitigate. In particular, we incorporate a financial sector that provides both credit and liquidity services following standard contracting and optimization problems.[3] Second, we calculate model-based *welfare measures* for different policy arrangements and rank them

[2]Changes in average reserve requirements in Colombia underestimate the actual impact because they do not capture changes in marginal rates and remuneration that increase the effectiveness of these measures (Vargas et al. 2010).

[3]Di Iasio and Quagliariello (2013) show that a microprudential regulatory regime that disregards the equilibrium effect of asset prices on incentives performs poorly in a micro model with endogenous liquidation of assets under distress.

accordingly. And third, we focus on a *shock to world interest rates*, which keeps rates low for an extended period of time and which is later on undone (rather than the standard AR(1) processes). This induces a long period of capital inflows followed by a reversal that resembles the unwinding of unconventional monetary policies in advanced economies. Thus, we study the interactions of these two policies during an event that is relevant for many countries at this juncture and where the potential tradeoffs between these two policies are least understood.[4]

The financial sector in our model features two types of representative intermediaries that operate in competitive markets: a lending and a liquidity intermediary, which interact with each other through an interbank market. The lending intermediary provides credit to entrepreneurs, solving an agency-cost problem as in Bernanke, Gertler, and Gilchrist (1999). For the liquidity intermediary, we extend the mechanism introduced by Choi and Cook (2012), and assume that liquidity services are produced with "excess reserves" and real resources.[5] This assumption provides natural links between the lending intermediaries and with the monetary authority, and allows us to endogenize not just default but also recovery rates, as well as the response to a countercyclical macroprudential instrument. Although the model does not deliver the type of systemic events (crises) that macroprudential policies aim to mitigate, the financial accelerator-cum-fire-sales mechanism we introduce produces a fair amount of amplification and persistence that makes the financial friction relevant for macroeconomic policies—in particular, to study interactions between monetary and macroprudential policies.[6]

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[4]The importance of shocks to world interest rates for emerging market business cycles has been emphasized in Neumeyer and Perri (2005).

[5]In Choi and Cook (2012), liquidity services are provided by non-financial firms, which makes it hard to relate to macroprudential policies. Breaking up intermediaries according to functions is a useful theoretical (Merton and Bodie 2004) and macro-modeling device (Gerali et al. 2010).

[6]The class of models with occasionally binding collateral constraints (Jeanne and Korinek 2010; Benigno et al. 2013; Bianchi and Mendoza 2013) allows for a definition of "crises" as the states of the world when the constraint is binding. For a study of optimal monetary policy when collateral constraints are binding (i.e., "crisis" episodes), see Braggion, Christiano, and Roldós 2009.

This financial sector is embedded in an otherwise-standard small open-economy New Keynesian model with Calvo-pricing nominal rigidities (as in Galí and Monacelli 2005). We study the transitional dynamics to the world interest rate shock and also derive a welfare function consistent with the underlying model, where tradeoffs between correcting both distortions may exist. As in Faia and Monacelli (2007), we study a restricted set of rules that we can rank according to that welfare metric. In particular, we consider Taylor-type rules, both standard and augmented with a credit growth argument (as in Christiano et al. 2010), and combine them with both a constant and a countercyclical reserve requirement—our simple macroprudential rule.

A large and protracted reduction in world interest rates produces large capital inflows and increases in aggregate demand, activity, the real exchange rate, and asset prices in what we call the "natural" economy—i.e., the one without price or financial frictions. The introduction of these frictions magnifies the cyclical fluctuations of most macro and financial variables—in particular, of asset prices and credit.

Our main results are the following. First, even though a pure or strict inflation-targeting (IT) regime neutralizes the nominal frictions in the model, it delivers too much asset price and credit volatility; thus, a standard or an adjusted Taylor rule that reacts to credit growth (as suggested by Christiano et al. 2010) neutralizes in part, albeit indirectly, the financial frictions, improving welfare relative to the IT regime. However, all these regimes are dominated in welfare terms by one that utilizes a countercyclical reserve requirement (aimed at the financial friction) together with a pure IT rule for monetary policy (aimed at the nominal friction). We interpret this result as reflecting the Tinbergen principle of "one instrument for each objective" and Mundell's "principle of effective market classification," whereby instruments should be paired with the objectives on which they have the most influence (see Beau, Clerc, and Mojon 2012 and Glocker and Towbin 2012).

Second, we show that "leaning against the wind" of financial instability—by, say, having the monetary policy rate respond to credit growth—may be a suboptimal solution. Third, once we use a macroprudential instrument in a countercyclical fashion, the evolution of the policy rate deviates substantially from the Taylor rule and suggests the need for close coordination of both instruments. In particular, while the "natural" interest rate of this economy declines with the world rate, the policy rate may indeed need to be increased to accommodate reserve requirements—in contrast to the Turkey experience in figure 1.

The paper is organized as follows. The next section lays out the model economy, with special focus on the financial sector, and describes the four monetary and macroprudential policy frameworks. Section 3 discusses a baseline calibration and the welfare measure we use to rank these policy frameworks. Section 4 studies the policy responses to the proposed world interest rate shocks, analyzing impulse responses and welfare rankings, followed by section 5 on the robustness of the results. Section 6 concludes the paper. The appendixes provide technical details on the model derivations and extensions.

2. Model Economy

The model is an extension of the financial accelerator framework developed by Bernanke, Gertler, and Gilchrist (1999), henceforth BGG, to an open-economy context. The presence of price rigidities induces a role for monetary policy to affect the real interest rate and correct the associated distortion. Similarly, the presence of a financial friction associated with the cost of monitoring defaulted borrowers suggests the potential role of a macroprudential instrument to reduce this other distortion. In addition to the BGG credit friction, we extend the mechanism in Choi and Cook (2012) whereby fire sales further amplify the financial accelerator mechanism. In Choi and Cook (2012), when a loan is defaulted, the capital seized by the lending intermediaries is sold at a discounted price due to the fact that the liquidation technology consumes resources. In this paper, we assume that, in addition to the use of real resources, the liquidation process also requires time and excess reserves in the financial sector, which produces a natural real-financial linkage and a role for reserve requirements to manage the intensity of the financial cycle.

In what follows we explain in more detail the different agents and their behavior in our model economy: households, capital and goods producers, entrepreneurs, and the financial sector.

2.1 Households

The intertemporal preferences of the households are characterized by

$$U_t = E_t \left[\sum_{i=0}^{\infty} \beta^i u \left(c_t, h_t, \frac{M_t}{P_t} \right) \right],$$

where c_t is the consumption basket, h_t is labor supply, and M_t/P_t are real money balances. The period-t household budget constraint equals consumption plus savings with real income:

$$c_t + \frac{D_t}{P_t} - \frac{e_t B^*_{H,t}}{P_t} + \frac{M_t}{P_t} = \frac{W_t}{P_t} h_t + R^D_{t-1} \frac{D_{t-1}}{P_t} - R^*_{t-1} \Theta_{t-1} \frac{e_t B^*_{H,t-1}}{P_t} + \frac{M_{t-1}}{P_t} + \Pi_t - \tau_t.$$

Household savings can be invested in three types of financial assets: deposits (D_t) with a return of R^D_t in t; foreign bonds ($B^*_{H,t}$) with a foreign currency return $R^*_t \Theta_t$ in t; and money balances (M_t). The household's income in period t derives from labor, returns from previous periods' holding of financial assets, and profits from firms Π_t (net of lump-sum taxes, τ_t).

Foreign bonds are expressed in foreign currency and e_t is the nominal exchange rate (units of domestic currency per unit of foreign currency). Θ_t is a risk premium for foreign bonds (liabilities), which is taken as given by the households, but is a function of the total indebtedness of the economy, $\Theta_t = \Theta(B^*_t)$. The real exchange rate is defined as $rer_t = e_t P^*_t / P_t$.

The optimal holding of deposits satisfies the following households' Euler equation:

$$1 = \beta R^D_t E_t \left[\frac{u_{c,t+1}}{u_{c,t}} \frac{1}{(1 + \pi_{t+1})} \right]. \tag{1}$$

The optimal holding of foreign bonds (liabilities) satisfies the following households' Euler equation:

$$1 = \beta R^*_t \Theta(B^*_t) E_t \left[\frac{u_{c,t+1}}{u_{c,t}} \frac{rer_{t+1}}{rer_t} \frac{1}{(1 + \pi^*_{t+1})} \right]. \tag{2}$$

The money demand by households is given by

$$u_{\frac{M}{P},t} = \frac{R_t^D - 1}{R_t^D} u_{c,t}, \tag{3}$$

and households' labor supply is characterized by

$$\frac{W_t}{P_t} = -\frac{u_{h,t}}{u_{c,t}}. \tag{4}$$

In this economy, households save in financial assets, but they don't manage the allocation and financing of the physical capital stock.

2.2 Production and Capital Accumulation

Competitive firms in this economy produce domestic goods (that are sold to domestic and foreign wholesalers) and capital goods (that are sold to entrepreneurs). Aggregate production of domestic goods is given by

$$y_t = a_t (k_t)^{\theta_y} (h_t)^{1-\theta_y}, \tag{5}$$

which is sold at price $P_{y,t}$. The demand for labor and the demand for capital services are given by

$$\frac{W_t}{P_t} = \frac{P_{y,t}}{P_t} \frac{(1-\theta_y) Y_t}{h_t}, \text{ and} \tag{6}$$

$$\frac{VMPK_t}{P_t} = rr_{K,t} = \frac{P_{y,t}}{P_t} \frac{\theta_y y_t}{k_t}, \tag{7}$$

where $VMPK_t$ and $rr_{K,t}$ are the nominal marginal productivity of capital and the real rental rate of capital, respectively. Capital is produced by perfectly competitive capital producers that buy installed capital from successful entrepreneurs, new capital from goods producers, and liquidated or restructured capital from liquidity intermediaries.

In contrast to the standard financial accelerator model (BGG 1999), we assume that defaulted capital requires time and resources to be liquidated and become productive again. Let $k_{D,t}$ and $k_{D,t}^{new}$ be, respectively, the stock of defaulted capital and the new defaulted capital in period t. Both the productive and defaulted capital depreciate at a rate δ. Each period, there is a probability η_K of turning one unit of defaulted capital into a productive one. In consequence, a fraction η_K of the undepreciated defaulted capital becomes productive. Thus, the evolution of the productive capital stock is given by

$$k_{t+1} = (1-\delta)(k_t - k_{D,t}^{new}) + \left(1 - \Delta\left(\frac{inv_t}{inv_{t-1}}\right)\right) inv_t \\ + \eta_K(1-\delta)k_{D,t}, \tag{8}$$

where Δ ( ) is an adjustment cost in the change of investment that can be interpreted as a time-to-build mechanism for capital accumulation. From the capital-goods-producer problem we obtain the demand for investment (new capital):

$$qr_t\left(1 - \Delta\left(\frac{inv_t}{inv_{t-1}}\right) - \Delta'\left(\frac{inv_t}{inv_{t-1}}\right)\frac{inv_t}{inv_{t-1}}\right) \\ + E_t\left[sd_{t,t+1}qr_{t+1}\left(\Delta'\left(\frac{inv_{t+1}}{inv_t}\right)\left(\frac{inv_{t+1}}{inv_t}\right)^2\right)\right] = 1, \tag{9}$$

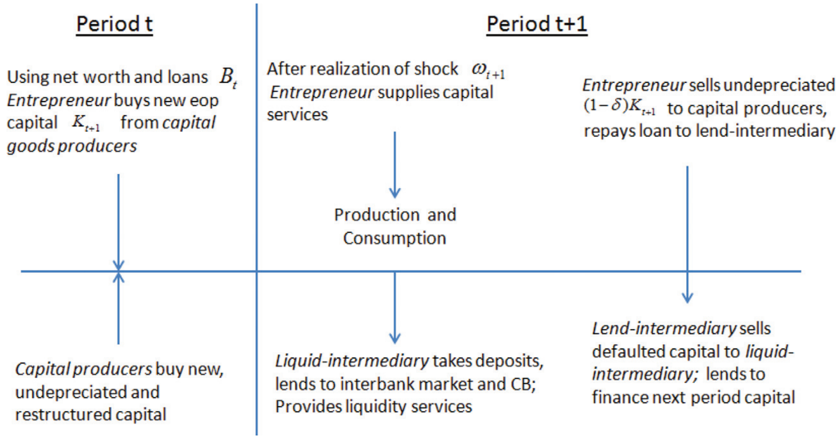
where $sd_{t,t+1}$ is the stochastic discount factor between period t and $t+1$ (the household intertemporal marginal rate of substitution of consumption, $sd_{t,t+1} = \beta u_{c,t+1}/u_{c,t}$), and $Q_t(qr_t)$ is the nominal (real) price of installed capital.

2.3 Financial Sector

The financial sector links depositors (households) and investors (entrepreneurs). It comprises two sets of intermediaries—lending and liquidity intermediaries—which interact through an interbank market and summarize the provision of credit and liquidity services in this economy.[7] In laying out this generic financial system, we follow Merton and Bodie (2004) and focus on the two key functions of providing credit and liquidity, while leaving the more specific institutional details to the calibration exercise—and the specifics of

[7] It is not uncommon in macroeconomic models to split the financial system into segments: Gerali et al. (2010), for instance, split the banking system into two "retail" branches and one "wholesale" unit.

Figure 2. Timing of Events



different actual economies. Entrepreneurs in this economy use their nominal net worth ($netn_t$) and loans (B_t) from the lending intermediaries to purchase new, installed physical capital, k_{t+1}, from capital producers. Entrepreneurs then experience an idiosyncratic technological shock that converts the purchased capital into $\omega_{t+1}k_{t+1}$ units at the beginning of the period (where ω_{t+1} is a unit-mean, log-normally distributed random variable with standard deviation equal to σ_ω), and rent capital to goods producers. If they are successful, entrepreneurs sell their capital to capital producers at the end of the period and repay their loans. If they are unsuccessful and default, the lending intermediary takes control of the capital and sells (at a fire-sale price) the capital to the liquidity intermediary, which uses real and financial resources to restructure and sell it back to capital producers (the timeline of events is summarized in figure 2).

