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Shocks Matter: Managing Capital Flows with Multiple Instruments in Emerging Economies

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Shocks Matter: Managing Capital Flows in Emerging Economies with Multiple Instruments[1]

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Abstract

We study the optimal management of capital flows in a small open economy model with financial frictions and multiple policy instruments. The paper reports two main findings. First, both foreign exchange intervention (FXI) and macroprudential polices are tools complementary to the monetary policy rate that can largely reduce inflation and output volatility in a scenario of capital outflows. Second, the optimal policy mix depends on the underlying shock driving capital flows. FXI takes the leading role in response to foreign interest rate shocks, while macroprudential policy becomes the prominent tool for domestic risk shocks. These results highlight the importance of calibrating the use of multiple instruments according to the underlying shocks that induce shifts in capital flows.

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1 Introduction

Over the last two decades central banks in emerging economies have been increasingly operating within an inflation targeting framework and relying on multiple instruments for the purpose of achieving their policy mandates (Figure 1). Based on the observed macroeconomic stability gains, one would quickly arrive at the conclusion that a multiple-tool policy framework is highly effective in terms of output and inflation stabilization (Figure 2). However, a theoretical framework is missing for understanding the rationale behind this practice by central banks in emerging economies. In this paper, we develop a DSGE model with financial frictions for analyzing the role of a multi-policy framework in stabilizing output and inflation in emerging economies. In particular, we focus on two questions relevant for policymaking in emerging economies: Are multiple instruments typically used by central banks complements or substitutes to the monetary policy rate? What is the optimal policy mix for addressing fluctuations in capital flows and the associated macroeconomic volatility?

This paper provides a quantitative answer to these two questions by using a small open economy model with financial frictions and multiple policy instruments. We incorporate financial frictions through a financial accelerator mechanism proposed by Bernanke et al. (1999). We also follow Gertler et al. (2007) and assume that a fraction of the debt is denominated in foreign currency. Liability dollarization is a widespread phenomenon in emerging economies (Dalgic, 2018) which increases the vulnerability of economies to capital flows movements and the associated fluctuations in exchange rate.[1] In the model we assume a central bank that relies on three policy instruments: the monetary policy rate, Foreign Exchange Intervention (FXI), and reserve requirements.[2] We focus our analysis on the optimal choice of policy instru-

[1] Sudden movements in capital flows can induce exchange rate volatility that can severely disrupt financial markets under liability dollarization, and hence generate negative feedback loops between the financial sector and real activity.

[2] Reserve requirements are commonly used by central banks in many emerging economies as a macroprudential instrument (See Federico et al., 2014).

ments in a scenario of capital outflows triggered by a domestic and an external shock. The external shock is modeled as an increase in the foreign interest rate, while the domestic shock is modeled as an increase in the risk of the idiosyncratic productivity of entrepreneurs.[3][4] Then, relying on a conventional loss function, we characterize the optimal FX reserves and reserve requirements policies for each of these shocks.

In our model, the proposed shocks generate trade-offs between output and inflation stabilization that motivate the use of multiple policy instruments by the central bank. For instance, in response to capital outflows the exchange rate depreciates triggering higher inflation, an increase in the cost of servicing debt denominated in foreign currency, and a decline in investment. While a monetary policy tightening can stabilize the exchange rate, at the same time it reduces asset prices, in turn deteriorating the financial position of firms, and inducing a contraction of investment and aggregate demand (Céspedes et al., 2004). In this context, additional tools such FX intervention or macroprudential policies can improve this trade-off. The central bank can optimally allocate instruments that directly address excess volatility in the foreign exchange market or disruptions in financial markets in order to stabilize the economy.

Moreover, FX intervention and macroprudential policies can have complementary roles for the purposes of macroeconomic and financial stability. In a scenario of capital flows a decision by the central banks to sell foreign currency, not only stabilizes the exchange rate, but also prevents an increase in the cost of servicing the foreign currency debt, improving the financial position of the firms. Similarly, an expansionary macroprudential policy measure, such as a reduction of the reserve requirements not only reduces the cost of credit, but also stimulates investment and foreign borrowing, reducing pressures in the foreign exchange market.

In order to understand the optimal policy mix in our model we extend the analysis

[3] While both types of shocks induce an episode of capital outflows and a contraction in aggregate demand, their transmission mechanisms are different.

[4] The risk shock is modeled as in Christiano et al. (2014).

by Poole (1970) on the optimal choice of policy instruments applied to a situation of capital outflows. Two are the key results of our paper. First, for all of type of shocks both FXI and reserve requirements are complementary tools to the monetary policy rate and help to stabilize economic activity, inflation, and financial conditions. By relying on FXI and reserve requirements, the central bank deploys instruments with the goal of smoothing exchange rate volatility and stabilizing the risk premium in financial markets. These complementary policies allow the policy rate to focus on the goal of price stability. Second, and consistent with Poole (1970), we find that the intensity at which each instrument is deployed depends on the underlying source triggering capital outflows. For a foreign interest rate shock, FXI takes the leading role in stabilizing the economy, followed by a modest adjustment in the reserve requirements and the policy rate. For domestic risk shocks, reserve requirements lead the response in stabilizing financial markets, accompanied by modest FXI interventions and adjustments in the policy rate.

Overall, our results provide a rationale for adopting a multi-tool policy framework in an environment with the financial frictions typically prevalent in emerging economies. Moreover, these results blend the policy prescriptions of Mundell (1968), which states that "policies should be paired with the objectives on which they have the most influence" and Poole (1970), who showed that the intensity at which each policy instrument is optimally deployed depends crucially on the source of the disturbance affecting the economy.

Our paper is related to several strands of the literature analyzing optimal policies under financial frictions. First, Cespedes et al. (2004) and Gertler et al. (2007) analyze the role of monetary policy in stabilizing an economy with financial frictions and liability dollarization. Second, Carrillo et al. (2018), Leduc and Natal (2016), Medina and Roldós (2018), and Aoki et al. (2018) study the optimal choice of monetary and macroprudential policies in economies with financial frictions. Third, Ghosh et al. (2016), Benes et al. (2015), Canzoneri and Cumby (2014), and Liu and Spiegel (2015), study the interaction between FXI and monetary policy. We contribute to the literature, by analyzing in an integrated policy framework, how three key policy instruments can optimally be deployed in response to alternative shocks. By extending the analysis of Poole (1970) to the optimal use of instruments for managing capital outflows, we provide a rationale for the prevalence of a multiple-policy framework in emerging economies.

Notice that in the paper we focus our analysis on the business-cycle implications of capital flows as in Blanchard et al. (2017). In particular, in our model, capital outflows in the short-run can lead to a contraction in output and higher inflation, which can increase macroeconomic volatility and can pose challenges to policymakers for fulfilling the central bank mandates. Nevertheless, there are alternative views on how capital flows affect emerging economies. In the long term, capital flows play an important role in convergence process in emerging economies (Lucas, 1990). However, in the presence of pecuniary externalities (Bianchi, 2011) capital flows can lead to overborrowing, and a higher incidence of financial crisis. In that context, it is optimal to impose capital controls to improve macroeconomic outcomes (Jeanne and Korinek, 2010). In this paper we evaluate the implications of capital flows on output and inflation through a loss function (Woodford, 2003). We view the results of the paper as complementary to the existing literature, since they provide an additional rationale for managing capital flows in the short-run, even in the absence of pecuniary externalities.

The remainder of the paper is organized as follows. Section 2 lays out the small open economy model with financial frictions. Section 3 discusses the calibration strategy. Section 4 presents the simulations results on the optimal choice of policy instruments for managing capital flows. Section 5 concludes.

2 A Small Open Economy Model with Financial Frictions

We developed a small open economy New Keynesian model following the work Christiano et al. (2005), Gertler et al. (2007), and Smets and Wouters (2007). The model features a domestic and imported good. The domestic goods is produced by firms relying on a constant return to scale technology that depends on capital and labor. Capital decisions by entrepreneurs face a financial constraint with a financial accelerator mechanism following Bernanke et al. (1999). Based on the work of Cespedes et al. (2004) and Gertler et al. (2007) for emerging economies, we assume that a fraction of the total corporate borrowing is denominated in foreign currency. The foreign currency denomination generates a balance sheet effect in response to fluctuations in the exchange rate that affects the leverage of entrepreneurs and the borrowing spread. Additionally, we consider a central bank that sets the domestic interest rate according to a Taylor-type rule, but also intervenes in the foreign exchange (FX) market and sets the reserve requirement ratios for financial intermediaries. These three instruments are deployed with the goal of stabilizing output and inflation. We assess the optimal policy mix according to a conventional loss function that depends on output and inflation volatility.

2.1 Households

The domestic economy is populated by a continuum of households indexed by $j \in [0, 1]$. The expected present value of the utility of household j is given by:

$$U_t(j) = E_t \sum_{i=0}^{\infty} \beta^i \frac{\left[C_{t+i}(j) - \zeta_L \frac{l_{t+i}(j)^{1+\sigma_L}}{1+\sigma_L}\right]^{\frac{\sigma_C - 1}{\sigma_C}}}{1 - 1/\sigma_C}, \tag{1}$$

where $l_t(j)$ is the labor effort and $C_t(j)$ is private consumption. The parameters σ_C and σ_L are the intertemporal elasticity of substitution and the inverse Frisch elasticity of labor supply with respect to real wages, respectively. ζ_L is the preference weight on the disutility from labor. The aggregate consumption $C_t(j)$ is defined by a CES aggregator of home and foreign goods:

$$C_t(j) = \left[\gamma_C^{\frac{1}{\eta_C}} C_{H,t}(j)^{\frac{\eta_C - 1}{\eta_C}} + (1-\gamma_C)^{\frac{1}{\eta_C}} C_{F,t}(j)^{\frac{\eta_C - 1}{\eta_C}}\right]^{\frac{\eta_C}{\eta_C - 1}}, \tag{2}$$

where $C_H(j)$ and $C_F(j)$ are the home and foreign goods consumed by household j, respectively. γ_C is the share of domestic goods in the consumption basket and η_C is the elasticity of substitution between home and foreign goods.

