Bank Foreign Liabilities and Capital Requirements*

Luigi Falasconi‡ Caterina Mendicino§ Dominik Supera¶

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Abstract

Setting bank capital requirements to appropriate high levels is essential to increase the resilience of the banking sector to domestic financial shocks. Higher bank capital requirements are, however, associated with a larger reliance on foreign liabilities which make the economy more vulnerable to external financial shocks. Sterilized foreign exchange rate interventions are effective in weakening this policy trade-off, and even more so for a strict inflation targeting central bank. A combination of both policy measures is desirable, especially when the distress in the banking sector is at high levels.

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‡University of Pennsylvania, Department of Economics.

§European Central Bank - Directorate General Research - Monetary Policy Research. Email: caterina.mendicino1@ecb.int

¶Columbia Business School, Department of Finance.

1 Introduction

In the wake of the 2008 Global Financial Crisis, major advanced and emerging markets economies agreed to strengthen bank capital requirements in order to build up the resilience of the banking sector to shocks and, hence, pursue macroeconomic and financial stability.[1] Many emerging economies have adopted an eclectic approach to financial stability which often relies on both domestic macroprudential measures and foreign policy interventions. While the existing literature has provided important insights on the prudential role of foreign exchange interventions and capital flow management tools (see e.g. Fahri and Werning, 2016; Schmitt-Grohé and Uribe, 2016; Bianchi and Mendoza, 2018) the effects of bank capital regulation in emerging market economies and their interaction with other prudential policy measures still remains largely unexplored.

This paper provides new results in this direction by focusing on the following issues. What are the costs and benefits of tighter bank capital requirements in small open economies? Are bank capital regulation and foreign exchange interventions substitutes? Or they entail complementary effects which depend, for instance, on the sources of financial risk?

We address these questions through the lens of a New Keynesian small open economy with an explicit banking sector in which exchange rate movements affect the economy both via the trade channel and the bank foreign liability channel. Our results highlight a novel trade-off for bank capital regulation between increasing the resilience of the banking sector to domestic financial shocks and amplifying its vulnerability to external shocks. This gives rise to the need for additional policy measures in order to fight financial instability.

Financial intermediaries in the model invest in a domestic risky asset using both domestic and foreign funding and are, therefore, subject to both domestic and external sources of financial vulnerabilities. Higher capital requirements limit bank leverage and reduce the vulnerability of banks to an increase in the riskiness of the domestic assets. However, by making banks safer, higher capital requirements also lead to a reduction in the cost of foreign

[1] Leading emerging market economies - like Argentina, Brazil, China, India, Mexico, Poland, South Africa and Turkey - which are members of the international financial standard-setting bodies (the Basel Committee on Banking Supervision and the Financial Stability Board) committed to implement the minimum regulatory requirements under Basel III other emerging, while some developing economies - like Colombia, Malaysia, Peru and Thailand - have adopted them on a voluntary bases and many others are considering whether to do so. See Hohl et al. (2018) for the adoption of Basel III standards around the world.

funding, This, allows banks to fund themselves with a larger share of foreign liabilities for banks. As a result, the economy is more vulnerable to external financial shocks. In setting the capital requirement level, the macroprudential authority faces a trade-off between insulating the economy from domestic financial shocks versus stabilizing it against external financial shocks.

We show that foreign exchange (FX) interventions are effective in mitigating the trade-off faced by the economy response to shocks under higher capital requirements. In response to adverse foreign financial shocks, i.e. a sudden increase in the foreign interest rate, the economy suffers the real and financial stability implications of the exchange rate depreciation. When sterilized FX interventions are available, both the increase in financial stability risks and the drop in economic activity are less severe. Our results suggest that bank capital requirement and FX interventions operate in a complementary way.

We also document the importance of bank default for the strength of the central bank response to exchange rate fluctuations.When bank default is higher, the economy benefits from stronger FX interventions. In addition, FX interventions are particularly effective in reducing the vulnerability of the economy to financial shocks under a strict inflation targeting regime which generally makes the economy more vulnerable to both domestic and external financial shocks. Finally, compared to capital management measures, FX interventions are more effective in dampening the economy response to shocks.

Related Literature. Our paper belongs to the recent and growing literature on the impact of changes in bank capital requirements in quantitative models (see e.g. Van Den Heuvel, 2008; Martinez-Miera and Suarez, 2014; Clerc et al., 2015; Mendicino et al., 2018; Begenau, 2020). While, existing papers assess the role bank capital requirements in close economy models, we extend the core model of bank default risk as in Mendicino et al. (2020) and Elenev et al. (2020) to include bank foreign liabilities. This allows us to highlight a novel trade-off of bank capital regulation between increasing the resilience of the banking sector to domestic financial shocks and amplifying its vulnerability to external shocks.

It also connects to the literature which studies macroprudential policy in small open economies (see e.g. Mendoza, 2010; Bianchi and Mendoza, 2011; Benigno et al., 2013; Bianchi, 2016; Fahri and Werning, 2016; Schmitt-Grohé and Uribe, 2016; Bianchi and Mendoza, 2018). We complement existing work by focusing on the distortions which engender externalities related to bank risk taking incentives, rather than relying on pecuniary externalities and/or aggregate demand externalities as the main rational for prudential policy interventions.

Our paper also contributes to the handful of papers which study the interaction of macro-prudential and foreign interventions in emerging markets (see e.g. Aoki et al., 2016; Korinek and Sandri, 2016; Basu et al., 2020; Adrian et al., 2022). The explicit consideration of bank default risk and the interaction of bank capital requirements with FX interventions distinguishes our work from previous papers.

The paper is organized as follows. Section 1 and 2 present the model economy and the calibration. Section 3 documents the effects of higher capital requirements and Section 4 highlights the role of FX interventions. Section 5 explores the interaction of these two policies and Section 6 focuses on monetary and capital flow management policies. Section 7 concludes.

2 Model Economy

Our model economy is populated by a household which provides consumption insurance to two types of members: workers and bankers, both of unitary measure. Workers supply labor to the production sector, deposit funds in the bank and hold capital. Bankers provide (inside) equity financing to the banks. In each period, with probability $1-\theta_b$ some bankers retire and become workers again and the same fraction of workers become bankers. Thus, the fraction of each type of household member remains constant. At the beginning of her activity each new banker receives an endowment from the household. Then, upon retirement the banker transfers her accumulated net worth to the household.

Banks invest in productive capital using the equity raised from the bankers, domestic currency deposits supplied by the workers and foreign currency bonds from international investors. Firms produce the final good using labor and capital using a Cobb-Douglas production function. Capital mostly financed by banks, but a part of it is directly held by the household. The latter is however subject to a management cost which reflects a less efficient management of investment compared to the bank.

Finally, the central bank sets the short-term nominal rate following a Taylor-type rule and engages in sterilized FX interventions. In addition, it also sets the level of capital requirement.

The next subsections describe the main ingredients in detail.[2]

2.1 Household

The household maximizes the discounted future stream of utility

$$\max_{\{C_{t+\tau},L_{t+\tau},K_{s,t+\tau},D_{t+\tau},B_{t+\tau}\}_{\tau=0,1,2,\ldots}} \mathbb{E}\left[\sum_{\tau=0}^{\infty}\beta^{t+\tau}\left[\log\left(C_{t+\tau}\right)-\frac{\varphi}{1+\eta}\left(L_{t+\tau}\right)^{1+\eta}\right]\right] \tag{1}$$

subject to:

$$\begin{aligned} & C_t+\left(q_t+s_t\right)K_{s,t}+D_t+B_t \\ \leq & \left[r_{k,t}+(1\text{–}\delta)\,q_t\right]K_{s,t-1}+w_tL_t+\frac{\widetilde{R}_t^dD_{t-1}}{\pi_t}+\frac{R_{t-1}B_{t-1}}{\pi_t}+T_{s,t}+\Pi_t+\Xi_t, \end{aligned} \tag{2}$$

where C_t denotes consumption, L_t hours worked in the production sector, w_t the real wage rate and $\pi_{t+1}=P_{t+1}/P_t$ is the inflation rate. Households directly hold capital $K_{s,t}$ subject to a per unit management cost s_t, with q_t being the real price, δ, the depreciation rate and $r_{k,t}$ the rental rate.

The deposit portfolio D_{t-1} pays a gross return equal to $\widetilde{R}_t^d=R_{t-1}^d-(1-\kappa)\Omega_t$, where R_{t-1}^d is the promised gross deposit rate paid by the fraction κ of insured deposits supplied by the household, while Ω_t is the average per unit loss on the fraction $1/\kappa$ of uninsured deposits. Finally, R_{t-1} is the gross short-term nominal interest rate paid on the risk free asset B_{t-1} (in zero net supply).[3]

$T_{s,t}$ is a lump-sum tax which balance the budget of the deposit insurance scheme and operational losses associated with the central bank FX interventions, if any. Π_t is the the

[2] See Online Appendix for the market clearing conditions and some variable definitions.

[3] Note that for $\kappa<1$, R_{t-1}^d needs to be higher than the free rate R_{t-1} in order for the household to be willing to save in the deposit portfolio.

aggregate net transfers from bankers to the household and Ξ_t the profits from the capital management firm.

2.2 Bankers

During their activity, bankers use their net worth ($n_{b,t}$) to provide equity financing (e_t) to the continuum of banks or to pay dividends ($dv_{b,t}$) to the household by solving the following problems

$$V_{b,t} = \max_{e_t, dv_{b,t}} \left\{ dv_{b,t} + \mathbb{E} \frac{\Lambda_{b,t+1}}{\pi_{t+1}} \left[\left(1-\theta_b\right) n_{b,t+1} + \theta_b V_{b,t+1} \right] \right\} \tag{3}$$

subject to $e_t + dv_{b,t} = n_{b,t}$, with $n_{b,t+1} = \frac{\rho_{b,t+1}(\omega)}{\Pi_{t+1}} e_t$ and $dv_{b,t} \geq 0$, where $\Lambda_{t+1} = C_t / C_{t+1}$ is the household's real stochastic discount factor and $\rho_{b,t+1}(\omega)$ is the gross rate of return of the banker portfolio of equity.

As in Gertler and Kiyotaki (2010), we guess that the value function is linear in net worth, such that (3) becomes $n_t \nu_t = \underset{e_t, dv_t}{max} \left\{ dv_t + \mathbb{E}_t \left[\Lambda_{b,t+1} \left(\left(1-\theta_b\right) + \theta_b \nu_{t+1} \right) n_{t+1} \right] \right\}$, where $\Lambda_{b,t+1} = \Lambda_{t+1} \left(1 - \theta_b + \theta_b \nu_{b,t+1}\right)$ and $\nu_{b,t}$ is the shadow value of one unit of bank equity.[4]

Finally, taking into account effects of retirement and the entry of new bankers, the evolution of active bankers' aggregate net worth can be described as:

$$n_t = \frac{\theta_b \rho_t e_{t-1} + \chi_b \left(1-\theta_b\right) \rho_t e_{t-1}}{\pi_t}. \tag{4}$$

2.2.1 Banks

The representative bank uses domestic funding in the form of (inside) equity $E_{b,t}$ and deposits D_t. Moreover, the bank issues bonds denominated in foreign currency D_t^* that promise a gross interest rate R_t^F. These funds are used to purchases claims $K^{b,t}$, from final goods producing firms at price $q_{k,t}$. There are no financing frictions between firms and banks. Hence, the firm promise the bankers the realized return on a unit of capital in next period in exchange for borrowed funds today, which is R_{t+1}^k. The bank's returns on the capital is subject to an idiosyncratic shock ω_{t+1}, such that the time $t+1$ gross return on assets is

[4] Note that as long as $\nu_{b,t} > 1$ bankers only pay a final dividend when they retire. See also (Mendicino et al., 2020).

$\omega_{t+1} R^k_{t+1} q_t K^b_t$. We assume that ω_{t+1} follows a log-normal distribution with a mean of one and standard deviation of $\sigma_{b,t}$, where the latter follows an AR(1) process.

The bank operates over one period. It defaults if its terminal net worth is negative. If it is instead positive it gives it back to the bankers at the end of the period. Hence, the bank maximizes the real net present value (NPV) of the bankers' equity stake conditional on not defaulting

$$\max_{K^b_t, \Theta_t, B^{CB}_t} \mathbb{E}\Bigg(\frac{\Lambda_{b,t+1}}{\pi_{t+1}} \max\Bigg\{ \omega_{t+1} R^K_{t+1} q_t K^b_t + R^{CB}_t B^{CB}_t \\ - \left[\Theta_t \left(\frac{f_{t+1}}{f_t} \frac{\pi_{t+1}}{\pi^*_{t+1}} R^F_t \right) + \frac{\varkappa}{2} \Theta^2_t + (1-\Theta_t) R^d_t \right] D^{tot}_t, 0 \Bigg\} \Bigg) - \nu_t E_t$$

subject to the balance sheet constraint

$$q_t K^b_t + B^{CB}_t = f_t D^*_t + D_t + E_t$$

and the capital requirement constraint

$$E_t \geq \phi q_t K^b_t$$

where D^{tot}_t is the sum of domestic deposits and foreign currency bonds, f_t is the real exchange rate and Θ is the fraction of funding denominated in foreign currency. B^{CB}_t are central bank bonds which are used in the sterilization process of any FX intervention. Equity E_t is valued at its equilibrium opportunity cost $\nu_{b,t}$. Banks are also subject to a convex costs of adjustment for the foreign liability share.

We denote by $F(\omega_{t+1})$ the distribution function of the idiosyncratic shock ω_{t+1} and by $\overline{\omega}_{t+1}$ the threshold realization below which bank defaults, so the probability of default is $F(\overline{\omega}_{t+1})$. We can write the bank's default threshold as

$$\overline{\omega}_{t+1} = \frac{\left[\Theta_t \left(\frac{f_{t+1}}{f_t} \frac{\pi_{t+1}}{\pi^*_{t+1}} R^F_t \right) + \frac{\varkappa}{2} \Theta^2_t + (1-\Theta_t) R^d_t \right] \left((1-\phi) q_t K^b_t + B^{CB}_t \right) - R^{CB}_t B^{CB}_t}{R^K_{t+1} q_t K^b_t}.$$

2.3 Deposit Insurance Scheme

A share of deposits are insured by a deposit insurance scheme (DIS). In the case of bank default, DIS takes the returns $(1-\mu)\omega_{t+1} R^k_{t+1} q_t K_{b,t}$ – where μ is a proportional repossession cost – pays the fraction κ of insured deposits in full, and pays a fraction $1-\kappa$ of the repossessed returns to the holders of uninsured deposits. Then the DIS ex-post balance its budget period-by-period by charging lump-sum taxes to the household.

2.4 Foreign Investors

Foreign creditors provide the continuum of banks with uninsured, defaultable debt. From the non-defaulting banks, they recover the rate R^F. From the defaulting banks, they only recover a fraction $(1-\mu)$ of the terminal value of the banks assets. Therefore, the required interest rate on foreign debt is pinned down by the participation constraint of foreign investors:

$$R_t^* + \gamma(e^{(\Theta-\Theta_{ss})} - 1) = \Theta_t \frac{(1-\mu)R_{t+1}^K q_t K_t^b}{\Theta_t d_t} \int_0^{\overline{\omega}_{t+1}} \omega dF_{t+1}(\omega_{t+1}) + R_t^F \int_{\overline{\omega}_{t+1}}^{\infty} dF_{t+1}(\omega) \quad (5)$$

where $\int_0^{\overline{\omega}_{t+1}} \omega_{t+1} dF(\omega_{t+1})$ is the share of total assets owned by banks which end up in default The LHS is characterized by the exogenous risk-free interest rate process

$$R_t^* = (1-\rho_{R^*})R^* + \rho_{R^*} R_{t-1}^* + \epsilon_t^* \quad (6)$$

and an exogenous component of the risk premium (ϵ_t^*) which follows as AR(1) process (see Schmitt-Grohé and Uribe (2003)).

