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ARTICLE

Financial openness, bank capital flows, and the effectiveness of macroprudential policies

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Abstract

This paper quantitatively examines the macroeconomic and welfare effects of macroprudential policies in open economies. We develop a small open economy dynamic stochastic general equilibrium (DSGE) model, where banks choose their funding sources (domestic vs. foreign deposits) and are subject to financial constraints. Our model predicts that banks reduce leverage in response to a macroprudential policy tightening, but increasingly rely on foreign funding. This endogenous shifts of funding composition significantly undermine the stabilizing effect and welfare gains of macroprudential policies. Our results also suggest macroprudential policies are less effective in financially more open economies, and optimal policy should take capital flows into consideration. Finally, we find empirical support for the model predictions in a group of developing and emerging economies.

Keywords: Credit intermediary, Financial frictions, Financial openness, Macroprudential policy

JEL Classifications: E32, E44, F38, F41

1. Introduction

Over recent decades, large swings of credit cycles have contributed significantly to macroeconomic and financial instability in many economies, particularly developing and emerging ones.[1] In an attempt to stabilize the boom and bust of credit cycles, regulators around the globe are working on adopting macroprudential policies.[2] Although there is a growing body of literature examining the effectiveness of macroprudential policies, few papers have quantitatively studied how financial openness affects their performance. However, empirical evidence in Hahm et al. (2013), Lane and McQuade (2014), and Baskaya et al. (2017) suggests that cross-border capital flows are closely related to domestic credit growth. Therefore, it seems crucial to take capital flows into account when evaluating the effectiveness of macroprudential policies.

In this paper, we employ a small open economy dynamic stochastic general equilibrium (DSGE) model with cross-border bank capital flows and financial imperfections to quantitatively assess the effect of financial openness on the macroeconomic and welfare implications of macroprudential policies. Our framework builds on the work done by Gertler and Karadi (2011) (GK henceforth), where banks extend credits to productive firms and collect deposits from domestic savers. An agency problem is introduced between the depositors and the banks due to the limited enforcement of financial contracts. The credit market imperfection generates an endogenous bank leverage constraint and a spread between the deposit rate and loan rate whose size depends on the financial conditions of the bank balance sheet. They show that the credit fluctuations areinefficient

because of the underlying financial imperfection, and credit policies that stabilize the credit cycles are welfare-improving.

Following Aoki et al. (2016), we extend the existing framework by allowing foreign deposits, in addition to domestic deposits, to be intermediated by local banks. A key assumption we make is that it is more difficult for foreigners to monitor domestic banks. As a result, the endogenous bank leverage constraint is tighter when foreign funding accounts for a larger proportion of total deposits. Banks therefore face a trade-off in the international financial market: Capital is less expensive in the international market, but it further constrains a bank's ability to leverage up and provide loans.[3] Banks trade-off higher profits per unit of credit with lower total credits extended when determining the optimal fraction of foreign funding in their liabilities. This mechanism allows our model to produce a positive correlation between credit growth and bank foreign financing ratio, which is consistent with the data.[4]

In our model economy, macroprudential regulations that restrict bank credit growth will simultaneously affect the bank financing source decisions. To understand the transmission mechanisms of macroprudential regulations, consider a tightening of regulations that discourages bank lending. Banks deleverage and contract credit expansion in response to such a policy change (the leverage channel). At the lower level of leverage, banks have an incentive to rely more on foreign deposits because the marginal benefit of the cost savings outweighs the marginal cost of less credit extension. This composition shift increases bank profitability and net worth relative to the scenario where the composition remains constant, which in turn relaxes a bank's leverage constraint and increases credit growth (the composition channel). Therefore, relative to a constant funding structure, the composition channel results in greater currency misalignment and higher credit growth in response to tighter regulations. This is an unintended consequence that undermines the stabilizing effect of macroprudential policies on credit growth.

We show that this composition channel is quantitatively crucial for macroprudential policy evaluation. In particular, our results suggest that the composition channel offsets the impact of a one-time macroprudential regulation tightening on credit growth by about 69%. In addition, it dampens the credit stabilizing effect and welfare gains of optimal leaning-against-the-wind macroprudential policy rule by 42% and 37%, respectively.

Because of the existence of the composition channel, financial openness plays an important role in influencing the effectiveness of macroprudential policies. Greater financial openness amplifies the magnitude of capital flows and leads to a stronger composition effect in response to regulations. This causes greater fluctuations of foreign financing and offsets more of the stabilizing effects of macroprudential policies on credit growth. Our model predicts macroprudential regulations are less effective in financially more open economies, and Ramsey optimal policy suggests macroprudential policies should take capital flows into account. Moreover, we find capital controls complement domestic macroprudential policies.

Finally, we systematically test the model predictions using cross-country panel regressions for a group of developing and emerging economies. After controlling for global financial cycles and country and banking sector characteristics, we find that macroprudential policies mitigate bank credit growth, which is in line with the leverage channel effect, but their effectiveness decreases with the degree of financial openness. Our results also imply that consistent with the composition channel effect, banks increasingly rely on foreign financing sources in response to macroprudential regulation tightening. In addition, higher fractions of foreign funding are associated with higher domestic credit growth. Our empirical analysis hence confirms that the currency composition shift in bank liabilities is a potential channel through which financial openness impacts the effectiveness of macroprudential policies.

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2. Literature review

We are certainly not the first ones to quantitatively assess the effectiveness of macroprudential regulations in a DSGE framework. One strand of macroprudential policy literature built upon the seminal contributions of Bernanke and Gertler (1989), Kiyotaki and Moore (1997), and Iacoviello (2005) to study the effects of borrower-based macroprudential policies, mainly loan-to-value ratios (LTVs). For instance, in closed economy setups, Gelain et al. (2013), Lambertini et al. (2013), Rubio and Carrasco-Gallego (2014), Alpanda and Zubairy (2017), and Rubio (2019) found that LTVs are effective in stabilizing the excessive credit cycles and improve social welfare. Similar conclusions emerge for open economies subject to external shocks as in Quint and Rabanal (2013), Mendicino and Punzi (2014), and Brzoza-Brzezina et al. (2015). Different from these studies, we introduce frictional financial intermediary and focus on evaluating financial-institution-based macroprudential regulations, such as reserve requirements and bank leverage constraints.

In this regard, our paper is closely related to the works that developed analytical frameworks in which bank balance sheet conditions amplify shocks to the real economy in the presence of financial frictions. For example, GK built a model with agency problem between depositors and banks, and employed it to examine the effects of credit policies. In frameworks with various types of frictions in the banking sector, Angeloni and Faia (2013), Angelini et al. (2014), and Tayler and Zilberman (2016) studied the interaction between capital requirements and monetary policy. They found room for cooperation to improve the effectiveness and welfare gains of policies, but the improvements are shock dependent. Benes and Kumhof (2015) showed the need for countercyclical capital buffers when bank lending is risky. Agénor (2019) studies the growth and welfare effects of macroprudential regulation in an OLG model of endogenous growth with banking and agency costs. Catullo et al. (2019) presents an agent-based model with individual choices of firms and banks and found that a combination of micro- and macroprudential policies reduces systemic risk.

The aforementioned studies provide useful insights on the effects of macroprudential policies, but they typically abstract from the realistic balance sheet structure of financial intermediaries. A few papers attempted to fill this gap. For example, Gertler et al. (2012) extended the GK framework to allow for an endogenous bank equity- and debt-financing choice and studied the effects of macroprudential policies on the ex-ante bank risk-taking behavior. Punzi and Rabitsch (2018) relaxed the assumption of a homogeneous borrower and allowed bank loans to have different risk profiles. Their results suggest macroprudential policies that restrict lending to higher risk groups are more effective than policies that target all groups. Brzoza-Brzezina et al. (2017) introduced foreign currency loans and found the presence of foreign currency loans does not significantly influence the effectiveness of macroprudential policy. We also take the balance sheet composition of banks into consideration, but different from the existing literature, our setup includes a choice of liability currency composition and hence features a different composition effect of macroprudential policies.

Regarding the effects of institution-based macroprudential regulations in open economies, Agénor et al. (2014), Aoki et al. (2016), and Agénor et al. (2018) developed open economy DSGE models with financial frictions and foreign financing. They found macroprudential regulations can stabilize the domestic economy and improve welfare. Dräger and Proaño (2020) incorporate cross-border banking in a two-region monetary union model and found that various types of macroprudential policies can mitigate macroeconomic volatility. The main difference between our work and theirs is that we evaluate how foreign openness impacts the effectiveness of macroprudential regulations through the banks' funding composition channel. To model the endogenous choice of funding sources, we follow Aoki et al. (2016) to differentiate funds by their degree of financial frictions. On the other hand, instead of evaluating the net effects of macroprudential policies as in Aoki et al. (2016), we disentangle the channels of macroprudential policies at

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work and assess their effects individually. In addition, we examine the design of optimal policy in the presence of balance sheet structure.

Our results imply that macroprudential regulations lead banks to shift toward greater currency mismatch on their balance sheets, which is an unintended consequence and particially offsets the stabilizing effects of policies. A few other papers have also identified unintended consequences of macroeconomic policies that are different from ours. For example, Aiyar et al. (2014) and Jiménez et al. (2017) found evidence of risk and regulatory arbitrage by unregulated banks. Hachem and Song (2016) and Hachem and Song (2017) showed that stricter liquidity standards can trigger unintended credit booms.

A growing body of literature is empirically investigating the effectiveness of macroprudential policies. For example, Claessens et al. (2013), Cerutti et al. (2017), Zhang and Zoli (2016), Bruno et al. (2017), and Akinci and Olmstead-Rumsey (2018) have conducted assessments of the effectiveness of macroprudential regulations in various economies over different time periods and found that, in general, macroprudential regulations have an impact on capital flows and domestic credit growth. Among these empirical studies, Cerutti et al. (2017) is the closest to ours. They constructed a macroprudential policy index (MPI) for 119 countries over the 2000–2013 period and concluded that macroprudential policies are generally effective in mitigating credit growth, but their effectiveness is weaker in more financially open countries because the use of macroprudential policies is associated with greater cross-border borrowing. Unlike Cerutti et al. (2017), who used economy-wide capital flows for evidence of regulation avoidance, we focus on the cross-border capital flows through the banking sector. Hence, our work complements Cerutti et al. (2017) to suggest that financial intermediaries may be responsible for the regulation arbitrage observed in the data.

The rest of the paper is organized as follows. Section 3 lays out the analytical framework, and Section 4 quantitatively evaluates the macroeconomic and welfare implications of macroprudential policies. Section 5 presents the empirical evidence that supports our model predictions. Finally, we offer some concluding remarks in Section 6.

3. Analytical framework

In this section, we lay out an infinite horizon DSGE model for a small open economy with a banking sector and financial frictions. The model consists of households, banks, and nonfinancial firms (goods producers, capital producers, and exporters). Banks are the only intermediaries that channel capital from domestic and international savers to the production firms, but they face an agency problem that limits their ability to raise funds. We specify each player's problem below.

3.1 Producers

There are three types of producers in the economy: goods producers, capital producers, and exporters.