Households have access to the following assets: non-contingent domestic bonds $B_t(j)$, deposits to financial intermediaries $D_t(j)$ in domestic currency , deposits $D_t^*(j)$ in foreign currency, non-contingent foreign debt $B_t^*(j)$, and domestic state contingent bonds $d_{t+1}(j)$. The gross return of the deposits in foreign currency is equal to risk-free foreign interest rate, R_t^*. Hence, the household budget constraint is given by:

$$\begin{aligned} &P_{C,t}C_t(j) + B_t(j) + D_t(j) + D_t^*(j) + E_t[q_{t,t+1}d_{t+1}(j)] - \mathcal{E}_t B_t^*(j) = \\ &W_t(j) l_t(j) + R_{t-1}B_{t-1}(j) + R_{D,t-1}D_{t-1}(j) + \mathcal{E}_t R_{t-1}^* D_{t-1}^*(j) \\ &+ d_t(j) + \Pi_t(j) + T_t(j) - \mathcal{E}_t B_{t-1}^*(j) R_{t-1}^* \Theta_{t-1}, \end{aligned} \tag{3}$$

where $\Pi_t(j)$ are profits received from domestic firms, $W_t(j)$ is the nominal wage set by household j, T_t are net lump-sum transfers from the government, and $\mathcal{E}_t$ is the nominal exchange rate. Foreign borrowing pays a premium (Θ_{t-1}) over the risk-free foreign rate and households do not internalize the effects of their borrowing decisions on the premium.[5] R_t and R_t^* are the gross interest rate of the non-contingent bonds in domestic and foreign currency, and $R_{D,t}$ is the gross interest rate of the deposits in domestic currency. In equilibrium we obtain that $R_{D,t} = R_t$. Households choose their optimal consumption and portfolio allocation by maximizing (1) subject to (3). By assuming a complete set of state-contingent claims, consumption is equalized across households despite differences in their supply of labor.

[5] This premium is introduced to model imperfect asset sustitutability and induce statioarity in the model. The exact functional form for $\Theta_t = \Theta(\cdot)$ will be discussed in section 2.7. See Schmitt-Grohé and Uribe (2003) for different ways to introduce stationarity in small open economy models.

2.2 Wage setting and labor supply

Each household j is a monopolistic supplier of a differentiated labor service. There is a set of perfectly competitive labor service assemblers that hire labor from each household and combine it into an aggregate labor service unit, l_t, that is then hired by the intermediate goods producer. The labor service unit is defined as

$$l_t = \left(\int_0^1 l_t(j)^{\frac{\epsilon_L - 1}{\epsilon_L}} dj \right)^{\frac{\epsilon_L}{\epsilon_L - 1}}, \tag{4}$$

where $l_t(j)$ corresponds to the labor supply of household j and ϵ_L is the elasticity of substitution of the household labor supply. The optimal composition of this labor service unit is obtained from the cost minimization problem of the assembler. The resulting demand for the labor service provided by household j is given by:

$$l_t(j) = \left(\frac{W_t\,(j)}{W_t} \right)^{-\epsilon_L} l_t, \tag{5}$$

where $W_t\,(j)$ is the wage rate set by household j and W_t is an aggregate wage index defined as $W_t = \left(\int_0^1 W_t(j)^{1-\epsilon_L} dj \right)^{\frac{1}{1-\epsilon_L}}$.

Following Erceg et al. (2000), we assume a wage setting process à la Calvo (1983). In each period, each household faces a constant probability $(1 - \phi_L)$ of being able to re-optimize its nominal wage. Once a household has decided a wage, she must supply any quantity of labor service demanded at that wage rate.

2.3 Capital producing firms

We assume a continuum of capital goods producers who operate in a perfectly competitive environment. The aggregate investment good bundle consists of a CES aggregator of home ($I_{H,t}$) and foreign goods ($I_{F,t}$):

$$I_t = \left[\gamma_I^{\frac{1}{\eta_I}} I_{H,t}^{\frac{\eta_I - 1}{\eta_I}} + (1 - \gamma_I)^{\frac{1}{\eta_I}} I_{F,t}^{\frac{\eta_I - 1}{\eta_I}} \right]^{\frac{\eta_I}{\eta_I - 1}},$$

where η_I is the elasticity of substitution between home and foreign investment goods, and γ_I is the share of domestic goods in investment. The law of motion of physical capital is given by:

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

where K_t is the stock of capital, Z_t is the rental rate of capital, and $S(.)$ is the investment adjustment cost.[6] Capital producing firms are perfectly competitive and take the price of capital, Q_t, as given. The capital goods producers then sell the capital goods to the entrepreneurs, who receive the rental rate of capital and the value of undepreciated capital as income.

2.4 Entrepreneurs

The financial accelerator mechanism follows the work of Bernanke et al. (1999) where the external finance premium depends positively on the entrepreneurs' leverage. In addition, we assume partial dollarization of the debt contract. We introduce this friction by allowing that a fraction of the debt service is indexed to foreign currency.

We assume a continuum of risk-neutral entrepreneurs in the economy. In period t, each entrepreneur uses the net worth N_t and loans from financial intermediaries to purchase physical capital K_{t+1} such that the following constraint holds:

$$N_t + B_{e,t} + \mathcal{E}_t B^*_{e,t} = Q_t K_{t+1}, \tag{6}$$

where $B_{e,t}$ is the loan in domestic currency and $B^*_{e,t}$ is the loan in foreign currency. In order to simplify the portfolio choice of currency composition of the loan, we will assume that a fraction ϕ of the loan is denominated in domestic currency and $1-\phi$ is denominated in foreign currency. Therefore, $B_{e,t} = \phi \bar{B}_{e,t}$ and $\mathcal{E}_t B^*_{e,t} = (1-\phi)\bar{B}_{e,t}$, where $\bar{B}_{e,t}$ is the total value of the loan and $1-\phi$ is the degree of dollarization of loans.

[6] The adjustment cost of investment satisfies: $S(1) = 1$, $S'(1) = 0$, $S''(1) = -\mu_S < 0$ (see Altig et al. (2005)).

Entrepreneurs rent capital to the firms and sell the undepreciated capital in period $t+1$ to capital goods producers. Each entrepreneur faces an idiosyncratic risk ω affecting the effective amount of capital available in $t+1$. The effective capital of entrepreneur in period $t+1$ is $\omega_{t+1}K_{t+1}$, where ω_{t+1} has a distribution with mean equal to one and density probability function given by $f_t(\omega)$ that varies over time. As in Christiano et al (2014), the variation of the distribution of ω captures changes in the degree of risk in the realization of ω. In particular, we assume that $\log(\omega_{t+1})$ follows a normal distribution with mean $m_{\omega,t}$ and standard deviation $\sigma_{\omega,t}$. Imposing that $m_{\omega,t} = -\sigma^2_{\omega,t}/2$, the mean of ω_{t+1} will always be one and the standard deviation $\sigma_{\omega,t}$. Shocks to $\sigma_{\omega,t}$, denoted as risk shocks, increase the dispersion of the realizations of ω_{t+1}, but preserving its mean at one. We assume that $\sigma_{\omega,t}$ follows an AR(1) process with autoregressive coefficient ρ_{σ_ω} and innovations, $\varepsilon_{\sigma_\omega,t}$, distributed normally with mean zero and standard deviation σ_{σ_ω}.

The ex-post return in period $t+1$ for the entrepreneur is given by:

$$\omega_{t+1}R^K_{t+1} = \omega_{t+1}\frac{Z_{t+1} + (1-\delta)Q_{t+1}}{Q_t}. \tag{7}$$

There is asymmetric information between entrepreneurs and financial intermediaries, that is, only entrepreneurs observe the realization of ω_{t+1}, while financial intermediaries can verify the realization after incurring in monitoring costs. The monitoring costs are proportional to investment income: $\mu\omega_{t+1}R^K_{t+1}Q_tK_{t+1}$, with $\mu \in (0,1)$. Hence, a financial contract will implement a mechanism to provide incentives for entrepreneurs to reveal the realization of ω_{t+1} to the financial intermediary. In particular, the debt contract is structured as follows. For every state with associated return on capital $\omega_{t+1}R^K_{t+1}$, entrepreneurs have to either service the state contingent debt or incur in a default. Debt in domestic currency has a gross interest rate of $R_{L,t+1}$ and debt in foreign currency has a gross rate of $R^*_{L,t+1}$. Thus, the effective interest rate $\bar{R}_{L,t+1}$ for the loan is defined as:

$$\bar{R}_{L,t+1} = \phi R_{L,t+1} + (1-\phi)\frac{\mathcal{E}_{t+1}}{\mathcal{E}_t}R^*_{L,t+1}. \tag{8}$$

When entrepreneurs default, the financial intermediary seizes their revenue, although a proportion μ of that revenue is lost in monitoring procedures. Therefore, entrepreneurs will always have incentives to pay the loan if the return $\omega_{t+1} R^K_{t+1}$ is high enough to do so. This logic implies that there will be a cutoff value for the realization of the idiosyncratic risk, $\bar{\omega}_{t+1}$, that satisfies:

$$\bar{\omega}_{t+1} R^K_{t+1} Q_t K_{t+1} = \bar{R}_{L,t} \bar{B}_{e,t} = \bar{R}_{L,t+1}(Q_t K_{t+1} - N_t). \tag{9}$$

If $\omega_{t+1} < \bar{\omega}_{t+1}$ the entrepreneur incurs in default and the financial intermediary recovers a fraction $1 - \mu$ of the revenue. This debt contract captures the asymmetries of information between lenders and borrowers that can only be circumvented with a costly state verification mechanism.

Assuming that financial intermediaries are competitive, the optimal debt contract maximizes the net expected benefits for entrepreneurs subject to the zero profit condition for financial intermediaries. The net expected benefits for entrepreneurs are:

$$\begin{aligned}
&\int_{\bar{\omega}_{t+1}}^{\infty} \omega R^K_{t+1} Q_t K_{t+1} f_t(\omega) d\omega - \bar{R}_{L,t} \bar{B}_{e,t} \int_{\bar{\omega}_{t+1}}^{\infty} f_t(\omega) d\omega \\
&= \int_{\bar{\omega}_{t+1}}^{\infty} \omega R^K_{t+1} Q_t K_{t+1} f_t(\omega) d\omega - \bar{\omega}_{t+1} R^K_{t+1} Q_t K_{t+1} \int_{\bar{\omega}_{t+1}}^{\infty} f_t(\omega) d\omega \\
&= \left[\int_{\bar{\omega}_{t+1}}^{\infty} \omega f_t(\omega) d\omega - \int_{\bar{\omega}_{t+1}}^{\infty} f_t(\omega) d\omega \right] R^K_{t+1} Q_t K_{t+1} = \Lambda_t(\bar{\omega}_{t+1}) R^K_{t+1} Q_t K_{t+1}.
\end{aligned} \tag{10}$$

The presence of subindex t in functions $f(\cdot)$ and $\Lambda(\cdot)$ reflects the variation over time of the entrepreneurs' risk, $\sigma_{\omega,t}$.