2.5 Consumption Goods Production Sector

We assume two types of domestic consumption production firms: intermediate good producers and final good producers. Intermediate good producers sell to two different buyers: the domestic final good producers that produce the final consumption good Y_t according to a CES technology, and the foreign import bundlers. Furthermore, a fraction ψ of intermediate good producers invoice their sales to the foreign import bundler in dollars and the remaining fraction $1-\psi$ invoices in home currency. Both types of firm invoice domestic sales in the home currency.

2.5.1 Final good producers

Final good producers are perfectly competitive and combine the continuum of intermediate goods $y_t(i)$ into a single final good Y_t according to a CES technology:

$$Y_t = \left(\int_0^1 y_t(i)^{\frac{1}{1+\theta}} di \right)^{1+\theta}.$$

As a result of profit maximization and the zero profit condition, intermediate good firm i faces a downward-sloping demand curve $y_t(i) = \left(\frac{p_t(i)}{P_t} \right)^{-\frac{1+\theta}{\theta}} Y_t$, where the CES aggregate price index is defined as $P_t = \left(\int_0^1 p_t(i)^{-\frac{1}{\theta}} di \right)^{-\theta}$, with $p_t(i)$ being the price of each intermediate good.

2.5.2 Intermediate good producers

There is a continuum $i \in [0, 1]$ of monopolistically competitive firms that produce a differentiated intermediate good $y_t(i)$ by combining labor $l_t(i)$, capital $k_t(i)$ and imported good $m_t(i)$ using a constant-returns-to-scale technology:

$$y_t(i) = A_t L_t(i)^{\alpha_l} K_{t-1}(i)^{\alpha_k} m_t(i)^{1-\alpha_k-\alpha_l}, \tag{7}$$

where α_k is the share of capital in production and α_l is the share of labor in production. A_t is a standard productivity shock which follows an AR(1) process.

Prices are sticky at the intermediate production sector and evolve according to the standard Calvo setup. Hence, prices are set for contractual periods of random length. Each contract expires with probability $1 - \xi$ per period. When the contract expires, the intermediate producer i sets the new price $\widetilde{p}_t(i)$ to maximize the present discounted value of future real profits over the validity of the contract. Intermediate good firms are owned by the household and distribute profits or losses back to it.

Finally, we assume that these firms are penniless and have to finance all their capital purchase through either bank loans $K_{b,t}$ or household capital $K_{h,t}$. At the end of the period t, in order to acquire K_t units of productive capital, the firms issue Z_t claims. Each claim is priced at the same price q_t as capital, that is as if banks and households own capital and rent it to firms.

2.5.3 Import Bundlers

Foreign import bundlers take intermediate inputs from the home country and combine them into a single final good. The home country's intermediate good firms are split between those who invoice in the domestic currency (PCP) and those who invoice in dollars (DCP). These import bundlers solve

$$\max_{y_t(i)} P_t^M M_t^* - \psi \int p_{HR,t}^R(i) y_{HR,t}^R(i) di - (1-\psi) \int \frac{p_{HR,t}^H(i)}{F_t} y_{HR,t}^H(i) di$$
$$\text{s.t. } M_t^* = \left(\int_0^1 y_{HR,t}(i)^{\frac{1}{1+\theta}} di \right)^{1+\theta}$$

where ψ is the share of domestic intermediate good producers who price in dollars. The subscripts and superscripts denote the origin, destination and invoicing currency of the prices / goods. Thus $p_{HR,t}^R(i)$ is the price of a good originating in the home market, destined for the RoW and priced in foreign currency. The solution to this problem generates two demand functions, one for goods priced in dollars and one for goods priced in home currency:

$$y_{HR,t}^R(i) = \left(\frac{p_{HR,t}^R(i)}{P_t^M} \right)^{-\frac{1+\theta}{\theta}} M_t^*$$
$$y_{HR,t}^H(i) = \left(\frac{p_{HR,t}^H(i)}{F_t P_t^M} \right)^{-\frac{1+\theta}{\theta}} M_t^*$$

The resulting price index for home country exports is then:

$$P_t^M = \left[\psi P_{HR,t}^R{}^{-\frac{1}{\theta}} + (1-\psi) P_{HR,t}^H{}^{-\frac{1}{\theta}} \right]^{-\theta},$$

where we are defining

$$P_{HR,t}^R = \left[\int p_{HR,t}^j(i)^{-\frac{1}{\theta}} di \right]^{-\theta}$$
$$P_{HR,t}^H = \left[\int \left(\frac{p_{HR,t}^H(i)}{F_t} \right)^{-\frac{1}{\theta}} di \right]^{-\theta}$$

Note that these price indices are both effectively priced in dollars. From this we can derive laws of motion

$$\left(\frac{P^R_{HR,t}}{P^M_t}\right)^{-\frac{1}{\theta}} = \xi\left(p^{j0}_{HR,t}\right)^{-\frac{1}{\theta}} + (1-\xi)\left(\frac{X^R_{t,t+1}}{\Pi^M_t}\frac{P^R_{HR,t-1}}{P^M_{t-1}}\right)^{-\frac{1}{\theta}}$$
$$\left(\frac{P^H_{HR,t}}{P^M_t}\right)^{-\frac{1}{\theta}} = \xi\left(p^{j0}_{HR,t}\right)^{-\frac{1}{\theta}} + (1-\xi)\left(\frac{X^H_{t,t+1}}{\Pi^M_t}\frac{f_{t-1}\Pi^R_t}{f_t\Pi_t}\frac{P^H_{HR,t-1}}{P^M_{t-1}}\right)^{-\frac{1}{\theta}}$$

Finally, we can then take the equation for import prices and rewrite it as:

$$1 = \psi\left(\frac{P^R_{HR,t}}{P^M_t}\right)^{-\frac{1}{\theta}} + (1-\psi)\left(\frac{P^H_{HR,t}}{P^M_t}\right)^{-\frac{1}{\theta}}$$

The import bundler must then decide on the total amount of the import bundle, M^*_t to produce. We assume they face a downward sloping demand curve of the form:

$$M^*_t = E_{x,t} = \left(\frac{P^M_t}{P^R_t}\right)^{-\varkappa^*} Y^* = (p^{MR}_t)^{-\varkappa^*} Y^* \tag{8}$$

where P^R_t is the price level in RoW and p^{MR}_t is the relative price which evolves according to:

$$p^{MR}_t = \frac{\Pi^M_t}{\Pi^R_t} p^{MR}_{t-1}.$$

2.6 Capital Sector

2.6.1 Capital Production

Producers of capital combine investment, I_t, with the previous stock of capital, K_{t-1}, in order to produce new capital which can be sold at nominal price Q_t. Capital producers face adjustment costs as in Jermann (1998), $S\left(\frac{I_t}{K_{t-1}}\right) = \frac{a_1}{1-\frac{1}{\psi_K}}\left(\frac{I_t}{K_{t-1}}\right)^{1-\frac{1}{\psi_K}} + a_2$, where a_1 and a_2 are chosen to guarantee that, in the steady state, the investment-to-capital ratio is equal to the depreciation rate and $S'\left(I_t/K_{t-1}\right)$ equals one. The law of motion of the capital stock can be written as

$$K_t = (1-\delta)\,K_{t-1} + S\left(\frac{I_t}{K_{t-1}}\right)K_{t-1}, \tag{9}$$

where δ is the depreciation rate of capital.

2.6.2 Capital Management Firms

A measure-one continuum of competitive firms operating with decreasing returns to scale manage the capital directly held by households in exchange for a fee s_t per unit of capital. These firms have a quadratic cost function, $z(K_{s,t}) = \frac{\varsigma}{2} K_{s,t}^2$, with $\varsigma > 0$. Their profit maximization implies $s_t = \varsigma K_{s,t}$.

2.7 Central Bank

Macroprudential policy. The macroprudential authority sets the level of capital requirement, ϕ.

Interest rate policy. The monetary authority sets the one-period short-term nominal interest rate R_t according to a Taylor-type policy rule:

$$R_t = R_{t-1}^{\rho_R} \left[\bar{R} \left(\frac{\pi_t}{\bar{\pi}} \right)^{\alpha_\pi} \left(\frac{GDP_t}{GDP_{t-1}} \right)^{\alpha_{GDP}} \right]^{1-\rho_R} \tag{10}$$

where ρ_R is the interest rate smoothing parameter, α_π and α_{GDP} determine the responses of the interest rate to GDP growth and inflation deviations from the target $\bar{\pi}$, respectively. $\bar{R}$ denotes the steady state level of the nominal interest rate.

FX interventions. The monetary authority also engages in sterilized foreign exchange (FX) interventions (see e.g. Carrasco and Florián Hoyle, 2021). When the central bank purchases (sells) official reserves of foreign exchange it issues (withdraws) a corresponding quantity of "sterilization" bonds (B_t^{CB}) to the banking sector. The central bank's balance sheet is, hence, given by

$$B_t^{CB} = f_t \mathcal{R}_t, \tag{11}$$

where $\mathcal{R}_t$ denotes official FX reserves. FX interventions induce the monetary authority to face operational losses since official FX reserves are invested abroad at the foreign interest rate R_t^*, while central bank bonds pay $R_t^{CB} > R^*$. Hence, the central bank's quasi-fiscal deficit is:

$$T_t^{CB} = \left(R_{t-1}^{CB} - \frac{f_t}{f_{t-1}} R^* \right) B_{t-1}^{CB}. \tag{12}$$

Such losses are financed through lump sum taxes on households.

Finally, as in Carrasco and Florián Hoyle (2021) we assume that the central bank sells/buy official FX reserves according to the following FX intervention rule:

$$\log B_t^{CB} = \log B^{CB} - \phi_{FX} \log \left(\frac{f_t}{f} \right), \tag{13}$$

where $\phi_{CB} > 0$ that governs the intensity with which the supply of central bank bonds responding to exchange rate movements. According to this rule, when the real exchange rate is above its steady state value (depreciates), the monetary authority sells official foreign reserves and, hence, withdraws "sterilization" bonds from the banking sector.

3 Model Calibration

The model is calibrated using quarterly macroeconomic, banking and financial data for the period 1996:1-2019:1 for Brazil.[5]

[TABLES 1 and 2 HERE]

We start by setting some model's parameters in line with existing literature. See Table 1. We set the Frisch elasticity of labor supply, η, equal to 0.276 and the labor disutility parameter, φ, to 3.4 and the capital-share parameter of the production function, α_k, equal to 0.33 as in Divino and Haraguchi (2021). The labor-share parameter of the production function, α_l, equals 0.51 (see e.g. Aoki et al., 2016), while the depreciation rate of physical capital, δ, equals 0.04. The average net markup of intermediate firms, θ, is 20% and the Calvo parameter, ξ, is 0.75. The bankruptcy cost parameter, μ_f, is set equal to a common value of 0.30.Regarding the monetary policy rule, we choose a degree of interest rate inertia, ρ_R, of 0.79, a moderate reaction to the output growth, α_{GDP}, of 0.16, and a reaction to inflation, α_π, of 2.42 as in De Castro et al. (2015). The share of goods invoiced in dollars, ψ, equals 0.9 in line with Gopinath et al. (2020). Finally, we set the foreign elasticity parameters $\varkappa^*$ to 1.5 and the auto-regressive parameters for the foreign financial shock to $\rho_{R^*} = 0.95$ in

[5]See Online Appendix for details on the data series used in the calibration.

the range of values used in the open economy literature (see e.g. Fernández-Villaverde et al., 2011).

We calibrate the remaining parameters simultaneously so as to match key data targets.[6] The steady state inflation parameter, $\overline{\pi}$, and the discount factor, β, directly pin down the inflation target (annual) of the Brazilian Central Bank's at 4.5% and the average real policy rate (SELIC) of 9%. The capital requirement level, ϕ, is set to the reference capital requirement of 8%. The share of insured deposits in bank debt κ is set to 0.44 in line with the data counterpart. The international real risk free rate, R^*, is set as to match the real market yield on U.S. Treasury securities at 3-month 0.03%.

The parameter of the capital management cost function, ς, is set such that the share of physical capital directly held by savers in the model matches the proportion of assets of the productive sector whose financing is not supported by banks estimated using Brazil flow of funds data. The new bankers' endowment parameter, χ_b is used to make the expected return on equity, ρ_b, equal to the average cost of equity of Brazilian banks. In addition, the survival rate of bankers, θ_b, is used so that the shadow value of bank equity, ν_b, matches the average price-to-book ratio of banks in Brazil. We set the standard deviation of the banks idiosyncratic shock $\bar{\sigma}_b$, to match the average probability of default of banks. We use the foreign costs parameter $\varkappa$ to match the mean of foreign bank liabilities as a share of total liabilities. The foreign goods demand steady-state level Y^* helps us to match the ratio of exports to GDP, and finally, the steady-state level of the central bank reserves is calibrated to match the ratio of FX reserves to GDP.

We calibrate ψ_K in the adjustment cost function of capital producing firms to match the standard deviation of investment relative to GDP. We use γ and σ_{R^*} simultaneously to match the standard deviation of the foreign liabilities share and σ_A and σ_b to match the standard deviations of GDP and bank default, respectively. As shown in Table 2, all targets are matches very closely.

[6]Since both aggregate and idiosyncratic reasons give rise to bank default, the model's moments are based on the second order approximate solution of the model as in Mendicino et al. (2018).

4 Bank Capital Requirements

The level of the capital requirement is an instrument in the hands of the macro-prudential authority to tackle financial stability issues. In what follows, we first study the long-run implications of changing capital requirements on the model allocation and financial stability risks. Next, we explore the role of capital requirements in response to domestic and foreign sources of financial distress.

4.1 Long Run Effects

[FIGURE 1 HERE]

We start by exploring the effects of changing the capital requirement level on key macroeconomic and financial variables. See Figure 1. Higher capital requirements, by reducing their leverage, make bank safer. A reduction in the probability of bank default initially leads to a fall in the cost of both domestic and foreign funding for banks. Cheaper bank funding implies that, everything else equal, banks are willing to invest more in corporate claims which, in equilibrium, translate in higher economic activity.

Starting from the calibrated level of 8 percent, higher capital requirements initially lead to a higher level of investment. Then, when the probability of bank default is already close to zero, further increased in capital requirements lead to a deterioration in investment. The latter effect reflects the increase in the relative scarcity of bank equity which is reflected in the overall increase in the domestic cost of bank funding. Higher capital requirements require bank investment to be funded by a larger share of more expensive equity. This leads to a reduction in the intermediation capacity of banks.

Interestingly, a reduction in the default probability of banks implies a reduction in the foreign funding cost. This somewhat counteract the increase in the domestic funding cost. At the same time it also implies that the reliance of the banking sector on foreign liabilities increases, which potentially makes the economy more susceptible to external shocks.

4.2 Stabilization Effects

[FIGURE 2 and 3 HERE]

In what follows, we study the response of the economy to domestic and foreign sources of distress in the banking sector for different levels of capital requirements.

Foreign financial shock. Figure 2 reports the effects of a shock to the foreign interest rate (ϵ_t^*). The black solid line displays the response of the economy to a foreign interest rate shock that implies a 1 percent drop in GDP for the baseline level of capital requirements of 8 percent.

In response to a sudden increase to the foreign interest rate, the real exchange rate depreciates and the economy experiences a financial recession. The raise in the cost of foreign funding, increases bank default risk on impact. The exchange rate depreciation induced by the increase in the foreign interest rate reduces banks' net worth with negative effects their intermediation capacity, leading to a drop in in the price of capital and aggregate investment.

