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小型開放經濟的資本移動與總體審慎政策

Capital Flows and Macroprudential Policy in a Small Open Economy

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小型開放經濟的資本移動與總體審慎政策
Capital Flows and Macroprudential Policy in a Small Open Economy

本論文係吳柏萱君（學號 R06323001）在國立臺灣大學經濟學系完成之碩士學位論文，於民國 108 年 7 月 12 日承下列考試委員審查通過及口試及格，特此證明

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摘要

本文以動態隨機一般均衡(DSGE)模型探討小型開放經濟體的貨幣政策與總體審慎政策制定，模型設定在新興凱因斯的架構下，國內的異質家戶可以同時持有本國資產或外幣資產，國際經濟情勢變化所造成的外生衝擊透過外國利率或匯率的變動影響本國經濟，政府通過發行貨幣或發行公債融通調整外匯存底所需的財源，在價格僵固、本國與外國資產間的不完全替代、以及不完全市場的設定下，從福利分析的角度而言，針對資本移動設計的總體審慎政策能夠提升整體的福祉，但也會造成不同家戶間的分配效果，使得政策的制定面臨取捨。此時貨幣政策除了考量通貨膨脹和產出之外，若是納入反映對外曝險的金融變數，雖然從最適的角度而言並非最佳，但若與總體審慎政策配合進行，則能夠消弭前述分配效果對部分家戶造成的損失，達到整個經濟體的柏拉圖改善(Pareto Improvement)。

關鍵詞：總體審慎政策；貨幣政策；小型開放經濟；動態隨機一般均衡；外匯存底；國際金融

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Abstract

This paper studies the design of monetary and macroprudential policies in a small open economy featuring borrowing and lending denominated in both local and foreign currency using a monetary dynamic stochastic general equilibrium (DSGE) model under the New Keynesian framework. The model economy is characterized by nominal rigidities, imperfect asset substitutability, and incomplete markets in which two types of domestic agents differing in their patience toward the future trade one-period nominal bonds with the rest of the world. In addition to the explicit modeling of the central bank's balance-sheet decisions concerning its foreign reserve holding and domestic money and government bond issuance, this paper evaluates two types of macroprudential policies, one currency-based and one residency-based, alongside alternative monetary policy rules. We calibrate the model to generate empirically documented patterns of policy interest rate response, real exchange rate movements, current account and foreign reserve adjustments in response to international capital flows. We find that optimal monetary and macroprudential policy call for temporary and countercyclical interventions in the flows of capital driven by external shocks, but these interventions also create sizable distributive effects among domestic households. Facing these policy trade-offs, our numerical analysis suggests that from a second-best perspective, augmenting the monetary policy rule to respond to financial variables associated with foreign exchange rate or interest rate risks can complement the proposed macroprudential policies in mitigating the distributive costs and achieve Pareto improvements through policy coordination.

Keywords: Small Open Economy; Macroprudential Policy; Monetary Policy; DSGE; Foreign Reserve; International Finance

JEL Classification: E42, E52, F31, F32, F38

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1 Introduction

Emerging market economies (EMEs) have experienced significant episodes of capital inflows and outflows in the last three decades. The capital inflows to Latin America and Asia in the 1990s and the subsequent outflows during crises[1], the surges of inflows to EMEs after the 2008 global financial crisis, and the capital flow reversals following the tightening monetary policies of the United States and other advanced economies are just a few widely noted examples[2]. These experiences have generated waves of discussions that reexamine the financial systems and drawn much attention to the role of macroprudential policies in increasing the "resilience to large and volatile capital flows" (IMF, 2017).

Empirical evidence covering a wide sample of EMEs before and after the 2008 crisis shows that countries with prudential policies for managing financial-stability risks from capital inflows pre-crisis were more resilient during the bust (Ostry et al., 2012). Their more recent study on how these countries respond to capital flows points to the mix of policy interest rates, foreign exchange interventions, macroprudential policies, and capital inflow controls (Ghosh, Ostry and Qureshi, 2017). In the meanwhile, the relevance of additional instruments other than the domestic interest rate policy, however, is not limited to emerging market economies. As Rey (2016) argures, monetary policy shocks of the United States can be "transmitted even to advanced countries with a fully flexible exchange rate", hence challenging the degree of monetary policy autonomy of all

[1]Calvo, Leiderman and Reinhart (1996) offers a comprehensive review of the facts and explanations of the capital inflows to developing countries in the 1990s and Arellano and Mendoza (2002) surveys the literature studying emerging market crises and develops a framework for the quantitative analysis of the financial frictions theories of "Sudden Stops"

[2]The volatile capital flows to EMEs during the period 2005–2013 have been documented in Ghosh, Ostry and Qureshi (2017)

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open economies. Thus, understanding how international shocks affect the domesic economy and the relative merits of the various measures in the policy maker's toolkit remains an important task for economies integrated into the global financial markets.

In this paper we study the design of monetary and macroprudential policies in a small open economy featuring borrowing and lending denominated in both local and foreign currency using a monetary discrete dynamic stochastic general equilibrium (DSGE) model under the New Keynesian framework. The model is mainly based on Liu and Spiegel (2015) and we follow Lambertini, Mendicino and Punzi (2013) in the welfare analysis. We model the economy as comprising of agents with heterogeneous discount factors, thus a fraction of home households are impatient relative to outsiders and borrow both locally and from abroad. We capture the transaction costs associated with financial markets by assuming a quadratic portfolio adjustment cost from the trading of one-period non-state-contingent bonds.

We first calibrate the model to generate the observed features of emerging market economies facing capital inflows driven by external factors documented in Chuhan, Claessens and Mamingi (1998) and Ghosh, Ostry and Qureshi (2017); that is, central banks raising the policy interest rate to address the primary concerns of inflation and economic overheating, a marked appreciation of the real exchange rate accompanying inflows driven by falling U.S. interest rates, and the absorption of inflows reflected partly in the increase in the current account deficits and partly in the increase in the central banks' official reserves.

Then we study the welfare implications of two types of macroprudential policies, one currency-based and one residency-based, in our quantitative analysis. Specifically, we consider a tax imposed on the interest earnings for domestic agents through foreign assets holdings and a tax on the interest earnings for foreign investors through holding domestic bonds. The first type of in-

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tervention creates a differential effective interest rate across domestic and foreign assets based on currency denomination for a given individual, while the second type creates a differential effective interest rate based on the residency of the transation parties for a given asset. We evaluate these macroprudential policies jointly with a baseline Taylor-rule monetary policy and augmented monetary rules that respond to financial variables reflecting the economy's risky foreign exposure.

We find that macroprudential policies countercyclical to international capital flows are welfare-improving at the social level, but the interventions also create distributive effects across the two types of households. Our quantitative results show that residency-based interventions benefit domestic borrowers but hurt domestic savers, while currency-based interventions benefit domestic savers but hurt domestic borrowers. We then show that a monetary policy that target domestic agents' foreign financial positions is generally not desirable when used in isolation, but it can reduce the distributive effects discussed above when used jointly with macroprudential policies. Our results suggest that with proper coordination, monetary and macroprudential policy can play complementary roles in achieving a Pareto improvement in an economy with nominal rigidy and incomplete financial markets. We note that our findings do not depend on the assumptions of *ex ante* net aggregate foreign borrowing nor differential domestic domestic and foreign interest rates in the steady state[3], and as our results show, persistent interventions in the private agents' intertemporal decisions are strictly inforior to temporary policy responses to shocks. Therefore our policy implications are consistent with the view that these management tools are meant to throw "sand in the wheels" but not to prevent the economy from harnessing the benefits of capital flows.

We next conduct a brief review of the theoretical foundations of macroprudential interventions

[3]The implications are discussed more thoroughly in the related literature section.

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in the financial market and related works in the study of monetary and macroprudential policies. We then discuss the relevance of our findings to policy designs and the relative contributions to the literature.

1.1 Related literature

The role of macroprudential policies in addressing pecuniary externalities that may lead to increased financial fragility has long been discussed in the literature. In an economy with financial frictions, overborrowing can arise and aggravate the economic conditions when a negative shock hits, and Lorenzoni (2008) shows that policy interventions that preventively restrict borrowings can restore constrained efficient allocations, though the welfare improvements from reduced costs of a financial crisis come at the cost of reducing investment *ex ante*, as he warns. In a small open economy with occasionally binding credit constraint, Bianchi (2011) quantifies that the policy gains from correcting the systemic credit externality include a reduction of the probability to a financial crisis by more than tenfold and a significant mitigation of the severity of consumption drop and real exchange rate fall that characterize emerging market crises. Bianchi and Mendoza (2018) study optimal macroprudential policy design in an environment in which financial amplification and fire sale externality working through collateral asset prices produce financial crises. They find that the forward-looking nature of asset prices, which is not present in the two works cited above, leads to time-inconsistent optimal policy under commitment and point that due to its complexity macroprudential policies can be counterproductive if not designed carefully. Dávila and Korinek (2018) identify two types of pecuniary externalities, distributive and collateral externalities, that arise in economies with financially constrained agents, and show that the externalities not only do not necessarily result in inefficiencies but the effects can in general

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go in any direction.