Goods Producers. The goods producers employ capital K_t, labor L_t, and imported goods M_t to manufacture final products Y_t. The final products can be used for consumption, investment, or export. The goods producers minimize input costs that is given by

$$\text{costs} = W_t L_t + R_t^K K_t + e_t M_t, \tag{1}$$

subject to a constant economies of scale with regard to production technology. This yields

$$Y_t = A_t \left(\frac{K_t}{\alpha_K}\right)^{\alpha_K} \left(\frac{L_t}{\alpha_L}\right)^{\alpha_L} \left(\frac{M_t}{\alpha_M}\right)^{\alpha_M}, \tag{2}$$

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where W_t denotes the real wage rate, R_t^K denotes the rental rate of capital, and e_t denotes the real exchange rate in units of home goods per foreign goods. Having constant economies of scale in production implies $\alpha_K + \alpha_L + \alpha_M = 1$. A_t denotes the technology level and follows an exogenous AR(1) process given by

$$\ln A_t = \rho_A \ln A_{t-1} + \varepsilon_t^A, \tag{3}$$

where ε_t^A is an i.i.d. disturbance that is normally distributed with a mean of zero and a standard deviation σ_A.

The goods producers' problem implies the following optimality conditions:

$$R_t^K = \frac{\alpha_K Y_t}{K_t}, \tag{4}$$

$$W_t = \frac{\alpha_L Y_t}{L_t}, \tag{5}$$

$$e_t = \frac{\alpha_M Y_t}{M_t}. \tag{6}$$

Capital Producers. The capital producers combine investment goods with undepreciated capital goods to produce new capital goods.

The capital accumulates through investment as

$$K_{t+1} = (1-\delta)K_t + \left[1 - \Phi\left(\frac{I_t}{I_{t-1}}\right)\right] I_t, \tag{7}$$

where δ is the capital depreciation rate, and $\Phi(I_t/I_{t-1}) = \kappa(I_t/I_{t-1} - 1)^2/2$ is a quadratic form of the investment adjustment cost.

The capital producers maximize the present value of profits as follows:

$$E_t \sum_{i=0}^{\infty} \Lambda_{t,t+i} \Pi_{t,t+i}^C, \tag{8}$$

subject to the dynamics of capital accumulation (7). We denote the stochastic discount factor as $\Lambda_{t,t+i}$, and the profit is given by

$$\Pi_t^C = Q_t K_{t+1} - Q_t(1-\delta)K_t - I_t, \tag{9}$$

where Q_t denotes the real price of capital.

The optimal choice of investment implies:

$$\begin{aligned} 1 = Q_t \left[1 - \frac{\kappa}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2 - \kappa\left(\frac{I_t}{I_{t-1}} - 1\right)\frac{I_t}{I_{t-1}}\right] \\ + \mathbb{E}_t \Lambda_{t,t+1}\left[\kappa Q_{t+1}\left(\frac{I_{t+1}}{I_t} - 1\right)\left(\frac{I_{t+1}}{I_t}\right)^2\right]. \end{aligned} \tag{10}$$

Exporters. The exporters sell home goods in a competitive international market. We assume the foreign demand for home goods is inversely related to the relative price of the export and positively related to foreign income. Specifically, the total exports are given by

$$EX_t = e_t^{\eta} Y^*, \tag{11}$$

where Y^* denotes an exogenous foreign income level, and η measures the price elasticity of foreign demand.

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3.2 Households

There is a continuum of identical households in a unit mass. Each representative household consists of bankers and workers. All workers supply labor and deposit a fraction of their income in home banks. Each banker manages a bank until retirement with probability $1-\sigma$. Bankers who exit become workers and transfer their retained earnings to their respective household. An equal number of workers become new bankers and receive $\xi/(1-\sigma)$ fraction of total assets from the household as start-up funds. We will set up the banker's problem in Section 3.3.

Each household chooses consumption c_t, labor supply l_t, and real bank deposit d_t to maximize lifetime utility:

$$E_0 \sum_{t=0}^{\infty} \beta^t \ln \left(c_t - \chi \frac{l_t^{1+\sigma_L}}{1+\sigma_L} \right), \tag{12}$$

subject to flow budget constraints, which is given by

$$c_t + d_t = W_t l_t + \Pi_t + R_{t-1} d_{t-1} + T_t. \tag{13}$$

We denote the gross interest rate on home deposits from time $t-1$ to t as R_{t-1}. T_t is the transfer of tax proceeds from the implementation of macroprudential policies which we will specify later. Π_t is the distribution of profits from the ownership of banks to the household and is given by

$$\begin{aligned} \Pi_t =& (1-\sigma)\{[R_t^K + (1-\delta)Q_t]K_t - R_{t-1}D_{t-1} - e_t R_{t-1}^* D_{t-1}^*\} \\ & - \xi [R_t^K + (1-\delta)Q_t]K_t, \end{aligned} \tag{14}$$

where the bank ownership profit Π_t consists of the retained earnings from the retiring bankers minus the start-up fund for the entering bankers.

The production firms pay no dividend in equilibrium since they operate in a perfectly competitive market. Notice that we assume workers cannot directly supply capital to the production firms due to their lack of expertise, nor can they directly engage in foreign transactions.

The optimality conditions of the household with respect to labor supply, consumption, and home deposit are given by

$$W_t = \chi l_t^{\sigma_L}, \tag{15}$$

$$\lambda_t = \frac{1}{\left(c_t - \chi \frac{l_t^{1+\sigma_L}}{1+\sigma_L} \right)}, \tag{16}$$

$$E_t(\Lambda_{t,t+1} R_t) = 1, \tag{17}$$

where $\Lambda_{t,t+1} = \beta \lambda_{t+1}/\lambda_t$ is the stochastic discount factor.

3.3 Banks

Banks issue deposits in both domestic and foreign financial markets and use their own net worth to fund capital investment in local firms. Each banker manages a bank until retirement. This retirement assumption rules out the possibility that banks may invest with any retained earnings. The objective of a typical bank is to maximize the present value of future dividends and net worth at retirement as follows:

$$V_t = E_t \left[\sum_{j=1}^{\infty} \Lambda_{t,t+j} \sigma^{j-1} (1-\sigma) n_{t+j} \right], \tag{18}$$

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where n_{t+j} is the net worth of the bank at retirement date $t+j$ with probability $\sigma^{j-1}(1-\sigma)$. $\Lambda_{t,t+j}$ is the stochastic discount factor of the representative household.

A representative bank's flow of funds is given by

$$Q_t k_{t+1} = n_t + d_t + e_t d_t^*, \tag{19}$$

where k_t, n_t, d_t, and d_t^* are capital investment, net worth, domestic deposit, and foreign deposit of this typical bank, respectively.

Notice that we assume banks borrow in their own currency in the domestic financial market and all foreign financial contracts are denominated in a foreign currency.[5] This assumption is relevant because developing and emerging economies often suffer from "original sin" and are unable to borrow internationally in their own currency.[6] Finally, we assume all the foreign funding has to be channeled through home banks to domestic capital investments. As a result, the currency composition in the bank balance sheet is mismatched, and banks face exchange rate risk.

A bank's net worth evolves as follows:

$$n_t = [R_t^K + (1-\delta)Q_t]k_t - R_{t-1}d_{t-1} - e_t R_{t-1}^* d_{t-1}^*, \tag{20}$$

where R_t^* is an exogenous foreign real gross interest rate between period t and $t+1$. Because numerous studies have found that the US interest rate is an important driver of international financial cycles, we introduce uncertainties into the foreign interest rate as:

$$\ln R_t^* = \rho_{R^*} \ln R_{t-1}^* + \varepsilon_t^{R^*}, \tag{21}$$

where $\varepsilon_t^{R^*}$ is an i.i.d. disturbance that is normally distributed with a mean of zero and a standard deviation σ_{R^*}.

Following Gertler and Karadi (2011) and Aoki et al. (2016), we model the limitation of bank fund-raising ability by introducing the following moral hazard problem:[7] Each period t, the banker decides whether to operate honestly or divert assets for family use after raising funds and investing at the beginning of this period. Specifically, the banker can divert a fraction $\Theta(x_t)$ of assets. As in Aoki et al. (2016), we assume a banker's ability to divert funds depends upon the sources of the funds:[8]

$$\Theta(x_t) = \theta\left(1 + \frac{\gamma}{2}x_t^2\right), \tag{22}$$

where $x_t = e_t d_t^* / Q_t k_{t+1}$ is the fraction of capital investment financed by foreign borrowing, which measures the severity of currency mismatch in the bank balance sheet. This financial friction specification implies the fraction of divertable assets rises with the foreign debt ratio because monitoring costs are usually higher for foreign lenders due to information asymmetry. Parameter θ measures the degree of agency cost and γ represents the degree of home bias in bank financing.

At the beginning of the period, the banker decides whether to divert assets. If the banker chooses to divert, the creditors will force the bank to go bankrupt and recover the remaining $1-\Theta(x_t)$ fraction of assets. Therefore, the following incentive constraint must hold for the creditors to supply funds to the banker:

$$V_t \geq \Theta(x_t) Q_t k_{t+1}. \tag{23}$$

The left-hand side is the continuation value of an honest bank, while the right-hand side is the amount gained from diverting assets.

The banker's problem is to maximize the continuation value of the bank by choosing the level of capital investment k_t, home borrowing d_t, and foreign borrowing d_t^*:

$$V_t = E_t\{\Lambda_{t,t+1}[(1-\sigma)n_{t+1} + \sigma V_{t+1}]\}, \tag{24}$$

subject to the flow of funds constraint (19) and the incentive constraint (23).

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We define $\psi_t \equiv V_t/n_t$ as the Tobin's Q ratio of the bank, and $\phi_t \equiv Q_t k_{t+1}/n_t$ as the leverage ratio of the bank. Then we can rewrite the bank's value function as

$$\psi_t = E_t[\Lambda_{t,t+1}(1-\sigma+\sigma\psi_{t+1})\frac{n_{t+1}}{n_t}], \tag{25}$$

and the evolution of net worth combined with the flow of funds constraints becomes:

$$\begin{aligned}\frac{n_{t+1}}{n_t} &= \frac{[R^K_{t+1}+(1-\delta)Q_{t+1}]}{Q_t}\frac{Q_t k_{t+1}}{n_t} - R_t\frac{d_t}{n_t} - R^*_t\frac{e_{t+1}}{e_t}\frac{e_t d^*_t}{n_t} \\ &= \left[\frac{(R^K_{t+1}+(1-\delta)Q_{t+1})}{Q_t} - R_t\right]\phi_t + \left[R_t - R^*_t\frac{e_{t+1}}{e_t}\right]\phi_t x_t + R_t,\end{aligned}$$

In the model, banks make optimal decisions concerning capital investments, domestic borrowing, and foreign borrowing. These choices are equivalent to choosing leverage ϕ_t and liability currency structure x_t, which are defined as the ratio of capital investments over net worth and the ratio of foreign deposits over capital investments, respectively. We can transform the bank's problem as one concerned with maximizing the Tobin's Q by choosing (ϕ_t, x_t):

$$\max \psi_t = \max(\mu_t\phi_t + \mu^*_{dt}\phi_t x_t + \nu_t),$$

subject to the incentive constraint:

$$\psi_t \geq \theta\left(1+\frac{\gamma}{2}x_t^2\right)\phi_t, \tag{26}$$

where

$$\mu_t = E_t\Omega_{t+1}\left[R_{K,t+1} - R_t\right], \tag{27}$$

$$\mu^*_{dt} = E_t\Omega_{t+1}\left[R_t - R^*_t\frac{e_{t+1}}{e_t}\right], \tag{28}$$

$$\nu_t = E_t\Omega_{t+1}R_t, \tag{29}$$

$$\Omega_{t+1} = \Lambda_{t,t+1}(1-\sigma+\sigma\psi_{t+1}). \tag{30}$$

$R_{K,t+1}$ is the rate of return of holding capital given by:

$$R_{K,t+1} = \frac{R^K_{t+1}+(1-\delta)Q_{t+1}}{Q_t}. \tag{31}$$

It is natural to think of Ω_{t+1} as the stochastic discount factor of the banker. From (27) and (28), we can see that μ_t is the credit spread between the domestic risk-free deposit rate and the capital rate of return, whereas μ^*_{dt} is the credit spread between the domestic risk-free deposit rate and the exchange-rate-adjusted foreign deposit rate. The first credit spread arises because the existence of financial friction limits the bank's ability to raise funds. The second spread arises since the agency problem intensifies as more funds are collected from the international market, which further restricts the bank's fund-raising ability. ν_t can be seen as present value of unit net worth.

