Macroprudential policy and foreign interest rate shocks: A comparison of different instruments and regulatory regimes

Chris Garbers and Guangling Liu

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Chris Garbers*and Guangling Liu †

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Abstract

This paper presents a generic small open economy real business cycle model with banking and foreign borrowing. We incorporate capital requirements, reserve requirements, and loan-to-value (LTV) regulation into this framework, and subject the model to a positive foreign interest rate shock that raises the country risk premium and reduces the supply of foreign funds. The results show that these macroprudential instruments can attenuate the impact of such a shock, and that this attenuation property increases with the strictness of the regulatory regime. Capital requirements and LTV regulation deliver the largest attenuation benefits and are shown to be close substitutes. That being said, capital requirements are shown to be more effective at leaning against the financial cycle whereas LTV regulation is more effective at stimulating the financial cycle. The analysis indicates that capital and reserve requirements can interact such that reserve requirements are most effective when used to supplement existing capital requirement or LTV measures. We find that financial and macroeconomic stability objectives are aligned following a positive foreign interest rate shock such that a macroprudential response to such shocks can be to the benefit of both objectives. Lastly, our results show that capital requirements and LTV regulation may exhibit decreasing returns to scale.

Keywords: Macroprudential policy, Open economy macroeconomics, Financial stability, Business cycle, Welfare, DSGE *JEL Classification:* E32, E44, E58, F38, F41, G28

1 Introduction

This paper presents a generic small open economy framework with loan-to-value (LTV) regulation, capital requirements, and reserve requirements, and assesses the ability of these instruments to insulate an economy from a positive foreign interest rate shock. Our interest in studying a macroprudential response to foreign interest rate shocks stems from the tightening cycle currently underway in the United States and the reliance of emerging markets on foreign sources of credit.[1] Emerging markets' preference for foreign

*Department of Economics, University of Stellenbosch, Stellenbosch, 7602, South Africa. E-mail address: garberschristoph@gmail.com

†Corresponding author: Department of Economics, University of Stellenbosch, Stellenbosch, 7602, South Africa. Tel: +27 21 808 2238 fax: +27 21 808 4637. E-mail address: davegliu@gmail.com

[1]See Clarida (2015) for a discussion on the challenges faced by the Federal Reserve in the current tightening cycle.

financing comes on the back of extensive quantitative easing and historically low interest rates in developed economies (Ahmed and Zlate, 2014; Shin, 2014). In this setting, the Federal Reserve's tightening efforts could increase the country risk premium of emerging markets, reducing their access to foreign funds (Bellas and Papaioannou, 2010; Dell'Erba et al., 2013). In turn, restricted access to foreign funds can limit credit, asset price, and output growth in these economies, with accompanied negative consequences for their domestic macroeconomic environment (Forbes and Warnock, 2012; Bruno and Shin, 2015; Banerjee et al., 2016).

We assess the impact of LTV, capital, and reserve requirements in isolation of other central bank tools, focusing on the transmission channels of each instrument and their comparative effectiveness in dealing with foreign interest rate shocks. In this chapter's model, the presence of a Kiyotaki and Moore (1997) collateral constraint amplifies the effects of positive foreign interest rate shocks, where macroprudential policy can offer shock attenuation benefits by limiting the feedback between the real and financial sector that results from this constraint. LTV regulation affects demand for real estate by limiting the degree to which real estate accumulation relaxes the model's collateral constraint, leading to reduced feedback between the real and financial sectors. Capital and reserve requirements affect the interest rate on entrepreneur loans, implying that these instruments proffer attenuation benefits by reducing demand for credit.

Macroprudential instruments have been shown as adept at addressing foreign shocks that are transmitted through the financial sector. For instance, Ozkan and Unsal (2014) find that the effectiveness of macroprudential policy is enhanced in the presence of financial shocks and foreign debt. In contrast, a monetary policy response to such shocks could be suboptimal. The cost-benefit framework of Svensson (2016) indicates that the costs associated with a monetary policy response to financial shocks outweigh the benefits. Glocker and Towbin (2012) and Bailliu et al. (2015) show that a coordinated monetary-macroprudential response offers few benefits over a setting where monetary policy and macroprudential policy operate independently. In Cesa-Bianchi and Rebucci (2017), monetary policy faces a trade-off between price and financial stability such that the introduction of a separate macroprudential instrument facilitates the simultaneous pursuit of both price and financial stability objectives. A capital control response to foreign interest rate shocks is also possible; however institutional support for such measures rests on the exhaustion of alternative policy tools (Fritz and Prates, 2014). Focusing on macroprudential instruments alone also facilitates the tractability of the analysis.