Pecuniary externality is not the only theoretical motivation that justifies macroprudential interventions. Farhi and Werning (2016) identify a different source of inefficiency, the aggregate demand externality, focusing on economies with nominal rigidities. They develop a framework in which both pecuniary and aggregate demand externalities can be incorporated, and their joint characterization of optimal monetary and macroprudential policies point to a Pigouvian corrective role of government interventions in financial markets that can overcome the identified market failures. Schmitt-Grohé and Uribe (2016) show that when nominal wage adjustments are downward rigid, the combination of a fixed exchange rate and free capital mobility creates a negative externality that causes overborrowing during booms and high unemployments during busts. Liu and Spiegel (2015) incorporate imperfect asset substitutability in a New Keynesian setting with nominal rigidities and incomplete markets, and find that the optimal policy response to foreign shocks calls for the joint use of capital account restrictions and adjustments of the government's portfolio of foreign reserves, domestic bond and money supply. Aoki, Benigno and Kiyotaki (2018) study monetary and financial policies explicitly modeling financial intermediaries that take deposits in domestic currency while also borrowing in foreign currency, and their results suggest significant welfare gains from cyclical macroprudential taxes on foreign borrowings.

Our modeling of household borrowing and saving and welfare evaluation are adapted from the closed economy model in Lambertini, Mendicino and Punzi (2013) that studies monetary and macroprudential policies that lean againts house-price and credit cycles. Korinek and Sandri (2016) also models an economy with domestic borrowers and savers that lend or borrow from foreign agents, but unlike our classification that distinguish between a currency-based and a residency-based policy, they differentiate between an intervention that segments domestic and

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international financial markets and one that impose a segmentation between borrowers and all types of lenders. In one application Farhi and Werning (2016) analyzed an environment with non-contingent nominal debt denominated in local and foreign currency, similar to the setting studied in our current paper, and used a two-period model to show that optimal policy calls for a higher tax on foreign-currency debt than local-currency debt. We follow Liu and Spiegel (2015) in the modeling of the central bank's balance-sheet decisions as well as the portfolio adjustment costs that lead to imperfect substitutability between domestic and foreign assets. We then extend the capital inflow tax in their model to a set of linear policy rules that allows the quantification of the relative welfare performance of different policy proposals and evaluate the optimal magnitude and persistence of interventions.

It is worth pointing out that in this paper we do not assume *ex ante* net aggregate foreign borrowing nor differential domestic and foreign interest rates in the steady state. As Schmitt-Grohé and Uribe (2017) pointed out, the assumption that households are impatient are needed in, for example, Bianchi (2011) cited above that calibrated the discount factor of the representative agent so that the average net foreign asset position-to-GDP ratio matches its historical average of -29% in Argentina, to generate empirically plausible frequencies of financial crises, and they demonstrated that countercyclical interventions on capital flows may no longer be optimal in alternative settings. On the other hand, Aoki, Benigno and Kiyotaki (2018) calibrated their model so that the steady state domestic interest rate is 2% higher annually than its foreign counterpart to reflect the higher growth prospects enjoyed by the emerging market economies. In this paper the differences between the two interest rates are driven by shocks capturing unexpected changes in the international financial market. Consistently, we find that policy rules that imply a persistent intervention of private intertemporal decisions are stricly inferior to temporary policy responses

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that are meant to mitigate the impact of external shocks.

2 The Model Economy

We start by constructing a model economy with international capital flows but imperfect substitutability between domestic and foreign assets. Domestic agents in this economy have access to both kinds of assets, but adjusting portfolio investments requires care and thus incurs transaction costs. In order to generate international borrowing and lending in both currencies, we model the economy as comprising of two types of households characterized by the heterogeneity in discounting future to the present.

2.1 Households

The small open economy is populated by a unit mass of domestic borrowers B and a unit mass of domestic savers S. The two types of agents differ in their subjective discount factors $\beta_B < \beta_S$, their asset and equity positions, and have preferences represented by

$$U_i = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta_i^t u\left(c_{it}, m_{it}, l_{it}\right), \tag{1}$$

where $\mathbb{E}(\cdot)$ is the expectations operator, $\beta_i \in (0,1)$ is the subjective discount factor of agent $i \in \{B, S\}$, c_{it} is a consumption index given by

$$c_{it} \equiv \left(\int_0^1 c_{it}(j)^{1-\frac{1}{\theta}} dj\right)^{\frac{\theta}{\theta-1}},$$

with $c_{it}(j)$ denoting the quantity of good j consumed by agent i in period t and $\theta > 1$ denoting the elasticity of substitution between different goods, m_{it} is real money holdings, and $l_{it} = 1 - n_{it}$ denotes leisure, where n_{it} represents hours worked.

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The households face a convex cost of holding financial assets in quantities different from their long-run levels. We assume the portfolio adjustment costs to be of a quadratic form with weights Ψ_1 and Ψ_2 measuring the size of the friction. Hence the sequential budget constraint of agent $i \in \{B, S\}$ is

$$P_t c_{it} + M_{it} + B_{it} + S_t B^\star_{it} = W_t n_{it} + M_{i,t-1} + R_{t-1} B_{i,t-1} + S_t R^\star_{t-1} B^\star_{i,t-1} + P_t d_{it} + P_t \frac{tr_t}{2} - \frac{\Psi_1}{2}\left(\frac{B_{it}}{P_t} - \frac{\overline{B}_i}{P}\right)^2 - \frac{\Psi_2}{2}\left(\frac{S_t B^\star_{it}}{P_t} - \frac{\overline{B}^\star_i}{P}\right)^2,$$

and the optimal allocation of consumption expenditures among different goods implies that

$$c_{it}(j) = \left(\frac{p_t(j)}{P_t}\right)^{-\theta} c_{it} \tag{2}$$

for all $j \in [0,1]$ representing the variety of goods, where $p_t(j)$ is the price of good j and $P_t \equiv \left(\int_0^1 P_t(j)^{1-\theta} dj\right)^{\frac{1}{1-\theta}}$ is an aggregate price index.

In this expression, M_{it} is the nominal money balance and $\frac{M_{it}}{P_t} = m_{it}$; B_{it} and $B^\star_{it}$ are holdings of one-period non-state-contingent domestic and foreign bonds, respectively; $R^\star_t$ is the world-determined gross nominal interest rate, S_t is the nominal exchange rate quoted as the price of a unit of foreign currency in terms of the domestic currency, and both $R^\star_t$ and S_t are taken as given by the small open economy; W_t denotes the nominal wage rate and $\frac{W_t}{P_t} = w_t$, R_t the domestic gross nominal interest rate; d_t is the profit income from the households' ownership shares of firms, denoted in terms of the composite consumption good; tr_t is a lump-sum transfer from the government; $\overline{B}_i$, $\overline{B}^\star_i$ are scalars denoting the long-run levels of the respective asset holdings and P is the steady state price level.

The world interest rate $R^\star_t$ is stochastic, and captures the "global financial cycle" phenomenon documented in Rey (2013). The nominal exchange rate S_t is modeled as an independent AR(1) process reflecting the observed persistent and volatile pattern found in empirical studies. We

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define the real exchange rate to be the ratio

$$\varepsilon_t \equiv \frac{S_t P_t^\star}{P_t},$$

where $P_t^\star$ denotes the world price level and is normalized so that $P_t^\star = P^\star = 1$ for all t.

Rewriting the sequential budget constraint in real terms gives

$$\begin{aligned} c_{it} + m_{it} + b_{it} + \varepsilon_t b_{it}^\star = w_t n_{it} + \frac{m_{i,t-1}}{\pi_t} + R_{t-1}\frac{b_{i,t-1}}{\pi_t} + \varepsilon_t R_{t-1}^\star b_{i,t-1}^\star \\ + d_{it} + \frac{tr_t}{2} - \frac{\Psi_1}{2}\left(b_{it} - \overline{b}_i\right)^2 - \frac{\Psi_2}{2}\left(\varepsilon_t b_{it}^\star - \overline{b}_i^\star\right)^2, \end{aligned} \tag{3}$$

where the lower-case letters are used to denote the real value of the corresponding variables. From now on we follow the convention of using lower-case letters for individual variables and upper-case letters for aggregate variables.

The agents maximize (1) subject to (3) taking prices as given. The maximization problem yields the following optimality conditions for each period t:

$$u_3(c_{it}, m_{it}, l_{it}) = w_t u_1(c_{it}, m_{it}, l_{it}), \tag{4}$$

$$u_1(c_{it}, m_{it}, l_{it}) = u_2(c_{it}, m_{it}, l_{it}) + \beta_i \mathbb{E}_t\left[u_1(c_{i,t+1}, m_{i,t+1}, l_{i,t+1})\frac{1}{\pi_{t+1}}\right], \tag{5}$$

$$u_1(c_{it}, m_{it}, l_{it})\left[1 + \Psi_1\left(b_{it} - \overline{b}_i\right)\right] = \beta_i \mathbb{E}_t\left[u_1(c_{i,t+1}, m_{i,t+1}, l_{i,t+1})R_t\frac{1}{\pi_{t+1}}\right], \tag{6}$$

and

$$u_1(c_{it}, m_{it}, l_{it})\left[1 + \Psi_2\left(\varepsilon_t b_{it}^\star - \overline{b}_i^\star\right)\right] = \beta_i \mathbb{E}_t\left[u_1(c_{i,t+1}, m_{i,t+1}, l_{i,t+1})R_t^\star\frac{\varepsilon_{t+1}}{\varepsilon_t}\right]. \tag{7}$$

