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Keywords: DSGE model, cross border flows, monetary policy macroprudential regulation

JEL Code: E44, E52, E61, F42, G28

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We present a small open economy New Keynesian model with financial intermediation to investigate the interaction between monetary policy and macroprudential regulations. Our model economy attempts to capture the vulnerability of emerging market economies in the face of external and domestic shocks. We build a model that closely captures the dynamics of emerging market economies to show that interest rate policy rules alone may not be an effective instrument to stabilize the economy under negative shocks. Monetary policy implementation through augmented Taylor rule (ATR) is an inadequate tool to absorb negative shocks given its conflict between inflation and exchange rate objectives. We show that the use of macroprudential regulations (MaPs) with simple Taylor rule improves business cycle dynamics relative to ATR under domestic and external shocks. We present two kinds of MaP regulations to show that they effectively mitigate losses during economic downturns and reduce excessive risk-taking behavior during economic booms when used along with a simple monetary policy rule (MP). In addition, we also conduct welfare evaluation that supports complementarity between MP and MaPs under different shocks.

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1 Introduction

Unconventional monetary policy (UMP) in advanced economies (AEs) has led to a surge of global liquidity in emerging market economies (EMEs) post the 2008 global financial crisis (GFC), exposing them to the global policy environment. One of the main concerns in this regard is 'amplified' capital inflows in EMEs during 'risk-on' periods (low global interest rate environment post-GFC) and sudden capital outflows when the risk is 'off' (expected interest rate normalization in advanced economies)[4]. EMEs' policymakers mainly face three challenges to macro-financial stability due to such high volatility in capital inflows/outflows (Forbes, Fratzscher, and Straub 2015; Claessens et al. 2014; Baskaya et al. 2017)- (1) reducing economic overheating due to inflows in the form of appreciating exchange rate, high inflation and credit boom; (2) minimizing the financial risk linked with prolonged periods of easy global liquidity flows and excess risk-taking due to lower risk perception; (3) facing extended phase of economic recession and debt overhang due to credit boom/bust cycles associated with excess capital inflows/outflows as observed in EMEs in the past.

Expansionary monetary policy adopted by AEs in the post-GFC period led to rapid expansion of cross-border flows to EMEs along with the gradual buildup of financial risks mainly due to currency mismatch, maturity mismatch and rollover risk. Such risks typically expose EMEs to negative spillover in the face of adverse global financial events. A recent such event was taper tantrum (2013) episode which led to high volatility in the financial market of EMEs due to a potential tightening of the US monetary policy: signaling gradual interest rate normalization from zero lower bound. The resultant sudden capital outflows from EMEs put pressure on their exchange rate and caused a decline in asset prices suggesting that their macro-financial stability is vulnerable to the sudden movement in cross border flows.

International credit flows can particularly intensify risks to EMEs which experience rapid

4. Risk-on/risk-off refers to an investment setting that is driven by changes in investor's risk tolerance in response to global policy environment. During the risk-on phase, risk perception is low and investors tend to engage in buying higher-risk securities. Risk-on periods are often linked with economic expansion, easy monetary policy and speculation. In contrast, during the risk-off period, risk perception is high and investors mostly buy safe/lower-risk assets such as treasury securities and government bonds. Such phases are often attached to economic contraction, stock market decline, policy uncertainty and a rush to safer investments including US treasury bills/bonds etc.

domestic credit growth (Avdjiev, McCauley, and McGuire 2012). Such credit flows are typically defined as credit that is backed by liabilities outside the borrower country. In other words, support for such credit is not sourced from the domestic deposit base. Countries with rapid growth in the share of international credit flows and its increasing contribution to credit-to-GDP ratio experienced the largest economic distress in the post-GFC period (Ehlers and McGuire 2017; Ehlers and Villar 2015). Post-crisis, credit growth slowed down in most of the EMEs and international credit contracted rapidly. The resultant negative spillovers contributed to financial instability and real economic slowdown.

EMEs' central banks typically implement different kinds of interest rate based monetary policy rules to maintain macroeconomic and financial stability. Even though the primary focus of monetary policy is price stability, it was widely recognized that this approach may not be sufficient to maintain macroeconomic stability post-GFC era in which external shocks can play a destabilizing role in the context of emerging economies. Extreme financial market volatility in EMEs during two key global phenomenon, the GFC (2008) and the taper tantrum (2013), have evidently shown that price stability based interest rate rules alone might not be effective in absorbing external shocks.

At times, the role of monetary policy extends achieving other macroeconomic objectives such as asset price stability, moderate credit growth, stable exchange rate in response to domestic and external shocks. During such shocks, interest rate rules may target the source of several kinds of shocks, namely nominal exchange rate, credit growth, asset prices and other important macroeconomic variables, to insulate the domestic economy from global and local market volatilities. However, the addition of other target variables as monetary policy objectives may not be beneficial for the economy. Research suggests that inclusion of exchange rate in addition to the output gap and inflation may bring minimal benefits and result in adverse outcomes and welfare reducing on certain occasions (Taylor 2001; Senay 2008).

An important example is the Reserve Bank of India (RBI) attempted interest rate defense to manage exchange rate volatility during taper tantrum (2013). Instead of reducing exchange rate volatility, it hurts domestic recovery and financial market stability (Goyal 2015). On the other hand, interest rate based rules may not adequately cover risks emanating from the financial sector to ensure systemic financial stability. They have limited ability to discourage the formation of asset price bubbles and effectively respond to a bubble collapse as seen during the GFC episode (Cecchetti 2008; Taylor 2009). Inclusion of asset prices in Taylor rule type of interest rate rules to avoid bubble crisis is not welfare improving as shown by an important paper by (Bernanke and Gertler 2000). This points to the need for effective policy instruments to correct asset market misalignments to achieve financial stability.

In light of the recent global crisis and its spillover on EMEs, it is now widely recognized that interest rate rules might not be adequate to respond to the interaction between the domestic economy, financial markets and the global financial environment (Alpanda, Cateau, and Meh 2018; Rey 2015). The policymakers face two key issues in this regard - (1) macroeconomic and financial stability of an economy are closely interlinked and attempts to pursue one objective without accounting for the other might not be effective in stabilizing the economy, and (2) given the inter-linkage, monetary policy (MP) may need to be complemented with other important policy tools such as macroprudential regulations (MaPs) to maintain financial stability, especially in the presence of the UMP type policy spillovers on EMEs. Such additional policy tools might be an effective instrument in avoiding the trade-off between macroeconomic and financial stability in case of interest rate based policy rules. The need for MaPs derives from the inherent procyclicality of financial markets. In other words, MaPs can moderate the impact of boom/bust episodes of cross border flows on the economy.

Given this background, we explore two key issues in this chapter: First, are macroprudential regulations, as an additional policy tool, complementary to monetary policy in achieving macro-financial objectives. Second, compared to extended interest rate rule, how does the interaction of simple interest rate rule with macroprudential regulations (MaPs) perform in the face of external and domestic shocks?

Since monetary policy and macroprudential rules affect the economy by altering aggregate demand/supply and respond to financial market development, they characteristically differ in their impact as follows (Borio and Lowe 2002; Ozkan and Unsal 2014) -

- Policy rate is a relatively sharp instrument and its movement affects all lending activities in the economy ignoring the relevance of a particular lending for economic stability. In contrast, MaPs can particularly target the riskier financial activities in the economy.

- Interest rate adjustment to maintain financial stability might be in conflict with macroeconomic objectives such as price stability, de-anchoring inflation expectations or exchange rate movements. An additional policy tool (MaPs) specifically devoted to financial stability can avoid this conflict and complement monetary policy.

- In an open economy set up, increasing the policy rate to reduce excessive credit growth may have a limited impact if banks or firms can borrow abroad at lower interest rates. In such a scenario, the policymaker can implement MaPs targeting credit growth to avoid excess credit expansion in the economy.

The potential need to implement MaP arises mainly for three reasons (Forbes 2019). First, MaPs help to build financial resilience and discourage excessive credit expansion in the economy. Second, they help to reduce structural vulnerabilities due to weaker institutions and thinner financial market which is a common feature of EMEs. Finally, MaPs are an important tool to mitigate the amplification of systemic risk within the economy. Several research studies present evidence that macroprudential regulations are helpful to maintain the supply of credit during downturns and to build financial resilience (Forbes, Fratzscher, and Straub 2015; IMF-FSB-ISB 2016).

This chapter is related to three interesting strands of literature focusing on the international monetary policy spillover, MaPs and cross border flows. More specifically, we contribute to the evolving literature on the interaction between monetary policy, macroprudential regulations and financial intermediation in the face of volatile cross border flows to the EMEs.

The first strand of literature studies the impact of MaPs containing negative externalities due to excessive risk taken by economic agents without internalizing its impact on financial stability. Crockett (2000) and Borio 2003 first emphasized the importance of MaPs in the context of financial instability and discussed the economic cost of their absence in form of asset price misalignments, misallocation of resources across sector hampering investment decisions and eventual output losses. Claessens 2015 provides a detailed overview of the role of MaPs in correcting market failure and externalities in the context of AEs and EMEs. The paper discusses several forms of MaPs (limits on credit growth, loan to value ratio, Pigovian taxes and other balance sheet restrictions), their implications for financial and economic stability and their possible interaction with monetary policy. More importantly, effective MaPs can contain macro-financial risk ex-ante and help to build countercyclical buffers to absorb shocks ex-post (IMF 2012).

MaPs are generally implemented to reduce excessive risks taken by financial intermediaries. Banks tend to take excessive risks during economic booms, which are mainly due to moral hazards (implicit government guarantees) and deposit insurance (Chari and Kehoe 2016; Farhi and Tirole 2012; Cociuba, Shukayev, and Ueberfeldt 2012). MaPs can prove to be an effective instrument to neutralize such externalities (Bakker et al. 2012; Galati and Moessner 2013). However, some studies also show that there are unintended consequences of MaPs. Ahnert et al. 2018 finds that stricter regulations on borrowing from banks in foreign currencies led to an increase in foreign currency-denominated debt issuance by corporations making them further vulnerable. Aiyar, Calomiris, and Wieladek 2014 shows that the rise in capital requirements of domestic banks caused foreign banks to raise their lending in the UK and it also led to a contraction in domestic bank lending. Research also shows that economies with stricter MaPs receive less cross border credit and attract lesser multinational operations (Temesvary, Ongena, and Owen 2018). MaPs also induce economic agents to internalize the consequences of their actions, prevent over-borrowing and avoid macroeconomic instability (Korinek 2009; Mendoza and Bianchi 2011; Jeanne and Korinek 2010).

The second strand of literature is related to the rapidly growing discussion over international monetary policy spillovers through cross border banking flows (Cetorelli and Goldberg 2012; Miranda-Agrippino and Rey 2015; Temesvary, Ongena, and Owen 2018). These papers provide evidence on the existence of monetary policy spillovers from host countries to other countries and show that globalized banks have become the main conduit to propagate shocks internationally. Unconventional US monetary policy shocks have transmitted globally and affected financial conditions of the economies with inflation targeting regime and flexible exchange rates reiterating the presence of the 'global financial cycle'. Further, research also shows that currency denomination of international bank lending is also an important dimension for the monetary spillover (Takáts and Temesvary 2017; Avdjiev and Takáts 2014). These papers find evidence that monetary policy spillovers are significantly large in international currencies (the US, Euro and Yen). Moreover, EMEs with a large dollar borrowing exposure faced a strong negative impact of cross border flows during the taper tantrum episode (2013).

Finally, the third strand of literature is linked with relatively limited literature on the interaction between monetary policy (MP) and macroprudential regulations (MaPs) (Angeloni, Faia, and Duca 2015; Unsal 2013; Quint and Rabanal 2014; Claessens 2013). These papers analyze the role of MaPs to stabilize financial markets when monetary policy focuses on macroeconomic stability. Since institutions are imperfect and each policy may not perfectly offset different kinds of shocks, co-ordination between MP and MaPs, separate decision making and clear accountability can play an important role in economic stability. Monetary policy restrictions can partly offset excess leverage due to positive productivity or asset price shock. MaPs in the form of countercyclical capital ratios are effective instruments in combination with MP to avoid leverage build up in the economy. Quint and Rabanal 2014 studies optimal combination of MP and MaPs for the Euro area and find that MaPs would help to lower macroeconomic volatility and work as a good substitute in the absence of national policies. Cociuba, Shukayev, and Ueberfeldt 2019 in a calibrated model shows that interest rate policy with state-contingent MaPs achieves efficiency. Interest rate policy reduces excessive risk-taking whereas leverage regulation instead of capital regulation has a stronger effect on risk-taking and complement interest rate rules. Interestingly, MaPs can also substantially change monetary policy transmission in the economy (Agénor, Alper, and Silva 2014).

Since there is a growing need to understand the joint policy interaction between MP and MaPs and its potential cost and benefits, we make an attempt in this chapter to investigate such a policy interaction in an EME type model economy in a DSGE model setup. We focus on the interaction of different kinds of monetary policy rules with macroprudential regulations and compare their relative effectiveness. We present an open economy New Keynesian DSGE model with explicit financial intermediaries that attract foreign capital in the presence of financial frictions. In this setup, we explore whether MaPs improve the effectiveness of monetary policy. The central bank may choose to adjust the nominal interest rate in response to output volatility and inflation gap (simple Taylor rule) or it may additionally target exchange rate volatility (augmented Taylor rule) in the presence of domestic and external shocks. We ask whether MaPs with simpler interest rate rules (Taylor rule) combined with MaPs are more effective than augmented Taylor rule. In other words, does a combination of simple Taylor rule with MaPs effectively reduce the additional exchange rate dimension of monetary policy under augmented Taylor rule?

We specifically attempt to analyze business cycle fluctuations in a small open economy (SOE) with cross border loans under three kinds of shocks: foreign interest rate shock, bank net worth shock and positive productivity shock. We focus on these shocks mainly for the following reasons.

First, positive foreign interest rate shock captures the impact of interest rate normalization in AEs on EMEs. We first compare the relative performance of the model economy under standard Taylor rule with MaPs and augmented Taylor rule policy adopted by the central bank in case of such external shock. In other words, we attempt to demonstrate the effectiveness of the capital regulation tax as macroprudential regulation. We present two potential macroprudential rules (MaP1 and MaP2) to compare their performance under an external shock. It would help to understand how an increase in foreign interest rate affects a small open economy with cross border loans since it is an important source of risk transmission from AEs. EMEs observed a surge in capital flows post-GFC due to search for higher yield which might result in larger volatility in case of interest rate normalization in the advanced economy.

Second, bank capital shock or net worth shock capture an exogenous decline in the quality of bank asset value similar to non-performing assets. Domestic banks usually lend aggressively during an economic boom. During good times, the banks' willingness to lend increases due to their overvalued net worth, low-risk perception and excess foreign borrowing. We analyze how a negative shock to the bank's net worth affects the SOE in the current set up and its repercussions on the economy. We compare and analyze the model dynamics under different monetary policy rules and macroprudential regulations as before. Third, a positive shock to total factor productivity to illustrate the performance of the economy under the policy rules listed above to see whether MaP rules may restrain the potential growth of the economy during good times under a similar policy regime as before.

This chapter makes three important contributions. First, in contrast to the existing line of literature on the interaction of MP and MaPs, we present an open economy model with a banking sector that borrows domestically and abroad explicitly. The presence of financial frictions in the banking sector captures the 'financial accelerator' effect in the face of domestic and external shocks. These features are important in the context of EMEs post-GFC because it enables us to analyze the impact of interest rate normalization in an advanced economy, domestic banking crisis situation or positive productive shock on the economy. Second, we impose macroprudential regulation in the form of capital regulation tax determined by credit/deposit ratio or credit/foreign borrowing ratio to see its effectiveness under each shock. We simulate and compare the effectiveness of the MaPs along with simple Taylor rule to that of augmented Taylor rule to assess whether the regulation can result in better economic outcomes and help to make monetary policy more streamlined and focused on price stability. This is important because the additional targets under monetary policy present conflicting objectives before the central bank in a situation of exchange rate appreciation and higher inflation in the economy. The third contribution of the paper is to show that the presence of MaPs is welfare improving compared to augmented Taylor rule under each shock. Since policymakers generally do not observe a shock in real-time, the presence of MaPs seems to be beneficial for the economy under different kinds of shocks and economic uncertainty.

The main findings of the chapter are as follows - First, the simple Taylor rule (STR) alone performs worse than augmented Taylor rule (ATR) under a foreign interest rate shock. However, we find significant improvement for STR combined with MaPs compared to augmented Taylor rule in the face of the foreign shock. This is because MaPs implemented on foreign borrowing directly influence the cost of external credit and discourage excessive risk-taking in the economy during a global liquidity expansion phase. In contrast, a positive shock in foreign interest rate (and reversal in cross-border flows) does not ensure the stability of riskier cross border-flows that may eventually contract due to better and stable investment opportunities in advanced economies.

Second, during a domestic net worth shock, STR with MaPs performs better than ATR. One important reason is that MaPs actively discourage excess leverage build up in the economy due to which the economy remains relatively more stable during domestic shock. Third, under a positive productivity shock, MaPs seem to have moderated the impact of such shocks instead of reducing the potential growth trajectory of the economy. Finally, the welfare evaluation exercise clearly indicates that STR with MaPs outperforms the ATR policy regime under each shock case suggesting the complementary nature of MaPs with simple interest rate rule and their relative effectiveness.