This essay contributes to the growing macroprudential literature through its comparison of LTV, capital, and reserve requirements in a small open economy model. In the existing literature, focus is placed on the interaction between monetary and macroprudential policy, or on the ability of macroprudential instruments to reduce the frequency with which economies find themselves in states where their financial frictions bind. These studies usually deploy a single rules-based macroprudential instrument in a closed economy environment, finding that macroprudential policy can be to the benefit of monetary policy, and that macroprudential regulation can limit the occurrence of states where financial frictions bind.[2] We take

[2]See Glocker and Towbin (2012), Agénor and da Silva (2014), Mendicino and Punzi (2014), and Rubio and Carrasco-Gallego (2014) for studies on the interaction of macroprudential and monetary policy. Benigno et al. (2013), Bianchi and Mendoza (2013), and Cesa-Bianchi and Rebucci (2017) deploy frameworks with occasionally binding financial frictions to show that macroprudential policy limits the frequency with which these frictions bind.

the desirability of macroprudential policy as indicated by this literature as given, and seek to enhance our understanding of the comparative effectiveness of different macroprudential instruments. By studying LTV, capital, and reserve requirements together, this analysis aims to provide insights into the difference between measures that operate on the supply (capital and reserve requirements) and demand (LTV regulation) sides of credit markets (Lim et al., 2011; Galati and Moessner, 2013).

To compare the effectiveness of these different macroprudential instruments, we distinguish between strict, baseline, and easy regulatory regimes and analyze the model's volatility and impulse response functions for each instrument-regime pair. This ad-hoc approach to studying the effects of macroprudential policy differs from the optimized rules-based instruments deployed elsewhere (see e.g., Brzoza-Brzezina et al., 2015). In this case, using an ad-hoc specification for different macroprudential instruments facilitates instrument comparison since the movement between regulatory regimes entails a standardized change in the calibration of each instrument. As a result, we can comment on the relative effectiveness of each instrument in dealing with foreign interest rate shocks, as well as the returns to scale of each instrument. This approach also affords an assessment of the trade-offs between financial and macroeconomic stability when macroprudential regulation is changed..

Although this methodological approach affords a comparison across macroprudential instruments and regimes, one could argue that the absence of monetary policy or capital controls from the model negates the value of this analysis. Indeed, capital controls and the policy rate are macroprudential instruments as both proffer a means through which authorities can pursue financial stability objectives. In the case of the policy rate, theoretical evidence indicates that traditional macroprudential instruments are more effective when foreign liabilities are sizable, or when the economy is hit with financial shocks (Glocker and Towbin, 2012; Ozkan and Unsal, 2014).[3] On the empirical front, the evidence indicates that a monetary policy reaction to financial stability concerns brings few benefits, if any at all (Bailliu et al., 2015; Aiyar et al., 2016; Svensson, 2016). In the case of capital controls, although support for their deployment has grown, these tools are still seen as a measure of last resort that should only be deployed once traditional macroprudential and policy rate measures have been exhausted.[4]

The results concur with existing evidence in that the deployment of macroprudential instruments can help to attenuate the negative consequences of foreign interest rate shocks. Capital requirements and LTV regulation offer large attenuation benefits that are of a similar magnitude. Reserve requirements also offer attenuation benefits, but these are small and diminish quickly. An assessment of the transmission channels of each instrument reveals that the smaller attenuation benefits of reserve requirements stem from their interaction with capital requirements. Thus, analyses that study reserve requirements in isolation of capital requirements may overstate the impact of this instrument as they do not account for this interaction (see e.g., Glocker and Towbin, 2012; Agénor and da Silva, 2014)

We also find that, following a positive foreign interest rate shock, macroeconomic and financial stability concerns become aligned such that macroprudential policy is able to address both simultaneously.[5] This

[3]The model presented here bears both of these features – the banker has foreign loans and we subject the model to a foreign interest rate shock that increases the country risk premium.

[4]Fritz and Prates (2014) provide an excellent review of the institutional debate on the use of capital controls.

[5]The coincidence of macroeconomic and financial stability objectives in the face of foreign interest rate shocks concurs with

result concurs with Angelini et al. (2014) where the authors find that, in the face of financial shocks, capital requirements proffer significant macroeconomic stabilization gains. Furthermore, our findings indicate that asymmetries exist between both macroprudential instruments and regimes. Specifically, strict macroprudential regulatory regimes reduce the impact of foreign interest rate shocks relative to easy regulatory regimes, and the impact of LTV and capital requirements diminishes as the regulatory regime becomes stricter. In contrast, the quantitative impact of reserve requirements does not change across regulatory regimes.