We assume that the foreign households are symmetrically described by the same utility representation as the domestic agents, with $\beta_\star$, $\Psi_1^\star$, and $\Psi_2^\star$ denoting the subjective discount factor and portfolio adjustment costs parameters, b_{ft} is the real value of domesic bonds held by foreign

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agents, and $b^{\star}_{ft}$ is the amount of foreign bonds held by foreign agents. Their intertemporal Euler equations are given by

$$u_1(c^{\star}_t, m^{\star}_t, l^{\star}_t)\left[1+\Psi^{\star}_1\left(\frac{b_{ft}}{\varepsilon_t}-\overline{b}_f\right)\right]=\beta_{\star}\mathbb{E}_t\left[u_1(c^{\star}_{t+1}, m^{\star}_{t+1}, l^{\star}_{t+1})R_t\frac{\varepsilon_t}{\varepsilon_{t+1}}\frac{1}{\pi_{t+1}}\right], \tag{8}$$

and

$$u_1(c^{\star}_t, m^{\star}_t, l^{\star}_t)\left[1+\Psi^{\star}_2\left(b^{\star}_{ft}-\overline{b}^{\star}_f\right)\right]=\beta_{\star}\mathbb{E}_t\left[u_1(c^{\star}_{t+1}, m^{\star}_{t+1}, l^{\star}_{t+1})R^{\star}_t\right]. \tag{9}$$

2.2 Firms

Assume that there is a continuum of firms $j\in[0,1]$, and each produces a differentiated product operating the same technology represented by the function

$$y_t(j)=A_t n_t(j) \tag{10}$$

where $n_t(j)$ is the amount of labor input hired by firm j and A_t is aggregate productivity shock.

Each firm faces a competitive input market and an identical isoelastic domestic demand schedule given by the horizontal sum of the demand functions described in equation (2) for the two types of households

$$y^d_t(j)=c_{Bt}(j)+c_{St}(j).$$

The firms take as given the real wage rate w_t and the aggregate price level P_t.

Firms are assumed to be owned by the savers, thus the equity-owning households receive a dividend flow of

$$d_{St}(j)=\left(\frac{p_t(j)}{P_t}-\frac{w_t}{A_t}\right)y_t(j)-\frac{\Psi_3}{2}\left(\frac{p_t(j)}{p_{t-1}(j)-1}\right)^2 C_t \tag{11}$$

each period from firm j and $d_{Bt}=0$, where $C_t=c_{Bt}+c_{St}$ and Ψ_3 reflects the size of the Rotemberg (1982) price adjustment costs faced by the monopolistic firms.

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The profit-maximizing firm j choose $(p_t(j), y_t(j))$ to maximize the expected discounted dividend flows

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \Lambda_{0,t} \left[\left(\frac{p_t(j)}{P_t} - \frac{w_t}{A_t} \right) y_t(j) - \frac{\Psi_3}{2} \left(\frac{p_t(j)}{p_{t-1}(j) - 1} \right)^2 C_t \right], \tag{12}$$

where $\Lambda_{0,t}$ is the stochastic discount factor of the equity-owning households.

2.3 Government

The domestic government conducts its monetary policy following a Taylor rule of the form

$$\ln(R_t) = \lambda_R \ln(R_{t-1}) + (1 - \lambda_R) \left\{ \lambda_\pi \ln(\pi_t) + \lambda_y [\ln(Y_t) - \ln(Y_{t-1})] + \ln(R) \right\} \tag{13}$$

where R is the steady state gross interest rate, λ_R is a smoothing parameter, λ_π and λ_y are the responses of the domestic interest rate to inflation and output growth.

In addition to the supply of money and domestic bonds, the government also adjusts its foreign bond holdings (foreign reserves) subject to the flow-of-funds constraint

$$\varepsilon_t \left(b^\star_{gt} - R^\star_{t-1} b^\star_{g,t-1} \right) = b_t - \frac{R_{t-1}}{\pi_t} b_{t-1} + m^s_t - \frac{m^s_{t-1}}{\pi_t}, \tag{14}$$

where $b^\star_{gt}$ is the real value (in foreign consumption good units, which is multiplied by the real exchange rate ε_t to be comparable with domestic real assets) of the government's foreign asset position, b_t is the real value of domestic bond supply (in domestic consumption good units), and m^s_t is the real value of money supply. The government's foreign reserve accumulations $b^\star_{gt} - R^\star_{t-1} b^\star_{g,t-1}$ are financed by new debt issuance (after paying off matured existing debts $\frac{R_{t-1}}{\pi_t} b_{t-1}$) and the seigniorage revenue of money.

The government manages international capital flows by imposing a time-varying proportional tax τ_t on the foreign holdings of domestic bonds b_{ft} and $\tau^\star_t$ on the domoestic holdings of foreign

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bonds $b_{it}^{\star}$, $i \in \{B,S\}$, and rebates the revenues to the households in a lump-sum manner so that

$$tr_t = \tau_{t-1} \frac{R_{t-1}}{\pi_t} b_{f,t-1} \tag{15}$$

and

$$tr_t^{\star} = \tau_{t-1}^{\star} \varepsilon_t R_{t-1}^{\star} b_{i,t-1}^{\star}. \tag{16}$$

The introduction of the macroprudential taxes changes the households' budget constraints to

$$\begin{aligned} c_{it} + m_{it} + b_{it} + \varepsilon_t b_{it}^{\star} = w_t n_{it} + \frac{m_{i,t-1}}{\pi_t} + R_{t-1} \frac{b_{i,t-1}}{\pi_t} + (1-\tau_t^{\star}) \varepsilon_t R_{t-1}^{\star} b_{i,t-1}^{\star} \\ + d_{it} + \frac{tr_t}{2} + \frac{tr_t^{\star}}{2} - \frac{\Psi_1}{2} \left(b_{it} - \overline{b}_i\right)^2 - \frac{\Psi_2}{2} \left(\varepsilon_t b_{it}^{\star} - \overline{b}_i^{\star}\right)^2, \end{aligned} \tag{17}$$

and the doemestic and foreign agents' first-order conditions (7) and (8), respectively, for holdings of financial assets from the other country to

$$u_1\left(c_{it}, m_{it}, l_{it}\right) \left[1 + \Psi_2 \left(\varepsilon_t b_{it}^{\star} - \overline{b}_i^{\star}\right)\right] = \beta_i \mathbb{E}_t \left[u_1\left(c_{i,t+1}, m_{i,t+1}, l_{i,t+1}\right)(1-\tau_t^{\star}) R_t^{\star} \frac{\varepsilon_{t+1}}{\varepsilon_t}\right] \tag{18}$$

and

$$u_1\left(c_t^{\star}, m_t^{\star}, l_t^{\star}\right) \left[1 + \Psi_1^{\star} \left(\frac{b_{ft}}{\varepsilon_t} - \overline{b}_f\right)\right] = \beta_{\star} \mathbb{E}_t \left[u_1\left(c_{t+1}^{\star}, m_{t+1}^{\star}, l_{t+1}^{\star}\right)(1-\tau_t) R_t \frac{\varepsilon_t}{\varepsilon_{t+1}} \frac{1}{\pi_{t+1}}\right]. \tag{19}$$

Since the small open economy in our model takes as given foreign variables, we interpret the bond demand for the two types of assets by foreigners to be the simplified Euler equations given by

$$1 + \Psi_1^{\star} \left(\frac{b_{ft}}{\varepsilon_t} - \overline{b}_f\right) = \beta_{\star} \mathbb{E}_t \left[(1-\tau_t) R_t \frac{\varepsilon_t}{\varepsilon_{t+1}} \frac{1}{\pi_{t+1}}\right] \tag{20}$$

$$1 + \Psi_2^{\star} \left(b_{ft}^{\star} - \overline{b}_f^{\star}\right) = \beta_{\star} R_t^{\star} \tag{21}$$

Thus the foreign agents' demand for foreign assets is completely independent of the home country's policies, but their demand for domestic bonds is not only an increasing function of the

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Taylor-rule interest rate described above, but also affected by domestic inflation rates and real exchange rate variations.

2.4 Equilibrium

Letting the aggregate output be defined as $Y_t \equiv \left(\int_0^1 y_t(j)^{1-\frac{1}{\theta}} dj\right)^{\frac{\theta}{\theta-1}}$ and denoting the total portfolio and price adjustment costs of the domestic economy by

$$\Psi_t \equiv \frac{\Psi_1}{2}\left[\left(b_{ht}^B - \overline{b}_h^B\right)^2 + \left(b_{ht}^S - \overline{b}_h^S\right)^2\right] + \frac{\Psi_2}{2}\left[\left(\varepsilon_t b_{Bt}^\star - \overline{b}_B^\star\right)^2 + \left(\varepsilon_t b_{St}^\star - \overline{b}_S^\star\right)^2\right] + \frac{\Psi_3}{2}(\pi_t - 1)^2 C_t,$$

market clearing in the goods market requires that the country's trade balance (net exports) is given by

$$TB_t = Y_t - C_t - \Psi_t, \tag{22}$$

that is, output is either consumed domestically, paid for adjustment costs, or consumed abroad.

Aggregate employment is given by the sum of employment across firms

$$N_t = \int_0^1 n_t(j)dj = \int_0^1 \frac{y_t(j)}{A_t} dj = \frac{Y_t}{A_t}, \tag{23}$$

in a symmetric equilibrium where $y_t(j) = y_t$ and $n_t(j) = n_{Bt}(j) + n_{St}(j)$, and labor market clearing requires that the real wage adjusts so that labor supply implied by equation (4) equals the firms labor demand.

