Macroprudential Use of Foreign Exchange Interventions

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Abstract

Emerging market economies often face volatile capital inflows, leading to sudden stops and capital flight that necessitate macroeconomic adjustments. The literature on macroprudential policy in this context has focused on the use of capital inflows taxes. However, foreign exchange interventions (FXI) are the most widely used prudential tool. This paper introduces market segmentation in international financial intermediation into a standard macro model of financial crises to examine its impact on optimal policy. The model features a small open economy with incomplete markets and an occasionally binding collateral constraint. The central bank uses FXI to create a wedge between domestic and international interest rates, leading to increased net foreign assets but also carry trade losses. The findings indicate that optimal FXI policy leans against the wind but less aggressively than in the absence of market imperfections, due to the increasing costs of interventions.

Keywords: Sudden Stops, Macroprudential Policy, Foreign Exchange Interventions
JEL Codes: E30, E58, F32, F34, F41

1 Introduction

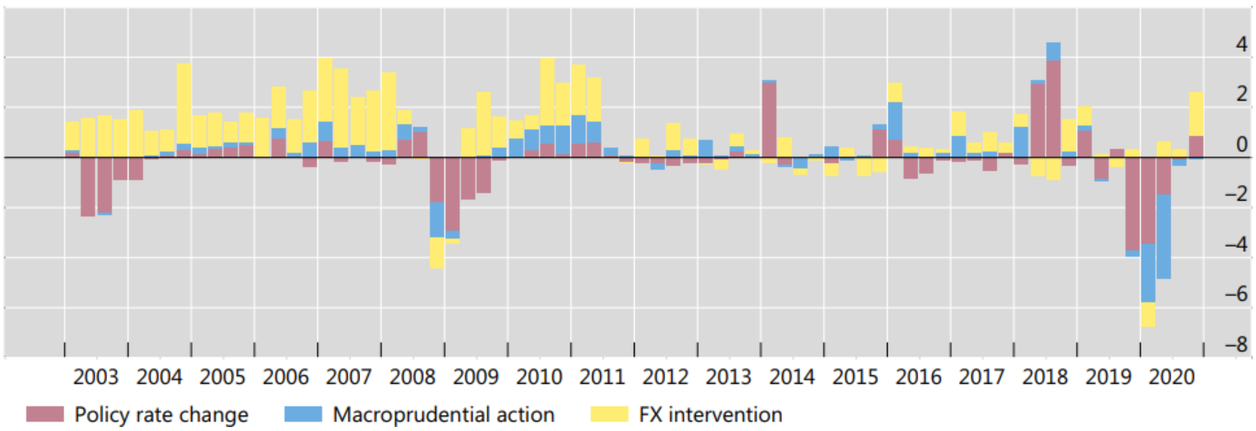
Emerging market economies are often subject to volatile capital inflows. Changes in international financial conditions can lead to episodes of sudden stops and capital flight, imposing the need of implementing macroeconomic adjustments. Moreover, the presence of domestic and international financial frictions amplifies the effects of these external shocks, typically causing deep recessions coupled with currency depreciation.

Governments in emerging markets have resorted to various tools to mitigate the effects of volatile capital flows such as monetary and fiscal policy, macroprudential policy and capital flow management measures (CFMs). In particular, governments have made an extensive use of Foreign Exchange Interventions (FXI) as a prudential tool (Figure 1). However, the literature studying optimal macroprudential policy in this context does not take into account some of the features that make FXI different from a capital inflows tax, the tool that is usually analyzed.

The accumulation of foreign reserves through FXI is different to capital inflows taxes in two relevant dimensions. On one hand, FXI are effective in the presence of frictions in international financial intermediation, usually in the form of inelastic demand for local currency bonds. These imply direct gains for the financial intermediaries or carry trade losses for the local economy. On the other hand, the implementation of the policy can be affected by the reaction of private agents who do not wish to change their asset position. As a consequence, governments' control over the net foreign asset position of the economy is weakened with respect to using capital inflows taxes.

In this paper, I introduce market segmentation in international financial intermediation in an otherwise standard macro model of financial crises and study how optimal policy is affected by this friction. The planner intervenes to correct a pecuniary externality (à la Bianchi (2011)) but has an incentive to smooth interventions over time as they are increasingly costly in size. I find that optimal FXI policy leans against the wind, but less so than when there are no market imperfections. For a standard calibration of the model, I show

Figure 1: Policy Response Intensity in EMEs



Source: Borio et al. (2023)

Policy intensity represented by the average across 17 EMs. Positive (negative) implies tightening (easing) of monetary policy rate, macroprudential tools and accumulation (decumulation) of international reserves.

that the effects of this friction can be quantitatively significant.

The model I consider builds on the workhorse model of capital flows and sudden stops in emerging markets (Mendoza (2002); Bianchi (2011)). It is a model of a small open economy with two sectors, a tradable and a non tradable goods sector. There are incomplete markets and it features an occasionally binding collateral constraint, where the collateral is given by aggregate GDP measured in units of the tradable good. The value of GDP is determined in equilibrium as it depends on the relative price of the two goods in the economy. This generates a pecuniary externality giving rise to inefficient private borrowing in the decentralized equilibrium. In this setup, when the economy receives a negative shock and households hit the borrowing limit, they do not internalize that there is aggregate deleverage which affects the value of collateral and the borrowing limit itself. The literature has found that a social planner can correct this externality by imposing a countercyclical capital inflows tax in this model.

On top of this structure I introduce constrained foreign financial intermediaries *a la* Gabaix & Maggiori (2015). This friction allows the central bank to generate a wedge between domestic and international interest rates through FXI. To accumulate reserves, the government can issue bonds in the local market or tax private agents directly, either way the local bond market will face an excessive supply of bonds that puts upward pressure on the domestic interest rate [1]. With frictionless intermediation no arbitrage opportunity could survive in equilibrium, but as the intermediaries are constrained there will be an equilibrium deviation from interest rate parity. As a consequence, the consolidated economy increases its stock of assets and liabilities in magnitudes such that there is an increase in the net foreign asset position. However, the assets and liabilities have different returns implying a loss when they expire. These are the carry trade losses generated by the initial accumulation of reserves.

