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Macroprudential Policies in Response to External Financial Shocks

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Macroprudential Policies in Response to External Financial Shocks
Prepared by Irineu de Carvalho Filho and DingXuan Ng*

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ABSTRACT: This paper examines how countries use Macroprudential Policies (MaPs) to respond to external shocks such as US monetary policy surprises or fluctuations in capital flows. Constructing a model of a small open economy with financial frictions and a MaP authority that adjusts loan to value (LTV) ratio limits on borrowers and capital adequacy ratio (CAR) limits on banks, we show that using MaPs where stochastic external financial shocks are present entails a trade-off between macro-financial volatility and GDP growth. The terms of the trade-off are a function of a few country characteristics that amplify financial channels of external monetary shocks. Estimating MaP reaction functions for a panel of 41 countries in the period 2000–2017, we find that countercyclical macroprudential policy in response to surprise US monetary tightening is more likely for countries with net short currency mismatches (that is, foreign currency denominated liabilities larger than foreign currency denominated assets), consistent with the model's predictions. The paper also finds that domestic credit and interest rates are more insulated from US monetary tightening for countries that employ MaPs countercyclically.

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WORKING PAPERS

Macroprudential Policies in Response to External Financial Shocks

Prepared by Irineu de Carvalho Filho and DingXuan Ng[1]

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1. Introduction

In recent years, an emerging empirical literature has studied the spillovers of advanced economies' financial and monetary developments on domestic macroeconomic and financial conditions in emerging market economies (EMEs). Researchers have found that US monetary policy shocks impact GDP growth and financial variables in a large set of global economies.[1] A number of studies have pointed to the important role of international capital flows in transmitting advanced economy development across borders. Rey (2015) and Miranda-Agrippino and Rey (2019) show that since the Global Financial Crisis (GFC), changes in interest rates in advanced economies have become increasingly correlated with a common global factor in financial conditions, giving rise to a "global financial cycle" that impacts countries across exchange rate regimes.

As exposures to global financial spillovers and awareness of their domestic impact have both increased, policy-makers in many EMEs have questioned the established tenet that external shocks can be fully accommodated by exchange rate flexibility, and have relied on a suite of other policy instruments, such as macroprudential instruments (MaPs), foreign exchange intervention (FXI) and capital flow management measures (CFMs). In particular, comprehensive data on the use of macroprudential policy instruments compiled in Alam et al. (2019) show that EMEs have gradually tightened macroprudential regulation from 2000 to 2016. Nevertheless, there is remarkable heterogeneity in how countries have used MaPs in practice. As Forbes (2020) has pointed out, the large number of instruments and lack of a consistent economic framework for MaPs use across countries means that even characterizing individual countries' macroprudential stance remains a challenge.

Despite their widespread usage in practice, theoretical underpinnings for the optimal implementation of MaPs are still in early stages of development. A significant theoretical literature has provided normative foundations for use of MaPs in the presence of market imperfections frictions, and showed that MaPs and conventional monetary policy can be complementary, focusing on closed economy settings (see e.g., Benigno et al. (2012); Angelini et al. (2014); Farhi and Werning (2016); Brunnermeier and Sannikov (2016)). For example, Farhi and Werning (2016) show that macroprudential interventions can be complementary with conventional monetary policies when there are aggregate demand externalities arising from liquidity traps that restrict monetary policy space. Nevertheless, the theoretical literature has shed little light on how MaPs use should vary with open-economy characteristics that empirical research has found to be likely correlated with countries' choice of MaP settings, including differences in the extent of integration with global financial markets, openness to trade and reliance on foreign currency debt.

This paper contributes to this theoretical literature by analyzing the effectiveness of MaPs within the context of a small open economy integrated into international financial markets. We extend the banking-sector DSGE model of Gerali, Neri, Sessa and Signoretti (2010), adding external trade and financial sectors, and conduct a positive analysis of how MaPs may impact financial volatility and macroeconomic outcomes, conditional on country characteristics. Similar to previous DSGE models with MaPs such as Angelini et al. (2014), macroprudential policies in this framework dampen financial accelerator mechanisms that arise from financial frictions in this economy. With external financial markets, we show that the negative externalities associated with financial frictions depend on country exposure to external financial risks. In particular, countries facing

[1] See, for example, Ehrmann and Fratzscher (2009), Dedola, Rivolta and Stracca (2017) and Iacoviello and Navarro (2019).

fickle supply of external credit and holding significant liabilities denominated in foreign currencies are highly impacted by external shocks that could be mitigated by appropriate usage of macroprudential tools.

The model assumes two sources of financial frictions in induce deviations from first-best domestic credit outcomes, with one relevant for domestic credit supply and the other relevant for credit demand. The former assumes adjustment costs for banks from deviating from a target capital adequacy ratio, while the latter assumes collateral constraints for domestic borrowers.

Both sources of financial frictions create financial channels through which external financial shocks impact domestic variables. Under loose global financial conditions and abundant capital inflows, which occur under expansionary US monetary policy, bank profits and asset prices rise. Rising bank profits and capital allows banks to increase bank lending even while maintaining constant leverage ratios, avoiding capital adequacy ratio adjustment costs. Rising asset prices loosens collateral constrains on borrowers and allow for increased domestic borrowing. Overall, the economy benefits from issuing external debt that helps to finance physical investment and contributes to GDP growth. However, external financial tightening shocks are transmitted to the domestic economy and financial system through the two financial channels in a symmetric manner, reducing bank profits and asset prices, thereby causing large declines in credit supply and demand. Consequently, external financial shocks increase the volatility of macro-financial variables for the economy, even as they allow for higher steady-state economic growth.

In the model, policymakers have access to two macroprudential tools: bank capital adequacy ratio requirements (a lender-based MaP) and loan-to-value ratio limits (a borrower-based MaP). We show that countercyclical MaPs mitigate the volatility in domestic macro-financial outcomes from exposure to external financial shocks, even while they potentially reduce GDP growth. In our context, countercyclical MaPs entail the tightening (loosening) of capital adequacy ratio and loan to value ratio limits in response to loosening (tightening) domestic financial conditions. Both MaPs, when applied countercyclically, reduce the volatility of credit by mitigating the financial channels of transmission. Under a loosening external monetary policy shock, countercyclical MaPs limit the growth of overall and external debt by raising bank capital requirements to limit bank lending and/or lowering LTV limits to limit borrowing. Conversely, when capital flows reverse or US monetary policy is tightened, countercyclical MaPs limit the fall in credit supply from declining bank capital and in credit demand from falling asset prices, thereby supporting investment and output.

Therefore, the model highlights how macroprudential settings trade off supporting growth in good times and minimizing economic impacts in bad times. A more aggressive countercyclical MaPs setting limits growth during good times, but limits economic damage in bad times. This tradeoff is shaped by a few country-specific parameters.

First, *currency denomination of debt*. In countries where financial intermediaries or corporates have unhedged liabilities denominated in foreign currencies, currency depreciation has the potential to trigger perverse negative dynamics by adversely impacting bank balance sheets, worsening the decline in bank lending and exacerbating the negative shock facing the economy. This has been called the financial channel of exchange rates (e.g., in Avdjiev, Koch and Shin, 2017; Shousha, 2019). The model suggests that for countries with large net short position in foreign currencies, the trade-off between economic growth and financial stability is likely tilted towards greater advantages from a countercyclical MaP response.

Second, *the elasticity of foreign credit supply to movements in real exchange rate.* Countries facing less fickle or more stable capital flows are likely to have milder contractions in bank balance sheets and more modest asset price declines when external financial conditions tighten. As a result, these countries are less likely to benefit from active countercyclical MaPs regime because they are less exposed to the risk of financial crises recessions driven by large swings in external credit.

Third, *the elasticity of the current account to movements in the real exchange rate*. When an external shock causes the domestic currency to depreciate, expenditure switching generates an improvement in the country's external balance, which goes in the opposite direction to the negative impact of a depreciation through the financial channel of exchange rates, reducing the risk of recession. Thus, countries whose current account responds swiftly and decisively to real exchange rate movements face smaller risks from negative external shocks of a financial nature, and have less to gain from an active countercyclical MaP regime. Gopinath, Boz, Casas, Díez, Gourinchas and Plagborg-Møller (2020) has shown that international trade increasingly operates on a dominant currency paradigm (DCP), where trade is invoiced in a few currencies. Under DCP, countries with a larger share of their exports invoiced in US dollars are likely to feature a more muted response of the current account to currency movements (Adler et al., 2020), which reduces the effectiveness the exchange rate as an automatic stabilizer via expenditure-switching.[2] The model suggests that countries with a low elasticity of the current account with respect to the real exchange rate may benefit relatively more from countercyclical MaPs for their role at supporting domestic credit during periods of tighter external financial conditions.

In the empirical section, this paper uses local linear projections (LLP) methods (Jordà, 2005) to estimate country-specific monetary and macroprudential policy impulse responses to US monetary surprises (defined as in Iacoviello and Navarro, 2019). The estimates control for the level of policy instruments prior to the US monetary surprises, domestic macroeconomic variables and other exogenous global shocks. We find remarkable heterogeneity in MaP policy impulse responses to US monetary policy surprises, which allows us to classify countries into two clusters: *countercyclical* and *non-countercyclical* macroprudential policy countries. The former group consists of countries that loosen (tighten) their macroprudential stance when the US tightens (loosens) monetary policy. Notably, the group of countercyclical MaP countries is well distributed geographically and includes both AEs and EMDEs.

The model's predictions on country characteristics that should be important for the effectiveness of using MaPs in response to external shocks are then tested empirically. In particular, we evaluate the effects of model parameters on the probability of a country belonging to the countercyclical MaP cluster. Among the country characteristics that we considered, the only significant determinant was the net foreign currency mismatch – the *greater* the *net long* currency mismatch, the *smaller* the probability that the country would have countercyclical MaPs. This finding fits the intuition from the model, as countries with negative currency mismatches (that is, where foreign currency liabilities are larger than assets denominated in foreign currency) have more to gain from countercyclical MaPs, *ceteris paribus*. Finally, we compare how the cyclicality of MaPs affects the behavior of a few key macroeconomic variables, finding that countercyclical MaPs countries have stronger credit growth and inflation in the medium-term in the aftermath of US monetary tightening surprises. Further, there is some evidence that countercyclical MaPs provide a limited boost to monetary policy autonomy over a very short-term after the initial shock.

This paper is related to the growing empirical literature evaluating the impact of MaPs on financial and economic outcomes. Overall, cross-country studies have found that MaPs are effective at dampening the credit

[2] The exchange rate may act as an automatic stabilizer even in the absence of significant expenditure-switching effects if a depreciation triggers capital inflows, as domestic assets become cheaper in foreign currency terms or investors adjust their portfolios.

cycle and reducing financial volatility.[34] The literature has also found evidence that MaPs can have side effects on variables beyond aggregate debt volume and volatility, negatively impacting macroeconomic variables. Richter, Schularick and Shim (2019) find that countercyclical MaPs can reduce economic growth, especially in EMs. Specifically, they use a narrative approach to show that tightening of the LTV ratio by 10 percentage points reduces GDP of emerging markets in their sample by approximately 1.1% after four years, while the effects on inflation are close to zero.[5] Our paper thus contributes new empirical evidence, and offers a structured delineation of the mechanisms underlying the tradeoff between financial volatility and growth from the use of countercyclical MaPs.

This paper is also related to the growing literature providing evidence that credit conditions in advanced economies are a significant driver of global financial flows, which implies that countries' external financing positions are likely to be highly dependent on credit supply from advanced economies ("push factors" for cross-border capital flows).[6] Estimating a Bayesian VAR to evaluate the impacts of US monetary policy movements on international financial flows, Miranda-Agrippino and Rey (2019) find that US monetary policy tightening leads to falling risky asset prices, rising bond spreads and retrenchments in capital flows (especially banking flows) globally.[7] Our model reproduces these dynamics by highlighting the risk-taking channel emphasized by the literature. Bruno and Shin (2012) provide a theoretical framework showing that during risk-on periods, capital inflows facilitate domestic currency appreciation, which bolsters the balance sheets of foreign creditors and leads to further inflows. These dynamics entail pecuniary externalities of debt that magnify the recipient country's financial system's exposure to currency risk when capital flows out during risk-off periods.

Finally, our paper is related to several studies that have investigated country characteristics that affect the intensity of spillovers from external financial shocks to domestic financial and economic conditions. The literature on currency mismatch in country debt, including Bordo and Meissner (2006), has found that high shares of foreign currency debt leave countries more susceptible to financial crises when sudden stops occur. Kearns, Schrimpf and Xia (2020) find that, among emerging market economies, large bilateral portfolio equity flows and high debt denominated in the currency of advanced economies are associated with greater impact of monetary policy spillovers from advanced economies. Our empirical work provides further confirmation of the importance of currency mismatch in the exposure of small open economies to US monetary policy shocks, and provides conditions under which MaPs can be effective policy responses.

[3] Cross-country studies such as Cerutti, Claessens and Laeven (2017) and Aizenmann, Chinn and Ito (2020) have shown that MaPs are effective at reducing financial volatility. Gambacorta and Murcia (2020) and Barroso, De Araujo, and Gonzalez (2020) found some evidence that MaPs helped stabilize the credit cycle in Argentina, Brazil, Colombia, Mexico and Peru, and contributed to reducing the risk associated to mortgage lending in Brazil.

[4] A pertinent wrinkle is that MaPs appear to have directionally asymmetric effects on aggregate credit, with tightening having larger impacts than loosening. Aizenmann, Chinn and Ito (2020) show that MaPs are more effective at reducing financial volatility during credit booms than busts, while Cantú, Gambacorta and Shim (2020), studying the results of tightening MaPs on consumer credit for Australia, Indonesia, New Zealand, the Philippines, and Thailand, found that tightening MaPs has larger effects than easing.

[5] See also Rojas, Vegh and Vuletin (2020), who find that when properly identified, changes in banks' reserve requirements lead to a decline in the level of economic activity, and Alam et al. (2019), who find that borrower-based MaPs reduced household debt have dampening effects on consumption.

[6] See Morais, Peydró, Roldán-Peña and Ruiz-Ortega (2018), for the case of Mexico, and di Giovanni, Kalemli-Ozcan, Ulu and Baskaya (2021) for the case of Turkey.

[7] Nevertheless, Cerutti, Claessens and Laeven (2017) present evidence that monetary conditions in the core account for a small part of the variation in total global capital flows.

2. Model

We construct a model of a small-open economy with financial frictions subject to domestic and external shocks. Our starting point is the closed economy model with financial intermediaries from Gerali et al. (2010), which we augment with external debt and trade sectors. Domestic consumers and producers have access to world import and export markets respectively, while the banking sector participates in international debt markets. The central bank is responsible for conventional monetary policy through setting a policy interest rate and two macroprudential policy instruments, capital adequacy ratios (CARs) for the banking system and loan-to-value ratios (LTVs) for domestic borrowers. The introduction of MaPs in the model is done in a similar fashion to Angelini et al (2014). As in Gerali et al. (2010, there are two financial frictions in the model: domestic borrowers face collateral constraints depending on the value of the physical capital they own; and the banks face credit frictions in the form of costs of deviating from a capital adequacy target. In equilibrium, both financial frictions have consequences to the real economy.