In equilibrium, money supply equals money demand, domestic bonds issued by the government equal that held by the domestic and foreign households, and total foreign asset holdings equals an exogenously given foreign bond supply $b_t^\star$. Thus

$$m_t^s = m_{Bt} + m_{St} \tag{24}$$

$$b_t = b_{Bt} + b_{St} + b_{ft} \tag{25}$$

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and

$$b_t^\star = b_{Bt}^\star + b_{St}^\star + b_{gt}^\star + b_{ft}^\star. \tag{26}$$

By definition the current account CA_t is the sum of the trade balance and net investment income on the country's net foreign asset positions

$$CA_t \equiv TB_t + \left\{ \left(\varepsilon_t R_{t-1}^\star - 1\right) b_{t-1}^\star - \left[R_{t-1}\left(1-\tau_{t-1}\right) - 1\right] \frac{b_{f,t-1}}{\pi_t} \right\} \tag{27}$$

(the macroprudential tax revenues from foreign asset holdings are rebated to the households thus are part of domestic income, so $\tau_t^\star$ does not appear in the previous expression). We can also express the current account as changes in net foreign assets using the balance of payment identities

$$CA_t = \Delta NFA_t \equiv \varepsilon_t \left(b_t^\star - b_{t-1}^\star\right) - \left(b_{ft} - b_{f,t-1}\right). \tag{28}$$

Before proceeding to the definition of competitive equilibrium, we first summarize in the next table the international transactions taking place in the model economy[4]. To determine the signs of the trade balance and the official reserves account is straightforward, but the conclusions for the investment income account and the capital account are much less obvious. It is clear that, for example, suppose that $b_{f,t-1}$ and $b_{S,t-1}^\star$ are both positive, indicating that the foreigners hold a positive amount of domestic-currency bonds and the domestic savers also hold a positive amount of foreign-currency bonds, then the former results in an interest payment by the country to foreigners, $(R_{t-1}-1)b_{f,t-1}$, while the latter results in a receipt by the country of interest from foreigners, $\varepsilon_t(R_{t-1}^\star - 1)b_{S,t-1}^\star$. However, if these variables flip signs due to changes in economic conditions, then the directions of the income flows also changes. The same is true for the capital account as it is determined by the asset/debt positions of the domestic borrowers and savers as

[4]The illustrations in Table 1 is adapted from Exhibit 4.1 in Bekaert and Hodrick (2017).

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well as the foreign agents. For example, an increase in the country's ownership of foreign assets, $b^{\star}_{S,t} - b^{\star}_{S,t-1} > 0$, gives rise to a capital outflow while a decrease in the country's ownership of foreign assests, $b^{\star}_{S,t} - b^{\star}_{S,t-1} < 0$, indicates a capital inflow. A decrease of foreign ownership of the country's assets, $b_{f,t} - b_{f,t-1} < 0$, gives rise to a capital outflow while an increase in foreign ownership of the country's assets, $b^{\star}_{S,t} - b^{\star}_{S,t-1} < 0$, indicates a capital inflow.

Table 1: The Balance of Payments

Account	**Debits** $(-)$	**Credits** $(+)$
CURRENT ACCOUNT		
(A) TRADE BALANCE	Imports if $TB_t < 0$	Exports if $TB_t > 0$
(B) INVESTMENT INCOME ACCOUNT	e.g., $(R_{t-1} - 1)b_{f,t-1}$	e.g., $\varepsilon_t(R^{\star}_{t-1} - 1)b^{\star}_{S,t-1}$
CAPITAL ACCOUNT		
	Capital outflows if $b^{\star}_{S,t} - b^{\star}_{S,t-1} > 0$	Capital inflows if $b_{f,t} - b_{f,t-1} > 0$
	Capital outflows if $b_{f,t} - b_{f,t-1} < 0$	Capital inflows if $b^{\star}_{S,t} - b^{\star}_{S,t-1} < 0$
OFFICIAL RESERVES ACCOUNT		
	Foreign reserves accumulation	Foreign reserves decrease
	if $b^{\star}_{g,t} - b^{\star}_{g,t-1} > 0$	if $b^{\star}_{g,t} - b^{\star}_{g,t-1} < 0$

Given government policies (the interest rate rule and macroprudential policy rules τ_t and $\tau^{\star}_t$ specified below) and exogenous processes $\{A_t, S_t, R^{\star}_t\}$, a competitive equilibrium of this economy is a sequence of prices $\{P_t, \pi_t, w_t, \varepsilon_t, R_t\}$ and quantities $\Big\{c_{Bt}, c_{St}, n_{Bt}, n_{St}, l_{Bt}, l_{St}, b_t, b_{Bt}, b_{St}, b_{ft}, b^{\star}_{Bt}, b^{\star}_{St}, b^{\star}_{gt}, b^{\star}_{ft}, b^{\star}_t, m_{Bt}, m_{St}, m^s_t, d_{Bt}, d_{St}, tr_{St}, tr_{Bt}, tr^{\star}_{Bt}, tr^{\star}_{St}, Y_t, N_t, C_t, \Psi_t, TB_t, CA_t, NFA_t\Big\}$ as well as the prices $\{P_t(j)\}$ and quantities $\{y_t(j), n_t(j)\}$ for each firm $j \in [0,1]$ such that

1. taking all prices but its own as given, the prices and allocations for each firm solves its profit-maximizing problem;

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2. taking all prices as given, the households' choices satisfy the optimality conditions as well as the budget constraints (we note that the assumption that only one of the two types of agents has access to equity holdings affects the inequality of consumption between the households);

3. markets for the final goods, labor, money balances, and bond holdings all clear.

3 Quantitative Analysis

In this section, we first calibrate the baseline economy in which there is perfect capital mobility, that is, $\tau_t = 0$ and $\tau_t^\star = 0$, and the home country's monetary policy follows the Taylor rule previously described. Then we turn our attention to evaluating the full toolkit available to the policy makers.

3.1 Calibration

We assume that a part of domestic agents are impatient relative to outsiders, thus they have incentives to borrow from foreign investors. We calibrate the economy to be such that in the non-stochastic steady state, domesic borrowers assume both foreign currency and domestic currency-denominated debts with levels matched by the positive amount of assets held by the domestic savers, that is, $-b_B = -b_B^\star = b_S = b_S^\star > 0$, thus net borrowing is zero in the non-stochastic steady state. We follow Lambertini, Mendicino and Punzi (2013) to calibrate the domestic agents' subjective discount factors $\beta_B = 0.97$ and $\beta_S = 0.9925$ in a quarterly setting, and assume that the foreign agents have the same discount rate as that of the domestic savers.

The borrows and savers in this economy share the same utility representation, with the func-

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tional form assumed to be given by

$$u(c,m,l) = \ln(c) + \phi_m \ln(m) - \phi_l \frac{(1-l)^{1+\eta}}{1+\eta}, \quad \phi_m,\ \phi_l, \text{ and } \eta > 0. \tag{29}$$

The utility weights for leisure $\phi_l = 34.01$ is calibrated so that the borrowers spend about one third of their time endowment working (and the equity-owning savers work roughly 16% less) in the non-stochastic steady state. The parameters regarding the macroeconomic and financial aspects of the model closely follows that in Liu and Spiegel (2015), in which the curvature parameter $\eta = 2$ so that the Frisch elasticity of labor supply is 0.5 (Keane and Rogerson, 2015) and the money demand parameter $\phi_m = 0.06$ (Chari, Kehoe and Mcgrattan, 2000).

Given the functional form of the utility representation, we can express the solution to the firms' profit maximization problem (12) in a symmetric equilibrium that $p_t(j) = P_t$ for all j as the following

$$\frac{w_t}{A_t} = \frac{\theta-1}{\theta} + \frac{\Psi_3}{\theta}\frac{C_t}{Y_t}\left[(\pi_t - 1)\pi_t - \beta_S \mathbb{E}_t(\pi_{t+1}-1)\pi_{t+1}\right]. \tag{30}$$

The domestic level of techonology that is common to all firms follows the process

$$\ln(A_t) = \rho_a \ln(A_{t-1}) + \varepsilon_{at} \tag{31}$$

with $\rho_a \in [0,1]$ and $\varepsilon_{at} \overset{i.i.d.}{\sim} N(0,\sigma_a)$. The mean level of the technology shock is normalized to one. The AR(1) process for the logged gross nominal foreign interest rate is

$$\ln(R_t^{\star}) = (1-\rho_r)\ln(R^{\star}) + \rho_r \ln\left(R_{t-1}^{\star}\right) + \varepsilon_{rt} \tag{32}$$

where ρ_r denotes the persistence of the shock, $R^{\star}$ is the steady-state level of the foreign interst rate, and ε_{rt} is an innovation to the shock and $\varepsilon_{rt} \overset{i.i.d.}{\sim} N(0,\sigma_r)$. The nominal exchange rate of the small open economy is modeled as

$$S_t = (1-\rho_s)S^{PPP} + \rho_s S_{t-1} + \varepsilon_{st} \tag{33}$$

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Table 2: Calibrated Parameters