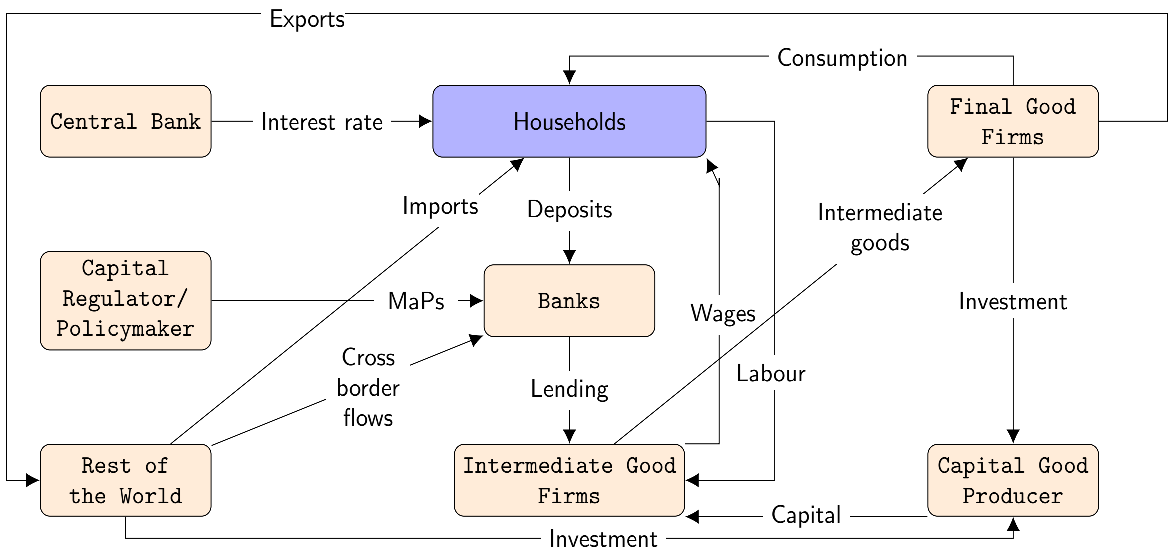
Rest of the paper is organized as follows. Section 2 discusses the structure of the model. Section 3 discuss the solution method, calibration and parameterization of the model. Section 4 presents results as impulse response functions. Section 5 describes the methodology of the welfare loss calculation and the related results and section 6 concludes.

2 Model

This model is related to the works of Gertler and Kiyotaki 2010; Gertler and Karadi 2011; Gabriel et al. 2010; Gali and Monacelli 2005; Cuadra and Nuguer 2018. In the baseline model framework, there are mainly six kinds of agents in a small open economy (SOE): households, banks, intermediate good firms, final good firms, capital producers and the central bank. Households work and buy riskless domestic debt. Banks are owned by households. They collect deposits domestically, borrows abroad (cross border loans) and lends to the intermediate good firms. There are three kinds of firms; intermediate good firms, final goods firms and capital producers.

Intermediate good firms produce wholesale goods using capital and labor and supply the output to final good firms. Intermediate good firms also choose prices to maximize profits and face adjustment costs leading to nominal price rigidity in the economy. Capital producers produce new capital using a mix of existing capital stock from intermediate goods producers and investment goods bought from final good producers and abroad. Final good firms or retail producers convert the wholesale good into the final product which is consumed domestically and rest is exported. The central bank adopts a standard Taylor rule to stabilize the economy. Since we model the financial intermediaries which also raise foreign capital to fund its domestic lending, their share between deposits and foreign borrowing depends upon domestic and foreign interest rates. The bank faces a risk premium if it borrows externally and its borrowing rate depends upon the expected change in the exchange rate, domestic price inflation and foreign nominal interest rate. Finally, we analyze the interaction of monetary and macroprudential policy, explicitly modeling banks exposed to currency mismatch and balance sheet shocks. Figure 1 roughly presents the model dynamics. The derivation for each section in the model discussed below is provided by the mathematical appendix A.

Figure 1: DSGE model diagram



2.1 Household

There is a continuum of infinitely-lived households of measure unity in the economy out of which share 'g' are workers and share '1-g' are bankers. Workers supply labor to the intermediate good producers and receive wages whereas each banker manages a financial intermediary and transfers profits to the household. There is perfect consumption insurance within the household[5]. Deposits are riskless one-period securities. The representative household chooses consumption (C_t), labor (L_t) from the following inter-temporal

5. It assumes consumption is constant over time and across states.

utility problem -

$$E_t \sum_{s=0}^{\infty} \beta^s \left[\frac{(C_{t+s} - h_b C_{t+s-1})^{(1-\sigma_c)}}{1-\sigma_c} - \frac{\chi}{1+\varphi} L_{t+s}^{1+\varphi} \right] \tag{1}$$

where E_t is the expectation operator conditional upon time t, β is the discount factor, φ is the inverse of Frisch elasticity χ is the weight of labor in the utility function and σ_c is the inverse of intertemporal elasticity and substitution and h_b captures the habit persistence of consumption. The household faces the following intertemporal budget constraint -

$$P_t C_t + D_{t+1} = W_t L_t + R_{nt} D_t + \mathit{\Pi}_t - T_t \tag{2}$$

where D_t is a riskless one period deposits that pays a return R_{nt} determined in period t, W_t is the nominal wage rate and $\mathit{\Pi}_t$ is the profit from owning banks and T_t is a nominal lump-sum tax collected by the government. First order conditions of utility maximization by the household are given as follows -

$$C_t : 1/R_{nt+1} = \beta \frac{\Lambda_{t+1}}{\Lambda_t \pi_{t+1}} \tag{3}$$

$$L_t : \frac{W_t}{P_t} = \frac{\chi L^{\varphi}}{\Lambda_t} \tag{4}$$

where - $\Lambda_t = (C_t - h_b C_{t-1})^{-\sigma_c} - \beta h_b E_t (C_{t+1} - h_b C_t)^{-\sigma_c}$ and aggregate price inflation, $\pi_t = \frac{P_t}{P_{t-1}}$.

2.1.1 Consumption good composition

The consumption bundle in the economy (C_t) consists of a home-produced good C_{Ht} and a foreign-produced good C_{Ft} as in Gali and Monacelli 2005 -

$$C_t = \left[w_c^{\frac{1}{\mu c}} C_{Ht}^{\frac{\mu c-1}{\mu c}} + (1-w_c)^{\frac{1}{\mu c}} C_{F,t}^{\frac{\mu c-1}{\mu c}} \right]^{\frac{\mu c}{\mu c-1}} \tag{5}$$

where μ_c is the elasticity of substitution between the domestic and foreign consumption goods and $0 < w_c < 1$ is the relative weight of home goods in the consumption bundle indicating the home bias in household preferences. The representative household decides to allocate her consumption expenditure between the domestic and foreign consumption goods. We further assume P_{Ht} and P_{Ft} are prices of the domestic consumption good and imported consumption good respectively. They also capture aggregate price level of a continuum of differentiated domestic and foreign goods varieties respectively. The household maximization of consumption basket subject to a budget constraint provides aggregate domestic price level P_t in the form of Dixit-Stiglitz (D-S) price index as -

$$P_t = \left[w_c \left(P_{Ht}\right)^{1-\mu c} + (1-w_c)(P_{Ft})^{1-\mu c}\right]^{\frac{1}{1-\mu c}} \tag{6}$$

The optimal choice of domestic consumption goods and imported consumption goods are given by standard intertemporal first order conditions -

$$C_{Ht} = w_c \left(\frac{P_{Ht}}{P_t}\right)^{-\mu c} C_t \tag{7}$$

$$C_{Ft} = (1-w_c) \left(\frac{P_{Ft}}{P_t}\right)^{-\mu c} C_t \tag{8}$$

Since we assume that foreign consumption bundle follows a symmetric setup as domestic consumption bundle, the export of consumption goods to the rest of the world is given in similar form as -

$$C^*_{Ht} = (1-w^*_c) \left(\frac{P_{Ht}}{rer_t P_t}\right)^{-\mu c^*} C^*_t \tag{9}$$

where C^*_{Ht} is the exported consumption good by the domestic economy and C^*_t is the total demand of consumption goods by the rest of the world. Moreover, $1 - w^*_c$ is the share of total good consumption by rest of world (ROW) that is exported from small open economy (SOE) and rer_t is the real exchange rate defined as $rer_t = \frac{P^*_t}{P_t} e_t$ where e_t is the nominal exchange rate and P^*_t is the foreign price level given exogenously. Since EMEs are small open economy, we assume the price of the imported good $P_{Ft} = e_t P^*_t$ (or $e_t = \frac{P_{Ft}}{P^*_t} \Rightarrow rer_t = \frac{P_{Ft}}{P_t}$).

2.2 Banks

As indicated earlier, '1-g' share of households are bankers and the rest are workers. Banks finance their lending through deposits from the household (d_t) and retained earnings from the previous period (n_t). In addition, banks can also borrow from abroad (b_t^*) to finance the lending. Banks are constrained in their ability to raise funds from households in the domestic economy. Following the previous literature, in order to limit the bankers' ability to overcome their financial constraints by saving, we introduce turnovers between workers and bankers within the household. To do that, we assume that there is i.i.d. probability σ that a banker continues being a banker next period and i.i.d. probability $1 - \sigma$ that it exits the next period (or, average survival rate equals $1/(1-\sigma)$). If the banker exits from the market, she returns the retained earnings to the household and becomes a worker. We also allow that a fraction of workers become bankers in each period to keep the number of bankers and workers fixed in the economy. To start the business, every new banker requires a startup fraction ξ of total assets of the banks. We covert the foreign borrowing FB_t in the domestic currency by multiplying it with nominal exchange rate and hence foreign borrowing in domestic currency becomes, $b_t^* = e_t FB_t$.

The balance sheet of a bank consists of the value of loans funded $Q_t s_t$ which equals the bank domestic deposits d_t, net worth n_t and foreign borrowing (or, cross border flows) b_t^*. The balance sheet of the bank is given as -

$$Q_t s_t = n_t + d_t + b_t^* \tag{10}$$

where deposits finance an exogenous fraction η of the net bank asset ($Q_t s_t - n_t$) and the rest is financed through foreign borrowing. The conditions are -

$$d_t = \eta(Q_t s_t - n_t) \tag{11}$$

$$b_t^* = (1 - \eta)(Q_t s_t - n_t) \tag{12}$$

The net worth of an individual bank at period t is defined as the earnings from the assets funded in the previous period ($Q_{t-1}s_{t-1}$) minus the borrowing cost paid on deposits (d_{t-1}^*)

and cross border flows (b^*_{t-1}) -

$$n_t = R_{kt}Q_{t-1}s_{t-1} - R_t d_{t-1} - R_{b,t}b^*_{t-1} n_t = (Z_t + (1-\delta)Q_t)s_{t-1} - R_t d_{t-1} - R_{b,t}b^*_{t-1} \quad (13)$$

where R_{kt} is the gross return on capital and Z_t is the dividend payment which can also be defined as the marginal rate of return on capital (both are defined later in equation (38)). $R_{b,t}$ is the interest payment on cross border loans (denominated in domestic currency, given later in equation (30)) and R_t is the real rate of return on deposits. Using equation (11) and (12) in (13) provides the condition -

$$n_t = Q_{t-1}s_{t-1}(R_{kt} - R_{ct}) + n_{t-1}R_{ct} \quad (14)$$

where R_{ct} is a weighted interest rate or a composite of the interest rates on deposits and foreign borrowing defined as -

$$R_{ct} = \eta R_t + (1-\eta)R_{bt} \quad (15)$$

Further, in period t, bank maximizes the present value of its net worth taking into account the probability of being a banker in the next period given the constant exit rate -

$$V_t = E_t \sum_{i=1}^{\infty} (1-\sigma)\sigma^{i-1}\Lambda_{t,t+i}n_{t+i} \quad (16)$$

Following the previous literature, we implement an agency problem here to limit the banker‘s ability to obtain funds. After the bank receives deposits, it can transfer a fraction of θ of funds to her family. Divertable funds consist of total assets minus foreign borrowing. If a bank diverts assets, it defaults on its loans and close down. Its creditors can reclaim the remaining share $1-\theta$ of the funds. Since the creditors are aware of bank's ability to divert funds, they would restrict the lending amount that represents borrowing constraints for banks. We have limited the borrowing constraints faced by the banks on the domestic deposits but not on the foreign borrowing (or cross border flows). In this way, households can limit the funds lent to banks. Since banks do not face a borrowing constraint on foreign borrowing, they cannot divert assets financed from foreign borrowing and creditors can perfectly recover the assets financed from foreign borrowing. In other words, banks are constrained to borrow from the domestic depositors but not from the foreign lenders; cross border flows move to the economy frictionlessly[6].

Assume that $V_t(s_t, b_t, d_t)$ is the maximized value at the end of period t. An incentive constraint must hold so that the banker can not divert funds -

$$V_t(s_t, b_t^*, d_t) \geq \theta(Q_t s_t - b_t^*) \tag{17}$$

This constraint ensures that the household would be willing to supply funds to the banker as long as the value of the bank is at least as large as the benefits from diverting funds. Rewriting equation (16) at period t takes the Bellman equation form -

$$V(s_t, b_t^*, d_t) = E_t \Lambda_{t,t+1} \left[(1-\sigma)n_t + \sigma \left\{ \max_{(s_{t+1}, b_{t+1^*}, d_{t+1})} V(s_{t+1}, b_{t+1}^*, d_{t+1}) \right\} \right] \tag{18}$$

Bank maximizes the objective function (18) subject to incentive constraint equation (17). To simplify the the optimization, we guess and verify that the form of the value function given by Bellman equation (18) is linear in asset and net worth as -

$$V_t(s_t, n_t) = \upsilon_{st} Q_t s_t + \upsilon_{nt} n_t \tag{19}$$

where υ_{st} and υ_{nt} are time varying parameters and defined as marginal value of assets and marginal value of net worth at time period t respectively. Rewriting the incentive constraint equation (17) using equation (19), we get equations for the balance sheet and leverage ratio (ϕ_t) of a bank -

$$Q_t s_t = \phi_t n_t \tag{20}$$

$$\phi_t = \frac{\theta(1-\eta) - \upsilon_{nt}}{\upsilon_{st} - \theta\eta} \tag{21}$$

Equation (20) provides a relationship between assets and net worth in a bank balance sheet. The leverage ratio equals the ratio of bank assets value to net worth. In other

6. We have chosen to remove borrowing constraints from foreign lenders or free movement of cross border flows for simplicity of the model. However, we can put the constraint to analyze an alternative scenario as follows - $V_t(s_t, b_t^*, d_t) \geq \theta(Q_t s_t - \omega b_t^*)$ where $0 < \omega < 1$ represents friction in foreign borrowing.

words, excess lending or reduced net worth can raise the leverage in banks. Further, leverage condition (equation (21)) suggests a negative association between the leverage ratio and the fraction that the bank diverts θ. This implies if a bank can divert a higher fraction of their assets, leverage or the ratio between assets and net worth falls because there are lesser assets remaining.

In the next step, we verify the form of the value function and following conditions on marginal value of assets and net worth have to satisfy for it to be correct -

$$\upsilon_{nt} = E_t \Lambda_{t,t+1} \Omega_{t+1} R_{ct+1} \tag{22}$$

$$\upsilon_{st} = E_t \Lambda_{t,t+1} \Omega_{t+1} (R_{kt+1} - R_{ct+1)} \tag{23}$$

$$\Omega_{t+1} = (1 - \sigma) + \sigma(\upsilon_{st+1} \phi_{t+1} + \upsilon_{nt+1}) \tag{24}$$

We define $\Lambda_{t,t+1}$ and Ω_{t+1} as 'stochastic discount factor' and 'shadow value of net worth' respectively. The shadow value of net worth (Ω_{t+1}) is a weighted average of marginal value for continuing and exiting banks as given by equation (24). The first term in the equation refers to the probability of exiting the banking sector (σ) and the second term corresponds to the marginal value of an extra unit of net worth given the probability of survival (1-σ) in the current period. The equation further shows if a surviving bank gets an additional unit of net worth, she can increase her benefits by extra unit of net worth (υ_{nt+1}) plus return from holding extra unit: extra unit of loans times leverage (υ_{st+1} ϕ_{t+1}).

Since asset value and leverage ratio vary counter-cyclically, the shadow value of net worth also moves countercyclically too. It suggests that an additional unit of net worth is more valuable during bad times than the good times. In the equation 23, R_{kt} is gross rate of return on bank assets (later defined in the equation (38)). According to the equation (22), the marginal value of net worth (υ_{nt}) is equal to expected augmented discount factor (the stochastic discount factor times the shadow value of net worth: $\Lambda_{t,t+1}$ Ω_{t+1}) times weighted interest rate based on deposits and foreign borrowing. From equation (23), we find that marginal value on assets (υ_{st}) is the expected value of product of the augmented discount factor and spread between the gross return on capital (R_{kt}) and weighted interest rate of deposits and foreign borrowing (R_{ct}). Since interest rate spread is also counter-cyclical in nature, the marginal value of asset is more valuable during recession that normal times.