The model is set in discrete time with an infinite horizon. The agents comprise of households (savers) who supply labor and make intertemporal consumption decisions; entrepreneurs (borrowers) who invest in physical capital, produce an intermediate domestic good and make intertemporal consumption decisions; a banking sector that takes deposits from households, borrows from international lending markets, and lends to entrepreneurs; and a central bank that sets monetary and macroprudential policies.[8]

2.1 Households

Households maximize period utility from consumption of the domestic final output and leisure.[9] The household problem each period can be stated as:

$$\max_{C_{H,t},N_t,D_t}\left\{E_0\sum_{t=0}^{\infty}\beta_H^t\left[\frac{C_{H,t}^{1-\rho_{C,H}}}{1-\rho_{C,H}}-\frac{N_t^{1+\rho_{N,H}}}{1+\rho_{N,H}}\right]\right\}$$

They are subject to the period budget constraint:

$$P_tC_{H,t}+D_t+T_t=w_tN_t+\frac{(1+i_{t-1}^D)D_{t-1}}{\pi_t}$$

$C_{H,t}$ is the consumption of the final good and N_t the labour supply; $\rho_{C,H}$ is the inverse intertemporal elasticity of substitution for consumption; $\rho_{N,H}$ is the inverse Frisch elasticity of labor supply; P_t is the domestic price level; D_t is the stock of deposits; w_t is the real wage; i_t^D is the deposit rate; π_t is the inflation rate. Consumption/savings and labor supply decisions are determined according to standard optimality conditions, taking the form of a consumption Euler equation and per-period equality of the marginal rate of substitution and marginal cost of consumption-leisure.

[8] The model also features capital goods producers, who produce and sell physical capital for use in the production of the domestic intermediate good. These are excluded from this exposition for brevity.

[9] In contrast to Gerali et al (2010), we do not assume two types of households who differ in their impatience. With only one type of household, there is no net borrowing between households in equilibrium. To simplify the baseline model, the housing sector is also omitted, making households net savers by construction.

2.2 Entrepreneurs

Entrepreneurs borrow from the banking sector to invest in capital goods. They combine the capital goods they own with labor from the household to produce the domestic intermediate good. Entrepreneurs maximize lifetime utility by adjusting consumption and borrowing, deciding on labor employed and physical capital investment for producing the domestic intermediate good, and borrowing from banks, while taking goods and input prices are given. The entrepreneur's problem can be stated as:

$$\max_{C_{E,t},B_t,K_{t+1},N_t}\left\{E_0\sum_{t=0}^{\infty}\beta_E^t\left[\frac{C_{E,t}^{1-\rho_{C,E}}}{1-\rho_{C,E}}\right]\right\}$$

They are subject to their period budget constraint, the domestic good production function and the collateralized borrowing constraint, which are written respectively as:

$$Y_t+B_t=P_tC_{E,t}+w_tN_t+\frac{(1+i_{t-1}^B)B_{t-1}}{1+\pi_t}+q_t(K_{t+1}-(1-\delta)K_t)$$

$$Y_t=A_tK_t^{\alpha}N_t^{1-\alpha}$$

$$(1+i_t^B)B_t\leq LTV_tq_tK_t(1-\delta)$$

$C_{E,t}$ is the entrepreneur's consumption of the final good, B_t is borrowing by entrepreneurs, and K_t and N_t are physical capital and labor employed by entrepreneurs to produce the domestic intermediate good Y_t, which is the numeraire for the model (with prices set to 1). i_t^B is the borrowing rate for entrepreneurs, LTV_t is the maximum loan-to-value ratio set for borrowers in the economy, and q_t is the price of a unit of the capital good. The entrepreneur's utility function has constant elasticity of substitution across time periods, and $\rho_{E,H}$ is the inverse intertemporal elasticity of substitution of consumption for entrepreneurs. The production function for intermediate goods is Cobb-Douglas, with total factor productivity parameter A_t.[10]

Like households, entrepreneurs optimize intertemporal consumption/savings decisions according to a consumption Euler equation. In addition, they make optimal decisions over bank borrowing B_t while subject to a collateralized borrowing constraint. This can be expressed as the entrepreneur's optimality condition for consumption:

$$C_{E,t}^{-\rho_{C,E}}-s_{E,t}=\beta_EC_{E,t+1}^{-\rho_{C,E}}\frac{1+i_t^B}{1+\pi_{t+1}} \qquad (1)$$

$s_{E,t}$ is the Lagrange multiplier on the entrepreneurs' borrowing constraint, and can be interpreted as the shadow price of entrepreneurs' additional borrowing. When the borrowing constraint is binding, and $s_{E,t}$>0, entrepreneurs are pushed off their intertemporal consumption Euler equation, and cannot smooth consumption across periods as well as under a first-best allocation. In particular, a binding borrowing constraint at time t means that the marginal utility of consumption is higher than under the first-best case, and therefore entrepreneurs would prefer to borrow more to invest and consume more in this period. The borrowing constraint becomes tighter as the asset price q_t or the maximum loan-to-value ratio LTV_t falls.

2.3 Trade

[10] Labor is mobile, but production of physical capital (detailed in the Appendix) is subject to quadratic adjustment costs. These costs limit the entrepreneur's ability to frictionlessly adjust output across periods.

Entrepreneurs export the domestic intermediate output in the world market, while consumers (both households and entrepreneurs) import the foreign intermediate good from overseas. To simplify the analysis, we assume that there is a single world market for the domestic economy's final good, rather than multiple destinations of export. In the baseline model, the standard producer currency pricing is assumed, so exported goods are sold in the world market at the domestic intermediate good price. Since the domestic intermediate good is used as the numeraire in our model, its price is normalized to 1 in all periods. Imports are listed at the world price P_t^f, expressed in foreign currency.

Households and entrepreneurs combine the domestic and foreign intermediate goods to form a final consumption good according to the constant elasticity of substitution function.

$$C_t^H + C_t^E = C_t = [\Lambda(Y_t - EX_t)^{\Psi} + (1-\Lambda)(IM_t)^{\Psi}]^{\frac{1}{\Psi}} \qquad (2)$$

In Equation (2), Y_t is the output of the domestic intermediate good, EX_t is exports of the domestic intermediate good, while IM_t is imports of foreign intermediate good. The final consumption good is therefore a CES combination of domestic intermediate goods consumed locally ($Y_t - EX_t$) and imported intermediate goods. Λ is a parameter for home bias in consumption.

The price of the domestic consumption good is a CES combination of domestic and foreign prices. The demand for imports can be derived as:[11]

$$IM_t = \left(\frac{1}{1-\Lambda}\right)^{\frac{1}{1-\psi}} \left(\frac{z_t}{P_t}\right)^{\frac{1}{1-\psi}} C_t \qquad (3)$$

Equation (3) implies that the demand for imports declines as the nominal exchange rate depreciates (rise in E_t), or as the foreign price rises (rise in P_t^f). As this is a model of a small open economy, we assume that the foreign price P_t^f is determined exogenously, as is the level of global output, Y_t^f. We assume that the demand for exports of the domestic intermediate good, EX_t is determined by:

$$EX_t = \left(\frac{1}{1-\Lambda^{\mathrm{f}}}\right)^{\frac{1}{1-\psi^f}} z_t^{\frac{1}{1-\psi^f}} Y_t^f \qquad (4)$$

Λ^f is an exogenous parameter that represents home-bias in foreign countries, analogous to the domestic home bias parameter Λ, while ψ^f is a parameter that determines the elasticity of export demand to the real exchange rate. The import and export demand elasticity parameters ψ and ψ^f are likely to be influenced by the composition of invoicing currencies in the country's exports. A large share of exports invoiced in a dominant currency could lead to lower elasticities of imports and exports to real exchange rate changes, driven by nominal exchange rate movements. As world prices are taken as exogenous, imports and exports are determined in partial equilibrium in our model.

With the domestic intermediate good as the numeraire, the domestic price level is defined as the following.

$$P_t = \left[1 + (1-\Lambda)^{(1-\psi)} z_t^{\frac{1-\psi}{\psi}}\right]^{\frac{\psi}{1-\psi}} \qquad (5)$$

[11] Please see Appendix A for a derivation of consumption demand functions in this economy.

Taking $z_t = E_t P_t^f$ as the real exchange rate, where E_t is the nominal exchange rate (local currency equivalent to one unit of foreign currency), Equation (5) implies that changes in the real exchange rate in period t contribute contemporaneously to price inflation in our model.[12]

2.4 Banks

Banks receive deposits from households and borrow from international markets, while making loans to domestic entrepreneurs for investments in physical capital. Banks are price-takers in both domestic deposit markets and international lending markets, as interest rates are set by the central bank in the former and by global financial conditions in the latter. However, they have market power in domestic lending markets, and impose a markup on their funding rates when making loans to entrepreneurs. Microfoundations for this setup follow Gerali et al (2010), which we extend by adding an international debt market. In particular, banks maximize their profits from financial intermediation minus a cost that is related to the deviation of their bank capital to loans ratio, $\frac{K_t^B}{B_t}$ (also, the inverse of the leverage ratio) from a capital adequacy ratio target (CAR_t). The bank chooses deposits D_t, foreign debt B_t^f and loans to entrepreneurs B_t in order to maximize profits:

$$\max_{D_t, B_t^f, B_t} J_t^B = (1+i_t^B)B_t - (1+i_t^D)D_t - \left(1+i_t^f\right)B_t^f\left[\zeta\,\frac{E[E_{t+1}]}{E_t} + (1-\zeta)\right] - K_t^B - \frac{\theta}{2}\left(\frac{K_t^B}{B_t} - CAR_t\right)^2 K_t^B$$

subject to the bank's balance sheet constraint and the law of motion for bank capital:

$$B_t = D_t + K_t^B + B_t^f[\zeta\,\frac{E[E_{t+1}]}{E_t} + (1-\zeta)]$$

$$K_{t+1}^B = (1-\delta^B)K_t^B + J_t^B$$

J_t^B is bank profits,[13] K_t^B is bank capital, and CAR_t is the target capital-adequacy ratio in each period. The main departure from the setup in Gerali et al (2010) is that banks have access to international debt market. Banks can borrow internationally at the foreign interest rate i_t^f, with loans from abroad denoted as B_t^f, expressed in local currency terms. Only a fraction $(1-\zeta) \in [0,1]$ of the bank's foreign borrowing can be hedged against foreign exchange risk, with the remaining ζ share of foreign debt exposed to nominal exchange rate movements from period t to t+1. Deviations of the bank capital to loans ratio $\frac{K_t^B}{B_t}$ from the capital adequacy ratio CAR_t incur quadratic costs, which constitute the financial friction on credit supply in our model.

Solving the bank's optimization conditions generates two equations. The first determines the spread between the domestic lending rate i_t^B and the domestic borrowing rate i_t^D, which increases in the distance between the bank capital-loans ratio and the capital adequacy ratio CAR_t.

$$i_t^B = -\theta\left(\frac{K_t^B}{B_t} - CAR_t\right)\frac{{K_t^B}^2}{B_t} + i_t^D + \mu^B \tag{6}$$

Equation (6) shows that the bank lending rate depends on borrowing costs for banks from depositors, i_t^D, bank markups μ^B, as well as the difference between bank capital-loan ratios and CAR_t. Specifically, the lower is $\frac{K_t^B}{B_t}$ relative to CAR_t, the greater the frictional costs incurred by banks, which pushes up bank lending rates i_t^B.

[13] In our setup, bank profits are distributed back to households as lump-sum dividends.

The second optimality condition determines the spread between the domestic borrowing rate i_t^D and the foreign borrowing rate, which returns a variant of the standard UIP condition.

$$1 + i_t^D = \left(1 + i_t^f\right)\left[\zeta \, \frac{E[E_{t+1}]}{E_t} + (1 - \zeta)\right] \quad (7)$$

Equation (7) differs from the standard UIP condition only in the extent to which nominal exchange rate movements correlate with interest rate differentials. The greater is ζ, that is, the greater the share of unhedged foreign borrowing, the higher the correlation. Intuitively, banks with a large share of unhedged foreign debt change their composition of borrowing between domestic and foreign sources sharply when there is a shock to future exchange rates, as that has large effects on the size of their liabilities. This leads to a sharp shift in demand for foreign borrowing, which drives changes in the interest rate differential between foreign and domestic sources.[14] On the other hand, a low share of unhedged foreign debt implies that changes in expectations of the future nominal exchange rate have little effect on the liabilities position of banks, and do not prompt a large shift in the composition of bank borrowing.

Finally, banks face an exogenous supply of foreign credit determined according to the equation:

$$B_t^f = \gamma \overline{B_t} \left(\frac{E[E_{t+1}]}{E_t}\right)^{\sigma_1} \left(1 + i_t^f\right)^{\sigma_2} \quad (8)$$

Equation (8) is parametrized such that the supply of foreign credit B_t^f rises (falls) as the foreign interest rate i_t^f falls (rises), so $\sigma_2 < 0$, and as the domestic currency E_t appreciates (depreciates), so $\sigma_1 < 0$. This is a simplified way of modeling cross-border capital flows under global financial cycles, in order to generate credit supply-driven fluctuations in domestic credit conditions over and above standard UIP effects. Unlike standard models where only the UIP condition, and by implication, the expected change in the exchange rate, determines cross-border capital flows, our model does not assume that the supply of foreign loanable funds is perfectly elastic as long as a (risk-adjusted) no arbitrage condition for capital flows holds. Instead, given the expected rate of appreciation of the exchange rate, $\frac{E[E_{t+1}]}{E_t}$, foreign investors make portfolio choices such that the supply of foreign credit varies with the foreign interest rate i_t^f. In effect, this constrains foreign credit to the domestic economy, simplifying results on endogenous capital flows in the two-country settings of Gourinchas (2018) and Kumhof et al. (2020) into a partial equilibrium setup. During risk-off periods, when center countries' borrowing rates rise, there is a tightening of global credit markets, while risk-on periods accompanying falling rates in center countries lead to a loosening of global credit supply. γ is a scaling parameter than determines the impact of exchange rate and foreign interest rate movements on the supply of foreign credit.

2.5 Central Bank

The central bank sets monetary and macroprudential policies, using the deposit rate i_t^D as instrument for the former, and two macroprudential policy instruments for the latter: a capital adequacy ratio for the banking system (CAR_t) and a loan to value ratio for domestic borrowers (LTV_t). The assumption for the central bank's conventional monetary policy function is a standard Taylor Rule that stipulates that the interest rate gradually responds to deviations of inflation and output from target levels.

$$1 + i_t^D = (1 + i_{ss}^D)^{(1-\rho_i)}(1 + i_{t-1}^D)^{\rho_i}\left(\left(\frac{\pi_t}{\pi_{ss}}\right)^{\phi_\pi}\left(\frac{Y_t}{Y_{ss}}\right)^{\phi_Y}\right)^{\rho_i} \quad (9)$$

[14] As the model assumes that banks are the only agent in the domestic economy that can access international debt markets, households do not have an arbitrage opportunity from the modified UIP condition.