Financial intermediaries are subject to a macroprudential regulation. In particular, we follow Leduc and Natal (2018) by assuming that financial intermediaries face a reserve requirement restriction, rr_t, which varies over time. The specification of the policy rule for the reserve requirement is explained in section 2.6. Reserves of financial intermediaries are assumed to be kept in "cash" and earn no interest rates. Thus, for a given reserve requirement rr_t, the opportunity cost of financial intermediaries to lend funds in domestic currency is $R_t/(1 - rr_t)$ and in foreign currency is $R^*_t/(1 - rr_t)$.[7] Hence, considering reserve requirements and foreign currency borrowing, the zero-

[7] We assume a uniform reserve requirement rate for each currency denomination. In section 5 we relax this assumption and set a differentiated reserve requirement for each currency.

profit condition for financial intermediaries becomes:

$$\begin{aligned}
&\left(\phi R_t + (1-\phi)\frac{\mathcal{E}_{t+1}}{\mathcal{E}_t}R_t^*\right)\frac{(Q_tK_{t+1}-N_t)}{1-rr_t} = \\
&\bar{R}_{L,t}\bar{B}_{e,t}\int_{\bar{\omega}_{t+1}}^{\infty} f_t(\omega)d\omega + (1-\mu)R_{t+1}^K Q_t K_{t+1}\int_0^{\bar{\omega}_{t+1}} f_t(\omega)d\omega = \\
&\left[\bar{\omega}_{t+1}\int_{\bar{\omega}_{t+1}}^{\infty} f_t(\omega)d\omega + (1-\mu)\int_0^{\bar{\omega}_{t+1}} f_t(\omega)d\omega\right]R_{t+1}^K Q_t K_{t+1} = \\
&\Gamma_t(\bar{\omega}_{t+1})R_{t+1}^K Q_t K_{t+1}
\end{aligned} \tag{11}$$

The subindex t in functions $f(\cdot)$ and $\Gamma(\cdot)$ reflects the variation over time of the entrepreneurs' risk, $\sigma_{\omega,t}$. The optimal debt contract will maximize (10) subject to (11) which implies the following condition:

$$\begin{aligned}
&sp_{t+1} = \frac{R_{t+1}^K(1-rr_t)}{(\phi R_t + (1-\phi)\frac{\mathcal{E}_{t+1}}{\mathcal{E}_t}R_t^*)} = \rho_t(\bar{\omega}_{t+1}), \\
&\text{where } \rho_t(\bar{\omega}_{t+1}) = (\Gamma_t(\bar{\omega}_{t+1}) - \Lambda_t(\bar{\omega}_{t+1})\frac{\Gamma_t'(\bar{\omega}_{t+1})}{\Gamma_t(\bar{\omega}_{t+1})})^{-1}
\end{aligned} \tag{12}$$

sp_{t+1} is a measure of the credit spread of the return to capital above the cost of funds for the financial intermediaries or what Bernanke et al. (1999) calls the "external finance premium". Using this last expression and condition (11), Bernanke et al. (1999) show that a log-normal distribution for ω_{t+1} implies a increasing relationship of the credit spread, sp_{t+1}, and the leverage of entrepreneurs defined by $\frac{Q_tK_{t+1}}{N_t}$:

$$sp_{t+1} = \Psi_t(\frac{Q_tK_{t+1}}{N_t}),\ \ \Psi_t'(\cdot) > 0 \tag{13}$$

Formally, the dependence on t of the function $\Psi_t(\cdot)$ corresponds to the variation in the risk, $\sigma_{\omega,t}$. Hence, $\Psi_t(\cdot) = \Psi(\cdot, \sigma_{\omega,t})$.

In order to describe the evolution of the entrepreneurs' net worth, we assume that a fraction γ_e of entrepreneurs survives in each period, while the rest exit the market and consume all their wealth. The entrepreneurs who exit the market are replaced by a new cohort that enters with initial real net wealth w_e. Thus, the entrepreneurs' net worth evolves according to:

$$N_t = \gamma_e \Lambda_t(\bar{\omega}_t)R_t^K Q_{t-1}K_t + w_e, \tag{14}$$

and the entrepreneurs who exit the market have the following consumption function:

$$C_{e,t} = \frac{(1-\gamma_e)\Lambda_t(\bar{\omega}_t)R_t^K Q_{t-1}K_t}{P_{C,t}} \tag{15}$$

2.5 Domestic firms

We consider three types of domestic firms. One type of firms are the intermediate good producers. Each of these firms has monopoly power and face a sticky prices that prevents them from adjusting prices optimally every period. A second type of firms are the retailers of home goods that assemble the differentiated intermediate goods and sell them in domestic and foreign markets. This last type firms operate in a competitive market. Third, the retailers of foreign goods that purchase homogenous goods from abroad, differentiate them, and set their prices in domestic currency a la Calvo (1983).

2.5.1 Intermediate good producers

Intermediate good producers can produce $Y_{H,t}(z_H)$ of a particular variety z_H, relying on constant returns to scale technology:

$$Y_{H,t}(z_H) = A_{H,t}\left(l_t(z_H)\right)^{1-\alpha}\left(K_t(z_H)\right)^{\alpha},$$

where $l_t(z_H)$ is the amount of labor used, $K_t(z_H)$ is the amount of physical capital rented, and $A_{H,t}$ represents the productivity level common to all firms. The parameter α determines the share of capital in production. By assuming sticky prices á la Calvo (1983), firms optimally adjust their prices when they receive a signal. In every period the probability of receiving a signal and adjusting their prices is $1-\phi_H$ for all firms. The chance of receiving this other signal is equal for all firms, and independent of their history.

2.5.2 Retailers of intermediate goods

Retailers of intermediate goods operate in a perfectly competitive market. In order to produce $Y_{H,t}$ units of home goods, they combine domestically produced intermediate varieties according to a constant elasticity of substitution function:

$$Y_{H,t} = \left[\int_0^1 Y_{H,t}(z_H)^{\frac{\epsilon_H - 1}{\epsilon_H}} dz_H \right]^{\frac{\epsilon_H}{\epsilon_H - 1}}, \tag{16}$$

where $Y_{H,t}(z_H)$ is the quantity of intermediate variety z_H used for final domestic goods and ϵ_H is the elasticity of substitution among varieties.

2.5.3 Retailers of foreign goods

The retailers of foreign goods sector consists of a continuum of firms that buy a homogenous good in the foreign market and turn the imported good into a differentiated one.[8] Competitive assemblers combine this continuum of differentiated imports into a final import good Y_F. The technology of importing assemblers is given by:

$$Y_{F,t} = \left[\int_0^1 Y_{F,t}(z_F)^{\frac{\epsilon_F - 1}{\epsilon_F}} dz_F \right]^{\frac{\epsilon_F}{\epsilon_F - 1}}, \tag{17}$$

where $Y_{F,t}(z_F)$ is the quantity of a differentiated import z_F used by the assemblers and ϵ_F is the elasticity of substitution among differentiated imported goods.

The retailers of foreign goods purchase the imports at a price $P^*_{F,t}$ abroad in foreign currency. Each retailer has monopoly power over a variety of imported good. We assume local currency price stickiness á la Calvo (1983) in order to allow for incomplete exchange rate pass-through to import prices. Each retailer adjusts the domestic price of its variety infrequently, when receiving a signal with probability $1 - \phi_F$ each period.

2.6 Central bank policies

The central bank relies on three policy instruments: the monetary policy rate, foreign exchange reserves, and reserve requirements. Monetary policy is implemented through a policy rule for the interest rate on domestic bonds. The rule implies that the policy

[8] This differentiating technology can be interpreted as brand naming.

rate adjusts in response to deviations of inflation and GDP from their steady state. We also allow for interest rate smoothing such that:

$$\frac{R_t}{\bar{R}} = \left(\frac{R_{t-1}}{\bar{R}}\right)^{\varphi_i} \left(\frac{1+\pi_{c,t}}{1+\overline{\pi}}\right)^{(1-\varphi_i)\varphi_\pi} \left(\frac{Y_t}{\overline{Y}}\right)^{(1-\varphi_i)\varphi_y}, \tag{18}$$

where $\bar{R}$ is the steady state value for R_t, φ_i defines the interest rate smoothing, φ_π and φ_y are the weights of inflation and GDP deviations in the monetary policy rule. In addition, foreign exchange intervention is implemented according to a rule aimed at stabilizing fluctuations in the real exchange rate depreciation:

$$\frac{F_t^*}{\overline{F}^*} = \left(\frac{F_{t-1}^*}{\overline{F}^*}\right)^{\rho_{fx}} \left(\frac{RER_t}{RER_{t-1}}\right)^{\theta_{fx}}, \tag{19}$$

where F_t^* is the stock of foreign exchange reserves, $\overline{F}^*$ is the steady state values of the foreign exchange reserves, θ_{fx} governs the intensity in which FX interventions stabilize the changes in the real exchange rate, and ρ_{fx} defines the persistence of the stock of FX reserves. Notice that this rule reflects a concern for targeting real exchange rate fluctuations, but not the level of the real exchange rate. Adjustments in the stock of FX reserves should satisfy the central bank's budget constraint :

$$\mathcal{E}_t F_t^* - B_t = \mathcal{E}_t F_{t-1}^* R_{t-1}^* - B_{t-1} R_{t-1} - T_t, \tag{20}$$

Hence, sterilized FX interventions are conducted by the issuance of domestic bonds and purchase of foreign bonds. Each period the central bank earns interest payments net of valuation effects of foreign reserves from the previous period equal to $\mathcal{E}_{t-1} F_{t-1}^* \left(R_{t-1}^* \mathcal{E}_t / \mathcal{E}_{t-1} - 1\right)$. The central bank also pays interests for stock of domestic bond from last period equal to $B_{t-1}(R_{t-1} - 1)$. The net profits from returns and capital gains are rebated to households through lump-sum transfers T_t.[9]