In a calibrated version of the model I show that optimal macroprudential policy in this context leans against the wind, but less so than when there are no direct losses of the policy. These costs introduce a smoothing incentive in the optimal policy. To implement larger spreads, the central bank needs to accumulate reserves and sell more domestic bonds. As a consequence losses increase for two reasons, the amount of bonds to be paid increases, and losses per bond are larger given by higher spreads. This implies that interventions are increasingly costly with size, so the planner implements larger spreads when the risk of a sudden stop is lower to avoid states of the world where optimal policy implies larger spreads. I show that the smoothing incentive increases with the elasticity of intermediaries' demand for local bonds[2] and discuss the calibration of the parameter that governs such demand. The baseline calibration considers a value in line with empirical estimates, but simulations of the model are not able to reproduce the levels of reserves in the data and its comovement with other variables. This poses a challenge for this literature as quantitative macroeconomic models need values of this parameter at odds with the empirical estimates.

Related Literature. This paper contributes to two strands of the literature. First it analyses the implementation of optimal macroprudential policy with a different tool, namely the accumulation of international reserves. There is an extensive literature studying opti-

[1]The former way of funding the increased reserves affects bond markets directly, the latter indirectly as private agents will react by increasing their borrowing

[2]Carry trade losses are higher as with a more elastic demand for local bonds, the amount of bonds that need to be sold to implement a given spread is larger.

mal macroprudential policy (Mendoza, 2002; Bianchi, 2011; Korinek & Sandri, 2016) and its implementation with capital inflows taxes and other macroprudential tools like capital requirements or loan-to-value regulations. These papers find that the different macroprudential measures analyzed are complementary to each other and that they should be applied in a countercyclical way. However, empirical studies (Fernández et al., 2015; Borio et al., 2023) have found that there is a limited usage of taxes to capital inflows whereas the accumulation of international reserves is large and widespread across emerging markets.

Recent literature has studied the implementation of optimal macroprudential policy through accumulation of international reserves (Arce et al., 2019; Jeanne & Sandri, 2016; Davis et al., 2023). The closest paper is Davis et al. (2023), who analyze FX interventions in a similar environment with constrained financial intermediaries. Crucially the intermediaries are domestic agents and as a consequence rebate their profits to the domestic economy and there are no losses for the economy as a whole. In this paper the intermediaries are foreign which implies direct losses of reserves accumulation.

The second strand of the literature this paper contributes to is the one studying optimal foreign exchange interventions policy. Jeanne & Rancière (2011) and Durdu et al. (2009) model reserves accumulation as an insurance against sudden stop episodes. Cavallino (2019) study foreign exchange interventions using a linear-quadratic New Keynesian model. Fanelli & Straub (2021) study optimal foreign exchange interventions in a setting where the central bank affects equilibrium allocations for distributional concerns. Adrian et al. (2022) explore how foreign exchange intervention and capital flow management complement each other and help strengthen monetary trade-offs. Hur & Kondo (2016) and Bianchi et al. (2018) consider reserves as a hedging mechanism against rollover risk. With respect to these papers, this one contributes by analyzing optimal foreign exchange interventions policy as an ex-ante tool to prevent or reduce the effects of sudden stop episodes taking into account the explicit losses that it implies.

The rest of the paper is structured the following way. Section 2 presents the model, its central characteristics and the main forces that guide optimal intervention policy. Section

3 shows the results of solving the model for a given calibration, highlighting the main features of the optimal policy functions. Finally, section 4 concludes.

2 Model

2.1 Setup

The structure of the model follows Bianchi (2011). It is a representative agent DSGE model of a small open economy with two sectors, a tradable goods sector and a non-tradable goods sector. Both sectors are modelled as endowments, the tradable goods can be exchanged internationally and the non-tradable goods must be consumed internally. There are three types of agents in the economy: a continuum of identical households of unitary mass, the central bank and foreign financial intermediaries. There are two markets where the agents interact, a domestic bond market and an international one.

Households. The households maximize the infinite sum of future discounted utilities and have preferences represented by a standard CRRA utility function over aggregate consumption.

$$U = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \frac{1}{1-\gamma} c_t^{1-\gamma}$$

Where β is the discount factor, γ the degree of relative risk aversion and c_t is aggregate consumption. The consumption basket is defined as a CES aggregation of tradable (c_T) and non-tradable (c_N) goods with elasticity of substitution equal to $\frac{1}{1+\eta}$.

$$c_t = \left(\omega c_{Tt}^{-\eta} + (1-\omega) c_{Nt}^{-\eta}\right)^{-\frac{1}{\eta}}$$

Households have access restricted to the domestic bond market and the economy faces a collateral constraint which limits how much it can borrow. Their budget constraint is given by:

$$c_{Tt} + p_{Nt}c_{Nt} - b^H_{t+1} = y_{Tt} + p_{Nt}y_{Nt} - R_{t-1}b^H_t + T_t$$

Where the price of tradable goods is normalized to one, p_N is the relative price of non tradable goods, b^H is the debt households issue, y_T and y_N are the endowments of each type of good, R is the gross domestic interest rate and T are transfers that the households receive from the government (taxes if they are negative).

Central bank. The central bank can borrow in both the domestic and the international bond markets. It has also access to lump-sum transfers to the households. Its budget constraint is given by:

$$b^*_{t+1} + b^{CB}_{t+1} = R_t b^{CB}_t + R^*_t b^*_t - T_t \tag{2.1}$$

Where b^* is the amount of foreign bonds the central bank holds, b^{CB} are the domestic bonds the central bank holds and R^* is the international interest rate. I impose that the central bank adds no additional borrowing capacity to the economy[3], in other words the collateral constraint holds for the consolidated borrowing by the domestic economy. I will solve the model imposing that the central bank finances the accumulation of reserves by issuing bonds in the local market ($b^*_{t+1} + b^{CB}_{t+1} = 0$)[4]. This implies that transfers are given by:

$$R_t b^{CB}_t + R^*_t b^*_t = -\tau_{t-1} b^*_t = T_t$$

[3]Absent this assumption the government could circumvent the collateral constraint when it binds like in Chi et al. (2021).

[4]Resorting to lump sum transfers doesn't affect the equilibrium allocations of consumption a net foreign assets of the economy. I discuss in the following section how this choice affects equilibrium private borrowing and the resulting correlation with reserves.