2.2.1 Aggregate bank net worth

We write economy wide bank leverage condition as -

$$Q_t S_t = \phi_t N_t \tag{25}$$

where capital letters in the equation (25) indicate aggregate variables for the banks at economy level (S_t and N_t). The net worth of existing bankers is equal to total earnings on the assets after deducting debt payments made in the previous period multiplied by the fraction of bankers who survive given by the probability σ, the related equation is -

$$NW_{E,t} = \{(\sigma)R_{kt}Q_{t-1}S_{t-1} - \sigma R_t D_{t-1} - \sigma R_{bt} B^*_{t-1}\} \tag{26}$$

We further assume that the family transfers a fraction $\frac{\xi}{1-\sigma}$ of the total assets of exiting bankers ($(1-\sigma)R_{kt}Q_{t-1}S_{t-1}$) to the new bankers. This can be represented as -

$$NW_{N,t} = \{(\xi)R_{kt}Q_{t-1}S_{t-1}\} \tag{27}$$

The law of motion for total net worth is $NW_t = NW_{N,t} + NW_{E,t}$ given as follows-

$$NW_t = \{(\sigma + \xi)R_{kt}Q_{t-1}S_{t-1} - \sigma R_t D_{t-1} - \sigma R_{bt} B^*_{t-1}\}BC_t \tag{28}$$

Aggregate net worth (NW_t) roughly captures the difference between total return on asset values and total interest payment on deposits and foreign borrowing adjusted with the probability of survival rate. BC_t represents bank capital shock or net worth shock and follows an autoregressive process (AR(1)) with zero mean and constant variance innovations (ϵ_t^{BC}). The shock process is given by -

$$log\frac{BC_t}{BC} = \rho_{BC} log\frac{BC_{t-1}}{BC} + \epsilon_t^{BC} \tag{29}$$

2.2.2 Cross border flows

The interest rate paid by the SOE banks on cross border flows is debt elastic (Schmitt-Grohé and Uribe 2003). Therefore, interest rate on foreign borrowing depends upon foreign nominal interest rate, expected exchange rate adjustment and risk premium on increasing foreign debt, the related equation is given as [7]-

$$R_{b,t+1} = \frac{R^*_{nb,t}}{\pi_{t+1}} \frac{e_{t+1}}{e_t} exp(\phi_{rp}(B^*_t - \bar{B}^*)) \tag{30}$$

where $R_{b,t+1}$ is gross real interest rate payment on foreign borrowing denoted in domestic currency. $R^*_{nb,t+1}$ is nominal foreign interest rate and it follows an AR(1) process with zero mean and constant variance innovation ($\epsilon_t^{Rnb^*}$) -

$$log\frac{R^*_{nb,t}}{R^*_{nb}} = \rho_{Rnb^*} log\frac{R^*_{nb,t-1}}{R^*_{nb}} + \epsilon_t^{Rnb^*} \tag{31}$$

As given in equation (30), we introduce a risk premium (ϕ_{rp}) in the model to make foreign borrowing stationary and keep its values very small so that it does not affect the dynamics of the model economy (Gertler, Gilchrist, and Natalucci 2007).

2.3 Firms

There are three kinds of firms in the model economy; intermediate goods firms or wholesale goods producers, final goods firms or retail firms and capital producers.

2.3.1 Final goods producers

Final goods producers combine different varieties of intermediate goods $Y_{Ht}(i)$ into a final good Y_{Ht} that sells at the competitive final good price P_{Ht}. They use constant returns to scale technology for production. The final good is given as the constant elasticity of

7. Bankers face a risk premium on the foreign borrowing and it is an increasing function of the deviation of foreign debt from its steady state level. In other words, bankers would face a higher interest rate on foreign borrowing with increasing foreign debt.

substitution (CES) composite of intermediate goods as follows -

$$Y_{Ht} = \left[\int_0^1 Y_{Ht(i)}^{\frac{(\zeta-1)}{\zeta}} di \right]^{\frac{\zeta}{\zeta-1}} \tag{32}$$

and the relation between final goods price (P_{Ht}) and intermediate goods price ($P_{Ht}(i)$) is -

$$P_{Ht} = \left[\int_0^1 P_{Ht(i)}^{(1-\zeta)} di \right]^{\frac{1}{1-\zeta}} \tag{33}$$

where $P_{Ht}(i)$ is monopolistically determined price of intermediate goods. Final good firms maximize profits in a competitive market and the optimization provides the relation between intermediate and final goods as -

$$Y_{Ht(i)} = \left(\frac{P_{Ht(i)}}{P_{Ht}} \right)^{-\zeta} Y_{Ht} \tag{34}$$

2.3.2 Intermediate goods producers

There is a continuum of intermediate goods firms indexed as $i \in [0, 1]$. They produce variety of goods indexed by i and engage in a monopolistic competition. They combine capital and labor to produce wholesale good $Y_{Ht}(i)$ using constant returns to scale technology. Intermediate good firms solve a two-stage problem in the model. In the first stage, the firms minimize total cost to choose optimal factor demands (capital and labor). Their total cost has three components. First, at the end of period t-1, firms purchase capital K_t from capital good producers to be used in the next period t at unit price Q_t. Second component is the labor cost. Third, at the end of period t, firms sell the undepreciated capital back to the capital good producers. Cost minimization problem of the intermediate good firms are subject to a production function as -

$$Y_{Ht}(i) = A_t L_t(i)^{\alpha} K_t(i)^{1-\alpha} \tag{35}$$

where $L_t(i)$, $K_t(i)$ and $Y_{Ht}(i)$ refers to labor, capital and output of an intermediate good firm. Further, A_t represents total factor productivity and follows an AR(1) process as -

$$log\frac{A_t}{A} = \rho_A log\frac{A_{t-1}}{A} + \epsilon_t^A \tag{36}$$

with zero mean and constant innovation shock ϵ_t^A. In a symmetric cost minimization setup, the firm obtains optimal factor demands, wages (w_t) and gross return on capital (R_{kt}) given by first order condition as [8] -

$$L_t : \quad w_t = mc_t\frac{\alpha Y_{Ht}}{L_t} \tag{37}$$

$$K_t : \quad R_{kt} = \frac{\left[mc_t(1-\alpha)\frac{Y_{Ht}}{K_t} + (1-\delta)Q_t\right]}{Q_{t-1}} \tag{38}$$

where $mc_t = \frac{P_{Ht}(i)}{P_{Ht}}$ is marginal cost and $mc_t(1-\alpha)\frac{Y_{Ht}}{K_t} = Z_t$, which is also defined as a dividend or marginal rate of return on capital.

Price setting mechanism (Rotemberg pricing)

In the second stage, intermediate good firms choose the price that maximize their discounted real profits. The firms also face a quadratic cost of price adjustment leading to sluggish price adjustment and resultant nominal rigidity or the price stickiness in the economy (Rotemberg 1982; Ireland 2001). The pricing mechanism ensures that monetary policy has a real impact on the economy. In this setup, firms pay quadratic adjustment cost ($AdjC_t$) due to their price adjustment with respect to benchmark inflation ($\bar{\pi}_H$) as follows -

$$AdjC_t(i) = \frac{\kappa}{2}\left(\frac{P_{Ht}(i)}{P_{Ht-1}(i)} - \bar{\pi}_H\right)^2 P_{Ht}Y_{Ht} \tag{39}$$

The optimization problem for the intermediate good producers subject to constraint equation (34) and (35) is given as -

$$E_t\left[\sum_{j=0}^{\infty}\beta^j\frac{\Lambda_{t+j}}{\Lambda_t}\left\{\frac{P_{Ht+j}(i)}{P_{t+j}}Y_{Ht+j}(i) - mc_{t+j}(i)Y_{Ht+j}(i) - \frac{AdjC_{t+j}(i)}{P_{t+j}}\right\}\right] \tag{40}$$

8. In a symmetric cost optimization setup, intermediate good firms choose same inputs, price and output.

After optimization with respect to prices ($P_{Ht}(i)$), we obtain pricing condition as -

$$\pi_{Ht}(\pi_{Ht} - \bar{\pi}_H) = \beta E_t \left(\frac{\Lambda_{t+1}}{\Lambda_t} \pi_{Ht+1}(\pi_{Ht+1} - \bar{\pi}_H) \frac{p_{Ht+1}Y_{Ht+1}}{p_{Ht}Y_{Ht}} \right) + \frac{\varepsilon}{k} \left(\frac{mc_t}{p_{Ht}} + \frac{1-\varepsilon}{\varepsilon} \right) \quad (41)$$

$$\text{where,} \qquad \pi_{Ht} = \pi_t \frac{p_{Ht}}{p_{Ht-1}}; \quad p_{Ht} = P_{Ht}/P_t \quad (42)$$

2.3.3 Capital goods producers

Capital good producers operate in a perfect competitive market and generate the new capital and repair worn-out capital. They generate new capital using purchased investment goods and repair depreciated capital purchased from the intermediate good firms. In other words, capital good producers use a combination of existing capital stock and the investment goods (from final good firms and abroad) subject to an adjustment cost and sell the new and refurbished capital to intermediate goods firms at price Q_t. At the end of period t-1, they sell new capital and repaired capital to the intermediate goods firms at price Q_t to use in the next period t. Since capital good producers are owned by the households, they return any profits to their owners. While there is no adjustment cost for the repaired capital, we assume that the producers face an adjustment cost to produce new capital which is given in the following equation as a quadratic function of investment growth as -

$$g\left(\frac{I_t}{I_{t-1}}\right) = \frac{\phi_x}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2 \quad (43)$$

To produce new capital goods and repair depreciated capital, the capital good producers need I_{t+k} units of investment goods at the unit price and incur an investment adjustment cost $g\left(\frac{I_{t+k}}{I_{t+k-1}}\right)$ for each unit of investment to produce the new capital goods and sell at the unit price Q_{t+k}. Capital producers maximize their expected discounted profits at time t by choosing new capital I_t in the following manner -

$$E_t \sum_{k=0}^{\infty} DS_{t,t+k} \left[Q_{t+k} \left\{ 1 - g\left(\frac{I_{t+k}}{I_{t+k-1}}\right) \right\} I_{t+k} - I_{t+k} \right] \quad (44)$$

The first order condition for the capital producer for the optimal capital goods is -

$$Q_t\left[1-g\left(\frac{I_t}{I_{t-1}}\right)-\frac{I_t}{I_{t-1}}g'\left(\frac{I_t}{I_{t-1}}\right)\right]+E_t\left[DS_{t,t+1}Q_{t+1}g'\left(\frac{I_t+1}{I_t}\right)\left(\frac{I_{t+1}}{I_t}\right)^2\right]=1 \quad (45)$$

and $DS_{t,t+k}(=\beta^k\frac{\Lambda_{t+k}}{\Lambda_t}=\frac{1}{R_{t+k}})$ is the discount factor. Further, the evolution of aggregate physical capital stock follows a law of motion -

$$K_{t+1}=(1-\delta)K_t+\left[1-\frac{\phi_x}{2}\left(\frac{I_t}{I_{t-1}}-1\right)^2\right]I_t \quad (46)$$

where K_t is the capital stock at the end of the period t. Capital accumulation in the next period t+1 (K_{t+1}) is the sum of new capital goods with adjustment cost and undepreciated capital $(1-\delta)K_t$ at the end of period t.

2.3.4 Investment good composition

As discussed above, the capital good producers use investment goods, for repairing depreciated capital goods and produce new capital goods, that consist of home and foreign produced investment goods I_{Ht} and I_{Ft}. The investment basket of the economy is given as -

$$I_t=\left[w_I^{\frac{1}{\mu I}}I_{Ht}^{\frac{\mu I-1}{\mu I}}+(1-w_I)^{\frac{1}{\mu I}}I_{Ft}^{\frac{\mu I-1}{\mu I}}\right]^{\frac{\mu I}{\mu I-1}} \quad (47)$$

As discussed in the section 2.1.1, capital goods producers face similar domestic price level given by D-S price index as -

$$P_t=\left[w_I\left(P_{H,t}\right)^{1-\mu I}+(1-w_I)(P_{F,t})^{1-\mu I}\right]^{\frac{1}{1-\mu I}} \quad (48)$$

Intertemporal first order conditions for the optimal home and foreign produced investment inputs are -

$$I_{Ht} = w_I \left(\frac{P_{Ht}}{P_t} \right)^{-\mu I} I_t \tag{49}$$

$$I_{Ft} = (1 - w_I) \left(\frac{P_{Ft}}{P_t} \right)^{-\mu I} I_t \tag{50}$$

Similarly, optimal choice of exported investment goods to the rest of the world is given by the following first order condition -

$$I^*_{Ht} = (1 - w^*_I) \left(\frac{P_{Ht}}{rer_t P_t} \right)^{-\mu I^*} I^*_t \tag{51}$$

where I_{Ht} is the domestic share of investment goods, I_{Ft} is the imported share of investment good, P_t is the aggregate price level of investment good. I^*_{Ht} the is exported investment good and I^*_t is the total demand of investment goods by the rest of the world. w_I is the share of home-produced good in the investment basket and $(1 - w_I)$ is the share of imported investment goods from the rest of the world and rer_t is the real exchange rate.

2.4 Central bank and government

In the present model, the central bank implements monetary policy by two types of interest rate rules -

1. Standard Taylor rule in which CB targets output and inflation gap given by -

$$log \frac{R_{nt}}{R_n} = \rho_r log \frac{R_{nt-1}}{R_n} + (1 - \rho_r) \left(\theta_y log \frac{Y_{Ht}}{Y_H} + \theta_\pi log \frac{\pi_t}{\pi} \right) + \epsilon_{rn,t} \tag{52}$$

2. Augmented Taylor rule in which CB targets change in nominal exchange rate in addition to output and inflation gap given by -

$$log \frac{R_{nt}}{R_n} = \rho_r log \frac{R_{nt-1}}{R_n} + (1 - \rho_r) \left(\theta_y log \frac{Y_{Ht}}{Y_H} + \theta_\pi log \frac{\pi_t}{\pi} + \theta_e log \frac{\triangle e_t}{e} \right) + \epsilon_{rn,t} \tag{53}$$

where R_{nt}, Y_{Ht} and π_t are the domestic nominal interest rate, domestic output, domestic price inflation respectively. R_n, Y_H and π are the respective steady state values. Further, ρ_r is the smoothing parameter and lies between zero and unit. Other parameters such as θ_y, θ_π and θ_e are the relative weights on output, inflation and exchange rate respectively in the Taylor rules whereas $\epsilon_{rn,t}$ is an exogenous shock to the monetary policy. The link between nominal and real interest rate (R_t) in the economy is provided by the Fisher equation as follows -

$$R_{t+1} = \frac{R_{nt}}{\pi_{t+1}} \tag{54}$$

We assume that the government in the model purchase an exogenous stream G_t of the final goods which are financed by lump-sum taxes imposed on the households. The government does not access the domestic or international capital markets and its budget constraint is given by -

$$G_t = T_t \tag{55}$$

2.5 Market clearing and equilibrium

The final goods output is used for domestic household's consumption (C_{Ht}), investment goods demand by capital producers (I_{Ht}), exported consumption and investment goods to the rest of the world (C^*_{Ht}, I^*_{Ht}) and domestic government consumption (G_{Ht}). Domestic market clears as -

$$Y_{Ht} = C_{Ht} + I_{Ht} + C^*_{Ht} + I^*_{Ht} + G_t \tag{56}$$

The National income accounting identity is given by -

$$P_{Ht}Y_{Ht}\left[1 - \frac{\kappa}{2}(\pi_{Ht} - \bar{\pi}_H)^2\right] = P_tC_t + P_tI_t + P_{Ht}G_t + TB_t \tag{57}$$

where TB_t is trade balance for the domestic economy. Current account dynamics, in presence of the cross-border flows, is given in the following manner -

$$R_{b,t}B^*_{t-1} - B^*_t = TB_t$$

Relationship between real and nominal exchange rate is given as -

$$\frac{e_t}{e_{t-1}} = \frac{RER_t}{RER_{t-1}}\frac{\pi_t}{\pi^*_t} \tag{58}$$

Terms of trade equation follows -

$$\frac{ToT_t}{ToT_{t-1}} = \frac{\pi_{F,t}}{\pi_{H,t}} \tag{59}$$

2.6 Macroprudential policy rules

To implement macroprudential policy, the policymaker imposes a capital regulation tax on foreign borrowing by the financial intermediaries: cross border flows. The objective of the tax is to reduce non-core liabilities of the bank (liabilities other than deposits). We include MaP regulation as two types of capital regulation taxes ($\tau_{t,1}$ or $\tau_{t,2}$), resulting in a modified equation of the bank's net worth as -

$$NW_t = [(\sigma + \xi)R_{k,t}Q_{t-1}S_{t-1} - \sigma R_t d_{t-1} - \sigma R_{b,t}\tau_{t,1}B^*_t]BC_t \tag{60}$$

or,

$$NW_t = [(\sigma + \xi)R_{k,t}Q_{t-1}S_{t-1} - \sigma R_t d_{t-1} - \sigma R_{b,t}\tau_{t,2}B^*_t]BC_t \tag{61}$$

For our model setup, the magnitude of the tax could be based on the ratio of credit growth and deposit growth or external borrowing growth. We use two kinds of macroprudential rules, MaP1 and MaP2, to analyze its interaction with the monetary policy and relative effectiveness to augmented interest rate rules. According to the MaP1 rule, the policymaker imposes a capital regulation tax based on the ratio of credit growth and foreign borrowing growth. Whereas, MaP2 rule implementation is based on the ratio of credit growth to deposit growth. The purpose of the differentiating between the two rules is to determine their relative effectiveness to absorb shocks and welfare evaluation. The policy rules are given by the following equations as -

MaP1 rule:

$$\tau_{t,1} = \left[\frac{\frac{S_{t+1}-S_t}{S_t}}{\frac{B^*_{t+1}-B_t}{B^*_t}} \right]^{\psi_{map}} \tag{62}$$

MaP2 rule:

$$\tau_{t,2} = \left[\frac{\frac{S_{t+1}-S_t}{S_t}}{\frac{D_{t+1}-D_t}{D_t}} \right]^{\psi_{map}} \tag{63}$$

where ψ_{map} is exogenous component of the tax whereas terms within the parenthesis are endogenous. The capital regulation tax further changes the government budget constraint as -

$$\text{in the case of } \tau_{t,1}: \qquad G_t = T_t + (\tau_{t,1} - 1)R_{b,t}B^*_t \tag{64}$$

or,

$$\text{in the case of } \tau_{t,2}: \qquad G_t = T_t + (\tau_{t,2} - 1)R_{b,t}B^*_t \tag{65}$$

3 Quantitative analysis and solution method

In this section, we discuss the calibrating assumptions of our analysis and proceed to calibrate the model. We present our results, in the following sections, obtained by the numerical simulations of the model economy using parameters that capture the features of an emerging market economy. Our results mainly consist of impulse response functions (IRFs) to demonstrate the model behavior under different shocks and policy paradigms. IRFs are estimated by first-order approximation to the model solution. Further, we carry out welfare calculations for deeper investigation of the model dynamics by computing second-order approximation to the equilibrium conditions. All computations are conducted using an open-source package, Dynare, in the MATLAB software environment.