Since firms price the final good in foreign currency, following a real depreciation the boost in exports is mild compared to the drop in imports. This implies a decline in net exports. Finally, the exchange rate depreciation also leads to an increase in domestic inflation and to an increase in the monetary policy rate due to the standard Taylor rule logic. The resulting increase in the real interest rate, further contributes to the reduction in economic activity.

Next, we explore the effects of higher capital requirements in the transmission of shocks to the foreign interest rate. Figure 2, dashed line reports the economy response under a 1 p.p. higher capital requirement. Interestingly, an economy with capital requirements of 9 percent suffers a deeper recession, as summarized by a 50 percent stronger drop in GDP at the through. This is because higher capital requirements translate into a larger share of foreign funding for banks. Hence, overall a shock to the foreign interest rate has a more sizable effect on the domestic economy.

Domestic financial shock. Figure 3 reports the response of the economy to a bank risk shock, i.e. a mean-preserving shock to the standard deviation ($\sigma_{b,t}$) of the idiosyncratic shock to bank asset returns. An increase in the volatility of bank asset returns translates in a higher probability of bank failure which leads to a reduction in investment and GDP. The black solid line displays the response of the economy to a bank risk shock that implies a 1 percent drop in GDP for the baseline level of capital requirements of 8 percent.

Also in this case the real exchange rate depreciates and there is a decline in net exports. The latter, however, drops by a less remarkable magnitude. Overall, for the same peak impact in GDP a financial recession induced by a domestic financial shock is characterized by a much stronger effect on the probability of bank failure but by a much milder response of foreign borrowing compared to a foreign financial shock.

Under a 1 p.p. higher capital requirement (dashed line) the impact of the bank risk shock is substantially mitigated. Better capitalized banks are indeed able to absorb the negative effects of the shock, leading to a less remarkable impact on bank net worth and, hence, on bank solvency. As a result, the transmission of the shock to the real economy is significantly reduced.

Differently from the case of foreign financial shocks, higher capital requirements can better insulate the economy from domestic financial shocks. Hence, in setting the capital requirement level, the macroprudential authority faces a trade off between stabilizing the economy against domestic and foreign financial shocks.

5 FX Interventions

We now assess the importance of foreign prudential policies in the form of FX interventions. The results in the previous section show that higher bank capital requirements do not necessarily protect the economy against foreign financial shocks. This suggests that policies that respond directly to variations in the real exchange rate could be helpful in contrasting the effects of shocks to the foreign interest rate.

Figure 2 (dotted line) reports the transmission of shocks to the foreign interest rate when in addition to a higher capital requirement the central bank also engages in FX interventions. The results shows that FX interventions are beneficial in mitigating both the economic and financial stability effects of foreign financial shocks.

Under FX interventions the central bank responds to an increase in the foreign interest rate by selling official FX reserves. FX interventions are calibrated such that on impact, the real exchange rate depreciates by around 6% compared to about 9% under the flexible exchange rate regime. As a result, banks' default rate increases by less on impact under the FX intervention regime. Overall, the drop in GDP is reduced by above 30 percent compared to an economy which only features higher capital requirements. See Figure 2 (dashed line).

Figure 3 (dotted line) shows that adopting FX interventions in addition to higher capital requirements also mitigate the impact of domestic financial shocks on economic activity, although to a lesser extent. This is due to the fact that the smoothing of the exchange rate has a direct effect on nominal variables and net exports. While FX interventions, do not have significant effects on the banking sector, the reduction in the exchange rate depreciation benefits the economy in response to domestic financial shocks.

In sum, FX interventions can reduce the policy trade-off between stabilizing the response to foreign and domestic financial shocks. By dampening the volatility of the real exchange rate, the adoption of FX interventions counterbalance the negative effects of capital requirement increases in response to foreign financial shocks, without compromising their effectiveness in response to domestic financial shocks.

6 Interaction of Policies

[FIGURE 4 HERE]

How do FX interventions and bank capital regulation interact? To address this question in what follows we study the optimal policy mix and its implications for macroeconomic ad financial stability.

6.1 Baseline Economy

The top panel of Figure 4 reports the optimal intensity of the FX interventions, ϕ_{FX}, for every level of bank capital requirement (left panel) and the associated welfare level (right panel). The results suggest that the increases with the capital requirement level. For higher levels of capital requirements the economy is more resilient to domestic financial shocks. However, it could be more vulnerable to foreign financial shocks. Hence, this requires a stronger response of the central bank to fight against exchange rate volatility. Overall, the two policies interact in a complementary way.

The optimal mix of policies requires a capital requirement level which is 3 p.p. higher than the baseline (about 11 percent) and an intensity of the FX intervention which implies a depreciation of the exchange rate of about 2 % on impact in response to a foreign financial shock which is substantially lower compared to the 8 % featured by the baseline economy. This policy mix delivers welfare gains of about 0.44 percent in consumption equivalent terms. Importantly, the hump shape in household welfare with reflects the trade-off faced by capital requirement increases discussed in Section 4.1.

Figures 2 and 3 (red solid line) report the response of the economy to domestic and foreign financial shocks, respectively, under the optimal policy mix. The economy is completely insulated to domestic financial shocks. The response of the economy to foreign financial shocks is also substantially mitigated. For instance, compared to the baseline economy the response of GDP is reduced by more than two thirds, whereas the fall in investment as well as the depreciation in the real exchange rate is reduced by about three forth. Macroeconomic stabilization comes along with important implication for financial stability. Indeed, the economy does not feature any sizable increase in the probability of bank failure.

6.2 Bank risk

[FIGURE 5 HERE]

We now explore the role of bank risk for the strenght of FX interventions.

Figure 5 reports the results. To this purpose we compare the policy mix in our baseline economy with a version of the economy with higher (blu dotted line) and lower (dashed red line) riskiness in bank asset results.[7] Higher volatility in bank asset returns translate in higher default risk for banks, which result in a higher cost of funds for the banking sector. In order to address financial stability concerns the optimal increase in the capital requirement level needs to be larger compared to the baseline case. Hence, when the riskiness in the banking

[7]For the high (low) risk case, we consider a dispersion of the idiosyncratic shocks to banks' loan portfolio returns, σ_b, such that before the increase in capital requirements takes place the probability of bank default is about 2.21% (low=1.03%) instead of the 1.59% of the baseline calibration.

sector is higher the optimal policy mix feature a higher level of capital requirements and, hence, also a stronger response to fluctuations in the foreign exchange rate. The opposite is instead true in the case of a lower riskiness in bank asset returns.

7 Other Policies

The main focus of the analysis in this paper is on bank capital regulation and FX interventions. For completeness in what follows we also explore the role of other policies. In particular, we study the role of monetary policy and alternative foreign prudential policies.

7.1 Monetary Policy

[FIGURE 6 and 7 HERE]

We now consider how the degree of monetary policy accommodation affects the transmission of financial shocks and the effectiveness of the optimal policy mix.

Figure 6 and 7 compare the transmission of a foreign and domestic financial shock under the baseline Taylor rule framework of monetary policy (black solid line) and a strict inflation targeting regime (black dashed line). The latter is characterized by a monetary authority which moves the policy rate in such a way to completely stabilize the inflation rate.

Under a strong inflation targeting, the monetary authority fully stabilizes inflation at a cost of exacerbating the increase in the real interest rate and the exchange rate depreciation. Hence, the monetary authority looses the ability to mitigate the effects of financial shocks. In contrast, under a standard Taylor-type rule, a more moderate response to deviations of inflation from the target limits the exchange rate depreciation, and the adverse bank balance sheet effects that amplify the recession. Overall, a strong inflation targeting regime makes the economy more vulnerable to both foreign and domestic financial shocks.

FX interventions can significantly reduce the depreciation of the exchange rate, and especially so under a strict inflation targeting regime (red dashed-dotted line) compared to the baseline Taylor-type monetary policy rule (red solid line). Hence, the optimal policy mix result to be more effective in reducing the vulnerability of the economy to foreign financial shocks under a strict inflation targeting regime, with welfare gains of about 0.01 % higher compared to the welfare gains in the baseline case.

7.2 Capital inflow tax

[FIGURE 12 and 13 HERE]

We start by considering the case of a tax, τ^c, on the bank inflow of foreign funds, $(1+\tau^c)\Theta_t\left(\frac{f_{t+1}}{f_t}R_t^F\right)$, such that the bank's default threshold is modified as follows:

$$\overline{\omega}_{t+1} = \frac{\left[(1+\tau_t^c)\Theta_t\left(\frac{f_{t+1}}{f_t}\pi_{t+1}R_t^F\right)+\frac{\varkappa}{2}\Theta_t^2+(1-\Theta_t)R_t^d\right]\left((1-\phi)q_tK_t^b+B_t^{CB}\right)-R_t^{CB}B_t^{CB}}{R_{t+1}^Kq_tK_t^b}.$$

Moreover, resources extracted from the capital inflows tax are rebated to households via a lump-sum transfer. Figure 12 compares the response of the economy to a foreign financial shock when bank capital requirements are complemented with a capital inflow tax (dashed line) or FX interventions (solid line), respectively. In both cases, we assume that the country adopts the optimal policy mix.

Compared to the baseline case, capital inflow tax can also limit the magnitude of an exchange rate depreciation and thus have the potential to mitigate the effect of foreign financial shocks. However, taxing the inflow of foreign funds for banks is also associated with a much slower accumulation of net foreign assets, which considerably worsens the balance sheet adjustment in the face of the shock.

On impact, bank default probability increases by less under the FX intervention regime. This is due the fact that under (optimal) FX interventions, the real exchange rate follows a smoother pattern that implies a larger drop in foreign borrowing on impact but a faster reversion to steady state. On the contrary, a capital inflow tax modifies the cost of borrowing in foreign currency relative to domestic currency in a more persistent way by distorting the optimal decision, as shown in the first-order condition with respect to the foreign liability share:

$$\mathbb{E}_t\left[\frac{\Lambda_{b,t+1}}{\pi_{t+1}}\Gamma'(\overline{\omega}_{t+1})\left((1+\tau_t^c)\frac{f_{t+1}}{f_t}\Pi_{t+1}R_t^F+\varkappa\Theta-R_t^d\right)\right]=0. \quad (14)$$

Overall, the impact of foreign financial shocks on economic activity is remarkably more reduced under FX interventions. Figure 13 shows that this is also the case for the response to domestic sources of distress in the banking sector.

8 Conclusions

We document the transmission of financial shocks in a quantitative small open economy model with bank default and domestic and foreign liability funding. Then we explore the impact of tighter bank capital requirements and their interaction with FX interventions. Our results provide interesting policy implications. Our analysis warns that higher bank capital requirements mitigate the impact of domestic financial shocks but might have adverse effect on the resilience of the economy from foreign financial shocks.

This paper also provides novel results on the prudential role of sterilized foreign exchange (FX) interventions in emerging economies. Our results demonstrate the importance of FX interventions to mitigate the economic and financial stability effects of foreign financial shocks. When FX interventions are available, the economy is less vulnerable to external sources of financial stability. Hence, a combination of both policy measures is desirable. FX interventions are particularly important in situations which exacerbate the volatility of the exchange rate such as a high bank default probability or the central bank follows a strict inflation targeting.

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Table 1: Model parameters

Preset parameters					
Disutility of labor	φ	3.4	Banks bankruptcy cost	μ_b	0.3
Frisch elasticity of labor	η	0.276	AR parameter bank risk	ρ_b	0.9
Capital share in production	α_k	0.33	Price elasticity of demand	θ	0.2
Labor share in production	α_l	0.51	Foreign elasticity of demand	$\varkappa^*$	1.5
Depreciation rate of capital	δ	0.04	Calvo probability	ξ	0.75
AR parameter foreign rate	ρ_{R^*}	0.95	Smoothing parameter (Taylor rule)	ρ_R	0.79
AR parameter TFP	ρ_A	0.9	Inflation response (Taylor rule)	α_π	2.42
Output growth response (Taylor rule)	α_{GDP}	0.16	Steady-state foreign inflation	$\bar{\pi}^*$	1
Calibrated parameters					
Discount factor of consumers	β	0.978	STD iid risk for banks	σ_b	0.0613
Capital requirement for banks	ϕ	0.08	Survival rate of bankers	θ_b	0.947
Share of insured deposits	κ	0.44	Capital adjustment cost parameter	ψ_k	32.615
Steady-state inflation	$\overline{\pi}$	1.011	Transfer from HH to bankers	χ_b	0.453
STD iid risk for foreign rate	σ_{R^*}	0.0006	Capital management cost	ς	0.0007
STD iid risk for TFP	σ_A	0.00368	mean STD iid risk for banks	σ_b	0.030
Share of dollar invoicing	ψ	0.9	Steady-state CB reserves	B_{CB}	0.066
Exogenous risk premium	γ	3.152	Foreign debt costs	$\varkappa$	0.3583
Steady-state foreign demand	Y^*	0.907	Steady-state international rate	R^*	1.00008

Note: Baseline parameterization of the model. STD iid risk refers to the standard deviation of the idiosyncratic shocks to the bank gross asset returns.

Table 2: Model fit

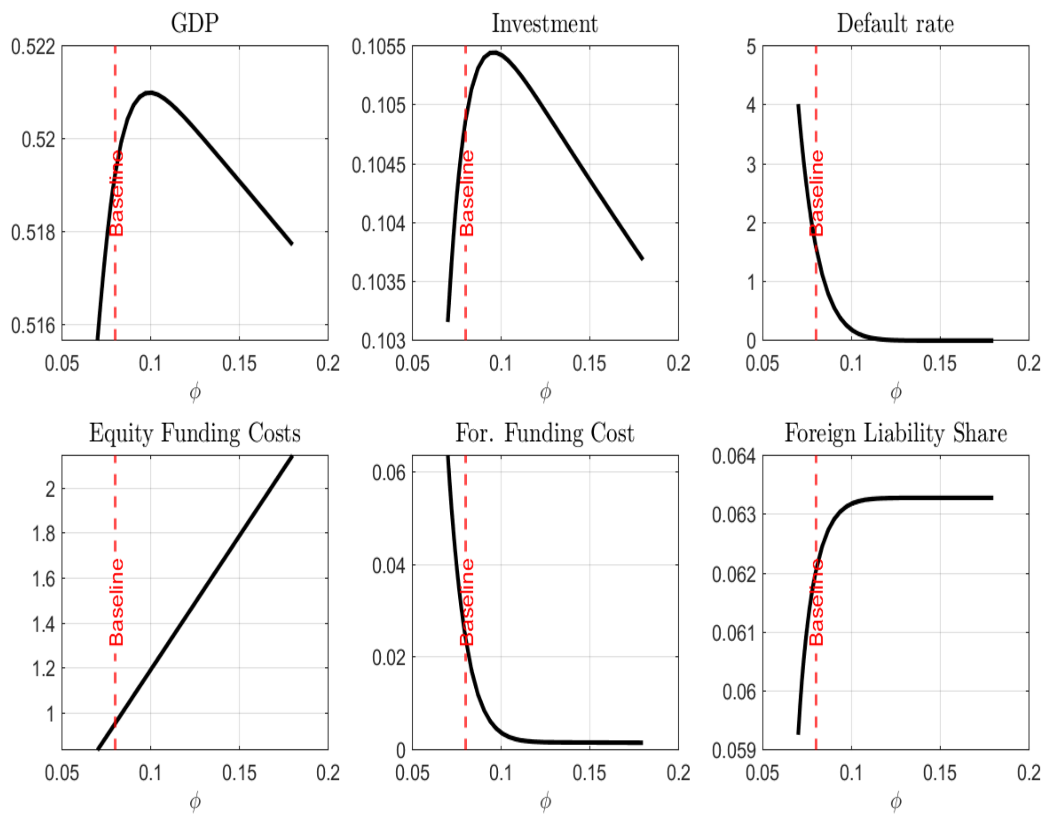
Targets	**Definition**	**Data**	**Model**
Banks' default	$F(\overline{\omega}_b) \times 400$	1.47	1.59
Real equity return of banks	$(\rho_b - 1) \times 400$	11.15	11.94
Banks' price to book ratio	v_b	1.2	1.16
Banks' foreign liabilities share	Θ	0.669	0.62
Reserves to GDP	$f_t \mathcal{R}_t / GDP$	0.125	0.127
Exports to GDP	Ex_t/GDP	0.11	0.15
Capital share of households	K_s/K	0.27	0.27
STD GDP	$\sigma(GDP)$	0.58	0.56
STD Inv/STD of GDP	$\sigma(I)/\sigma(GDP)$	3.95	3.96
STD banks' foreign liabilities share	$\sigma(\Theta)$	1.03	1.15
STD banks' default	$\sigma(F(\overline{\omega}_b) \times 400)$	1.33	1.53

Note: Data targets used to calibrate the model as well as the corresponding model values.