Finally, in the case of the reserve requirement rule responds to variations in the credit spread:

$$\frac{rr_t}{\overline{rr}} = \left(\frac{rr_{t-1}}{\overline{rr}}\right)^{\rho_{rr}} (sp_{t-1})^{\theta_{rr}},$$

[9] In the simulations the costs of sterilized foreign exchange intervention are of second order importance, and are summarized by the lump-sum transfers. For an empirical analysis on the costs and benefits of FX intervention see Brandao et al. (2020).

where $\overline{rr}$ is the steady state value for reserve requirements, θ_{rr} controls the degree of reaction of reserve requirement to the external finance spread, and ρ_{rr} determines the persistence of the reserve requirement rule.[10]

2.7 Aggregation and equilibrium conditions

In each period, markets for assets, labor, capital, domestic, and foreign goods clear. For assets, we express the aggregate holdings of deposits, domestic bonds, and foreign debt as:

$$D_t = \int_0^1 D_t(j),\ D_t^* = \int_0^1 D_t^*(j),\ B_t = \int_0^1 B_t(j),\ B_t^* = \int_0^1 B_t^*(j) \tag{21}$$

Given the reserve requirement restriction for financial intermediaries, in equilibrium:

$$D_t(1 - rr_t) = B_{e,t} \text{ and } D_t^*(1 - rr_t) = B_{e,t}^*. \tag{22}$$

The equilibrium in the labor and capital markets are given by:

$$l_t = \left(\int_0^1 l_t(j)^{\frac{\epsilon_L - 1}{\epsilon_L}} dj \right)^{\frac{\epsilon_L}{\epsilon_L - 1}} = \int_0^1 l_t(z_H) dz_H \tag{23}$$

$$K_t = \int_0^1 K_t(z_H) dz_H. \tag{24}$$

The equilibrium conditions for the final home good is:

$$Y_{H,t} = C_{H,t} + C_{e,H,t} + I_{H,t} + C_{H,t}^* + \mu \left(\int_0^{\bar{\omega}_{t+1}} f_t(\omega) d\omega \right) R_{t+1}^K Q_t K_{t+1} \tag{25}$$

In the expression above, $C_{H,t}^*$ corresponds to the volume of export of final domestic goods and it is modelled as:

$$C_{H,t}^* = \zeta^* \left(\frac{P_{H,t}}{\mathcal{E}_t P_t^*} \right)^{-\eta^*} C_t^*, \tag{26}$$

[10] The lag is the financial spread in the rule is needed to have a more stable solution. With a contemporaneous reaction to the spread the model solution finds more regions in the rule's parameters where the conditions for stationarity and determinacy are not satisfied.

where ζ^* corresponds to the share of domestic goods in the consumption basket of foreign agents, and where η^* is the price elasticity of this demand.

The equilibrium for the foreign goods market is:

$$Y_{F,t} = C_{F,t} + C_{e,F,t} + I_{F,t} = \left(\int_0^1 Y_{F,t}(z_F)^{\frac{\epsilon_F - 1}{\epsilon_F}} dz_F \right)^{\frac{\epsilon_F}{\epsilon_F - 1}} \tag{27}$$

Combining the households, entrepreneurs and government budget constraints, we obtain the balance of payment equation that describes the dynamics of the net foreign assets:

$$\mathcal{E}_t(F_t^* - B_t^*) \;\; = \;\; R_{t-1}^* \left(\mathcal{E}_t F_{t-1}^* - \Theta_t \mathcal{E}_t B_{t-1}^* \right) + X_t - M_t \tag{28}$$

where X_t and M_t are the values of exports and imports, respectively. They are defined by $X_t = P_{H,t} C_{H,t}^*$ and $M_t = \mathcal{E}_t P_{F,t}^* \int_0^1 Y_{F,t}(z_F) dz_F$.

It worth noting the role played by the endogenous risk premium Θ_t in the model. Following Chang et al. (2015), this risk premium governs the transmission mechanism of FXI because determines the degree of asset substitution between domestic and foreign bonds. As indicated in equation (20), an accumulation of FX reserves is financed by increasing the supply of domestic bonds which are purchased by households. In the case of perfect asset substitution ($\Theta_t = 1$), households will respond to this excess of supply of bonds by borrowing from the rest of the world, fully offsetting the impact of FX reserves accumulation. In order to implement effective sterilized FXI, we assume that Θ_t depends on the stock of foreign and domestic bonds expressed in foreign currency: $\Theta_t = \Theta\left(B_t^*, \frac{B_t}{\mathcal{E}_t}\right)$. For this specification, we will define two key elasticities that will define the degree of imperfect asset substitution:

$$\frac{\partial \Theta}{\partial B_t^*} \frac{B_t^*}{\Theta\left(B_t^*, \frac{B_t}{\mathcal{E}_t}\right)} = \varrho_1 \;, \; \frac{\partial \Theta}{\partial \frac{B_t}{\mathcal{E}_t}} \frac{\frac{B_t}{\mathcal{E}_t}}{\Theta\left(B_t^*, \frac{B_t}{\mathcal{E}_t}\right)} = \varrho_2.$$

3 Calibration

The model is calibrated at a quarterly frequency. We set the steady values of the model to match relevant ratios for an average of developing and emerging economies. For some of the model parameters, we use standard values found in the literature. We set the discount factor $\beta = 0.9975$ consistent with a steady state risk-free rate of 1 percent, Household preferences have a unitary intertemporal substitution elasticity ($\sigma_C = 1$) and a Frisch elasticity of the labor supply equal to 1/2 ($\sigma_L = 2$). The consumption and investment baskets have a share of 30 percent of imported goods, whereas the substitution elasticity between domestic and imported goods is 0.5. The share of imported goods broadly matches the average import-GDP ratio for an average of 155 emerging and developing countries in the IMF WEO database for the period 2000-2018 (27 percent).

The financial accelerator block of the model is calibrated following Bernanke et al. (1999) and Gertler et al. (2007) and is consistent with a credit spread of 3.5 percent in annual terms, an annual default rate of 3 percent, a capital-net worth ratio of 2, a survival rate of entrepreneurs of 97.5 percent. We also assume a log-normal distribution for the idiosyncratic shock ω_t affecting the return to capital. This calibration strategy implies endogenously values for bankruptcy cost (μ) and the steady value for the dispersion of ω_t (σ_ω).

The degree of liability dollarization is set to 50 percent ($\phi = 0.5$). This is consistent with the average and median financial dollarization in emerging economies of 43 and 47 percent, respectively. The degree of dollarization was obtained from the Levy-Yeyati (2006) database for the period 1995-2004 in a sample of emerging economies.[11] The reserve requirement in the steady state is equal to 6 percent, which matches the median value of the reserve requirements during the period 2000-2013 in the sample of countries in the Federico et al. (2014) database.

[11] List of countries: Azerbaijan; Bolivia; Bulgaria; Costa Rica; Croatia; Egypt; Estonia; Georgia; Hungary; Jamaica; Kazakhstan; Latvia; Lithuania; Moldova; Paraguay; Peru; Philippines; Qatar; Romania; Russia; Turkey; Ukraine; Uruguay.

The capital share α is set to 0.5. We choose the value of the depreciation rate of capital in order to obtain an investment-output ratio of 20 percent. The value of the size of exports (parameter ζ^*) is chosen in order to have net exports equal to one percent at the steady state which broadly matches the average net export-GDP ratio of 1.2 percent in a sample of 155 developing and emerging economies since 2010. The stock of FX reserves at the steady state ($\bar{F}^*$) is selected to have a ratio with respect to output equal to 25 percent, which matches the average value for the same group of 155 developing and emerging countries. The value for $\bar{B}^*$ adjusts accordingly to be consistent in the steady state with a net export of 1 percent of GDP and the magnitude of FX reserves.

Table 1: Baseline Calibration

Parameter	Value	Description
β	0.998	Discount Factor
σ_C	1.00	Intertemporal substitution elasticity
σ_L	2.00	Inverse of the labor supply elasticity
γ_C	0.30	Share of imported goods in consumption
η_C	0.5	Substitution elasticity b/w H and F in consumption
γ_I	0.30	Share of imported goods in investment
η_I	0.5	Substitution elasticity b/w H and F in investment
μ_S	2.5	Parameter for adjustment cost in investment
$\bar{sp}^4$	1.035	Credit spread in annual terms in the SS
$4 \times F(\bar{\omega})$	0.03	Default premium in annual terms in the SS
$\bar{Q}\bar{K}/\bar{N}$	2.00	Capital-Networth ratio of entrepreneurs in the SS
γ_e	0.975	Survival rate of entrepreneurs
$\bar{rr}$	0.06	Reserve requirement in the SS
ϕ	0.50	Degree of financial dollarization
α	0.5	Capital share in domestic production
$\bar{I}/\bar{Y}$	0.20	Investment-output ratio in the SS
$(\bar{X}-\bar{M})/\bar{Y}$	0.01	Net export-output ratio in the SS
η^*	0.5	Price elasticity of exports

Regarding nominal rigidities we use standard parameter values considered in the literature. We set Calvo parameters for wages and prices consistent with an average duration of optimized wages and prices of 4 quarters ($\phi_L = \phi_H = \phi_F = 0.75$). The monetary policy rule has standard values with smoothing in the changes of the interest rate: $\varphi_i = 0.70$, $\varphi_\pi = 1.5$, and $\varphi_y = 0.5/4$. Changes in the foreign interest rate are very persistent ($\rho_{R^*} = 0.95$) consistent with the evidence of Neumeyer and Perri (2005). Following the estimation in Christiano et al (2014), risk shocks also are highly persistent ($\rho_{\sigma_\omega} = 0.95$).