3.1 Calibration and model parameterization

In this section, we present the relevant parameters for model calibration. The parameters mainly capture broader characteristics of emerging market economies where financial frictions are particularly important (Aguiar and Gopinath 2007; Gabriel et al. 2010; Gertler, Gilchrist, and Natalucci 2007; Cuadra and Nuguer 2018). The relevant parameters are base on the previous literature. The set of parameters is listed in table 1.

Table 1: Parameter values for model calibration

Parameter notation	Values	Variable
β	0.99	Discount factor
h_b	0.6	Consumption habit
χ	2	Weight of relative utility of labor
σ_c	3	Risk aversion
α	0.33	Effective capital share
δ	0.018	Depreciation
κ	3.00	Adjustment cost
φ	0.276	Inverse Frisch elasticity of labor
δ	0.069	depreciation rate
ξ	0.002	Start up fraction
θ	0.407	Fraction of diverted assets
ζ	7.67	Elasticity of substitution among good varieties
σ	0.9683	Survival rate
μ_{ct}	1.5	Consumption substitution elas.
μ_{it}	0.25	Investment substitution elas.
G/Y	0.15	Ratio of govt expenditure to output

In addition to this, we have taken a share of domestic goods in consumption and investment baskets, w_c and w_i, as 0.8 and 0.7 respectively following the literature. For the financial intermediary, we calibrate relevant parameters by targeting three key values that closely capture the features of EMEs: interest rate spread for 100 basis points in the steady-state, leverage ratio in the steady-state as 5 and average survival years for banks as 8 (Gertler and Kiyotaki 2010; Gertler and Karadi 2011). Based on these targets, we obtain the proportion of assets transferred to the new banks (ξ) as 0.002, the average survival probability of a bank (σ) as 0.9683 and fraction of diverted bank assets (θ) as 0.352.

In case of capital producers, investment adjustment parameter (ϕ_x) is 2. For Rotemberg price adjustment, the value for the parameter for price adjustment relative to last period

(κ) is 0.001 (Gali and Monacelli 2005). Further, foreign debt elasticity of risk premium (ψ_{risk}) is set to 0.015. The risk premium is taken to be 0 in the steady state and included in the model to obtain a well defined steady state for foreign borrowing (Schmitt-Grohé and Uribe 2003). Following the previous literature, we choose standard value of policy persistence (ρ_{rn}) as 0.7, policy rate response to inflation, output and change in nominal exchange rate (θ_{π},θ_y, θ_e) are 1.5, 0.5 and 0.2 respectively for the Taylor rule implementation by the central bank. We follow the previous literature for the shock parameters in the economy. To capture the effect of foreign interest rate shock, we choose persistence parameter (ρ_{Rb^*}) as 0.70 and standard deviation of the shock as 0.01. For domestic net worth shock, persistence parameter (ρ_{NW}) is 0.50 and standard deviation of the shock is kept at 0.01. For productivity shock, we take persistence parameter value (ρ_Y) as 0.50 and standard deviation of the shock as 0.01.

4 Model results: impulse response functions (IRFs)

Based on the above model, we discuss the role of monetary policy and macroprudential policy under three important shocks EMEs typically face, namely - (1) External shock as a positive shock in foreign interest rate (2) Negative domestic shock as a negative shock in banks' net worth (3) Positive domestic shock as a positive shock in total factor productivity (TFP). We chose these three important shocks for specific reasons. Shock 1 attempts to capture the potential repercussions of an event like interest rate normalization in AEs on EMEs as observed during taper announcement by Federal Reserve Board (2013). Shock 2 closely captures a negative domestic shock in which financial intermediaries face an exogenous decline in their net worth i.e. sudden increase in non-performing assets. Shock 3 captures the general case scenario where the economy observes a positive productivity shock due to technological improvement or related reforms that improve total factor productivity in the economy.

We analyze the behavior of the model economy under each shock through two monetary policy (or, interest rate) rules and two policy rules - (A) simple Taylor rule (TR) targeting output and inflation gap, (B) augmented Taylor rule (ATR) that targets change in nominal exchange rate in addition to inflation and output gap, (C) macroprudential policy rule 1 (MaP1) targeting the ratio of credit to foreign borrowing and (D) macroprudential policy rule 2 (MaP2) targeting the ratio of credit to domestic deposits.

We first present a baseline case where we compare model dynamics under TR (with no MaP regulation) and ATR in the face of external shock namely, positive shock in foreign interest rate. We find that the model economy experience larger losses under the simple Taylor rule than under ATR. However, there is empirical evidence that the use of exchange rate stabilization under interest rate rules may help reduce extreme volatility and that it can also have larger repercussions on borrowers' balance sheets and on trade balances for EMEs (Amato and Gerlach 2002; Berganza and Broto 2012). It can further present conflicting objectives for policymakers as they will have to choose between inflation and exchange rate targets during capital outflows. A policy reaction to such conflicting objectives has the ability to hamper the growth objectives of an economy and it is highly relevant for EMEs. In other words, interest rate rule as ATR may not always be an effective policy instrument. Given this background, we present an alternative policy scenarios where policymakers can use a combination of macroprudential rule with simple Taylor rule to analyze its effectiveness relative to ATR kind of interest rate rule in absorbing the domestic and external shocks.

We further illustrate the combination of interest rate policy rules with MaPs to stabilize the model economy in the face of external shock. We have mainly discussed and compared two cases of policy responses under this shock - (1) Taylor rule (TR) with MaP1 or Augmented Taylor rule (ATR) and (2) Taylor rule (TR) with MaP2 or Augmented Taylor rule (ATR). We further discuss the implications of similar policy responses under two domestic shocks, i.e net worth shock and productivity shock, in the following sections.

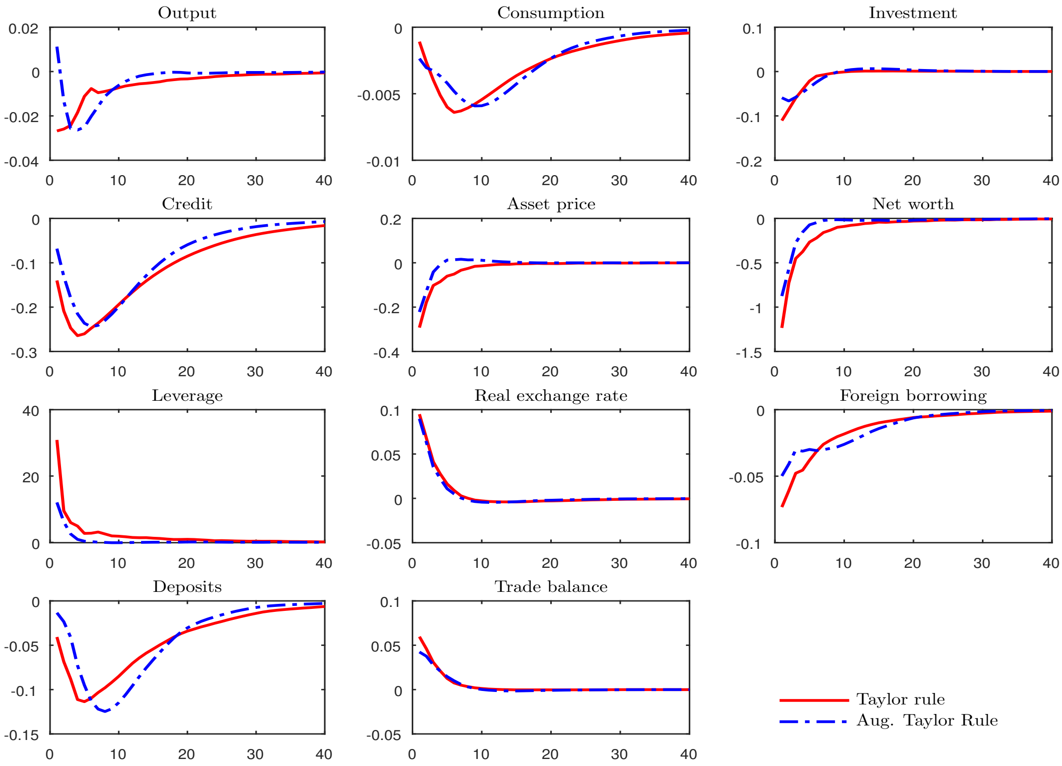
We find two key results. First, Taylor rule with MaPs performs relatively better than ATR to reduce negative spillover on the economy in most of the shock scenarios. Second, macroprudential policies are effective tools to reduce the repercussions of external shocks on the economy. It mostly proves to be an important instrument to maintain the resilience of the financial system. Between the two MaP rules, *MaP2 rule* is relatively more effective to stabilize the economy. We observe that MaPs affect the financial system through the bank capital channel in the face of external shock. They reduce the volatility of the bank's net worth and the leverage ratio. Their impact on the real economy is transmitted largely through the amount of investment and lending. In this manner, MaPs are helpful in reducing negative spillovers and in discouraging boom and bust cycles in the economy amplified by cross border flows. They also prove to be useful to mitigate losses under a negative net worth shock. In addition to this, during productivity shock, we observe that MaP rules moderately affect the economy and may largely prove to be useful to avoid overheating of the economy.

4.1 External shocks, monetary policy and macroprudential policy regimes

Case 1. Simple Taylor rule and augmented Taylor rule (No MaP regulation)

Figure 2 depicts the IRFs for the baseline model. It shows the impact of a positive foreign interest rate shock on the model economy under two different monetary policy regimes without any capital regulation. A positive shock to the foreign interest rate increases the interest payments and makes future borrowing costlier. In effect, banks' net worth drops as per the equation (28) and in effect, banks reduce their foreign borrowing. The IRFs clearly show that net worth and foreign borrowing declines at the shock impact in the current quarter. In effect, currency also depreciates. Further, banks' net worth reduction increases the leverage and tightens the borrowing constraint which leads to fire sale of assets and depresses asset values. As a consequence, credit declines resulting in lower investment and output. However, we observe differential decline in the macroeconomic variables under two different monetary policy implementations.

Figure 2: Impulse response function to a 1% positive shock to foreign interest rate (R^*_{bt})



Note: y-axis represenst deviation from steady state and x-axis represents quarters

Augmented Taylor rule under exchange rate (change) management performs better compared to the simple Taylor rule adopted by the central bank. Under ATR, the economy does not face output decline at the shock impact, it slowly declines later and comes back to the steady-state level within 15 quarters. A possible intuition for this improvement is that the central bank under ATR raises the nominal interest rate to reduce domestic currency depreciation and its volatility due to capital outflows in the case of a positive shock in the foreign interest rate. In effect, reduction in capital outflows is smaller under ATR as captured through less reduction in foreign borrowing as shown in figure 2.

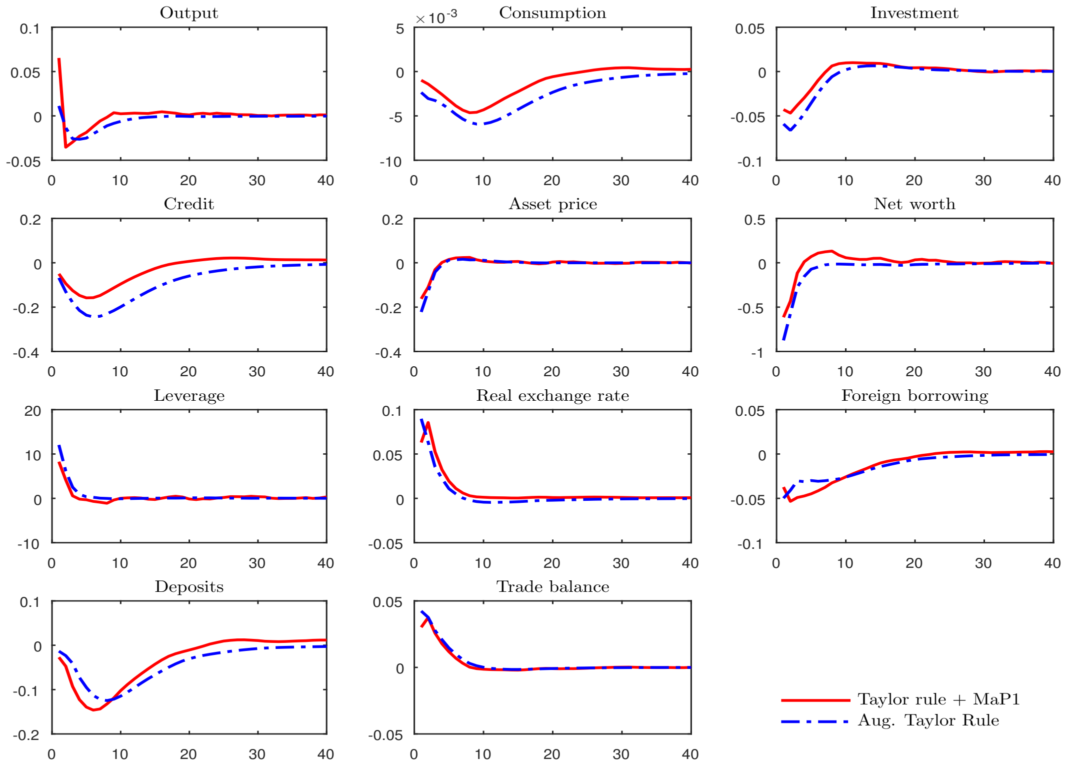
The model economy observes a smaller decline in credit, asset prices, investment and consumption relative to the case under simple Taylor rule. Despite the better performance under ATR, there can be a potential conflict between inflation and exchange rate management under Taylor rule type monetary policy management as discussed in the previous section. With this background, we present two cases to compare the model performance under Taylor rule with capital regulation and augmented Taylor rule in the following section. Each case includes one type of capital regulation (MaP1 or MaP2) in addition to the simple Taylor rule and their effectiveness is compared to ATR. Both MaP rules are implemented as capital regulation tax on foreign borrowing and mainly utilized as a countercyclical measure to mitigate the negative impact of a positive shock in foreign interest rate.

Case 2. Simple Taylor rule with MaP rule 1 and augmented Taylor rule

In this case, policymakers target the ratio of credit growth to foreign borrowing growth $\left(\frac{\frac{\triangle S_{t+1}}{S_t}}{\frac{\triangle BF_{t+1}}{BF_t}}\right)$ as MaP1 rule and tax banks' external borrowing accordingly. Typically, a higher amount of foreign borrowing combined with a lower risk perception by banks leads to excessive lending in the economy. In such a scenario, the economy may overheat and suffer more in case of adverse external shocks. The MaP1 rule discourages excessive lending through foreign borrowing by directly taxing the foreign capital.

Figure 3 shows that the MaP1 rule is effective as countercyclical capital regulation by reducing the impact of foreign interest rate shock and that it performs relatively better than augmented Taylor rule. In the presence of MaP1, net worth and credit show a relatively smaller decline to the case when policymaker only have ATR policy (henceforth referred to as the only ATR case).

Figure 3: Impulse response function to a 1% positive shock to foreign interest rate (R^*_{bt})



Note: y-axis represents deviation from steady state and x-axis represents quarters

As a consequence, contraction in credit and investment is smaller in this case. Output and consumption fall slower and quicker to return to their respective steady-states. The mechanism at play during MaP1 is as follows - capital regulation tax on foreign borrowing reduces excessive lending. It results in a moderate build-up in net worth and leverage. As a consequence, credit and investment move in tandem.

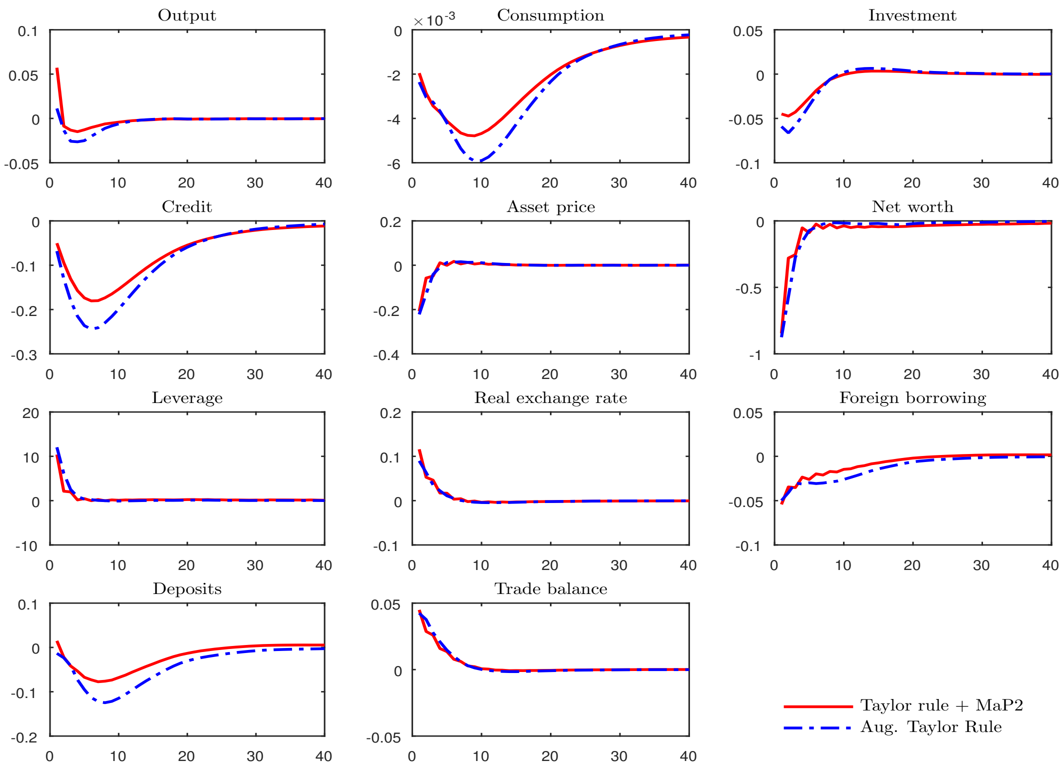
MaP1 rule stabilizes the financial system by discouraging direct foreign borrowing to avoid currency mismatch in the bank's balance sheet and making it more resilient in the face of exchange rate fluctuations due to external shock. In this scenario, bank capital remains less affected by interest rate shock when such a shock hits the economy. Fall in asset prices, credit and investment remain relatively smaller. The model economy remains more resilient in the presence of MaP1 and improves economic performance relative to the only ATR case.