Where τ is defined as the spread between the domestic and the international interest rate.

Occasionally binding collateral constraint. The collateral constraint is given by:

$$-b_{t+1}^{H} - b_{t+1}^{*} - b_{t+1}^{CB} \geq -\kappa_t \bigg(y_{Tt} + p_{Nt} y_{Nt} \bigg)$$

The borrowing limit is defined as a fraction κ of the value of current income. The credit constraint captures the empirical fact that current income is relevant for access to credit markets and has been shown to be important to account for the dynamics of capital flows in emerging markets (Mendoza, 2002).

Financial intermediaries. These are foreign agents modelled as in Fanelli & Straub (2021). There is a continuum of financial intermediaries with heterogeneous participation cost (j) and position limits (X).

$$\max_{b_{t+1}^{I}} V_t = (R_t - R_t^{*})(-b_{t+1}^{I}) - j(-b_{t+1}^{I})$$

Investing is optimal for all investors such that their cost is lower than some threshold. As the their objective function is linear the marginal financier has cost equal to the interest rate spread. Defining $\Gamma = X^{-1}$

$$b_{t+1}^{I} = -\frac{1}{\Gamma}(R_t - R_t^{*}) = -\Gamma^{-1}\tau_t \tag{2.2}$$

Equation (2.2) represents the optimal demand of domestic bonds. A positive interest rate spread induces the intermediaries to buy local bonds, as long as $\Gamma > 0$. This demand is inelastic and the no-arbitrage condition doesn't hold giving rise to endogenous UIP deviations. Given a spread, the larger Γ, the lower the intermediaries' demand.

Carry trade losses. For each unit of domestic bonds the intermediaries hold, they make net earnings equal to the interest rate spread. This implies that the total amount of profits they make in equilibrium is given by $\Gamma^{-1}\tau_t^2$. As these agents are foreigners these profits translate into losses for the domestic economy.

2.2 Optimality conditions and equilibrium

Household optimization and pecuniary externality. Taking as given the central bank policy, the first order conditions of the household problem are the following.

$$\frac{1-\omega}{\omega}\left(\frac{c_{Tt}}{c_{Nt}}\right)^{1+\eta} = p_{Nt} \tag{2.3}$$

$$u_T(c_t) = \beta R_t \mathbb{E}_t u_T(c_{t+1}) + \mu_t \tag{2.4}$$

$$c_{Tt} + p_{Nt}c_{Nt} - b_{t+1}^H = y_{Tt} + p_{Nt}y_{Nt} - R_{t-1}b_t^H + T_t \tag{2.5}$$

$$-b_{t+1}^H - b_{t+1}^* - b_{t+1}^{CB} \geq -\kappa_t\Big(y_{Tt} + p_{Nt}y_{Nt}\Big) \tag{2.6}$$

The first condition represents the optimal relative demand of tradabale to non-tradable goods, given by the CES structure of the consumption aggregator. Equation (2.4) is the Euler equation, where $u_T(c_t)$ is short hand for $\frac{\partial u(c_t)}{\partial c_t}\frac{\partial c_t}{\partial c_{Tt}}$ and μ_t is the Lagrange multiplier associated with the credit constraint. This multiplier is equal to zero whenever equation (2.6) is not binding, and positive otherwise.

The interaction of equations (2.3), (2.5) and (2.6) show the effects of the pecuniary externality in this economy. Households don't internalize the effect of their consumption choices on the value of collateral. This implies that when the economy receives a shock that makes the credit constraint binding, households are forced to deleverage but don't internalize that there is aggregate deleveraging. As a consequence non-tradable prices and the value of collateral decrease, which makes households deleverage even more.

Market clearing conditions and equilibrium. There are two markets that need to clear in this economy, the non-tradable goods market and the domestic bond market.

$$c_{Nt} = y_{Nt} \tag{2.7}$$

$$b^H_{t+1} + b^{CB}_{t+1} + b^I_{t+1} = 0 \tag{2.8}$$

An equilibrium in this economy is defined by a sequence of allocations $\{c_{Nt}, c_{Tt}, b^H_{t+1}, b^I_{t+1}\}$ and prices $\{R_t, p_{Nt}\}$ that given an initial level of debt positions $\{b^H_1, b^I_1, b^{CB}_1, b^*_1\}$, and intervention policy by the central bank $\{b^{CB}_{t+1}, b^*_{t+1}, T_t\}$ and a path of the shocks $\{\kappa_t, y_{Nt}\}$ solves simultaneously equations (2.2)-(2.8).

Equilibrium characterization. Combining equations (2.2), (2.5), (2.7) and (2.8) we obtain the economy's resource constraint.

$$a_{t+1} = y_{Tt} - c_{Tt} - R^*_{t-1} a_t - \Gamma^{-1} \tau^2_{t-1}$$

Where a_t is the net foreign asset position of the economy (equal to $-b^H_t - b^{CB}_t - b^*_t$). The last term in this expression reflects that if interest rate spreads are realized in equilibrium the economy suffers carry trade losses.

Using the market clearing condition for the non-tradable good, and the optimal relative demand we get that in the equilibrium to credit constraint is given by:

$$-b^H \geq -\kappa \left[y^T + \frac{1-\omega}{\omega} \left(\frac{c_T}{y^N} \right)^{1+\eta} y^N \right]$$

2.3 Social planner's problem

The central bank is the social planner in this economy. It will increase welfare in the economy by internalizing the effects that individual consumption choices have on the value of collateral. The tool the central bank has to affect allocations in the economy is the accumulation of reserves.

Reserves accumulation. The accumulation of reserves is financed through an increase in the supply of bonds in the domestic market, which puts an upward pressure in the local interest rate[5]. A spread is sustained in equilibrium as the intermediaries cannot arbitrage away this difference and as consequence the economy suffers a carry trade loss in the following period. Households change their consumption-saving decision through two effects, borrowing becomes more expensive and future income is lower, both push households to marginally save, increasing the economy's net foreign asset position.