2.3.1 Lending Intermediaries

Lending intermediaries get funds from the interbank market and lend them to entrepreneurs through BGG-type debt contracts. Since only the entrepreneurs observe the realization of the shock, they have an incentive to misrepresent the outcome, and this creates an agency-cost distortion that the debt contract attempts to minimize.

For each unit of capital, a successful entrepreneur obtains a nominal payoff equal to the rental rate of capital and the price of the undepreciated capital:

$$payn_t = P_t(rr_{K,t} + (1-\delta)qr_t) = VMPK_t + (1-\delta)Q_t. \tag{10}$$

The contracts are characterized by a lending interest rate, R^l_{t+1}, such that if the entrepreneur has a realization of ω_{t+1} and $\omega_{t+1}payn_{t+1}k_{t+1} \geq R^l_{t+1}B_t$, he pays back the loan in full to the lending intermediaries; if the realization falls short ($\omega_{t+1}payn_{t+1}k_{t+1} < R^l_{t+1}B_t$), the entrepreneur defaults on the loan.

It is convenient to define the *average* rate of return of capital as

$$R^K_{t+1} = \frac{VMPK_{t+1} + (1-\delta)Q_{t+1}}{Q_t}. \tag{11}$$

At the end of period t the entrepreneur has net worth N_t and borrows B_t from the lending intermediary to buy k_{t+1}. An endogenous cutoff $\bar{\omega}_{t+1}$ determines which entrepreneurs repay and which ones default, and it is determined by the expression

$$\bar{\omega}_{t+1}R^K_{t+1}Q_t k_{t+1} = R^l_{t+1}B_t. \tag{12}$$

This equation implies that, ceteris paribus, the lending rate R^l_{t+1} moves with the cutoff $\bar{\omega}_{t+1}$. Thus, instead of characterizing the loan contract in terms of R^l_{t+1}, we can do it in terms of $\bar{\omega}_{t+1}$.

When the entrepreneur defaults, the lending intermediary audits and takes control of the investment, which then is sold to the liquidity intermediary. In this case, the lending intermediaries still obtain the benefit of renting capital to output producers, but the default has costs due to the fact that the undepreciated capital is sold at a nominal (real) fire-sale price $FS_t(fsr_t = FS_t/P_t)$. Thus, the actual payment that a lending intermediary can obtain from a defaulted loan ($\omega_t < \bar{\omega}_t$) is $\omega_t k_t(VMPK_t + FS_t)$.

The lending intermediary determines the cutoff $\bar{\omega}_t$ with the zero-profit condition:

$$\begin{aligned}(1-\Phi(\bar{\omega}_t;\ \sigma_\omega))R^l_t B_{t-1} + k_t(VMPK_t + (1-\delta)FS_t)\\ \times \int_0^{\bar{\omega}_t} \omega d\Phi(\omega;\ \sigma_\omega) = R^{IB}_{t-1}B_{t-1},\end{aligned} \tag{13}$$

where $\Phi(\omega_t;\ \sigma_\omega)$ is the cumulative probability distribution (CDF) of ω_t given its standard deviation σ_ω, R^{IB}_{t-1} is the gross cost of funds, and B_{t-1} is nominal borrowing. Using the relationship between R^l_{t-1} and $\bar{\omega}_t$, we can define the cost of default as

$$\mu_t = \frac{(Q_t - FS_t)(1-\delta)}{payn_t}. \tag{14}$$

In contrast to BGG (1999), who assume a constant μ_t, here the cost of default is endogenous and depends on the difference between the market prices of installed and defaulted capital. Under financial stress, fire-sale prices differ substantially from the price of installed capital, decreasing recovery values and increasing the cost of default.

Thus, we can define the share of $payn_t k_t$ going to the lending intermediaries as

$$g(\bar{\omega}_t, \mu_t, \sigma_\omega) = \bar{\omega}_t(1 - \Phi(\bar{\omega}_t; \sigma_\omega)) + (1-\mu_t)\int_0^{\bar{\omega}_t} \omega d\Phi(\omega; \sigma_\omega) \tag{15}$$

and the share of $payn_t k_t$ going to entrepreneurs as

$$f(\bar{\omega}_t, \sigma_\omega) = \int_{\bar{\omega}_t}^{\infty} \omega d\Phi(\omega; \sigma_\omega) - \bar{\omega}_t(1 - \Phi(\bar{\omega}_t; \sigma_\omega)). \tag{16}$$

The optimal conditions for the loan contract that maximizes the entrepreneur payoff, subject to the lending intermediary zero-profit condition, are the following (see appendix 1 for details):

$$\begin{aligned} Q_t E_t \left\{ R^{IB}_t \frac{f_{\bar{\omega}}(\bar{\omega}_{t+1}, \sigma_\omega)}{g\bar{\omega}(\bar{\omega}_{t+1}, \mu_{t+1}, \sigma_\omega)} \right\} \\ = E_t \left\{ \frac{payn_{t+1}}{\rho(\bar{\omega}_{t+1}, \mu_{t+1}, \sigma_\omega)} \frac{f_{\bar{\omega}}(\bar{\omega}_{t+1}, \sigma_t)}{g\bar{\omega}(\bar{\omega}_{t+1}, \mu_{t+1}, \sigma_\omega)} \right\}, \end{aligned} \tag{17}$$

which represents an arbitrage condition for the loans to entrepreneurs, and the breakeven condition for financial intermediaries:

$$g(\bar{\omega}_{t+1}, \mu_{t+1}, \sigma_\omega) payn_{t+1} k_{t+1} = R^{IB}_t B_t. \tag{18}$$

In expression (17), $\rho(\cdot)$ can be interpreted as a risk premium, and it is defined as

$$\rho(\bar{\omega}_t, \mu_t, \sigma_\omega) = \left[g(\bar{\omega}_t, \mu_t, \sigma_\omega) - f(\bar{\omega}_t, \sigma_\omega) \frac{g\bar{\omega}(\bar{\omega}, \mu_t, \sigma_\omega)}{f\bar{\omega}(\bar{\omega}_t, \sigma_\omega)} \right]^{-1}. \tag{19}$$

In order to describe the evolution of the entrepreneurs' net worth, we will assume that a fraction $1 - \lambda$ of entrepreneurs survive to the next period while the rest (a fraction λ) die and consume all their wealth. The dead entrepreneurs are replaced by a new mass of entrepreneurs that start with a real net wealth equal to τ_E. For simplicity, we will consider that the surviving entrepreneurs also receive this real net wealth transfer. Thus, the net worth of entrepreneurs evolves according to

$$netn_t = (1 - \lambda) f(\bar{\omega}_t, \sigma_\omega) payn_t k_t + P_t \tau_E, \tag{20}$$

and the dying entrepreneurs have the following consumption:

$$c_{K,t} = \lambda \ f(\bar{\omega}_t, \sigma_\omega) \frac{payn_t}{P_t} k_t. \tag{21}$$

2.3.2 Liquidity Intermediaries

Liquidity intermediaries receive deposits from households paying a gross rate R_t^D, and lend in the interbank market at an interest rate R_t^{IB} (and to the monetary authority at a rate R_t^{RE}). They use "excess reserves" and final goods to provide liquidity services that amount to liquidating or restructuring the capital of unsuccessful entrepreneurs.[8]

We assume that the demand for liquidation services is related to the stock of defaulted capital:

$$lq_t = v k_{D,t}. \tag{22}$$

The evolution of defaulted capital is given by

$$k_{D,t+1} = (1 - \eta_K)(1 - \delta) k_{D,t} + k_{D,t+1}^{new}, \tag{23}$$

[8]Real resources are needed to conduct due diligence, assess future cash flows of failed capital, and return it to productive use. "Excess reserves" are the financial or liquid resources needed to buy that capital or distressed assets. As noted by Gorton and Huang (2004), there are many notions of "liquidity," and they mostly refer to situations where not all assets can be used to buy all other assets at a point in time. This amounts to a "liquidity-in-advance" constraint, as summarized in the technology below.

where $k_{D,t+1}^{new}$ is the amount of new defaulted capital at the end of period $t+1$,

$$k_{D,t+1}^{new} = k_{t+1} \int_0^{\bar{\omega}_{t+1}} \omega d\Phi(\omega; \sigma_\omega). \tag{24}$$

Liquidity intermediaries provide these liquidity services using a technology that combines excess reserves and final goods in a complementary way:[9]

$$lq_t = \min[Z(n_t)^{1-\alpha_{lq}}; \quad Z_{xr}(xr_t)^{1-\alpha_{xr}}]. \tag{25}$$

Thus, the problem of the liquidity intermediaries is to maximize current profits from lending to interbank markets and to the monetary authority as well as producing other liquidity services:[10]

$$\max_{n_t, s_t, \left(\frac{D_t}{P_t}\right)} \left\{ [(1-s_t)R_t^{IB} + s_t^{MA} R_t^{RE} - R_t^D] \frac{D_t}{P_t} \frac{P_t}{R_t^D} - P_t n_t \right\}$$

$$s.t. \; lq_t = Z(n_t)^{1-\alpha_{lq}}$$

$$lq_t = Z_{xr}(xr_t)^{1-\alpha_{xr}}$$

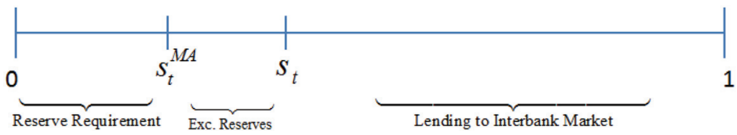
$$xr_t = (s_t - s_t^{MA}) \frac{D_t}{P_t},$$

where (D_t/P_t) is the real amount of deposits, a fraction $(1-s_t)$ of which is lent in the interbank market. The monetary authority imposes a reserve requirement of s_t^{MA}, and xr_t are excess reserves used in liquidation services (see figure 3). Since the opportunity cost of funding for liquidity intermediaries is R_t^D, they discount the end-of-period net benefits of lending in the interbank market by this interest rate.

[9]The use of reduced-form technologies to produce financial services is common in monetary policy models (see, for instance, Chari, Christiano, and Eichenbaum 1995; Edwards and Vegh 1997; Goodfriend and McCallum 2007; Christiano, Motto, and Rostagno 2010; and Cúrdia and Woodford 2010). It is important for financial resources to be needed in the liquidation services to relate these to fire sales, but our results still go through when some degree of substitution between real and financial resources is allowed.

[10]The full dynamic problem of the liquidity intermediary is presented in appendix 2.

Figure 3. Liquidity Intermediary Allocation Problem



Optimality conditions for the liquidation services determine the fire-sale price of defaulted capital (see appendix 2):

$$FS_t = \eta_K Q_t - \nu(f_t + g_t) + (1-\eta_K)(1-\delta)E_t\left[\frac{sd_{t,t+1}}{1+\pi_{t+1}}FS_{t+1}\right], \tag{26}$$

where f_t and g_t are the marginal costs of liquidation services attributed, respectively, to the use of final goods and excess reserves. These marginal costs of liquidation services are an important determinant of the spread between the interbank and deposit rates:

$$R_t^{IB} = \frac{g_t}{P_t}\frac{(1-\alpha_{lq})lq_t}{xr_t}R_t^D. \tag{27}$$

This spread can also be expressed in terms of the macroprudential policy instrument, the time-varying reserve requirement s_t^{MA} (assuming $R_t^{RE} = 1$):

$$R_t^{IB} = (1-s_t^{MA})^{-1}[R_t^D - s_t^{MA}]. \tag{28}$$

Finally, equilibrium in the interbank market means that the fraction of entrepreneurs' debt financed in the interbank market has to be equal to the fraction of real deposits of the liquidity intermediaries lent in the interbank market:

$$\frac{D_t}{P_t}(1-s_t) = \frac{B_t}{P_t}. \tag{29}$$

2.4 Aggregation and Price Rigidities

Total demand for final goods is given by

$$da_t = c_t + c_{K,t} + inv_t + n_t, \tag{30}$$

where final goods are a composite of domestic and imported goods:[11]

$$y_{s,t} = [(1-\alpha_d)^{1/\theta_d}(y_t - x_t)^{1-1/\theta_d} + (\alpha_d)^{1/\theta_d}(y_{f,t})^{1-1/\theta_d}]^{\frac{\theta_d}{\theta_d - 1}}, \tag{31}$$

where x_t are exports of domestically produced goods while $y_{f,t}$ are imports of foreign goods.

The real marginal cost of final goods is given by (α_d is the share of foreign goods)

$$mgcr_t = \left[(1-\alpha_d)\left(\frac{P_{y,t}}{P_t}\right)^{1-\theta_d} + (\alpha_d)(rer_t)^{1-\theta_d}\right]^{\frac{1}{1-\theta_d}}, \tag{32}$$

and the relative demand for domestic and imported goods in the final good basket is

$$\frac{y_t - x_t}{y_{f,t}} = \frac{(1-\alpha_d)}{\alpha_d}\left(\frac{rer_t}{P_{y,t}/P_t}\right)^{\theta_d}, \tag{33}$$

where rer_t is the real exchange rate as defined previously, and θ_d is the elasticity of substitution between domestic and foreign goods in the composite good.

The wholesale firms that produce differentiated domestic goods operate in monopolistically competitive markets and set prices à la Calvo (1983). Thus, in each period only a fraction $1-\phi_p$ of the firms can change optimally their prices while all other firms can adjust the price according to a fraction $\chi_p \in [0,1]$ of past inflation. A log-lineal version of the Phillips curve of final good inflation is (see appendix 3 for a complete derivation of the conditions)

$$\log(1+\pi_t) = \frac{\beta}{1+\beta\chi_p} E_t[\log(1+\pi_{t+1})] + \frac{\chi_p}{1+\beta\chi_p}\log(1+\pi_{t-1}) + \frac{(1-\phi_p)(1-\beta\phi_p)}{\phi_p(1+\beta\chi_p)}\log\left(\frac{mgcr_t}{MC}\right). \tag{34}$$

[11]Details of the aggregation and the role of price-setting wholesalers can be found in appendix 3.

Finally, the balance-of-payments identity implies that

$$rer_t B_t^* = R_{t-1}^* \Theta\left(B_{t-1}^*\right) \frac{B_{t-1}^*}{(1+\pi^*)} rer_t - \frac{P_{y,t}}{P_t} x_t + rer_t (y_{f,t}), \quad (35)$$

where $B_t^* = B_{H,t}^*$ is the stock of foreign debt of the economy, R_t^* is the (gross) foreign interest rate, and π^* is the foreign inflation rate.