Taken together, the analysis indicates that LTV and capital requirements are effective in dealing with foreign interest rate shocks where the magnitude of their effects are quite similar. Thus, changes to LTV regulation can easily be substituted by changes to capital requirements. Nevertheless, the results indicate that choosing between between macroprudential instruments depends on the objectives of the regulator. Specifically, capital requirements are shown to be more effective at leaning against the financial cycle whereas LTV regulation is more effective at stimulating the financial cycle. In the case of reserve requirements, the smaller attenuation benefits associated with this instrument points to its effectiveness as a supplement to existing capital requirement or LTV measures.

The remainder of the paper proceeds as follows. Section 2 presents the model framework, with its calibration provided in section 3. The analysis on the ability of macroprudential instruments to deal with foreign interest rate shocks is contained in section 4. Lastly, section 5 concludes.

2 The model

The generic small open economy is populated by households, entrepreneurs, bankers, and exogenous foreign lenders. Households consume, accumulate real estate, and supply labor to entrepreneurs. Households are the savers in this economy, providing bankers with one-period interest bearing deposits. Entrepreneurs take on the role of borrowers in this economy. They combine their real estate holdings with household labor to produce output, where the use of real estate in production affords use of the real estate price and credit as measures of financial stability (see e.g.,, Angelini et al., 2014). To finance their demand for the factors of production, entrepreneurs incur one-period interest bearing loans with bankers, subject to a collateral constraint. Bankers intermediate the flow of credit between savers and borrowers. In addition to the funds provided by households, bankers finance entrepreneurial loan extension through funds provided by foreign lenders.

We subject this model economy to a positive world interest rate shock designed to mimic a change in the stance of foreign monetary policy. This shock increases the country risk premium and bankers' external financing costs, restricting credit extension to entrepreneurs. In turn, the entrepreneur's collateral constraint affords dynamic feedback between interest rates, credit quantities, and asset prices such that positive world interest rate shocks see a large and persistent decline in credit, asset prices, and output.

This framework incorporates LTV, capital, and reserve requirements to insulate the economy from such

the empirical evidence of Claessens et al. (2012), Antonakakis et al. (2015), and Dees (2016) in that stronger links between the financial and business cycle during times of distress provides scope for welfare improvements through macroprudential regulation.

shocks. LTV regulation is imposed on the demand side of the credit market (entrepreneurs), whilst capital and reserve requirements are imposed on the supply side of the credit market (bankers). Each macroprudential instrument has a different transmission channel, where this analysis comprises a comparison of their effectiveness in dealing with the shock. In this regard, we study the effects of a standardized discretionary change in the calibration of each instrument on the impulse response functions and steady state standard deviations of the economy. We present the model economy that incorporates these three instruments below.

2.1 Households

The representative household maximizes its expected lifetime utility function

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta_h^t \left\{ \log(C_t^h) + j \log(H_t^h) + \tau \log(1 - N_t) \right\}, \tag{1}$$

subject to the following budget constraint

$$C_t^h + D_t + q_t(H_t^h - H_{t-1}^h) + T_t = R_{t-1}^d D_{t-1} + W_t N_t. \tag{2}$$

In the household's utility function, the discount factor is given by β_h, whilst j and τ are utility parameters related real estate holdings (H_t^h) and leisure ($1 - N_t$). C_t^h and N_t give household consumption and labour supply, respectively. q_t denotes the price of real estate in units of consumption and W_t gives the wage rate. D_t denotes one-period bank deposits which earn a gross interest rate of R_t^d. Lastly, T_t gives lump-sum taxes imposed by the government.

Denoting $m_t^h \equiv \frac{\beta_h C_t^h}{\mathbb{E}_t C_{t+1}^h}$ the household's stochastic discount factor, the first order conditions for deposits (D_t), real estate (H_t^h), and labour (N_t) are as follows:

$$1 = m_t^h R_t^d, \tag{3}$$

$$q_t = \frac{j C_t^h}{H_t^h} + m_t^h \mathbb{E}_t q_{t+1}, \tag{4}$$

$$W_t = \frac{\tau C_t^h}{1 - N_t}. \tag{5}$$

Condition 3 provides the behavioural rule for the benchmark domestic interest rate in the economy. It requires R_t^d to be such that the current period utility cost of deposits equates to the returns in the following period. The asset pricing equation (4) equates the value of real estate to its direct utility benefits in units of consumption plus the discounted utility benefit it offers in the next period through its influence on household wealth. Lastly, equation 5 sees the optimal wage rate equalling the marginal rate of substitution between consumption and leisure.