The MAP authority wields two macroprudential instruments, and the policy rules are expressed as:

$$LTV_t = LTV_{ss}{}^{(1-\rho_{LTV})} LTV_{t-1}{}^{\rho_{LTV}} \left(\left(\frac{B_t}{B_{ss}}\right)^{\phi_{B,LTV}} \left(\frac{q_t}{q_{ss}}\right)^{\phi_{q,LTV}} \right)^{\rho_{LTV}} \tag{10}$$

$$CAR_t = CAR_{ss}{}^{(1-\rho_{CAR})} CAR_{t-1}{}^{\rho_{CAR}} \left(\left(\frac{B_t}{B_{ss}}\right)^{\phi_{B,CAR}} \left(\frac{q_t}{q_{ss}}\right)^{\phi_{q,CAR}} \right)^{\rho_{CAR}} \tag{11}$$

A minimum loan-to-value ratio, LTV_t, applies to domestic entrepreneurs. We assume that, as seen in Equation (10), LTV_t is adjusted in response to deviations of total borrowing by entrepreneurs in the economy, B_t, and physical asset price q_t. A capital-adequacy target imposes bank leverage requirements for the banking sector. As shown in Equation (11), CAR_t is also assumed to adjusted in response to deviation of total entrepreneur borrowing and asset prices. For the domestic economy, LTV_t constitutes a MaP for credit demand, and CAR_t is a MaP for credit supply. In the baseline model, we assume that the policy vector $\{i_t^D, LTV_t, CAR_t\}$ is uncoordinated. That is, we have three policy functions, with conventional monetary policy decided by a Taylor Rule, and MaPs decided by similar Taylor-like rules that take credit variables as arguments.

2.6 Exogenous Shocks

The model has four sources of exogenous shocks: (i) a shock to domestic productivity A_t (ii) a shock to foreign demand Y_t^f, (iii) a shock to domestic markups μ_t, and (iv) a shock to foreign interest rates i_t^f. For the analysis in this paper, we focus on the effects of a shock to foreign interest rates, which is the main interest in this paper and generates our key insights. The shocks to each of these exogenous variables are assumed to follow AR(1) processes.

$$i_t^f = 1 - \rho^{i^f} + \rho^{i^f} i_{t-1}^f + \epsilon_t^{i^f} \tag{13}$$

3. Static Model

To gain intuition on the novel aspects of our model, which entail a tractable international debt market for the banking sector and an international output market for households and entrepreneurs, we introduce a simplified static version of the model, that replicates our baseline model's steady state properties.

The focus in the static model is on the interaction between shocks to international financial conditions and equilibrium in the domestic economy. To do so, the static model is assumed to only contain three markets – for foreign borrowing by banks, for domestic borrowing and domestic deposits. The two sources of financial frictions in the model directly affect the three financial markets in the model, and isolating them within a static model enables us to perform comparative static analysis and describe their impacts on a small open economy.

We introduce a static version of Equation (7), the UIP equation:

$$1 + i^d = \frac{1 + i^f}{E} \tag{14}$$

The static version of UIP retains the structure of the dynamic UIP equation, with E representing the steady state change in exchange rate, , so that it is equal to interest rate differentials in equilibrium.

In the international borrowing market, the foreign interest rate is taken as exogenous, with the supply curve for foreign credit adapted from equation (8) in the dynamic model, which states that the supply of foreign credit is increasing in the nominal exchange rate and decreasing in the foreign interest rate. The static version of the foreign credit supply equation (Equation 6), which establishes the credit supply curve for banks given a given level of bank capital and deposit rate, is:

$$B^f = \gamma \bar{B}(E)^{\sigma_1}(1+i^f)^{\sigma_2} \quad (15)$$

In equilibrium, bank's foreign borrowing equals the difference between the domestic demand for borrowing by entrepreneurs and the sum of bank capital and household deposits, so that the following market clearing condition is satisfied:

$$B^f = B - D \quad (16)$$

Equation 16 states that foreign credit must be equal to the portion of domestic credit not satisfied by domestic deposits. Note the assumption that $B^f > 0$, implying that the country is a net debtor. *Ceteris paribus*, the exchange rate E adjusts to clear the market for foreign borrowing by banks.

The domestic borrowing rate i^b depends on the domestic deposit rate, as well as costs incurred by banks from deviating from CAR.

$$i^b = i^d - \theta\left(\frac{K^B}{B} - CAR\right)\left(\frac{K^B}{B}\right)^2 \quad (17)$$

Equation (17) shows that for a given deposit rate i^D and stock of bank capital K^B, there is a positive relationship between loan rates and total loans. That is, as loan rates rise, banks would be willing to incur greater costs of deviating from capital adequacy rates to make more loans.

Demand for borrowing by entrepreneurs is determined by the static version of Equation (1), which can be written as:

$$1 + \frac{s_E(B, q^k)}{\lambda_E(R^k)} = \beta_E(1 + i^b) \quad (18)$$

$\lambda_E(R^k)$ is the shadow price of entrepreneurs' consumption, which is equal to the marginal utility of consumption, as in the standard consumption Euler equation. We assume that $\lambda_E(R^k)$ is increasing in the real return from investment, R^k.[15] Intuitively, as R^k rises, future incomes rise, increasing the marginal cost of consumption, leading to a fall in consumption and a rise in λ_E. $s_E(B, q^k)$ is the shadow price of borrowing for entrepreneurs, that is assumed to be decreasing in total borrowing B and decreasing in asset price q^k.[16] $s_E(B, q^k)$ is the marginal utility to the entrepreneur of loosening her borrowing constraint. Intuitively, at higher levels of borrowing, the entrepreneur's marginal utility of loosening the borrowing constraint falls, as returns from greater borrowing are lower. Additionally, when asset prices rise, the borrowing constraint loosens, and marginal utility from further loosening the borrowing constraint falls. As such, for a given level of q^k and R^k, when the borrowing rate i^b rises, the demand for total borrowing falls, leading to a rise in the shadow price of borrowing s_E.

[15] This assumption follows the intuition of the dynamic model, where the shadow price of consumption rises when a rise in returns to capital leads to higher permanent income, we assume that λ_E is increasing in R^k.

[16] In the dynamic model, the shadow price of borrowing falls when rising asset prices loosen the borrowing constraint, or when total borrowing rises. Correspondingly, we assume that s_E is decreasing in total borrowing and decreasing in asset prices q^k (assuming the borrowing constraint binds).

In equilibrium, the price of loans i^b clears the market for total debt, given four parameters. On the side of credit supply (bank lending), Equation (17) shows that an increase in i^d shifts the bank lending curve leftwards, and a fall in K^B shifts the bank lending curve leftwards. On the side of credit demand (entrepreneur borrowing), Equation (18) shows that a fall in q^K shifts the entrepreneur borrowing curve leftwards, and a fall in R^K shifts the entrepreneur borrowing curve leftwards.

To close the model, we introduce an equation for deposits by households D, analogous to the households' consumption Euler equation in the dynamic model. The static version of this equation captures the essential intuition: due to the intertemporal substitution effect, households raise their savings and reduce their consumption in response to a rise in the deposit rate.

$$\Lambda_H(D) = \beta_H(1 + i^d) \tag{19}$$

$\lambda_H(D)$ is the shadow price of household consumption. Reflecting the standard intuition from the consumption Euler equation that λ_H is decreasing in consumption, and also the household budget constraint where savings (and deposits) fall as consumption rises, we assume in the static model that $\lambda_H(D)$ is increasing in the level of deposits D.

Equilibrium in the static model is defined as a vector of prices $\{E, i^b, i^d\}$ and a vector of quantities $\{B^f, B, D\}$ that solves the six equations numbered (14) to (19), with all other parameters given exogenously. We now highlight three channels through which shocks can impact foreign borrowing in our static framework: the investment channel, the exchange rate channel and the balance sheet channel. Imposing market clearing in the market for foreign credit, and combining Equations (15) and (16), we have:

$$\gamma\bar{B}(E)^{\sigma_1}(1 + i^f)^{\sigma_2} = B^f = B(\underbrace{i^b, K^B,}_{\text{Balance Sheet Channel}} q^K, \underbrace{R^K}_{\text{Net Exports Channel}}) - D(\underbrace{i^d}_{\text{Investment Channel}}) \tag{20}$$

Balance Sheet Channel *Net Exports Channel* *Investment Channel*

The LHS of Equation (20) is the expression for foreign credit supply, and on the RHS is the expression for foreign credit demand. The demand for foreign credit is the difference of total debt in the economy, which depends on the deposit rate i^b, bank capital K^B, asset prices q^K and real returns from capital R^K, and domestic deposits, which depends on i^d. We can use Equation (20) to analyze the three channels through which exogenous shocks, to i^f, K^B, q^K or R^K can affect foreign borrowing in equilibrium.

Investment channel: An exogenous shock's impacts on foreign borrowing via effects on the deposit rate i^d is termed here as the (domestic) investment channel. An increase in the deposit rate will lead to a rise in household deposits as households save more (see Equation 19), but reduce demand for domestic borrowing as banks raise interest rates (see Equation 17). With lower demand for domestic borrowing and higher supply of domestic credit, the demand for foreign borrowing falls, and foreign borrowing declines in equilibrium.

Net exports channel: A shock's impact on the rate of return to physical capital R^K via changes in net exports is the net exports channel. A shock that causes the exchange rate to appreciate increases the relative price of the domestic output good versus the foreign output good, resulting in reductions in net exports. This reduces total output/income in the domestic economy and reduces R^K, causing declines in credit demand.

The Investment and Net Exports channels represent standard Mundell-Fleming channels of macroeconomic equilibration in response to a tightening in global financial conditions—the former leads to a net reduction in foreign borrowing and a reduction in the capital/financial account (via a narrowing of the S-I gap) and the latter is associated with worsening terms of trade, leading to a fall in the current account.
Balance sheet channel: The model features two financial frictions that give rise to financial channels of shocks that operate on top of the above two standard effects, by affecting balance sheet positions of lenders

and borrowers. These balance sheet channels create the scope for financial shocks to have macroeconomic effects beyond the above two standard channels. We provide an illustration of how each financial friction generates balance sheet channels of monetary shocks.

(i) A financial friction in credit supply: costs incurred by banks for deviating from a target bank capital requirement.

Banks adjust lending and borrowing behavior depending on their capital adequacy. Assuming that the economy starts from an initial steady state, a shock that reduces (increases) K^{B} pushes off banks' optimality condition in Equation 17, increasing costs incurred from deviating from CAR and inducing banks to reduce (increase) credit supply to entrepreneurs. This in turn reduces (raises) investment and output in the domestic economy.

(ii) A financial friction in credit demand: collateralized borrowing constraints on borrowers depending on LTV_t generate a financial accelerator mechanism.

Since borrowers' credit demand is constrained by their LTV ratio, a shock to the economy that affects asset prices q^K results in a tighter borrowing constraint, reducing credit demand. Balance sheet channels interact with investment and exchange rate channels to compound effects of initial shocks. Consider a shock to the foreign interest rate. It affects the banking sector's balance sheets by changing the value of bank liabilities, therefore affecting the present value of bank profits. An increase in foreign borrowing rates reduces bank profits, and reduces credit supply in the domestic economy, leading to contractions in borrowing and investment, over and above the standard investment channel. Furthermore, if an increase in foreign interest rate generates depreciation pressure on the domestic currency via the UIP condition, liabilities increase for banks that have net liabilities in foreign currency and increases the size of balance sheet effects, leading to larger reductions in net borrowing from abroad than under the exchange rate channel alone.

Proposition 1: *Under the static model, a rise in the foreign interest rate leads to a decline in domestic credit, if the net export channel is assumed to be zero. Further, the presence of bank and entrepreneur balance sheet channels increases the magnitude of the impact of the foreign interest rate change on domestic credit. A countercyclical MaP policy, defined as an inverse relationship between CAR or LTV with B, cushions the decline of credit in the economy. Conversely, procyclical MaPs magnify the decline in total debt.*

Proof: See Appendix.

Proposition 1 shows the divergent comparative statics of two different MaP regimes in our static model, capturing some of the key intuitions that explain the behavior of our dynamic model. A countercyclical MaP regime is characterized by looser macroprudential policy settings (higher LTV and lower CAR) when total debt declines as a result of positive foreign interest rate shock. To explain the result in Proposition 1 intuitively, note that a countercyclical MaP regime simply reduces the effects of financial frictions on total debt. Higher LTV ratios reduce the extent to which borrowing constraints bind for entrepreneurs, while lower CAR reduce the costs incurred by banks from increasing borrowing when bank capital falls. By loosening the constraints on borrowing and lending, it is unsurprising that countercyclical MaPs reduce the decline in domestic credit when the foreign interest rate rises.

The proof of Proposition 1 formalizes this intuition. Countercyclical MaPs affect the macro-financial effects of a change in i^f by reducing the magnitude of balance sheet effects. The reduction of bank balance sheet effects reduces the extent of the leftward shift of the domestic credit supply curve. The smaller size of the shift in domestic credit supply itself reduces the leftward shift of the domestic credit demand schedule, by reducing entrepreneur balance sheet effects. In each case, countercyclical MaPs have the potential to modulate financial channels of a change in borrowing rates that transmit through balance sheets (of borrowers and lenders respectively).

4. Model Simulations

The dynamic model is log-linearized around its steady state, with a solution method akin to the flexible-price equilibrium in Gerali et al. (2010). We now numerically simulate the fully dynamic model and plot impulse response functions (IRFs) for selected model variables in response to a positive shock to i_t^f.

The model's standard parameters, such as those characterizing household, entrepreneur and worker preferences (β_H, β_E, ρ_N) as well as production technologies (α, δ) are calibrated using standard values from the small open economy models in the literature (e.g., Guerrieri et al., 2013). The foreign GDP parameter, Y^f is set very large, so that the domestic country has a small economy relative to the rest of the world, and elasticities of imports and exports to the real exchange rate are set so that the country maintains a current account deficit in steady state, and so a deprecation (appreciation) of the real exchange rate leads to a rise (fall) in net exports. In the steady state, the domestic deposit rate i_{ss}^D is calibrated to exceed the foreign borrowing rate i_{ss}^f, so that the country is a net borrower, and the share of foreign-currency denominated debt is set at $\zeta = 0.3$ to equal the share of foreign borrowing in total bank borrowing. We set bank parameters so that the steady state bank capital to asset ratio is 0.10, and the entrepreneur's loan-to-value ratio is 0.55, which is the lower bound of estimates by Iacoviello (2005).[17] Our baseline model calibration is not meant to resemble the economy of any specific small-open economy. The following estimates are presented to demonstrate the direction and profile of model behavior with respect to an unexpected tightening in global financial conditions, with magnitudes of effects not corresponding to particular countries.