Table 1 (cont): Baseline Calibration

Parameter	Value	Description
ϕ_L	0.75	Calvo parameter in wages
ξ_L	0.0	Indexation to past inflation in wages
ϵ_L	6.0	Substitution elasticity across labor varieties
ϕ_H	0.75	Calvo parameter in the prices of H goods
ξ_H	0.0	Indexation to past inflation in prices of H goods
ϵ_H	11.0	Substitution elasticity across H varieties
ϕ_H	0.75	Calvo parameter in the prices of F goods
ξ_H	0.0	Indexation to past inflation in prices of F goods
ϵ_H	11.0	Substitution elasticity across F varieties
φ_i	0.70	Smoothing of the monetary policy rule
φ_π	1.50	Reaction to inflation in the monetary policy rule
φ_y	0.125	Reaction to output in the monetary policy rule
ρ_{R^*}	0.95	Persistence coefficient of foreign interest rate shocks
ρ_{σ_ω}	0.95	Persistence coefficient of risk shocks
ϱ_1	0.001	External risk premium elasticity to B^*
ϱ_2	0.035	External risk premium elasticity to $\frac{B_t}{\mathcal{E}_t}$

For calibrating the parameters governing the risk premium, Θ_t, we proceed as follows. First, as in Schmitt-Grohe and Uribe (2003) we calibrate $\varrho_1 = 0.01$. We set a value close to zero in order to guarantee stationarity of the model. Second, we calibrate ϱ_2 based on the empirical evidence of Bayoumi et al. (2015), who find that an increase of 1 percent of GDP in the stock of foreign reserves improves the current account balance around 0.4 percent of GDP. Consistent with this evidence we set $\varrho_2 = 0.035$.

Finally, the parameters for the FXI and reserves requirement rules are chosen to minimize a conventional loss function based on output and inflation volatility ($L =$

$var(y_t) + var(\pi_t))$ subject to a specific shock.[12][13] We focus our analysis on two alternative shocks: (i) the foreign interest rate (R_t^*); and (ii) the entrepreneurs' risk ($\sigma_{\omega,t}$). We also consider two regimes with additional instruments for each shock. One regime optimizes only the reserve requirement rule, keeping foreign reserve constant. The other regime optimizes simultaneously the rules for reserve requirement and FXI.[14] The value of the optimized rule parameters for each of the shocks are shown in Table 2.[15][16]

Table 2: Optimized Rules for Reserve Requirement and FXI

	Only RR rule		Both rules			
Type of shock	ρ_{rr}	θ_{rr}	ρ_{fx}	θ_{fx}	ρ_{rr}	θ_{rr}
R_t^*	0.81	-6.00	0.99	-6.36	0.91	-0.29
$\sigma_{\omega,t}$	0.00	-0.89	0.00	-23.11	0.00	-0.89

[12] In our model the goal of the central bank is to stabilize output and inflation. In practice, the central bank might have additional goals such as financial stability. See Arce et al. (2019) for an optimal policy analysis taking into account financial stability concerns.

[13] Throughout the simulations we set the coefficients of the Taylor rule at the calibrated values and optimize the coefficients for the FXI and reserve requirement rules. We found that the additional stabilization gains from optimizing the coefficients of the Taylor rule are fairly small. Those simulations are available upon request.

[14] This regime comparison can illustrate the role played by each additional instrument in stabilizing the economy.

[15] For the case with only a rule for the reserve requirement we need to restrict the values for $\theta_{rr} \geq -6$ in order to guarantee a unique rational expectations equilibrium. For the case where only the FXI rule is operating we obtain the coefficients $\rho_{fx} = 0.99$ $\theta_{fx} = 12.52$ for foreign interest rate shocks and $\rho_{fx} = 0.00$ $\theta_{fx} = -39.30$ for risk shocks. Table 7 summarizes the macroeconomic outcomes when this FXI rule is operating.

[16] Notice that the persistence coefficients for foreign exchange intervention and reserve requirement are relatively high (higher even than the persistence of shocks for FXI). This is consistent with the results existing in the literature (Fanelli and Straub, 2019), where the optimal policy is highly persistent and involves intervening in the foreign exchange market even when the shock has faded. The rationale for these results relies on the logic of forward guidance (Eggerston and Woodford, 2003), where announcements of a persistent use in the policy have powerful macroeconomic effects.

4 Optimal Choice of Policy Instruments

In this section we analyze the optimal policy mix to be implemented by the central bank in response to two alternative shocks: an increase in the foreign interest rate and an increase in the domestic idiosyncratic risk affecting the entrepreneurs. Both shocks induce capital flows of similar magnitude as a percentage of GDP, however these propagate to the economy differently, as it will be shown in the impulse response analysis. For each shock, we analyze the dynamic response of the economy under three scenarios. First, the case where the central bank deploys only the monetary policy rate. Second, we assume that the central bank deploys both the reserve requirements and the policy rate. In the third case, the central bank deploys all three instruments. For the second and third case, the central bank deploy rules for the foreign exchange reserves and reserve requirements that minimize the loss function.

Figure 3 shows the responses to an increase of 1 percent in the foreign interest rate R_t^*. The black line with asterisk corresponds to the impulse response functions of the model when the central bank operates only with the monetary policy rate. As expected, the increase in the foreign interest rate generates an exchange rate depreciation –both nominal and real. The capital outflows that triggers this shock manifests in an improvement in the trade balance. The exchange rate depreciation exerts pressures on inflation through the import prices. Despite an output contraction, policy rate raises in order to stabilize inflation. The financial accelerator mechanism with partial dollarization induces a widening of the credit spread and an associated decline in investment. Hence, the capital outflow episode is contractionary and the monetary policy rate faces a dilemma since inflation is rising at the same time as GDP and investment are falling.

What are the potential macroeconomic stabilization gains if the central bank decides to deploy FX reserves and reserve requirements in addition to the policy rate? The dotted blue line shows the responses to same shock, but when the central bank implements an optimal policy rule for reserve requirements in addition to the interest rate rule. The active use of only the reserve requirement can attenuate only part of the macroeconomic effects of the foreign interest rate shock on output and inflation. Since a loosening of reserve requirements can stimulate output and inflation in the same direction, this tool has limited power to fully address a situation of high inflation and low output. As a result the optimal reserve requirement policy is capable of partially stabilizing output and inflation in the medium term.

The red line shows the case when FXI and reserve requirement are operating in addition to the interest rate rule. This scenario illustrates the large macroeconomic stabilization gains from relying on FXI in response to foreign interest rate shocks. The optimal policy mix consists in selling of foreign exchange reserves by the central bank to contain exchange rate pressure and a moderate reduction in the reserve requirement to stabilize output. Clearly, these two instruments have a countercyclical orientation to respond to this capital outflows episode. Interestingly, the contraction in GDP and investment is greatly attenuated. At the same time, the depreciation is less intense and, consequently, inflation is tamed. Hence, the monetary policy faces less constrained and the rise of the interest rate is smaller. The increase in the credit spread is also moderated. Finally, we observe that the aggregate size of the capital outflows is partially contained as trade balance increases by less than in the baseline case. Hence, the deployment of the additional instruments such as FXI and reserve requirement helps substantially to reduce the negative macroeconomic effects of a capital outflow episodes. It is also worth noting that between these two instruments, FXI is used more intensely relative to the reserve requirement.[17]

In figure 4 we analyze the impulse response functions to risk shock of 8 percent. Following the same legends, the black line with asterisk corresponds to a situation where only the policy is operating. The higher risk translates into a higher probability of de-

[17] In response to a foreign interest rate shock, the model predicts a rather small loss in FX reserves (about 2 percent of GDP). However, for larger shocks, the central bank might fully deplete its stock of reserves posing additional challenges to the central bank. For an analysis of FXI policies with non-negativity constraints see Basu et al. (2018).

fault by the entrepreneurs and, in equilibrium, the lending contract requires a higher credit spread to compensate the higher default rate. In consequence, investment and aggregate demand fall. GDP is lowered, but the contraction in aggregate demand is higher, implying an improvement in the trade balance. Thus, this shock also materializes in a net capital outflow and an exchange rate depreciation. In the short run, inflation falls showing the dominance of the reduction in aggregate demand over the exchange depreciation, but after a few quarters inflation rises. Following the dynamic of inflation, the interest rate initially declines and then increases afterwards.

The dotted blue line in figure 4 shows the impulse responses when we add the reserve requirement rule to the central bank toolkit. In contrast to the scenario of a foreign interest rate shock, having only an optimal reserve requirement rule achieves a substantial macroeconomic stabilization in response to risk shocks. Adding an optimal FXI response to the use of reserve requirement induces some minor additional gains in terms of macroeconomic stabilization

In the same way as with the foreign interest rate shock, these two additional instruments are implemented in a countercyclical manner. However, in contrast to the foreign interest rate shock, reserve requirement is used more intensively and the sell of FX reserves is moderate. The combination of these two policy instruments largely stabilizes investment, output, and inflation. This implies a smaller adjustment of the trade balance and the associated net capital outflows. In this scenario, the two additional policy instruments allow the implementation of a much smaller reduction in the interest rate and gradual normalization later on.

A few important principles emerge from this quantitative analysis. Relying on reserve requirements and FXI is critical for dealing with capital outflows as these instruments can largely stabilize output and inflation. However, the optimal policy mix of these instruments ultimately depends on the underlying shock triggering the capital outflow episode . When the capital outflows are originated from changes in the foreign financial conditions, the FXI has a leading role in stabilizing the economy. In contrast, when capital outflows are originated from domestic risk shocks, the response of the reserve requirement is key in managing capital outflows. In sum, policymakers should not rely on the same policy instruments for managing capital outflows, regardless of the underlying shocks hitting the economy.

5 Model extensions

In this section we evaluate three model extensions in order to evaluate the robustness of our results to alternative setups. First, we expand the FXI and reserve requirement rules, allowing both of them to react simultaneously to variations in the real exchange rate and the financial spread. Second, we introduce differentiated reserve requirement ratios for foreign and domestic currency borrowing. Finally, we assume a scenario where the central bank can also manage capital outflows relying on a capital flow tax.