We focus on the case where the incentive constraint is binding, which yields:

$$\psi_t = \Theta(x_t)\phi_t. \tag{32}$$

The first-order conditions with respect to ϕ_t and x_t yield:

$$\mu_t + \mu^*_{dt}x_t = \theta\left(1+\frac{\gamma}{2}x_t^2\right)\lambda_t, \tag{33}$$

and

$$\mu^*_{dt} = \theta\gamma x_t\lambda_t, \tag{34}$$

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where λ_t is the Lagrangian multiplier associated with the incentive constraint (26). The left-hand side of condition (33) is the marginal return of taking one more unit of leverage, whereas the right-hand side is the marginal cost of tightening the financial constraint, which has a shadow price of λ_t. Condition (34) equates the marginal value of financing through foreign funds to the marginal cost of additional leverage constraint imposed by the participation condition of foreign lenders. We can see from (34) that if the incentive constraint is binding, that is $\lambda_t > 0$, then $\mu^*_{dt} > 0$. A positive μ^*_{dt} in turn implies the uncovered interest rate parity fails to hold as in (28).

Combining these two first-order conditions yields:

$$x_t = \frac{\mu_t}{\mu^*_{dt}} \left[-1 + \sqrt{1 + \frac{2}{\gamma} \left(\frac{\mu^*_{dt}}{\mu_t} \right)^2} \right]. \tag{35}$$

The equation above relates the choice of bank liability currency structure x_t to the credit spreads μ_t and μ^*_{dt}, which we interpret as the marginal profit per unit of domestic and foreign deposit respectively. We obtain the relationship between the foreign debt ratio and the relative profit margin in Lemma 1.

Lemma 1. *The foreign debt ratio x_t increases with the relative profit margin between foreign and domestic deposits μ^*_{dt}/μ_t.*

Proof. See Appendix A.1 □

The intuition of this lemma is straightforward. The bank relies more on foreign financing if the marginal profit from using foreign deposits rises relative to using domestic deposits.

Next, we substitute the Tobin's Q ratio given by (32) into the bank's objective function and solve for the bank's leverage:

$$\phi_t = \frac{\nu_t}{\Theta(x_t) - (\mu_t + \mu^*_{dt} x_t)}. \tag{36}$$

3.4 Macroprudential policy

Countries typically adopt various macroprudential measures. In the benchmark, we use reserve requirement ratio as the policy instrument since it is among the most frequently employed macroprudential policy measures in developing and emerging economies.[9] Additionally, in our model, the financial friction arises between bank and depositor; hence reserve requirement ratio seems to be the most direct policy instrument and allows for a straightforward interpretation.[10]

Specifically, we assume each period the regulator requires the banks to hold a fraction τ^B_t of their total deposits as reserves. The bank's flow of funds becomes:

$$Q_t k_{t+1} = n_t + (1 - \tau^B_t)(d_t + e_t d^*_t), \tag{37}$$

where τ^B_t represents a reserve requirement ratio on bank deposits.

We assume the regulator commits to adjust the reserve requirement ratio following a countercyclical policy rule that targets the deviation of aggregate credit growth from its long-run level, which is given by

$$\tau^B_t = \omega^B [\ln(Q_t K_{t+1}) - \ln(QK)], \tag{38}$$

where Q and K denote their steady-state level. ω^B measures the aggressiveness of the policy responsiveness. This rule systematically captures the leaning-against-the-wind nature of reserve requirements, which is often mentioned by regulators in developing and emerging economies.

We assume the reserves collected from the banks are rebated to the households in a lump sum fashion such that:[11]

$$T_t = \tau^B_t (D_t + e_t D^*_t). \tag{39}$$

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The reserve requirement ratio τ^B enters into the optimality conditions for foreign debt ratio and leverage as

$$x_t^{policy} = \frac{\mu_t^{policy}}{\mu_{dt}^*}\left[-1+\sqrt{1+\frac{2}{\gamma}\left(\frac{\mu_{dt}^*}{\mu_t^{policy}}\right)^2}\right], \tag{40}$$

and

$$\phi_t^{policy} = \frac{\nu_t^{policy}}{\Theta\left(x_t^{policy}\right)-\left(\mu_t^{policy}+\mu_{dt}^* x_t^{policy}\right)}, \tag{41}$$

where

$$\mu_t^{policy} = E_t\Omega_{t+1}\left[R_{K,t+1}-\frac{R_t}{1-\tau_t^B}\right], \tag{42}$$

$$\nu_t^{policy} = E_t\Omega_{t+1}\left[\frac{1}{1-\tau_t^B}R_t\right]. \tag{43}$$

In order to see how the reserve requirements influence bank leverage, we take the partial derivative of ϕ_t^{policy} in equation (41) with respect to τ_t^B and present the outcome in (44).[12] It is clear that the marginal effect of reserve requirements on bank leverage can be decomposed into two components: The first component captures the direct impact, whereas the second component indirectly affects bank leverage through the marginal effect of on the liability structure x_t. We label the first component as the leverage channel and the second component as the composition channel.

$$\frac{\partial\phi_t^{policy}}{\partial\tau_t^B} = \underbrace{\frac{\frac{\partial\nu_t^{policy}}{\partial\tau_t^B}-\frac{\partial\mu_t^{policy}}{\partial\tau_t^B}\phi_t^{policy}}{\Theta(x_t^{policy})-\left(\mu_t^{policy}+\mu_{dt}^* x_t^{policy}\right)}}_{\text{Leverage Channel}} + \underbrace{\frac{\phi_t^{policy}\left[\mu_{dt}^*-\theta\gamma x_t^{policy}\right]}{\Theta(x_t^{policy})-\left(\mu_t^{policy}+\mu_{dt}^* x_t^{policy}\right)}\frac{\partial x_t^{policy}}{\partial\tau_t^B}}_{\text{Composition Channel}}, \tag{44}$$

Most of the existing quantitative studies on the effects of macroprudential regulations in open economies assume an exogenous liability currency composition. However, under such an assumption, macroprudential policy τ_t^B do not affect the foreign debt ratio x_t, that is, $\partial x_t^{policy}/\partial\tau_t^B = 0$. Since the literature often overlooks the composition channel of macroprudential policy, one of our contributions is to quantitatively assess the extent to which the composition shift affects the policy implications on macroeconomic dynamics and welfare as we do in Section 4.

3.5 Equilibrium

The goods market clearing condition reads as

$$Y_t = C_t + I_t + EX_t. \tag{45}$$

The balance of payments of this economy is given by

$$D_t^* = R_{t-1}^* D_{t-1}^* + M_t - \frac{1}{e_t}EX_t. \tag{46}$$

In aggregate, the accumulation of bank net worth follows:

$$N_t = (\sigma+\xi)[R_t^K+(1-\delta)Q_t]K_t - \sigma R_{t-1}D_{t-1} - \sigma e_t R_{t-1}^* D_{t-1}^*, \tag{47}$$

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and the bank balance sheet is given by

$$Q_t K_{t+1} = N_t + (1 - \tau_t^B)(D_t + e_t D_t^*). \tag{48}$$

The total leverage ratio ϕ_t and foreign financing ratio x_t of the banking sector are as follows:

$$\phi_t = \frac{Q_t K_{t+1}}{N_t}, \tag{49}$$

$$x_t = \frac{e_t D_t^*}{Q_t K_{t+1}}. \tag{50}$$

Finally, we define the competitive equilibrium below.

Definition 1. *The competitive equilibrium is defined as follows:*

(1) Given the prices $\{W_t, Q_t, R_t\}$*, the households solve their problem by choosing* $\{c_t, d_t, l_t\}$*.*
(2) Given the prices $\{W_t, R_t^K, e_t, Q_t\}$*, the exogenous productivity process* A_t*, nonfinancial firms solve their problem by choosing* $\{L_t, K_{t+1}, M_t, I_t, EX_t\}$*.*
(3) Given the prices $\{R_t^K, R_t, R_t^*, e_t, Q_t\}$*, initial net worth* n_0*, and the macroprudential policy* $\{\tau_t^B\}$*, the banks solve their problem by choosing* $\{d_t, d_t^*, k_{t+1}\}$*.*
(4) All the markets clear.

4. Quantitative analysis

4.1 Calibration

In our calibration, we use annual data of banking, macroeconomic, and financial variables from 38 developing and emerging economies between the years 2001 and 2013.[13] We present the calibration strategy below and parameter values in Table 1.

Production. Over our sample period, the average gross capital-formation-to-GDP ratio is 0.24, and the average imports-to-GDP ratio is 0.43. To match these two moments, we set the capital share α_K to 0.33 and the import share α_M to 0.30. The constant returns to scale assumption then implies labor share α_L to be 0.37. We follow Gertler et al. (2007) to set the annual depreciation rate of capital δ to 0.1, which is a standard value in the business cycle literature. We calibrate the price elasticity of foreign demand to be 1.5 to match the volatility of the foreign debt ratio. The investment adjustment cost parameter is assigned to be 1.2 in order to match the cyclicality of the foreign debt ratio.

Households. We set the discount factor at 0.94, which implies a 6% annual deposit rate as observed in our sample. We let the international interest rate be 2%, which is equal to the average US interest rate over the sample period. We set the degree of risk aversion to be 1, which is a standard value used in the business cycle literature. The inverse of Frisch elasticity of labor supply is set at 0.6, a number taken from Garcia-Cicco et al. (2010). The labor supply capacity χ is chosen to match the one third working hours per period.

Banks. We follow Aoki et al. (2016) to calibrate the parameters of banks. Bank survival rate σ is chosen to match the annual dividend payout rate of $(1 - \sigma) = 24\%$. We jointly pick the values of parameters (θ, γ, ξ) to match the leverage ratio, the spread between the loan rate and the deposit rate, and the foreign-debt-to-GDP ratio. The loan rate is approximately 10%, and the average foreign-debt-to-GDP ratio is about 0.1 in the data. The leverage ratio of the banking sector is about 13 during the sample period, which is much higher than that of the nonfinancial sector. As in GK, we make the steady-state leverage ratio 4, which represents the average ratio of the nonfinancial sector and the banking sector.