Table 3: Welfare Analysis

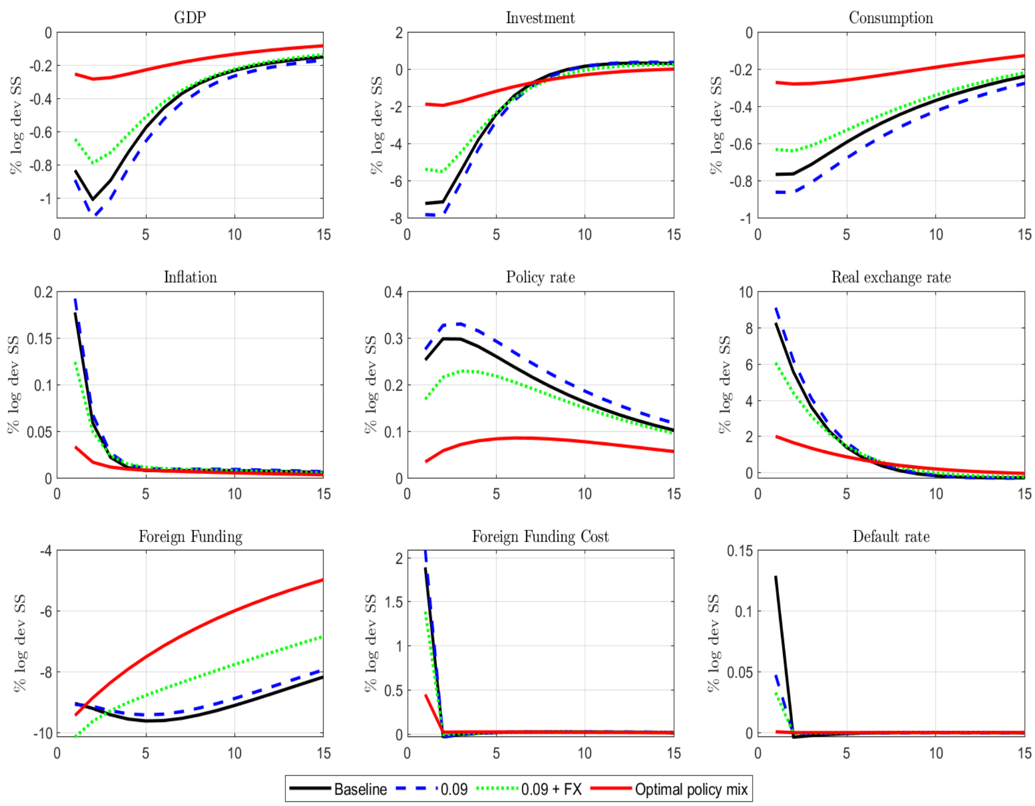
	Baseline	FX	$\pi_t = \bar{\pi}$	Optimal MP + FX
Cons. Equiv. $\mathcal{W}$	0.4374%	0.4379%	0.4380%	0.4382%
ϕ	11.103%	11.103%	11.103%	11.103%
ϕ_{CB}	-	7.17	6.26	6.90
α_{π}	-	-	-	10
α_{GDP}	-	-	-	0.29

Figure 1: Long run effects of capital requirements (ϕ)



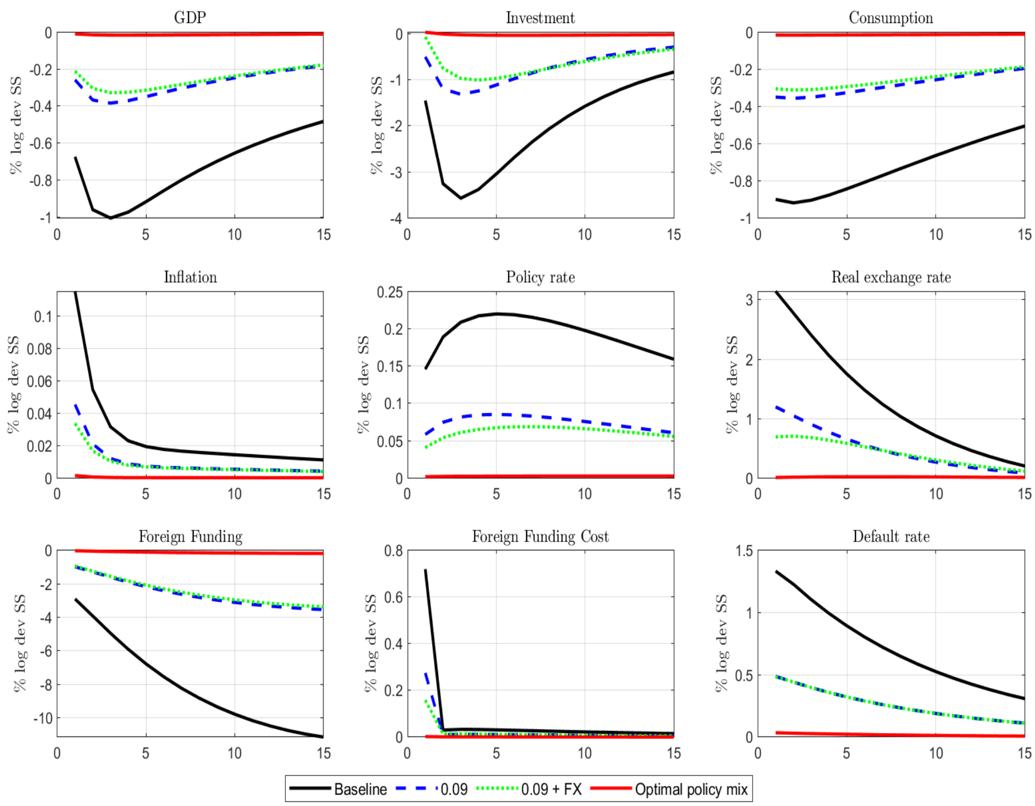
Stochastic mean of key macroeconomic and financial variables w.r.t. ϕ. Probability of bank default and funding costs reported in annualized percentage terms. The dashed vertical line indicates the values corresponding to the baseline level of capital requirements of 8%.

Figure 2: IRFs to a Foreign Financial Shock



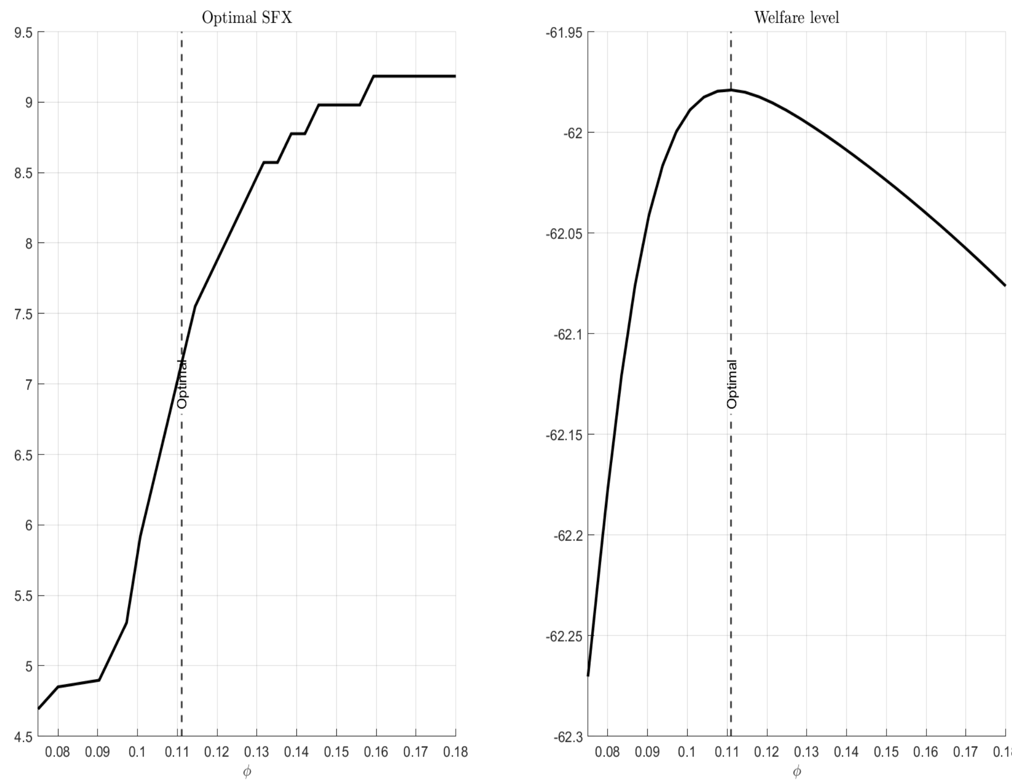
Note: Impulse-response functions to a negative foreign interest rate shock (ϵ_t^*): baseline 8% CR (black solid line), 9% CR (blue dashed line), 9% CR & FX (green dotted line) and optimized policy mix (red solid line).

Figure 3: IRFs to a Domestic Financial Shock



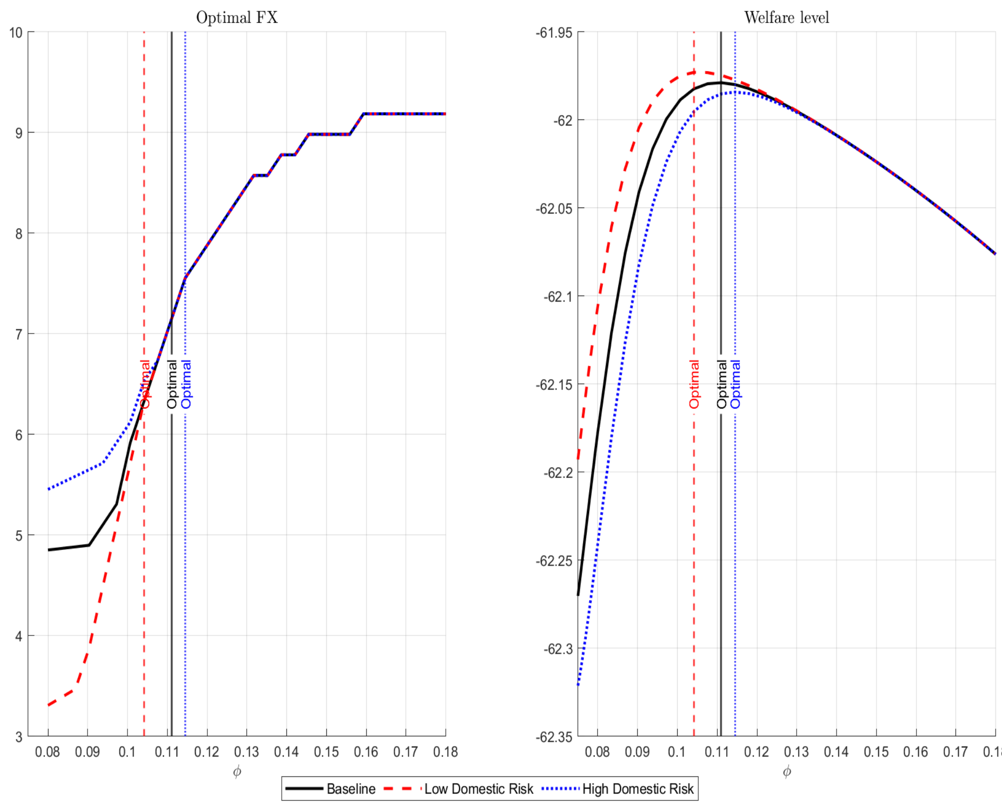
Note: Impulse-response functions to a negative risk shock to bank asset returns under alternative policies: baseline 8% CR (black solid line), 9% CR (blue dashed line), 9% CR & FX (green dotted line) and optimized policy mix (red solid line).

Figure 4: Optimal FX intensity for different levels of capital requirements



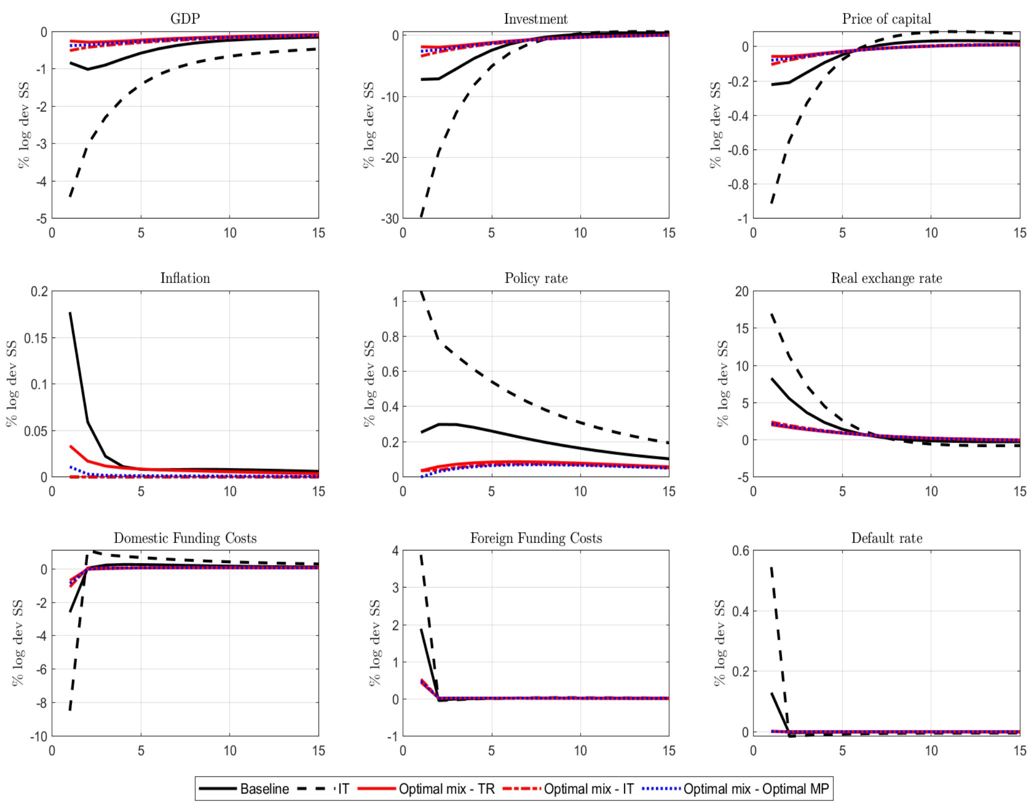
Note: Left panel: Welfare maximizing ϕ_{FX} for different levels of bank capital requirements ϕ. Right panel: Welfare level corresponding to the FX and CR mix reported in the left panel. The vertical dashed line indicates the optimal policy mix.