The problem of the planner is given by

$$\max_{c_t^T, \tilde{a}_{t+1}, a_{t+1}, \tau_{t+1}, \mu_t} \sum_{t=0}^{\infty} \beta^t U(c(c_t^T, y^N))$$

$$y_t^T - c_t^T + \tilde{a}_t - a_{t+1} = 0 \qquad (\hat{\lambda}_t)$$

$$u_T(c_t) = \beta(R_t^* + \tau_{t+1})\mathbb{E}_t u_T(c_{t+1}) + \mu_t \qquad (\hat{\xi}_t)$$

$$\tilde{a}_{t+1} + \Gamma^{-1}\tau_{t+1}^2 - R_t^* a_{t+1} = 0 \qquad (\hat{\nu}_t)$$

$$a_{t+1} \geq -\kappa_t \left[y_t^T + \frac{1-\omega}{\omega} \left(\frac{c_t^T}{y^N} \right)^{1+\eta} y^N \right] \qquad (\hat{\mu}_t)$$

$$0 = \mu_t \left[- a_{t+1} - \kappa_t \left[y_t^T + \frac{1-\omega}{\omega} \left(\frac{c_t^T}{y^N} \right)^{1+\eta} y^N \right] \right] \qquad (\hat{\chi}_t)$$

$\tilde{a}$ are resources in hand (the relevant state variable that the planner can choose), is given by the return on the net foreign asset position ($R^* a$) minus the carry trade losses ($-\Gamma^{-1}\tau^2$). The rest of the constraints are the credit constraint (where the planner incorporates how prices are affected by the consumption choices), the resource constraint, and the private Euler equation as the central bank internalizes how private agents will react to a given intervention. Note that whenever the collateral constraint binds the private Euler equation doesn't, and vice-versa.

[5] The central bank could finance the accumulation of reserves with with lump-sum taxes from the households. That case would imply a different amount of private debt, but the effects on the net foreign asset position and private consumption would remain the same

2.4 Prudential motive versus intervention smoothing

Combining the first order conditions we get to the following expression for the social planner's Euler equation.

$$\begin{aligned} u_T(c_t) =& \beta R_t^* \mathbb{E}\Bigg(u_T(c_{t+1}) + \Psi_{t+1}\hat{\mu}_{t+1} \\ & - \hat{\xi}_{t-1}(R^* + \tau_t) u_{TT}(c_t) + \hat{\xi}_t[(R^* + \tau_{t+1}) u_{TT}(c_{t+1}) + u_{TT}(c_t)] - \hat{\xi}_{t+1} u_{TT}(c_{t+1}) \Bigg) \end{aligned}$$

Where Ψ is the derivative of the collateral constriant with respect to tradable consumption[6] and $c_{\tilde{a}}$ is the derivative of the consumption policy function with respect to $\tilde{a}$. The term $\hat{\mu}_{t+1}\Psi_{t+1}$ in the first line captures the pecuniary externality effect, which has the same features as the one in Bianchi (2011), as households don't internalize this effect they are over-borrowing in the absence of an intervention by the central bank.

The additional terms in the expression capture how private agents react to the central bank's intervention, and give rise to a smoothing incentive in the interventions policy. The reason why this effects arises is that the planner maximizes subject to the household's Euler equation as an implementability constraint. This constraint is not satisfied trivially as it implies that an intervention at time t has effects on three periods. At 't' it has the straightforward effect of reducing the level of current consumption. This relaxes the implementability constraint at 't-1', households in the previous period are willing to reduce borrowing given the lower consumption at 't'. On the other hand, a lower level of current today increases the level of assets the following period, relaxing the implementability constraint at 't+1'. Even if there is no probability of a binding constraint in the next period the planner has an incentive to intervene, as this way it improves the asset position of the future planner who may face a higher risk of a binding constraint and need to intervene more. This incentive towards smoothing interventions is reminiscent to the one analyzed

[6]Its expression is given by: $\Psi = (1+\eta)\kappa\frac{1-\omega}{\omega}(c_T/y^N)^\eta$

in Fanelli & Straub (2021).

3 Quantitative exercise

To study how the macroprudential motive to intervene and the smoothing incentive interact with each other I analyse and compare three scenarios. A benchmark economy, where the central bank intermediates on behalf of households and fixes interest rate spreads to zero, and two economies where the planner implements the constrained efficient allocation facing different degrees of financial frictions. The first scenario (benchmark economy) is equivalent to the decentralized equilibrium in an economy with no frictions in international financial markets (with zero spreads the value of Γ turns irrelevant) and the domestic and international interest rates equal each other. The second scenario features a level of frictions such that there are no carry-trade losses ($\Gamma \to \infty$). This scenario resembles one where market imperfections are absent and the planner fully corrects the pecuniary externality. Finally, in the last scenario there are market imperfections (Γ is calibrated to a finite number) and optimal policy balances welfare gains of correcting the pecuniary externality with the losses from carry trade.

3.1 Calibration

With the exception of the demand elasticity of intermediaries (Γ), I follow the calibration proposed by Arce et al. (2019) who calibrate their model to the mexican economy in the period from 1980 to 2015. Providing a quantification of the demand elasticity of the financial intermediaries is challenging for several reasons. This parameter may vary across states of the economy or markets. For example, we would expect it to be higher during a financial crisis, or lower in liquid markets. The recent literature relates it to the risk bearing capacity of the financial intermediaries, drawing a connection with the volatility of exchange rates (when this risk is not hedged) and the monetary regime. I abstract from these considerations and take it as a fixed parameter of the economy as it allows the discussion over the main differences that they print into the optimal policy in this context. I take as baseline calibration a value of 1 taken from Broner et al. (2021), and as an alternative calibration I consider a higher value of 5[7].

	Value
Interest Rate	$R^* = 1.04$
Risk Aversion	γ=2
Elasticity of Subsitution	1/(1+η)=0.83
Weight on Tradables in CES	ω=0.33
Stochastic structure y^T	$\rho^y = 0.24$, σ^y=0.034
Stochastic structure κ	$\rho^k = 0.82$, σ^k=0.11, $\bar{\kappa}$=0.46
Discount Factor	β=0.94
Intermediaries demand elasticity	Γ=[1,5]

Table 1: Calibrated parameters

3.2 Results

The presence of this friction affects substantially the constrained efficient allocation. The welfare gains of implementing the optimal policy, relative to the 'zero-spreads' policy, are reduced by roughly 50% for the calibration considered.