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Table 1. Parameters

Parameter	Description	Value	Target
Banks			
θ	Severity of agency cost	0.57	Leverage ratio
γ	Home bias in bank finance	22.77	Foreign-debt-to-GDP ratio
ξ	Fraction of total assets to new banks	0.015	Risk premium
σ	Survival probability	0.76	Dividend payout rate
Households			
β	Discount rate	0.94	Domestic deposit rate
R^*	World interest rate	1.02	US policy rate
σ_H	Degree of risk aversion	1	Standard value
σ_L	Inverse of Frisch elasticity	0.6	Garcia-Cicco et al. (2010)
χ	Labor supply capacity	8.12	Labor hours
Producers			
α_K	Capital share in production	0.33	Capital share
α_L	Labor share in production	0.37	Labor share
α_M	Import share in production	0.30	Import share
δ	Depreciation rate of capital	0.10	Gertler et al. (2007)
κ	Investment adjustment cost	1.2	corr(x, GDP)
η	Price elasticity of foreign demand	1.5	std(x)
Shock process			
ρ_A	Persistence of TFP	0.49	TFP process
σ_A	Std. Dev. of TFP	0.018	TFP process
ρ_{R^*}	Persistence of US interest rate	0.72	US interest rate process
σ_{R^*}	Std. Dev. of US interest rate	0.014	US interest rate process
Policy			
ω^B	Responsiveness of macroprudential policy	0	No policy intervention

Table 2. Steady-state value: annually

Steady state	Description	Model	Data
R	Domestic deposit rate	1.06	1.06
R^*	US interest rate	1.02	1.02
R_K	Capital rate of return	1.10	1.10
D^*/GDP	Foreign-debt-to-GDP ratio	0.10	0.10
I/GDP	Investment-to-GDP ratio	0.24	0.24
M/GDP	Import-to-GDP ratio	0.43	0.43
EX/GDP	Export-to-GDP ratio	0.43	0.38
C/GDP	Consumption-to-GDP ratio	0.76	0.68

Shock Process. We estimate first-order autoregressive processes for the average TFP for the sample countries and US interest rate to obtain parameters for the shock processes. The TFP data comes from the Total Economy Database.

To gauge the empirical performance of our model, we compare the model's implied first- and second-order moments with the data counterparts in Tables 2 and 3. Overall, our model matches the data relatively well. The model is able to generate a more volatile consumption relative to output and a countercyclical trade balance, which are salient features in the data of developing and

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Table 3. Second business cycle moments: data versus model

Variable		Standard deviation (%)	Standard deviation relative to GDP	Correlations with GDP
GDP	Model	2.59	1	1
	Data	2.73	1	1
Consumption	Model	2.81	1.08	0.94
	Data	3.70	1.35	0.64
Investment	Model	5.13	1.98	0.84
	Data	11.12	4.07	0.75
NX/GDP	Model	0.97	0.37	-0.46
	Data	2.43	0.89	-0.32
Credit	Model	4.99	1.93	0.90
	Data	12.09	4.43	0.43
Foreign debt ratio	Model	12.30	4.74	0.03
	Data	12.94	4.74	0.06

Notes: Note(s): The data-implied moments are calculated after HP-filtering in logs except the NX-to-GDP ratio and foreign debt ratio, which are detrended in levels, and averaged across countries. The model-implied moments are calculated using simulation variables following the same method. The sample period covers 2001–2013, and the set of countries is listed in Appendix B.

emerging economies.[14] The model also predicts procyclical credit growth and positive correlation between bank foreign debt ratio and credit growth that are consistent with the data.

4.2 Disentangle transmission channels

Given that our model produces satisfactory business cycle moments, we now turn to quantitatively examining the effects of macroprudential regulations. Recall that one key finding from our theoretical analysis is that a higher reserve requirement ratio leads to greater cross-border borrowing, which in turn feeds back to credit growth through currency composition shifts. To disentangle the effects of regulation changes on credit growth via different channels, we first turn off the composition channel by replacing the x_t^{policy} with x_t in equation (41). Since x_t does not depend on τ_t^B, this implies that the second term in equation (44), which captures the composition channel effect, becomes zero. The leverage is now given by

$$\phi_t^{lev} = \frac{\nu_t^{policy}}{\Theta(x_t) - \left(\mu_t^{policy} + \mu_{dt}^* x_t\right)}, \tag{51}$$

where the reserve requirement policy affects the leverage ratio through its impact on ν_t^{policy} and μ_t^{policy}.

We can turn off the leverage channel as well by setting the optimal leverage decision in (41) as

$$\phi_t^{comp} = \frac{\nu_t}{\Theta(x_t^{policy}) - \left(\mu_t + \mu_{dt}^* x_t^{policy}\right)}. \tag{52}$$

Now the only term that contains the reserve requirement ratio is x_t^{policy}. This implies that the policy influences the leverage ratio through its impact on the funding structure, without direct impact on ν_t and μ_t.

Temporary Macroprudential Policy Tightening. Let us first consider the effect of a one-time 5% increase of the reserve requirement ratio.[15] Figure 1 plots the dynamics of macroeconomic and

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Table 4. Effects of a transitory tightening of reserve requirements[a]

Variable	Overall effect (%)	Leverage channel (%)	Composition channel (%)	Effect offset (%)[b]
Credit	−2.30	−7.44	5.14	69
Output	−0.30	−0.55	0.25	45
Net worth	−5.72	−20.01	14.30	71
Capital price	−2.06	−6.90	4.83	70
Credit spread	2.63	3.96	−1.33	34
Foreign debt ratio	−3.36	−12.85	9.49	74

[a]This table shows the percentage deviation from steady states of key macroeconomic and financial variables subject to a one-period 5% increase of the reserve requirement ratio. We report their effect upon impact with the exclusion of the foreign debt ratio and output, which is calculated by averaging five periods. This is because the foreign debt ratio and output returns to its steady-state gradually in response to the temporary policy shock.
[b]This column reports the how much the regulation tightening effect through the leverage channel is offset by the existence of the composition channel. The offsetting effect is calculated as (1 − Overall Effect/Leverage Channel)%.

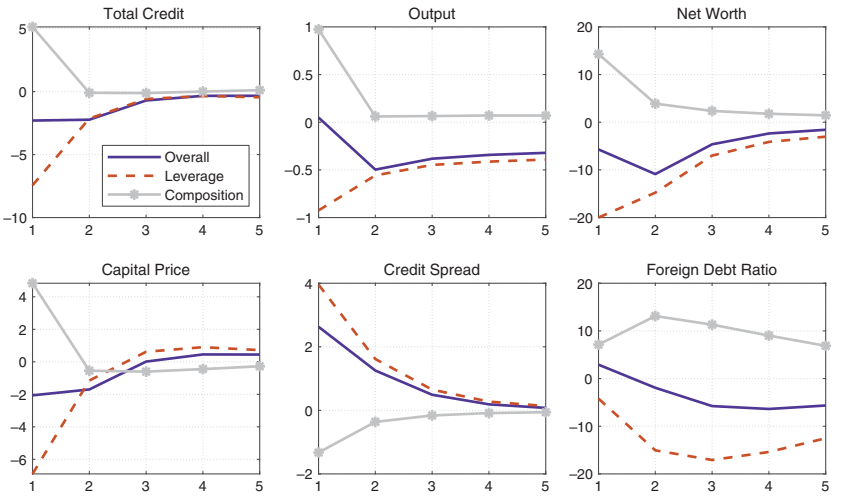

Figure 1. Macroeconomic dynamics after an increase of the reserve requirement ratio.

financial variables in response to this regulation tightening. The solid blue line shows the overall policy impact. We can see that a regulation tightening reduces bank credit, net worth, and output while increasing the credit spread. We also present the leverage and composition channel effects in dashed red line and gray dotted line, respectively, in the same figure. Notice that in the absence of the leverage channel, banks shift toward foreign financing and credit growth rises instead of falling in response to the regulation change. This occurs in sharp contrast to the objective of the regulators, and highlight the importance of taking into consideration the impact of macroprudential policies on banks' liability composition.

Table 4 reports the numerical result of this transitory 5% increase of reserve requirement ratio on key macroeconomic and financial variables. It is easy to verify that the overall effect equals the sum of the effects from the two channels. More importantly, the two channels work in opposite directions: The leverage channel contains credit growth, whereas the composition channel accelerates credit growth. The last column reports how much of the regulation effect would be offset if we take into account the composition channel. We can see that allowing the banks to choose their liability composition significantly weakens the effectiveness of macroprudential regulations.

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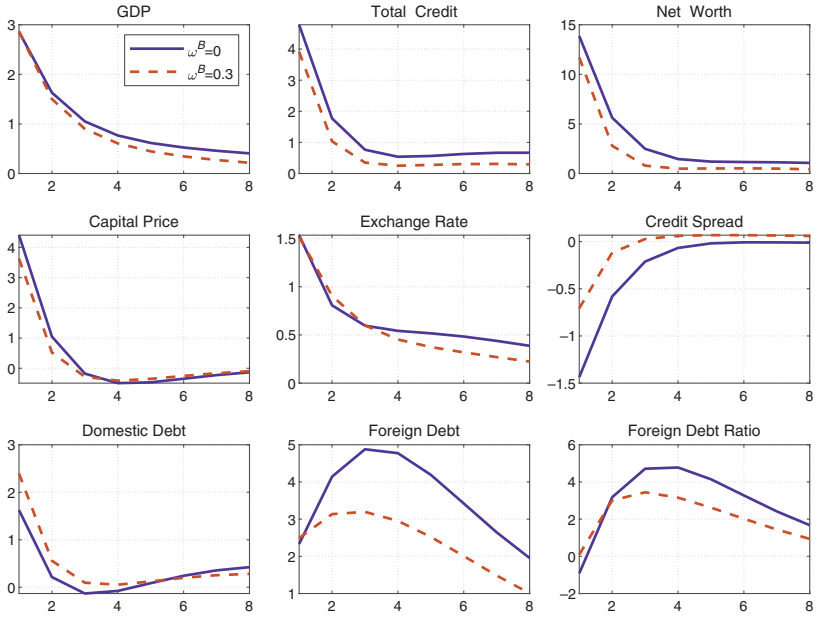

Figure 2. Macroeconomic dynamics in response to a positive productivity shock with and without reserve requirements.

For example, the macroprudential tightening would have lowered credit growth by 7.4%, instead of 2.3%, in the absence of the composition channel.

Countercyclical Macrorprudential Policy. Next, we examine the stabilizing effect of macroprudential policy when the economy is subject to productivity shocks.[16] Figure 2 plots the impulse responses of key macroeconomic and financial variables to a 1% positive productivity shock. The solid blue line shows the baseline dynamics with no reserve requirements, and the dashed red line presents the dynamics with a leaning-against-the-wind reserve requirement policy rule in place.

From Figure 2, we can see that without reserve requirements, the rise in productivity leads to a higher marginal product of physical capital investment and to increasing demand for capital, which in turn lifts up the capital price. Since the asset side of the bank balance sheet consists of capital investments, a higher capital price improves the bank balance sheet and increases bank net worth. This improvement relaxes the financial constraints on banks so that they are able to extend more loans to the production sector. The credit boom further drives up the demand for capital, which amplifies the macroeconomic effects of productivity shocks. In an open economy framework, this financial amplification effect is greater because the positive productivity shock appreciates the domestic currency. As a fraction of bank liability is denominated in foreign currency, appreciation further strengthens the bank balance sheet and leads to even higher credit growth.

Since our model features an endogenous bank financing choice, the expansion of the bank balance sheet is associated with a shift of liability structures. The impulse response functions in Figure 2 show that both the credits and foreign debt ratio rise after a favorable productivity shock. This is because an economic boom raises the investment rate of return, hence banks extend more loans and generate higher profits. The higher profits relax bank financial constraints, so banks can rely more on foreign financing. Stochastic simulation produces a positive correlation between credit growth and the foreign debt ratio, which is in line with the data.

The leaning-against-the-wind reserve requirements stabilize macroeconomic variables during economic booms as illustrated by the dashed red line. The rise of reserve requirements mitigates the credit growth and capital inflows. Lower credit growth in turn reduces the growth of capital investment and output. Moreover, the composition shift of bank liability to foreign funding is less significant with regulation, which results in a lower degree of currency mismatch.