Figure 5: Optimal FX intensity for different levels of capital requirements: the degrees of risk in the banking sector



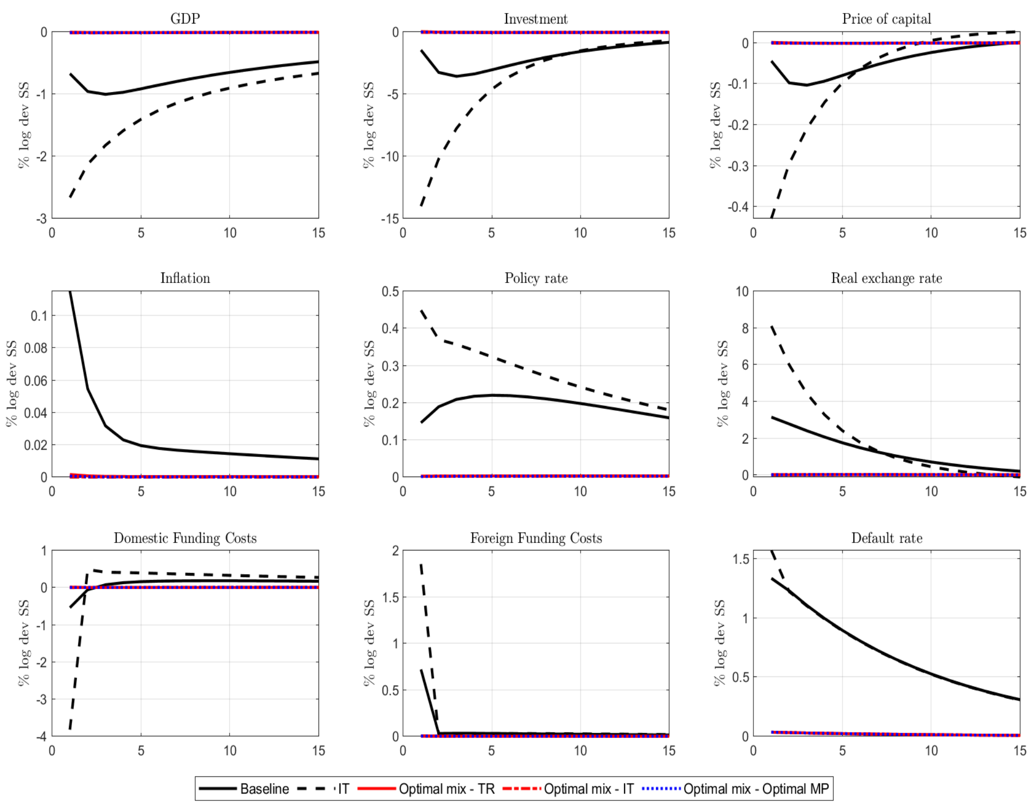
Note: Left panel: Welfare maximizing ϕ_{FX} for different levels of bank capital requirements ϕ for different domestic financial risk. Right panel: Welfare level corresponding to the FX and CR mix reported in the left panel. The vertical dashed line indicates the optimal policy mix.

Figure 6: IRFs to a Foreign Financial Shock: Monetary Policy



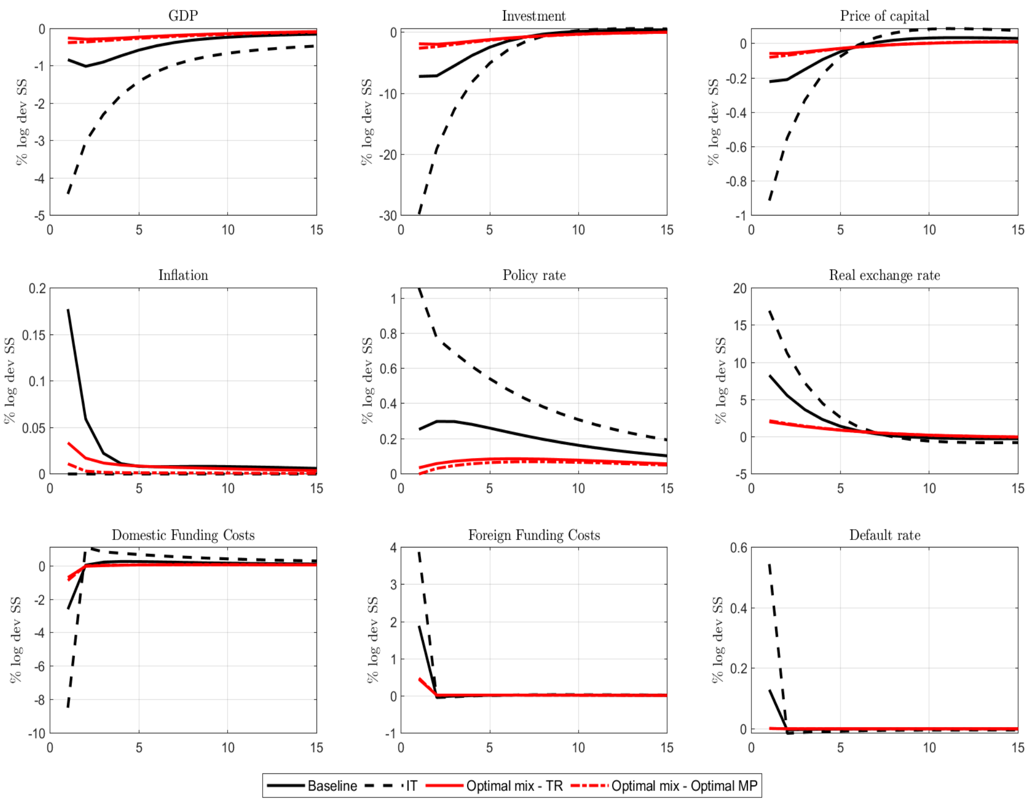
Note: Impulse-response functions to a negative shock to the foreign interest rate under alternative policies: baseline Taylor Rule (black solid line), Strict Inflation Targeting (black dashed line), Optimal (CR&FX) policy mix under baseline Taylor Rule (red solid line) and Optimal (CR&FX) policy mix under strict Inflation Targeting (red dashed line).

Figure 7: IRFs to a Domestic Financial Shock: Monetary Policy



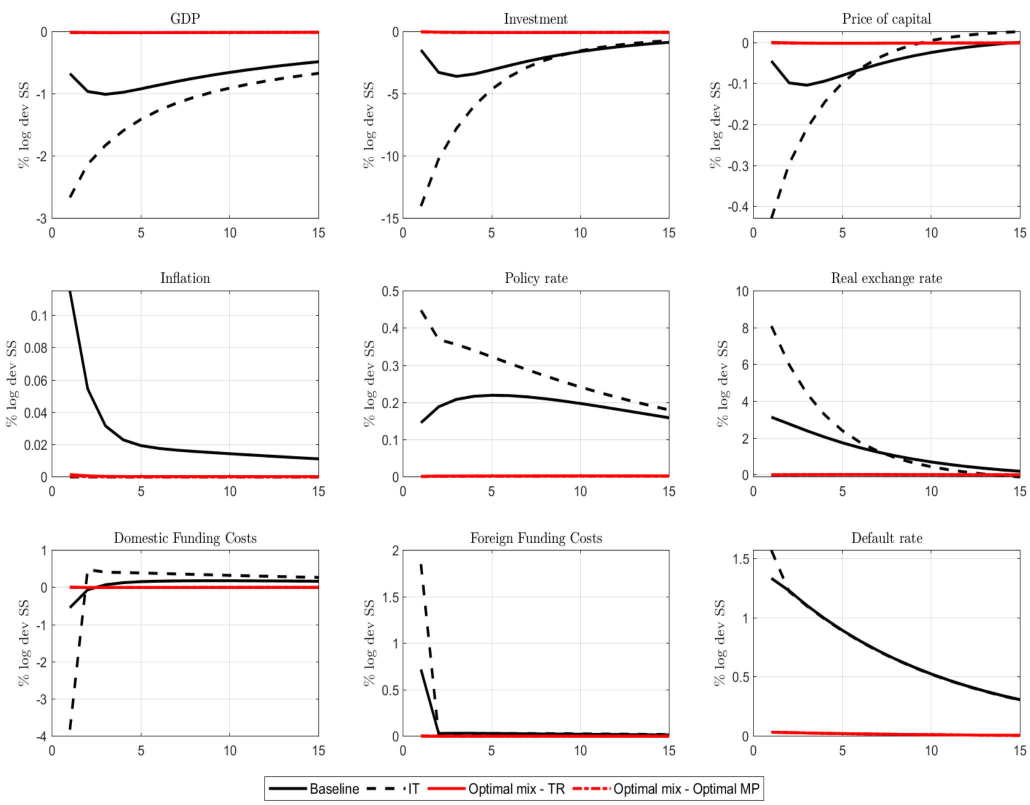
Note: Impulse-response functions to a negative risk shock to bank asset returns under alternative policies: baseline Taylor Rule (black solid line), Strict Inflation Targeting (black dashed line), Optimal (CR&FX) policy mix under baseline Taylor Rule (red solid line) and Optimal (CR&FX) policy mix under strict Inflation Targeting (red dashed line).

Figure 8: IRFs to a Foreign Financial Shock: Monetary Policy



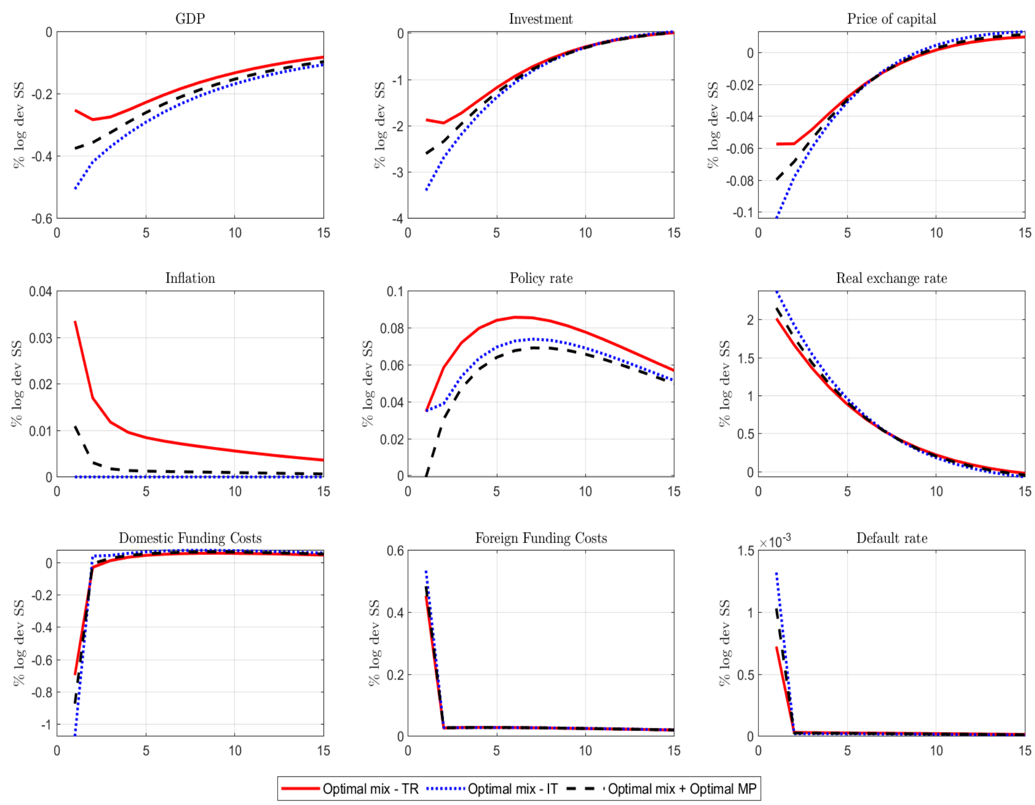
Note: Impulse-response functions to a negative shock to the foreign interest rate under alternative policies: baseline Taylor Rule (black solid line), Strict Inflation Targeting (black dashed line), Optimal (CR&FX) policy mix under baseline Taylor Rule (red solid line) and Optimal (CR&FX) policy mix under strict Inflation Targeting (red dashed line).

Figure 9: IRFs to a Domestic Financial Shock: Monetary Policy



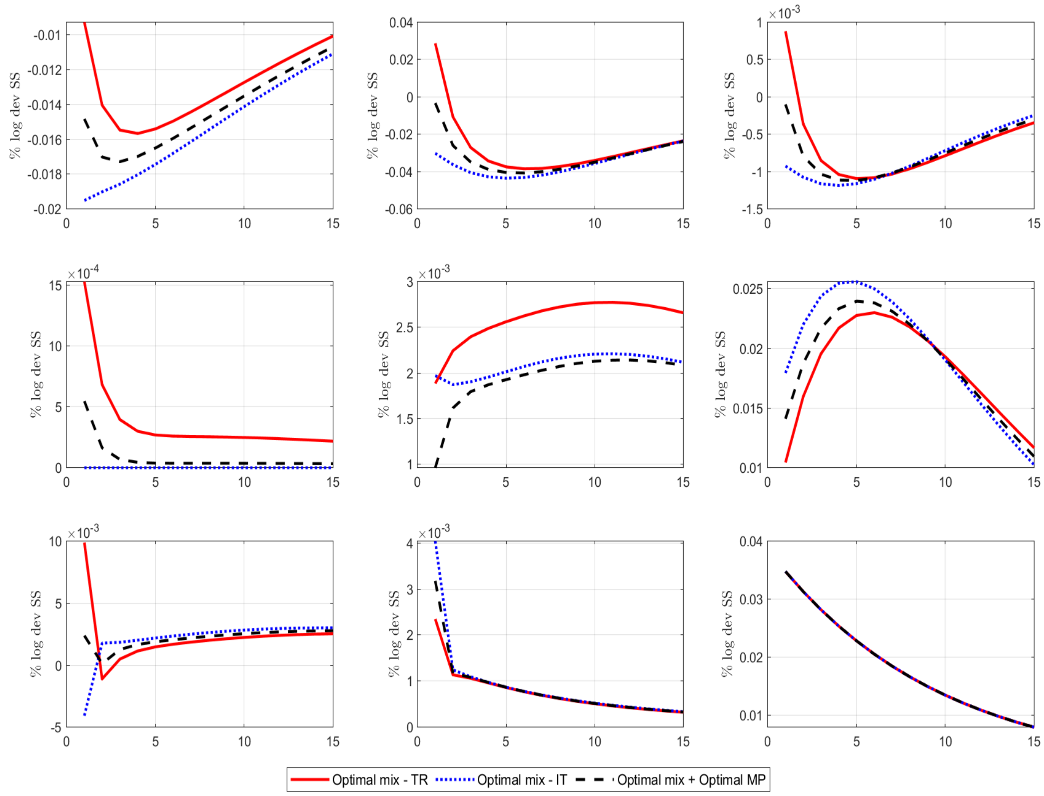
Note: Impulse-response functions to a negative risk shock to bank asset returns under alternative policies: baseline Taylor Rule (black solid line), Strict Inflation Targeting (black dashed line), Optimal (CR&FX) policy mix under baseline Taylor Rule (red solid line) and Optimal (CR&FX) policy mix under strict Inflation Targeting (red dashed line).