The foreign demand for exports is modeled as

$$x_t = \bar{x} \left(\frac{rer_t}{P_{y,t}/P_t} \right)^{\theta^*}, \quad (36)$$

where θ^* is the price elasticity of the foreign demand for domestic goods, and the exogenous evolution of the foreign interest rate is given by the following stochastic process:

$$\log\left(\frac{R_{t+1}^*}{R^*}\right) = \rho_{R*} \log\left(\frac{R_t^*}{R^*}\right) + \varepsilon_{R*,t+1}. \quad (37)$$

2.5 Alternative Monetary and Macroprudential Frameworks

We start with a specification that removes the price rigidities and financial frictions, which we denote as the "natural" allocation of the model economy. When both frictions are present, we need to characterize the macroeconomic policies implemented to complete the model economy. We assume that the monetary policy instrument is the interbank market rate, R_t^{IB}, and that the macroprudential tool is the time-varying reserve requirement, s_t^{MA}. We set different rules for these instruments as a way to define alternative monetary and macroprudential arrangements.

(i) *Standard Taylor-type rule and constant reserve requirement.*[12] In this case monetary policy is characterized by the following reaction rule for the interbank rate (in annual terms):

$$\log\left(\frac{R_t^{IB}}{1+r}\right) = \psi_R \log\left(\frac{R_{t-1}^{IB}}{1+r}\right) + (1-\psi_R)\left(\psi_\pi \log(1+\pi_t) + \psi_y \log(y_t)\right),$$

[12]Most IT emerging market countries follow Taylor-type rules for setting policy rates; some of them also react to external variables like the real exchange rate (see Aizenman, Hutchison, and Noy 2011 and Ostry, Ghosh, and Chamon 2012). We focus on simple rules here and elaborate on others in the "robustness" section 5.4.

where we set $\psi_R = 0, \psi_\pi = 1.5$, and $\psi_y = 0.5$. The reserve requirement, s_t^{MA}, is constant and equal to its steady-state value, $s_t^{MA} = 0.10$.

(ii) *Inflation-targeting regime and constant reserve requirement.* In this situation monetary policy is modeled as an implicit contingent rule that achieves a full stabilization of inflation in every period and every state. As in the previous case, the reserve requirement is constant at its steady-state level.

(iii) *Augmented Taylor-type rule with a countercyclical reaction to credit (entrepreneurs' loan).* In this case, we extend the Taylor-type rule described in (i) to include a countercyclical reaction to fluctuations in entrepreneurs' loan:

$$\log\left(\frac{R_t^{IB}}{1+r}\right) = \psi_R \log\left(\frac{R_{t-1}^{IB}}{1+r}\right) + (1-\psi_R)\left(\psi_\pi \log(1+\pi_t) + \psi_y \log(y_t) + \psi_b \log(b_t)\right),$$

where we consider $\psi_R = 0, \psi_\pi = 1.5, \psi_y = 0.5$, and $\psi_b = 0.25$. Again, the reserve requirement is constant at its steady-state level.

(iv) *Inflation-targeting regime combined with a countercyclical reserve requirement.* As in case (ii), the interbank rate follows an implicit rule that guarantees that inflation is fully stabilized in every period and state. The inflation-targeting regime is combined with a macroprudential rule that adjusts the reserve requirement countercyclically to accommodate domestic financial conditions, as summarized by excess reserves.[13] This possibility is modeled as follows:

$$\log\left(\frac{s_t^{MA}}{s^{MA}}\right) = -\phi_{xr} \log\left(\frac{xr_t}{xr}\right),$$

where $\phi_{xr} = 10$.

[13] Edwards and Vegh (1997) demonstrate the desirability of using a countercyclical reserve requirement in the context of a fixed-exchange-rate regime; however, they assume that the reserve requirement moves directly with foreign interest rates rather than with domestic financial conditions.

3. Baseline Calibration and Welfare Analysis Methodology

The model is calibrated for a quarterly frequency.[14] Thus, households' discount factor will be set at $\beta = 0.99$ while households' utility per period is specified as

$$u\left(c_t, h_t, \frac{M_t}{P_t}\right) = \ln\left(c_t - \gamma_h \frac{(h_t)^{1+\sigma_L}}{1+\sigma_L}\right) + \frac{a_m}{j}\left(\frac{M_t}{P_t}\right)^j,$$

where $\sigma_L = 1, \gamma_h$ is such that, in the steady state, hours worked corresponds to a third of the available hours for the representative household ($h = 1/3$). The steady-state inflation rate is set at zero ($\pi = 0, \pi^* = 0$), implying that, at the steady state, the (gross) deposit rate is $R^D = 1/\beta = 1.01$, which is approximately 4 percent on an annual basis.

The Calvo parameter is set at $\phi_p = 0.75$, which means that the average duration of not having optimally reset prices is four quarters. For the indexation of prices to past inflation, we choose full indexation with $\chi_p = 1.00$.

The ratio of net exports to GDP is 0.5 percent, which implies a foreign debt to annual GDP of around 12.4 percent. We model the external spread as $\Theta(B_t^*) = (B_t^*/B^*)^{\varrho}$ and we set a very elastic schedule or foreign supply of funds with $\varrho = 0.001$, similar to the value used by Schmitt-Grohé and Uribe (2003) to produce simulations close to a case with a fully elastic foreign supply of funds. The share of foreign goods in the final goods composite is 30 percent ($\alpha_d = 0.30$), while the elasticity of substitution between home and foreign goods is less than one ($\theta_d = \theta^* = 0.5$).

We assume that investment adjustment costs do not affect the steady-state allocations and $Q/P = 1$. This adjustment cost of investment satisfies $\Delta(1) = \Delta'(1) = 0$ and $\Delta''(1) = 5$, as in Smets and Wouters (2007). We choose a quarterly depreciation rate of capital of 2.5 percent ($\delta = 0.025$). The probability of selling the defaulted capital is set at $\eta_K = 1/4$, which implies that on average

[14] The model is calibrated to resemble a prototypical emerging market economy such as the ones in figure 1.

the defaulted capital takes one year to be restructured and become productive again.

The production technology assumes a share of capital around one-third ($\theta_y = 0.36$), and by normalization we set $a = 1$ at the steady state. The reserve requirement at the steady state is $s^{MA} = 0.10$, and assuming $R^{RE} = 1$ we have that $R^{IB} = R^D + s^{MA}/(1 - s^{MA})(R^D - R^{RE}) = 1.0112$, which is equivalent to a steady-state interbank rate of 4.5 percent on an annual basis.

For the financial contract we use three main parameters: (i) an annual default rate of 3 percent; (ii) a leverage ratio of 40 percent ($B/k = 0.4$); and (iii) an average cost of liquidation of $\mu = 0.60$. The default rate is in line with the value proposed by BGG (1999), while the leverage ratio is a midpoint between BGG (1999) and the leverage ratio estimated by Gonzalez-Miranda (2012) for a sample of traded companies in Latin American countries. These parameter values imply a risk premium at the steady state $\rho(\bar{\omega}, \mu, \sigma_\omega) = 1.0234$, a recovery rate,

$$recov_t = \frac{(1 - \mu_t) \int_0^{\bar{\omega}_t} \omega d\Phi(\omega; \sigma_\omega) payn_t k_t}{\Phi(\bar{\omega}_t; \sigma_\omega)[R^{IB}_{t-1} B_{t-1}]},$$

of around 36 percent. This implies a return to capital and a lending rate of around 15 and 7 percent, respectively, in annualized terms. We impose a death rate of entrepreneurs of 1 percent quarterly ($\lambda = 0.01$). With this parameter, the entrepreneurs' debt and deposits, as a percentage of GDP in annual terms, are about 55 percent and 61 percent, respectively.

For the liquidation services, we use $\alpha_{lq} = \alpha_{xr} = 0.3$, which is coherent with the calibration used by Choi and Cook (2012). We normalize the steady-state marginal cost of final goods and excess reserves needs for the liquidation services (f and g) such that the excess reserves corresponds to 0.25 percent of deposits. This normalization implies that excess reserves are around 0.15 percent as a percentage of annual GDP.

We perform a numerical approximation of the equilibrium conditions to solve for the dynamics around the deterministic steady state of the model (see appendix 4 for the full set of equilibrium conditions of the model economy). The simulations are performed with a first-order approximation. However, to compute the welfare we use a second-order approximation, which allows us to obtain the welfare ranking among alternative policy frameworks (Faia and Monacelli 2007).[15] More precisely, we use a pruned state-space system for the second-order approximation (see Andreasen, Fernández-Villaverde, and Rubio-Ramírez 2013).[16] Although we have households and entrepreneurs, for the computation of welfare only the utility of households matters since entrepreneurs are risk neutral. Also, for the welfare computation we assume that the weight of real money balances in the household's utility is very small, such that $a_m \approx 0$.

We compute welfare as the second-order approximation of the ergodic mean of the discounted value of the utility function of households. Thus, welfare of policy framework i is computed as the second-order approximation of

$$W(i) = E_0 \left\{ \sum_{t=0}^{\infty} \beta^t \ln \left(c(i)_t - \gamma_h \frac{\left(h(i)_t\right)^{1+\sigma_L}}{1+\sigma_L} \right) \right\}.$$

Then, we compute the cost of policy framework i in terms of consumption such as a λ_i that satisfies

$$W(i) = \frac{1}{1-\beta} \ln \left(\bar{c}(1-\lambda_i) - \gamma_h \frac{(\bar{h})^{1+\sigma_L}}{1+\sigma_L} \right),$$

where $\bar{c}$ and $\bar{h}$ are the steady-state levels of consumption and labor without nominal and financial frictions.

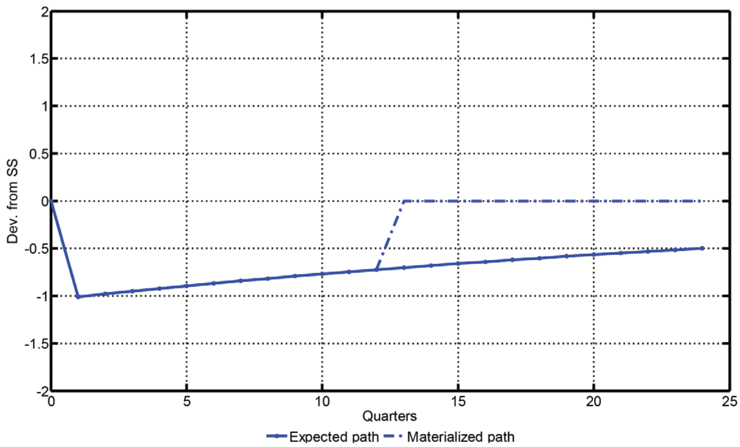
Recall that the process for the foreign interest rate is given by

$$\log \left(\frac{R^*_{t+1}}{R^*} \right) = \rho_{R*} \log \left(\frac{R^*_t}{R^*} \right) + \varepsilon_{R*,t+1},$$

[15] Ozcan and Unsal (2013) follow a similar strategy to study productivity and financial shocks.

[16] It is worth noting that this second-order approximation includes a constant term for the dynamic behavior of each endogenous variable. These constants capture the effects of volatility in the level of each variable implied by each alternative policy regime and conditional on the same distribution of the shocks of the foreign interest rate. Starting from the same deterministic steady state, these constants account for the transitional effect to the ergodic means, which are different across alternative policy regimes (see Faia and Monacelli 2007).

Figure 4. Expected and Materialized Path for the Foreign Interest Rate



where $\varepsilon_{R*,t+1}$ is an iid shock with mean zero and standard deviation equal to σ_{R*}. Assuming that the only source of fluctuations is the foreign interest rate, the welfare of each policy regime is computed assuming ρ_{R*} equal to 0.97 and σ_{R*} equal to 0.25 percent.

4. Policy Responses to Capital Inflows and Reversals

We consider the responses of the model economy to a transitory reduction in the foreign interest rate, which is initially perceived to be highly persistent. However, after twelve quarters, the foreign interest rate unexpectedly rises to its original level. This situation is associated with large capital inflows and a "sudden stop" in the twelfth quarter. Figure 4 illustrates the path for the foreign interest rate.

We study this specific scenario for a couple of reasons. First, the initial, protracted decline in world interest rates captures the extended period of accommodative monetary policies in advanced countries after Lehman's bankruptcy. In the model, both the monetary authority and private-sector agents share the initial view that the world rate can be approximated with an AR(1) process with estimated coefficient of ρ_{R*} close to one, which implies a very persistent reduction in the foreign interest rate. Second, it is uncertain how the process of "normalization" of monetary policy is going to pan out, especially in the United States. A review of recent tightening episodes (see IMF 2013b) suggests that there are no clear tightening patterns and that long rates (perhaps more relevant for capital flow recipient countries) followed an even less predictable pattern; in the 1994–95 episode, however, long rates spiked right after the beginning of the tightening process. It is in this type of scenario where macroprudential policies are expected to contribute the most.

More precisely, we analyze a situation of an unanticipated shock $\varepsilon_{R*,t} < 0$, which induces a reduction in the foreign interest rate which is perceived to last according to a persistence coefficient $\rho_{R*} = 0.97$.[17] However, after p quarters, the expectation of the low foreign interest rate is reversed unexpectedly to its original level ($\varepsilon_{R*,t+p} = -(\rho_{R*})^{p-1}\varepsilon_{R*,t}$). This scenario is similar to those discussed in the "news" literature (Jaimovich and Rebelo 2009; Christiano et al. 2010) whereby an initial signal of future positive developments (high future productivity there, low foreign rates here) later on turn out to be incorrect.