5.1 Expanded rules

In the benchmark model we specify simple rules for FXI and the reserve requirement according to the Mundell principle (Mundell, 1968), that is "policies should be paired with the objectives on which they have the most influence". In this subsection, we simulate the model with a set of policy rules with expanded targets, allowing FXI and reserve requirements to react simultaneously to variations in the real exchange rate and the financial spread. In particular, we consider the following rules for FXI and reserve requirements:

$$\frac{F_t^*}{\overline{F}^*} = \left(\frac{F_{t-1}^*}{\overline{F}^*}\right)^{\rho_{fx}} \left(\frac{RER_t}{RER_{t-1}}\right)^{\theta_{fx}} (sp_{t-1})^{\eta_{fx}}$$

$$\frac{rr_t}{\overline{rr}} = \left(\frac{rr_{t-1}}{\overline{rr}}\right)^{\rho_{rr}} (sp_{t-1})^{\theta_{rr}} \left(\frac{RER_t}{RER_{t-1}}\right)^{\eta_{rr}}$$

Table 3 presents the parameters for the new optimized rules. Figure 5 shows the impulses responses for a model economy under the expanded rules (dotted green line) for output, inflation, real exchange rate and the financial spread. This figure also presents the responses under the base case (only policy rate) and when the optimize rules with only one target are implemented. The responses to foreign interest rate and risk shocks are presented in Panel A and B, respectively. Even though the parameters for the expanded rules are different to the one target rules presented in table 2, the responses of the main macroeconomic variables are quite similar across the different rule specifications. Hence, we can conclude that most of the improvement in the macroeconomic stabilization is obtained conditioning reserve requirement and FXI to one target variable according to the Mundell principle. Implementing more complex rules for these additional instruments provide stabilization gains, but its relative contribution in comparison to the single target rules are small.

Table 3: Expanded rules for reserve requirement and FXI

Type of shock	ρ_{fx}	θ_{fx}	η_{fx}	ρ_{rr}	θ_{rr}	η_{rr}
R_t^*	0.98	-0.01	-5.89	0.99	-0.07	0.00
$\sigma_{\omega,t}$	0.00	-51.82	-3.46	0.00	-0.69	0.00

5.2 Reserve requirement differentiated in foreign and domestic currency

Since the model economy financial intermediation is partially dollarized, the central bank in principle could deploy differentiated reserve requirement for domestic and foreign currency borrowing. Here we analyze how our results changes in terms of macroeconomic stabilization when the central bank implements differentiated reserve requirements. For this extension, equations (11) and (12) must be modified accordingly:

$$\phi \frac{R_t}{1 - rr_t^d} + (1 - \phi) \frac{\mathcal{E}_{t+1}}{\mathcal{E}_t} \frac{R_t^*}{1 - rr_t^*} = \Gamma_t(\bar{\omega}_{t+1}) R_{t+1}^K Q_t K_{t+1}$$

$$sp_{t+1} = \frac{R_{t+1}^K}{\phi \frac{R_t}{1 - rr_t^d} + (1 - \phi) \frac{\mathcal{E}_{t+1}}{\mathcal{E}_t} \frac{R_t^*}{1 - rr_t^*}} = \rho_t(\bar{\omega}_{t+1})$$

where rr_t^d and rr_t^* are the reserve requirement for deposits in domestic and foreign currency, respectively. The specification for the FXI rule is the same as equation (19), but we assume the following specification for the two type of reserve requirements:[18]

$$\frac{rr_t^d}{\overline{rr}} = \left(\frac{rr_{t-1}^d}{\overline{rr}}\right)^{\rho_{rr^d}} (sp_{t-1})^{\theta_{rr^d}}$$

$$\frac{rr_t^*}{\overline{rr}} = \left(\frac{rr_{t-1}^*}{\overline{rr}}\right)^{\rho_{rr^*}} \left(sp_{t-1}^*\right)^{\theta_{rr^*}}$$

Table 4 shows the parameters for the rules for the differentiated reserve requirement and FXI. The optimized coefficients indicates differences between the domestic and foreign currency reserve requirements according to the type of shock simulated in the model. However, figure 6 shows that output stabilization achieved by relying on differentiated reserve requirements is quantitative indistinguishable from the baseline case of a uniform reserve requirement. For the foreign interest rate shock, the possibility of having differentiated reserve requirements, allows the central bank to tolerate a slightly larger exchange rate depreciation, which helps to boost output in the short run. The differentiated reserve requirement allows this additional exchange rate depreciation without triggering additional balance sheet effects in foreign currency borrowing. For this model extension, also it will be the case that FXI takes the leading role in responding to foreign interest rate shocks while reserve requirements are more used more intensively in the case of risk shocks.

Table 4: Optimized rules for Differentiated reserve requirements and FXI

Type of shock	ρ_{fx}	θ_{fx}	ρ_{rr^*}	θ_{rr^*}	ρ_{rr^d}	θ_{rr^d}
R_t^*	0.00	-1.95	0.63	-1.35	0.99	-0.19
$\sigma_{\omega,t}$	0.00	-4.20	0.00	-0.37	0.00	-1.51

5.3 Capital flow tax

One alternative policy instrument for managing the capital account is a capital flow tax. In this subsection, we analyze how the optimal responses of this additional

[18] Since our focuss is on business cycle response the value of the reserve requirement in each currency is the same in the steady state.

instruments assuming that the central bank refrains from conducting FXI. The implementation of a capital flow tax modifies the households budget constraint (3). The capital flow tax affects the effective cost of borrowing paid by the households. Thus, the effective foreign interest rate will be now $R^*_{t-1}(1+\tau_{kf,t-1})-1$, where $\tau_{kf,t-1}$ is the capital flow tax on foreign debt issued in period $t-1$. The reserve requirement rule will have the same specification as in equation (21) and the capital flow tax will have the following rule:

$$\left(\frac{1+\tau_{kf,t}}{1+\bar{\tau}_{kf}}\right)=\left(\frac{1+\tau_{kf,t-1}}{1+\bar{\tau}_{kf}}\right)^{\rho_{kf}}\left(\frac{RER_t}{RER_{t-1}}\right)^{\theta_{kf}}$$

Figure 7 shows the response of the economy to this new additional instrument, following the same structure used for figures 5 and 6. Table 6 shows the optimized coefficients for the capital flow tax and reserve requirement rules, which highlights that the optimal response features a reduction in the capital flow tax when the real exchange rate depreciate in response to a rise in the foreign interest rate or in the domestic risk. Importantly, the exact reaction of the capital flow tax to the real exchange depends on the type of shock affecting the economy, resembling the results obtained when using the FXI as policy instrument. Moreover, the responses in Figure 7 shows that the allocation derived from implementing FXI policies and the ones obtained from the capital flow tax are exactly the same, which is in line with the equivalence result of these two policy instruments stressed by Davis et al. (2019) and Arce et al. (2019).

Table 6: Optimized rules for capital flow tax and reserve requirement

Type of shock	ρ_{kf}	θ_{kf}	ρ_{rr}	θ_{rr}
R^*_t	0.99	-0.23	0.91	-0.29
$\sigma_{\omega,t}$	0.00	-0.84	0.00	-0.89

To summarize the macroeconomic gains for the different regimes, the loss function for each of the model specifications is shown in table 7. The results presented in this table highlights the stabilization role of each regime presented in the impulse response figures. Simple policy rules for FXI and reserve requirement featuring one target achieves a substantial improvement in macroeconomic stabilization relative to the case where only monetary policy is operating. Expanding the targets of the rules or introducing differentiated reserve requirements can reduce the loss function, but the additional gains are marginal relative the baseline case of optimized rules for FXI and reserve requirement. Relying only on reserve requirement or FXI as an additional instrument also provide benefits in terms of macroeconomic stabilization, but the simultaneous use of FXI and reserve requirement tends to provide the largest gains. Combining reserve requirement with FXI or capital flow tax deliver exactly the same macroeconomic stabilization. Moreover, the alternative regimes analyzed in this section also stresses a higher effectiveness of reserve requirement against risk shocks than for foreign interest rate shocks, whereas FXI or capital flow tax are more effective to deal with foreign interest rate shocks.

Table 7: Macroeconomic variances and loss function in each regime and shock

	For shocks in R^*			For shocks in $\sigma_{\omega,t}$		
Regime	$Var(\pi)$	$Var(y)$	Loss	$Var(\pi)$	$Var(y)$	Loss
No additional instruments	7.26	110.94	118.20	2.73	61.91	64.64
Rule for RR only	3.10	24.90	27.99	0.07	1.04	1.11
Rule for FXI only	0.72	15.38	16.10	2.44	27.81	30.25
Rules for RR and FXI	0.29	4.19	4.48	0.07	0.99	1.06
Expanded rules for RR and FXI	0.09	1.17	1.26	0.05	0.29	0.34
Rules for diff. RR and FXI	0.26	1.88	2.15	0.06	0.88	0.94
Rules for RR and cap. flow tax	0.29	4.19	4.48	0.07	0.99	1.06

6 Conclusions

In the early 2000s there was a consensus on how macroeconomic theory was shaping economic policy in many aspects, including the adoption of inflation targeting frameworks (Chari and Kehoe, 2006). However, the implementation of multiple-tool policy frameworks in emerging economies, in particular during global financial crises, have shown us that the practice of macroeconomic policy is ahead of the economic theory.

In particular, emerging market economies rely on multiple policy instruments, with no theoretical underpinning on their optimal implementation over the business cycle. The main purpose of this paper is to rationalize this practice in emerging economies in the context of the management of the capital flows. In doing so, we develop small open economy model calibrated to a representative emerging economy where capital flows and the associated exchange rate movements can disrupt financial intermediation making it more difficult the conduct of monetary policy.

In this context, our model simulation highlights two main messages. First, complementing the monetary policy rate with FX interventions and reserve requirements can largely stabilize the economy during episodes of capital outflows. Second, the exact policy mix of these instruments depends on the underlying shock hitting the economy. When capital outflows are triggered by external shocks such as change in the foreign interest rate, FX intervention takes the leading role in stabilizing the economy. However, when the shock is originated domestically, such as an increase in domestic risk, reserve requirements plays a predominant role in containing the volatility of financial markets, and hence contributing to output and inflation stabilization.