Figure 1 shows model responses to a positive shock to i_t^f. This increases the cost of borrowing from international markets, and stimulates a fall in overall debt. We compare outcomes between an economy that uses countercyclical MaPs, and one that does not.

Under the no-MaP baseline calibration for our model, we assume that the central bank does not use LTV_t or CAR_t levers at all, and varies only the domestic policy rate. In our baseline calibration, the country is a net external borrower in the steady state, which is to say that B^f is strictly positive. As the country is simultaneously unable to fully hedge against currency risk, the country also holds a net short foreign currency position.

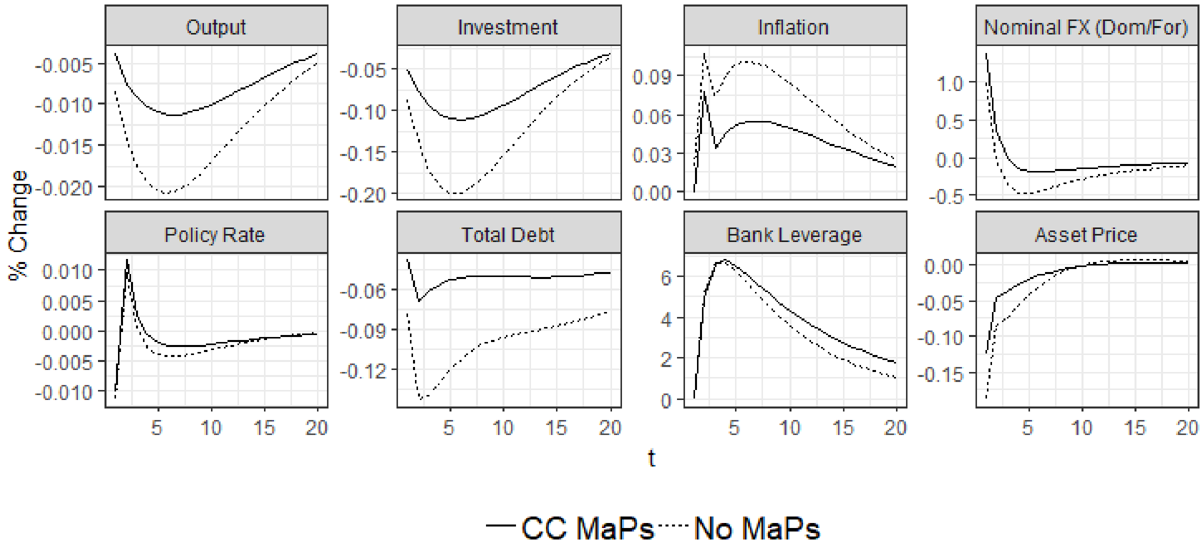
Figure 1 shows that under the no-MaPs baseline, a positive foreign interest rate shock leads to a sharp decline in total debt, and consequently falling investment and output upon impact of the shock. Falling output induces the central bank to reduce policy rates. However, the depreciation of the domestic currency increases import prices, which pass through to higher inflation, and the central bank subsequently reacts by raising the policy rate in the period after the shock. Meanwhile, the depreciation of the currency acts as an automatic stabilizer for output by raising net exports.

Rising external borrowing costs for banks also act via the balance sheet channel to reduce bank profitability, which increases bank leverage. Finally, higher domestic lending rates, resulting from temporarily higher deposit rates and higher foreign borrowing costs, lower the demand for investment and lead to a fall in asset prices.

Relative to the no MaP economy, the declines in both output and debt are tempered under a countercyclical MaP regime. As total debt and asset prices fall, LTV_t is raised and CAR_t is lowered, according to the authorities' MaP response functions (see Equations 10 and 11). Higher LTV_t loosens borrowing constraints on domestic borrowers, while lower CAR_t reduces the costs of increasing bank lending (conditional on bank capital levels). Both policies mitigate the fall in total domestic lending and investment, which reduces the fall in output.

[17] Parameters used to calibrate the baseline no-MaP economy are detailed in the Appendix.

Figure 1: Effects of a shock to i_t^f, for an economy with countercyclical MaPs versus no MaPs.



Notes: The interest rate shock imparts a 1%-pt increase to ϵ_t^f with an autocorrelation coefficient of $\rho^{if} = 0.4$, and all parameters as in the baseline model calibration. Under the countercyclical MaPs regime, $\phi_{B,LTV} = -0.5, \phi_{q,LTV} = -0.5, \phi_{B,CAR} = 0.5, \phi_{q,CAR} = 0.5$. Under the no MaPs regime, all four parameters are set to 0.

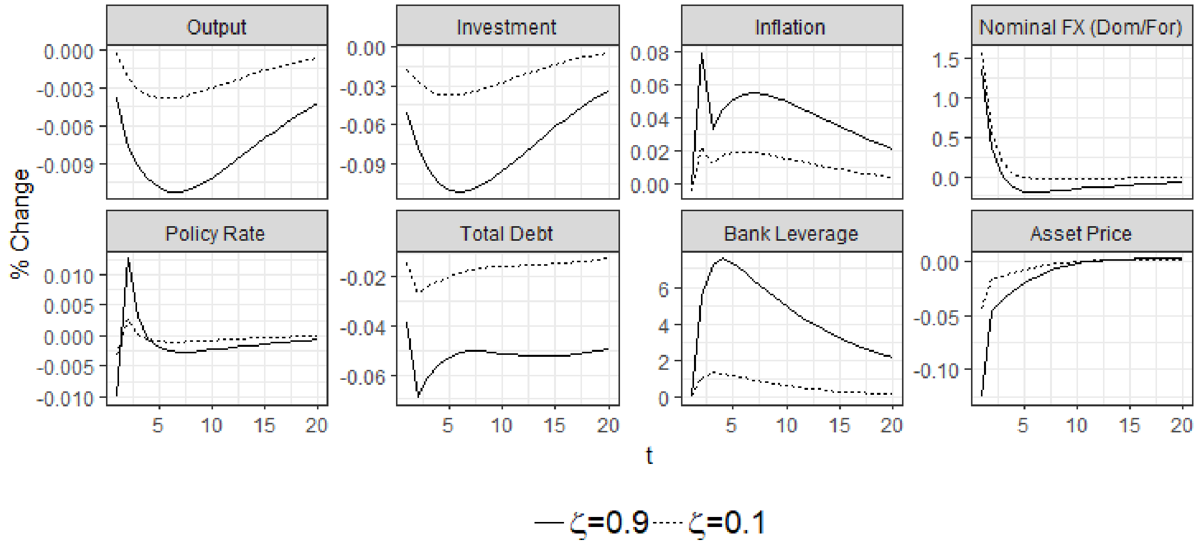
Countercyclical MaPs thus constrain the volatility of macroeconomic and financial outcomes around the steady state of the economy in the presence of random shocks to i_t^f. While they drag on economic growth during periods of loose global financial conditions, they also reduce the depth of recessions during periods of tightness. We now highlight the importance of three country parameters to the effects of shocks to i_t^f on macroeconomic outcomes. The first key parameter, ζ, represents the share foreign currency borrowing within a country's total net borrowing. ζ is important in determining the impact of a foreign interest rate shock on bank liabilities. The second parameter is γ, the elasticity of a country's foreign credit supply to a change in foreign interest rate. The third parameter, ψ^f, the elasticity of export demand with respect to the real exchange rate, affects the ability of the exchange rate (assumed to be flexible in the model) to function as an automatic stabilizer via the current account. We now investigate the effects of shocks to i_t^f on variables in our model, under the no-MaP baseline calibration of the small-open economy.

ζ – Share of foreign currency debt

A shock to i_t^f will have a larger impact on bank lending when ζ is large, via the impacts of the shock to i_t^f on bank profits. A large share of foreign-currency denominated borrowing currency depreciation leads to larger increases in bank liabilities. As a result, banks must aggressively reduce leverage, leading to a further decline in bank lending. The decline in credit supply leads to an increase in domestic lending rates and thus a fall in asset prices, tightening borrowing constraints on borrowers and leading to a decline in overall borrowing.

We simulate the model's differential responses to a positive shock to a positive shock to the foreign interest rates, while varying ζ. These are shown in Figure 2.

Figure 2: Effects of a shock to i_t^f for different ζ



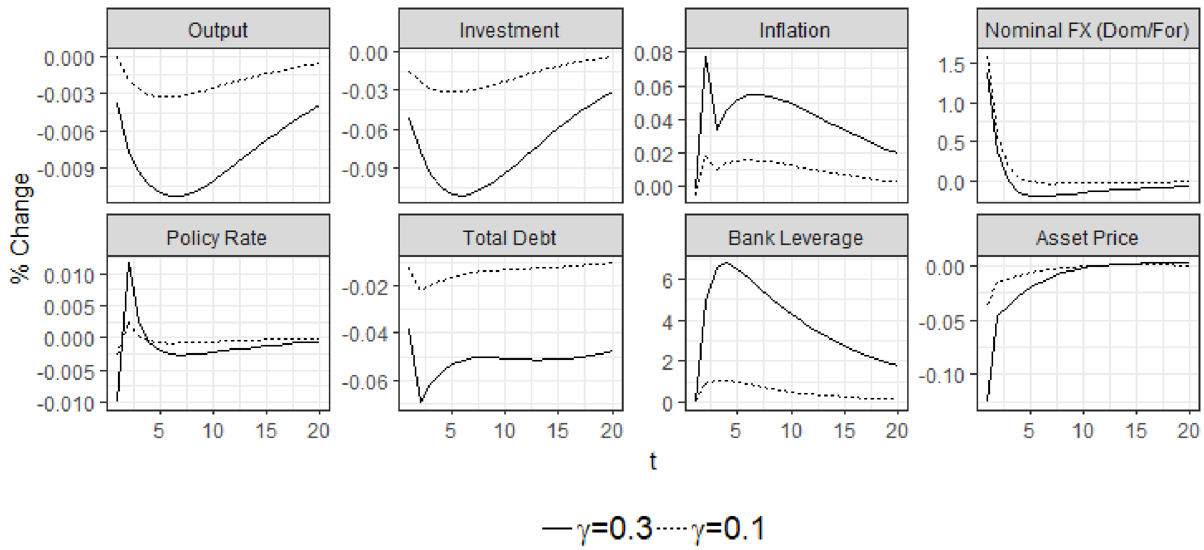
Notes: The interest rate shock is modeled as a 1% positive increase in ϵ_t^f with all parameters remaining the same as in the baseline calibration of the model, with the exception of ζ. High values of ζ increase the share of foreign-currency denominated debt within total debt in the steady state.

When ζ is high, the rise in foreign rates has a larger positive impact on borrowing rates charged by the bank in equilibrium (see Equation 7), As such, Figure 2 shows that a country with high ζ experiences larger declines in total borrowing and investment, in the event of a positive shock to i_t^f. As bank profits fall, so does bank capital, leading to a larger rise in bank leverage for a high ζ country. This reflects that the size of ζ is important for determining the size of balance sheet effects of a positive foreign interest rate shock and that high values of ζ increase the size of the balance sheet channels of external monetary shocks.

γ – Responsiveness of foreign credit supply to foreign interest rate

For countries with high γ, a change in the foreign interest rate has large impacts on the supply of foreign credit (see Equation 8). Varying γ affects the domestic economy through similar channels to ζ above, by affecting the size of impacts on credit supply and in turn, bank lending. Specifically, if γ is high, a shock to the foreign interest rate causes a large contraction in foreign credit supply, leading to large declines in bank profits and declines in bank lending. Figure 3 shows the model's differential responses to a positive shock to the foreign interest rates, while varying γ.

Figure 3: Effects of a shock to i_t^f for different γ



Notes: The interest rate shock is modeled as a 1% positive increase in ϵ_t^f with all parameters remaining the same as in the baseline calibration of the model, with the exception of γ. High values of γ increase the effect of a foreign interest rate change on the supply of foreign debt.

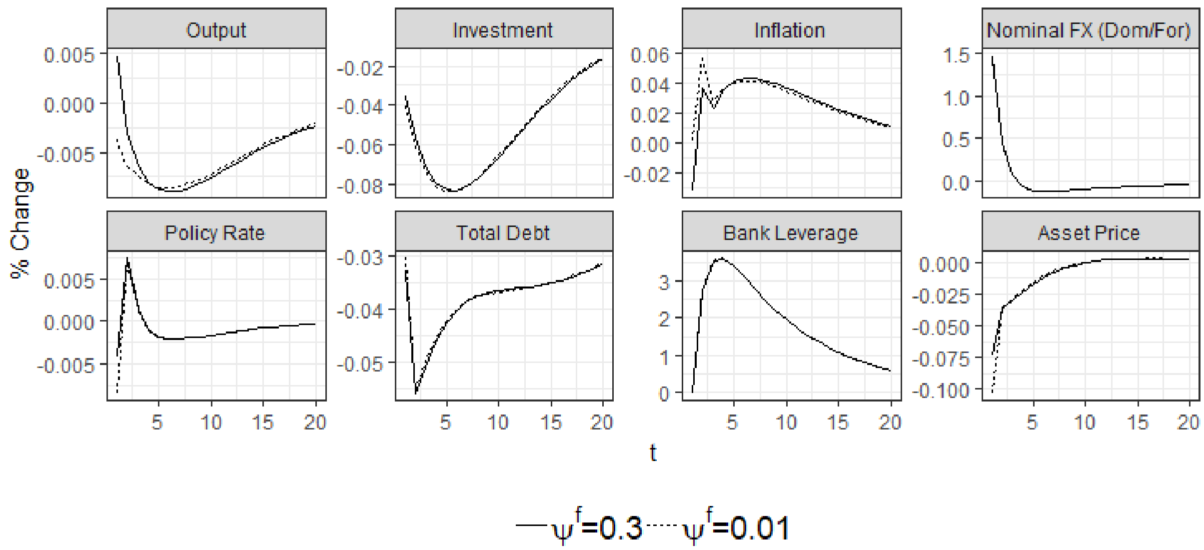
Similar to Figure 2, the IRFs show that under high γ, a positive shock to i_t^f leads to a sharp decline in foreign credit supply and a large increase in domestic borrowing costs for banks. This leads to a sharp decline in total debt and via strong balance sheet effects as banks reduce lending and borrowing constraints are tightened. The larger fall in overall investment underlies a more negative output response

ψ^f – Responsiveness of exports to the real exchange rate

In the model, ψ^f determines the responsiveness of export demand to changes in the real exchange rate. A flexible exchange rate helps to insulate domestic monetary policy from external interest rate shocks in our framework, as higher foreign borrowing costs that lead to an immediate depreciation of the domestic currency leads to a rise in the current account balance and counteracts contractionary effects on output from the investment channel.

Countries with high elasticity of export demand ψ^f see larger increases in net exports for a given increase in the foreign interest rate, leading to positive effects on output and consumption. Responses to a positive shock to the foreign interest rate for different values of ψ^f are shown in Figure 4.