Policy functions. The optimal spread policy function implies countercyclical interventions (Figure 2). As the exposure to the risk of the collateral constraint becoming binding increases (lower net foreign assets or share of income that can be used as collateral) the planner intervenes more. This resembles the usual result of a countercyclical capital inflows tax due to macroprudential reasons.

The optimal policies in the two scenarios with high and low degree of financial frictions cross each other. In the segmented markets scenario, the social planner implements lower spreads when the risk is high and vice-versa when risk is low. This comes as consequence of the smoothing incentive mentioned earlier, the planner avoids large interventions as these are increasingly costly.

[7]See Maggiori (2022) for a deeper discussion on the nature and estimation of this parameter.

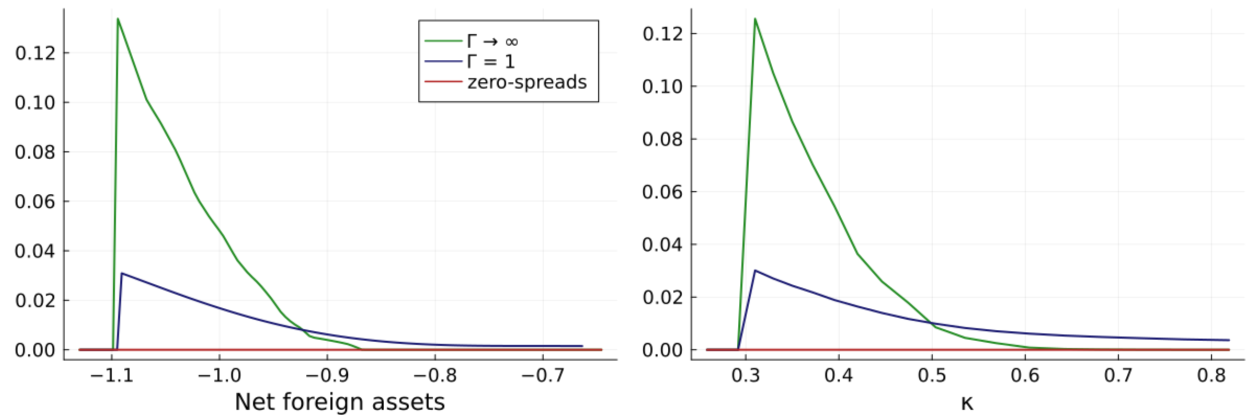


Figure 2: Spread policy function

A similar pattern can be observed in the policy functions of consumption and net foreign assets position (Figure 3). Comparing with the zero-spreads policy, the planner implements higher levels of net foreign assets over the whole state space. Relative to the scenario with no carry trade losses it implements slightly higher levels of net foreign assets when the risk of a binding constraint is low, but lower levels when the risk high.

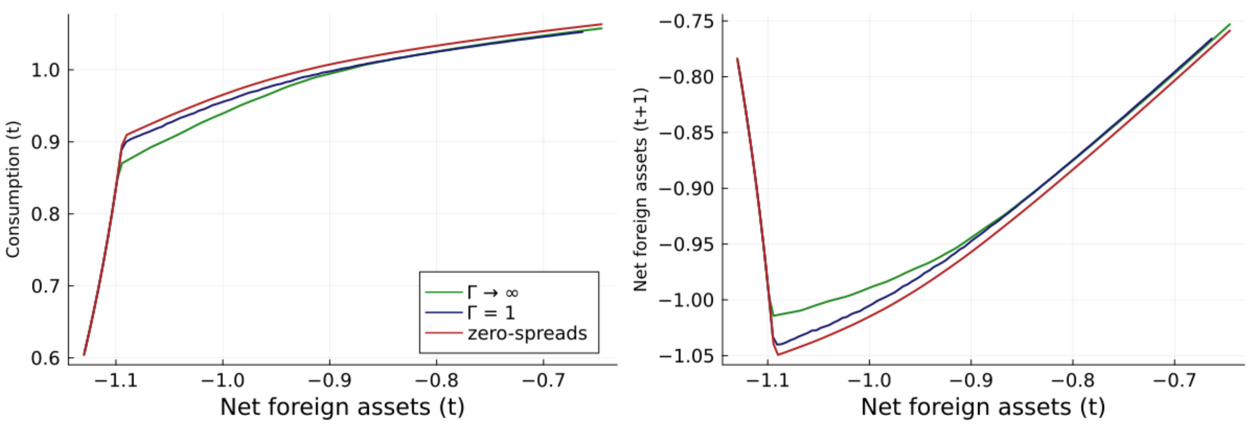


Figure 3: Consumption and savings policy functions

Ergodic Distributions. The distribution of net foreign assets of the economy with imperfect markets lies in between the other two scenarios. Moving to interest rate spreads, the planner in the economy with imperfect markets intervenes more frequently (73% vs 56%), but the size of interventions is smaller (right panel of Figure 4[8]).