Case 3. Taylor rule with MaP rule 2 and augmented Taylor rule

In this case, MaP2 rule targets ratio of credit growth to deposit growth $\left(\frac{\frac{\triangle S_{t+1}}{S_t}}{\frac{\triangle D_{t+1}}{D_t}}\right)$. This is an alternative rule that can be used to implement macroprudential policy. The mechanism at play is closely similar to the previous case. Figure 4 demonstrates that all variables behave similarly as in *case 2* except improvement in foreign borrowing, deposits, and output. We observe that deposits remain unaffected at shock impact and decline slowly before reaching a steady state. The decline in output is less sharp and quicker to return to its steady state.

MaP based on credit to deposit ratio growth is likely to discourage lending through non-core liabilities. A higher ratio indicates that bank loans are not financed through the core deposits which makes banks more vulnerable in case of external shocks. During stress scenarios, higher risk perception builds up and fire sale of assets reduces asset prices rapidly, bank capital declines and the economy experiences less credit and investment. To avoid such a scenario, the MaP2 rule regulates lending and incentivizes banks to avoid taking risks through the accumulation of non-core liabilities.

Figure 4: Impulse response function to a 1% positive shock to foreign interest rate (R^*_{bt})



Note: y-axis represents deviation from steady state and x-axis represents quarters

In comparison, the MaP2 rule marginally improves over MaP1 rule and registers a smaller decline in output, deposits and foreign borrowing. This could possibly happen because the MaP2 rule is based on deposit liabilities and sweeps away all risky sources of non-core liabilities including foreign borrowing to finance excess bank lending. On the other hand, MaP1 is based on foreign currency liabilities which is relatively smaller in comparison to deposits and only accounts for foreign borrowing, leaving other riskier source such as short term debt in the economy, that might lessen its effectiveness under the current shock.

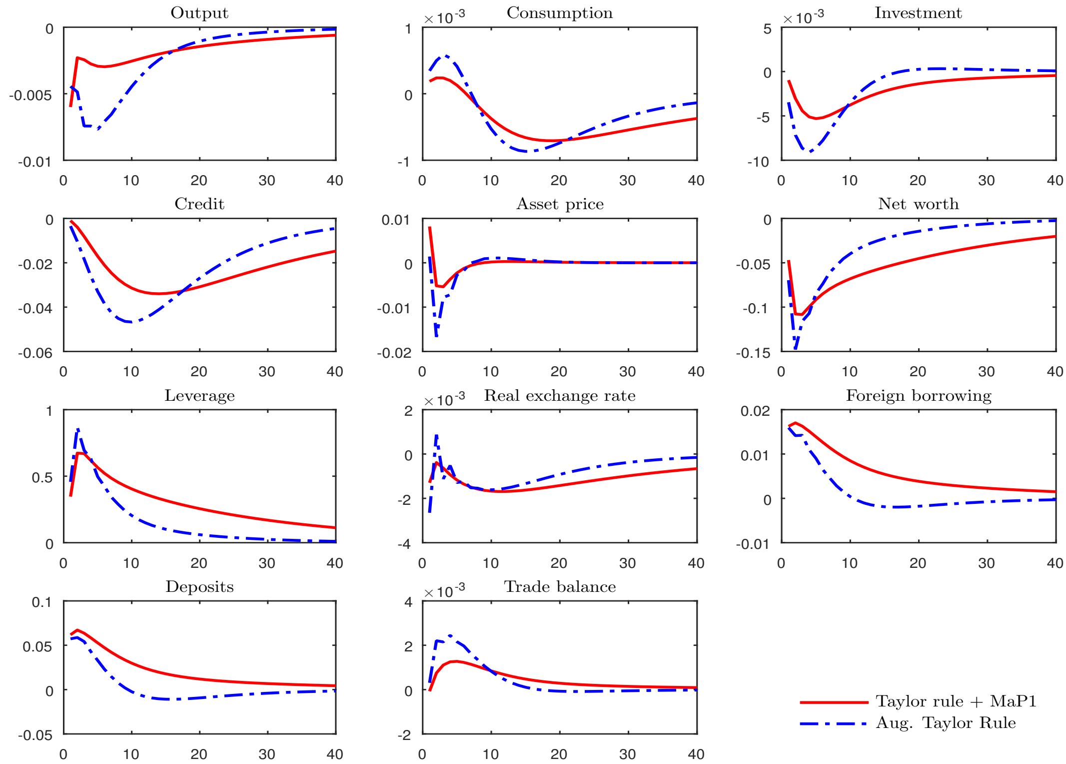
4.2 Domestic shocks, monetary policy and macroprudential policy regimes

We show IRFs for the model economy under the negative net worth shock in figure 5 and 6 and compare the model dynamics under interaction of monetary policy with MaPs (TR with capital regulation tax) with that under only augmented Taylor rule (ATR) case. Under the net worth shock, we attempt to capture exogenous decline in the value of the bank assets such as rise in non-performing loans and see if the economy could perform better through the interaction of TR with MaP1 or MaP2 rule relative to only ATR case.

Case 1. Simple Taylor rule with MaP rule 1 and augmented Taylor rule

Figure 5 compares the impulse responses due to negative net worth shock under TR with MaP1 rule and under only ATR case. The IRFs clearly indicate the transmission of exogenous decline in bank capital to business cycle fluctuations through a decline in output at shock impact. Under such a shock, supply-side financial accelerator constraint plays an important role in propagating and amplifying its impact on the economy. Net worth shock affects the economy through two channels. First, an exogenous decline in net worth affects the banks' ability to borrow in the capital market. In other words, it tightens the banks' borrowing constraint which might increase the fire sale of assets and decrease asset values. Second, since the banks are leveraged, the impact of fall in asset values on net worth would be equivalent to the leverage ratio. As the leverage progressively builds up during the boom, the economy might experience a larger fall in banks' net worth due to negative bank capital shock. The decline in net worth feeds into real economic activity through a decline in asset prices, credit, investment and output at shock impact.

Figure 5: Impulse response function to a 1% negative shock to bank net worth (NW_t)



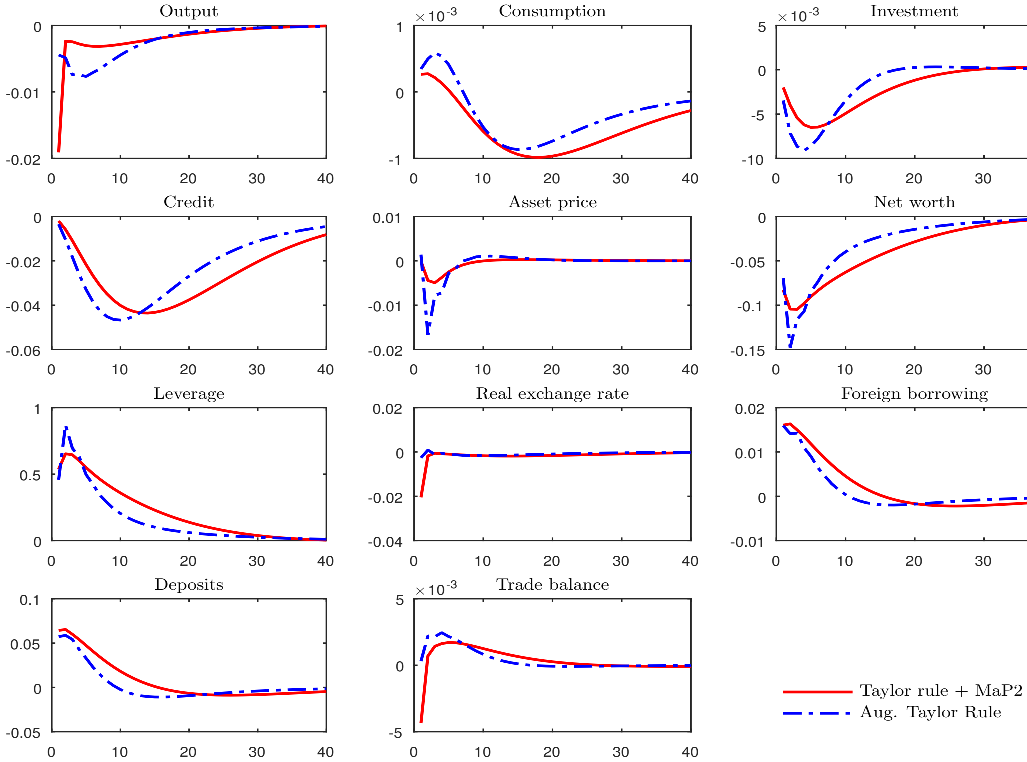
Note: y-axis represents deviation from steady state and x-axis represents quarters

Comparing different policy regimes in this case, we observe that Taylor rule with MaP1 rule fares better than augmented Taylor rule as shown by a lesser reduction in credit, investment and output. TR with MaP1 reduces the impact of the shock mainly through discouraging leverage build up in the economy. In effect, it leads to a smaller reduction in key macroeconomic variables such as asset prices, foreign borrowing and deposits which translates into a lower output and investment.

Case 2. Simple Taylor rule with MaP rule 2 and augmented Taylor rule

In this case, the model economy performance is closely similar to the previous case. MaP2 rule imposition in presence of Taylor rule lessens excessive lending and the model economy experiences smaller losses when faced with a negative net worth shock as shown in figure 6. Net worth shock is a domestic shock, which could be a possible reason for the similar outcome under ATR with MaP1 or MaP2.

Figure 6: Impulse response function to a 1% negative shock to bank net worth (NW_t)



Note: y-axis represents deviation from steady state and x-axis represents quarters

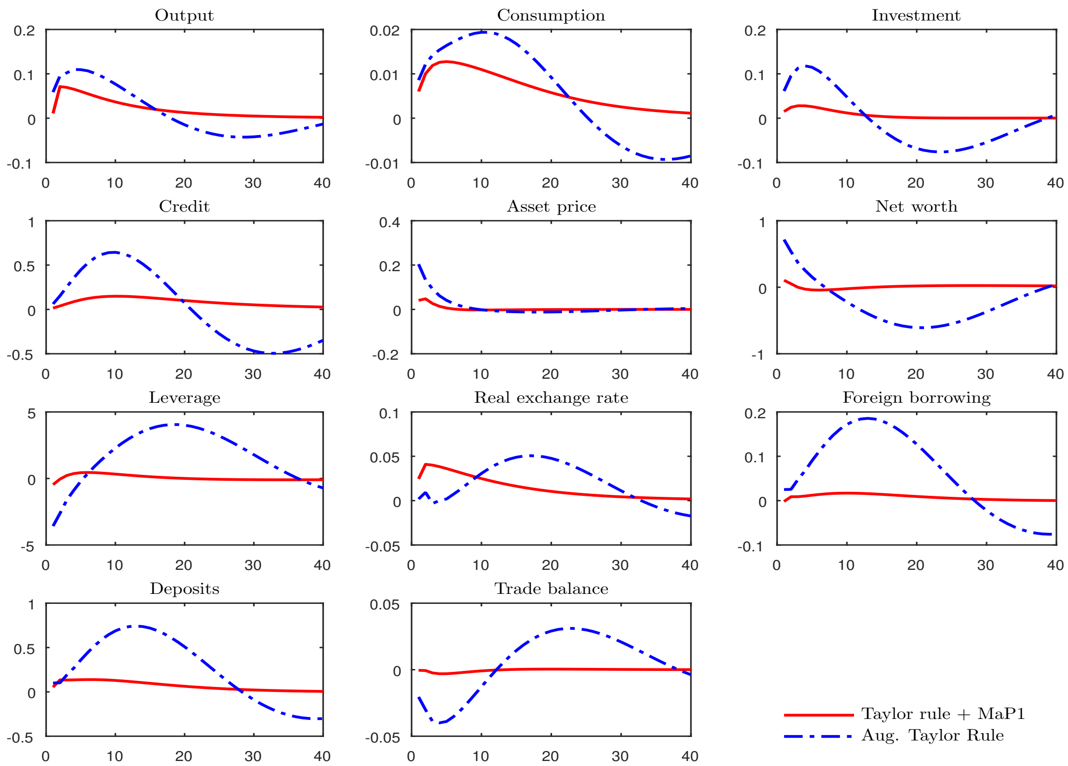
Since the shock originated domestically, both MaP rules only help to reduce business cycle fluctuations by hampering the transmission of the net worth shock through the model economy. Such rules seem to actively discourage reckless foreign borrowing to finance excess domestic lending which might not be the case under only ATR policy. As a consequence, we observe relatively higher losses in the model economy under ATR type monetary policy implementation without any capital regulation.

In the last two cases, we mainly discussed the impact of negative shocks on the economy and how MaPs can prove to be a useful tool in reducing losses during bad times. However, there is a general criticism of MaPs rules that emphasizes its role in stifling the growth potential of the economy during good times. In the next section, we discuss the impact of MaPs during positive productivity shocks.

4.3 Productivity shocks, monetary policy and macroprudential policy regimes

Figures 7 and 8 demonstrate the model performance in the face of positive TFP shock under two different policy rules. The mechanism underlying the impact of this shock is as follows - an exogenous positive shock in productivity increases production at shock impact and raises the demand for capital for a larger investment. In effect, bank credit picks up, raising the banks' net worth. Total investment increases in the economy. In addition to this, demand for labor increases wages and consumption for the household.

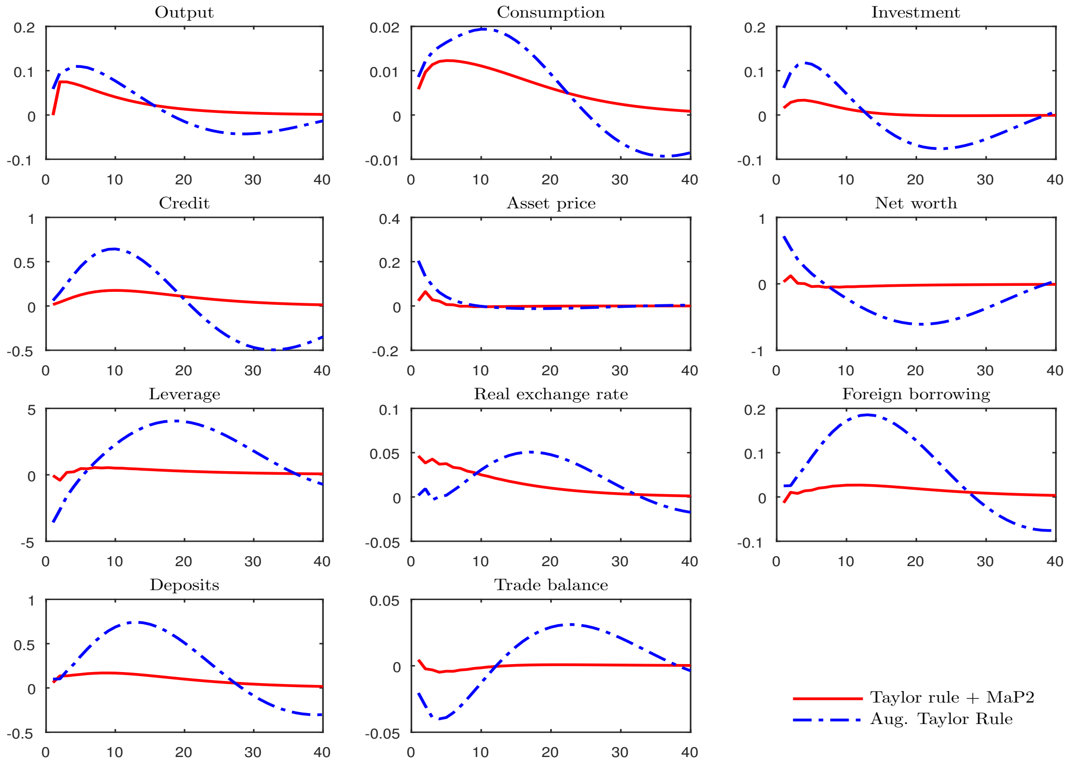
Figure 7: Impulse response function to a 1% positive shock to TFP (A_t)



Note: y-axis represents deviation from steady state and x-axis represents quarters

We notice in figures 7 and 8 that output does not increase immediately at shock impact under Taylor rule with MaPs, unlike under the ATR case. However, in both cases, output picks up after the first quarter and achieves a similar peak as observed under ATR. Credit remains relatively subdued under the presence of MaP rules and bank leverage is stable in the economy. Additionally, a rise in asset prices and currency appreciation is relatively moderate. We find that the economy observe lesser investment and currency appreciation under MaP1 rule at the TFP shock impact. The economic performance under the two MaPs rules are closely similar under the TFP shock.

Figure 8: Impulse response function to a 1% positive shock to TFP A_t)



Note: y-axis represents deviation from steady state and x-axis represents quarters

Altogether, we find that MaPs implemented with simple Taylor rule allows the economy to pick up output and investment growth gradually as is the case under ATR policy whereas they keep a check on excess lending and asset price bubbles. Since EMEs are prone to external and internal shocks at regular intervals, MaPs seem to contribute to absorbing the shock effectively during bad times and gradually allow the economy to obtain its growth objective during good times while keeping a check over extreme volatility in financial markets.