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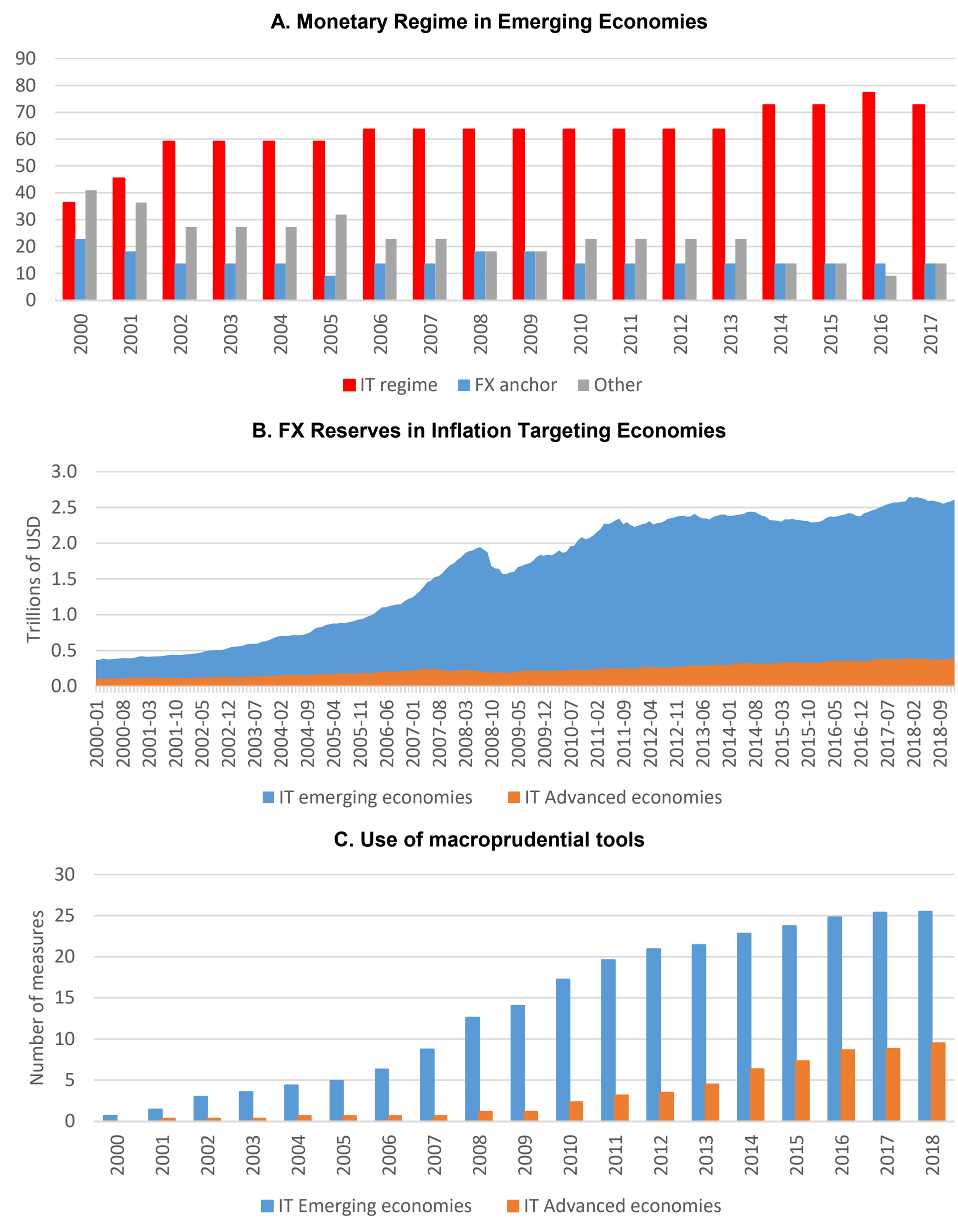
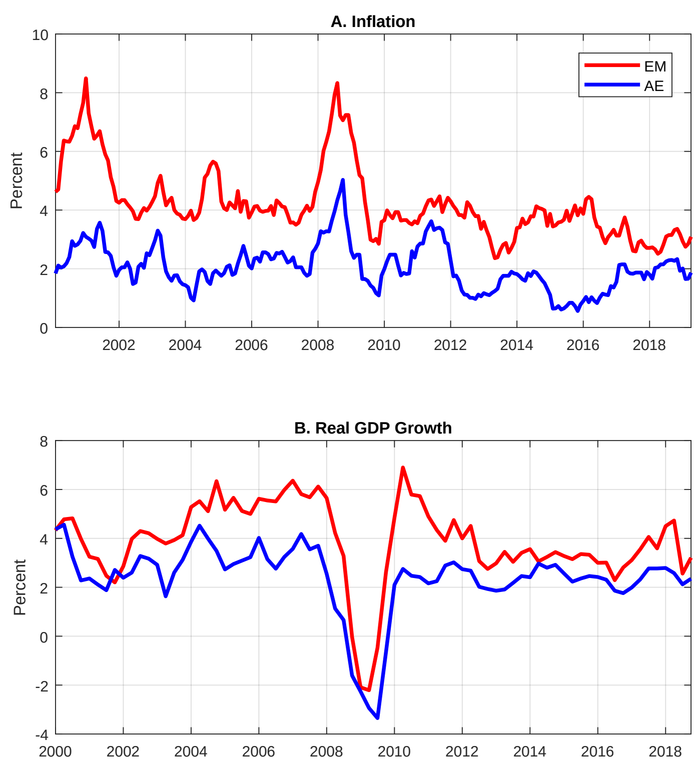
Figure 1: Evolution of Policy Frameworks in Emerging and Advanced Economies



Sources: BIS (2019)

Figure 2: Inflation and Real GDP Growth in Emerging Economies with Inflation Targeting



Source: BIS.