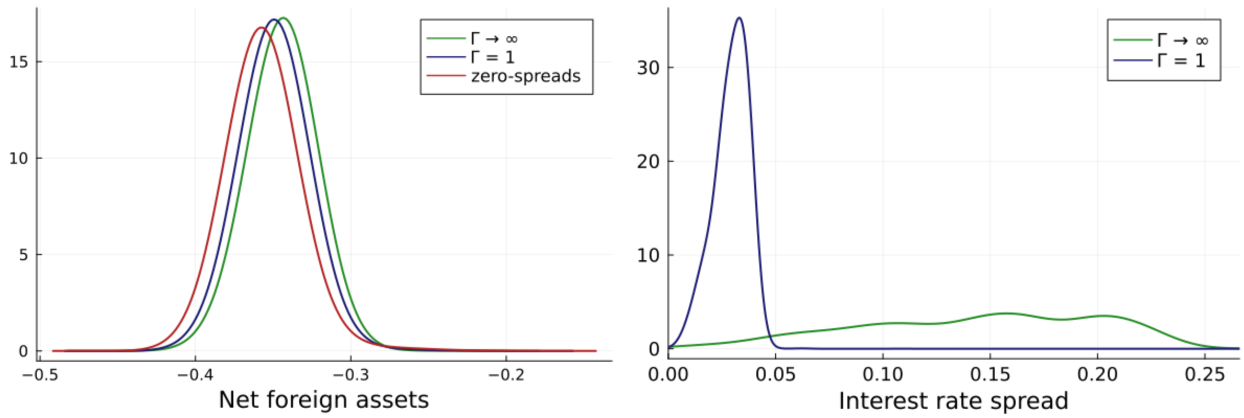


Figure 4: Ergodic Distributions

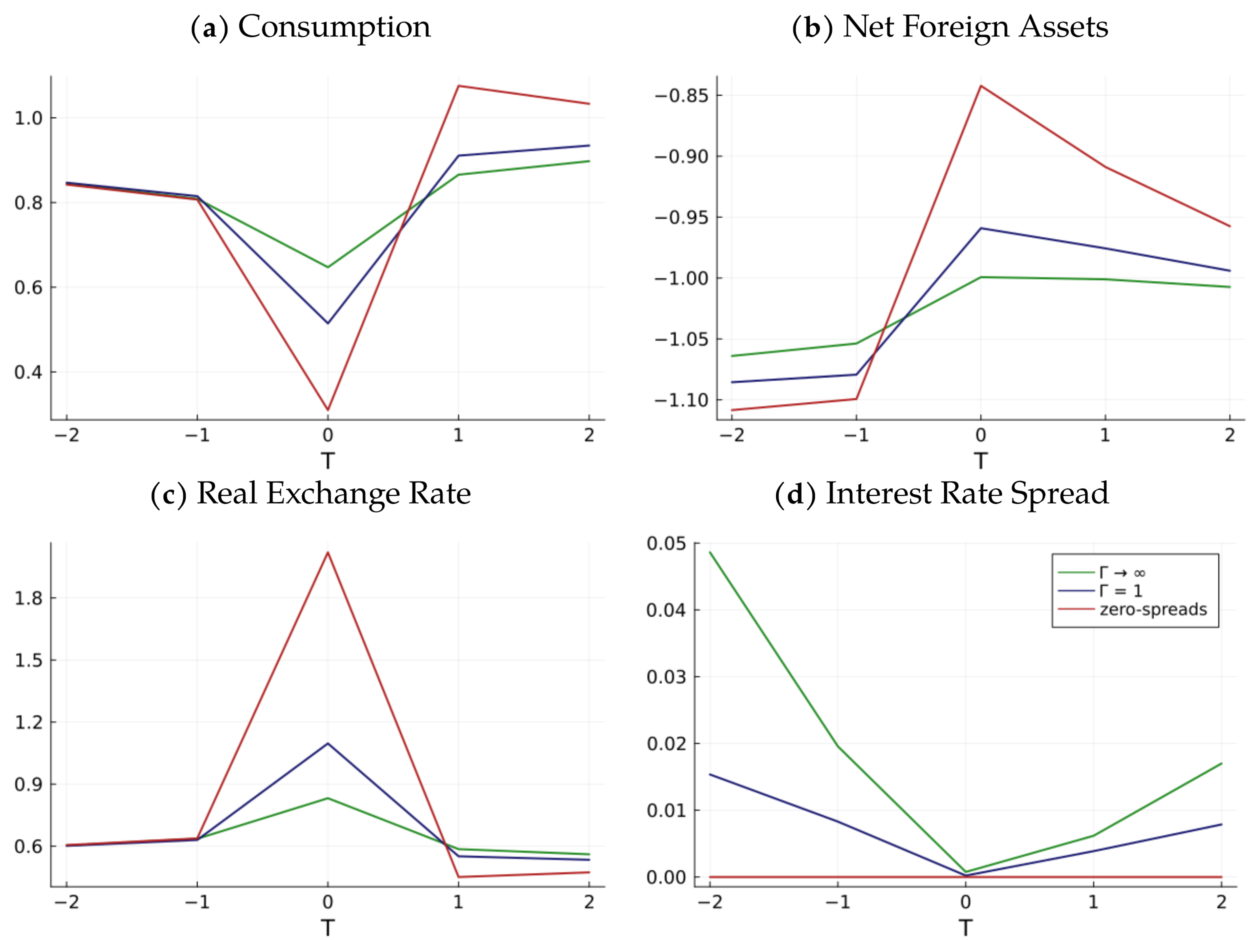
3.3 Discussion

Sudden Stops. To study the financial stability gains and how the optimal policy behaves around sudden stops I perform the following event study analysis. First, I simulate the economy given the same path of the shocks under the three scenarios. Second, I identify episodes of sudden stops as moments where the current account rises over two standard deviations in the 'zero-spreads' simulation. Then, I compute the average of equilibrium variables for the three scenarios over a window of five periods around the sudden stop. Figure 5 shows the results.

Notably, the blue and green scenarios (those with optimal policies) reduce the incidence of the financial crises. The planner is able to sustain higher levels of consumption given the higher level of net foreign assets with which the economy receives the shock that triggers the crisis episode. As a consequence of the response of consumption, the real exchange rate is more volatile around the crisis in the scenario with no interventions. Note that the reduction in such volatility is a consequence of the ex-ante macroprudential role of reserves, which allows the economy to face these shocks with a better financial stance. This is different from the ex-post role to avoid excessive depreciation of the currency that

[8] The right panel of Figure 4 shows the density of interventions conditional on them being positive.

Figure 5: Sudden Stops under the three scenarios



reserves have in models with nominal rigidities.

Comparing the scenarios with optimal policies but different local bond demand elasticity we see that the evolution is similar around the sudden stop episode. Even with smaller interventions, the planner that faces a more elastic demand manages to avoid most of the negative effects of the crisis. This highlights the usefulness of macroprudential tools in a context where market imperfections imply direct costs to their implementation (foreign exchange interventions with carry-trade losses in this context).

Sensitivity to Γ. I solve the model for a larger value of Γ to analyze how the optimal policy is modified. The main changes can be seen in Figure 6 where I reproduce the policy function plots for the interest rate spread. Increasing Γ reduces the carry trade losses without modifying the prudential motive for intervention, which is given by the pecuniary externality. As a consequence, the planner is willing to produce larger interventions when the probability of a future crisis is higher.