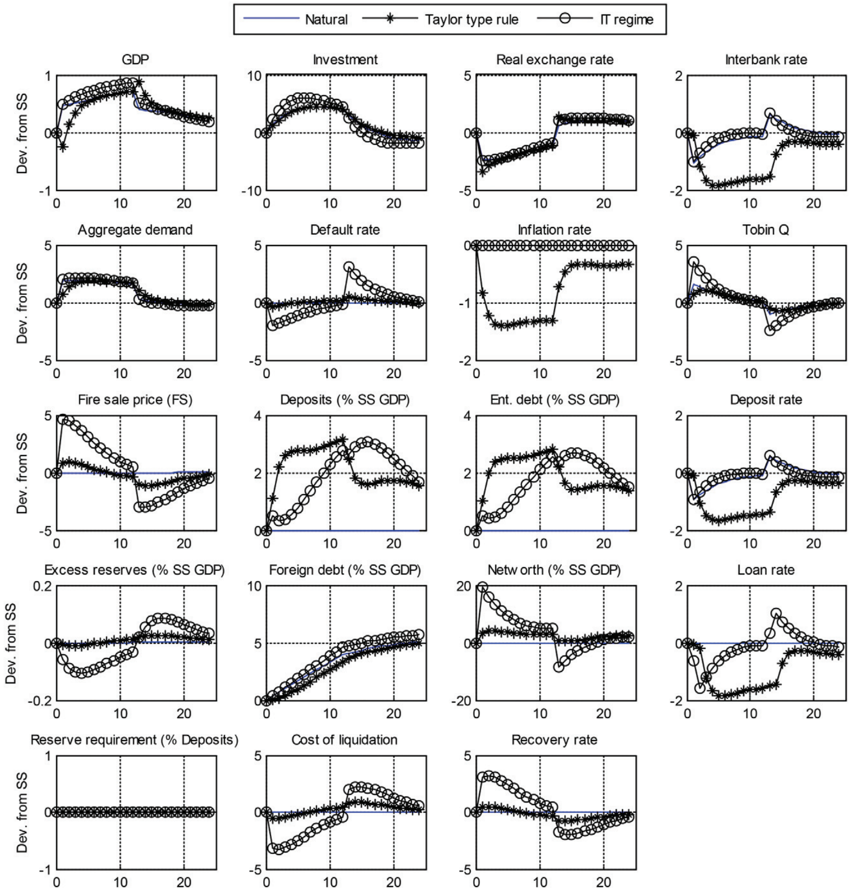
The reduction in world interest rates triggers a sharp increase in aggregate demand, GDP, and asset prices (see figure 5, thin line). The "natural" (interbank) rate in the model without frictions follows the world rate and induces a current account deficit (i.e., an increase in foreign borrowing) and a real exchange rate appreciation. When the world rate unexpectedly increases back to its pre-shock level twelve quarters later, it sets in motion the reverse process, but the intrinsic dynamics of the model deliver only a slowdown in the increase in foreign debt—rather than a "sudden stop" or reversal of flows.

The first policy response we analyze is when the monetary authority follows a "standard" Taylor rule (Taylor 1993).[18] In this

[17]This is the estimated coefficient of an autoregressive process of order 1 for the federal funds rate since 2000.

[18]In reading the results with our benchmark model with nominal and financial frictions, it is worth keeping in mind the well-known results that with only nominal frictions, IT constitutes an optimal regime (Woodford 2003) and that, likewise, countercyclical macroprudential instruments (akin to Pigouvian taxes) are optimal to manage credit booms and busts (Jeanne and Korinek 2010). In appendix 5, we show these two optimality results for one-friction-only versions of our model when facing the world interest rate shock.

Figure 5. Comparing the Responses under Natural, Taylor-Type Rule, and IT Regime



case, the policy ("interbank") rate does not fall in the first quarter, leading to a sharp increase in the real interest rate that triggers a deflationary cycle and a stronger real exchange rate appreciation. The policy rate starts falling after the first quarter, even beyond the natural rate, and induces a sharp increase in credit (entrepreneur debt).

The pure inflation-targeting (IT) regime stabilizes inflation but exacerbates fluctuations in aggregate demand and asset prices.

Table 1. Welfare Comparison under Foreign Interest Rate Shocks

Policy Framework	Welfare	Ranking	λ
Standard Taylor-Type Rule	−82.37	2	16.8%
IT Regime	−83.56	4	17.4%
Augmented Taylor-Type Rule	−82.45	3	16.8%
IT Regime and Countercyclical RR	−75.09	1	12.8%

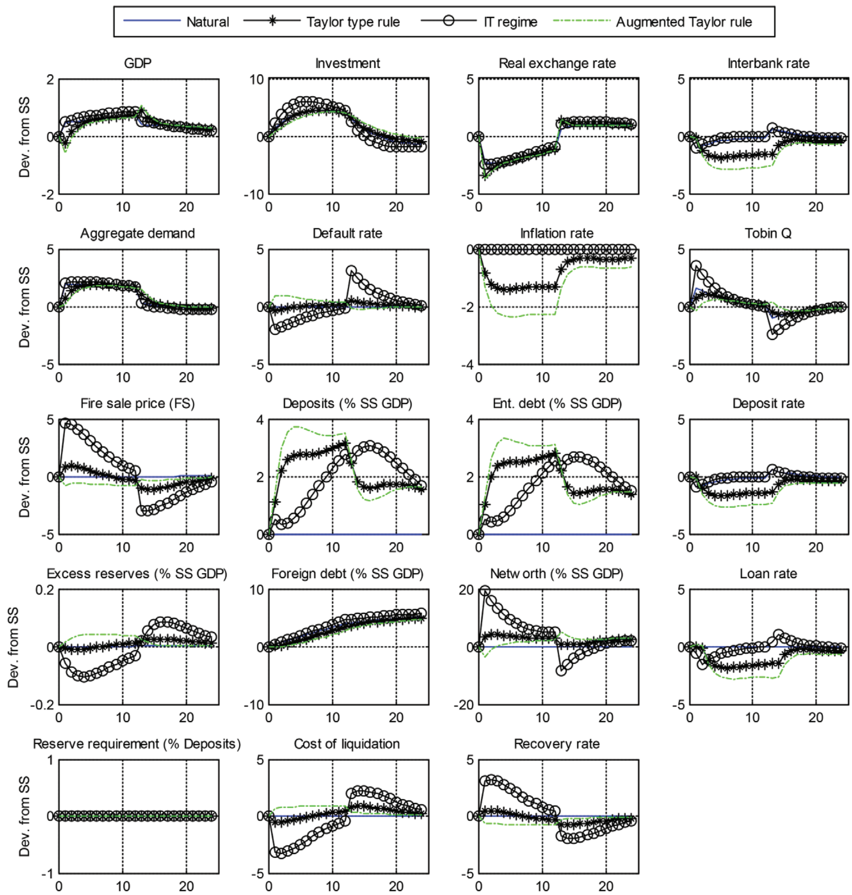
Entrepreneur debt does not increase as much as before, in part because the sharp increase in the price of capital ("Tobin Q" in figure 5) increases net worth, reducing the need for external funds. Associated with the higher asset price volatility are sharper swings in default and recovery rates, as well as a highly procyclical cost of liquidation (in contrast to the constant one in BGG 1999). The procyclicality of the financial sector is also reflected in the more cyclical behavior of excess reserves used to provide liquidity services: they fall in the first three years and are restored when world interest rates go back up thereafter.

As shown in table 1, welfare is higher with the standard Taylor rule than with the IT regime. The IT regime fully neutralizes the nominal friction but induces higher financial volatility and a higher cost of the financial frictions; the Taylor rule neutralizes partly the latter by smoothing the associated GDP fluctuations.

A more direct way to respond to the enhanced financial volatility is to add a term associated with credit growth in the Taylor rule.[19] The results are shown in figure 6. By resisting further the drive to lower interest rates in the first period, this "augmented Taylor rule" (ATR) delivers stronger deflationary pressures. And the further smoothing of asset prices contains the increase in net worth, with the ironic result that credit ends up growing faster than with the standard Taylor rule (TR). As a result, the ATR is dominated in welfare terms by the standard TR (table 1). This result contrasts with the one found in Christiano et al. (2010), where the addition

[19]This is akin to "leaning against the wind," although the expression could be applied more broadly to responses to asset prices and other indicators of financial conditions.

Figure 6. Comparing the Responses under Natural, IT Regime, and Augmented Taylor



of credit growth to the standard Taylor rule improves welfare. The reason for the different result is that the shock in Christiano et al. (2010) is an expected increase in productivity that *raises* the natural interest rate. Here the initial shock *lowers* the natural interest rate, so adding credit growth with a positive coefficient in the Taylor rule moves the economy further away from the natural path. The result is, however, in agreement with Christiano et al. (2010) in the sense that focusing exclusively on goods price inflation can lead to sharp moves in asset prices, thus making it desirable to move away from strict inflation targeting (that is here dominated by both the TR and ATR in welfare terms, table 1).

An alternative way to respond to both the nominal and financial frictions is to use another, macroprudential instrument: a countercyclical reserve requirement (s_t^{MA}), as defined in regime (iv) in section 2.5.[20]

Reserve requirements increase substantially in the first two years, from 10 percent of deposits to just above 30 percent at the end of the first year. More importantly, they are reduced to less than the original 10 percent rate after the reversal in world interest rates (as done by several emerging market countries in the aftermath of the Lehman bankruptcy; see figure 1). The combined monetary–macroprudential regime brings all macroeconomic variables closer to their "natural levels" and smoothes the volatility of financial variables (figure 7). In particular, it is much more effective in containing credit growth than the augmented Taylor rule, and delivers clear welfare gains relative to all other regimes (table 1).

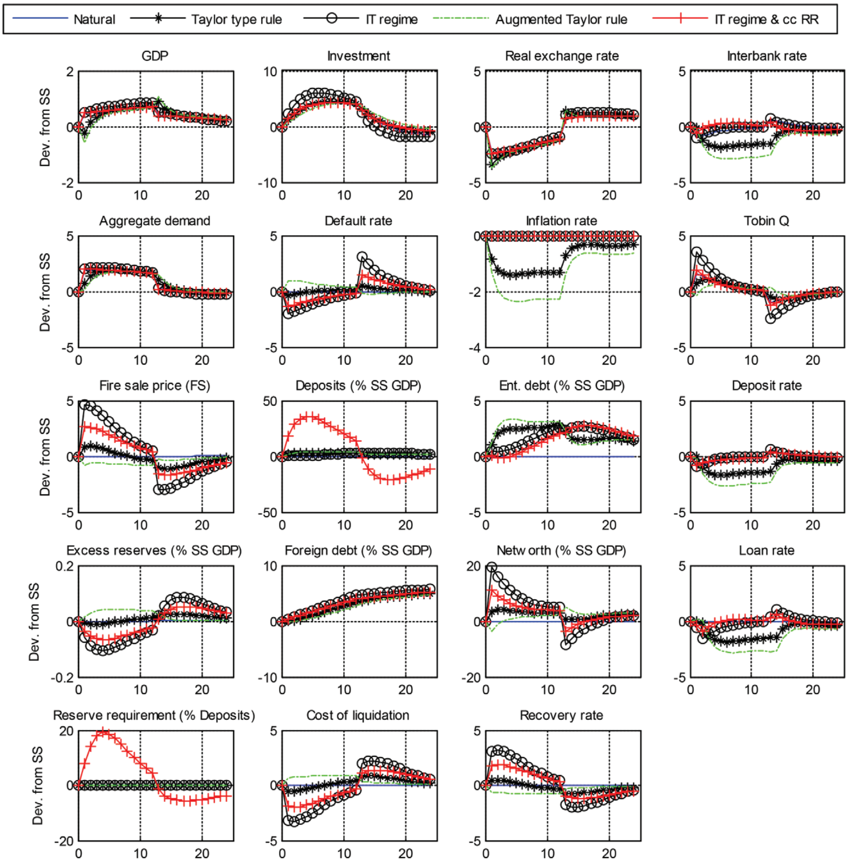
The fact that the use of the macroprudential instrument improves welfare beyond the augmented Taylor rule underscores the drive to expand the macroeconomic policies toolkit (IMF 2013a). Financial frictions abound, and the use of an additional cyclical instrument results in a better management of the two frictions/distortions in the model. We interpret this result as reflecting the Tinbergen principle of "one instrument for each objective" and Mundell's "principle of effective market classification," whereby instruments should be paired with the objectives on which they have the most influence (see Beau, Clerc, and Mojon 2012 and Glocker and Towbin 2012).

In this case, the macroprudential instrument mitigates the financial friction while the monetary policy rate neutralizes the nominal friction.

It is also important to note that the use of the macroprudential instrument has implications for the monetary policy instrument. In

[20]Bianchi (2011) demonstrates that, for a very generic bank balance sheet, capital and reserve requirements have similar effects (see also Benigno 2013). Agénor, Alper, and Pereira da Silva (2013) study interactions between interest rate rules and a Basel III-type countercyclical capital regulatory rule in the management of housing demand shocks.

Figure 7. Comparing the Responses under Natural, IT Regime, Augmented Taylor, and IT Regime Combined with Countercyclical Reserve Requirement



particular, while the "natural" interest rate falls in the early part of the exercise, the policy rate falls only marginally but is driven above its original level after one year, to accommodate the impact of the increased reserve requirement. As noted in IMF (2013a), "the conduct of both policies will need to take into account the effects they have on each other's main objectives"; we would add that this exercise demonstrates also the need to coordinate both policy instruments, especially when dealing with swings in capital flows.