Figure 4: Effects of a shock to i_t^f for different ψ^f



Notes: The interest rate shock is modeled as a 1% positive increase in ϵ_t^f with all parameters remaining the same as in the baseline calibration of the model, with the exception of ψ^f. High values of ψ^f increase the elasticity of demand for the country's exports.

Figure 4 shows that on impact, both countries see equal deprecation of their domestic currencies. The country with higher ψ^f sees a stronger positive net export response, which is strong enough to induce a positive overall output response. With higher domestic production, expenditure switching from imports to the domestic output dampens inflationary pressures from the currency depreciation, and strong demand for domestic output mitigates against the fall in domestic investment and asset prices. In contrast, if exports respond weakly to currency depreciation (perhaps as exports are predominantly invoiced in a dominant currency), the net exports channel fails to provide output stabilization, and balance sheet channels dominate (mainly via sharper asset price declines), leading to output losses.

To summarize, high ζ and high γ lead to large balance sheet effects from an external monetary shock. This implies that a shock to the foreign interest rate is likely to result in large disruptions to financial variables, sharply curtailing total debt, raising bank leverage and reducing asset prices. On the other hand, high ψ^f leads to a larger exchange rate channel, which increases the ability of currency movements to function as automatic stabilizers via current account improvements.

5. Optimal Macroprudential Policy

Proposition 1 shows that in our simplified static economy, countercyclical MaPs limit the growth of debt during periods of loose global financial conditions, while reducing the size of declines when conditions tighten. Figure 1 showed that similar results apply when we apply a positive to shock to i_t^f to our dynamic economy. In effect, a countercyclical MaP regime reduces the volatility of macroeconomic and financial outcomes in response to foreign interest rate shocks. At the same time, Figures 2 – 4 showed that countries with certain characteristics experience larger macrofinancial impacts of shocks to i_t^f. In this section, we analyze optimal calibration of MaPs by a rules-based MaP authority which seeks to maximize welfare, conditional on country characteristics ζ, γ and ψ^f.

The MaP authority's utility is defined as a function of first and second moments of foreign interest rate shock impacts, increasing in mean output impact $\Delta\bar{Y}_{i^f}$, and decreasing in the variation of output and debt, denoted by $\sigma^Y_{i^F}$ and $\sigma^B_{i^F}$.

$$\max_{\{\phi^{\text{MAP}}\}} V(\mu_{\Delta Y}, \sigma^2_{\Delta Y}, \sigma^2_{\Delta B}\,;\,\zeta, \gamma, \psi^f)$$

Intuitively, the MaP authority chooses MaP response parameters $\phi^{\text{MAP}} = \{\phi^{LTV,b}, \phi^{LTV,q}, \phi^{CAR,b}, \phi^{CAR,q}\}$ to maximise mean output gains from external financial inflows, while minimizing overall volatility in aggregate output and debt. $\mu_{\Delta Y} = E_{i^f}[Y_t - Y_{\_ss}]$ is the mean deviation of economic growth from steady state levels under a negative shock to the foreign interest rate i^f_t. $\sigma^2_{\Delta Y} = Var_{i^f}\,[Y_t - Y_{ss}]$ and $\sigma^2_{\Delta B} = Var_{i^f}\,[B_t - B_{ss}]$ are the variance of output and total debt, for a given stochastic distribution for external interest rate shocks. We assume a standard mean-variance linear function $V(\cdot) = \alpha_1\mu_{\Delta Y} - \alpha_2(\sigma^2_{\Delta Y} + \sigma^2_{\Delta B})$ for this analysis.

We can show that optimal MaP parameters ϕ^{MAP} vary with country characteristics, described by the vector $\{\zeta, \gamma, \psi^f\}$. Note that $\frac{d\mu_{\Delta Y}}{d\zeta} > 0$ and $\frac{d\mu_{\Delta Y}}{d\gamma} > 0$. Intuitively, countries with high denominations of foreign currency debt and with highly elastic foreign credit supply derive greater economic growth benefits from an unexpected loosening of external financial conditions, as borrowing in foreign currency while the domestic currency is appreciating leads to positive balance sheet effects. Higher values for ϕ^{MAP}, implying a more countercyclical MaP regime, dampens the positive effects on economic growth from external financial inflows. Formally, we can show that $\frac{d^2\mu_{\Delta Y}}{d\zeta d\phi^{\text{MAP}}} < 0$.

Balance sheet effects from external interest rate shocks also imply that volatility of output and total debt are also increasing in ζ, γ, so $\frac{d\sigma^2_{\Delta Y}}{d\zeta} > 0$ and $\frac{d\sigma^2_{\Delta B}}{d\zeta} > 0$. We have also shown that higher current account responsiveness to the real exchange rate mitigates output volatility, so $\frac{d\sigma^2_{\Delta Y}}{d\psi^f} < 0$. Further countercyclical MaPs act directly to mitigate the volatility of output and debt. As a result, $\frac{d^2\sigma^2_{\Delta Y}}{d\zeta d\phi^{\text{MAP}}} < 0$. These simple comparative statics show that tightening macroprudential policies for countries with high ζ , high γ and low ψ^f can more significantly dampen the tradeoff between mean growth and financial system volatility.

Figure 5 demonstrates the model-implied tradeoff between growth and stability in tightening MaP regime choice for two example countries. Country A is characterized by higher ζ , higher γ and lower ψ^f than Country B, representing a country that experiences a steep growth and stability tradeoff from cross-border capital flows.

Figure 5: Growth Stability Tradeoff of MaPs

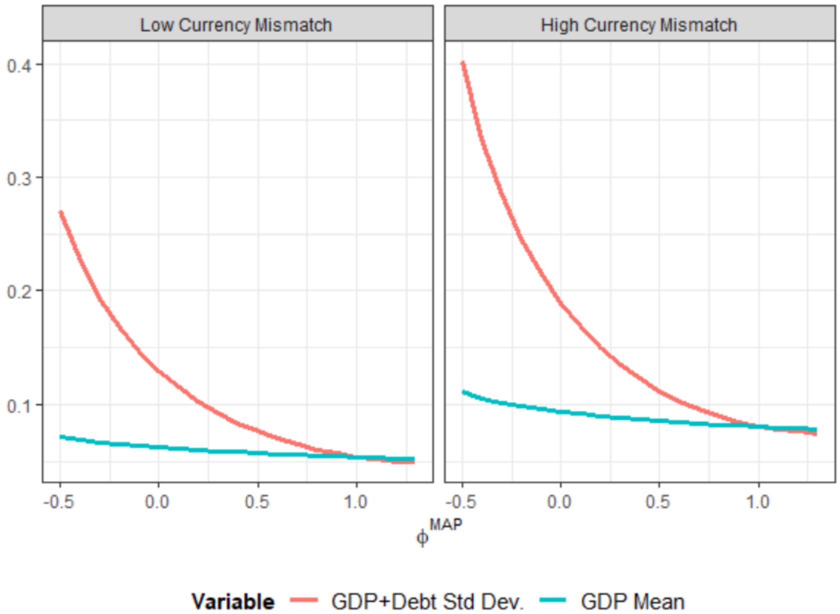


Figure 6: Country Welfare Varying by MaP Response

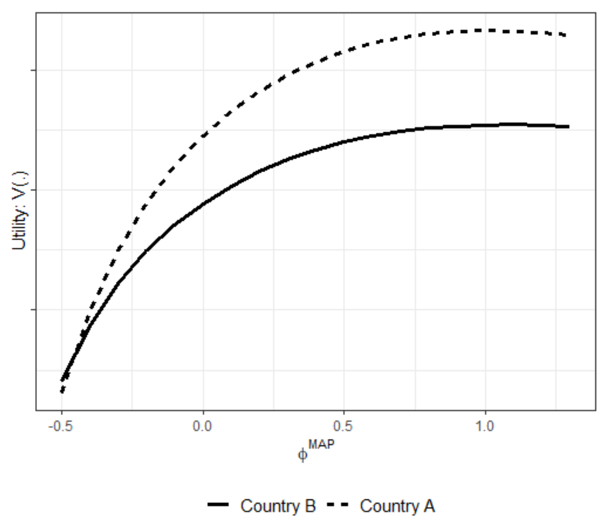


Figure 6 presents results from model simulations for $\mu_{\Delta Y}$ (in e) and $\sigma^2_{\Delta Y} + \sigma^2_{\Delta B}$ (in red) for Country A (in dashed lines) and Country B (in solid lines), as the tightness for MaP setting ϕ^{MAP} varies. The simulations for each country are conducted for a range of parameter values for ϕ^{MAP} , specifically, for $\phi^{LTV} = (-1.5{,}0.5)$ and $\phi^{CAR} = (-0.5{,}1.5)$. The horizontal axis in Figure xx shows the absolute value for all four MaP tightness parameters, with increase representing a tightening. To illustrate, the left extremum on the horizontal axis, $\phi^{\text{MAP}} = -0.5$, shows outcome values when countries adopt a procyclical MaPs setting – that is, where they loosen MaPs when debt volumes and asset prices increase, and tighten when those variables fall.

For both countries, the growth-stability tradeoff for MaPs exists, as shown by declining red and blue lines in Figure 5 as ϕ^{MAP} rises. Low values of ϕ^{MAP} are associated with higher values of average GDP growth (due to a negative foreign interest rate shock), as well as higher volatility in GDP and debt. In addition, Figure 5 shows that Country A sees steeper $\sigma^2_{\Delta Y} + \sigma^2_{\Delta B}$ declines as ϕ^{MAP} rises than Country B, showing that tightening MaPs has larger effects on dampening the growth-stability tradeoff for Country A. This is demonstrated in Figure xx, which shows how $V(\cdot)$ varies with ϕ^{MAP} for each country. Country A sees greater marginal utility from tightening MaPs than Country B for a large region of plausible values for ϕ^{MAP}. While both countries under this set of simulations maximise welfare for approximately the same values of ϕ^{MAP}, the larger gains from countercyclical MaPs for Country A reflect the greater reductions in output and debt volatility afforded by MaPs for countries with high ζ , high γ and low ψ^f. On the other hand, the gradient of growth outcomes when varying ϕ^{MAP} is largely invariant to country characteristics.

Note that our model does not imply that countries with higher values for ζ and γ have higher optimal values of ϕ^{MAP}. Intuitively, this is because these countries face a steeper growth-stability tradeoff—tighter countercyclical MaPs impose large negative impacts on growth while sharply reducing volatility. However, for low values of ϕ^{MAP}, the stability gains from countercyclical MaPs far outweigh the impacts on growth in countries with high ζ and γ (that are subject to large balance sheet effects).

6. Empirical Evidence

This section will examine how countries adjust macroprudential settings in response to US monetary policy surprises by estimating the impulse response functions (IRFs) of a broad index of macroprudential stance to the US monetary policy surprise series estimated by Iacoviello and Navarro (2019), which includes changes in monetary policy stance through interest rate changes and quantitative easing.

While the main focus of this paper is on macroprudential policy response to US monetary policy surprises, we also control for two other exogenous shocks: a proxy for global financial market risk appetite, the VIX; and the proxy for fluctuations in financial globalization by Blanchard, Adler and de Carvalho Filho (2015), which consists, for each country, the ratio of gross private capital flows to GDP for all the other countries in the world.[18]

As a first step, we estimate country-specific IRFs for 40 countries, based on data availability. Based on those IRFs, we split the sample into two macroprudential style clusters: countries whose macroprudential settings are counter-cyclical to US monetary policy (i.e., those where macroprudential settings are loosened when US monetary policy is tightened and vice-versa) and those that are not.[19] Next, we analyze the determinants of countries' macroprudential style. Finally, we compare outcomes across those two macroprudential style clusters.

6.1 Country-specific IRFs

We estimate individual countries' multivariate policy response to external drivers, using the local linear projections model (Jordà, 2005). This paper uses quarterly data from 2000 to 2017 for a panel of 40

[18] 'Private capital flows' refer by flows for which both parts (sender and receiver) are in the private sector. For instance, when a US fund buys a Mexican government bond, that is not a private capital flow.

[19] The latter group includes countries that rarely or never adjust their macroprudential settings, adjust in a manner that is uncorrelated to US monetary policy development or adjust procyclically (i.e., tightening macroprudential settings when US tightens monetary policy).

countries[20], of which 16 are emerging markets[21] and 24 advanced economies (among them, 11 are euro area members).

Our measure of macroprudential stance is the number of cumulative tightening or loosening decisions in the Integrated Macroprudential Policy (iMaPP) database (Alam et al., 2019).[22] The iMaPP database compiles records of tightening and loosening actions on 17 instruments at a monthly frequency, from 1990Q1 to 2016Q4. For each instrument, the observation takes the value of 1 for tightening, -1 for loosening and 0 for no change.[23] For instance, the measure of macroprudential stance is equal to 0 for Switzerland from 1990Q1 when the series for that country started to 2007Q4. In 2008Q1, as Switzerland tightened leverage limits for banks, the index of macroprudential stance changed to 1 (meaning, there was 1 net tightening macroprudential adjustment since the beginning of the series, as of 2008Q1). Among the 40 countries in our sample, during 108 quarters (1990Q1-2016Q4), the highest value for the macroprudential stance was 54 reached by China in 2016Q4, which represents an average of one net tightening measure per 2 quarters. At the other extreme, by 2000Q2 the index reached -11 for Brazil at the end of a cycle of macroprudential loosening actions that started in 1996Q3.[24]

In an integrated policy framework, countries use more than one instrument to respond to a given shock. Therefore, we also estimate countries' monetary policy response to US monetary surprises. For that, the exercise uses the policy interest rate or a market-determined short-term interest rate (for the countries which do not explicitly set a policy interest rate).

We consider four country-specific macroeconomic variables as determinants of the macroprudential stance: inflation, output gap, real exchange rate and the credit-to-GDP ratio.

Following the literature, alongside the US monetary surprises, the estimates also control for market risk-aversion, using the VIX (as in De Bock et al., 2015; Rey, 2015), and a measure of the global gross capital flows cycle, as in Blanchard et al. (2015). Excluding the VIX and gross capital flows cycle variables does not substantively alter the results.

6.2 Identification and Instrumental Variables

For each country j, we estimate their policy response function using the method of local projection to estimate impulse response functions (Jordà, 2005) to shocks on variables that are exogenous to their economies,

[20] Those are Australia, Austria, Belgium, Brazil, Canada, Chile, China, Colombia, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, India, Indonesia, Ireland, Israel, Italy, Japan, Korea, Malaysia, Netherlands, New Zealand, Norway, Peru, Philippines, Poland, Portugal, Romania, Russia, Singapore, South Africa, Spain, Sweden, Switzerland, Thailand, Turkey, and United Kingdom.

[21] Those are Brazil, Chile, China, Colombia, Hungary, India, Indonesia, Malaysia, Peru, Philippines, Poland, Romania, Russia, South Africa, Thailand and Turkey.