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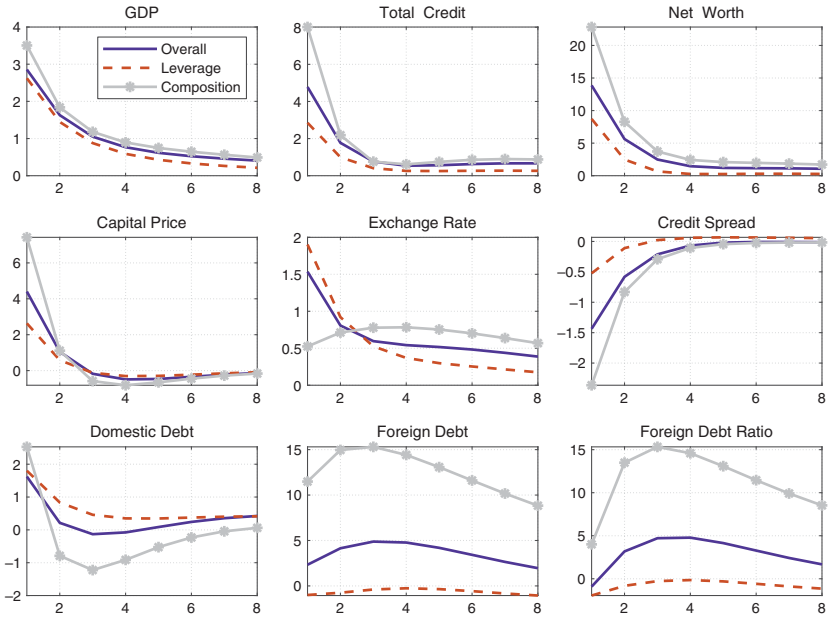

Figure 3. Effects of reserve requirements in response to a positive productivity shock: different channels.

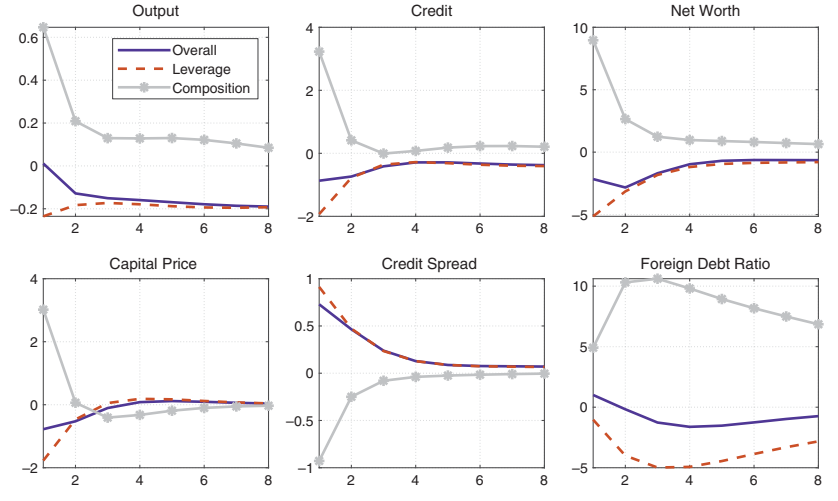

Figure 4. Net effects of reserve requirements in response to a positive productivity shock: different channels.

We report the policy effect when either the leverage or the composition channel operates in the dashed red line and gray line with dots respectively in Figure 3, whereas the blue line shows the overall policy effect. We can see that the two transmission channels of regulations yield opposite outcomes, and when transmitted solely through the composition channel, higher reserve requirement ratio may even amplify an economic disturbance. In addition, we plot the net policy impact under different transmission channels in Figure 4.[17] It is clear from the blue line that the output and credit growth become stabilized with regulations when both channels are turned on. However, the composition channel alone amplifies the credit boom in response to a productivity increase.

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Table 5. Standard deviations and welfare gains under various reserve requirements responsiveness[a]

	$\omega^B = 0.1$			$\omega^B = 0.3$		
Variable	Overall effect	Leverage channel	Effect offset (%)	Overall effect	Leverage channels	Effect offset (%)
Credit	0.89	0.80	45	0.76	0.58	44
Output	0.96	0.93	46	0.92	0.86	47
Net worth	0.90	0.80	51	0.79	0.59	48
Capital price	0.92	0.82	57	0.82	0.61	54
Credit spread	0.79	0.70	28	0.49	0.38	18
Foreign debt ratio	0.96	0.85	75	0.90	0.74	63
Welfare gain	0.011	0.016	36	0.015	0.024	36

[a]No-regulation serves as the benchmark scenario. The values reported in the first and fourth columns are the ratio of standard deviations and welfare gains relative to the benchmark in the presence of macroprudential regulations. The second and the fifth columns are the ratio of standard deviations and welfare gains relative to the benchmark when the composition channel of macroprudential regulation is turned off. The third and the last columns report the percentage of the policy effect offset by the existence of the composition channel, which is calculated as (Leverage Channel - Overall Effect)/(1-Leverage Channel)%.

4.3 Welfare analysis

We are also interested in the welfare evaluation of macroprudential policies. We define the welfare gain as the non-stochastic steady-state consumption households are willing to give up to live in an economy with policy interventions.[18] In particular, we express the lifetime utility as

$$V_0 = E_0 \sum_{t=0}^{\infty} \beta^t U(c_t, l_t) = E_0 \sum_{t=0}^{\infty} \beta^t U(c(1+\lambda_a), l) \tag{53}$$

where c and l are the steady-state level of consumption and labor, respectively. Therefore, λ_a represents the welfare gain expressed in steady-state consumption.

We report the standard deviations of key variables and welfare gains across different degrees of reserve requirement policy responsiveness in Table 5. The benchmark scenario is an economy with no regulation. The first and fourth columns report the ratio of standard deviations and welfare gains relative to the benchmark in the presence of reserve requirements. We can see that reserve requirements stabilize all the macroeconomic and financial variables, and generate sizable welfare gains. We then turn off the composition channel and show the policy impact through the leverage channel only in the second and the fifth columns. We can see that ignoring the composition channel substantially inflates the stabilization effect and overstates the welfare gains from regulations for all the scenarios considered. The third and the last columns report the policy effect offset by the existence of the composition channel.

It is evident from Table 5 that the credit cycle stabilizing effect of macroprudential regulations is significantly reduced in the presence of capital flows through banks. Because the existing literature examining the effectiveness of macroprudential regulations in an open economy framework often assumes an exogenous liability composition and shies away from endogenous composition shifts, their models tend to produce biased estimates of the effects of regulations. We can also see that the strength of the composition channel is weakened as the responsiveness of macroprudential regulations increases.

4.4 Financial openness

In the analysis so far, we have maintained the assumption that the financial account is completely open. In this section, we introduce an adjustment cost on cross-border capital flows. We follow

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Table 6. Effects of a transitory reserve requirements tightening under various degrees of financial openness[a]

	$\zeta = 0$		$\zeta = 1$		$\zeta = 2$	
Variable	Overall effect	Effect offset (%)	Overall effect	Effect offset (%)	Overall effect	Effect offset (%)
Credit	−2.30	69	−2.56	68	−2.64	65
Output	−0.30	45	−0.34	16	−0.35	12
Net worth	−5.72	71	−6.66	68	−6.87	66
Capital price	−2.06	70	−2.31	69	−2.38	66
Credit spread	2.63	34	2.80	32	2.83	29
Foreign debt ratio	−3.36	74	−3.98	69	−4.37	63

[a]This table shows the percentage deviation from steady states of key macroeconomic and financial variables subject to a one-time regulation tightening. We report their effect upon impact with the exclusion of the foreign debt ratio and output, which is calculated by averaging five periods. This is because the foreign debt ratio and output returns to its steady state gradually in response to the temporary policy shock.

Chang et al. (2015) and Davis et al. (2021) to interpret this cost as representing a combination of policy and market barriers to access the international financial market since it directly affects the magnitude of capital flows, which is a common de facto measure for financial openness used in the empirical literature. We then vary the degrees of financial openness to assess how it impacts the effectiveness of macroprudential regulations.

In particular, we assume the bank pays a quadratic adjustment cost when its foreign deposits deviate from the steady-state value. The bank's flow of funds constraint (37) becomes:

$$Q_t k_{t+1} = n_t + (1 - \tau_t^B)(d_t + e_t d_t^*) - \zeta (D_t^* - D^*)^2 e_t d_t^*, \tag{54}$$

where ζ controls the degree of financial openness. A higher ζ raises the costs of capital flows and hence represents a lower degree of financial openness.

Financial openness directly affects the interest rate spread between domestic and foreign deposits μ_{dt}^*, which is now given by

$$\mu_{dt}^* = E_t \Omega_{t+1} \left[\left(1 - \frac{\zeta (D_t^* - D^*)^2}{(1 - \tau_t^B)} \right) R_t - R_t^* \frac{e_{t+1}}{e_t} \right]. \tag{55}$$

We can see that a higher adjustment cost narrows the interest rate spread and makes the substitution from domestic to foreign funding less profitable. Hence, the composition channel is weakened in a financially more closed economy. Table 6 reports the effect of a one-time regulation tightening under different degrees of financial openness. It is easy to see that the effectiveness of macroprudential regulation is stronger in more financially closed economies.

Next, we study the optimal reserve requirement policy rule and report the findings in Table 7. We can see that the welfare gain peaks at a mild degree of aggressiveness when $\omega^B = 0.49$ in a fully open economy, and the welfare gain is about 0.016% of the steady-state consumption level. As financial openness rises, it is desirable to implement a more responsive macroprudential policy rule. This is because the composition channel presented in our model dampens the effectiveness of reserve requirements, and the composition channel becomes stronger when capital flows are less managed. Therefore, reserve requirements should be more aggressive to stabilize the credit cycles.

4.5 Ramsey optimal policy

A natural question then is how does the optimal reserve requirement policy behave in the presence of the composition channel? To address this question, we solve for the Ramsey planner's problem, employing reserve requirements as the policy instrument.[19]

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Table 7. Standard deviations and welfare gains under various degrees of financial openness

	$\zeta = 0$		$\zeta = 1$		$\zeta = 2$	
Variable	Optimal $\omega^B = 0.49$	Effect offset (%)	Optimal $\omega^B = 0.39$	Effect offset (%)	Optimal $\omega^B = 0.34$	Effect offset (%)
Credit	0.69	42	0.72	43	0.74	43
Output	0.91	47	0.91	47	0.92	47
Net worth	0.72	46	0.75	47	0.77	47
Capital price	0.75	51	0.78	53	0.80	53
Credit spread	0.31	9	0.39	13	0.44	16
Foreign debt ratio	0.86	54	0.88	59	0.89	61
Welfare gain	0.016	37	0.016	29	0.017	19

Note(s): No-regulation serves as the benchmark scenario. The values reported in all the columns are the ratio of standard deviations and welfare gains relative to the benchmark under each degree of financial openness.