Table 2. Welfare Comparison with Foreign Borrowing

Policy Framework	**Welfare**	**Ranking**	**λ**
Standard Taylor-Type Rule	−83.48	2	17.3%
IT Regime	−84.57	4	17.9%
Augmented Taylor-Type Rule	−83.50	3	17.3%
IT Regime and Countercyclical RR	−69.92	1	9.7%

5. Robustness

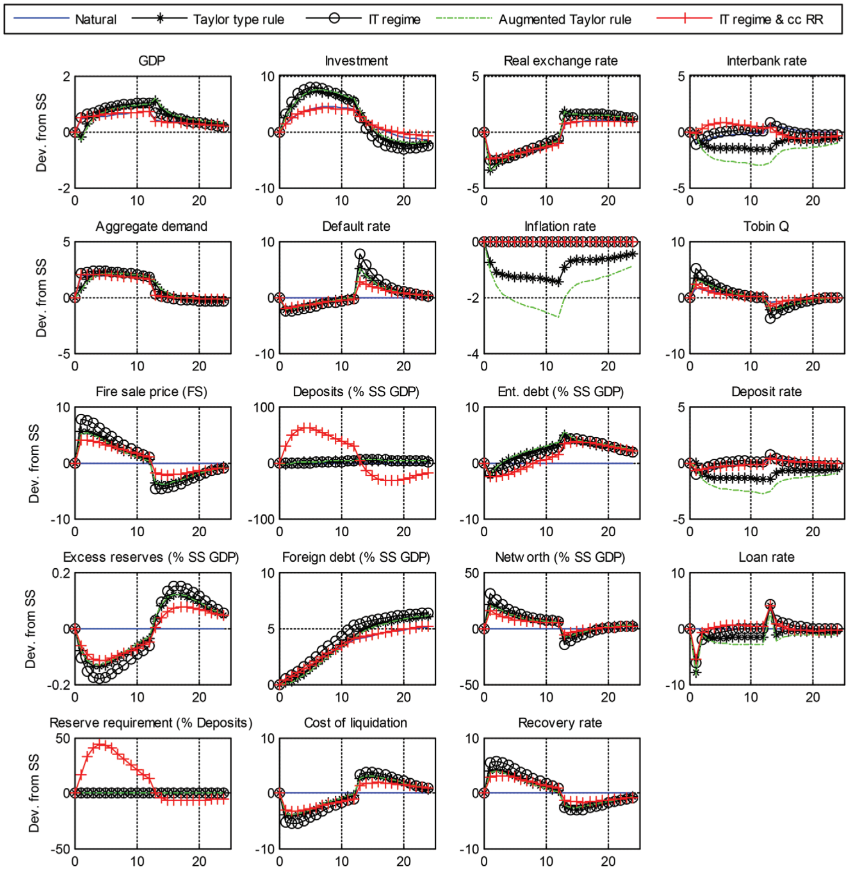
In this section, we analyze the robustness of the results discussed in the previous section. In particular, we study ways in which both the financial and the nominal distortions could be enhanced and how those changes might alter the policy rankings. We also explore a calibration where liquidity services represent a larger share of financial services, and study a popular family of rules for emerging market economies—that adds the exchange rate as a third argument. We conclude with an analysis of standard macro shocks in our model economy.

5.1 Foreign Borrowing and Dollarization

So far the only agents that hold foreign liabilities are the households. In this section, we assume that both entrepreneurs and lending intermediaries have direct access to external funding in world markets. For simplicity, we assume that these levels of borrowing are constant, thus capturing only the valuation or “balance sheet” effects associated with such borrowing (see appendix 6 for details). We also allow, in a separate exercise, for dollarization of credit, i.e., half of the entrepreneurs’ borrowing can be done in dollar-indexed instruments (appendix 7).

The case where entrepreneurs and lending intermediaries have direct access to external funding yields the same ranking of policies as before (table 2). With dollarized liabilities, the initial real exchange rate appreciation magnifies the increase in entrepreneurs’ net worth and requires less borrowing—indeed there is an initial reduction in credit. This case exemplifies an economy that is more integrated financially to the rest of the world, hence there is more

Figure 8. The Role of Partial Dollarization in the Entrepreneurs' Loan



transmission of the world interest rate shock and lending interest rates fall substantially in the early periods.

The case with partial dollarization of entrepreneurs' borrowing exacerbates the financial distortion, leading to more financial volatility (or instability) and to a change in the ranking of policies. As can be seen in figure 8, aggregate demand, GDP, the real exchange rate, and financial variables fluctuate much more than before (with the default rate spiking to almost 10 percent and net worth increasing by more than 20 percent of GDP after the initial shock). As shown

Table 3. Welfare Comparison with Partial Dollarization in Entrepreneurs' Loans

Policy Framework	Welfare	Ranking	λ
Standard Taylor-Type Rule	−84.74	2	18.0%
IT Regime	−85.17	3	18.2%
Augmented Taylor-Type Rule	−85.33	4	18.3%
IT Regime and Countercyclical RR	−56.07	1	0.9%

in table 3, the IT regime with macroprudential policies continues to dominate all other monetary policy "only" regimes, but now the IT regime dominates the augmented Taylor rule.

5.2 Wage Rigidities

To model wage rigidities in a simple manner, we follow closely Blanchard and Galí (2007), assuming that only a fraction $1-\phi_w$ of households can demand a real wage increase consistent with labor market conditions as summarized by equation (4). The rest of the households (a fraction ϕ_w) adjust nominal wages according to inflation. Hence, the aggregate nominal wage inflation is given by

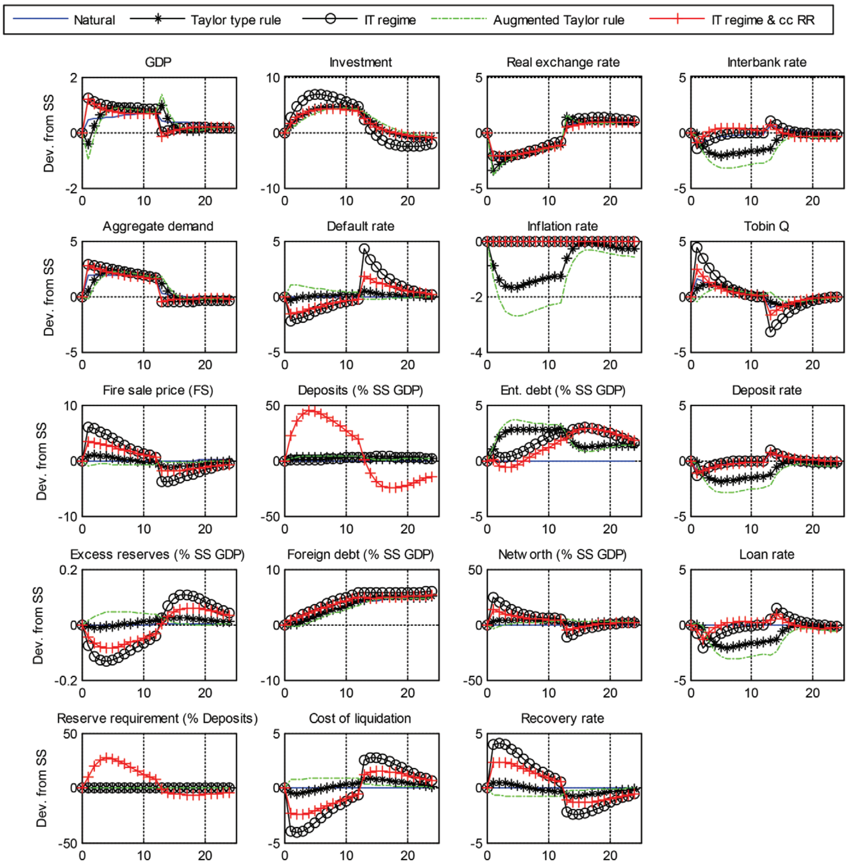
$$\log\left(1+\pi_t^w\right) = (1-\phi_w)\left(\log\left(-\frac{u_{h,t}}{u_{c,t}}\right) - \log\left(\frac{W_{t-1}}{P_{t-1}}\right) + \log\left(1+\pi_t\right)\right) + \phi_w \log\left(1+\pi_t\right), \tag{38}$$

and the evolution of the aggregate real wage is given by

$$\begin{aligned}\log\left(\frac{W_t}{P_t}\right) - \log\left(\frac{W_{t-1}}{P_{t-1}}\right) &= \log\left(1+\pi_t^w\right) - \log\left(1+\pi_t\right) \\ &= (1-\phi_w)\left(\log\left(-\frac{u_{h,t}}{u_{c,t}}\right) - \log\left(\frac{W_{t-1}}{P_{t-1}}\right)\right).\end{aligned} \tag{39}$$

This specification is meant to capture the notion that real wages may respond with inertia to labor market conditions and that inflation fluctuations can be a source of dynamics of real wages. For the model

Figure 9. The Role of Wage Rigidities



simulations under wage rigidities, we use $\phi_w = 0.875$, which corresponds to a case where households set their nominal wages every eight quarters.

The addition of this nominal rigidity further exacerbates asset price and default/recovery fluctuations (figure 9), as well as exchange rate movements. And the welfare gains of using the countercyclical reserve requirement are even larger than with only price rigidities—reaching 7 percent of steady-state consumption, compared with 4 percent in the benchmark case (table 4).

Table 4. Welfare Comparison with Wage Rigidities

Policy Framework	Welfare	Ranking	λ
Standard Taylor-Type Rule	−82.19	2	16.7%
IT Regime	−83.69	4	17.6%
Augmented Taylor-Type Rule	−82.30	3	16.7%
IT Regime and Countercyclical RR	−70.40	1	10.0%

5.3 Larger "Excess Reserves"

As noted in section 2.3, "excess reserves" are liquid assets that facilitate the purchase of defaulted or distressed capital. Hence, they may encompass a broader set of assets than the strict definition of excess reserves in traditional banks.[21] High-quality liquid assets, such as those included in the numerator of the *liquid coverage ratio* (Basel Committee on Banking Supervision 2013) would be closer to the spirit/nature of the assets used by our liquidity intermediary to buy defaulted/distressed assets.

In this section, we explore the robustness of our results to a larger size of what we call "excess reserves." Our baseline calibration assumes that 0.25 percent of deposits are kept as excess reserves, and this could be considered a small fraction if one recognizes that banks hold around 10 percent of assets in trading-related assets (King 2010) and around 12 percent in government securities.[22] However, the simplicity of our financial intermediaries' balance sheet constrains how much we can increase "excess reserves" without deviating from other stylized facts we adopted for our calibration. Thus, we assume in this section that "excess reserves" are 1.5 percent of

[21] Gray (2011) noted that reserves are used to smooth settlement of transactions and respond to unexpected deposit withdrawals. When reserves are kept for prudential purposes, they could be held not just with vault cash and deposits at the central bank but also with liquid treasury securities.

[22] The four countries in figure 1 hold on average 12.4 percent of total assets in government securities, but there is wide variation across countries; for Brazil and Turkey the figure is around 20–24 percent, while for Colombia and Peru it is around 2–4 percent (averages for the period 1998–2012). It is worth noting that this holding of government securities has been reduced in Brazil since 2006, reaching around 13 percent of total assets in 2012.

deposits (six times bigger than in the baseline).[23] Since the amount of "excess reserves" is related to the resources demanded for liquidation services, we need to increase the average default rate (and reduce the average recovery rate) to induce a higher proportion of "excess reserves." We select a quarterly default rate of 4 percent and an average value of μ such that the recovery rate is around 31 percent on average.[24] We also modify the curvature of the liquidation technology setting $\alpha_{lq} = \alpha_{xr} = 0.15$. The remaining parameters of the liquidation services technology remain the same as the baseline calibration.[25]

The alternative calibration gives a higher role to financial frictions, resulting in more volatile asset prices, more volatile default and recovery rates, and a loan rate that is more procyclical. Interestingly, an inflation-targeting regime may not require a fall in the monetary policy rate in the boom phase of the cycle, in contrast to the responses in the baseline calibration—though this response of monetary policy is not effective in stabilizing GDP, aggregate demand, or the financial variables (figure 10). Thus, a more procyclical financial sector constrains how loose monetary policy can be in response to a reduction in the world interest rate. In terms of welfare, the results still show the superiority of a policy mix that uses simultaneously an inflationtargeting regime with a countercyclical reserve requirement, though the welfare gains are smaller (table 5). More important, using the reserve requirement requires a monetary policy rate that increases in the boom phase and is reduced in the downturn. This behavior accommodates the countercyclical use of reserve requirements and highlights a bigger deviation of the monetary policy rate from the natural rate.

[23] In the case of Peru, the sum of government securities and cash held by commercial banks in the period 2003–12 was equivalent to 25 percent of deposits, while the effective reserve requirement was about 23.5 percent. In the same period, excess reserves were 0.35 percent of deposits.

[24] This higher default rate could be rationalized as the "distress" rate obtained in estimates from credit default swap rates (see Hull, Predescu, and White 2004).

[25] This calibration implies the following for steady-state rates: $R^K = 38.5\% > R^L = 15.8\% > R^{IB} = 4.5\% > R^D = 4\%$.

Figure 10. The Role of Higher Excess Reserves

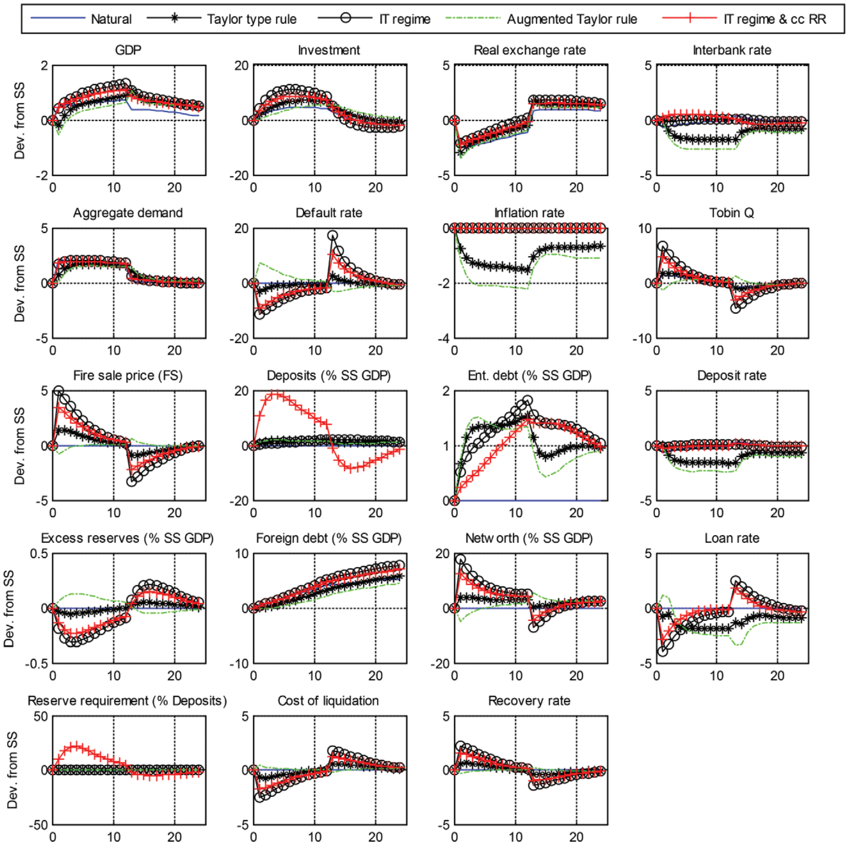


Table 5. Welfare Comparison with Higher Excess Reserves

Policy Framework	Welfare	Ranking	λ
Standard Taylor-Type Rule	−89.72	2	20.5%
IT Regime	−92.59	4	21.9%
Augmented Taylor-Type Rule	−90.09	3	20.7%
IT Regime and Countercyclical RR	−86.08	1	18.7%

5.4 Taylor Rule with "Fear of Floating"

Several emerging economies follow Taylor-type rules that also react to external variables—in particular, real exchange rates (see Aizenman, Hutchison, and Noy 2011; Ostry, Ghosh, and Chamon 2012).[26] This behavior of central banks has been called "fear of floating," as they try to smooth real exchange rate fluctuations to protect dollarized balance sheets from the amplification effects demonstrated in section 5.2. Hence, empirical estimates of the Taylor rules for emerging economies postulate a rule as

$$\log\left(\frac{R_t^{IB}}{1+r}\right) = \psi_R \log\left(\frac{R_{t-1}^{IB}}{1+r}\right) + (1-\psi_R)\left(\psi_\pi \log\left(1+\pi_t\right)\right.$$
$$\left. + \psi_y \log\left(y_t\right) + \psi_{rer} \log\left(rer_t\right)\right),$$

where $\psi_{rer} > 0$. In this way, the monetary policy rate is lower than what would be dictated by the standard Taylor rule when the real exchange rate is appreciating. Using our benchmark model, we study the welfare metrics, adding this alternative rule. To our benchmark calibration, we add $\psi_{rer} > 0.1$, which is consistent with the estimates by Ostry, Ghosh, and Chamon (2012). The results are presented in table 6. It is interesting to note that the IT regime with the countercyclical macroprudential instrument continues to deliver the highest welfare ranking. It is also interesting that even with the financial friction, a simple Taylor rule dominates the ones that react to credit growth or the real exchange rate.