5 Welfare evaluation

The previous analysis shows that monetary policy and its interaction with macroprudential regulation minimize macroeconomic and financial distortions of the economy and maximize welfare under domestic and external shocks. In this part of analysis, we consider four policy responses (TR, ATR, TR+MaP1 and TR+MaP2 rule) whose objective is to maximize the welfare of the household conditional on the steady-state of the model economy. To assess their relative performance, we compute welfare costs associated with each policy scenario relative to the time-invariant equilibrium of the optimal Ramsey policy case following Schmitt-Grohé and Uribe 2007 and Faia and Monacelli 2007. More precisely, we calculate the welfare cost in the form of consumption equivalence using a second-order approximation of the felicity function under two different policy regimes (Schmitt-Grohé and Uribe 2004; Schmitt-Grohé and Uribe 2007). In other words, the welfare cost represents the fraction of consumption (%) required to equate welfare under a particular policy scenario to the one provided under the benchmark optimal Ramsey policy case in the face of a particular shock. We conduct a second-order approximation for the welfare evaluation specifically because the mean value of the endogenous variables are equal to their deterministic steady-state values under first-order approximation, resulting in the same aggregate welfare under a policy scenario.

To conduct welfare cost/loss analysis, we first calculate aggregate welfare with time-invariant equilibrium under the Ramsey policy as the lifetime utility conditional on the state of the economy at time 0 in the following form -

$$V_0^{RP} = E_0 \sum_{s=0}^{\infty} \beta^t U(C_t^{RP}, L_t^{RP}) \tag{66}$$

where E_0 is the conditional expectation at time period 0, C_t^{RP} and L_t^{RP} refer to contingent plans of consumption and labor under the Ramsey policy. Second, we calculate aggregate welfare under an alternative policy regime conditional on the initial steady-state 0 as -

$$V_0^{AP} = E_0 \sum_{s=0}^{\infty} \beta^t U(C_t^{AP}, L_t^{AP}) \tag{67}$$

Where C_t^{AP} and L_t^{AP} are contingent plans of consumption and labor under an alternative policy regime. Further, we define λ^w as the welfare cost of implementing an alternative policy regime instead of the Ramsey policy. λ^w denotes the welfare cost as a fraction of the consumption that the household needs to forgo under Ramsey policy (RP) regime to remain indifferent to an alternative policy regime (AP). Therefore, we can redefine V_0^{AP} with λ^w as -

$$V_0^{AP} = E_0 \sum_{s=0}^{\infty} \beta^t U((1-\lambda_w)C_t^{RP}, L_t^{RP}) \tag{68}$$

A positive value of λ_w suggests that there is a welfare loss associated with an alternative policy regime relative to Ramsey policy. A higher value of λ_w suggests a larger welfare loss under the given policy regime and that the policy is less desirable from a welfare perspective. In this setup, we express aggregate welfare in a recursive form for the calculation of λ_w following the approach of Gertler and Karadi 2011; Schmitt-Grohé and Uribe 2004-

$$V_{0,t} = U(C_t, L_t) + \beta E_t V_{0,t+1} \approx \overline{V_0} + 0.5\Delta(V_0) \tag{69}$$

Where $\overline{V_0}$ is the welfare at the deterministic steady-state and $\Delta(V_0)$ is the constant correction term under second-order approximation which represents the second-order derivative of the policy function with respect to the variance of the shock.

To compare alternative policy rules with the Ramsey policy regime in terms of welfare cost, we numerically search for optimal parameters for monetary policy rules. The optimized rules are quite effective as they provide welfare levels that are close to Ramsey policy (Schmitt-Grohé and Uribe 2007). To obtain optimal parameters, we run a grid search for alternative policy rules over the intervals $\rho_r \in$ [0,1] and θ_π, θ_Y and $\theta_e \in$ [0,3]. We select the boundary points of the parameters as per the literature and technical constraints. Appendix B lists optimal parameters for monetary policy rules.

Table 2 displays consumption equivalent welfare loss in operating the economy under four different policy regimes (TR, ATR, TR+MaP1, and TR+MaP2) relative to Ramsey optimal policy under the three different shocks; Foreign interest rate, domestic net worth and technology shock. Our main finding is that Taylor rule combined with macroprudential rules is the most effective under each shock since welfare loss is the lowest in these cases. The model economy under ATR policy performs worst under each shock since welfare loss is the highest under this case.

We also observe that welfare loss is the highest when foreign interest rate shock hits the economy whereas it is the least under domestic net worth shock. The worst performance under the augmented Taylor rule suggests that EMEs' central bank should avoid using

Table 2: Welfare loss under different policy regimes

Policy regime	Welfare loss (%)
Foreign interest shock	
Ramsey policy	-
Simple Taylor rule	0.01023
Augumented Taylor rule (with exchange rate)	0.03212
Taylor rule with MaP1	0.00441
Taylor rule with MaP2	0.00441
Domestic net worth shock	
Ramsey policy	-
Simple Taylor rule	0.00192
Augumented Taylor rule (with exchange rate)	0.00218
Taylor rule with MaP1	0.00049
Taylor rule with MaP2	0.00049
Productivity shock	
Optimal Ramsey policy	-
Simple Taylor rule	0.00953
Augumented Taylor rule (with exchange rate)	0.02594
Taylor rule with MaP1	0.00397
Taylor rule with MaP2	0.00397

interest rate adjustment under such a shock and choose macroprudential regulation to stabilize the economy. On the other hand, MaPs with the Taylor rule seem to minimize welfare loss under a positive productivity shock which suggests that MaPs remain effective during a positive technological shock and they help to avoid overheating the economy as seen in the previous section. Altogether, the performance of MaP1 and MaP2 remains almost similar and are highly effective in minimizing welfare loss under different shocks. Our findings suggest that the interaction of macroprudential regulation with monetary policy is beneficial for a small open economy similar to EMEs and that it plays an important role in macroeconomic stabilization under external and domestic shocks.

6 Conclusion

One of the important lessons from the recent global financial crisis (2008) and taper tantrum episode (2013) is to make financial stability the cornerstone of macroeconomic management. The financial imbalances built up post-GFC and the recurrent volatility due to high volatility in cross border flows expose the inadequacy of monetary policy in maintaining macroeconomic stability in emerging economies. In light of this, risk-prone countries need an effective policy tool to target financial stability as an additional objective. There is a growing consensus that MaPs can become an additional tool to target financial stability and correct financial imbalances while monetary policy focuses on price and output stability. MaPs are mainly important to ex-ante mitigate risks during an economic boom and build countercyclical buffers to deal with shocks in the case of economic downturns ex-post.

This paper presents an open economy NK DSGE model with a financial intermediary that attracts cross border inflows in the form of foreign borrowing to assess the role of macro-prudential regulation and monetary policy in macroeconomic stabilization. We build the model to conduct policy simulations and welfare analysis and find that macroprudential regulation is complementary to monetary policy to maintain economic stability and reduces welfare loss under external and domestic shocks. We find that a combination of MaPs with simple interest rate rules is relatively more effective compared to ATR policy that adjusts policy rates in response to exchange rate volatility during a shock. The policy combination can be effective to reducing negative spillover due to interest rate fluctuations in AEs. We further find that MaPs are also effective instruments to deal with a domestic banking crisis. When MaPs are in place to discourage riskier capital inflows, the economy experiences a smaller decline in foreign borrowing and output in response to a net worth shock.

We also find that MaPs are not contractionary in nature during a positive productivity shock. Instead of being adversely affected, the economy experiences a moderate and sustained rise in the business cycle in the presence of MaPs in this case.. We complemented the IRF analysis with welfare evaluation to find that EMEs with MaPs and simple TR observe least welfare losses under each shock compared to the only ATR policy case. The least welfare loss occurs under a domestic net worth shock whereas the largest welfare loss happens during a foreign interest rate shock. Welfare analysis further provide evidences that EMEs generally observe relatively larger losses during an external shock and MaPs are an important and effective instrument to contain risks during such a scenario.

Countercyclical macroprudential regulation as capital regulation tax is an effective instrument in the presence of a simple monetary policy rule to discourage excessive cross border flows and excess leverage buildup. It is highly effective under various types of shocks and our analysis clearly emphasizes that its role is complementary to monetary policy. However, such policies face constraints in the real world where they cannot perfectly target their objectives or completely offset economic distortions. Institutions and market infrastructures of EMEs are typically imperfect and they face time inconsistency and political economy constraints for effective policymaking. In such an economic environment, policy coordination between monetary policy and macroprudential regulation becomes highly important for better economic outcomes. We need better institutional design to distinguish between the two policy functions without crossing each other's mandate through separate decision-making, communication and accountability among policymakers. It is also understood that there is a potential trade-off in using countercyclical policies due to lower output in the medium term, EME policymakers may need to choose whether they should adopt such policies judiciously to minimize macroeconomic risks given the circumstances in the global and domestic economy and the nature of the shocks.

References

Agénor, Pierre-Richard, Koray Alper, and Luiz A Pereira da Silva. 2014. "Sudden floods, macroprudential regulation and stability in an open economy." *Journal of International Money and Finance* 48:68–100.

Aguiar, Mark, and Gita Gopinath. 2007. "Emerging market business cycles: The cycle is the trend." *Journal of Political Economy* 115 (1): 69–102.

Ahnert, Toni, Kristin Forbes, Christian Friedrich, and Dennis Reinhardt. 2018. *Macroprudential FX regulations: shifting the snowbanks of FX vulnerability?* NBER Working Paper 25083. National Bureau of Economic Research.

Aiyar, Shekhar, Charles W Calomiris, and Tomasz Wieladek. 2014. "Does macro-prudential regulation leak? Evidence from a UK policy experiment." *Journal of Money, Credit and Banking* 46 (s1): 181–214.

Alpanda, Sami, Gino Cateau, and Césaire Meh. 2018. "A policy model to analyze macroprudential regulations and monetary policy." *Canadian Journal of Economics/Revue canadienne d'économique* 51 (3): 828–863.

Amato, Jeffery D, and Stefan Gerlach. 2002. "Inflation targeting in emerging market and transition economies: Lessons after a decade." *European Economic Review* 46 (4-5): 781–790.

Angeloni, Ignazio, Ester Faia, and Marco Lo Duca. 2015. "Monetary policy and risk taking." *Journal of Economic Dynamics and Control* 52:285–307.

Avdjiev, Stefan, Robert N McCauley, and Patrick McGuire. 2012. *Rapid credit growth and international credit: challenges for Asia.* BIS Working Papers 377. Bank for International Settlements.

Avdjiev, Stefan, and Előd Takáts. 2014. "Cross-border bank lending during the taper tantrum: the role of emerging market fundamentals." *BIS Quarterly Review September.*

Bakker, Bas B., Giovanni Dell'ariccia, Luc Laeven, Jérôme Vandenbussche, Deniz Igan, and Hui Tong. 2012. *Policies for Macrofinancial Stability; How to Deal with Credit Booms.* IMF Staff Discussion Notes 12/06. International Monetary Fund.

Baskaya, Yusuf Soner, Julian Di Giovanni, Şebnem Kalemli-Özcan, José-Luis Peydró, and Mehmet Fatih Ulu. 2017. "Capital flows and the international credit channel." *Journal of International Economics* 108:S15–S22.

Berganza, Juan Carlos, and Carmen Broto. 2012. "Flexible inflation targets, forex interventions and exchange rate volatility in emerging countries." *Journal of International Money and Finance* 31 (2): 428–444.

Bernanke, Ben, and Mark Gertler. 2000. *Monetary Policy and Asset Price Volatility.* NBER Working Paper 7559. National Bureau of Economic Research.

Borio, Claudio. 2003. "Towards a macroprudential framework for financial supervision and regulation?" *CESifo Economic Studies* 49 (2): 181–215.

Borio, Claudio, Philip Lowe, et al. 2002. "Assessing the risk of banking crises." *BIS Quarterly Review* 7 (1): 43–54.

Cecchetti, Stephen G. 2008. "Measuring the macroeconomic risks posed by asset price booms." In *Asset Prices and Monetary Policy,* 9–43. University of Chicago Press.

Cetorelli, Nicola, and Linda S Goldberg. 2012. "Banking globalization and monetary transmission." *The Journal of Finance* 67 (5): 1811–1843.

Chari, Varadarajan V, and Patrick J Kehoe. 2016. "Bailouts, time inconsistency, and optimal regulation: A macroeconomic view." *American Economic Review* 106 (9): 2458–93.

Claessens, Stijn. 2015. "An Overview of Macroprudential Policy Tools." *Annual Review of Financial Economics* 7 (1): 397–422.

———. 2013. "Interactions between monetary and macroprudential policies in an interconnected world." In *Bank of Thailand-IMF conference on Monetary Policy in an Interconnected World, Bangkok,* vol. 31.

Claessens, Stijn, Mr M Ayhan Kose, Mr Luc Laeven, and Fabian Valencia. 2014. "Policies for Macro-Financial Stability: Dealing with Credit Booms and Busts." In *Financial Crises : Causes, Consequences, and Policy Responses.* Internatinal Monetary Fund.

Cociuba, Simona E, Malik Shukayev, and Alexander Ueberfeldt. 2012. *Do low interest rates sow the seeds of financial crises?* EPRI Working Paper 2012-1. Economic Policy Research Institute (EPRI), Department of Economics, University of Western Ontario.

———. 2019. "Managing risk taking with interest rate policy and macroprudential regulations." *Economic Inquiry* 57 (2): 1056–1081.

Crockett, Andrew. 2000. *Marrying the micro-and macro-prudential dimensions of financial stability.* speech.

Cuadra, Gabriel, and Victoria Nuguer. 2018. "Risky banks and macro-prudential policy for emerging economies." *Review of Economic Dynamics* 30:125–144.

Ehlers, Torsten, and Patrick McGuire. 2017. "Foreign banks and credit conditions in EMEs." *BIS Paper,* no. 91d.

Ehlers, Torsten, and Agustín Villar. 2015. "The role of banks." In *What do new forms of finance mean for EM central banks?,* edited by Bank for International Settlements, 82:9–40. Bank for International Settlements.

Faia, Ester, and Tommaso Monacelli. 2007. "Optimal interest rate rules, asset prices, and credit frictions." *Journal of Economic Dynamics and control* 31 (10): 3228–3254.

Farhi, Emmanuel, and Jean Tirole. 2012. "Collective moral hazard, maturity mismatch, and systemic bailouts." *American Economic Review* 102 (1): 60–93.

Forbes, Kristin, Marcel Fratzscher, and Roland Straub. 2015. "Capital-flow management measures: What are they good for?" *Journal of International Economics* 96:S76–S97.

Forbes, Kristin J. 2019. "Macroprudential Policy: What We've Learned, Don't Know, and Need to Do." In *AEA Papers and Proceedings,* 109:470–75.

Gabriel, Vasco, Paul Levine, Joseph Pearlman, Bo Yang, et al. 2010. *An estimated DSGE model of the Indian economy.* NIPE Working Papers 29/2010. NIPE - Universidade do Minho.

Galati, Gabriele, and Richhild Moessner. 2013. "Macroprudential policy–a literature review." *Journal of Economic Surveys* 27 (5): 846–878.

Gali, Jordi, and Tommaso Monacelli. 2005. "Monetary policy and exchange rate volatility in a small open economy." *The Review of Economic Studies* 72 (3): 707–734.

Gertler, Mark, Simon Gilchrist, and Fabio M Natalucci. 2007. "External constraints on monetary policy and the financial accelerator." *Journal of Money, Credit and Banking* 39 (2-3): 295–330.

Gertler, Mark, and Peter Karadi. 2011. "A model of unconventional monetary policy." *Journal of Monetary Economics* 58 (1): 17–34.

Gertler, Mark, and Nobuhiro Kiyotaki. 2010. "Financial intermediation and credit policy in business cycle analysis." In *Handbook of Monetary Economics,* 3:547–599. Elsevier.

Goyal, Ashima. 2015. "External shocks." In *India Development Report,* edited by Mahendra Dev. New Delhi: IGIDR / Oxford University Press. http://www.igidr.ac.in/pdf/publication/WP-2014-046.pdf.

IMF. 2012. *The Interaction of Monetary and Macroprudential Policies.* IMF Policy Paper. International Monetary Fund.

IMF-FSB-ISB. 2016. *Elements of Effective Macroprudential Policies. Lessons from International Experience.* Technical report.

Ireland, Peter N. 2001. "Sticky-price models of the business cycle: Specification and stability." *Journal of Monetary Economics* 47 (1): 3–18.

Jeanne, Olivier, and Anton Korinek. 2010. *Managing credit booms and busts: A Pigouvian taxation approach.* NBER Working Paper 16377. National Bureau of Economic Research.

Korinek, Anton. 2009. "Systemic risk-taking: Amplification effects, externalities, and regulatory responses. University of Maryland." *Unpublished Manuscript.*

Mendoza, Mr Enrique G, and Javier Bianchi. 2011. *Overborrowing, Financial Crises and 'Macro-Prudential'Policy?*, 11-24. International Monetary Fund.

Miranda-Agrippino, Silvia, and Hélene Rey. 2015. *US monetary policy and the global financial cycle.* NBER Working Paper 21722. National Bureau of Economic Research.

Ozkan, F. Gulcin, and Filiz D Unsal. 2014. *On the use of Monetary and Macroprudential Policies for Small Open Economies.* IMF Working Papers 14/112. International Monetary Fund.

Quint, Dominic, and Pau Rabanal. 2014. "Monetary and Macroprudential Policy in an Estimated DSGE Model of the Euro Area." *International Journal of Central Banking* 10 (2): 169–236.