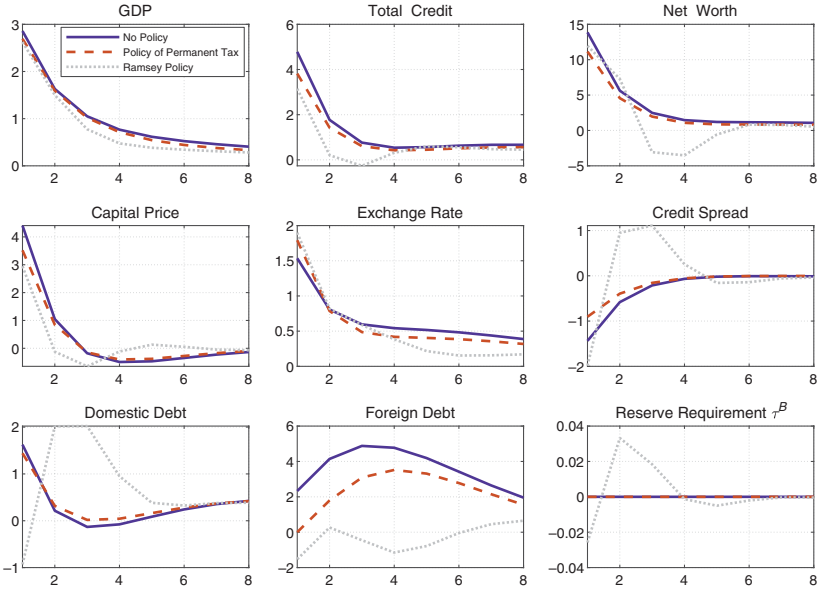

Figure 5. Impulse responses to a positive productivity shock under optimal policy. Note: "Policy of permanent Tax" is the case that τ_t^B equals to the Ramsey steady state τ^B.

Two implications emerge from the Ramsey optimal policy. First, the Ramsey steady state of τ^B equals -7.3%, which implies that the regulator should subsidize deposits in the steady state because the existence of financial frictions causes undersupply of funding and hence a low level of investment. Second, the policy should respond to foreign debt growth. We can see this from Figure 5, which presents the impulse responses to a productivity shock under a Ramsay optimal policy in the gray dotted line.

Since the Ramsey optimal policy suggests that reserve requirements should react to capital flows, we extend the simple policy rule in (38) to include changes of foreign deposits as an additional target. The extended policy rule is given by

$$\tau_t^B = \omega^B[\ln(Q_t K_{t+1}) - \ln(QK)] + \omega^{D*}[\ln(e_t D_t^*) - \ln(eD^*)], \tag{56}$$

where ω^{D*} measures the policy responsiveness to foreign debt growth.

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Table 8. Optimal simple rules

Targets	ω^B	ω^{D^*}	Welfare gains
Credit growth	0.49	–	0.016
Credit growth and foreign debt growth	0.46	0.134	0.020

Note: Welfare gains are relative to the benchmark, which has no policy.

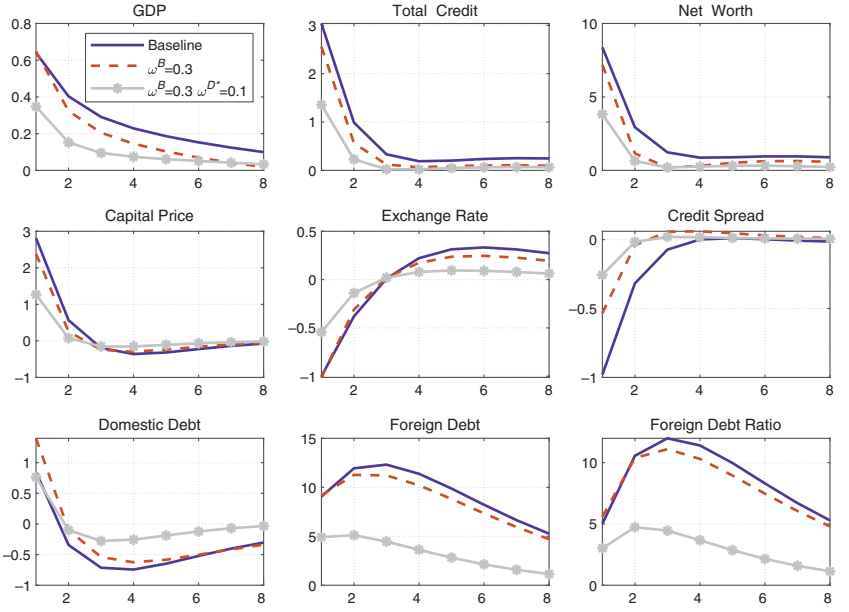

Figure 6. Reserve requirements and capital controls.

Table 8 compares the welfare gains under optimal simple rules with different targets. We can see that the optimal simple rule with both credit growth and foreign debt growth as targets achieves higher welfare relative to a single target rule.

4.6 Capital controls

The results above suggest managing capital flows improves welfare in our model; however, letting one policy instrument respond to two targets may compromise its effectiveness. Therefore we introduce capital controls as an additional policy tool in the model to examine its interaction with reserve requirements. In particular, we follow Korinek and Sandri (2016) to model capital controls as a tax on foreign borrowing such that the bank's flow of funds becomes:

$$Q_t k_{t+1} = n_t + (1 - \tau_t^B)(d_t + (1 - \tau_t^*)e_t d_t^*). \tag{57}$$

We assume the regulator commits to adjusting the capital flow tax to target the deviation of foreign debt from its long-run level. Specifically,

$$\tau_t^* = \omega^{D*}[\ln(e_t D_t^*) - \ln(eD^*)], \tag{58}$$

where ω^{D*} measures the aggressiveness of the policy responsiveness.

Figure 6 reports the impulse responses to foreign interest rate shock between the situations with reserve requirements only and with both reserve requirements and capital controls.[20] We can see that credit growth is slower in the presence of both policies, and welfare analysis also shows that the introduction of capital controls improves welfare by 0.01% of permanent consumption.

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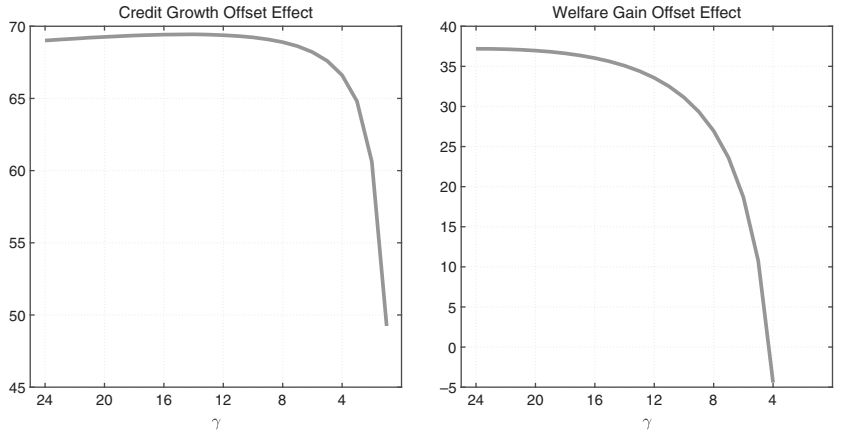

Figure 7. Offseting effect under various degrees of financial development.

4.7 Financial development

In this section, we evaluate how a higher level of financial development impacts the effectiveness of reserve requirements. We interpret financial development as the reduction of information friction across borders. In our model, this friction is captured by the parameter γ. When γ is low, international creditors bear less monitoring cost on domestic borrowers. Since the composition channel highlighted in this paper hinges on this monitoring cost, Figure 7 clearly shows that the offsetting effect through the composition shifts decreases as γ decreases but remains quantitatively significant for a large range of γ.

4.8 Foreign-currency-denominated domestic deposits

Many developing and emerging economies use foreign currency in domestic transactions.[21] In particular, we find that for a group of developing and emerging economies, the proportion of domestic deposits denominated in foreign currencies is around 38%.[22] Therefore, we examine how the presence of foreign-currency-denominated domestic deposits affects our results. To illustrate the key mechanism without over complicating our model, we assume all domestic deposits are in foreign currency units.

Figure 8 shows that the responses to an increase of the reserve requirements are qualitatively similar to the baseline case (all domestic debt is in domestic currency), but the policy becomes more effective in containing credit growth. This is because the tightening of reserve requirements causes a depreciation that would affect credit growth more when a higher share of bank liability is in foreign currency.

4.9 Sensitivity analysis

We have shown that the composition channel plays a quantitatively important role for the effectiveness of reserve requirements. In this section, we perform a sensitivity analysis to evaluate the extent to which the strength of the composition channel depends on parameter values.

From equation (44), we can see that the strength of the composition channel depends on the relative profit margin between foreign and domestic deposits μ^*_{dt}/μ_t, which is related to the severity of the agency cost θ and the foreign interest rate R^*_t. We vary the value of those parameters and recompute the offsetting effect of the composition channel on credit growth and welfare gains. Table 9 presents the results.

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Table 9. Sensitivity analysis

	Credit growth offset effect (%)	Standard deviations offset effect (%)	Welfare gain offset effect (%)	Financial openness complementary effect (%)
Baseline	69	42	37	15
More severe agency cost ($\theta = 0.7$)	68	37	30	5
Higher leverage ratio ($\phi = 5$)	71	46	36	14
Lower domestic deposit rate ($R = 1.04$)	76	38	34	11
Lower capital rate of return ($R^K = 1.08$)	83	70	53	62

Note(s): The credit growth, standard deviations, and welfare gain offsetting effect are calculated as (1-Overall Effect/Leverage Channel)%. The financial openness complementary effect is calculated as the percentage change of the policy effect from a financially open economy to a more financially closed economy ($\zeta = 2$).

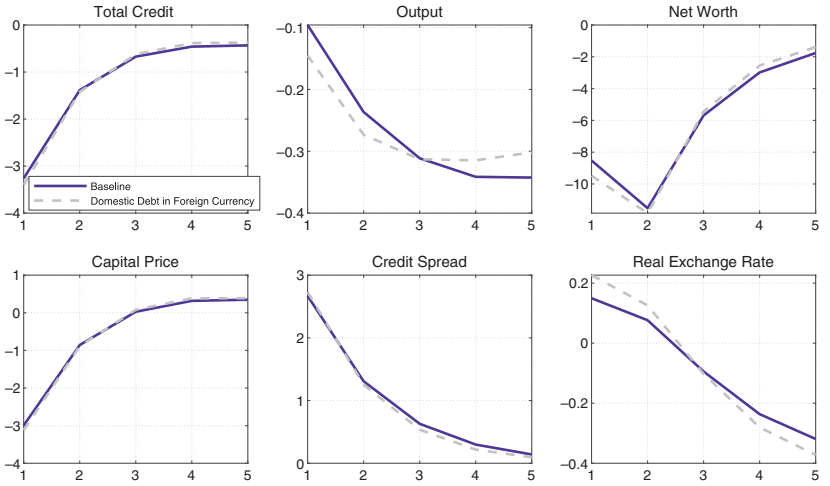

Figure 8. Impulse responses to an increase of the reserve requirement ratio: different domestic debt denominations.

Overall, the offsetting effect remains substantial across all the parameter values, which dampens the stabilizing effect of reserve requirements on credit growth, and hence reduces the welfare gains. Moreover, we examine the sensitivity of the complementary effect of capital account management on reserve requirements. The last column reports the percentage changes of policy effect from a financially open economy to a more financially closed economy ($\zeta = 2$). We can see that a higher degree of financial integration significantly dampens the effectiveness of reserve requirements under all parametrizations. Not surprisingly, the complementary effect rises as the composition effect becomes stronger.

5. Empirical evidence on the effects of macroprudential policies

5.1 Data descriptions

We employ a cross-country panel data set to conduct our empirical tests on the model predictions. We use the same macroeconomic and financial data as in the calibration and supplement them with the macroprudential policy measures established by Cerutti et al. (2017). Regression variables and data sources are reported in Table 10, and the sample countries are listed in Appendix B. The sample period covers 2001–2013.