Parameter	Description	Value
Preference		
β_B	Borrower's subjective discount factor	0.97
β_S	Saver's subjective discount factor	0.9925
$\beta_\star$	Foreigner's subjective discount factor	0.9925
ϕ_l	Utility weight on leisure	0.06
ϕ_m	Utility weight on money balances	34.01
η	Inverse of Frisch elasticity of labor supply	2
Production		
ρ_a	Persistence of technology shocks	0.9
σ_a	Standard deviation of technology shocks	0.005
θ	Elasticity of substitution between differentiated goods	10
Ψ_3	Price adjustment costs	60
Monetary Policy		
λ_R	Monetary policy inertia	0.59
λ_π	Monetary policy inflation feedback	1.44
λ_y	Monetary policy output feedback	0.52
Asset Holdings		
ρ_r	Persistence of foreign interest rate shocks	0.9
σ_r	Standard deviation of foreign interest rate shocks	0.001
ρ_s	Persistence of nominal exchangne rate shocks	0.99
σ_s	Standard deviation of nominal exchangne rate shocks	0.005
Ψ_1	Portfolio adjustment costs: domestic bonds, domestic households	0.01
Ψ_2	Portfolio adjustment costs: foreign bonds, domestic households	0.01
$\Psi_1^\star$	Portfolio adjustment costs: domestic bonds, foreign households	0.01
$\Psi_2^\star$	Portfolio adjustment costs: foreign bonds, foreign households	0.01

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where $\rho_s \in [0,1]$, $\varepsilon_{st} \overset{i.i.d.}{\sim} N(0, \sigma_s)$, and S^{PPP} denotes the exchange rate such that the internal purchasing power of the domestic currency equals its external purchasing power.

The Taylor rule governing the domestic policy interest rate follows the estimation by Iacoviello and Neri (2010). The parameters are summarized in Table 1.

3.2 Baseline Case

We first examine the macroeconomic behavior of the model economy with free capital mobility facing changes in the international financial market. Figure 1 shows the impulse response of the aggregate and price variables to an unexpected foreign interest rate decline expressed as percentage deviations from the non-stochastic steady states (the current account CA_t, domestic bond supply b_t, domestic households' foreign asset holdings $b^{\star}_{Bt} + b^{\star}_{St}$, foreign households' domestic asset holdings b_{ft}, and the government's foreign reserves $b^{\star}_{gt}$ are expressed as percentage of the steady-state output level since those variables are zero in the non-stochastic steady states).

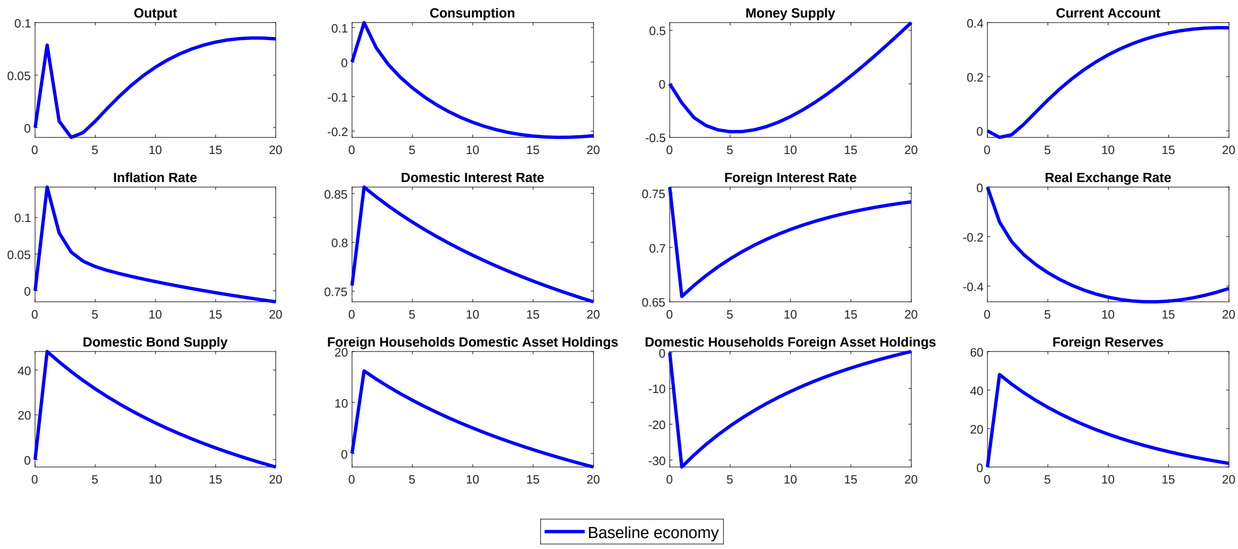

Figure 1: Impulse Responses to a Negative Foreign Interest Rate Shock

Empirical researches on the capital inflows to Latin America and Asia in the 1990s have

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documented the interest rates decline of the United States as an important common driver of the portfolio investment flows to these developing economies aside from their country-specific characteristics (Chuhan, Claessens and Mamingi, 1998). The response of our model economy to a foreign interest drop features a large capital inflow and an accompanying real exchange rate appreciation, and generally matches the observations in Calvo, Leiderman and Reinhart (1993) that capital inflow increases were channeled partly to private consumptions and reflected in the current account deficits and partly to the government's foreign reserve accumulations.

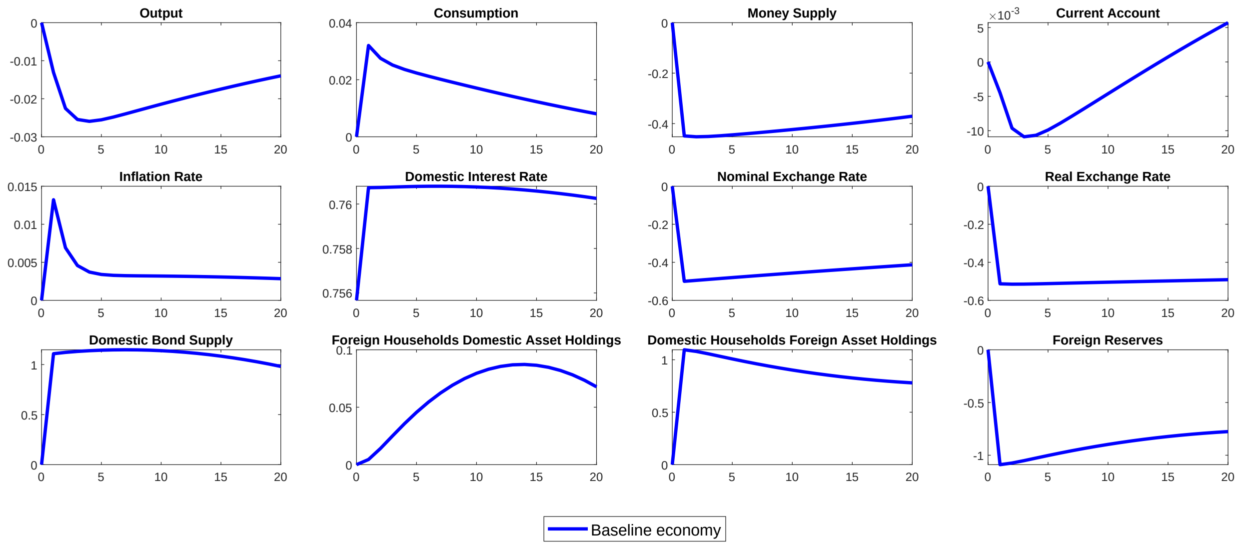

Figure 2: Impulse Responses to an Unexpected Nominal Exchange Rate Appreciation

Figure 2 shows that an unexpected nominal exchange rate appreciation leads to a rise in consumption financed by current account deficit. Figure 3 presents the case in which a negative technology shock hits the small open economy, which shows that the domestic agents borrow from abroad in response to the lower home productions. We next turn our attention to policies that aim to mitigate the effects of shocks originated outside the domestic economy.

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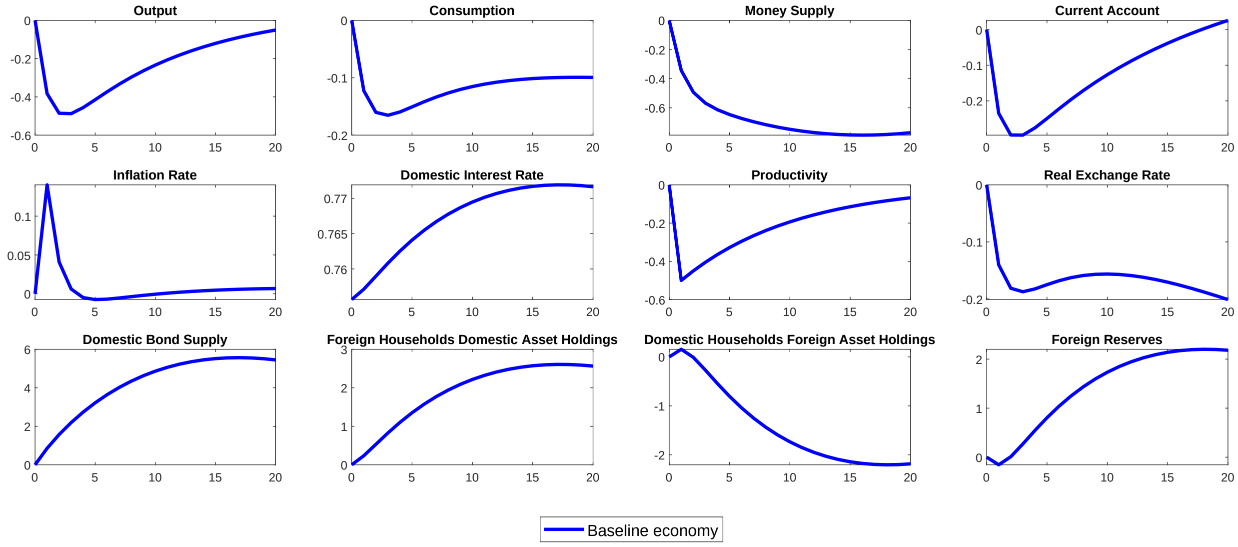