Figure 3: Responses to a foreign interest rate shock

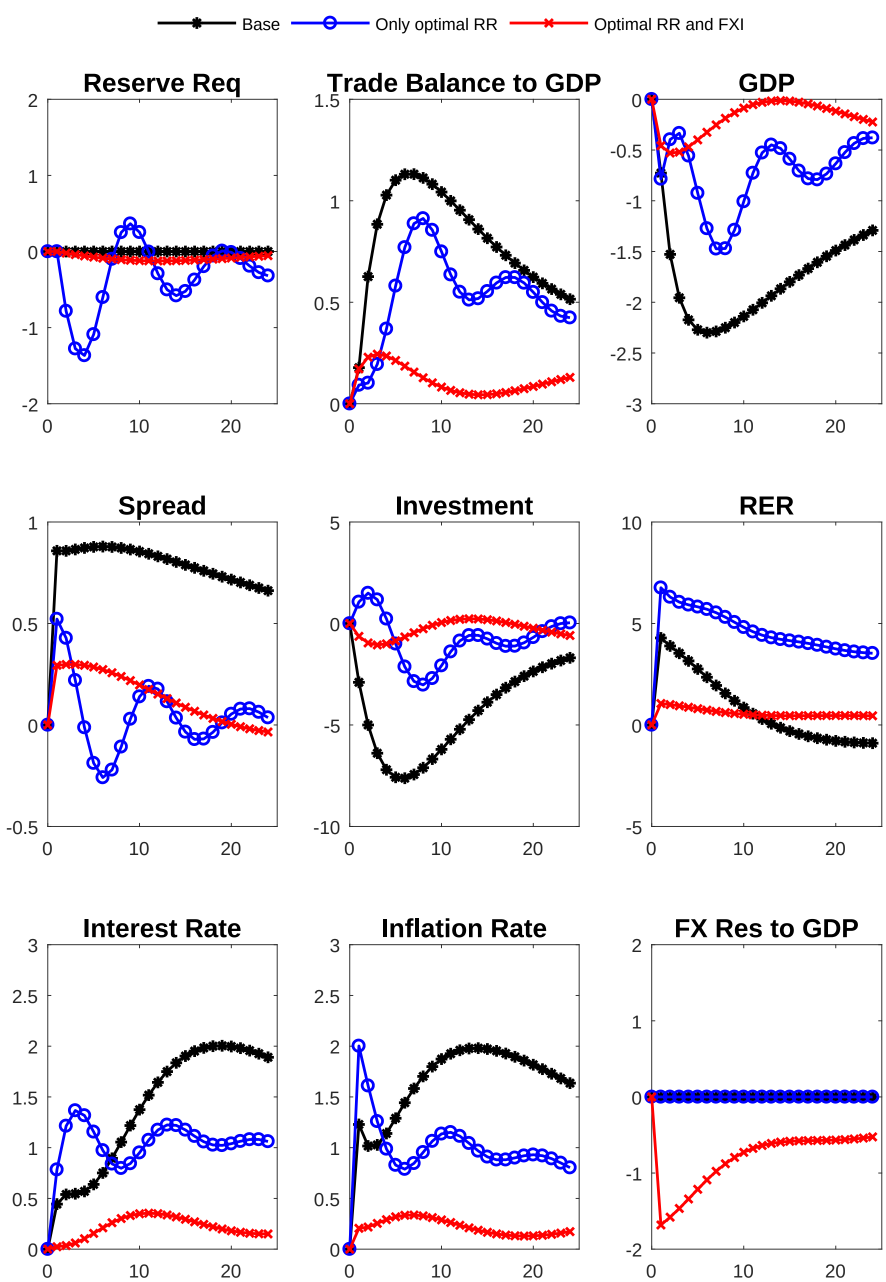


Figure 4: Responses to a risk shock

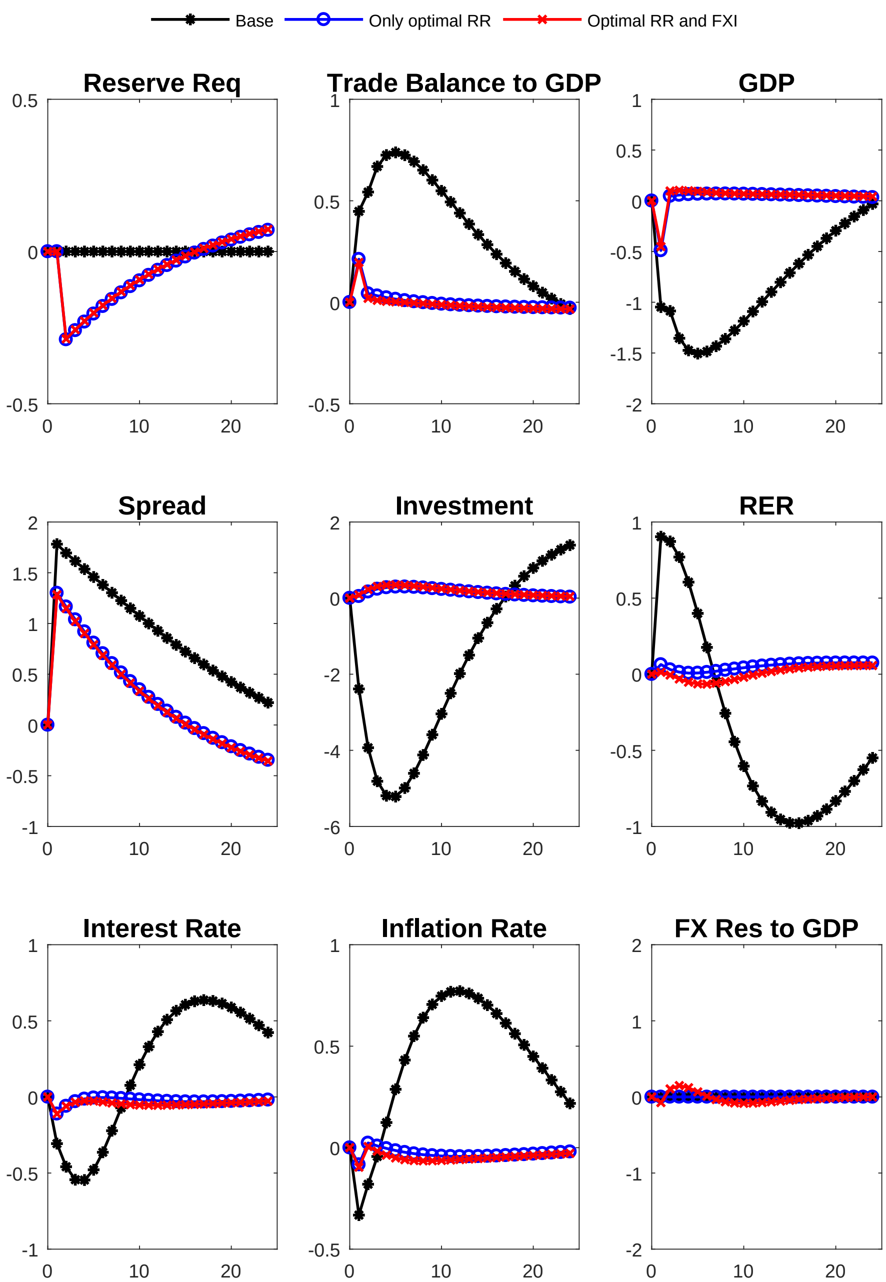


Figure 5: Responses to foreign interest and risk shocks. Expanded rules.

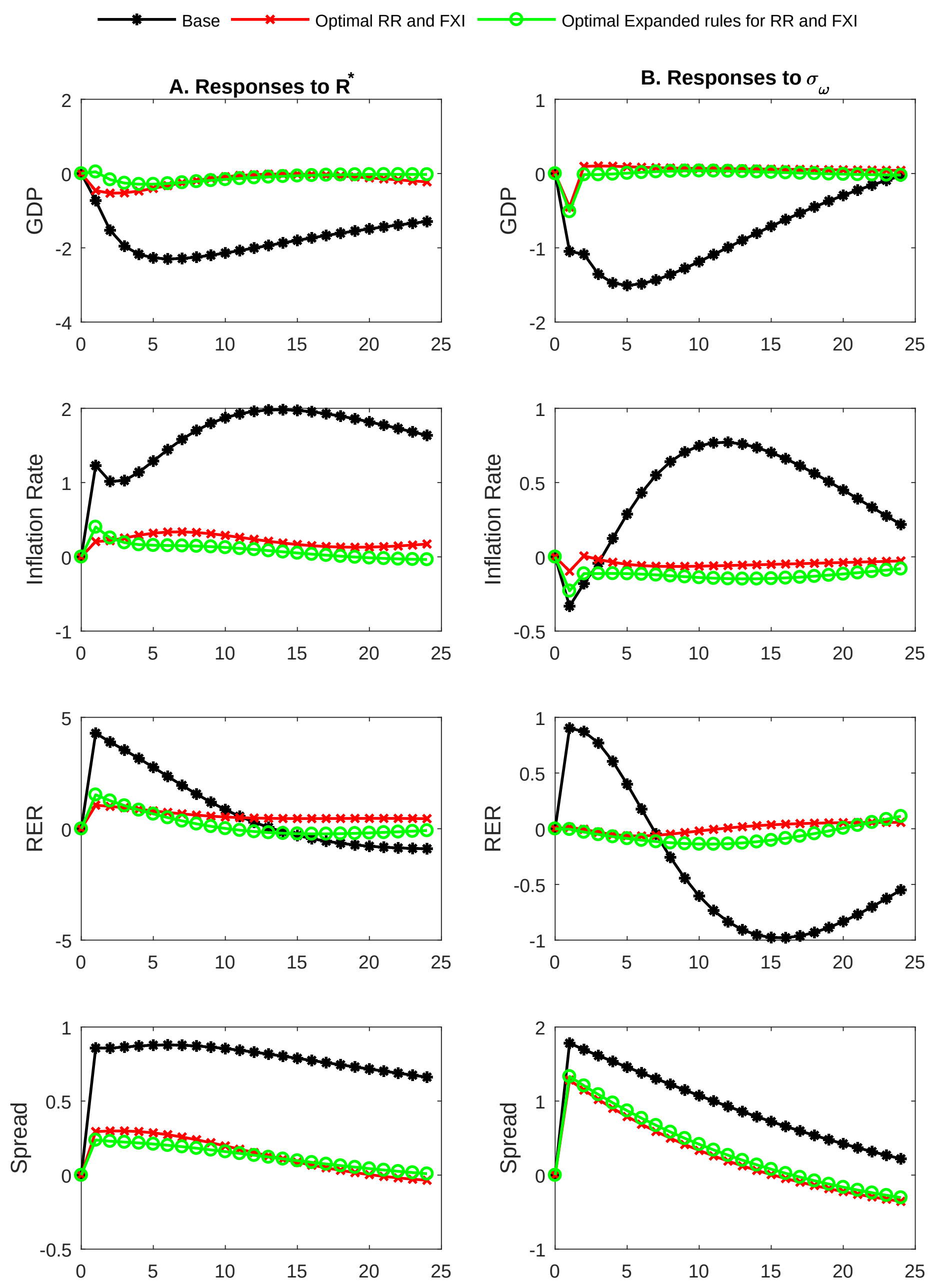


Figure 6: Responses to foreign interest and risk shocks. Differentiated reserve requirements.

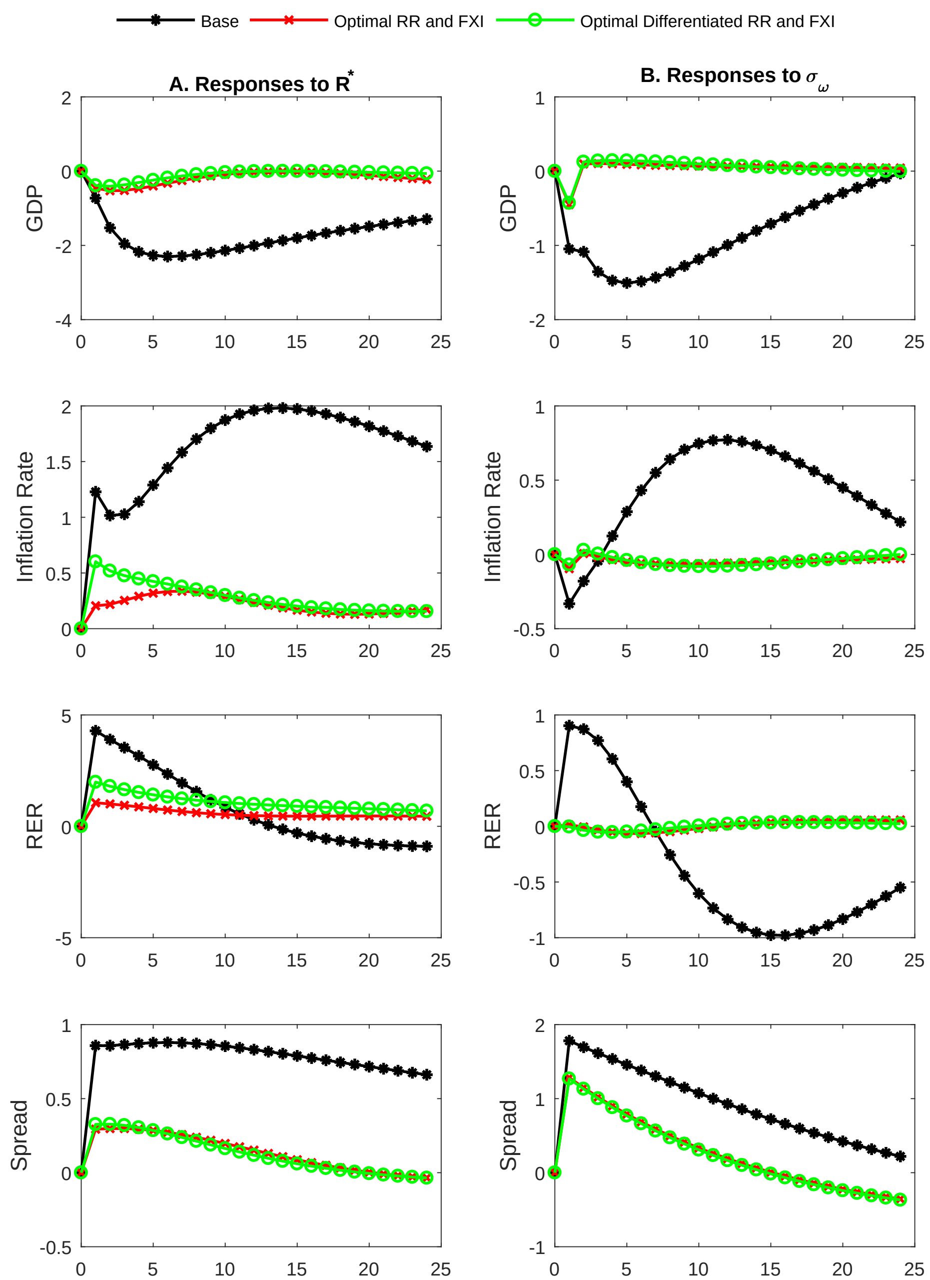


Figure 7: Responses to foreign interest and risk shocks. Rules for capital flow tax and reserve requirement.