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Table 10. Regression variables and data sources

Variable	Definition	Data Source
Dependent variables		
Bank credit growth	Annual growth rate of real bank credit (%)	IMF IFS database and BIS
Foreign liability ratio	Banks' foreign liability in percentage of banks' domestic credits (%)	IMF Quarterly External Debt Statistics (QEDS) database
Explanatory variables		
MPI	Macroprudential policy index	IMF Global Macroprudential Policy Instruments (GMPI) survey
Financial openness	Degree of financial openness	Chinn-Ito index
Other control variables		
M2 growth	Annual growth rate of broad money (%)	World Bank database
GDP growth	Annual growth rate of real GDP (%)	World Bank database
US policy rate	Federal funds rate (%)	IMF IFS database
Exchange rate	Annual currency appreciation rate against the US dollar (%)	IMF IFS database
Leverage ratio	Leverage of domestic banks	Global Financial Development Database
Profit	Bank return on assets (%, before tax)	Global Financial Development Database
Competition	Boone indicator	Global Financial Development Database

Dependent Variables. We use the real growth rate of domestic claims on the private sector of depository corporations as a proxy for bank credit growth. We measure the currency composition of bank liability by the foreign liability ratio, which is calculated as a bank's gross external debt position divided by the domestic claims on the private sector. This variable is of interest because we want to assess how macroprudential policies influence bank liability currency composition and how the composition shift in turn impacts the effectiveness of macroprudential policies when it comes to countering credit growth.

Explanatory Variables. The key explanatory variable in our analysis is the cross-country usage of macroprudential policies. We follow Cerutti et al. (2017) to construct our MPI based on the IMF's survey of Global Macroprudential Policy Instruments (GMPI). The GMPI survey covers 18 different macroprudential policy instruments including capital account management tools, such as Limits on Foreign Currency Loans, which specifically regulate foreign exchange transactions. We exclude capital account management instruments when constructing our MPI since one of our objectives is to study how financial openness influences the effectiveness of macroprudential policies. Therefore our MPI is more narrowly defined and applies equally to both domestic and international financial transactions. This results in a total of 11 instruments in our index, and we summarize them in Table B.2 in Appendix B. Notice that two of the instruments restrict the borrower's ability to obtain loans while the others limit the financial institution's ability to extend loans, so we also separate these two groups of instruments in our robustness check. Each instrument is coded as a binary value, which is 1 if the instrument was in place and 0 otherwise. We sum up the scores of all the instruments to obtain the value of our MPI.

Another important explanatory variable is the degree of financial openness. In the benchmark regression, we use the Chinn-Ito index developed by Chinn and Ito (2006) as our preferred proxy of financial openness. This index measures the de jure extent of the openness in cross-border financial transactions and has been used extensively in empirical studies, such as Aizenman et al. (2008), Baltagi et al. (2009), and Kose et al. (2009), to represent financial openness. In the robustness check, we use the capital control measures constructed by Fernandez

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et al. (2016) and the de facto financial openness measures in Larrain and Stumpner (2017) as alternatives.

Control Variables. We control for important demand- and supply-side factors that may influence bank credit growth. On the demand side, we include the real GDP growth rate, which reflects the investment opportunities of the nonfinancial production sector. On the supply side, since broad money (M2) growth typically reflects the domestic monetary policy stance and determines the supply of credit, we include it in our regression. We also include the appreciation rate of the bilateral exchange rate between the domestic currency and US dollar and the degree of financial openness. In order to control the impact of the global financial cycle, we also include VIX.

In addition to economy-wide conditions, we control for banking sector characteristics as well. We include the return on assets as a proxy of profitability and the Boone indicator,[23] which measures the degree of competition present in the banking industry.

When examining the effects of MPI on the currency composition of bank liability, we control for both the push and pull factors associated with capital flows. For the pull factors, we include the US federal funds rate,[24] which reflects the global financial market liquidity condition. We consider the domestic banking sector's leverage ratio to be a measure of the riskiness of the domestic financial system and include it as a push factor.

5.2 Empirical specifications

We propose the following regression model to evaluate the effectiveness of macroprudential policies and the impact of financial openness on the effects of those macroprudential policies:

$$Y_{i,t} = \alpha Y_{i,t-1} + \beta_0 MPI_{i,t} + \beta_1 X_{i,t} + \beta_2 finopen + \beta_3 finopen \times MPI_{i,t} + \mu_i + \nu_{i,t}, \quad (59)$$

where $Y_{i,t}$ is the dependent variable (real domestic bank credit growth) and the $Y_{i,t-1}$ is the lagged dependent variable. The $X_{i,t}$ are the control variables. $finopen \times MPI_{i,t}$ represents the interaction term between financial openness and the MPI. The μ_i are the unobserved country fixed effects, and the $\nu_{i,t}$ are the error terms.

In order to investigate how macroprudential policies affect the currency composition of bank liability as well as the feedback effect of composition shifts on credit growth, we perform additional tests on the relationship between the foreign liability ratio and the MPI, and on the relationship between credit growth and the foreign liability ratio:

$$L_{i,t} = \alpha L_{i,t-1} + \beta_0 MPI_{i,t} + \beta_1 X_{i,t} + \mu_i + \nu_{i,t}, \quad (60)$$

and

$$Y_{i,t} = \alpha Y_{i,t-1} + \beta_0 L_{i,t-1} + \beta_1 X_{i,t} + \mu_i + \nu_{i,t}, \quad (61)$$

where $L_{i,t-1}$ is the bank foreign liability ratio last period and $Y_{i,t}$ is the bank credit growth.

Because the adoption of macroprudential regulations may be a reaction to high credit growth and a high foreign debt ratio, we employ the system GMM method with country fixed effects to estimate the regression models in order to alleviate the potential reverse causality problem. Then to avoid overidentification and weak instrument problems, we treat the lagged dependent variable and the MPI as endogenous and other control variables as exogenous. We use lag of two periods of dependent variable and the MPI as instruments.

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Table 11. Effectiveness of macroprudential policies on bank credit growth

	(1)	(2)	(3)	(4)	(5)	(6)
	credit_	credit_	credit_	credit_	credit_	credit_
Variables	growth	growth	growth	growth	growth	growth
MPI	−4.193***	−4.197***	−5.804**	−3.918***	−3.378**	-8.982***
	(1.082)	(1.283)	(2.400)	(1.116)	(1.480)	(3.241)
L.credit_growth	0.272***	0.238***	0.201**	0.253***	0.199**	0.204**
	(0.0885)	(0.0886)	(0.0969)	(0.0899)	(0.0872)	(0.0923)
m2growth	0.427***	0.456***	0.425***	0.390***	0.413***	0.409***
	(0.113)	(0.101)	(0.108)	(0.106)	(0.122)	(0.128)
gdp_growth	1.401***	1.108***	1.029***	1.374***	1.093***	1.122***
	(0.250)	(0.295)	(0.334)	(0.252)	(0.327)	(0.373)
exchange_rate_change		−0.325***	−0.247*		−0.323**	−0.232*
		(0.121)	(0.135)		(0.125)	(0.134)
finopen		−0.503	−15.34		0.245	−29.46**
		(4.196)	(10.09)		(4.355)	(12.57)
VIX		0.00217	−0.0394		0.0606	0.0476
		(0.160)	(0.160)		(0.159)	(0.134)
finopen × MPI			6.859**			12.14***
			(3.300)			(4.527)
profit				0.453	0.345	0.608
				(0.383)	(0.408)	(0.505)
competition				−6.161	−11.51	−12.62
				(6.444)	(10.80)	(11.52)
Observations	432	425	425	431	424	424
Number of countries	38	38	38	38	38	38
Hansen J-test	0.687	0.763	0.742	0.754	0.786	0.885
AR(2)	0.385	0.380	0.439	0.362	0.378	0.371

Note(s): ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$, and standard errors are in parentheses. "L." represent lagged variables.

5.3 Empirical results

Table 11 reports the regression result of model (59). We can see that across all the specifications, the coefficient in front of the MPI is always negative and significant, which indicates that macroprudential policies are effective in mitigating credit growth. This result is robust when we include the domestic aggregate variables in column 1, global factors in addition to the domestic variables in columns 2 and 3, and the banking sector characteristics in the last three columns. The lagged dependent variable is positive and significant, which indicates persistent credit growth. The coefficients in front of M2 growth and real GDP growth is positive and significant, which is consistent with our expectations.

Columns 3 and 6 contain the interaction term between financial openness and the MPI. The coefficient for the interactive item is positive and significant. This result suggests that the marginal effect of macroprudential policies on curbing credit growth weakens in financially more open economies. The interaction between MPI and financial openness is a bit more robust when including a proxy for profits and competition. Higher profits tends to increase credit growth, and since profits is negatively correlated with the term MPI, omitting this proxy will underestimates the effects on the interaction term. Our result thus implies the importance of taking into consideration the heterogeneous structure of the banking sector across countries when assessing the effectiveness of macroprudential policies.

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Table 12. Effects of macroprudential policies on bank foreign liability ratio

	(1)	(2)	(3)	(4)
	bank_foreigndebt_	bank_foreigndebt_	bank_foreigndebt_	bank_foreigndebt_
Variables	ratio	ratio	ratio	ratio
MPI	10.06***	7.197***	10.84***	3.483*
	(0.561)	(2.036)	(0.758)	(2.050)
L.bank_foreigndebt_ratio	0.0235***	0.0248***	0.0238***	0.0248***
	(0.00101)	(0.00275)	(0.000998)	(0.00315)
leverage_ratio	1.969***	2.284***	1.993***	2.216***
	(0.0473)	(0.126)	(0.0499)	(0.126)
exchange_rate_change		0.0538		1.862***
		(0.0901)		(0.261)
us_rate		−3.308***		−1.870***
		(0.554)		(0.591)
finopen		32.77***		41.39***
		(7.839)		(6.841)
VIX		−3.239***		−2.587***
		(0.151)		(0.176)
Profit			−0.952***	−0.0777
			(0.132)	(0.512)
Competition			3.230	−7.410
			(2.234)	(20.98)
Observations	261	256	261	256
Number of Countries	33	33	33	33
Hansen J-test	0.860	0.765	0.879	0.952
AR(2)	0.0277	0.0710	0.0290	0.0524

Note(s): ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$, and standard errors are in parentheses. "L." represent lagged variables. In total, 33 out of 38 countries in our sample report a bank gross external debt position.

Next, we regress the bank foreign liability ratio against the MPI as in model (60) to examine whether macroprudential regulations affect the composition of bank liabilities in addition to credit growth. Table 12 presents the estimation result. Looking at columns 1 through 4, we can see that the coefficient of the MPI is positive and statistically significant after controlling for bank leverage and other sector-wide characteristics. This result is robust after controlling economy-wide and global factors. The evidence thus implies tighter macroprudential regulations induce banks to lean toward foreign deposits.

Finally, we regress bank credit growth on the foreign liability ratio as in model (61) and report the outcome in Table 13. We can see that the coefficient of the lagged foreign liability ratio is positive and significant. This result suggests that a higher foreign liability ratio leads to a higher domestic bank credit growth rate. Taking together the results in Tables 12 and 13, we can infer that more restrictive macroprudential regulations increase credit growth by shifting the financing structure toward foreign deposits. A higher foreign liability ratio implies greater currency mismatch in the bank balance sheet.

Therefore, our empirical findings suggest that although overall macroprudential policy interventions are successful in mitigating credit growth, they may encourage banks to take higher risks by shifting the currency composition of bank liabilities and undermining the effectiveness of regulations. Thus, our empirical findings support the predictions of our DSGE model.