[22] This measure of macroprudential stance has been widely used in the literature, even although it does not account for the magnitude of the changes in macroprudential stance and is not suited for cross-country comparisons about the level of macroprudential stance (for criticism of this measure, see Forbes, 2020).

[23] The 17 macroprudential instruments are: countercyclical capital buffer, capital conservation buffer, capital requirement for banks, limits on bank leverage, loan loss provision requirements, limits on growth or volume of credit by banks, loan restrictions, limits on foreign currency lending, limits to loan-to-value ratios, limits to the debt-service-to-income and the loan-to-income ratios, tax and levies on specific transactions, minimum requirements for liquidity measures, limits to the loan-to-deposit ratio, limits on net or gross open foreign exchange positions, reserve requirements for macroprudential purposes, measures to mitigate risks from global and domestic systemically important financial institutions (SIFIs), and other macroprudential measures not captured in the previous categories.

[24] While this measure of macroprudential stance has been proven useful in the empirical research, Bergant and Forbes (2021) have raised concerns about some challenges. It only captures whether a country tightened or loosened, but does not measure the intensity of the action. It also bunches together different instruments that may have different effects at different country settings.

controlling for lagged observations of domestic variables. For instance, the response to the US policy rate i_t^{US} can be obtained by estimating the following equation:

$$E\left[\boldsymbol{X}_{jt+k}|\boldsymbol{X}_{jt-1}, Z_{jt-1}, i_t^{US}\right] = \boldsymbol{X}_{jt-1}\theta_{jk}^{X} + Z_{jt-1}\varphi_{jk}^{Z} + i_t^{US}\theta_{jk}^{US} + VIX_t\theta_{jk}^{VIX} + flows_t\theta_{jk}^{flows}$$

Where $\boldsymbol{X}_{jt+k}$ is a policy variable (e.g., domestic interest rate, cumulative macroprudential net tightenings) controlled by country j, observed k periods in the future; Z_{jt-1} is a vector of state variables describing both country j and the global economy. In the specification presented in this paper Z_{jt-1} includes lagged values of domestic macroeconomic variables (inflation, GDP, credit-to-GDP and real exchange rate) and external drivers (US monetary surprises, VIX and global capital flows).

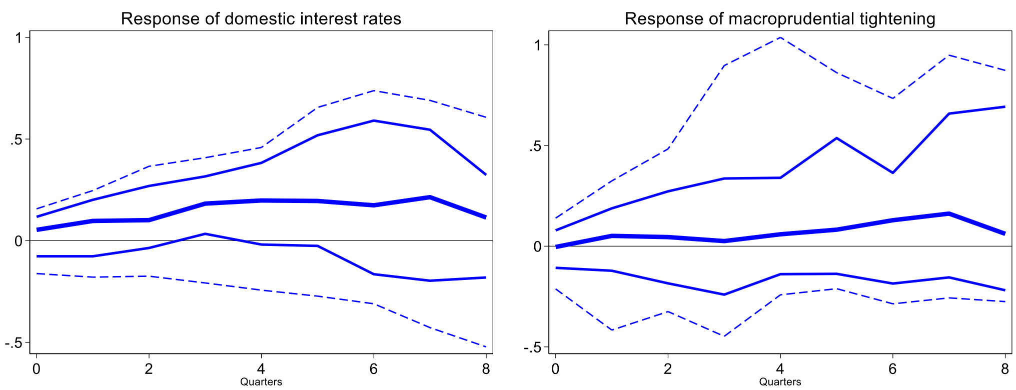
The impulse response function for country *j* to a US monetary surprise is then the sequence of estimated θ_{jk}^{US} for k=1 to N.[25]

$$IR(t, k, \boldsymbol{X}, []) = E\left[\boldsymbol{X}_{it+k}|\boldsymbol{X}_{it-1}, Z_{jt-1}, i_t^{US} + \Delta\right] - E\left[\boldsymbol{X}_{it+k}|\boldsymbol{X}_{it-1}, Z_{jt-1}, i_t^{US}\right] = \theta_{jk}^{US} \quad (21)$$

7. Results

There is significant heterogeneity in countries' monetary policy and macroprudential responses to the US monetary policy surprises. To illustrate this heterogeneity, it is useful to visualize those responses. Figure 7 shows the median, 10-, 20-, 80- and 90- percentiles of the impulse response functions for those shocks for 40 countries. For the median country, US monetary policy surprises are associated with an increase in their nominal policy rate and a slight tightening of macroprudential settings, but there are countries both tightening or loosening monetary and macroprudential policy in the aftermath of a US monetary policy surprise (a positive surprise means US policy tightening). For instance, while the IRF for Russia implies that it would take one tightening of macroprudential instrument on net 4 quarters after a US surprise tightening of 1 percentage point, the one for Turkey implies 1.5 net tightening actions on average over the same period.

Figure 7: Country Impulse Responses Functions to 1% pt Shock to US Interest Rate



Note: Based on 40 countries. The thicker line is the median of countries' impulse response functions and the other lines depict 10, 20, 80 and 90 percentiles.

[25] This specification implies that macroprudential and monetary policy do not react to contemporaneous domestic macroeconomic variables.

7.1 Clusters of Macroprudential Policy Styles

Figure 7 shows remarkable heterogeneity in macroprudential response to US monetary surprises across countries. When the US monetary policy is tightened, countries loosen, tighten or maintain their macroprudential policy stance. Since we are interested in exploring macroprudential policy as part of the cyclical toolbox, it is useful to classify countries into those which loosen macroprudential stance when the US tightens monetary policy, i.e., those that use macroprudential policy counter-cyclically and those that do not.[26]

We classify countries as having counter-cyclical macroprudential response based on two criteria. First, we filter the countries for which the average from 0 to 4 quarters of the impulse response of the number of MAP tightening actions to a US monetary tightening surprise is negative and its 66 percent confidence interval does not include zero. Then we exclude countries that have performed less than 10 adjustments in their macroprudential settings over the sample period. The first criterion selects 11 countries and the second one drops Chile, which only made 2 adjustments in their MAP settings over the sample period. Thus, this rule classifies 10 countries as having counter-cyclical macroprudential policies (Table 1). Figure E1 in the Annex displays the 66 percent confidence intervals for the average 0 to 4 quarters of the impulse response of the number of MAP actions to a US monetary tightening surprise.

Table 1: Classification of countries with respect to macroprudential policy response to US monetary surprises

Counter-cyclical macroprudential response to US monetary surprises (10)	*Other countries (30)*	
Belgium	Austria	Italy
Finland	Australia	Japan
Indonesia	Brazil	Korea
Israel	Canada	Netherlands
Malaysia	Chile	New Zealand
Poland	China	Norway
Spain	Colombia	Peru
Sweden	Czech Republic	Philippines
Turkey	Denmark	Portugal
United Kingdom	France	Romania
	Germany	Russia
	Greece	Singapore
	Hungary	South Africa
	India	Switzerland
	Ireland	Thailand

Note: For each country, we calculated the impulse response functions for the cumulative number of macroprudential actions to a US monetary policy surprise. Countries are classified as having counter-cyclical macroprudential style if the average IRF from 0-4 quarters is negative and greater than one standard error.

7.2 Determinants of macroprudential policy response

We investigate if the choice of a countercyclical macroprudential response to US monetary policy is driven by country characteristics that determine the exposure or vulnerability of the economy to external shocks. We

[26] The latter includes countries that do not adjust macroprudential stance in response to cyclical factors and those that adjust it in procyclical way.

estimate a probit model for macroprudential style using a cross-section of 40 countries.[27] Based on our theoretical model, we considered as explanatory variables (for definitions, see Table E.2 in the Annex): the sensitivity of net inflows to US monetary policy surprises (a proxy for the parameter σ_1 in equation (8)); the sensitivity of exports to real exchange rate (a proxy for the parameter ψ^f in equation (4)); a measure of volatility of net private capital flows as percent of GDP; external debt liabilities in foreign currency to GDP as percent of GDP (Benetrix, 2019) and currency mismatches as percent of GDP (Benetrix, 2019).

Table 2: Determinants of counter-cyclical macroprudential style

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Sensitivity of net inflows to US monetary surprises	-0.070 [0.231]	-0.108 [0.250]	-0.038 [0.221]				
Sensitivity of exports to real exchange rate	0.183 [0.232]	0.150 [0.255]		0.184 [0.232]			
Volatility of private capital flows as % of GDP	0.186 [0.227]	0.217 [0.251]			0.150 [0.212]		
External debt liabilities in foreign currency (% GDP)		0.026 [0.264]				-0.058 [0.239]	
Currency mismatch as % of GDP		**0.641** **[0.292]**					**0.612** **[0.268]**
Number of observations	40	39	40	40	40	39	39

Note: The regressions were estimated using a probit model and also include a constant. The dependent variable is an indicator of countercyclical macroprudential style. Standard errors in square brackets; all variables are standardized to zero mean and unitary standard error. Bold numbers indicate coefficients that are significant at the 10% level.

The first column of Table 2 reports the results for the subset of determinants that excludes the currency mismatch and external debt liability variables from Benetrix (2019). The results show that countercyclical style is not correlated with neither the sensitivity of net inflows to US monetary surprises nor the sensitivity of exports to real exchange rate (respectively, proxies for the parameters σ_1 in equation (8) and ψ^f in equation (4)). It is also not correlated with the volatility of net private capital flows as percent of GDP.

When considering all those variables together (Table 2, columns 1-2), the only variable that was statistically significant was the currency mismatch as percent of GDP, with a positive sign. This variable is positive for countries which are net short on debt liabilities denominated in foreign currency, so their balance sheet deteriorates when their currency depreciates. In other words, a net short position in foreign currency *increases* the likelihood of countries adopting a countercyclical macroprudential style in response to US monetary policy surprises. The same results are found when we run simple regressions, with one explanatory variable (Table 2, columns 3-8).

When a country is net short on foreign currency, a depreciation causes a net loss for its balance sheet *ceteris paribus*. Thus, a currency mismatch also means that the financial channel of exchange rates (Avdjiev, Koch and Shin, 2017) through which a depreciation could negatively affect the economy by weakening domestic balance sheets is operational. All in all, the results in Table 2 are consistent with the view that countries use countercyclical macroprudential policy to mitigate the perverse effects of the financial channel of exchange rates following a US monetary tightening.

7.3 Different responses to a US monetary policy surprise

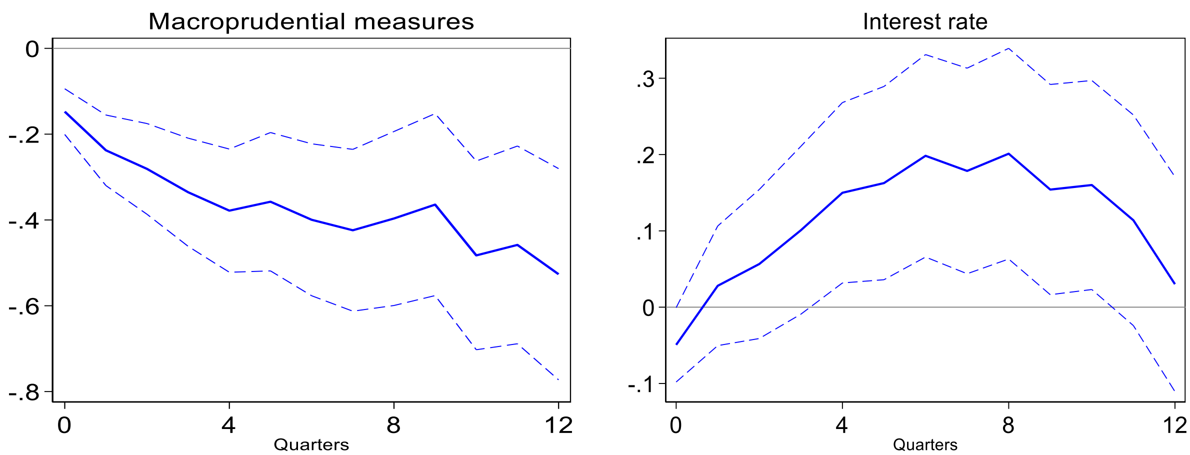
[27] The results should be interpreted under the light of the small sample size and measurement errors in some of the dependent variables, which are estimated.

To estimate the differences in macroprudential and monetary policy across the two macroprudential styles, we estimated impulse response functions using local linear projections in a system of seemingly unrelated regressions (SUR) in order to account for the joint determination of monetary and macroprudential policy.

Policy Response

Figure 8 reports the differences between the IRFs for countercyclical countries and other countries. As expected by the definition of countercyclical policy, those countries do loosen macroprudential stance on net in the aftermath of surprise US monetary tightening, relative to other countries (chart on the left); interestingly, there are some significant differences in the path of their monetary policy. At first, immediately after the US monetary policy surprise, they have less tight monetary policy (chart on the right); after 4 months, the countercyclical MAP countries have tightened interest rates by about 15 basis points more than the other countries; but there are no differences in their interest rate response after 8 quarters. In other words, countries with countercyclical macroprudential style take longer to adjust their policy interest rates in response to a US monetary policy surprise, seem to slightly overshoot relative to other countries after 1 year, but end up in the same place after 2 years have passed. The evidence can be interpreted as countercyclical macroprudential style providing a limited boost to monetary policy autonomy over a very short-term.

Figure 8: Impulse response to US monetary surprise, difference between counter-cyclical macroprudential countries and others



Note: Estimates based on local linear projections estimated in a system of seemingly unrelated regressions (SUR), controlling for up to 2 lags of domestic variables (interest rate, number of net tightening macroprudential actions, credit-to-GDP, GDP growth, REER and inflation), external shocks (US monetary policy, VIX and global capital flows), seasonal and country fixed effects. Dashed lines represent 66 percent confidence intervals.

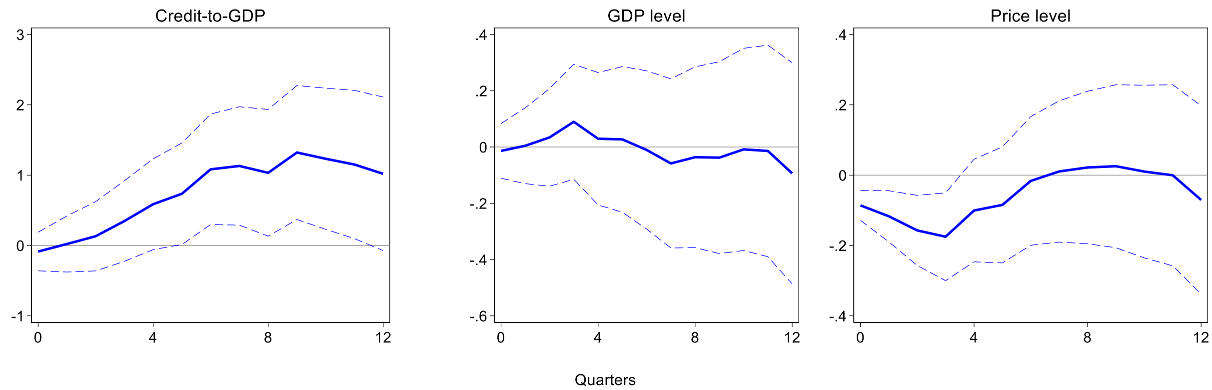
Domestic Macroeconomic Outcomes

Our estimates also show how different macroprudential policy frameworks intermediate the effects of external shocks on domestic macroeconomic outcomes. From the outset, bear in mind that as we compare outcomes for clusters of countries with different macroprudential styles, the differences in outcomes across policy styles are likely underestimated because of mismeasurement in the assignment of countries into policy styles clusters.