Rey, Hélène. 2015. *Dilemma not Trilemma: The Global Financial Cycle and Monetary Policy Independence.* NBER Working Paper 21162. National Bureau of Economic Research.

Rotemberg, Julio J. 1982. "Sticky prices in the United States." *Journal of Political Economy* 90 (6): 1187–1211.

Schmitt-Grohé, Stephanie, and Martın Uribe. 2003. "Closing small open economy models." *Journal of international Economics* 61 (1): 163–185.

Schmitt-Grohé, Stephanie, and Martin Uribe. 2007. "Optimal simple and implementable monetary and fiscal rules." *Journal of Monetary Economics* 54 (6): 1702–1725.

Schmitt-Grohé, Stephanie, and Martın Uribe. 2004. "Solving dynamic general equilibrium models using a second-order approximation to the policy function." *Journal of Economic Dynamics and Control* 28 (4): 755–775.

Senay, Ozge. 2008. "Interest rate rules and welfare in open economies." *Scottish Journal of Political Economy* 55 (3): 300–329.

Takáts, Előd, and Judit Temesvary. 2017. "Can macroprudential measures make cross-border lending more resilient? Lessons from the taper tantrum."

Taylor, John B. 2009. *The financial crisis and the policy responses: An empirical analysis of what went wrong.* NBER Working Paper 14631. National Bureau of Economic Research.

———. 2001. "The role of the exchange rate in monetary-policy rules." *American Economic Review* 91 (2): 263–267.

Temesvary, Judit, Steven Ongena, and Ann L Owen. 2018. "A global lending channel unplugged? Does US monetary policy affect cross-border and affiliate lending by global US banks?" *Journal of International Economics* 112:50–69.

Unsal, D. Filiz. 2013. "Capital Flows and Financial Stability: Monetary Policy and Macroprudential Responses." *International Journal of Central Banking* 9 (1): 233–285.

A Mathematical appendix

A.1 Consumption good composition

Consumption good basket for domestic economy consists of consumption of domestically produced good and imported good from the rest of the world and it is given as -

$$C_t = \left[w_c^{\frac{1}{\mu c}} C_{Ht}^{\frac{\mu c-1}{\mu c}} + (1-w_c)^{\frac{1}{\mu c}} C_{F,t}^{\frac{\mu c-1}{\mu c}} \right]^{\frac{\mu c}{\mu c-1}} \tag{E.1}$$

Domestic economy face budget constraint -$P_{Ht}C_{Ht} + P_{Ft}C_{Ft} = M_t$ where M_t is total expenditure of the domestic economy to consume C_{Ht} and C_{Ft}. To obtain optimal bundle of C_{Ht} and C_{Ft}, we maximize the consumption good basket subject to the budget constraint. Optimization set up is given as -

$$\max_{(C_{Ht}, C_{Ft})} \left[w_c^{\frac{1}{\mu c}} C_{Ht}^{\frac{\mu c-1}{\mu c}} + (1-w_c)^{\frac{1}{\mu c}} C_{F,t}^{\frac{\mu c-1}{\mu c}} \right]^{\frac{\mu c}{\mu c-1}} + \lambda_t [M_t - P_{Ht}C_{Ht} + P_{Ft}C_{Ft}] \tag{E.2}$$

$$C_{Ht}: \left[w_c^{\frac{1}{\mu c}} C_{Ht}^{\frac{\mu c-1}{\mu c}} + (1-w_c)^{\frac{1}{\mu c}} C_{F,t}^{\frac{\mu c-1}{\mu c}} \right]^{\frac{1}{\mu c-1}} w_c^{\frac{1}{\mu c}} C_{Ht}^{-\frac{1}{\mu c}} = \lambda_t P_{Ht}$$

$$\implies C_{Ht}^{\frac{-1}{\mu c}} w_c^{\frac{1}{\mu c}} C_{Ht}^{-\frac{1}{\mu c}} = \lambda_t P_{Ht}$$

$$\implies C_{Ht} = \lambda_t w_c (P_{Ht})^{-\mu_c} C_t$$

Similarly,

$$C_{Ft} = \lambda_t (1-w_c)(P_{Ft})^{-\mu_c} C_t$$

Ratio of C_{Ht} and C_{Ft} provides -

$$\frac{C_{Ht}}{C_{Ft}} = \frac{w_c}{1-w_c} \left(\frac{P_{Ht}}{P_{Ft}} \right)^{-\mu_c} \implies C_{Ht} = \frac{w_c}{1-w_c} \left(\frac{P_{Ht}}{P_{Ft}} \right)^{-\mu_c} C_{Ft}$$

Replacing the value of C_{Ht} in the consumption basket equation above, we get -

$$C_t = \left[w_c^{\frac{1}{\mu c}} \left\{ \frac{w_c}{1-w_c} \left(\frac{P_{Ht}}{P_{Ft}} \right)^{-\mu_c} C_{Ft} \right\}^{\frac{\mu c}{\mu c-1}} + (1-w_c)^{\frac{1}{\mu c}} C_{F,t}^{\frac{\mu c-1}{\mu c}} \right]^{\frac{\mu c}{\mu c-1}}$$

$$= \left[w_c^{\frac{1}{\mu c}} \left\{ \left(\frac{w_c}{1-w_c} \right)^{\frac{\mu c}{\mu c-1}} \left(\frac{P_{Ht}}{P_{Ft}} \right)^{1-\mu_c} C_{Ft}^{\frac{\mu c}{\mu c-1}} \right\} + (1-w_c)^{\frac{1}{\mu c}} C_{F,t}^{\frac{\mu c-1}{\mu c}} \right]^{\frac{\mu c}{\mu c-1}}$$

$$C_t^{\frac{\mu c-1}{\mu c}} = \left[w_c (1-w_c)^{\frac{1-\mu c}{\mu c}} \left(\frac{P_{Ht}}{P_{Ft}} \right)^{1-\mu_c} C_{Ft}^{\frac{\mu c}{\mu c-1}} + (1-w_c)^{\frac{1}{\mu c}} C_{F,t}^{\frac{\mu c-1}{\mu c}} \right]$$

$$= \left[(1-w_c)^{\frac{1-\mu_c}{\mu c}} C_{F,t}^{\frac{\mu c-1}{\mu c}} P_{Ft}^{\mu_c-1} \left\{ w_c P_{Ht} + (1-w_c) P_{Ft}^{1-\mu_c} \right\} \right]$$

$$C_t^{\frac{\mu c-1}{\mu c}} = \left[(1-w_c)^{\frac{1-\mu_c}{\mu c}} C_{F,t}^{\frac{\mu c-1}{\mu c}} P_{Ft}^{\mu_c-1} \left\{ P_t \right\}^{1-\mu_c} \right]$$

where $P_t = \left\{ w_c P_{Ht}^{1-\mu_c} + (1-w_c) P_{Ft}^{1-\mu_c} \right\}^{\frac{1}{1-\mu_c}}$. We further rearrange the terms to find -

$$C_t = C_{Ft} P_{Ft}^{\mu_c} (1-w_c)^{-1} P_t^{-\mu_c}$$

$$\implies C_{Ft} = (1-w_c) \left(\frac{P_{Ft}}{P_t} \right)^{-\mu_c} C_t \tag{E.3}$$

$$\text{similarly, } C_{Ht} = w_c \left(\frac{P_{Ht}}{P_t} \right)^{-\mu_c} C_t \tag{E.4}$$

Putting the values of C_{Ht} and C_{Ft} in the budget constraint equation ($P_{Ht}C_{Ht} + P_{Ft}C_{Ft} = M_t = P_tC_t$), we get -

$$P_{Ht} w_c \left(\frac{P_{Ht}}{P_t} \right)^{-\mu_c} C_t + P_{Ft}(1-w_c) \left(\frac{P_{Ft}}{P_t} \right)^{-\mu_c} C_t = P_t C_t$$

After rearranging terms, we get similar pricing condition as above - -

$$P_t = \left\{w_c P_{Ht}^{1-\mu_c} + (1-w_c) P_{Ft}^{1-\mu_c}\right\}^{\frac{1}{1-\mu_c}}$$

$$\Longrightarrow 1 = \left\{w_c \left(\frac{P_{Ht}}{P_t}\right)^{1-\mu_c} + (1-w_c)\left(\frac{P_{Ft}}{P_t}\right)^{1-\mu_c}\right\}^{\frac{1}{1-\mu_c}}$$

Using conditions, $\frac{P_{Ht}}{P_t} = p_t$ and $\frac{P_{Ft}}{P_t} = rer_t$, we get -

$$\Longrightarrow 1 = \left\{w_c p_{Ft}^{1-\mu_c} + (1-w_c) rer_t^{1-\mu_c}\right\}^{\frac{1}{1-\mu_c}} \tag{E.5}$$

On similar lines, pricing condition (CPI inflation) for rest of the world (foreign economy) is -

$$P_t^* = \left\{(1-w_c^*) P_{Ht}^{*(1-\mu_c^*)} + w_c^* P_{Ft}^{*(1-\mu_c^*)}\right\}^{\frac{1}{1-\mu_c^*}} \tag{E.6}$$

Based on this, the export of domestic consumption goods to the foreign economy is given as (the derivation is on the lines of the domestic economy) -

$$C_{Ht}^* = (1-w_c^*)\left(\frac{P_{Ht}^*}{P_t^*}\right)^{-\mu_c^*} C_t^*$$

Relation between price of domestic good in foreign prices and domestic prices in given as - $P_{Ht} = e_t P_{Ht}^*$. We use this condition to find -

$$C_{Ht}^* = (1-w_c^*)\left(\frac{P_{Ht}}{e_t P_t^*}\right)^{-\mu_c^*} C_t^*$$

$$\Longrightarrow C_{Ht}^* = (1-w_c^*)\left(\frac{P_{Ht}}{P_t}\frac{P_t}{e_t P_t^*}\right)^{-\mu_c^*} C_t^*$$

$$C_{Ht}^* = (1-w_c^*)\left(\frac{P_{Ht}}{P_t rer_t}\right)^{-\mu_c^*} C_t^* \tag{E.7}$$

We can do similar derivations for the different kind of investment goods - domestic consumption, foreign import and export (I_{Ht}, I_{Ft} and I^*_{Ht})

A.2 Households

Household maximizes the utility function -

$$U(C_t, L_t) = E_t \sum_{s=0}^{\infty} \beta^s \left[\frac{(C_{t+s} - h_b C_{t+s-1})^{(1-\sigma_c)}}{1-\sigma_c} - \frac{\chi}{1+\varphi} L_{t+s}^{1+\varphi} \right] \tag{E.8}$$

subject to the budget constraint (BC) -

$$P_t C_t + D_{t+1} = W_t L_t + R_{nt} D_t + \mathit{\Pi}_t - T_t$$

The Lagrange setup for maximization -

$$L = E_t \sum_{s=0}^{\infty} \beta^s \left[U(C_t, L_t] + \lambda_t (BC_t) \right] \tag{E.9}$$

First order conditions for optimal choice of C_t, L_t and D_{t+1}-

$$C_t : \qquad \frac{(1-\sigma c)(C_t - h_b C_{t-1})^{-\sigma_c}}{(1-\sigma_c)} - \lambda_t P_t - h_b \beta \frac{(1-\sigma c)(C_t - h_b C_{t-1})^{-\sigma_c}}{(1-\sigma_c)} = 0 \tag{E.10}$$

$$L_t : \qquad \frac{-\xi(1+\varphi)}{(1+\varphi)} L_t^{\varphi} + \lambda_t W_t = 0 \tag{E.11}$$

$$D_{t+1} : \qquad -\lambda_t + \lambda_{t+1} R_{nt+1} = 0 \tag{E.12}$$

$$\Rightarrow \frac{\lambda_t}{\lambda_{t+1}} = R_{nt+1} \tag{E.13}$$

Equation (E.10) becomes -

$$(C_t - h_b C_{t-1})^{-\sigma_c} - \beta h_b (C_{t+1} - h_b C_t)^{-\sigma_c} = \lambda_t P_t$$

$$\Rightarrow \Lambda_t = \lambda_t P_t \tag{E.14}$$

$$\text{where,} \qquad (C_t - h_b C_{t-1})^{-\sigma_c} - \beta h_b (C_{t+1} - h_b C_t)^{-\sigma_c} = \Lambda_t$$

We can write equation (E.14) as -

$$\lambda_t = \frac{\Lambda_t}{P_t};\ \lambda_{t+1} = \frac{\Lambda_{t+1}}{P_{t+1}}$$

$$\Longrightarrow \frac{\lambda_{t+1}}{\lambda_t} = \frac{\Lambda_{t+1} P_t}{\Lambda_t P_{t+1}}$$

We can use this condition in equation (E.13), we get -

$$\frac{1}{R_{nt+1}} = \frac{\Lambda_{t+1}}{\Lambda_t \pi_{t+1}} \tag{E.15}$$

For optimal condition of labor, we arrange equation (E.11) to get -

$$\chi L_t = \lambda_t W_t$$

Using equation (E.14) in equation (E.11) provides optimizing condition for labor as-

$$\frac{W_t}{P_t} = \frac{\chi L_t}{\Lambda_t}$$

A.3 Intermediate goods producers

There is a continuum of intermediate good firms that produce differentiated wholesale product $Y_t(i)$ using constant returns to scale technology given as -

$$Y_i(i) = A_t L_t^{\alpha}(i) K_t^{1-\alpha}(i) \tag{E.16}$$

Intermediate good firms solve two-stage problem. In the first stage, they minimize total cost to obtain optimal factor demands by symmetric cost minimization problem. Total cost consists of three parts - (1) Capital purchase from capital good producers at the end of period t-1 to be used in period t and rent paid on it ($r_{kt}Q_{t-1}K_t$). (2) Labor wages (w_tL_t) and (3) Net earnings on selling the undepreciated capital back to capital good producer at the end of period t ($Q_t(1-\delta)K_t - Q_{t-1}K_t$). Therefore, cost minimization problem for the firms is -

$$\min_{K_t,L_t} [r_{kt}Q_{t-1}K_t + w_tL_t - (Q_t(1-\delta)K_t - Q_{t-1}K_t)] + \lambda_t[Y_t - A_tL_t^{\alpha}K_t^{1-\alpha}] \tag{E.17}$$

First order conditions for optimal labor and capital are given as -

$$L_t: \quad w_t = \lambda_t\alpha A_tL_t^{\alpha-1}K_t^{1-\alpha} = \lambda_t\alpha\frac{Y_t}{L_t}$$

$$K_t: \quad r_{kt}Q_{t-1} - (Q_t(1-\delta) - Q_{t-1}) = \lambda_t(1-\alpha)\frac{Y_t}{K_t}$$

Lagrange multiplier can be alternatively interpreted as a marginal cost because it refers to an increase in total cost due to marginal change in output. Hence,

$$\lambda_t = mc_t$$

$$\implies w_t = mc_t\frac{\alpha Y_t}{L_t} \tag{E.18}$$

$$\implies r_{kt}Q_{t-1} - (Q_t(1-\delta) - Q_{t-1}) = mc_t(1-\alpha)\frac{Y_t}{K_t}$$

After rearranging the terms, we get -

$$(1+r_{kt}) = R_{kt} = \frac{mc_t(1-\alpha)\frac{Y_t}{K_t} + (1-\delta)Q_t}{Q_{t-1}} \tag{E.19}$$

In the second stage, the firm choose prices to maximize the discounted real profits given as -

$$E_t\left[\sum_{j=0}^{\infty}\beta^j\frac{\Lambda_{t+j}}{\Lambda_t}\left\{\frac{P_{Ht+j}(i)}{P_{t+j}}Y_{Ht+j}(i)-mc_{t+j}(i)Y_{Ht+j}(i)-AdjC_{t+j}(i)\right\}\right] \tag{E.20}$$

where adjustment cost and output for an intermediate good firm is -

$$AdjC_t(i)=\frac{\kappa}{2}\left(\frac{P_{Ht}(i)}{P_{Ht-1}(i)}-\bar{\pi}_H\right)^2 P_{Ht}Y_{Ht} \; and \; Y_{Ht(i)}=\left(\frac{P_{Ht(i)}}{P_{Ht}}\right)^{-\zeta}Y_{Ht}$$

Using these condition in equation (E.20) provides -

$$\begin{aligned}E_t\Bigg[\sum_{j=0}^{\infty}\beta^j\frac{\Lambda_{t+j}}{\Lambda_t}\Bigg\{&\frac{P_{Ht+j}(i)}{P_{t+j}}\left(\frac{P_{Ht+j}(i)}{P_{Ht+j}}\right)^{-\zeta}Y_{Ht+j}-mc_{t+j}(i)\left(\frac{P_{Ht+j}(i)}{P_{Ht+j}}\right)^{-\zeta}Y_{Ht+j}\\ &-\frac{\kappa}{2}\left(\frac{P_{Ht+j}(i)}{P_{Ht+j-1}(i)}-\bar{\pi}_H\right)^2P_{Ht+j}Y_{Ht+j}\Bigg\}\Bigg]\end{aligned} \tag{E.21}$$