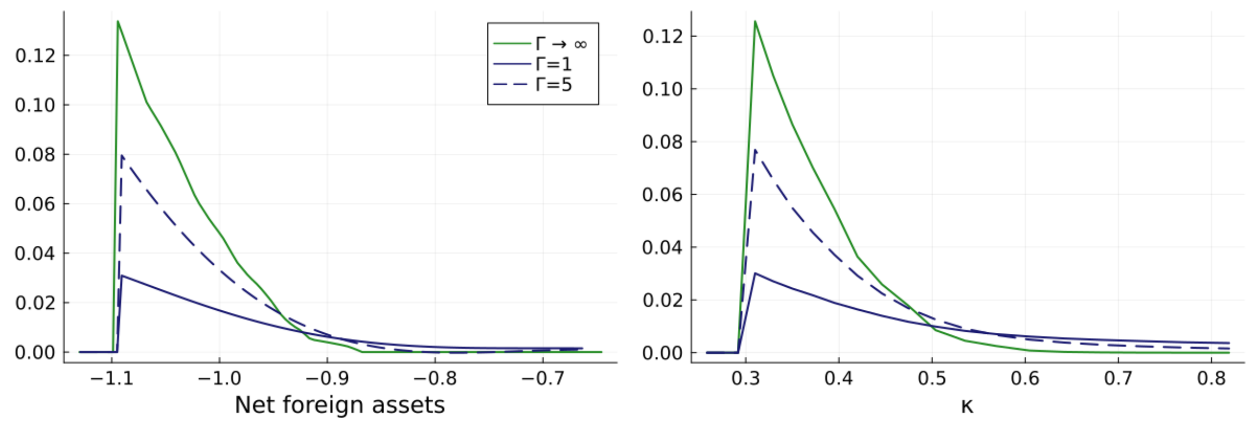


Figure 6: Spread policy function

This result helps to build intuition on what the optimal policy would be in the presence of a varying Γ. In particular, it is reasonable to assume that this parameter increases close to the occurrence of financial crises, reducing the costs of larger interventions and allowing the planner to implement high spreads when they are most desirable. In other words, a countercyclical value of Γ should reduce the incentives to smooth interventions.

Optimal Reserves to GDP ratio. The long run level of reserves to GDP ratio is only 0.6% in the model with $\Gamma = 1$ or 0.3% with $\Gamma = 5$. This is well below the levels in the data (around 10% for a sample of emerging countries from 1980-2015) suggesting a lower value for Γ. A lower Γ implies that given an interest rate spread, the carry trade losses are higher and the quantity of reserves required to implement it is larger. The planner chooses smaller spreads close to crises, but the amount of reserves accumulated to generate them is higher. Moreover, it intervenes more frequently, implementing larger spreads when the risk of a crisis is low.

In a similar model (where the financiers are domestic and there are no carry-trade losses) Davis et al. (2023) use a value of 0.05 and get a steady state level of reserves of 8%, Adrian et al. (2022) calibrate this parameter to 0.06 for emerging markets to match a 20% steady state level of reserves in a model where FXI are used to prevent sudden stops [9]. Figure 7 shows the results of solving the model for several values of Γ in terms of the long run level of reserves over GDP. The results suggest that a smaller value of Γ would move the model's results closer to the data. As discussed in the baseline calibration of the model, the empirical studies that estimate this parameter place it at higher values. Of course, the accumulation of reserves in the data is not only driven by macroprudential reasons, but the results given by the simulated model are an order of magnitude smaller than in the data. This poses a challenge to the literature, quantitative macroeconomic models require values of Γ that are not supported by the empirical estimations.

[9] The literature that studies the role of reserves as a hedging mechanism for sovereign debt risk is able to support a level of 3%-6% (see Corsetti & Maeng (2023), Bianchi et al. (2018))

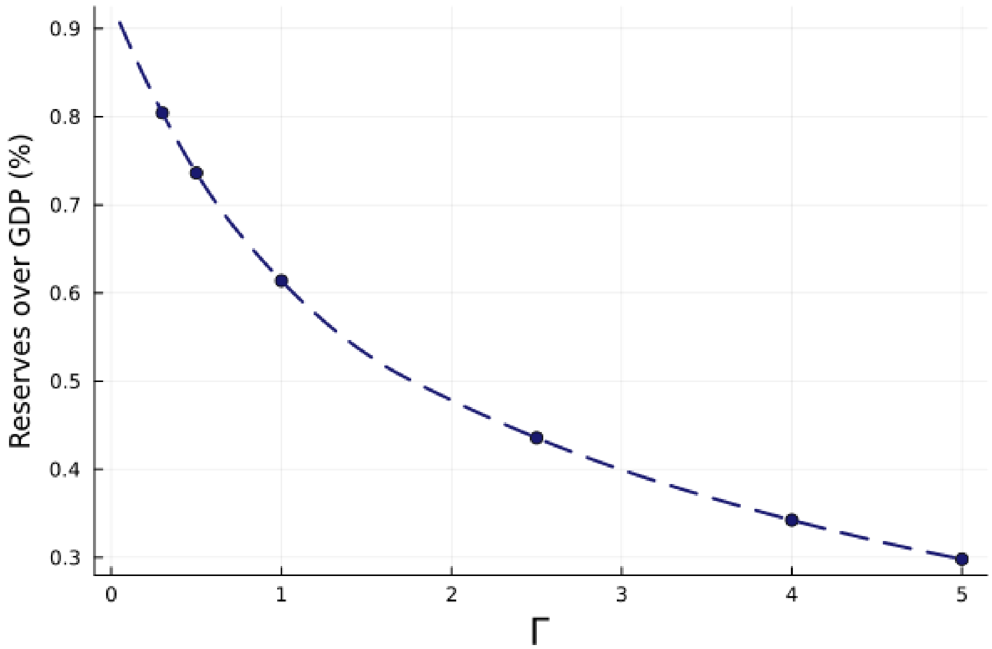


Figure 7: Long Run level of Reserves

Reserves and Private Debt. Arce et al. (2019) highlight the fact that private debt and reserves are positively correlated. To reproduce this empirical fact in my model I need to discuss how the accumulation of reserves is funded. Until now it was irrelevant if the government sold domestic bonds or raised lump-sum taxes. However, if the government only sells bonds the model predicts a negative association as there is a crowding-out of the private borrowing. If the government uses lump-sum taxes we get that private agents will increase their borrowing[10].