Figure 10: IRFs to a Foreign Financial Shock: Optimal Monetary Policy



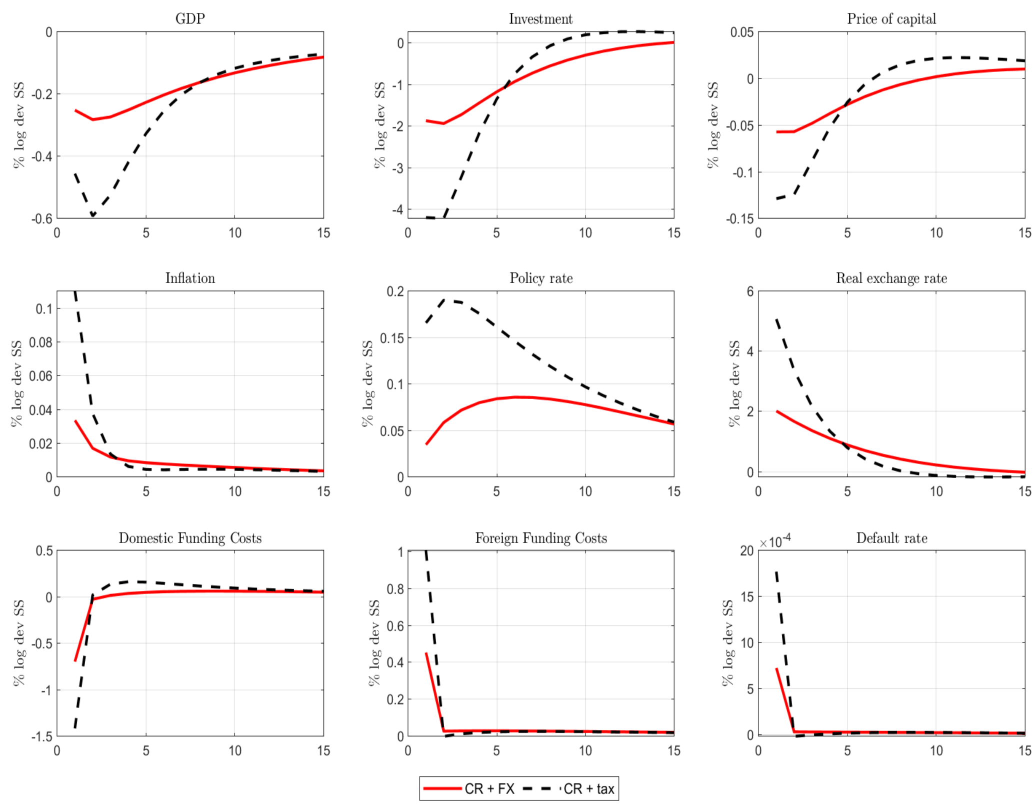
Note: Impulse-response functions to a negative shock to the foreign interest rate under alternative policies: Optimal (CR&FX) policy mix under baseline Taylor Rule (red solid line), Optimal (CR&FX) policy mix under strict Inflation Targeting (blue dotted line), Optimal (CR&FX&MP) mix (black dashed line).

Figure 11: IRFs to a Domestic Financial Shock: Optimal Monetary Policy



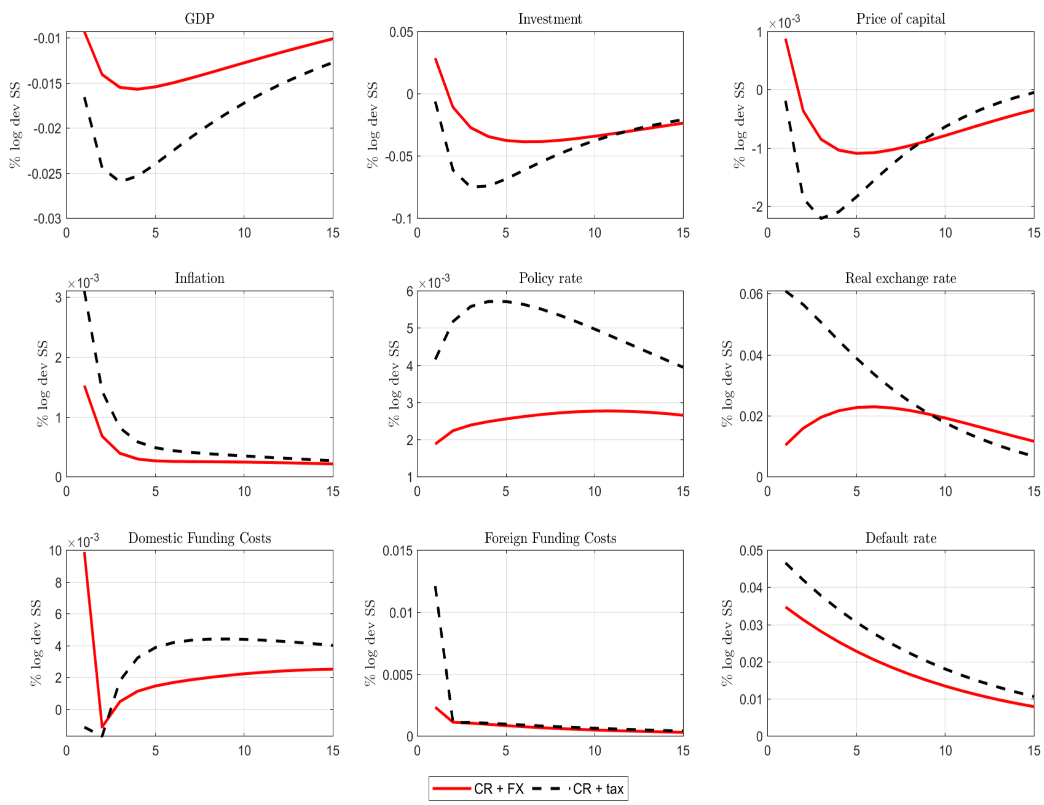
Note: Impulse-response functions to a negative shock to the foreign interest rate under alternative policies: Optimal (CR&FX) policy mix under baseline Taylor Rule (red solid line), Optimal (CR&FX) policy mix under strict Inflation Targeting (blue dotted line), Optimal (CR&FX&MP) mix (black dashed line).

Figure 12: IRFs to a Foreign Financial Shock: Capital Inflow Management



Note: Impulse-response functions to a negative shock to the foreign interest rate (ϵ_t^*) under alternative foreign prudential policies: Optimal policy mix between bank capital requirements and FX interventions (black solid line), Optimal policy mix between bank capital requirements and tax on foreign liabilities inflow (black dashed line).

Figure 13: IRFs to a Domestic Financial Shock: Capital Inflow Management



Note: Impulse-response functions to a negative shock to a negative risk shock to bank asset returns under alternative foreign prudential policies: Optimal policy mix between bank capital requirements and FX interventions (black solid line), Optimal policy mix between bank capital requirements and tax on foreign liabilities inflow (black dashed line).

Online Appendix

A Model Details

A.1 Import Bundlers

In the Rest of the World (RoW) there exist import bundlers who take intermediate inputs from the home country and combine them into a single final good. The home country's intermediate good firms are split between those who invoice in the domestic currency (PCP) and those who invoice in dollars (DCP /LCP). Import bundlers solve

$$\max_{y_t(i)} P_t^M M_t^* - \psi \int p_{HR,t}^R(i) y_{HR,t}^R(i) di - (1-\psi) \int \frac{p_{HR,t}^H(i)}{F_t} y_{HR,t}^H(i) di$$
$$\text{s.t. } M_t^* = \left(\int_0^1 y_{HR,t}(i)^{\frac{1}{1+\theta}} di \right)^{1+\theta}$$

where ψ is the share of domestic intermediate good producers who price in dollars. The subscripts and superscripts denote the origin, destination and invoicing currency of the prices / goods. Thus $p_{HR,t}^R(i)$ is the price of a good originating in the home market, destined for the RoW and priced in RoW currency (dollars).

The solution to this problem generates two demand functions, one for goods priced in dollars and one for goods priced in home currency:

$$y_{HR,t}^R(i) = \left(\frac{p_{HR,t}^R(i)}{P_t^M} \right)^{-\frac{1+\theta}{\theta}} M_t^*$$
$$y_{HR,t}^H(i) = \left(\frac{p_{HR,t}^H(i)}{F_t P_t^M} \right)^{-\frac{1+\theta}{\theta}} M_t^*$$

The resulting price index for home country exports is then:

$$\begin{aligned} P_t^M &= \left[\psi \int p_{HR,t}^R(i)^{-\frac{1}{\theta}} di + (1-\psi) \int \left(\frac{p_{HR,t}^H(i)}{F_t} \right)^{-\frac{1}{\theta}} di \right]^{-\theta} \\ &= \left[\psi {P_{HR,t}^R}^{-\frac{1}{\theta}} + (1-\psi) {P_{HR,t}^H}^{-\frac{1}{\theta}} \right]^{-\theta}, \end{aligned}$$

where we are defining

$$P_{HR,t}^R = \left[\int p_{HR,t}^j(i)^{-\frac{1}{\theta}} di \right]^{-\theta},$$
$$P_{HR,t}^H = \left[\int \left(\frac{p_{HR,t}^H(i)}{F_t} \right)^{-\frac{1}{\theta}} di \right]^{-\theta}.$$

Note that these price indices are both effectively priced in dollars. From this we can derive laws of motion as follows

$$
\begin{aligned}
{P^R_{HR,t}}^{-\frac{1}{\theta}} &= \xi\Big(p^{R*}_{HR,t}\Big)^{-\frac{1}{\theta}} + (1-\xi)\Big(X^R_{t,t+1}P^R_{HR,t-1}\Big)^{-\frac{1}{\theta}} \\
\left(\frac{P^R_{HR,t}}{P^M_t}\right)^{-\frac{1}{\theta}} &= \xi\left(\frac{p^{R*}_{HR,t}}{P^M_t}\right)^{-\frac{1}{\theta}} + (1-\xi)\left(X^R_{t,t+1}\frac{P^R_{HR,t-1}}{P^M_t}\right)^{-\frac{1}{\theta}} \\
\left(\frac{P^R_{HR,t}}{P^M_t}\right)^{-\frac{1}{\theta}} &= \xi\Big(p^{j0}_{HR,t}\Big)^{-\frac{1}{\theta}} + (1-\xi)\left(\frac{X^R_{t,t+1}}{\Pi^M_t}\frac{P^R_{HR,t-1}}{P^M_{t-1}}\right)^{-\frac{1}{\theta}}
\end{aligned}
$$

and

$$
\begin{aligned}
{P^H_{HR,t}}^{-\frac{1}{\theta}} &= \xi\left(\frac{p^{H*}_{HR,t}}{F_t}\right)^{-\frac{1}{\theta}} + (1-\xi)\left(X^H_{t,t+1}\frac{F_{t-1}}{F_t}P^H_{HR,t-1}\right)^{-\frac{1}{\theta}} \\
\left(\frac{P^H_{HR,t}}{P^M_t}\right)^{-\frac{1}{\theta}} &= \xi\left(\frac{p^{H*}_{HR,t}}{F_tP^M_t}\right)^{-\frac{1}{\theta}} + (1-\xi)\left(X^H_{t,t+1}\frac{f_{t-1}\Pi^R_t}{f_t\Pi_t}\frac{P^H_{HR,t-1}}{P^M_t}\right)^{-\frac{1}{\theta}} \\
\left(\frac{P^H_{HR,t}}{P^M_t}\right)^{-\frac{1}{\theta}} &= \xi\Big(p^{j0}_{HR,t}\Big)^{-\frac{1}{\theta}} + (1-\xi)\left(\frac{X^H_{t,t+1}}{\Pi^M_t}\frac{f_{t-1}\Pi^R_t}{f_t\Pi_t}\frac{P^H_{HR,t-1}}{P^M_{t-1}}\right)^{-\frac{1}{\theta}}
\end{aligned}
$$

Finally, we can then take the equation for import prices and rewrite it as:

$$
1 = \psi\left(\frac{P^R_{HR,t}}{P^M_t}\right)^{-\frac{1}{\theta}} + (1-\psi)\left(\frac{P^H_{HR,t}}{P^M_t}\right)^{-\frac{1}{\theta}}
$$

Define $\rho^j_{HR,t} = P^j_{HR,t}P^M_t$ then we can collect 3 equations in 3 unknowns $(\Pi^M_t, \rho^H_{HR,t}, \rho^R_{HR,t})$:

$$
\begin{aligned}
1 &= \psi\Big(\rho^R_{HR,t}\Big)^{-\frac{1}{\theta}} + (1-\psi)\Big(\rho^H_{HR,t}\Big)^{-\frac{1}{\theta}} \\
\Big(\rho^R_{HR,t}\Big)^{-\frac{1}{\theta}} &= \xi\Big(p^{R0}_{HR,t}\Big)^{-\frac{1}{\theta}} + (1-\xi)\left(\frac{X^R_{t,t+1}}{\Pi^M_t}\rho^R_{HR,t-1}\right)^{-\frac{1}{\theta}} \\
\Big(\rho^H_{HR,t}\Big)^{-\frac{1}{\theta}} &= \xi\Big(p^{H0}_{HR,t}\Big)^{-\frac{1}{\theta}} + (1-\xi)\left(\frac{X^H_{t,t+1}}{\Pi^M_t}\rho^H_{HR,t-1}\right)^{-\frac{1}{\theta}}
\end{aligned}
$$

The import bundler must then decide on the total amount of the import bundle, M^*_t to produce. We assume they face a downward sloping demand curve of the form:

$$
M^*_t = E_{x,t} = \left(\frac{P^M_t}{P^R_t}\right)^{-\varkappa^*} Y^*_t = (p^{MR}_t)^{-\varkappa^*}Y^*_t \tag{15}
$$

where P^R_t is the price level in RoW and p^{MR}_t is the relative price which evolves according to:

$$
p^{MR}_t = \frac{\Pi^M_t}{\Pi^R_t}p^{MR}_{t-1}.
$$

It will also be convenient to define the price of home country exports relative to the home country price level $p_t^{MH} = F_t P_t^M P_t$. Note that this is not the same as the real exchange rate since, in general, $P_t^M \neq P_t^R$. It is also worth noting that $p_t^{MH} = f_t p_t^{MR}$. This relative price then evolves according to

$$p_t^{MH} = \frac{F_t}{F_{t-1}} \frac{\Pi_t^M}{\Pi_t} p_{t-1}^{MH} = \frac{f_t}{f_{t-1}} \frac{\Pi_t^M}{\Pi_t^R} p_{t-1}^{MH}$$

A.2 Intermediary goods producers

Intermediate goods producers sell to two different buyers: the domestic final goods producers and the foreign import bundlers. Furthermore, a fraction ψ of intermediate goods producers invoice their sales to the import bundler in dollars and $1-\psi$ invoice in home currency. Both types of firm invoice domestic sales in the home currency.