5.5 Preference and Technology Shocks

Even though the main goal of the paper is to study policy responses to world interest rate shocks (and the associated fluctuations in capital flows to emerging markets), in this section we study the behavior of our model to standard preference (demand) and technology (supply) shocks. We extend the model to include a preference shock. Hence, the intertemporal preferences of the households are now characterized by

[26] Both papers find that in fourteen to sixteen inflation-targeting emerging markets, real exchange rates are statistically significant in Taylor rules estimated with panel regressions.

Table 6. Welfare Comparison under Fear of Floating

Policy Framework	Welfare	Ranking	λ
Standard Taylor-Type Rule	−82.37	2	16.8%
IT Regime	−83.56	4	17.4%
Augmented Taylor-Type Rule	−82.45	3	16.8%
IT Regime and Countercyclical RR	−75.09	1	12.8%
Taylor Rule with Fear of Floating	−85.77	5	18.5%

Table 7. Welfare Comparison under Demand Shocks

Policy Framework	Welfare	Ranking	λ
Standard Taylor-Type Rule	−78.22	4	14.5%
IT Regime	−77.94	2	14.4%
Augmented Taylor-Type Rule	−78.21	3	14.5%
IT Regime and Countercyclical RR	−75.83	1	13.2%

$$U_t = E_t\left[\sum_{i=0}^{\infty}\beta^i\varphi_{g,t}u\left(c_t, h_t, \frac{M_t}{P_t}\right)\right],$$

where $\varphi_{g,t}$ is an exogenous preference shock that evolves as

$$\log\left(\varphi_{g,t+1}\right) = \rho_\varphi \log\left(\varphi_{g,t}\right) + \varepsilon_{\varphi,t+1}.$$

Here $\varepsilon_{\varphi,t+1}$ is an iid innovation with mean zero and standard deviation equal to σ_φ. Table 7 shows the welfare computation, assuming that the only source of fluctuations are demand shocks with $\rho_\varphi = 0.80$ and σ_φ equal to 5 percent. We can see that the IT regime with countercyclical reserve requirements continues to be the optimal choice, even for this purely "macro" shock.

We consider next only technology shocks. Recall that the aggregate production of domestic goods is given by

$$y_t = a_t\left(k_t\right)^{\theta_y}\left(h_t\right)^{1-\theta_y},$$

Table 8. Welfare Comparison under Productivity Shocks

Policy Framework	**Welfare**	**Ranking**	$\boldsymbol{\lambda}$
Standard Taylor-Type Rule	−86.37	2	18.8%
IT Regime	−91.27	4	21.3%
Augmented Taylor-Type Rule	−84.19	1	17.7%
IT Regime and Countercyclical RR	−88.71	3	20.0%

and we thus model productivity fluctuations as

$$\log(a_{t+1}) = \rho_a \log(a_t) + \varepsilon_{a,t+1},$$

where $\varepsilon_{a,t+1}$ is an iid innovation with mean zero and standard deviation equal to σ_a. Having productivity shocks as the only source of fluctuations with $\rho_a = 0.97$ and $\sigma_a = 3$ percent, table 8 presents the welfare computation.

It is well known that (positive) technology or supply shocks deliver a difficult tradeoff of expanding activity and lower inflation that is best managed under our parameterization by a standard Taylor rule. Nevertheless, in the face of these shocks, the countercyclical reserve requirement still improves welfare relative to a pure IT regime.[27]

6. Conclusions

The use of macroprudential policy instruments has become increasingly popular in the aftermath of the 2007–09 financial crisis. In this paper we have shown that the use of cyclical macroprudential policies increases welfare, especially in the context of an inflation-targeting regime. We obtain our result in a model with a fairly general but microfounded financial system that provides credit and liquidity services. The dominance of a regime that uses monetary policy to mitigate a nominal friction and a countercyclical reserve

[27]This is consistent with results in Christiano et al. (2010) and in Gambacorta and Signoretti (2014) that show that leaning against the wind improves welfare when the economy is subject to productivity shocks, although they do it with a very different financial intermediary structure than the one in this paper.

requirement to mitigate the financial friction is robust to institutional features such as dollarization of liabilities (that tend to exacerbate financial frictions), wage rigidities (that increase nominal frictions), and alternative calibrations of the financial system and/or policy rules.

The paper also shows the importance of coordinating the use of the monetary policy rate to the countercyclical macroprudential policy instrument. When both instruments are used, the monetary policy rate may deviate substantially from the rate associated with a pure IT regime (and that of the economy's natural rate that follows closely the world interest rate).

Our results also point to the potential perils of "leaning against the wind" of financial instability regardless of the nature of the shock hitting the economy. IMF (2012) suggests that when macroprudential policies operate less than perfectly, monetary policy may lean against the credit cycle—but also provides a number of cases and conditions under which this may not be optimal, especially in the open economy. In this paper, we have shown that when world interest rates are reduced dramatically, as in the current juncture, responding with the policy rate to increases in credit growth may not always be the right policy response.

Our results are robust to a number of modifications that exacerbate either friction as well as to different specifications of the Taylor rule. In particular, we show how dollarized liabilities—a hallmark of many emerging markets—exacerbate financial frictions and make the welfare gains of combining IT with a countercyclical macroprudential instrument even larger. They also show how a more procyclical financial system—also a feature of emerging markets—constrains how loose domestic monetary policy can be in response to loose global monetary conditions.

Appendix 1. The Lending Problem

The lending problem results from the following maximization of the entrepreneurs' payoff:

$$\max_{k_{t+1},\bar{\omega}_{t+1}} E_t\{payn_{t+1}k_{t+1}f(\bar{\omega}_{t+1},\sigma_\omega)\} \tag{40}$$

$$s.t. \quad payn_{t+1}k_{t+1}g(\bar{\omega}_{t+1},\mu_{t+1},\sigma_\omega) \geq R_t^{IB}B_t = R_t^{IB}(Q_tk_{t+1} - netn_t)$$

for all states in $t+1$, where $B_t = Q_t k_{t+1} - netn_t$ is the domestic loan to the entrepreneurs with net worth $netn_t$.

The first-order conditions with respect to k_{t+1} and $\bar{\omega}_{t+1}$ for this problem are

$$E_t \left\{ \begin{array}{c} payn_{t+1} f\left(\bar{\omega}_{t+1}, \sigma_\omega\right) \\ + \varphi_{t+1}(payn_{t+1} g(\bar{\omega}_{t+1}, \mu_{t+1}, \sigma_\omega) - Q_t R_t^{IB}) \end{array} \right\} = 0 \tag{41}$$

$$payn_{t+1} k_{t+1} f_{\bar{\omega}}(\bar{\omega}_{t+1}, \sigma_\omega) + \varphi_{t+1} payn_{t+1} k_{t+1} g_{\bar{\omega}}(\bar{\omega}_{t+1}, \mu_{t+1}, \sigma_\omega) = 0, \tag{42}$$

where φ_{t+1} is the Lagrange multiplier in condition (40). Combining (41) and (42), we obtain

$$\begin{aligned} & Q_t E_t \left\{ R_t^{IB} \frac{f_{\bar{\omega}}(\bar{\omega}_{t+1}, \sigma_\omega)}{g_{\bar{\omega}}(\bar{\omega}_{t+1}, \mu_{t+1}, \sigma_\omega)} \right\} \\ & \quad = E_t \left\{ \frac{payn_{t+1}}{\rho(\bar{\omega}_{t+1}, \mu_{t+1}, \sigma_\omega)} \frac{f_{\bar{\omega}}(\bar{\omega}_{t+1}, \sigma_\omega)}{g_{\bar{\omega}}(\bar{\omega}_{t+1}, \mu_{t+1}, \sigma_\omega)} \right\}, \end{aligned} \tag{43}$$

where $\rho(\cdot)$ is a risk premium defined as

$$\rho\left(\bar{\omega}_t, \mu_t, \sigma_\omega\right) = \left[g\left(\bar{\omega}_t, \mu_t, \sigma_\omega\right) - f\left(\bar{\omega}_t, \sigma_\omega\right) \frac{g\bar{\omega}\left(\bar{\omega}_t, \mu_t, \sigma_\omega\right)}{f\bar{\omega}\left(\bar{\omega}_t, \sigma_\omega\right)} \right]^{-1}. \tag{44}$$

To express in real terms, we can define $payr_t = payn_t/P_t$ and $qr_t = Q_t/P_t$ and rewrite (43) as

$$\begin{aligned} & qr_t E_t \left\{ R_t^{IB} \frac{f_{\bar{\omega}}(\bar{\omega}_{t+1}, \sigma_\omega)}{g_{\bar{\omega}}(\bar{\omega}_{t+1}, \mu_{t+1}, \sigma_\omega)} \right\} \\ & \quad = E_t \left\{ (1+\pi_{t+1}) \frac{payr_{t+1}}{\rho(\bar{\omega}_{t+1}, \mu_{t+1}, \sigma_\omega)} \frac{f_{\bar{\omega}}(\bar{\omega}_{t+1}, \sigma_\omega)}{g_{\bar{\omega}}(\bar{\omega}_{t+1}, \mu_{t+1}, \sigma_\omega)} \right\}, \end{aligned} \tag{45}$$

where $1 + \pi_{t+1} = P_{t+1}/P_t$. Similarly, defining entrepreneurs' debt and net worth in real terms ($b_t = B_t/P_t$ and $netr_t = netn_t/P_t$), we can have the following expressions for the recovery rate, net worth evolution, and entrepreneurs' consumption:

$$recov_t = \frac{(1-\mu_t) \int_0^{\bar{\omega}_t} \omega d\Phi(\omega; \sigma_\omega) payr_t k_t (1+\pi_t)}{\Phi(\bar{\omega}_t; \sigma_\omega)[R_{t-1}^{IB} b_{t-1}]} \tag{46}$$

$$netr_t = (1-\lambda) f(\bar{\omega}_t, \sigma_\omega) payr_t k_t + \tau_E \tag{47}$$

$$c_{K,t} = \lambda\ f(\bar{\omega}, \sigma_\omega) payr_t k_t. \tag{48}$$

Appendix 2. The Problem of Liquidity Intermediaries

This appendix presents the liquidity intermediaries problem in a dynamic form, a slightly more general presentation than in the text. Since the defaulted capital held by the liquidity intermediary is a state variable, the full optimization problem can be written in a recursive manner. Let $L(k_{D,t})$ denote the present discounted benefits of having a stock of defaulted capital equal to $k_{D,t}$. This value can be expressed in a recursive form as follows:

$$L\left(k_{D,t}\right) = \max_{n_t, s_t, \left(\frac{D_t}{P_t}\right)} \left\{ \eta_K q_t k_{D,t} + \left[\left(1 - s_t\right) R_t^{IB} + s_t^{MA} R_t^{RE} - R_t^D\right] \right.$$

$$\left. \times \frac{D_t}{P_t} \frac{P_t}{R_t^D} - P_t n_t + E_t \left[sd_{t,t+1} L\left(k_{D,t+1}\right) \frac{P_t}{P_{t+1}} \right] \right\}$$

$$s.t. \quad k_{D,t+1} = \left(1 - \eta_K\right)\left(1 - \delta\right) k_{D,t} + k_{D,t+1}^{new} \tag{49}$$

$$lq_t = \nu k_{D,t} = Z\left(n_t\right)^{1-\alpha_{lq}} \tag{50}$$

$$lq_t = \nu k_{D,t} = Z_{xr}\left(xr_t\right)^{1-\alpha_{xr}} \tag{51}$$

$$xr_t = \left(s_t - s_t^{MA}\right) \frac{D_t}{P_t}, \tag{52}$$

where $sd_{t,t+1}$ is the stochastic discount factor between period t and $t+1$. The current benefits of the liquidity intermediaries include the sale of the defaulted capital, which occurs with probability η_K at period t. From the law of large numbers, a fraction η_K of the stock of defaulted capital is sold each period. The Lagrangian of the maximization problem in the right-hand side is

$$\mathcal{L} = \left\{ \eta_K q_t k_{D,t} + \left[\left(1 - s_t\right) R_t^{IB} + s_t^{MA} R_t^{RE} - R_t^D\right] \frac{D_t}{P_t} \frac{P_t}{R_t^D} - P_t n_t \right\}$$

$$+ f_t \left(Z\left(n_t\right)^{1-\alpha_{lq}} - \nu k_{D,t} \right)$$

$$+ g_t \left(Z_{xr} \left(\left(s_t - s_t^{MA}\right) \frac{D_t}{P_t} \right)^{1-\alpha_{xr}} - \nu k_{D,t} \right)$$

$$+ E_t \left[sd_{t,t+1} L\left(\left(1 - \eta_K\right)\left(1 - \delta\right) k_{D,t} + k_{D,t+1}^{new} \right) \frac{P_t}{P_{t+1}} \right],$$

where f_t and are g_t the Lagrange multipliers in constraints (50) and (51), respectively. These Lagrange multipliers can be interpreted as the marginal cost of providing liquidation services from final goods and excess reserves. The first-order conditions for n_t, s_t, and $\frac{D_t}{P_t}$ are

$$n_t : -P_t + f_t \frac{(1-\alpha_{lq})lq_t}{n_t} = 0 \Rightarrow \frac{f_t}{P_t} = \frac{n_t}{(1-\alpha_{lq})lq_t} \tag{53}$$

$$s_t : -\frac{R_t^{IB}}{R_t^D} P_t + g_t \frac{(1-\alpha_{xr})lq_t}{xr_t} = 0 \Rightarrow \frac{R_t^{IB}}{R_t^D} = \frac{g_t}{P_t} \frac{(1-\alpha_{xr})lq_t}{xr_t} \tag{54}$$

$$\begin{aligned} \left(\frac{D_t}{P_t}\right) : & \frac{\left[(1-s_t) R_t^{IB} + s_t^{MA} R_t^{RE} - R_t^D\right]}{R_t^D} P_t \\ & + g_t \frac{(1-\alpha_{xr}) lq_t}{xr_t} \left(s_t - s_t^{MA}\right) = 0 \\ & \Rightarrow \frac{\left[R_t^D - (1-s_t) R_t^{IB} - s_t^{MA} R_t^{RE}\right]}{R_t^D} \\ & = \frac{g_t}{P_t} \frac{(1-\alpha_{xr})lq_t}{xr_t} \left(s_t - s_t^{MA}\right). \end{aligned} \tag{55}$$