To test this implications quantitatively in the model I simulate the economy and estimate equation (3.1), where a_{it}, b_{it} and x_{it} are the stock of reserves, private external debt and the current account balance for simulated data coming from the model. This exercise is also

[10]The only allocations that are affected by the choice of how to finance foreign exchange interventions are central bank's and households' domestic bond holdings. The rest of the equilibrium objects are invariant to this choice. Denote $\{\tau^\star, \tilde{a}^\star, a^\star, c^{T\star}\}$ the corresponding equilibrium levels of these variables. Domestic bonds issuance $(-b^{I\star})$ can be backed out from the intermediaries demand for local bonds (2.2) and depending on how the central bank finances the accumulation of reserves this will be equal to central bank's debt or be part of the private agent's stock of debt. Finally, using the net foreign assets identity we get the level of reserves.

performed in the data to take as reference[11][12].

$$\Delta a_{it} = \alpha_i + \alpha_t + \beta \Delta b_{it} + \gamma x_{it} + \varepsilon_{it} \tag{3.1}$$

Table 2: Regression results

	Data	$\Gamma = 0.5$	$\Gamma = 1$	$\Gamma = 5$
Private Ext Debt	0.184	0.216	0.088	0.035
	(0.007)	(0.000)	(0.000)	(0.000)
Current Account	0.253	0.024	0.006	-0.013
	(0.000)	(0.038)	(0.508)	(0.000)

The results in table 2 show that the model fails to replicate the data in the baseline calibration. However, results are closer to the data for a lower value of Γ. Overall, the model requires a lower calibrated value of Γ than the one suggested by the evidence provided by the empirical literature.

4 Conclusions

Emerging market economies are often subject to volatile capital inflows. Governments in these markets have resorted to various tools to mitigate the effects of volatile capital flows but the main one in terms of the frequency it is used are foreign exchange interventions. However, the literature studying optimal macroprudential policy in this context doesn't take into account some of the features that make FXI different from a capital inflows tax, the tool that is usually analyzed.

[11] The countries are selected by the following criteria. First, they need to be not classified as 'Advanced economies' nor 'Low income countries' by the IMF or the World Bank respectively. They need to have no missing data in the International Debt Statistics, the WEO and in the Lane & Milesi-Ferretti (2018) database. Finally, countries that have a net foreign asset position above or below 150% are excluded. This leaves us with 23 countries.

[12] The data for private external debt measure comes from the International Debt Statistic and corresponds to the non publicly guaranteed external debt. GDP, Current Account and International Reserves are taken from the updated dataset constructed by Lane & Milesi-Ferretti (2018). The sample goes from 1980 to 2015.

In this paper, I study the optimal macroprudential policy when such is implemented with foreign exchange interventions. I introduce a friction in international financial intermediation in an otherwise standard model of a small open economy that faces the risk of financial crises. The friction is such that the central bank is able to drive a wedge between the domestic and world interest rates through the implementation of FXI. This wedge implies carry trade losses for the domestic economy, which are not present when macroprudential policy is implemented through capital inflows taxes.

The carry-trade losses are more than linearly increasing with the size of interventions. This introduces a smoothing incentive in the optimal policy, the planner intervenes not only to reduce the severity of the crises (correcting the pecuniary externality), but also to avoid those states of the world where interventions are large. As a consequence, I find that the optimal FXI policy leans against the wind, but less so than when there are no market imperfections. For a standard calibration of the model, I show that the effects of this friction can be quantitatively significant.

I show that the smoothing incentive increases with the elasticity of intermediaries' demand for local bonds and discuss the calibration of the parameter that governs such demand. The baseline calibration considers a value in line with empirical estimates, but simulations of the model are not able to reproduce the levels of reserves in the data and its comovement with other variables. This poses a challenge for this literature as quantitative macroeconomic models require a value of this parameter at odds with the empirical estimates.

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Appendix

A Appendix

A.1 Derivation of Euler equation of social planner

The first order conditions of the Social Planner's problem are given by

$$\hat{\lambda}_t = u_T(c_t) + \hat{\xi}_{t-1}(R^* + \tau_t)u_{TT}(c_t) - \hat{\xi}_t u_{TT}(c_t) + \Psi_t(\hat{\mu}_t - \hat{\chi}_t \mu_t) \qquad (c_t^T)$$

$$\beta \mathbb{E} \hat{\lambda}_{t+1} + \hat{\nu}_t = 0 \qquad (\tilde{a}_{t+1})$$

$$\hat{\lambda}_t = -R_t^* \hat{\nu}_t - \hat{\mu}_t - \mu_t \hat{\chi}_t \qquad (a_{t+1})$$

$$\hat{\xi}_t \beta \mathbb{E}_t u_T(c_{t+1}) = \hat{\nu}_t 2\Gamma^{-1}\tau_{t+1} \qquad (\tau_{t+1})$$

$$\hat{\xi}_t = \hat{\chi}_t \left[- a_{t+1} - \kappa_t \left[y_t^T + \frac{1-\omega}{\omega} \left(\frac{c_t^T}{y^N} \right)^{1+\eta} y^N \right] \right] \qquad (\mu_t)$$

Now to derive the social planner's Euler equation

$$\hat{\lambda}_t = \beta R_t^* \mathbb{E} \hat{\lambda}_{t+1} - \hat{\mu}_t - \mu_t \hat{\chi}_t$$

Assuming that the borrowing constraint is currently slack and substituting the expression for $\hat{\lambda}$:

$$\begin{aligned} u_T(c_t) =& \beta R_t^* \mathbb{E} \bigg(u_T(c_{t+1}) + \Psi_{t+1} \hat{\mu}_{t+1} \\ & - \hat{\xi}_{t-1}(R^* + \tau_t) u_{TT}(c_t) + \hat{\xi}_t [(R^* + \tau_{t+1}) u_{TT}(c_{t+1}) + u_{TT}(c_t)] - \hat{\xi}_{t+1} u_{TT}(c_{t+1}) \bigg) \end{aligned}$$