First order condition with respect to $P_{Ht}(i)$ is given as -

$$\begin{aligned}P_{Ht}(i): \quad & -\zeta\frac{P_{Ht}(i)}{P_t}\left(\frac{P_{Ht}(i)}{P_{Ht}}\right)^{-\zeta-1}\frac{Y_{Ht}}{P_{Ht}}+\zeta mc_t\left(\frac{P_{Ht}(i)}{P_{Ht}}\right)^{-\zeta-1}\frac{Y_{Ht}}{P_{Ht}}+\left(\frac{P_{Ht}(i)}{P_{Ht}}\right)^{-\zeta}\frac{Y_{Ht}}{P_t}\\ & -\kappa\left(\frac{P_{Ht}(i)}{P_{Ht-1}(i)}-\bar{\pi}_H\right)\frac{P_{Ht}Y_{Ht}}{P_{Ht-1}(i)P_t}\\ & +\beta\left[\frac{\Lambda_{t+1}}{\Lambda_t}\kappa\left(\frac{P_{Ht+1}(i)}{P_{Ht}}-\bar{\pi}_H\right)\frac{P_{Ht+1}(i)}{P_{Ht}^2(i)}\frac{P_{Ht+1}Y_{Ht+1}}{P_{t+1}}\right]=0\end{aligned}$$

$$\begin{aligned}\implies (1-\zeta)\left(\frac{P_{Ht}(i)}{P_{Ht}}\right)^{-\zeta}\frac{Y_{Ht}}{P_t}+\zeta mc_t\left(\frac{P_{Ht}(i)}{P_{Ht}}\right)^{-\zeta-1}\frac{Y_{Ht}}{P_{Ht}}-\kappa\left(\frac{P_{Ht}(i)}{P_{Ht-1}(i)}-\bar{\pi}_H\right)\frac{P_{Ht}Y_{Ht}}{P_{Ht-1}(i)P_t}\\ +\beta\left[\frac{\Lambda_{t+1}}{\Lambda_t}\kappa\left(\frac{P_{Ht+1}(i)}{P_{Ht}}-\bar{\pi}_H\right)\frac{P_{Ht+1}(i)}{P_{Ht}^2(i)}\frac{P_{Ht+1}Y_{Ht+1}}{P_{t+1}}\right]=0\end{aligned}$$

Imposing symmetric equilibrium, where $\mathrm{P}_{Ht}(i) = P_{HT}$, we get -

$$\implies (1-\zeta)\frac{Y_{Ht}}{P_t} + \zeta mc_t \frac{Y_{Ht}}{P_{Ht}} - \kappa\left(\frac{P_{Ht}}{P_{Ht-1}} - \bar{\pi}_H\right)\frac{P_{Ht}Y_{Ht}}{P_{Ht-1}P_t}$$

$$+ \beta\left[\frac{\Lambda_{t+1}}{\Lambda_t}\kappa\left(\frac{P_{Ht+1}}{P_{Ht}} - \bar{\pi}_H\right)\frac{P_{Ht+1}}{P_{Ht}}\frac{P_{Ht+1}Y_{Ht+1}}{P_{t+1}P_{Ht}}\right] = 0$$

Divide both sides by $\frac{Y_{Ht}}{P_t}$and $\frac{P_{Ht}}{P_t} = p_t$

$$\implies (1-\zeta)+\zeta\frac{mc_t}{p_{Ht}}-\kappa\left(\frac{P_{Ht}}{P_{Ht-1}} - \bar{\pi}_H\right)\frac{P_{Ht}}{P_{Ht-1}}+\beta\left[\frac{\Lambda_{t+1}}{\Lambda_t}\kappa\left(\frac{P_{Ht+1}}{P_{Ht}} - \bar{\pi}_H\right)\frac{P_{Ht+1}}{P_{Ht}}\frac{p_{Ht+1}Y_{Ht+1}}{p_{Ht}Y_{Ht}}\right] = 0$$

Taking the value $\frac{P_{Ht}}{P_{Ht-1}} = \pi_{Ht}$, we get

$$\implies (1-\zeta) + \zeta\frac{mc_t}{p_{Ht}} - \kappa\left(\pi_{Ht} - \bar{\pi}_H\right)\pi_{Ht} + \beta\left[\frac{\Lambda_{t+1}}{\Lambda_t}\kappa\left(\pi_{Ht+1} - \bar{\pi}_H\right)\pi_{Ht+1}\frac{p_{Ht+1}Y_{Ht+1}}{p_{Ht}Y_{Ht}}\right] = 0$$

$$\implies \pi_{Ht}(\pi_{Ht} - \bar{\pi}_H)\pi_{Ht} = \beta\left[\frac{\Lambda_{t+1}}{\Lambda_t}\left(\pi_{Ht+1} - \bar{\pi}_H\right)\pi_{Ht+1}\frac{p_{Ht+1}Y_{Ht+1}}{p_{Ht}Y_{Ht}}\right] + \frac{\zeta}{\kappa}\frac{mc_t}{p_{Ht}} + \frac{1-\zeta}{\kappa}$$

Finally, we get -

$$\pi_{Ht}(\pi_{Ht}-\bar{\pi}_H)\pi_{Ht} = \beta\left[\frac{\Lambda_{t+1}}{\Lambda_t}\left(\pi_{Ht+1} - \bar{\pi}_H\right)\pi_{Ht+1}\frac{p_{Ht+1}Y_{Ht+1}}{p_{Ht}Y_{Ht}}\right] + \frac{\zeta}{\kappa}\left[\frac{1-\zeta}{\zeta} + \frac{mc_t}{p_{Ht}}\right] \quad \text{(E.22)}$$

where

$$\pi_{Ht} = \frac{P_{Ht}}{P_{Ht-1}} = \frac{P_{Ht}}{P_t}\frac{P_t}{P_{t-1}}\frac{P_{t-1}}{P_{Ht-1}}$$

$$\implies \pi_{Ht} = \frac{p_{Ht}}{p_{Ht-1}}\pi_t \quad \text{(E.23)}$$

A.4 Final goods producers

The optimization problem for the final goods firms is given as -

$$\max P_{Ht}Y_{Ht} - \int_0^1 P_{Ht}(i)Y_{Ht}(i)di \tag{E.24}$$

subject to

$$Y_{Ht} = \left(\int_0^1 Y_{Ht}(i)^{\frac{\zeta-1}{\zeta}} di\right)^{\frac{\zeta}{\zeta-1}}$$

Replacing the value of Y$_{Ht}$ in the above equation -

$$\max_{Y_{Ht}(i)} P_{Ht}\left(\int_0^1 Y_{Ht}(i)^{\frac{\zeta-1}{\zeta}} di\right)^{\frac{\zeta}{\zeta-1}} - \int_0^1 P_{Ht}(i)Y_{Ht}(i)di \tag{E.25}$$

First order condition with respect to Y$_{Ht}(i)$, we get -

$$P_{Ht}\left(\int_0^1 Y_{Ht}(i)^{\frac{\zeta-1}{\zeta}} di\right)^{\frac{1}{\zeta-1}} - Y_{Ht}(i)^{-\frac{1}{\zeta}} = P_{Ht}(i)$$

$$\implies P_{Ht}Y_{Ht}^{\frac{1}{\zeta}}Y_{Ht}^{-\frac{1}{\zeta}} = P_{Ht}(i)$$

Finally, we get the relation between the output of intermediate good firm and final good firm as -

$$\implies Y_{Ht}(i) = \left(\frac{P_{Ht}(i)}{P_{Ht}}\right)^{-\zeta} Y_{Ht} \tag{E.26}$$

A.5 Capital producers

Capital producer maximizes the expected discounted profits to choose I_t -

$$E_t \sum_{k=0}^{\infty} DS_{t,t+k}\left[Q_{t+k}\left\{1 - g\left(\frac{I_{t+k}}{I_{t+k-1}}\right)\right\} I_{t+k} - I_{t+k}\right]$$

where $DS_{t,t+k}$ is discount factor and it equals to : $\frac{1}{R_{t+k}} = \beta^k \frac{\Lambda t,t+k}{\Lambda_t} \frac{P_t}{P_{t+k}}$.

The first order condition for investment -

$$I_t : DS_{t,t}\left[Q_t\left\{1 - I_t g'\left(\frac{I_t}{I_{t-1}}\right)\frac{1}{I_{t-1}} - g\left(\frac{I_t}{I_{t-1}}\right)\right\} - 1\right]$$

$$+ E_t DS_{t,t,+1}\left[Q_{t+1}\left\{I_{t+1} g'\left(\frac{I_{t+1}}{I_t}\right)\frac{I_{t+1}}{I_t^2}\right\}\right] = 0$$

$$\left[Q_t\left\{1 - \frac{I_t}{I_{t-1}} g'\left(\frac{I_t}{I_{t-1}}\right) - g\left(\frac{I_t}{I_{t-1}}\right)\right\}\right] + E_t DS_{t,t,+1}\left[Q_{t+1}\left\{g'\left(\frac{I_{t+1}}{I_t}\right)\frac{I_{t+1}^2}{I_t^2}\right\}\right] = 1 \tag{E.27}$$

where ,

$$g\left(\frac{I_t}{I_{t-1}}\right) = \frac{\phi_x}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2$$

A.6 Banks

Banks face σ probability to continue in the next period and (1-σ) probability to exit in the next period. We can write the value function as -

$$V_t = E_t \sum_{i=1}^{\infty} (1-\sigma)\sigma^{i-1} \Lambda_{t,t+i} n_{t+i} \tag{E.28}$$

or,

$$V_t = E_t[(1-\sigma)\Lambda_{t,t+1} n_{t+1} + \sigma(1-\sigma)\Lambda_{t,t+2} n_{t+2} + \sigma^2(1-\sigma)\Lambda_{t,t+3} n_{t+3} + ...]$$

where the first term corresponds to the net worth of a bank exiting in the first period, the second term corresponds to the net worth of a bank exiting in the second period and so on. Now -

$$V_t = E_t[(1-\sigma)\Lambda_{t,t+1} n_{t+1} + \sigma(1-\sigma)\Lambda_{t,t+1}\Lambda_{t+1,t+2} n_{t+2} + \sigma^2(1-\sigma)\Lambda_{t,t+1}\Lambda_{t+1,t+3} n_{t+3} + ...]$$

$$= E_t \Lambda_{t,t+1}[(1-\sigma)n_{t+1} + \sigma(1-\sigma)\Lambda_{t+1,t+2}n_{t+2} + \sigma^2(1-\sigma)\Lambda_{t+1,t+3}n_{t+3} + ...]$$

The value function becomes -

$$V_t = E_t \Lambda_{t,t+1}[(1-\sigma)n_{t+1} + \sigma V_{t+1}] \tag{E.29}$$

where,

$$V_{t+1} = E_t \sum_{i=1}^{\infty}(1-\sigma)\sigma^{i-1}\Lambda_{t+1,t+1+i}\, n_{t+1+i}$$

or, we can alternatively write value function as -

$$V(s_t, b_t^*, d_t) = E_t \Lambda_{t,t+1}[(1-\sigma)n_{t+1} + \sigma V(s_{t+1}, b_{t+1}^*, d_{t+1})] \tag{E.30}$$

Bank maximize the value function subjective to borrowing constraint as follows -

$$\max_{(s_{t+1}, b_{t+1^*}, d_{t+1})} V(s_t, b_t^*, d_t) = E_t \Lambda_{t,t+1}\left[(1-\sigma)n_t + \sigma\left\{\max_{(s_{t+1}, b_{t+1^*}, d_{t+1})} V(s_{t+1}, b_{t+1}^*, d_{t+1})\right\}\right] \tag{E.31}$$

subject to -

$$V_t(s_t, b_t^*, d_t) \geq \theta(Q_t s_s - b_t^*) \tag{E.32}$$

Leverage condition -

We guess and verify the linear form of the value function as -

$$V_t = \upsilon_{st} Q_t s_t + \upsilon_{nt} n_t \tag{E.33}$$

Using equation (E.32) and (E.33), we get -

$$\upsilon_{st} Q_t s_t + \upsilon_{nt} n_t = \theta(Q_t s_s - b_t^*) \tag{E.34}$$

since we have d_t and b_t^* -

$$d_t = \eta(Q_t s_t - n_t); \qquad b_t^* = (1-\eta)(Q_t s_t - n_t) \tag{E.35}$$

using value of b_t^*, equation (E.34) becomes -

$$\upsilon_{st} Q_t s_t + \upsilon_{nt} n_t = \theta(Q_t s_s - (1-\eta)(Q_t s_t - n_t))$$

After solving the algebra, we get

$$Q_t s_t = \left\{ \frac{\theta(1-\eta) - \upsilon_{nt}}{\upsilon_{st} - \theta\eta} \right\} n_t$$

This equation provides the leverage condition in the form as-

$$Q_t s_t = \phi_t n_t \tag{E.36}$$

where -

$$\phi_t = \left\{ \frac{\theta(1-\eta) - \upsilon_{nt}}{\upsilon_{st} - \theta\eta} \right\} \tag{E.37}$$

Marginal value of asset value and net worth (υ_{st} and υ_{nt}) -

Using equation (E.30) and (E.33), we obtain -

$$V_t = E_t \Lambda_{t,t+1}[(1-\sigma)n_{t+1} + \sigma(\upsilon_{s+1} Q_{t+1} s_{t+1} + \upsilon_{nt+1} n_{t+1})]$$

using leverage condition $Q_{t+1} s_{t+1} = \phi_{t+1} n_{t+1}$, above equation becomes -

$$V_t = E_t \Lambda_{t,t+1}[(1-\sigma)n_{t+1} + \sigma(\upsilon_{s+1} \phi_{t+1} n_{t+1} + \upsilon_{nt+1} n_{t+1})]$$

or -

$$V_t = E_t \Lambda_{t,t+1}[(1-\sigma) + \sigma(\upsilon_{s+1} \phi_{t+1} + \upsilon_{nt+1})] n_{t+1}$$

or,

$$V_t = E_t \Lambda_{t,t+1} \Omega_{t+1} n_{t+1} \tag{E.38}$$

where

$$\Omega_{t+1} = [(1-\sigma) + \sigma(\upsilon_{s+1}\phi_{t+1} + \upsilon_{nt+1})] \tag{E.39}$$

We can transform and differentiate the net worth to get the values $\upsilon_{st}$and υ_{nt}. Net worth evolve as -

$$n_t = R_{kt} Q_{t-1} s_{t-1} - R_t d_{t-1} - R_{b,t} b^*_{t-1}$$

using values of d_t and b^*_t from equation (E.35), we get -

$$\begin{aligned}
n_t &= R_{kt} Q_{t-1} s_{t-1} - R_t \eta (Q_{t-1} s_{t-1} - n_{t-1}) - R_{b,t}(1-\eta)(Q_{t-1} s_{t-1} - n_{t-1}) \\
&= Q_{t-1} s_{t-1} [R_{kt} - R_t \eta - R_{bt}(1-\eta)] + n_{t-1}[R_{bt}(1-\eta) + R_t \eta] \\
&= Q_{t-1} s_{t-1} [(R_{kt} - R_{bt}) + \eta(R_{bt} - R_t)] + n_{t-1}[R_{bt} - \eta(R_{bt} - R_t)] \\
&= Q_{t-1} s_{t-1} [R_{kt} - ((1-\eta)R_{bt} + \eta R_t)] + n_{t-1}[(1-\eta)R_{bt} + \eta R_t] \\
n_t &= Q_{t-1} s_{t-1} [R_{kt} - R_{ct}] + n_{t-1}[R_{ct}]
\end{aligned}$$

where $R_{ct} = (1-\eta)R_{bt} + \eta R_t$. Using the value of net worth, value function in equation (E.38) changes to (and equate to value function in equation (E.33)) -

$$V_t = E_t \Lambda_{t,t+1} \Omega_{t+1} \{(R_{kt+1} - R_{ct+1}) Q_t s_t + R_{ct+1} n_t\} = \upsilon_{st} Q_t s_t + \upsilon_{nt} n_t \tag{E.40}$$

We differentiate the value function with respect to $Q_t s_t$ and n_t for optimal conditions. First order conditions -

$$Q_t s_t : \qquad \frac{\partial V_t}{\partial Q_t s_t} = E_t \Lambda_{t,t+1} \Omega_{t+1} (R_{kt+1} - R_{ct+1}) = \upsilon_{st} \tag{E.41}$$

$$n_t : \qquad \frac{\partial V_t}{\partial n_t} = E_t \Lambda_{t,t+1} \Omega_{t+1} R_{ct+1} = \upsilon_{nt} \tag{E.42}$$

Aggregate net worth -

Aggregate net worth consists of the net worth of surviving bankers and new bankers which is given as -

$$NW_t = NW_{E,t} + NW_{N,t}$$

Since old bankers survive with probability σ in the next period and exiting bankers transfer $\frac{\xi}{1-\sigma}$ fraction of their total assets $((1-\sigma)Q_t s_t)$ to new bankers, the net worth equation becomes -

$$NW_t = \sigma(R_{kt}Q_{t-1}S_{t-1} - R_t D_{t-1} - R_{bt}B^*_{t-1}) + (1-\sigma)\left(\frac{\xi}{(1-\sigma)}\right)(R_{kt}Q_{t-1}S_{t-1})$$

$$NW_t = (\sigma + \xi)(R_{kt}Q_{t-1}S_{t-1}) - \sigma(R_t D_{t-1} - R_{bt}B^*_{t-1}) \tag{E.43}$$

B Optimal simple rules parameter

Table B.1: Optimal parameter values under different policy regimes

Parameter	Taylor rule	Augmented Taylor rule	Taylor rule + MaP1 rule	Taylor rule + MaP2 rule
Foreign interest shock				
ρ_r	0.9988436	0.9999084	0.9942435	0.9999623
θ_π	2.9988751	2.9964373	2.9945665	2.9999781
θ_y	0.0001799	0.0001297	0.0007317	0.3672280
θ_e	-	2.9995322	-	-
Domestic net worth shock				
ρ_r	0.9988436	0.9999084	0.9942435	0.9831901
θ_π	2.9988751	2.9964373	2.9945665	2.9434412
θ_y	0.0001799	0.0001297	0.0007317	0.4486960
θ_e	-	2.9995322	-	-
Productivity shock				
ρ_r	0.9988436	0.9999084	0.9942435	0.9942820
θ_π	2.9988751	2.9964373	2.9945665	2.9945985
θ_y	0.0001799	0.0001297	0.0007317	0.0007319
θ_e	-	2.9995322	-	-