A.2.1 Domestic Currency Invoicers

Their pricing problem can be written as follows:

$$\max_{p_{HH,t}^H(i), p_{HR,t}^H(i)} \mathbb{E}_t \left[\sum_{\tau=0}^{\infty} \Lambda_{t,t+\tau} \xi^\tau \left(\frac{X_{t,t+\tau}^H p_{HH,t}^H(i)}{P_{t+\tau}} y_{HH,t+\tau}^H(i) + \frac{X_{t,t+\tau}^H p_{HR,t}^H(i)}{P_{t+\tau}} y_{HR,t+\tau}^H(i) - mc_{t+\tau}(i) y_{t+\tau}^H(i) \right) \right]$$

$$\begin{aligned} \text{s.t. } y_{HH,t+\tau}^H(i) &= \left(X_{t,t+\tau}^H \frac{p_{HH,t}^H(i)}{P_{t+\tau}} \right)^{-\frac{1+\theta}{\theta}} Y_{t+\tau} \\ y_{HR,t+\tau}^H(i) &= \left(X_{t,t+\tau}^H \frac{p_{HR,t}^H(i)}{F_{t+\tau} P_{t+\tau}^M} \right)^{-\frac{1+\theta}{\theta}} M_{t+\tau}^* \\ y_{t+\tau}^H(i) &= y_{HR,t+\tau}^H(i) + y_{HH,t+\tau}^H(i) \end{aligned}$$

We get two first-order conditions. Starting with $p_{HR,t}^H(i)$:

$$\mathbb{E}_t \sum_{\tau=0}^{\infty} \Lambda_{t,t+\tau} \xi^\tau \left[\frac{X_{t,t+\tau}^H}{P_{t+\tau}} y_{HR,t+\tau}^H + \left(\frac{X_{t,t+\tau}^H p_{HR,t}^{H*}(i)}{P_{t+\tau}} - mc_{t+\tau} \right) \frac{\partial y_{HR,t+\tau}^H(i)}{\partial p_{HR,t}^{H*}(i)} \right] = 0$$

Note that the derivative of firm sales abroad with respect to price is given by:

$$\begin{aligned} \frac{\partial y_{HR,t+\tau}^H(i)}{\partial p_{HR,t}^H(i)} &= -\frac{1+\theta}{\theta} \left(X_{t,t+\tau}^H \frac{p_{HR,t}^H}{F_{t+\tau} P_{t+\tau}^M} \right)^{-\frac{1}{\theta}} M_{t+\tau}^* \frac{X_{t,t+\tau}^H}{F_{t+\tau} P_{t+\tau}^M} \\ &= -\frac{1+\theta}{\theta} \left(\frac{y_{HRt+\tau}^H(i)}{p_{HR,t}^H(i)} \right) \end{aligned}$$

Subbing this in to the above first-order condition:

$$\mathbb{E}_t \sum_{\tau=0}^{\infty} \Lambda_{t,t+\tau} \xi^\tau \left[\frac{X^H_{t,t+\tau}}{P_{t+\tau}} y^H_{HR,t+\tau} - \left(\frac{X^H_{t,t+\tau} p^{H*}_{HR,t}(i)}{P_{t+\tau}} - mc_{t+\tau} \right) \frac{1+\theta}{\theta} \left(\frac{y^H_{HRt+\tau}}{p^{H*}_{HR,t}(i)} \right) \right] = 0$$

$$\mathbb{E}_t \sum_{\tau=0}^{\infty} \Lambda_{t,t+\tau} \xi^\tau \left[\frac{X^H_{t,t+\tau} p^{H*}_{HR,t}(i)}{P_{t+\tau}} y^H_{HR,t+\tau} - \left(\frac{X^H_{t,t+\tau} p^{H*}_{HR,t}(i)}{P_{t+\tau}} - mc_{t+\tau} \right) \frac{1+\theta}{\theta} y^H_{HRt+\tau} \right] = 0$$

$$\mathbb{E}_t \sum_{\tau=0}^{\infty} \Lambda_{t,t+\tau} \xi^\tau \left[\frac{X^H_{t,t+\tau} p^{H*}_{HR,t}(i)}{P_{t+\tau}} y^H_{HR,t+\tau} \left(1 - \frac{1+\theta}{\theta} \right) + mc_{t+\tau} \frac{1+\theta}{\theta} y^H_{HRt+\tau} \right] = 0$$

$$\mathbb{E}_t \sum_{\tau=0}^{\infty} \Lambda_{t,t+\tau} \xi^\tau \left[\frac{X^H_{t,t+\tau} p^{H*}_{HR,t}(i)}{P_{t+\tau}} y^H_{HR,t+\tau} \right] = (1+\theta) \mathbb{E}_t \sum_{\tau=0}^{\infty} \Lambda_{t,t+\tau} \xi^\tau \left[mc_{t+\tau} y^H_{HRt+\tau} \right]$$

$$\mathbb{E}_t \sum_{\tau=0}^{\infty} \Lambda_{t,t+\tau} \xi^\tau \left[X^H_{t,t+\tau} \frac{p^{H*}_{HR,t}(i)}{F_t P^M_{t+\tau}} p^{MH}_{t+\tau} y^H_{HR,t+\tau} \right] = (1+\theta) \mathbb{E}_t \sum_{\tau=0}^{\infty} \Lambda_{t,t+\tau} \xi^\tau \left[mc_{t+\tau} y^H_{HRt+\tau} \right]$$

$$\underbrace{\mathbb{E}_t \sum_{\tau=0}^{\infty} \Lambda_{t,t+\tau} \xi^\tau \left[X^H_{t,t+\tau} p^{H0}_{HR} p^{MH}_{t+\tau} y^H_{HR,t+\tau} \right]}_{G^H_t} = \underbrace{(1+\theta) \mathbb{E}_t \sum_{\tau=0}^{\infty} \Lambda_{t,t+\tau} \xi^\tau \left[mc_{t+\tau} y^H_{HRt+\tau} \right]}_{B^H_t}$$

The second first-order condition is similar and can be written as:

$$\mathbb{E}_t \left[\sum_{\tau=0}^{\infty} \Lambda_{t,t+\tau} \xi^\tau \frac{p^{H*}_{HH,t}}{P_{t+\tau}} X^H_{t,t+\tau} y^H_{HH,t+\tau} \right] = (1+\theta) \mathbb{E}_t \left[\sum_{\tau=0}^{\infty} \Lambda_{t,t+\tau} \xi^\tau mc_{t+\tau} y^H_{HH,t+\tau} \right]$$

$$\underbrace{\mathbb{E}_t \left[\sum_{\tau=0}^{\infty} \Lambda_{t,t+\tau} \xi^\tau X^H_{t,t+\tau} p^{H0}_{HH} y^H_{HH,t+\tau} \right]}_{=G_t} = \underbrace{(1+\theta) \mathbb{E}_t \left[\sum_{\tau=0}^{\infty} \Lambda_{t,t+\tau} \xi^\tau mc_{t+\tau} y^H_{HH,t+\tau} \right]}_{=B_t}$$

A.2.2 Dollar Invoicers

Their pricing problem can be written as follows:

$$\max_{p^H_{HH,t}(i), p^R_{HR,t}(i)} \mathbb{E}_t \left[\sum_{\tau=0}^{\infty} \Lambda_{t,t+\tau} \xi^\tau \left(\frac{X^H_{t,t+\tau} p^H_{HH,t}(i)}{P_{t+\tau}} y^H_{HH,t+\tau}(i) + \frac{X^R_{t,t+\tau} F_{t+\tau} p^R_{HR,t}(i)}{P_{t+\tau}} y^R_{HR,t+\tau}(i) - mc_{t+\tau}(i) y^R_{t+\tau}(i) \right) \right]$$

$$\text{s.t. } y^H_{HH,t+\tau}(i) = \left(X^H_{t,t+\tau} \frac{p^H_{HH,t}(i)}{P_{t+\tau}} \right)^{-\frac{1+\theta}{\theta}} Y_{t+\tau}$$

$$y^H_{HR,t+\tau}(i) = \left(X^R_{t,t+\tau} \frac{p^H_{HR,t}(i)}{P^M_{t+\tau}} \right)^{-\frac{1+\theta}{\theta}} M^*_{t+\tau}$$

$$y^R_{t+\tau}(i) = y^H_{HR,t+\tau}(i) + y^H_{HH,t+\tau}(i)$$

The first-order condition with respect to $p^H_{HH,t}$ is precisely the same as before. The first-order condition with respect to p^R_{HR} is

$$\mathbb{E}_t \sum_{\tau=0}^{\infty} \Lambda_{t,t+\tau}\xi^{\tau}\left[\frac{F_{t+\tau}X^R_{t,t+\tau}}{P_{t+\tau}} y^R_{HR,t+\tau} + \left(\frac{X^R_{t,t+\tau}F_{t+\tau}p^R_{HR,t}(i)}{P_{t+\tau}} - mc_{t+\tau}\right)\frac{\partial y^R_{HR,t+\tau}(i)}{\partial p^R_{HR,t}(i)}\right] = 0$$

Similar to before, the derivative of firm sales abroad with respect to the price is

$$\begin{aligned}
\frac{\partial y^R_{HR,t+\tau}(i)}{\partial p^R_{HR,t}(i)} &= -\frac{1+\theta}{\theta}\left(X^R_{t,t+\tau}\frac{p^R_{HR,t}}{P^M_{t+\tau}}\right)^{-\frac{1}{\theta}} M^*_{t+\tau}\frac{X^R_{t,t+\tau}}{P^M_{t+\tau}} \\
&= -\frac{1+\theta}{\theta}\left(\frac{y^R_{HRt+\tau}(i)}{p^R_{HR,t}(i)}\right)
\end{aligned}$$

and again subbing this into the first-order condition:

$$\begin{aligned}
\mathbb{E}_t \sum_{\tau=0}^{\infty} \Lambda_{t,t+\tau}\xi^{\tau}\left[\frac{F_{t+\tau}X^H_{t,t+\tau}}{P_{t+\tau}} y^R_{HR,t+\tau} - \left(\frac{X^H_{t,t+\tau}F_{t+\tau}p^R_{HR,t}}{P_{t+\tau}} - mc_{t+\tau}\right)\frac{1+\theta}{\theta}\left(\frac{y^R_{HRt+\tau}}{p^R_{HR,t}}\right)\right] &= 0 \\
\mathbb{E}_t \sum_{\tau=0}^{\infty} \Lambda_{t,t+\tau}\xi^{\tau}\left[\frac{X^R_{t,t+\tau}F_{t+\tau}p^R_{HR,t}}{P_{t+\tau}} y^R_{HR,t+\tau} - \left(\frac{X^R_{t,t+\tau}F_{t+\tau}p^R_{HR,t}}{P_{t+\tau}} - mc_{t+\tau}\right)\frac{1+\theta}{\theta} y^R_{HRt+\tau}\right] &= 0 \\
\mathbb{E}_t \sum_{\tau=0}^{\infty} \Lambda_{t,t+\tau}\xi^{\tau}\left[\frac{X^R_{t,t+\tau}F_{t+\tau}p^R_{HR,t}}{P_{t+\tau}} y^R_{HR,t+\tau}\left(1 - \frac{1+\theta}{\theta}\right) + mc_{t+\tau}\frac{1+\theta}{\theta} y^R_{HRt+\tau}\right] &= 0 \\
\mathbb{E}_t \sum_{\tau=0}^{\infty} \Lambda_{t,t+\tau}\xi^{\tau}\left[\frac{X^R_{t,t+\tau}F_{t+\tau}p^R_{HR,t}}{P_{t+\tau}} y^R_{HR,t+\tau}\right] &= (1+\theta)\mathbb{E}_t \sum_{\tau=0}^{\infty} \Lambda_{t,t+\tau}\xi^{\tau}\left[mc_{t+\tau} y^R_{HR,t+\tau}\right] \\
\mathbb{E}_t \sum_{\tau=0}^{\infty} \Lambda_{t,t+\tau}\xi^{\tau}\left[X^R_{t,t+\tau}\frac{p^R_{HR,t}}{P^M_{t+\tau}} p^{MH}_{t+\tau} y^R_{HR,t+\tau}\right] &= (1+\theta)\mathbb{E}_t \sum_{\tau=0}^{\infty} \Lambda_{t,t+\tau}\xi^{\tau}\left[mc_{t+\tau} y^R_{HR,t+\tau}\right] \\
\underbrace{\mathbb{E}_t \sum_{\tau=0}^{\infty} \Lambda_{t,t+\tau}\xi^{\tau}\left[X^R_{t,t+\tau} p^{R0}_{HR} p^{MH}_{t+\tau} y^R_{HR,t+\tau}\right]}_{G^R_t} &= \underbrace{(1+\theta)\mathbb{E}_t \sum_{\tau=0}^{\infty} \Lambda_{t,t+\tau}\xi^{\tau}\left[mc_{t+\tau} y^R_{HR,t+\tau}\right]}_{B^{RR}_t}
\end{aligned}$$

A.3 Three Phillips Curves

A.3.1 Domestic Currency Export Prices

$$\mathbb{E}_t \sum_{\tau=0}^{\infty} \Lambda_{t,t+\tau}\xi^{\tau}\left[X^H_{t,t+\tau}\frac{p^{H*}_{HR,t}(i)}{F_t P^M_{t+\tau}} p^{MH}_{t+\tau} y^H_{HR,t+\tau}\right] = (1+\theta)\mathbb{E}_t \sum_{\tau=0}^{\infty} \Lambda_{t,t+\tau}\xi^{\tau}\left[mc_{t+\tau} y^H_{HRt+\tau}\right]$$

Taking the LHS first and subbing in the definition of $y^H_{HR,t} = \left(p^H_{HR,t}(i)F_t P^M_t\right)^{-\frac{1+\theta}{\theta}} M^*_t$:

$$G^H_t = \mathbb{E}_t \sum_{\tau=0}^{\infty} \Lambda_{t,t+\tau}\xi^\tau \left[\left(X^H_{t,t+\tau}\frac{p^{H*}_{HR,t}}{F_{t+\tau}P^M_{t+\tau}}\right)^{-\frac{1}{\theta}} p^{MH}_{t+\tau} M^*_t\right]$$

Now exclude the first summand and follow the usual steps to write in recursive form:

$$G^H_t = p^{MH}_t \left(\frac{p^{H*}_{HR,t}}{F_t P^M_t}\right)^{-\frac{1}{\theta}} M^*_t + \mathbb{E}_t \sum_{\tau=1}^{\infty} \Lambda_{t,t+\tau}\xi^\tau \left[\left(X^H_{t,t+\tau}\frac{p^{H*}_{HR,t}}{F_{t+\tau}P^M_{t+\tau}}\right)^{-\frac{1}{\theta}} p^{MH}_{t+\tau} M^*_{t+\tau}\right]$$
$$G^H_t = p^{MH}_t \left(\frac{p^{H*}_{HR,t}}{F_t P^M_t}\right)^{-\frac{1}{\theta}} M^*_t + \mathbb{E}_t \xi \Lambda_{t,t+1}\left(X^H_{t,t+1}\frac{p^{H*}_{HR,t}}{p^{H*}_{HR,t+1}}\right)^{-\frac{1}{\theta}} G^H_{t+1}$$
$$G^H_t = p^{MH}_t \left(\frac{p^{H*}_{HR,t}}{F_t P^M_t}\right)^{-\frac{1}{\theta}} M^*_t + \mathbb{E}_t \xi \Lambda_{t,t+1}\left(X^H_{t,t+1}\frac{p^{H0}_{HR,t}}{p^{H0}_{HR,t+1}}\frac{F_t P^M_t}{F_{t+1}P^M_{t+1}}\right)^{-\frac{1}{\theta}} G^H_{t+1}$$
$$G^H_t = p^{MH}_t \left(p^{H0}_{HR,t}\right)^{-\frac{1}{\theta}} M^*_t + \mathbb{E}_t \xi \Lambda_{t,t+1}\left(\frac{X^H_{t,t+1}}{\Pi^M_{t+1}}\frac{p^{H0}_{HR,t}}{p^{H0}_{HR,t+1}}\frac{f_t \Pi^R_{t+1}}{f_{t+1}\Pi_t}\right)^{-\frac{1}{\theta}} G^H_{t+1}$$

We now take the RHS and go through the very same steps:

$$B^H_t = (1+\theta)\mathbb{E}_t \sum_{\tau=0}^{\infty} \Lambda_{t,t+\tau}\xi^\tau \left[mc_{t+\tau}\left(X^H_{t,t+\tau}\frac{p^{H*}_{HR,t}}{F_{t+\tau}P^M_{t+\tau}}\right)^{-\frac{1+\theta}{\theta}}\right]$$