Figure 3: Impulse Responses to a Negative Technology Shock

3.3 Policy Experiments

In this section we evaluate monetary and macroprudential policy designs in the context of market frictions and capital flows driven by global factors. Sources of inefficiency arise not only from distortions related to nominal rigidities, but also from the fact that only a fraction of households are owners to the markup-charging monopolistically competitive firms. Furthermore, portfolio adjustment costs of private asset holdings drive a wedge between expected returns of domestic and foreign securities, thus a friction in international risk sharing. Financial stability concerns lead many to call for measures that curb foreign exposures that make the economy vulnerable to foreign interest rate or exchange rate shocks, or worries that large capital inflows push up inflation challenges domestic policy makers to find ways to insulate the economy from foreign influences. We compare alternative policies by first considering a macroprudential regulation taking as given the specified interst rate rule. Next we augment the interest rate rule to respond to financial variables and study the policy implications jointly with the macroprudential regulation.

Consider the social welfare function V_t defined by the weighted average of the expected dis-

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counted utility of the heterogeneous domestic households V_{Bt} and V_{St}

$$V_t \equiv (1-\beta_B)\,V_{Bt} + (1-\beta_S)\,V_{St},$$

where

$$V_{it}\left(m_{i,t-1}, b_{i,t-1}, b^{\star}_{i,t-1}\right) \equiv \max_{\{c_s, m_s, l_s\}_{s=0}^{\infty}} \mathbb{E}_t \sum_{k=t}^{\infty} \beta_i^k u\left(c_{i,t+k}, m_{i,t+k}, l_{i,t+k}\right), \quad i \in \{B, S\}.$$

Given the competitive equilibrium conditions and the interest rate rule defined in the previous section, we evaluate the welfare implications of macroprudential policies that respond to international capital flows specified by the rules

$$\tau_t = c_1 \tau_{t-1} + (1-c_1)\,\overline{\tau} + (1-c_1)\,c_2\left(b_{ft} - b_{f,t-1}\right) \tag{34}$$

and

$$\tau_t^{\star} = d_1 \tau_{t-1}^{\star} + (1-d_1)\,\overline{\tau}^{\star} + (1-d_1)\,d_2\left(b^{\star}_{Bt} - b^{\star}_{B,t-1}\right) \tag{35}$$

where τ_t is the tax rate imposed on capital inflows $b_{f,t}$, broadly interpreted as a measure to discourage foreign liabilities ($b_{f,t}$ is the foreign holdings of domestic bonds), $\tau_t^{\star}$ is the tax rate on domestic agents' holdings of foreign assets or debts that are susceptible to exchange rate or foreign interest rate risks $b^{\star}_{i,t}$, $i \in \{B, S\}$, c_1, c_2, d_1, and d_2 are scalar coefficients, and $\overline{\tau}$ and $\overline{\tau}^{\star}$ are the steady state levels of the respective tax rates.

We search numerically the coefficients c_1, c_2, d_1, and d_2 to maximize the social welfare function (using second-order approximations around the non-stochastic steady states) in moderate regions in which stable equilibrium is defined, and we focus our attention to cyclical policies that do not impose permanent wedges into the intertemporal Euler conditions (thus $\overline{\tau}^{\star} = \overline{\tau}^{\star} = 0$). We find that rules that are persistent, that is, policy rules with nonzero coefficients relating current tax rates with its one-period lag, are strictly dominated by rules that react only to capital inflows

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or foreign debt buildups. Thus the welfare implications of the considered macroprudential policy rules can be summarized by the relation between the policy weights c_2, d_2 and the corresponding conditional welfare levels presented in the following figure.

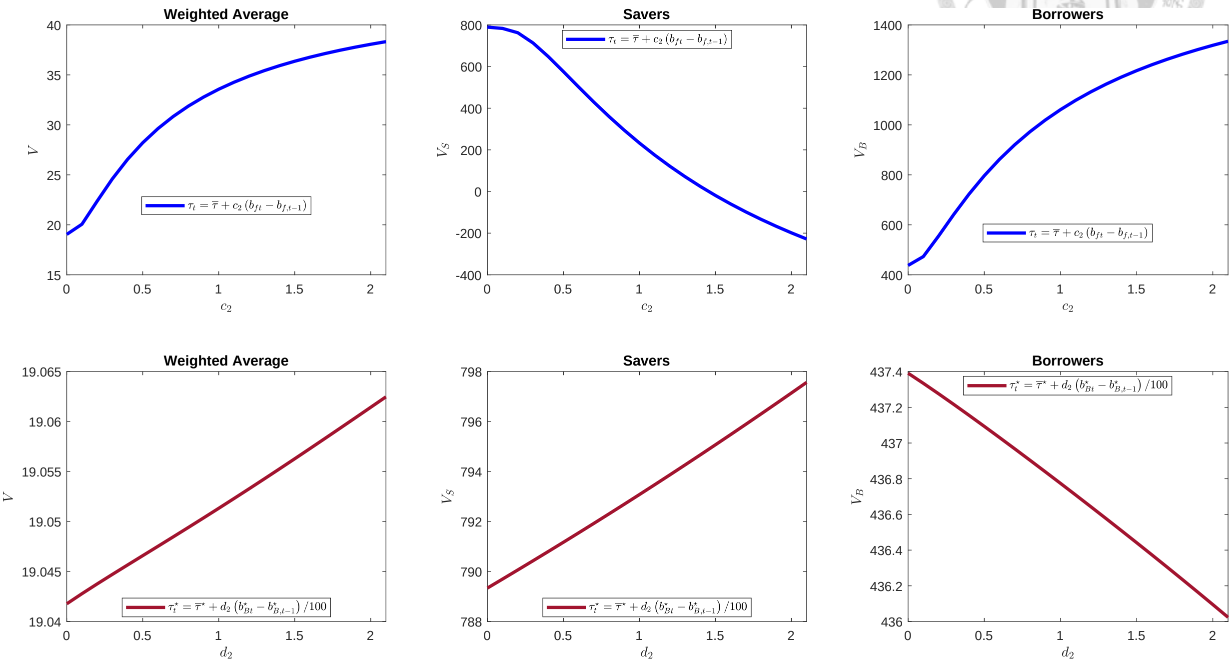

Figure 4: Conditional Welfare of Macroprudential Policy Rules

Althought the two rules target a different set of households, the previous taxes foreign households and results in a perceived difference in the effective interest rates between home and foreign agents regarding the same asset, while the other targets domestic households by discriminating against the currency denominating the asset or debt, the effects are both welfare-improving at the social level but assymmetric at the individual level. By construction the agents differ in their levels of patience toward the future, and a fraction of domestic households borrow in foreign currency while the other lend to the rest of the world. To see how the policies affect the economy as a whole and the two types of agents separately, we first present the impulse response to foreign shocks in which the thick dashed lines represent the policy experiment under the rule $\tau_t^{\star} = \overline{\tau}^{\star} + d_2\left(b_{Bt}^{\star} - b_{B,t-1}^{\star}\right)$. In both scenarios, monetary policy follows the given interest rate

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rule. We present the effect of the inflow tax (τ_t) together with the augmented Taylor rule discussed below.

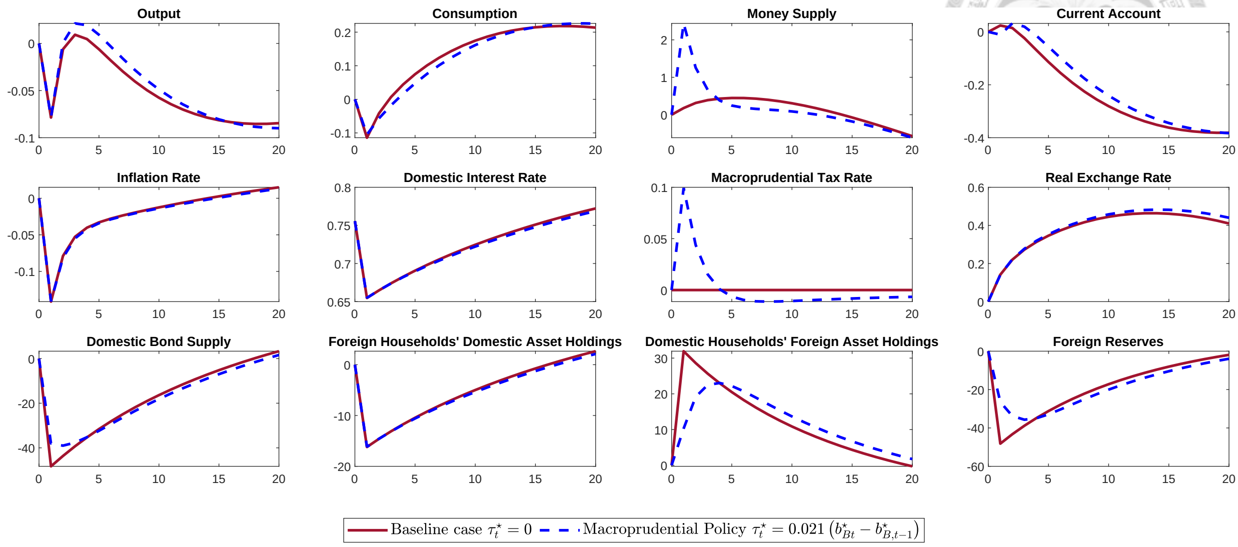

Figure 5: Effect of Macroprudential Policy ($\tau_t^\star$) to a Positive Foreign Interest Rate Shock