To complete the characterization of the solution of the dynamic problem, the envelope condition for the recursive problem is

$$\begin{aligned} L'(k_{D,t}) = {} & \eta_K q_t - \nu (f_t + g_t) + (1-\eta_K)(1-\delta) \\ & \times E_t \left[sd_{t,t+1} L'(k_{D,t+1}) \frac{P_t}{P_{t+1}} \right]. \end{aligned} \tag{56}$$

Defining the presented discounted value of one unit of more defaulted capital as the fire sales ($L'(k_{D,t}) = FS_t$), (56) can be expressed as

$$\frac{FS_t}{P_t} = \eta_K \frac{q_t}{P_t} - \nu \left(\frac{f_t}{P_t} + \frac{g_t}{P_t} \right) + (1-\eta_K)(1-\delta) E_t \left[sd_{t,t+1} \frac{FS_{t+1}}{P_{t+1}} \right]. \tag{57}$$

Appendix 3. Price Rigidities, the Phillips Curve, and Aggregation of Final Goods Demand

There is one final good produced using the intermediate composite goods:

$$da_t = \left(\int_0^1 (da_{i,t})^{\frac{\epsilon-1}{\epsilon}} \, di \right)^{\frac{\epsilon}{\epsilon-1}}, \tag{58}$$

where ϵ is the elasticity of substitution across the composite intermediate goods and da_t is total domestic demand. The final good market is perfectly competitive, and the demand for each intermediate composite good i is given by

$$da_{i,t} = \left(\frac{P_{i,t}}{P_t} \right)^{-\epsilon} da_t \quad \text{for all } i, \tag{59}$$

where $P_{i,t}$ is the price of the intermediate composite good i. The aggregate price level of domestic demand is then

$$P_t = \left(\int_0^1 (P_{i,t})^{1-\epsilon} \, di \right)^{\frac{1}{1-\epsilon}}. \tag{60}$$

Each intermediate composite producer has the same technology:

$$da_{i,t} = \left[(1-\alpha_d)^{1/\theta_d} (y_{i,t})^{1-1/\theta_d} + (\alpha_d)^{1/\theta_d} (y_{f,i,t})^{1-1/\theta_d} \right]^{\frac{\theta_d}{\theta_d-1}}, \tag{61}$$

where $y_{i,t}$ and $y_{f,i,t}$ are, respectively, the amount of domestic and foreign goods used by the intermediate composite producer i. The cost minimization implies

$$\frac{y_{i,t}}{y_{f,i,t}} = \frac{(1-\alpha_d)}{\alpha_d} \left(\frac{rer_t}{P_{y,t}/P_t} \right)^{\theta_d}, \tag{62}$$

and the marginal cost (expressed in real terms) is

$$mgcr_t = \frac{mgc_t}{P_t} = \left[(1-\alpha_d) \left(\frac{P_{y,t}}{P_t} \right)^{1-\theta_d} + (\alpha_d) \left(\frac{e_t P_t^*}{P_t} \right)^{1-\theta_d} \right]^{\frac{1}{1-\theta_d}}, \tag{63}$$

which is the same for all intermediate goods producers, because they face the same prices of domestic and foreign goods and their technology is constant return to scale. For the same reason, we can obtain

$$\frac{\int_0^1 y_{i,t} di}{\int_0^1 y_{f,i,t} di} = \frac{y_t - x}{y_{f,t}} = \frac{(1-\alpha_d)}{\alpha_d} \left(\frac{rer_t}{P_{y,t}/P_t} \right)^{\theta_d}, \tag{64}$$

where we have used the fact that total demand for domestic goods is composed by the demand of intermediate composite producers and exports, x_t. The intermediate composite good producers set prices following Calvo's (1983) mechanism of price adjustment. In each period, a fraction $1-\phi_p$ of the producers can change optimally their prices. All other producers can only index their prices to past inflation with a weight χ_p. Thus, the problem for the intermediate composite producers i is the following:

$$\max_{P_{i,t}} E_t \left\{ \sum_{j=0}^{\infty} sd_{t,t+j} (\phi_p)^j \left(\frac{P_{i,t} \left(\frac{P_{t+j-1}}{P_{t-1}} \right)^{\chi_p}}{P_{t+j}} - mgcr_{t+j} \right) da_{i,t+j} \right\}$$

$$s.t.\, da_{i,t+j} = \left(\frac{P_{i,t} \left(\frac{P_{t+j-1}}{P_{t-1}} \right)^{\chi_p}}{P_{t+j}} \right)^{-\epsilon} da_{t+j}.$$

The first-order condition of this problem is

$$P_{i,t} (\epsilon - 1) E_t \left\{ \sum_{j=0}^{\infty} sd_{t,t+j} (\phi_p)^j \left(\frac{\left(\frac{P_{t+j-1}}{P_{t-1}} \right)^{\chi_p}}{P_{t+j}} \right)^{-\epsilon} da_{t+j} \right\}$$
$$= \epsilon E_t \left\{ \sum_{j=0}^{\infty} sd_{t,t+j} (\phi_p)^j mgcr_{t+j} da_{t+j} \right\}. \tag{65}$$

Defining the following expressions in recursive manner,

$$\Omega_{1,t} = mgcr_t + \beta \phi_p E_t \left\{ \left(\frac{(1+\pi_t)^{\chi_p}}{(1+\pi_{t+1})} \right)^{-\epsilon} \frac{da_{t+1}}{da_t} \frac{u_{c,t+1}}{u_{c,t+1}} \Omega_{1,t+1} \right\} \tag{66}$$

$$\Omega_{2,t} = \frac{P_{i,t}}{P_t} + \beta\phi_p E_t \left\{ \left(\frac{(1+\pi_t)^{\chi_p}}{(1+\pi_{t+1})} \right)^{1-\epsilon} \left(\frac{P_{i,t}/P_t}{P_{i,t+1}/P_{t+1}} \right) \right.$$
$$\left. \times \frac{da_{t+1}}{da_t} \frac{u_{c,t+1}}{u_{c,t+1}} \Omega_{2,t+1} \right\}, \tag{67}$$

the optimal condition for price $P_{i,t}$ (65) can be written as

$$(\epsilon - 1)\, \Omega_{2,t} = \epsilon \Omega_{1,t}. \tag{68}$$

Using Calvo's pricing mechanism, we can express the price-level aggregation as

$$1 = \phi_p \left(\frac{(1+\pi_{t-1})^{\chi_p}}{(1+\pi_t)} \right)^{1-\epsilon} + (1-\phi_p) \left(\frac{P_{i,t}}{P_t} \right)^{1-\epsilon}. \tag{69}$$

Finally, the relationship between domestic demand and supply of final goods is given by

$$da_t disp_t = y_{S,t}, \tag{70}$$

where $disp_t \geq 1$ is the inefficiency attributed to price dispersion and $y_{S,t}$ is the aggregate supply of the composite goods, defined as

$$y_{s,t} = \left[(1-\alpha_d)^{1/\theta_d} (y_t - x_t)^{1-1/\theta_d} + (\alpha_d)^{1/\theta_d} (y_{f,t})^{1-1/\theta_d} \right]^{\frac{\theta_d}{\theta_d - 1}}. \tag{71}$$

Again using the properties of Calvo's pricing mechanism, this price dispersion term evolves as

$$disp_t = \phi_p \left(\frac{(1+\pi_{t-1})^{\chi_p}}{(1+\pi_t)} \right)^{-\epsilon} disp_{t-1} + (1-\phi_p) \left(\frac{P_{i,t}}{P_t} \right)^{-\epsilon}. \tag{72}$$

Appendix 4. Complete Set of Equilibrium Conditions

The equilibrium for the model economy, given macroeconomic policy rules for R_t^{IB} and s_t^{MA}, is a sequence for c_t, h_t, $\frac{M_t}{P_t}$, R_t^D, rer_t, $\frac{W_t}{P_t}$, y_t, $\frac{P_{y,t}}{P_t}$, $rr_{K,t}$, k_{t+1}, inv_t, $k_{D,t+1}$, $k_{D,t+1}^{new}$, qr_t, $payr_t$, fsr_t, $f(\bar{\omega}_t, \sigma_\omega)$, $g(\bar{\omega}_t, \mu_t, \sigma_\omega)$, $\bar{\omega}_t, \mu_t, b_t, netr_t$, $\rho(\bar{\omega}_t, \mu_t, \sigma_\omega)$, $defrate_t$,

$recov_t, c_{K,t}, lq_t, n_t, xr_t, s_t,\ D_t/P_t,\ fr_t,\ gr_t,\ da_t,\ y_{s,t},\ x_t,\ y_{f,t},\ mgcr_t,$ $\pi_t,\ B_t^*,\ P_{i,t}/P_t,\ \Omega_{1,t},\ \Omega_{2,t},\ disp_t$, such that the following conditions are satisfied:

$$1 = \beta R_t^D E_t \left[\frac{u_{c,t+1}}{u_{c,t}} \frac{1}{(1+\pi_{t+1})} \right] \tag{73}$$

$$1 = \beta R_t^* \Theta \left(B_t^* \right) E_t \left[\frac{u_{c,t+1}}{u_{c,t}} \frac{rer_{t+1}}{rer_t} \frac{1}{(1+\pi_{t+1}^*)} \right] \tag{74}$$

$$u_{\frac{M}{P},t} = \frac{R_t^D - 1}{R_t^D} u_{c,t} \tag{75}$$

$$\frac{W_t}{P_t} = -\frac{u_{h,t}}{u_{c,t}} \tag{76}$$

$$y_t = a_t \left(k_t \right)^{\theta_y} \left(h_t \right)^{1-\theta_y} \tag{77}$$

$$\frac{W_t}{P_t} = \frac{P_{y,t}}{P_t} \frac{\left(1-\theta_y\right) y_t}{h_t} \tag{78}$$

$$rr_{K,t} = \frac{P_{y,t}}{P_t} \frac{\theta_y y_t}{k_t} \tag{79}$$

$$\begin{aligned} k_{t+1} = {} & (1-\delta)\left(k_t - k_{D,t}^{new}\right) + \left(1 - \Delta\left(\frac{inv_t}{inv_{t-1}}\right)\right) inv_t \\ & + \eta_K (1-\delta) k_{D,t} \end{aligned} \tag{80}$$

$$k_{D,t} = (1-\eta_K)(1-\delta) k_{D,t-1} + k_{D,t}^{new} \tag{81}$$

$$\begin{aligned} & qr_t \left(1 - \Delta\left(\frac{inv_t}{inv_{t-1}}\right) - \Delta'\left(\frac{inv_t}{inv_{t-1}}\right) \frac{inv_t}{inv_{t-1}} \right) \\ & + \beta E_t \left[\frac{u_{c,t+1}}{u_{c,t+1}} qr_{t+1} \left(\Delta'\left(\frac{inv_{t+1}}{inv_t}\right) \left(\frac{inv_{t+1}}{inv_t}\right)^2 \right) \right] = 1 \end{aligned} \tag{82}$$

$$\mu_t = \frac{(qr_t - fsr_t)(1-\delta)}{payr_t} \tag{83}$$

$$payr_t = (rr_{K,t} + (1-\delta) qr_t) \tag{84}$$

$$f(\bar{\omega}_t, \sigma_\omega) = \int_{\bar{\omega}_t}^{\infty} \omega d\Phi(\omega; \sigma_\omega) - \bar{\omega}_t (1 - \Phi(\bar{\omega}_t; \sigma_\omega)) \tag{85}$$

$$g(\bar{\omega}_t, \mu_t, \sigma_\omega) = \bar{\omega}_t(1 - \Phi(\bar{\omega}_t; \sigma_\omega)) + (1 - \mu_t) \int_0^{\bar{\omega}_t} \omega d\Phi(\omega; \sigma_\omega) \quad (86)$$

$$(1 + \pi_t)\, payr_t k_t g(\bar{\omega}_t, \mu_t, \sigma_\omega) = R^{IB}_{t-1} b_{t-1} \quad (87)$$

$$b_t = (qr_t k_{t+1} - netr_t) \quad (88)$$

$$qr_t E_t \left\{ R^{IB}_t \frac{f_{\bar{\omega}}(\bar{\omega}_{t+1}, \sigma_\omega)}{g_{\bar{\omega}}(\bar{\omega}_{t+1}, \mu_{t+1}, \sigma_\omega)} \right\} = E_t \left\{ \frac{(1 + \pi_{t+1}) payr_{t+1}}{\rho(\bar{\omega}_{t+1}, \mu_{t+1}, \sigma_\omega)} \frac{f_{\bar{\omega}}(\bar{\omega}_{t+1}, \sigma_\omega)}{g_{\bar{\omega}}(\bar{\omega}_{t+1}, \mu_{t+1}, \sigma_\omega)} \right\} \quad (89)$$