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Table 13. Effect of foreign liability ratio on bank credit growth

	(1)	(2)	(3)	(4)
Variables	credit_growth	credit_growth	credit_growth	credit_growth
L.bank_foreigndebt_ratio	0.0673***	0.0674***	0.0631***	0.0629***
	(0.00560)	(0.00611)	(0.00618)	(0.00629)
L.credit_growth	0.260***	0.239***	0.209**	0.183*
	(0.0880)	(0.0922)	(0.105)	(0.107)
m2growth	0.448***	0.429***	0.502***	0.475***
	(0.101)	(0.104)	(0.103)	(0.115)
gdp_growth	1.438***	1.388***	0.795**	0.785**
	(0.262)	(0.270)	(0.363)	(0.369)
exchange_rate_change			−0.535***	−0.520***
			(0.171)	(0.160)
Finopen			−3.167	−5.261
			(5.531)	(8.140)
VIX			−0.177	−0.111
			(0.206)	(0.206)
Profit		0.578		0.369
		(0.372)		(0.367)
Competition		−4.846		−7.259
		(3.822)		(5.081)
Observations	335	334	327	326
Number of Countries	38	38	38	38
Hansen J-test	0.883	0.925	0.895	0.891
AR(2)	0.444	0.422	0.406	0.398

Note(s): ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$, and standard errors are in parentheses. "L." represent lagged variables.

6. Conclusion

The adoption of macroprudential policies has become the top priority for many countries since the 2008 global financial crisis, but their design and effectiveness are still under debate. In this paper, we quantitatively evaluate the macroeconomic and welfare implications of macroprudential policies in an open economy DSGE model with cross-border capital flows through the banking sector. In our framework, banks choose leverage as well as their financing sources (domestic vs. foreign deposits), subject to capital market imperfections. The financial frictions limit a bank's ability to raise funds, both from domestic and international financial markets, but the problem is more severe in the latter market. Banks trade-off the relatively lower funding cost with the more restrictive leverage constraint when borrowing in the international market. Our model shows that banks reduce credit growth in response to macroprudential policy tightening and rely more on foreign borrowing. We find empirical evidence that is consistent with our model predictions for a group of developing and emerging economies.

Our results have three broad implications. First, taking the bank balance sheet composition into consideration is crucial to evaluate the effectiveness of macroprudential policies as some frequently employed macroprudential policy instruments may shift the composition and cause unintended consequences. Second, in financially open economies, macroprudential policies should take capital flows into consideration. Third, capital controls complement macroprudential policies in stabilizing the economic fluctuations.

Our analytical framework is subject to three caveats. First, we do not introduce bank equity and the borrower's balance sheet in the model. This limits us to examining the effectiveness of

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commonly adopted macroprudential policy tools, such as capital requirements and LTV ratio, in our framework. Second, we assume all domestic transactions use domestic currency, but this is not typically the case for developing and emerging economies. Allowing currency substitution in domestic transactions would generate a composition channel that is distinct from the current one. Third, including nominal rigidities would allow us to analyze the effects of monetary policy in our model and the coordination between monetary policy and macroprudential policy. We plan to take them into consideration in future work.

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Notes

1 See Reinhart and Rogoff (2009), Gourinchas and Obstfeld (2012), Schularick and Taylor (2012), and Mendoza and Terrones (2012) for empirical evidence.

2 Credit cycle stabilization is certainly not the only target of macroprudential regulations, but it is one of the most important ones. For example, Yellen (2011) stated, "Macroprudential policies will be aimed at countering the pro-cyclical nature of credit and leverage, leaning against the wind when systemic risk is accumulating."

3 In the appendix of the working paper version, we show a positive exchange-rate-adjusted money market interest rate spread exists between a group of developing and emerging economies and the USA. Our model attributes this spread to the higher information friction domestic borrowers face in the international market.

4 This correlation is also documented by Hahm et al. (2013), Lane and McQuade (2014), and Baskaya et al. (2017) for many countries.

5 In Section 4.8, we relax this assumption to allow domestic deposits to be denominated in foreign currency units.

6 See Eichengreen and Hausmann (1999) for evidence of this original sin.

7 We attribute the rise of banks' leverage constraints to capital market imperfections due to an agency problem between the banks and the depositors, but not to regulatory constraints. Both modeling strategies are common in the literature, and they lead to the same financial amplification effect. The leverage constraints in our model can be seen as an endogenous participation condition for households to deposit in banks and cannot be moved by the regulator. Suppose the regulator has access to policy measures that can directly move these leverage constraints, then the economy could achieve its first-best allocation. However, this goal has long proven elusive to policymakers in developing and emerging economies. Recognizing the limitations of such first-best policy measures, we analyze second-best measures that take the existence of financial constraints as given.

8 The dependence of leverage constraints on financing sources is due to the different degrees of capital market frictions in domestic and international financial markets. Caballero and Krishnamurthy (2001) and subsequent papers also used this assumption to generate different leverage constraints in the domestic and international financial markets.

9 Cerutti et al. (2017) documents that the reserve requirement ratio ranked the third most commonly used macroprudential policy measures.

10 Other theoretical analysis on the macroprudential role of reserve requirements include Glocker and Towbin (2012), Chang et al. (2017), and Agénor et al. (2018).

11 Aoki et al. (2016) assumes the macroprudential tax proceeds are fully rebated to the banks, whereas we assume the rebate goes to the households. This is not an innocuous assumption in this model setup. Under the rebate assumption in Aoki et al. (2016), reserve requirements only indirectly affect bank leverage by shifting the currency composition of banks' liabilities (the composition channel), but there is no direct effect on the bank leverage (the leverage channel). We provide a formal proof of this result in an accompanying paper, Jin and Xiong (2020).

12 We provide detailed derivations in Appendix A.2.

13 The country list is in Table B.1, Appendix B.

14 See Aguiar and Gopinath (2007) and Garcia-Cicco et al. (2010) for a discussion of the empirical regularities for developing and emerging economies.

15 We let τ_t^B rises to 0.05 in the first period from the steady state and goes back to the steady state afterward.

16 We present the macroeconomic dynamics in response to foreign interest rate shocks in the appendix of the working paper version. The results are qualitatively the same as under productivity shocks.

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17 The net policy impact is calculated as the difference of impulse responses between the no policy scenario and the scenario with policy.
18 We solve the model to the second order and run a simulation to obtain the sequence of utility measure.
19 We present the setup and equilibrium conditions of the Ramsey problem in the appendix of the working paper version.
20 We use foreign interest rate shocks instead of TFP shocks since capital controls are more relevant in the presence of external disturbances. The results are qualitatively similar under TFP shocks.
21 For example, Melvin and Ladman (1991), Calvo and Gramont (1992), Kamin and Ericsson (2003), and Valev (2010) documented a large proportion of transactions are denominated in foreign currency in developing and emerging economies. They labeled this phenomenon as dollarization (or currency substitution) and discussed potential determinants. Brzoza-Brzezina et al. (2017) documents a large fraction of loans in an emerging economy is in foreign currency and shows its impact on the conduct of monetary and macroprudential policy.
22 The sample economies that we used to calculate this ratio include Algeria, Argentina, Armenia, Azerbaijan, Bahrain, Belarus, Bosnia and Herzegovina, Croatia, Egypt, Georgia, Indonesia, Kazakhstan, Kyrgyzstan, Laos, Macedonia, Moldova, Oman, Paraguay, Peru, Qatar, Romania, Russia, Saudi Arabia, Serbia, South Africa, Tajikistan, Turkey, United Arab Emirates, Ukraine, Uruguay, Yemen, and Zambia. Data source: CEIC database.
23 The Boone indicator is calculated as the elasticity of profits to marginal costs.
24 After the federal funds rate hits the zero lower bound, we use the shadow federal funds rate computed in Wu and Xia (2016).

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Appendices

Appendix A. Proofs

A.1 Proof of Lemma 1

Define $f = \mu_{dt}^*/\mu_t$, and rewrite (35) as

$$x(f) = \frac{1}{f}\left[-1 + \sqrt{1 + \frac{2}{\gamma}(f)^2}\right]. \tag{A1}$$

Taking the derivative of x with respect to f yields:

$$\begin{aligned}\frac{\partial x}{\partial f} &= f^{-2} + \frac{1}{2}\left[\left(\frac{1}{f}\right)^2 + \frac{2}{\gamma}\right]^{-\frac{1}{2}}(-2)\frac{1}{f^3} \\ &= \frac{1}{f^2}\left[1 - \frac{1}{\sqrt{1 + \frac{2}{\gamma}(f)^2}}\right].\end{aligned} \tag{A2}$$

Notice that the term in the square bracket of the last equation is greater than zero, so x_t increases with μ_{dt}^*/μ_t.

A.2 Derivative of Leverage with respect to Reserve Requirement Policy

We define a new function $F_t(\phi_t^{policy}, \tau_t^B) \equiv \phi_t[\Theta(x_t^{policy}) - (\mu_t^{policy} + \mu_{dt}^* x_t^{policy})] - v_t^{policy} = 0$. Taking the partial derivative with respect to τ_t^B yields:

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$$\begin{aligned}\frac{\partial \phi_t^{policy}}{\partial \tau_t^B} &= -\frac{F_{\tau_t^B}}{F_{\phi_t^{policy}}} \\ &= \frac{\frac{\partial\{v_t^{policy} - \phi_t^{policy}[\Theta(x_t^{policy}) - (\mu_t^{policy} + \mu_{dt}^* x_t^{policy})]\}}{\partial \tau_t^B}}{\Theta(x_t^{policy}) - (\mu_t^{policy} + \mu_{dt}^* x_t^{policy})} \\ &= \frac{\frac{\partial v_t^{policy}}{\partial \tau_t^B} - \frac{E_t \Omega_{t+1} R_t \phi_t^{policy}}{(1-\tau_t^B)^2}}{\Theta(x_t^{policy}) - (\mu_t^{policy} + \mu_{dt}^* x_t^{policy})} + \frac{\phi_t^{policy}[\mu_{dt}^* - \theta\gamma x_t^{policy}]}{\Theta(x_t^{policy}) - (\mu_t^{policy} + \mu_{dt}^* x_t^{policy})} \frac{\partial x_t^{policy}}{\partial \tau_t^B}.\end{aligned} \tag{A3}$$

Appendix B. List of Countries and Macroprudential Policy Index

The table below lists all the countries in our sample.

Table B.1. List of countries

Albania	Argentina	Armenia	Bangladesh
Belarus	Brazil	Bulgaria	Chile
Colombia	Costa Rica	Croatia	Ecuador
El Salvador	Georgia	Hungary	India
Indonesia	Jamaica	Kazakhstan	Kyrgyzstan
Macedonia	Malaysia	Mauritius	Mexico
Moldova	Morocco	Nepal	Pakistan
Paraguay	Philippines	Poland	Russian
South Africa	Sri Lanka	Thailand	Turkey
Uganda	Ukraine		

Note: The classification criteria for Developing and Emerging Economies is the based on IMF WEO (April 2016).

Table B.2. Macroprudential Policy Index (MPI)

Instrument	Name
Borrower based	
Loan-to-Value Ratio Caps	LTV_CAP
Debt-to-Income Ratio	DTI
Financial institution based	
Dynamic Loan-Loss Provisioning	DP
Countercyclical Capital Requirement	CTC
Leverage Ratio	LEV
Capital Surcharges on SIFIs	SIFI
Limits on Interbank Exposures	INTER
Concentration Limits	CONC
Limits on Domestic Currency Loans	CG
Reserve Requirement Ratios	RR
Levy/Tax on financial institutions	TAX
LTV_CAP + DTI + DP + CTC + LEV + SIFI + INTER +CONC+CG+RR+TAX	MPI

Note(s): The binary index measure for each instrument is taken from Cerutti et al. (2017). The macroprudential policy index (MPI) is calculated by summing up the scores of all 11 instruments.

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