We find (Figure 9) that countries with countercyclical macroprudential style show relatively faster growth in credit to GDP in the aftermath of a US surprise monetary tightening, with the difference relative to other countries peaking at about 8 to 10 quarters after the shock. There are no significant differences in the path of

GDP. In a first moment, inflation is lower in the countercyclical style countries, but in cumulative terms, there is no difference over a 2-year horizon after the shock.

Figure 9: Difference in impulse response to US monetary surprise, between counter-cyclical macroprudential countries and others



Note: Estimates based on local linear projections estimated in a system of seemingly unrelated regressions (SUR), controlling for up to 2 lags of domestic variables (credit-to-GDP, GDP growth, REER and inflation), external shocks (US monetary policy, VIX and global capital flows), seasonal and country fixed effects. Dashed lines represent 66 percent confidence intervals.

The empirical analysis shows that countries that use countercyclical MaPs have lower domestic interest rates, higher aggregate credit, and lower inflationary responses the year after the impact of the shock, relative to those that do not. These results are consistent with our model's predictions on the impacts of countercyclical MaPs. The positive analysis of the model presented in Section 3 and 4 shows that these effects are a result of the ability of countercyclical MaPs (acting on either credit supply or credit demand) to dampen the balance sheet effects of the unexpected foreign interest rate increase. By reducing balance sheet effects of a sudden withdrawal of foreign credit supply on domestic banks and borrowers, countercyclical MaPs support the lending capacity of banks and the borrowing capacity of domestic borrowers. In so doing, countercyclical MaPs help to reduce the depreciationary pressures on the domestic currency, and reduce the upward pressure on domestic interest rates. With weaker upward pressure on interest rates applied by the external financial shock, countries may also have greater flexibility to implement countercyclical monetary policy, lowering interest rates in response to contractionary effects of the external financial tightening. For import-dependent open economies, relieving depreciationary pressures on the currency also reduces imported inflation, contributing to smaller price increases in the short term.

Our normative analysis of countercyclical MaPs finds that countries that are net short on foreign currency debt, or hold a large share of unhedged foreign currency-denominated debt, are likely to derive greater benefits from a more countercyclical MaP stance. Results from Table 2 provide some preliminary evidence that countries may be acting optimally in this regard—countries that are net short on foreign currency debt are also more likely to adopt a countercyclical MaPs stance. However, we are unable to find similar evidence of optimal MaPs setting for other country variables that our model predicts should affect the MaPs stance.

8. Conclusions

Investigating the effectiveness of MaPs within the context of a small open economy integrated into international financial markets, we conduct a positive analysis of the impacts of MaPs on financial volatility and macroeconomic outcomes, and show that MaPs can have significant impacts when a small-open economy with financial frictions is hit by external financial shocks. In particular, policymakers face a tradeoff between supporting growth during periods of capital inflows and minimizing economic impacts in the event of a capital flow reversal shock. A more aggressive countercyclical MaPs setting limits growth during normal times, but limits economic damage during reversals. We also find that the welfare implications of the choice of a MaPs stance depends on several country characteristics. Countries with high shares of foreign currency debt, high elasticity of capital flows to the real exchange rate, and low elasticity of the current account to the real exchange rate stand to benefit the most from countercyclical MaPs.

Using a panel dataset of 40 countries, countries are classified by the macroprudential style they tend to adopt empirically, and divided into two clusters: countercyclical and non-countercyclical macroprudential policy countries, where the former are those countries which loosen macroprudential stance when the US tightens monetary policy. We find that countries that use countercyclical MaPs have lower domestic interest rates, higher aggregate credit, and lower inflationary responses the year after the impact of the shock, relative to those that do not. These results are consistent with our positive analysis on the impacts of countercyclical MaPs. Further, countries with large negative currency mismatches (that is, where liabilities are larger than assets in foreign currency) face trade-offs that are more likely to use countercyclical macroprudential policies, which is indicative evidence that countries are implementing countercyclical MaPs optimally in this regard.

Annexes

A. Model

To close the model, we introduce assumptions for physical capital producers and the domestic output goods market.

A.1 Capital goods producers

Capital goods are produced by capital goods producers, who sell capital goods to entrepreneurs in a perfectly competitive market. Capital goods are produced using units of entrepreneurs' final consumption good as input, which are converted one-to-one into capital goods. Capital goods producers maximize their lifetime discounted utility, in units of final consumption good, which can be expressed as:

$$\max_{I_t}\left\{E_0\sum_{t=0}^{\infty}\beta_E^t\left[q_t^k I_t - C_{EI,t}\right]\right\}$$

Capital goods producers are subject to quadratic adjustment costs of adjusting their per-period production of capital goods, I_t, which characterizes the law of motion for capital goods in the model

$$K_t = (1-\delta)K_{t-1} + \left(1-\frac{\kappa}{2}\left(\frac{I_t}{I_{t-1}}-1\right)^2\right)I_t$$

Solving the capital goods producer's utility maximization problem, we derive an equilibrium condition for the price of capital goods (also entrepreneurs' assets that qualify as collateral in our model) using the first-order condition, which has the form of an Euler equation for investment.

$$1 = q_t\left(1-\frac{\kappa}{2}\left(\frac{I_t}{I_{t-1}}-1\right)^2 - \kappa\left(\frac{I_t}{I_{t-1}}-1\right)\left(\frac{I_t}{I_{t-1}}\right)\right) + \beta^E\frac{\lambda_{E,t+1}}{\lambda_{E,t}}q_{t+1}\kappa\left(\frac{I_t}{I_{t-1}}-1\right)\left(\frac{I_t}{I_{t-1}}\right)^2$$

On the left-hand side of the above Euler equation for investment is simply the marginal cost of spending one unit of entrepreneurs' consumption on a unit of capital good, which is simply 1. The right hand side is the return to investment in units of consumption goods.

A.2 Consumption goods market

Perfectly competitive retailers sell domestic intermediate goods or foreign intermediate goods to consumers. Like in the model of Gerali et al. (2010), retailers buy domestic intermediate goods from domestic goods wholesalers (at cost of 1, as the domestic intermediate good is the numeraire) and foreign intermediate goods from imported goods wholesalers, and combine them to produce final consumption goods. Total domestic consumption C_t is produced according to a CES production function of domestic and imported intermediate goods, given by $C_t = [\Lambda(Y_t - EX_t)^{\Psi} + (1-\Lambda)(IM_t)^{\Psi}]^{\frac{1}{\Psi}}$, where $Y_t - EX_t$ is domestic production of intermediate goods net of exports, and IM_t are imported intermediate goods. Λ represents a home-bias "preference" parameter for consuming the domestic intermediate good. In this subsection, domestic intermediate goods that are consumed domestically is denoted as $y_t = Y_t - EX_t$.

Retailers take the prices of domestic and imported intermediate goods as given, and decide on the quantities of each to buy in order to maximize profits. Formally, retailers' maximization problems can be expressed in the form of the following expression.

$$\text{Max}_{\{y_t, IM_t\}} P_t C_t - y_t - z_t IM_t$$

Subject to:

$$C_t = [\Lambda(y_t)^{\Psi} + (1-\Lambda)(IM_t)^{\Psi}]^{\frac{1}{\Psi}}$$

Retailers' per-period profits are determined by their current period revenues, $P_t C_t$, net of their current period costs $y_t + z_t IM_t$. Each period, retailers take the foreign price level P_t^f and the nominal exchange rate E_t as given. The first order condition for the quantity of domestic intermediate goods is:

$$P_t y_t^{\psi-1} C_t^{\left(\frac{1-\psi}{\psi}\right)} = 1$$

This implies that the demand curve for domestic intermediate goods can be expressed as:

$$y_t = \left(\frac{1}{\Lambda}\right)^{\frac{1}{1-\psi}} \left(\frac{1}{P_t}\right)^{\frac{1}{1-\psi}} C_t$$

Analogously, we can derive the demand for imports in this system as:

$$IM_t = \left(\frac{1}{1-\Lambda}\right)^{\frac{1}{1-\psi}} \left(\frac{z_t}{P_t}\right)^{\frac{1}{1-\psi}} C_t$$

Retailers buy domestic and imported intermediate goods from wholesalers in a monopolistically competitive market. The home bias parameter Λ and the parameter ψ reflect consumer preferences for domestic intermediate goods relative to imported domestic goods and the elasticity of substitution between the two intermediate goods respectively, and ensure that the law of one price does not hold perfectly in this model. Reflecting differentiated imported and domestic intermediate goods, wholesalers have price-setting powers in this market. Wholesalers of domestic intermediate goods solve the profit-maximizing problem:

$$\max_{\{P_t\}} y_t - P_t mc_t y_t$$

Constant returns to scale production of domestic intermediate goods implies that the total cost of domestic intermediate goods sold domestically is simply the product of the nominal marginal cost of domestic goods production, $P_t mc_t$, where mc_t is the marginal cost of domestic intermediate good production, and the quantity of domestic intermediate goods sold domestically, or y_t. Total revenues are simply y_t, as domestic intermediate goods are the numeraire. In effect, wholesalers maximize profits by choosing $\frac{1}{Pt}$, the relative price of domestic intermediate goods relative to the domestic price level.

The first order condition for the domestic wholesaler's profits maximizing problem is:

$$\psi mc_t = \frac{1}{P_t}$$

This is simply the familiar result from standard DSGE models that price markups under monopolistically competitive markets are constant.

A.3 Balance sheet channels of a foreign interest rate shock in the static model

In order to simulate the impact of a shock to the foreign interest rate i^f, we first characterize the partial equilibrium impact of a foreign exchange rate shock on exchange rate movements, considering only the balance sheet channels of the shock.

Given an exogenous shock to the foreign interest rate, the exchange rate E clears the market for foreign debt. Equilibrium in the market for foreign credit is depicted in Figure (x). In the static framework, Equation (15) shows that for a given foreign interest rate, foreign borrowing by banks is an increasing function of the exchange rate. Intuitively the supply of foreign credit falls as the domestic currency appreciates (and E_t falls), and returns from savings in the domestic economy fall relative to the foreign economy.

We now endogenize K^B and q^K in our static model. To do so, we use simplified versions of equations in our dynamic model. First, bank capital K^B is reduced to the static bank profit function:

$$K^B = (1 + i^b)B - (1 + i^d)D - (1 + i^f)B^f - \frac{\theta}{2}\left(\frac{K^B}{B} - CAR\right)^2 K^B \quad \text{(A1)}$$

Bank capital is simply per-period profits, derived as the revenue from making loans, net of costs of deposits and foreign borrowing, as well as frictional costs of deviating from the capital adequacy ratio.

Asset prices in the dynamic model are the shadow prices of marginal units of physical capital, with quadratic costs of adjustment for investment. As such, the model is equivalent to Tobin's q models, except that entrepreneurs are subject to borrowing costs from banks that deviate from capital's real rates of return. As such, for our static model, we introduce a simplified equation for asset price based on the standard Tobin's q equation, $\frac{I}{K} = (q^K - 1)$, since borrowing costs reduce entrepreneurs' returns from debt-funded investment. Asset prices are thus determined according to the equation:

$$\frac{I(R^K)}{K} = (q^K - 1) - i^b * LEV \quad \text{(A2)}$$

The above can be interpreted using the same intuition as a standard Tobin's q. The ratio of investment (which increases in the marginal product of capital) to the capital stock, $\frac{I(R^K)}{K}$ should be equal to $(q - 1)$ if the firm does not rely on borrowing for investment. When $(q^K - 1)$ exceeds $\frac{I(R^K)}{K}$, the firm should increase investment. When entrepreneurs rely on debt for borrowing, however, some profit from additional investment must be used to make interest payments, with the interest rate normalized by the prevailing stock of debt per capital unit, denoted LEV for entrepreneur leverage.

B. Model Calibration

The baseline model, under which MaP policy instruments are constant, is calibrated by assuming parameter values specified in Table B1.

Table B1: Baseline Model Calibration Parameters

Parameter	*Description*	*Baseline Calibration*
β_H	Household discount rate	0.996
β_E	Entrepreneur discount rate	0.975
ρ_N	Frisch elasticity of labor supply	1
LTV	Fixed LTV ratio	0.55
mc_t^{μ}	Domestic output good markup	6/5
α	Domestic output good producer Cobb-Douglas parameter	0.2
κ	Physical capital good producer adjustment cost parameter	5
δ	Physical capital depreciation rate	0.05
π_{ss}	Steady state domestic inflation	1
i_{ss}^D	Steady state deposit rate	(1/0.996 – 1)
θ	Bank CAR adjustment cost parameter	11
CAR	Fixed capital adequacy ratio	0.10
μ^B	Bank loan rate markup	0.005
δ^B		(1/0.996 – 1) + 0.005/0.12
ρ_i	Adjustment parameter for interest rate monetary policy rule	0.77
ϕ_π	Weight on inflation gap for monetary policy rule	0.5
ϕ_Y	Weight on output gap for monetary policy rule	2.5
ρ^A	Technology shock autocorrelation parameter	0.95
ρ^μ	Markup shock autocorrelation parameter	0.5
ρ^{i^f}	Foreign interest rate autocorrelation parameter	0.4
γ	Responsiveness of foreign credit supply to foreign interest rate	0.3
$\bar{B}$	Foreign credit supply stock	0.9
ψ	Price elasticity of foreign credit supply	0.3
ζ	Share of bank's unhedged foreign currency debt	0.3
Λ	Home bias parameter for domestic consumers	0.99
Λ^f	Home bias parameter for foreign consumers	0.05
ψ	Parameter for elasticity of domestic imports to real exchange rate	0.5
ψ^f	Parameter for elasticity of domestic exports to real exchange rate	0.01
Y_t^f	Foreign GDP	Exp(-0.8)

C. Proof of Proposition 1

The proof is in two parts. First, we show that $\frac{dB}{di^f} < 0$, which will prove the first sentence of the Proposition. Second, we show that that $\frac{d^2B}{di^f dCAR} > 0$, which implies that raising CAR makes $\frac{dB}{di^f}$ even more negative.

Demand for total borrowing is given by Equation 18, while supply is given by Equation 17. We examine the effects on each of a shock to the foreign interest rate. Note that denoting B^d and B^s as the demand and supply schedules for total borrowing respectively, Equations 17 and 18 imply that $\frac{dB^d}{di^b} < 0$ and $\frac{dB^s}{di^b} > 0$, that is, the demand and supply curves are downward and upward sloping in the domestic borrowing rate respectively.