$$\rho(\bar{\omega}_t, \mu_t, \sigma_\omega) = \left[g(\bar{\omega}_t, \mu_t, \sigma_\omega) - f(\bar{\omega}_t, \sigma_\omega) \frac{g_{\bar{\omega}}(\bar{\omega}_t, \mu_t, \sigma_\omega)}{f_{\bar{\omega}}(\bar{\omega}_t, \sigma_\omega)} \right]^{-1} \quad (90)$$

$$recov_t = \frac{(1 - \mu_t) \int_0^{\bar{\omega}_t} \omega d\Phi(\omega; \sigma_\omega) payr_t k_t (1 + \pi_t)}{\Phi(\bar{\omega}_t, \sigma_\omega)[R^{IB}_{t-1} b_{t-1}]} \quad (91)$$

$$defrate_t = \Phi\left(\bar{\omega}_t, \sigma_\omega\right) \quad (92)$$

$$netr_t = (1 - \lambda)\, f\left(\bar{\omega}_t, \sigma_\omega\right) payr_t k_t + \tau_E \quad (93)$$

$$c_{K,t} = \lambda f\left(\bar{\omega}_t, \sigma_\omega\right) payr_t k_t \quad (94)$$

$$lq_t = \nu k_{D,t} \quad (95)$$

$$k^{new}_{D,t} = k_t \int_0^{\bar{\omega}_t} \omega d\Phi(\omega; \sigma_\omega) \quad (96)$$

$$lq_t = Z\left(n_t\right)^{1-\alpha_{lq}} \quad (97)$$

$$lq_t = Z_{xr}\left(xr_t\right)^{1-\alpha_{xr}} \quad (98)$$

$$fsr_t = \eta_K qr_t - \nu(fr_t + gr_t) + (1 - \eta_K)(1 - \delta)\beta E_t \left[\frac{u_{c,t+1}}{u_{c,t+1}} fsr_{t+1} \right] \quad (99)$$

$$fr_t = \frac{\left(n_t\right)^{\alpha_{lq}}}{Z(1 - \alpha_{lq})} \quad (100)$$

$$\frac{R^{IB}_t}{R^D_t} = gr_t \frac{(1 - \alpha_{xr}) lq_t}{xr_t} \quad (101)$$

$$\frac{\left[R_t^D-(1-s_t)\,R_t^{IB}-s_t^{MA}R_t^{RE}\right]}{R_t^D}=gr_t\frac{(1-\alpha_{xr})lq_t}{xr_t}\left(s_t-s_t^{MA}\right) \tag{102}$$

$$xr_t=(s_t-s_t^{MA})\frac{D_t}{P_t} \tag{103}$$

$$\frac{D_t}{P_t}\,(1-s_t)=b_t \tag{104}$$

$$\Omega_{1,t}=mgcr_t+\beta\phi_pE_t\left\{\left(\frac{(1+\pi_t)^{\chi_p}}{(1+\pi_{t+1})}\right)^{-\varepsilon}\frac{da_{t+1}}{da_t}\frac{u_{c,t+1}}{u_{c,t+1}}\Omega_{1,t+1}\right\} \tag{105}$$

$$\Omega_{2,t}=\frac{P_{i,t}}{P_t}+\beta\phi_pE_t\left\{\left(\frac{(1+\pi_t)^{\chi_p}}{(1+\pi_{t+1})}\right)^{1-\varepsilon}\left(\frac{P_{i,t}/P_t}{P_{i,t+1}/P_{t+1}}\right)\right.$$
$$\left.\times\ \frac{da_{t+1}}{da_t}\frac{u_{c,t+1}}{u_{c,t+1}}\Omega_{2,t+1}\right\} \tag{106}$$

$$(\varepsilon-1)\,\Omega_{2,t}=\varepsilon\Omega_{1,t} \tag{107}$$

$$1=\phi_p\left(\frac{(1+\pi_{t-1})^{\chi_p}}{(1+\pi_t)}\right)^{1-\varepsilon}+(1-\phi_p)\left(\frac{P_{i,t}}{P_t}\right)^{1-\varepsilon} \tag{108}$$

$$da_t disp_t=y_{s,t} \tag{109}$$

$$disp_t=\phi_p\left(\frac{(1+\pi_{t-1})^{\chi_p}}{(1+\pi_t)}\right)^{-\varepsilon}disp_{t-1}+(1-\phi_p)\left(\frac{P_{i,t}}{P_t}\right)^{-\varepsilon} \tag{110}$$

$$da_t=c_t+c_{K,t}+inv_t+n_t \tag{111}$$

$$y_{s,t}=\left[(1-\alpha_d)^{1/\theta_d}(y_t-x_t)^{1-1/\theta_d}+(\alpha_d)^{1/\theta_d}(y_{f,t})^{1-1/\theta_d}\right]^{\frac{\theta_d}{\theta_d-1}} \tag{112}$$

$$mgcr_t=\left[(1-\alpha_d)\left(\frac{P_{y,t}}{P_t}\right)^{1-\theta_d}+(\alpha_d)(rer_t)^{1-\theta_d}\right]^{\frac{1}{1-\theta_d}} \tag{113}$$

$$\frac{y_t-x_t}{y_{f,t}}=\frac{(1-\alpha_d)}{\alpha_d}\left(\frac{rer_t}{P_{y,t}/P_t}\right)^{\theta_d} \tag{114}$$

$$rer_t B_t^* = R_{t-1}^* \Theta\left(B_{t-1}^*\right) \frac{B_{t-1}^*}{(1+\pi_t^*)} rer_t - \frac{P_{y,t}}{P_t} x_t + rer_t(y_{f,t}) \quad (115)$$

$$x_t = \bar{x} \left(\frac{rer_t}{P_{y,t}/P_t}\right)^{\theta^*}. \quad (116)$$

Appendix 5. Interest Rate Shocks with Only One Friction

In this appendix, we show that, for our specific world interest rate shocks, IT is the optimal policy for a model with nominal frictions and that a countercyclical reserve requirement is also the best response with only financial (and no nominal) frictions.

Welfare Gains of Inflation Targeting without Financial Frictions

We subtract from the baseline model any features related to the financial accelerator mechanism. Table 9 shows the welfare gains of the inflation-targeting regime compared with the standard Taylor rule.

Welfare Gains of Countercyclical Reserve Requirement without Price Rigidities

Note that this exercise is equivalent to comparing the welfare under the inflation-targeting regime with inflation targeting and countercyclical reserve requirement in the baseline model. These results are reproduced in table 10.

Table 9. Welfare Comparison under Only Price Rigidities

Policy Framework	Welfare	Ranking	λ
Standard Taylor-Type Rule	−85.29	2	18.3%
IT Regime	−76.71	1	13.7%

Table 10. Welfare Comparison under Only Financial Frictions

Policy Framework	Welfare	Ranking	λ
Constant RR	−83.5624	2	6.4%
Countercyclical RR	−75.0940	1	1.8%

Appendix 6. Extension with Foreign Funding for Lending Intermediaries and Entrepreneurs

In contrast to other studies, and to boost balance sheet effects, we can allow for the possibility that the financial intermediaries use foreign funds to finance entrepreneurs besides the interbank market. For simplicity, we assume the amount of external funds available in each period for the lending intermediaries is constant in foreign currency ($\bar{b}^*_{LI}$). Likewise, the entrepreneurs also have access to external funds to finance their investment in capital. Again, we consider that the amount of external funds for the entrepreneurs is constant in foreign currency ($\bar{b}^*_E$). Since in equilibrium

$$E_t\left[\frac{R_t^{IB}}{1+\pi_{t+1}}\right] \geq E_t\left[\frac{R_t^*\Theta_t}{1+\pi^*_{t+1}}\frac{rer_{t+1}}{rer_t}\right],$$

both lending intermediaries and entrepreneurs will use the complete amount of external funds each period. The presence of these external funds will imply a direct balance sheet effect of exchange rate movements, which can magnify the impact of capital flows through the financial accelerator mechanism.

Thus, the loan contract now solves the following maximization problem:

$$MaxE_t\left\{payr_{t+1}k_{t+1}f\left(\bar{\omega}_{t+1},\sigma_t\right)\right\}$$

$$\begin{aligned} s.t.\ \ & payr_{t+1}k_{t+1}g\left(\bar{\omega}_{t+1},\mu_{t+1},\sigma_t\right) \\ & \geq \frac{R_t^{IB}}{1+\pi_{t+1}}(b_t - rer_t\bar{b}^*_{LI}) + \frac{R_t^*\Theta_t}{1+\pi^*_{t+1}}\frac{rer_{t+1}}{}\bar{b}^*_{LI} \end{aligned} \tag{117}$$

for all states in $t+1$, where $b_t = (qr_t k_{t+1} - netr_t - rer_t\bar{b}^*_E)$ is the domestic loan to the entrepreneurs with net worth $netr_t$.

The equilibrium condition for the loan contract and entrepreneurs' variables are stated as follows. Arbitrage condition for the loans to entrepreneurs:

$$\begin{aligned} & qr_t E_t\left\{\left[\frac{R_t^{IB}}{1+\pi_{t+1}}\right]\frac{f_{\bar{\omega}}\left(\bar{\omega}_{t+1},\sigma_t\right)}{g_{\bar{\omega}}\left(\bar{\omega}_{t+1},\mu_{t+1},\sigma_t\right)}\right\} \\ & \quad = E_t\left\{\frac{payr_{t+1}}{\rho\left(\bar{\omega}_{t+1},\mu_{t+1},\sigma_t\right)}\frac{f_{\bar{\omega}}\left(\bar{\omega}_{t+1},\sigma_t\right)}{g_{\bar{\omega}}\left(\bar{\omega}_{t+1},\mu_{t+1},\sigma_t\right)}\right\}. \end{aligned} \tag{118}$$

Definition of the recovery rate of financial intermediaries' loans:

$$recov_t = \frac{(1-\mu_t)\int_0^{\bar{\omega}_t}\omega d\Phi(\omega,\sigma_{t-1})payr_t k_t(1+\pi_t)}{\Phi(\bar{\omega}_t;\sigma_{t-1})\left[R_{t-1}^{IB}(b_{t-1}-rer_{t-1}\bar{b}_{LI}^*)+\frac{R_{t-1}^*\Theta_{t-1}(1+\pi_t)rer_t}{1+\pi_t^*}\bar{b}_{LI}^*\right]}. \quad (119)$$

Definition of the risk premium:

$$\rho(\bar{\omega}_t,\mu_t,\sigma_{t-1}) = \left[g(\bar{\omega}_t,\mu_t,\sigma_{t-1}) - f(\bar{\omega}_t,\sigma_{t-1})\frac{g_{\bar{\omega}}(\bar{\omega}_{t+1},\mu_{t+1},\sigma_t)}{f_{\bar{\omega}}(\bar{\omega}_{t+1},\sigma_t)}\right]^{-1}. \quad (120)$$

Budget constraints of entrepreneurs:

$$b_t = qr_t k_{t+1} - netr_t - rer_t\bar{b}_E^*. \quad (121)$$

Breakeven condition for financial intermediaries:

$$g(\bar{\omega}_t,\mu_t,\sigma_{t-1})\, payr_t k_t = \left[\frac{R_{t-1}^{IB}}{1+\pi_t}\right](b_{t-1}-rer_{t-1}\bar{b}_{LI}^*) + \left[\frac{R_{t-1}^*\Theta_{t-1}}{1+\pi_t^*}\frac{rer_t}{}\right]\bar{b}_{LI}^*. \quad (122)$$

Real net worth of entrepreneurs:

$$netr_t = (1-\lambda)\left(f(\bar{\omega}_t,\sigma_{t-1})\, payr_t k_t - \frac{R_{t-1}^*\Theta_{t-1}}{1+\pi_t^*}\frac{rer_t}{}\bar{b}_E^*\right) + \tau_E. \quad (123)$$

Again, all entrepreneurs receive a lump-sum transfer, τ_E, but now they also make an interest payment for the constant amount of foreign debt $\bar{b}_E^*$ taken each period. Thus, a real appreciation of the currency increases the resources of entrepreneurs, improving their financial position and the demand for investment. As before, when an entrepreneur dies, which happens with a rate λ, he consumes all his wealth. Thus, consumption of entrepreneurs is

$$c_{K,t} = \lambda\left(f(\bar{\omega}_t,\sigma_{t-1})payr_t k_t - \frac{R_{t-1}^*\Theta_{t-1}}{1+\pi_t^*}\frac{rer_t}{}\bar{b}_E^*\right) \quad (124)$$

$$\frac{D_t}{P_t}(1-s_t) = (b_t - rer_t\bar{b}^*_{LI}). \tag{125}$$

Appendix 7. Financial Dollarization of the Entrepreneurs' Loans

Another modification of the baseline model can be the possibility that the loan contract to the entrepreneurs is set in or indexed to foreign currency (dollars). Under this situation, we define $\psi \in [0,1]$ as the fraction of the loan set in domestic currency and $1-\psi$ as the fraction of the loan in foreign currency. For the exercise reported, we consider $\psi = 0.5$.

Thus, the loan contract now solves the following problem:

$$\begin{aligned} &MaxE_t\left\{payr_{t+1}k_{t+1}f\left(\bar{\omega}_{t+1},\sigma_t\right)\right\} \\ &s.t.\ \ payr_{t+1}k_{t+1}g\left(\bar{\omega}_{t+1},\mu_{t+1},\sigma_t\right) \\ &\quad \geq \left(\psi\frac{R_t^{IB}}{1+\pi_{t+1}} + (1-\psi)\frac{\tilde{R}_t^*}{1+\pi_{t+1}^*}\frac{rer_{t+1}}{rer_t}\right)b_t \end{aligned} \tag{126}$$

for all states in $t+1$, where $\tilde{R}_t^* = R_t^{IB}E_t\left[\frac{rer_t}{rer_{t+1}}\frac{(1+\pi_{t+1}^*)}{(1+\pi_t^*)}\right]$ is the ex ante real interest rate in terms of the foreign currency. We then find the first-order conditions of this problem as we did in appendix 1.

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