We next evaluate the two-prone policy mix that allows the government to target international capital flows using both the inflow tax τ_t and an augmented Taylor rule that respond to a financial variable x_t

$$\ln(R_t) = \lambda_R \ln(R_{t-1}) + (1-\lambda_R)\left\{\lambda_\pi \ln(\pi_t) + \lambda_y\left[\ln(Y_t) - \ln(Y_{t-1})\right] + \ln(R) + \lambda_b \ln\left(\frac{x_t}{x_{t-1}}\right)\right\}$$

where $x_t \in \left\{b_{B,t}^\star, b_{S,t}^\star\right\}$. Since under our calibration $b_{B,t}^\star$ is always negative while $b_{S,t}^\star$ is always positive, the ratio x_t/x_{t-1} is positive, and hence $\lambda_b > 0$ implies that the authority raises domestic interst rate when the economy is accumulating either foreign debt $\left(x_t = b_{B,t}^\star\right)$ or foreign asset $\left(x_t = b_{B,t}^\star\right)$. In the following numerical experiment, we denote

$$\text{Rule 1} = -\lambda_b \ln\left(\frac{b_{B,t}^\star}{b_{B,t-1}^\star}\right) \quad \text{and} \quad \text{Rule 2} = \lambda_b \ln\left(\frac{b_{S,t}^\star}{b_{S,t-1}^\star}\right)$$

adjust the policy weight λ_b in the augmented Taylor rule

$$\ln(R_t) = \lambda_R \ln(R_{t-1}) + (1-\lambda_R)\left\{\lambda_\pi \ln(\pi_t) + \lambda_y\left[\ln(Y_t) - \ln(Y_{t-1})\right] + \ln(R) + \text{Rule k}\right\}, \quad (36)$$

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$k \in \{1,2\}$ to maximize the conditional welfare values. We present the four scenarios in the following figure, with the dashed lines denoting the interest-rate response to financial variables without macroprudential policies and the solid lines denoting the joint use of both instruments.

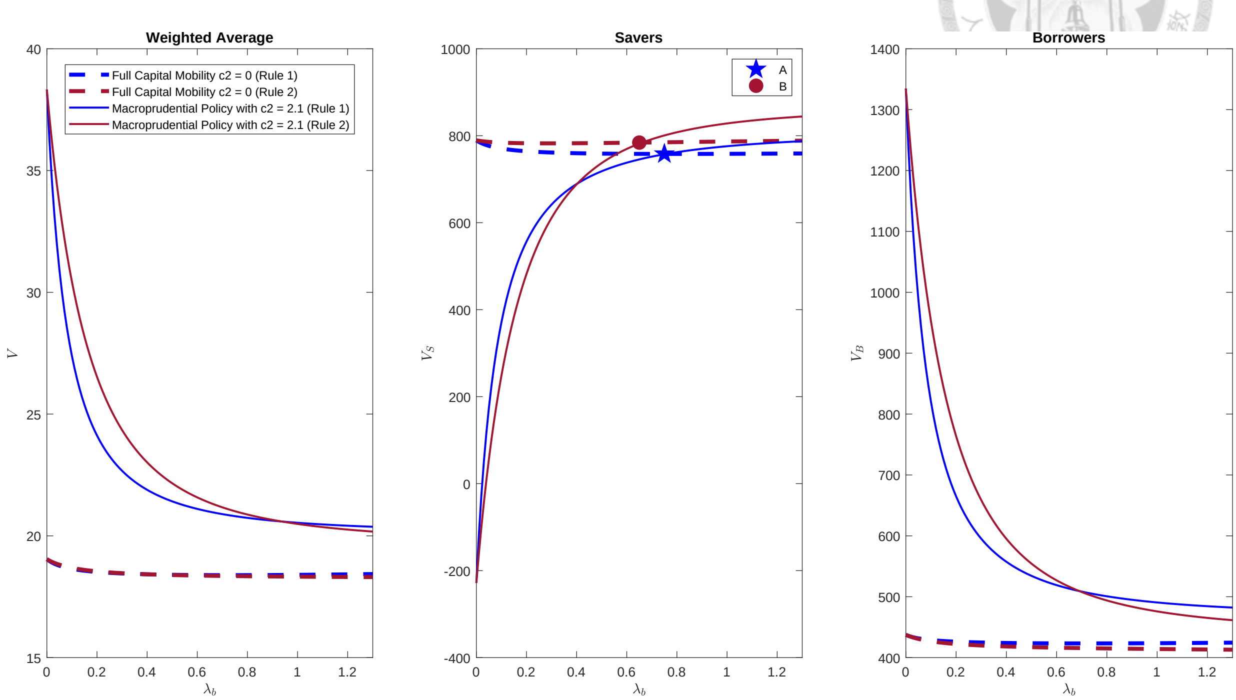

Figure 6: Conditional Welfare of Macroprudential Policy and Augemented Taylor Rule

We find that with the macroprudential policy or not, social welfare is a decreasing function of the the policy weight λ_b in the augmented Taylor rule, hence the optimized rule goes back to the capital inflow tax with the baseline interest rate rule. However, from our previous discussion and an examination of figure 7, we learn that the social welfare improvements come at the expense of the drastic welfare loss of domestic savers. This observation leads us to consider the "second-best" policy combination that makes both types of agents "at least not worse-off" with the introduction of the macroprudential policy. We represent the two local solutions associated with Rule 1 and Rule 2 by the points A and B, respectively, in figure 6.

In our numerical experiment, the "second-best" policy rule correspond to the smallest λ_b in the augmented Taylor rules that make the domestic savers indifferent between the free-capital-

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mobility scheme and the macroprudential rules. Since the borrowers are always better-off (than the welfare level corresponding to $\lambda_b = 0$ of the dashed lines) in the considered interval, the policy combinations A, B represent a Pareto improvement from the baseline economy. We plot the impulse response of the three scenarios, baseline, macroprudential policy ($c_2 = 0.021$) with baseline interest-rate rule, and macroprudential policy with augmented Taylor rule (Rule 2), in Figure 7.

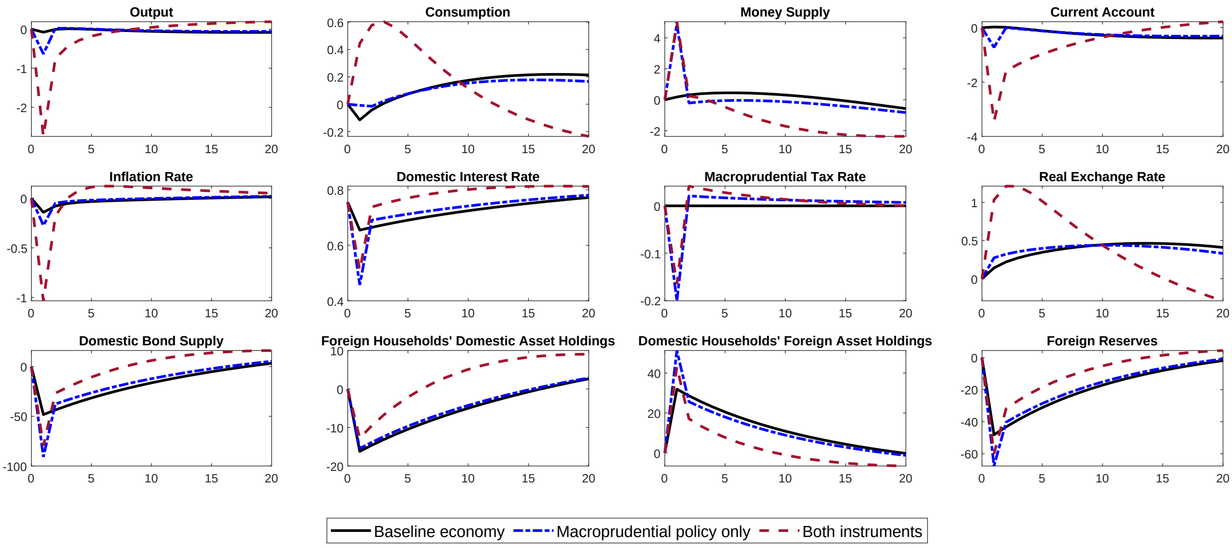

Figure 7: Impulse Responses to a Positive Foreign Interest Rate Shock

4 Conclusion

Consistent with the open economy literature of the study of macroprudential policies, our results show that prudential measures targeting capital flows are generally welfare-improving. However, such welfare gains may not be Parato improvements taking into account the existence of both borrowers and savers in a given economy. We consider two types of macroprudential rules distinguished by the target of taxation. Depending on the policy objective, one can choose to impose the regulation based on residency of the transacting parties or the currency demonination of the

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transaction. We show that the traditional instrument policy interest rate can be augmented to respond to foreign debt or asset growth, and the joint use of the monetary and macroprudential policies can achieve an allocation that improves the well being of both types of agents.