We examine the impact of a foreign interest rate shock on supply of borrowing. $\frac{dB^s}{di^f} = \frac{\partial B^s}{\partial i^d}\frac{\partial i^d}{\partial i^f} + \frac{\partial B^s}{\partial K^B}\frac{\partial K^B}{\partial i^f}$. The first term of the right-hand side captures the effects on domestic credit supply of a higher deposit rate, that is, the so-called investment channel of a foreign interest rate shock. Equation 17 implies that $\frac{\partial B^s}{\partial i^d} < 0$, as supply of domestic credit declines as funding costs rise. By UIP, $\frac{\partial i^d}{\partial i^f} > 0$ (Equation 15), and so the first term on the RHS is strictly negative. As for the second term, we have assumed that $\frac{\partial K^B}{\partial i^f} < 0$, which follows from Equation A1, which says that bank capital declines as foreign funding costs rise. Further, $\frac{\partial B^s}{\partial K^B} > 0$ for any given i^b, reflecting that higher bank capital allows banks to lend more. Consequently, the second term on the RHS is also strictly negative, which represents the bank balance sheet channel of our model. We therefore have that $\frac{dB^s}{di^f} < 0$—that is, a rise in the foreign interest rate shifts the domestic credit supply curve leftward.

Next, we examine the derivative of domestic credit demand wrt the foreign interest rate. $\frac{dB^d}{di^f} = \frac{\partial B^d}{\partial R^K}\frac{\partial R^K}{\partial i^f} + \frac{\partial B^d}{\partial q^K}\frac{\partial q^K}{\partial i^f}$. Considering that the first derivative of λ_E, $\lambda_E'(R^k) < 0$ and $\frac{\partial s_E}{\partial B} < 0$, Equation 18 shows that $\frac{\partial B^d}{\partial R^K} > 0$. That is, demand for borrowing rises as the return to capital rises. However, in our static model, $\frac{\partial R^K}{\partial i^f} = 0$, as the net export channel is assumed to be not operative. This implies that the first term on the RHS is equal to 0. As for the second term on the RHS, $\frac{\partial B^d}{\partial q^K} > 0$, given that $\frac{\partial s_E}{\partial B} < 0$ and $\frac{\partial s_E}{\partial q^K} > 0$. Intuitively, a rise in q^K relaxes entrepreneurs' borrowing constraints and allows them to borrow more. From the asset pricing equation, Equation A2, $\frac{\partial q^K}{\partial i^f} < 0$ as long as $\frac{\partial R^K}{\partial i^f} = 0$ and $\frac{\partial i^b}{\partial i^f} > 0$, representing the entrepreneur balance sheet channel.

In sum, a rise in the foreign interest rate generates a leftward shit in the supply schedule for domestic borrowing, which in itself generates a leftward shift in the demand schedule for domestic credit.

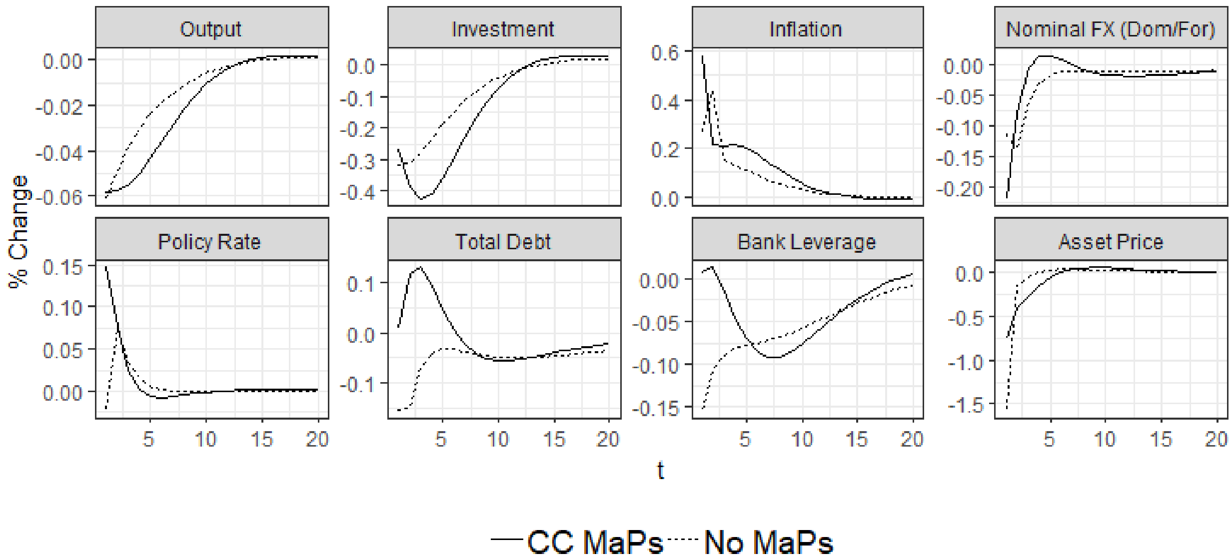
A countercyclical MaP policy means that $\frac{dB}{dCAR} < 0$ by definition. It then follows immediately that $\frac{d^2B}{di^f dCAR} > 0$. Similarly, a countercyclical MaP policy using LTV-ratios as the policy instruments, rather than CAR, would mean that $\frac{dB}{dLTV} < 0$, leading to a similar result.

D. Model Simulations

D.1 Model Response to a Domestic Price Markup Shock

To demonstrate the basic behavior of the dynamic baseline model, Figure C1 shows the impulse response of key variables in the model to a positive price markup shock, generally used in the literature to simulate a domestic monetary shock (see, e.g., Smets and Wouters, 2003). Figure C1 compares the economy's responses when a MaP regime is in place, to one where MaPs are not used at all.

Figure D1: IRFs for a positive shock to price markups μ_t



Notes: The price markup shock is modeled as a 1% positive increase in ϵ_t^{μ} under the baseline calibration of the model.

In response to a positive price markup shock, output declines, as a price markup shock essentially increases monopoly rents and reduces potential output even under flexible prices, as is standard in closed-economy DSGE models. The positive markup shock increases marginal costs, in effect a cost push shock that raises output prices temporarily. The central bank raises the policy rate in response to higher inflation, leading to a decline in investment and consumption. Higher domestic interest rates lead to an immediate appreciation of the domestic currency due to the UIP condition and net capital inflows increase, leading to expenditure switching by domestic consumers and a fall in net exports via the exchange rate channel of monetary policy. On the other hand, higher domestic rates also reduce bank lending and investment via the investment channel of monetary policy, as the share of liquid assets (deposits) rises relative to illiquid assets (capital investment). Thus far, the account of the model's response to a domestic monetary shock has not invoked financial frictions.

Financial frictions play a role through the balance sheet channel. When MaPs are not used, higher domestic policy rates (equivalent to deposit rates in the model) negatively impact bank profits and bank capital, leading to banks needing to reduce lending to maintain capital adequacy ratios. This leads to lower domestic credit supply, although some of the decline in bank lending is offset by lower relative costs of international borrowing by banks. At the same time, the temporary fall in output reduces the marginal returns to investment, leading to a fall in asset prices. This tightens borrowing constraints for entrepreneurs, reducing credit demand. In combination, falling credit supply and falling credit demand lead to a sharp fall in borrowing (and debt) and investment.

The solid lines in Figure D1 show the model's response when MaPs respond countercyclically to total debt and asset price changes. In this example, an unrealistically aggressive countercyclical MaP response is assumed to illustrate potential effects. As the price markup shock transmits a negative impulse to total debt and asset prices as explained above, the banking capital adequacy ratio CAR_t rises while the loan-to-value ratio LTV_t falls. Higher CAR_t This leads to a rise in a rise in bank lending even as bank capital falls, pushing up bank leverage, and lower LTV_t leads to increased borrowing by domestic entrepreneurs. In aggregate, total debt rises, rather than declines, on impact of the shock, while the decline in asset prices is strongly mitigated. In other words, the MaP response is strong enough to induce a rise in borrowing even when the central bank has raised policy rates.

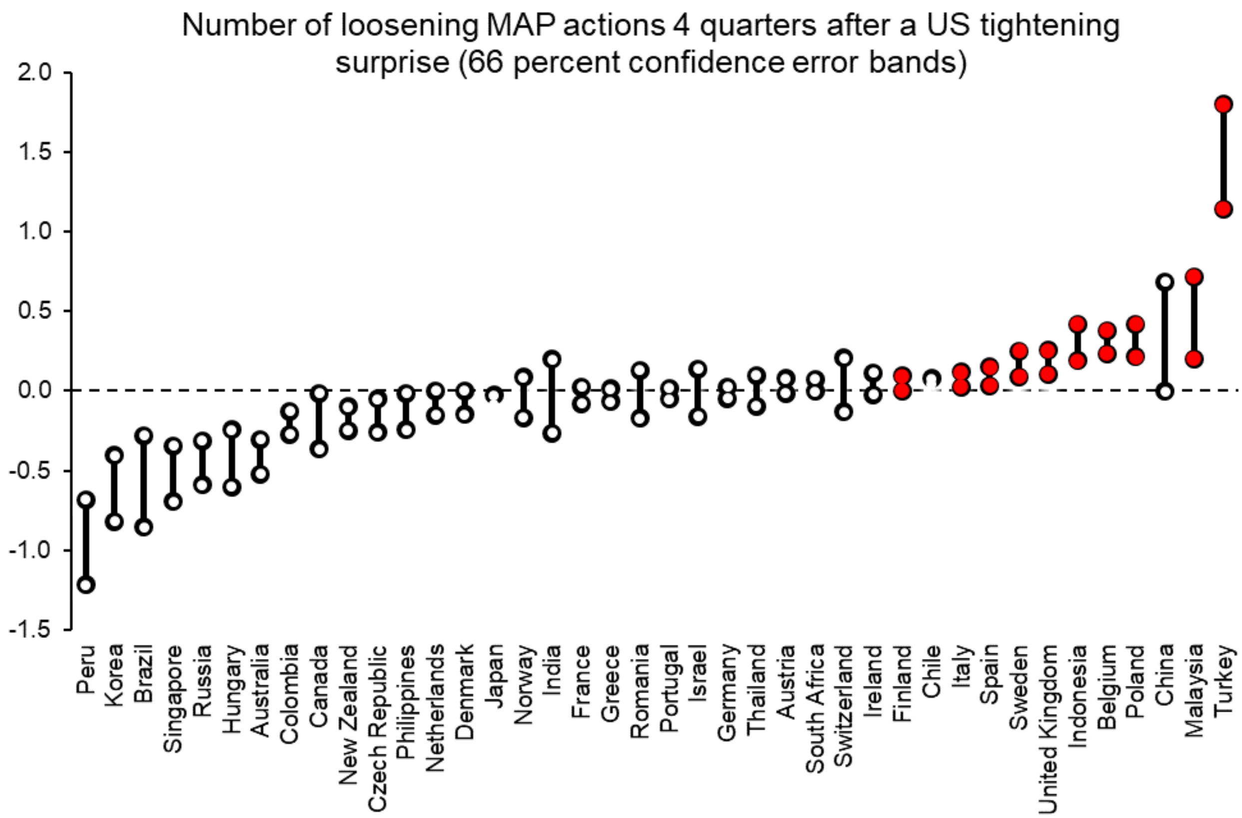
However, the effects on investment and output are not straightforward. As credit demand for external borrowing rises, the domestic currency must appreciate by more, and the deposit/policy rate must rise by more, to reach equilibrium in credit markets. While the MaP response reduces the decline of output and investment on impact (via balance sheet effects), the rising domestic policy rate and appreciating exchange rate puts downward pressure on investment and output (via investment and exchange rate effects). Under an exceptionally aggressive countercyclical MaP regime, this leads to larger negative impacts on output after the initial shock relative to the no-MaP baseline.

E. Empirical Annex

Table E.1. List of countries

Euro area (11)	Other advanced (13)	Emerging markets (16)
Austria	Australia	Brazil
Belgium	Canada	Chile
Finland	Czech Republic	China
France	Denmark	Colombia
Germany	Israel	Hungary
Greece	Japan	India
Ireland	Korea	Indonesia
Italy	New Zealand	Malaysia
Netherlands	Norway	Peru
Portugal	Singapore	Philippines
Spain	Sweden	Poland
	Switzerland	Romania
	United Kingdom	Russia
		South Africa
		Thailand
		Turkey

Figure E1. Estimate of the average number of net loosening MAP actions in response to a US monetary tightening surprise.



Note: For each country, we calculated the impulse response functions for the cumulative number of macroprudential actions to a US monetary policy surprise. For exposition purposes, this chart shows MAP loosening as positive. For each country, the circles represent the lower and upper bounds of 66 percent confidence intervals around the average IRF estimate. Red circles denote countries which were classified as having counter-cyclical MAP style.

Table E.2. Description of the variables

Global drivers:	
glFlows	Global private sector gross capital flows to non-reserve currency countries as a percent of world GDP, excluding the country of interest. Those are calculated based on the variable *icapfl* from the IMF Research department database Financial Flows Analytics (FFA).
Vix	Chicago Board Options Exchange's CBOE Volatility Index.
mpShock	US monetary policy surprises, estimated by Iacoviello and Navarro (2019)
Macroeconomic outcomes:	
credit2y	Credit to the non-financial sector, in percent of GDP (seasonally adjusted). Source: BIS (downloaded on November 1, 2019). For Peru, used IFS series (32D___XDC: Monetary, Monetary Survey, Claims on Private Sector (Non-Standardized Presentation), Domestic Currency)
lreer	Real effective exchange rate, in logs. Effective weights are based on trade exposures and real exchange rate is calculated using CPIs. An increase corresponds to a real appreciation. Source: IMF/INS.
Inflation	Annualized quarterly CPI inflation with seasonal adjustment.
Policy levers:	
maps	Net macroprudential tightening/loosening, from Alam et al. (2019). A value of +1 in a quarter implies that there was one tightening measure more than there were loosening measures in a quarter.
IR	Policy interest rate.
Determinants of countercyclical macroprudential style:	
Sensitivity of net inflows to US monetary policy surprises	For each country, that is the coefficient on the US monetary policy surprise in a regression of private capital flows as percent of GDP over one year ahead on the US monetary policy surprise, with the sample period starting in 1990Q1.
Sensitivity of exports to real exchange rate	For each country, that is the coefficient on the log real effective exchange rate in a regression of net exports as percent of GDP on that variable and the IMF-WEO output gap, with the sample period starting in 1990Q1.
Volatility of net private capital inflows (as percent of GDP)	Net private capital inflows as percent of GDP were obtained from the IMF Financial Flows Analytics database. The volatility is estimated for the period 2000-2019.
External debt liabilities in foreign currency (% GDP)	Average of the variable L_debt_FC_GDP in Benetrix (2019) from 2000 to 2017
Currency mismatches as percent of GDP	Average of the variable fxagg in Benetrix (2019) from 2000 to 2017, multiplied by -1, so larger positive numbers imply that the country has a larger short position on foreign currency.

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