Now exclude the first summand and follow the usual steps to write in recursive form:

$$B^H_t = (1+\theta)mc_{t+\tau}\left(\frac{p^{H*}_{HR,t}}{F_t P^M_t}\right)^{-\frac{1+\theta}{\theta}} M^*_t + (1+\theta)\mathbb{E}_t \sum_{\tau=1}^{\infty} \Lambda_{t,t+\tau}\xi^\tau \left[mc_{t+\tau}\left(X^H_{t,t+\tau}\frac{p^{H*}_{HR,t}}{F_{t+\tau}P^M_{t+\tau}}\right)^{-\frac{1+\theta}{\theta}}\right]$$
$$B^H_t = (1+\theta)mc_{t+\tau}\left(\frac{p^{H*}_{HR,t}}{F_t P^M_t}\right)^{-\frac{1+\theta}{\theta}} M^*_t + (1+\theta)\mathbb{E}_t \Lambda_{t,t+1}\left(X^H_{t,t+1}\frac{p^{H*}_{HR,t}}{p^{H*}_{HR,t+1}}\right)^{-\frac{1+\theta}{\theta}} B^H_{t+1}$$
$$B^H_t = (1+\theta)mc_{t+\tau}\left(p^{H0}_{HR,t}\right)^{-\frac{1+\theta}{\theta}} M^*_t + (1+\theta)\mathbb{E}_t \Lambda_{t,t+1}\left(\frac{X^H_{t,t+1}}{\Pi^M_{t+1}}\frac{p^{H0}_{HR,t}}{p^{H0}_{HR,t+1}}\frac{f_t \Pi^R_{t+1}}{f_{t+1}\Pi_t}\right)^{-\frac{1+\theta}{\theta}} B^H_{t+1}$$

To complete the Phillips curve for domestic currency exports we simply add:

$$G^H_t = B^H_t$$

A.3.2 Dollar Exporter Prices

At the risk of overkill, I lay out the same steps for the dollar price exporters.

$$
\begin{aligned}
G_t^R &= p_t^{MH}\left(\frac{p_{HR,t}^{R*}}{P_t^M}\right)^{-\frac{1}{\theta}} M_t^* + \mathbb{E}_t \sum_{\tau=1}^{\infty} \Lambda_{t,t+\tau}\xi^\tau \left[X_{t,t+\tau}^H \left(\frac{p_{HR,t}^{R*}}{P_{t+\tau}^M}\right)^{-\frac{1}{\theta}} p_{t+\tau}^{MH} M_{t+\tau}^*\right] \\
G_t^R &= p_t^{MH}\left(\frac{p_{HR,t}^{R*}}{P_t^M}\right)^{-\frac{1}{\theta}} M_t^* + \mathbb{E}_t \xi \Lambda_{t,t+1}\left(X_{t,t+1}^H \frac{p_{HR,t}^{R*}}{p_{HR,t+1}^{R*}}\right)^{-\frac{1}{\theta}} G_{t+1}^R \\
G_t^R &= p_t^{MH}\left(\frac{p_{HR,t}^{R*}}{P_t^M}\right)^{-\frac{1}{\theta}} M_t^* + \mathbb{E}_t \xi \Lambda_{t,t+1}\left(X_{t,t+1}^H \frac{p_{HR,t}^{R0}}{p_{HR,t+1}^{R0}} \frac{P_{t+1}^M}{P_t^M}\right)^{-\frac{1}{\theta}} G_{t+1}^R \\
G_t^R &= p_t^{MH}\left(p_{HR,t}^{R0}\right)^{-\frac{1}{\theta}} M_t^* + \mathbb{E}_t \xi \Lambda_{t,t+1}\left(\frac{X_{t,t+1}^H}{\Pi_{t+1}^M} \frac{p_{HR,t}^{R0}}{p_{HR,t+1}^{R0}}\right)^{-\frac{1}{\theta}} G_{t+1}^R
\end{aligned}
$$

Similar procedure for the RHS.

$$
\begin{aligned}
B_t^R &= (1+\theta) mc_t \left(\frac{p_{HR,t}^{R*}}{P_t^M}\right)^{-\frac{1+\theta}{\theta}} M_t^* + (1+\theta)\mathbb{E}_t \sum_{\tau=1}^{\infty} \Lambda_{t,t+\tau}\xi^\tau \left[mc_{t+\tau}\left(X_{t,t+\tau}^H \frac{p_{HR,t}^{R*}}{P_{t+\tau}^M}\right)^{-\frac{1+\theta}{\theta}}\right] \\
B_t^R &= (1+\theta) mc_t \left(\frac{p_{HR,t}^{R*}}{P_t^M}\right)^{-\frac{1+\theta}{\theta}} M_t^* + (1+\theta)\mathbb{E}_t \Lambda_{t,t+1}\left(X_{t,t+1}^H \frac{p_{HR,t}^{R*}}{p_{HR,t+1}^{R*}}\right)^{-\frac{1+\theta}{\theta}} B_{t+1}^R \\
B_t^R &= (1+\theta) mc_t \left(p_{HR,t}^{R0}\right)^{-\frac{1+\theta}{\theta}} M_t^* + (1+\theta)\mathbb{E}_t \Lambda_{t,t+1}\left(\frac{X_{t,t+1}^H}{\Pi_{t+1}^M} \frac{p_{HR,t}^{R0}}{p_{HR,t+1}^{R0}}\right)^{-\frac{1+\theta}{\theta}} B_{t+1}^R
\end{aligned}
$$

We complete the Phillips curve for dollar exports by noting that

$$G_t^R = B_t^R$$

A.3.3 Domestic Final Good Prices

Noting finally that we can write the recursive version of B_t and G_t in the same way as before

$$
\begin{aligned}
G_t &= \left(p_{HH,t}^{H0}\right)^{-\frac{1}{\theta}} Y_t^d + \mathbb{E}_t \xi \Lambda_{t,t+1}\left(\frac{X_{t,t+1}^H}{\Pi_{t+1}} \frac{p_{HH,t}^{H0}}{p_{HH,t+1}^{H0}}\right)^{-\frac{1}{\theta}} G_{t+1} \\
B_t &= (1+\theta) mc_t \left(p_{HH,t}^{H0}\right)^{-\frac{1+\theta}{\theta}} Y_t^d + (1+\theta)\mathbb{E}_t \Lambda_{t,t+1}\left(\frac{X_{t,t+1}^H}{\Pi_{t+1}} \frac{p_{HH,t}^{H0}}{p_{HH,t+1}^{H0}}\right)^{-\frac{1+\theta}{\theta}} B_{t+1} \\
G_t &= B_t
\end{aligned}
$$

These are largely unchanged from the old version. Similarly, the law of motion for domestic price inflation is standard:

$$\Pi_t^{-\frac{1}{\theta}} = \xi(\tilde{p}_{0,t}\Pi_t)^{-\frac{1}{\theta}} + (1-\xi)X_{t-1,t}^{-\frac{1}{\theta}}$$

A.4 Law of Motion for Price Dispersion Terms

The price dispersion term for goods destined for domestic consumption has the same law of motion as before:

$$\Delta_t = \int_0^1 \left(\frac{p^H_{HH,t}(i)}{P_t}\right)^{-\frac{1+\theta}{\theta}} di$$

$$\Delta_t = (1-\xi)\int_0^1 \left(\frac{p^{H*}_{HH,t}(i)}{P_t}\right)^{-\frac{1+\theta}{\theta}} di + \xi \int_0^1 \left(\frac{X_{t-1,t}p^H_{HH,t-1}}{P_t}\right)^{-\frac{1+\theta}{\theta}} di$$

$$\Delta_t = (1-\xi)\left(p^{H0}_{HH,t}\right)^{-\frac{1+\theta}{\theta}} + \xi\left(\frac{X_{t-1,t}}{\Pi_t}\right)^{-\frac{1+\theta}{\theta}} \int_0^1 \left(\frac{p^H_{HH,t-1}}{P_{t-1}}\right)^{-\frac{1+\theta}{\theta}} di$$

$$\Delta_t = (1-\xi)\left(p^{H0}_{HH,t}\right)^{-\frac{1+\theta}{\theta}} + \xi\left(\frac{X_{t-1,t}}{\Pi_t}\right)^{-\frac{1+\theta}{\theta}} \Delta_{t-1}$$

Going through similar steps for the dispersion of dollar priced exports:

$$\Delta^R_t = \int_0^1 \left(\frac{p^R_{HR,t}(i)}{P^M_t}\right)^{-\frac{1+\theta}{\theta}} di$$

$$\Delta^R_t = (1-\xi)\int_0^1 \left(\frac{p^{R*}_{HR,t}(i)}{P^M_t}\right)^{-\frac{1+\theta}{\theta}} di + \xi \int_0^1 \left(\frac{X^R_{t-1,t}p^R_{HR,t-1}}{P^M_t}\right)^{-\frac{1+\theta}{\theta}} di$$

$$\Delta^R_t = (1-\xi)\left(p^{R0}_{HR,t}\right)^{-\frac{1+\theta}{\theta}} + \xi\left(\frac{X^R_{t-1,t}}{\Pi^M_t}\right)^{-\frac{1+\theta}{\theta}} \int_0^1 \left(\frac{p^R_{HR,t-1}}{P^M_{t-1}}\right)^{-\frac{1+\theta}{\theta}} di$$

$$\Delta^R_t = (1-\xi)\left(p^{R0}_{HR,t}\right)^{-\frac{1+\theta}{\theta}} + \xi\left(\frac{X^R_{t-1,t}}{\Pi^M_t}\right)^{-\frac{1+\theta}{\theta}} \Delta^R_{t-1}$$

Lastly, the dispersion of exports priced in the home currency:

$$\Delta^H_t = \int_0^1 \left(\frac{p^H_{HR,t}(i)}{F_t P^M_t}\right)^{-\frac{1+\theta}{\theta}} di$$

$$\Delta^H_t = (1-\xi)\int_0^1 \left(\frac{p^{H*}_{HR,t}(i)}{F_t P^M_t}\right)^{-\frac{1+\theta}{\theta}} di + \xi \int_0^1 \left(\frac{X^H_{t-1,t}p^H_{HR,t-1}}{F_t P^M_t}\right)^{-\frac{1+\theta}{\theta}} di$$

$$\Delta^H_t = (1-\xi)\left(p^{H0}_{HR,t}\right)^{-\frac{1+\theta}{\theta}} + \xi\left(\frac{X^H_{t-1,t}F_{t-1}}{\Pi^M_t F_t}\right)^{-\frac{1+\theta}{\theta}} \int_0^1 \left(\frac{p^H_{HR,t-1}}{F_{t-1}P^M_{t-1}}\right)^{-\frac{1+\theta}{\theta}} di$$

$$\Delta^H_t = (1-\xi)\left(p^{R0}_{HR,t}\right)^{-\frac{1+\theta}{\theta}} + \xi\left(\frac{X^H_{t-1,t}f_{t-1}\Pi^R_t}{\Pi^M_t f_t \Pi_t}\right)^{-\frac{1+\theta}{\theta}} \Delta^R_{t-1}$$

A.5 Total Output

Aggregating potential output, we have the following:

$$
\begin{aligned}
A_t K_t^{\alpha_K} L_t^{\alpha_L} M_t^{1-\alpha_K-\alpha_L} &= \int_0^1 y_{HH,t}^H(i)di + \int_0^{\psi} y_{HR,t}^R(i)di + \int_{\psi}^1 y_{HR,t}^H(i)di \\
&= \int_0^1 \left(\frac{p_{HH,t}^H(i)}{P_t}\right)^{-\frac{1+\theta}{\theta}} diY_t^d + \psi \int_0^1 \left(\frac{p_{HR,t}^R(i)}{P_t^M}\right)^{-\frac{1+\theta}{\theta}} diM_t^* + \\
(1-\psi) &\int_0^1 \left(\frac{p_{HR,t}^H(i)}{F_t P_t^M}\right)^{-\frac{1+\theta}{\theta}} diM_t^* \\
&= \Delta_t Y_t^d + \psi \Delta_t^R M_t^* + (1-\psi)\Delta_t^H M_t^*
\end{aligned}
$$

where we define Y_t^d as the output destined for domestic use. That is:

$$Y_t = Y_t^d + p_t^{MH} M_t^*.$$

A.6 Current Account

The aggregate net foreign asset position, which is equal to FX official reserves minus aggregate foreign liabilities in the banking system evolves through the trade balance

$$D_t^* - \mathcal{R}_t - R_{t-1}^F D_{t-1}^* + R^* \mathcal{R}_{t-1} = M_t - p_t^{MR} E_{x,t}.$$

A.7 Deposit insurance agency (DIA)

The total cost of default from banks writes in real terms:

$$TC_t = \int_0^{\overline{\omega}_t} \left\{ \frac{R_{d,t-1}}{\Pi_t}(1-\Theta_{t-1})d_{t-1} + \frac{\varkappa}{2}\frac{\Theta_{t-1}^2}{\Pi_t} d_{t-1} - (1-\Theta_{t-1})(1-\mu_b)\omega_t \frac{R_t^K}{\Pi_t} q_{t-1} K_{t-1}^b - \frac{R_{t-1}^{CB}}{\Pi_t} b_{t-1}^{CB} \right\} \mathrm{d}F(\omega_t)$$

A share $T_t = \kappa TC_t$ of this total cost is financed by a lump-sum tax levied on saving households. The remaining share of total default cost is $(1-\kappa)TC_t$ incurred by the saving households as a loss on their deposits (there is only partial insurance). When there is default, the contractual return is actually guaranteed by the DIA but the HH in addition have to pay a tax proportional on their deposits of an amount such that DIA budget is balanced. Thus,

$$\widetilde{R}_t^d = \frac{R_{t-1}^d}{\Pi_t} - (1-\kappa)\frac{TC_t}{d_{t-1}}$$

.

B Data used in the calibration

- Gross Domestic Product: value of Real GDP, chain linked values, seasonally adjusted. Source: Instituto Brasileiro de Geografia e Estatística (IBGE).

- Investment: gross fixed capital formation investment. Source: Banco Central do Brasil (BCB).

- Reserves: Reserves position (end of previous month) at the central bank. Source: BCB.

- Households capital share: we set our calibration target for this variable by identifying it with the proportion of assets of the NFC sector whose financing is thorough debt securities and other instruments (and not loans from banks). Source: BCB.

- Exports over GDP: Exports: value Goods for Brazil, Percent of GDP, Annual, Not Seasonally Adjusted. Datasource: FRED.

- Return on Equity: bank's Return on Equity for Brazil, Percent, Annual, Not Seasonally Adjusted. Datasource: FRED.

- Price to book ratio of banks: data from 22 banks listed on the Brazilian stock exchange (BMF Bovespa). Source: Economatica.

- Probability of default: `https://www.bcb.gov.br/pec/wps/ingl/wps304.pdf` presents the average default rate for companies from different sectors. We extract average default rate for finance and insurance sector.

- Share of insured deposits: Brazil has two protection mechanisms for deposits: "Credit Guarantee Fund" (FGC) and Guarantor Credit Union Fund (FGCoop). We calculate the ratio between total deposits and insured deposits. Source: BCB and Fundo Garantidor de Crédito (FGC).

- Foreign liabilities of banks: liabilities to nonresidents - Other Depository Corporations (ODC). The following institutions are classified as ODC: commercial banks, multiple banks, Federal Savings Bank, credit cooperatives, investment and development banks, credit, finance and investment companies, savings and loan institutions, mortgage companies, real estate credit companies, State Savings Banks (which existed until November, 1998) and financial investment funds. The Exchange banks are excluded from the coverage because they are classified as Other Financial Corporations. In the case of funds, it is included the assets and liabilities of the following entities, which are classified by Instruction CVM no. 409: short-term, fixed income, multimarket, referenced and exchange funds. Source: BCB.

- Foreign real risk-free interest rate: market yield on U.S. Treasury securities at 3-month constant maturity, quoted on investment basis, weighted by US GDP Deflator. Source: FRED.