As noted in the literature review section, existing researches have repeatedly pointed out that the conduct of monetary and macroprudential policy is a challenging task due to the complicated nature of various forms of financial frictions. The current work seeks to contribute to policy discussions by providing a tractable specification of relevant concerns facing a typical small open economy and presenting the costs and benefits associated with various proposed policy rules. Future research possibilities include a further look into the interaction with capital flows and inequality or an extension to sector-specific financial regulations within the domestic economy.

Appendices

In this appendix, we summarize the first-order conditions, market clearing conditions, and the policy equations given the functional form of the utility representation. The equations are labeled to correspond to that in the main text, and in order to keep the expressions concise, some variables are substituted out and the resulted equations are labeled starting from (A.1).

$$\frac{1}{c_{Bt}} = \phi_m \frac{1}{m_{Bt}} + \beta_B \mathbb{E}_t \left(\frac{1}{c_{B,t+1}} \frac{1}{\pi_{t+1}} \right) \tag{5B}$$

$$\frac{1}{c_{St}} = \phi_m \frac{1}{m_{St}} + \beta_S \mathbb{E}_t \left(\frac{1}{c_{S,t+1}} \frac{1}{\pi_{t+1}} \right) \tag{5S}$$

$$\frac{1}{c_{Bt}} \left[1 + \Psi_1 \left(b_{Bt} - \bar{b}_B \right) \right] = \beta_B \mathbb{E}_t \left(\frac{1}{c_{B,t+1}} R_t \frac{1}{\pi_{t+1}} \right) \tag{6B}$$

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$$\frac{1}{c_{St}}\left[1+\Psi_1\left(b_{St}-\overline{b}_S\right)\right]=\beta_S\mathbb{E}_t\left(\frac{1}{c_{S,t+1}}R_t\frac{1}{\pi_{t+1}}\right) \tag{6S}$$

$$\frac{1}{c_{Bt}}\left[1+\Psi_2\left(\varepsilon_t b^{\star}_{Bt}-\overline{b}^{\star}_B\right)\right]=\beta_B\mathbb{E}_t\left[\frac{1}{c_{B,t+1}}\frac{1}{\pi_{t+1}}\left(1-\tau^{\star}_t\right)R^{\star}_t\frac{\varepsilon_{t+1}}{\varepsilon_t}\right] \tag{18B}$$

$$\frac{1}{c_{St}}\left[1+\Psi_2\left(\varepsilon_t b^{\star}_{St}-\overline{b}^{\star}_S\right)\right]=\beta_S\mathbb{E}_t\left[\frac{1}{c_{S,t+1}}\frac{1}{\pi_{t+1}}\left(1-\tau^{\star}_t\right)R^{\star}_t\frac{\varepsilon_{t+1}}{\varepsilon_t}\right] \tag{18S}$$

$$1+\Psi^{\star}_1\left(\frac{b_{ft}}{\varepsilon_t}-\overline{b}_f\right)=\beta_{\star}\mathbb{E}_t\left[(1-\tau_t)R_t\frac{\varepsilon_t}{\varepsilon_{t+1}}\frac{1}{\pi_{t+1}}\right] \tag{20}$$

$$1+\Psi^{\star}_2\left(b^{\star}_{ft}-\overline{b}^{\star}_f\right)=\beta_{\star}R^{\star}_t \tag{21}$$

$$\begin{aligned}\varepsilon_t\left(b^{\star}_{gt}-R^{\star}_{t-1}b^{\star}_{g,t-1}\right)=&\left(b_{Bt}+b_{St}+b_{ft}\right)-\frac{R_{t-1}}{\pi_t}\left(b_{B,t-1}+b_{S,t-1}+b_{f,t-1}\right)\\&+\left(m_{St}+m_{Bt}\right)-\frac{m_{S,t-1}+m_{B,t-1}}{\pi_t}\end{aligned} \tag{14}$$

$$\phi_l\frac{Y_t^{\eta}}{Z_t^{1+\eta}}c_{Bt}\left[\left(\frac{c_{Bt}}{c_{St}}\right)^{\frac{1}{\eta}}+1\right]^{-\eta}=\frac{\theta-1}{\theta}+\frac{\Psi_3}{\theta}\frac{C_t}{Y_t}\left[\left(\frac{\pi_t}{\pi}-1\right)\frac{\pi_t}{\pi}-\beta_S\mathbb{E}_t\left(\frac{\pi_{t+1}}{\pi}-1\right)\frac{\pi_{t+1}}{\pi}\right] \tag{A.1}$$

$$\begin{aligned}Y_t=&\left\{\left[\left(b^{\star}_{Bt}+b^{\star}_{St}\right)-R^{\star}_{t-1}\left(b^{\star}_{B,t-1}+b^{\star}_{S,t-1}\right)\right]+\left[\left(b_{Bt}+b_{St}\right)-\frac{R_{t-1}}{\pi_t}\left(b_{B,t-1}+b_{S,t-1}\right)\right]\right.\\&\left.-\frac{R_{t-1}\tau_{t-1}}{\pi_t}b_{f,t-1}\right\}+\left\{\left(m_{Bt}+m_{St}\right)-\frac{\left(m_{B,t-1}+m_{S,t-1}\right)}{\pi_t}\right\}+\left[1+\frac{\Psi_3}{2}\left(\frac{\pi_t}{\pi}-1\right)^2\right]C_t\\&+\frac{\Psi_1}{2}\left[\left(b_{Bt}-\overline{b}_B\right)^2+\left(b_{St}-\overline{b}_S\right)^2\right]+\frac{\Psi_2}{2}\left[\left(b^{\star}_{Bt}-\overline{b}^{\star}_B\right)^2+\left(b^{\star}_{St}-\overline{b}^{\star}_S\right)^2\right]\end{aligned} \tag{A.2}$$

Since $w_t=A_t\frac{\theta-1}{\theta}+\frac{\Psi_3}{\theta}\frac{C_t}{Y_t}\left[\left(\pi_t-1\right)\pi_t-\beta_S\mathbb{E}_t\left(\pi_{t+1}-1\right)\pi_{t+1}\right]$ from equation (30), we have

$$\begin{aligned}&\left(c_{St}-c_{Bt}\right)+\left(m_{St}-m_{Bt}\right)+\left(b_{St}-b_{Bt}\right)+\left(b^{\star}_{St}-b^{\star}_{Bt}\right)=R^{\star}_{t-1}(b^{\star}_{S,t-1}-b^{\star}_{B,t-1})+\\&Y_t-\frac{2}{\left(\phi_l\right)^{\frac{1}{\eta}}}\left(w_t\right)^{1+\frac{1}{\eta}}\left(_{Bt}\right)^{-\frac{1}{\eta}}+\left[\frac{\Psi_3}{2}(\pi_t-1)^2\right]C_t+\left(\frac{m_{S,t-1}}{\pi_t}-\frac{m_{B,t-1}}{\pi_t}\right)+R_{t-1}\left(\frac{b_{S,t-1}}{\pi_t}-\frac{b_{B,t-1}}{\pi_t}\right)\\&-\frac{\Psi_1}{2}\left[\left(b_{St}-\overline{b}_S\right)^2-\left(b_{Bt}-\overline{b}_B\right)^2\right]-\frac{\Psi_2}{2}\left[\left(b^{\star}_{St}-\overline{b}^{\star}_S\right)^2-\left(b^{\star}_{Bt}-\overline{b}^{\star}_B\right)^2\right]\end{aligned} \tag{A.3}$$

$$0=b^{\star}_{Bt}+b^{\star}_{St}+b^{\star}_{gt}+b^{\star}_{ft}. \tag{26}$$

$$\ln\left(A_t\right)=\rho_a\ln\left(A_{t-1}\right)+\varepsilon_{at} \tag{31}$$

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$$\ln(R_t^\star) = (1-\rho_r)\ln(R^\star) + \rho_r \ln\left(R_{t-1}^\star\right) + \varepsilon_{rt} \tag{32}$$

$$S_t = (1-\rho_s)\,S^{PPP} + \rho_s S_{t-1} + \varepsilon_{st} \tag{33}$$

For $k \in \{0,1,2\}$, with Rule 0 = 0 corresponding to the baseline Taylor rule and

$$\text{Rule 1} = -\lambda_b \ln\left(\frac{b_{B,t}^\star}{b_{B,t-1}^\star}\right) \quad \text{and} \quad \text{Rule 2} = \lambda_b \ln\left(\frac{b_{S,t}^\star}{b_{S,t-1}^\star}\right),$$

the monetary policy equation is given by

$$\ln(R_t) = \lambda_R \ln(R_{t-1}) + (1-\lambda_R)\left\{\lambda_\pi \ln(\pi_t) + \lambda_y\left[\ln(Y_t) - \ln(Y_{t-1})\right] + \ln(R) + \text{Rule k}\right\}, \tag{36}$$

while the macroprudential policy rules are given by

$$\tau_t = c_1 \tau_{t-1} + (1-c_1)\,\overline{\tau} + (1-c_1)\,c_2\left(b_{ft} - b_{f,t-1}\right) \tag{34}$$

$$\tau_t^\star = d_1 \tau_{t-1}^\star + (1-d_1)\,\overline{\tau}^\star + (1-d_1)\,d_2\left(b_{Bt}^\star - b_{B,t-1}^\star\right). \tag{35}$$

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