2.2 Entrepreneurs

Entrepreneurs allocate their available resources between real estate, loans from domestic banks, and labour to maximize their lifetime utility function given by

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta_e^t \left\{ \log(C_t^e) \right\}, \tag{6}$$

where β_e is the entrepreneurial discount factor and C_t^e gives entrepreneurial consumption. The budget constraint for entrepreneurs is given by

$$C_t^e + q_t(H_t^e - H_{t-1}^e) + R_t^l L_{t-1} + W_t N_t = Y_t + L_t. \tag{7}$$

The left hand side of equation 7 represents entrepreneurs' total expenditure, which consists of consumption (C_t^e), purchases of real estate ($q_t(H_t^e - H_{t-1}^e)$), gross repayments on loans from the previous period ($R_t^l L_{t-1}$), and the wage bill ($W_t N_t$). As per the right hand side of (7), these expenditures are financed with total income (Y_t) and new loans incurred with domestic bankers (L_t).

Here we introduce the first macroprudential instrument – the LTV ratio. We assume that entrepreneurs' borrowing capacity is limited to a fraction ν_e of the expected value of their real estate stock in the next period:

$$\mathbb{E}_t R_{t+1}^l L_t \leq \nu_e \mathbb{E}_t q_{t+1} H_t^e. \tag{8}$$

Following Iacoviello (2005), the entrepreneur's production technology has a Cobb-Douglas functional form with input shares of α for real estate and $(1-\alpha)$ for labour:

$$Y_t = (H_{t-1}^e)^{\alpha} (N_t)^{1-\alpha}. \tag{9}$$

With this specification for the production function, the entrepreneur's real estate holdings can be thought of as a proxy for physical capital.

Letting $m_t^e \equiv \frac{\beta_e C_t^e}{\mathbb{E}_t C_{t+1}^e}$ and $\Lambda_t^e \equiv \frac{\lambda_t^e}{C_t^e}$ denote entrepreneurs' stochastic discount factor and the multiplier on (8) respectively, optimal entrepreneurial behaviour generates the following first order conditions for H_t^e, L_t, and N_t:

$$q_t = m_t^e \left(\frac{\alpha \mathbb{E}_t Y_{t+1}}{H_t^e} + \mathbb{E}_t q_{t+1} \right) + \nu_e \lambda_t^e \mathbb{E}_t q_{t+1}, \tag{10}$$

$$1 = (m_t^e + \lambda_t^e) \mathbb{E}_t R_{t+1}^l, \tag{11}$$

$$W_t = \frac{(1-\alpha) Y_t}{N_t}. \tag{12}$$

Condition 10 relates the current period marginal cost of real estate accumulation to the sum of its discounted marginal product and the utility benefits that it proffers through a relaxation of the entrepreneur's collateral constraint (equation 8). Equation 11 is the asset pricing equation for domestic borrowing . Lastly, (12) sees that labor gets paid its marginal product.

To ensure that entrepreneurs are borrowing constrained in equilibrium (i.e. $\lambda^e > 0$), requires a restriction on the feasible value of their discount factor. Formally, so long as

$$\beta_e < \frac{\beta_b}{1 - (1 - \vartheta)\lambda^c}, \tag{13}$$

it will be the case that $\lambda^e > 0$.[6] This implies that entrepreneurs are relatively more impatient than households and ensures that entrepreneur wealth is insufficient to finance production in equilibrium (see, Iacoviello, 2005).

2.3 Bankers

Bankers are consumption maximizers, making use of household deposits and foreign funds to extend loans to entrepreneurs. In their loan extension, bankers are subject to capital and reserve requirements. The representative banker's objective function is given by

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta_b^t \left\{ \log(C_t^b) \right\}, \tag{14}$$

where C_t^b and β_b denote their consumption and discount factor, respectively. The banker's budget constraint is given by

$$C_t^b + L_t + R_{t-1}^d D_{t-1} + R_{t-1}^f B_{t-1}^f + \zeta_t = D_t + B_t^f + R_t^l L_{t-1} + \zeta_{t-1}. \tag{15}$$

In (15) above, L_t denotes current period loan extension to entrepreneurs which accrues gross interest of R_{t+1}^l, repayable in the next period. Similarly, bankers pay gross interest of R_t^d and R_t^f on household deposits (D_t) and foreign funds (B_t^f). Lastly, ζ_t denotes one-period interest free required reserves.

[6] To derive this result, substitute the steady state of (11) into the steady state of (20) for R^l, and require that $\lambda^e > 0$.

Bankers are subject to capital requirements on their net-assets excluding required reserves. Letting $BK_t = L_t + \zeta_t - D_t - B_t^f$ denote bank capital, the capital requirement is given by

$$D_t + B_t^f \leq (1-\vartheta)L_t + \zeta_t, \tag{16}$$

where ϑ determines the proportion of bank assets that must be backed by bank capital.

Following Agénor et al. (2014), bankers are required to hold a fraction of their domestic liabilities as reserves. Reserve requirements are governed by condition 17:

$$\zeta_t \geq \varphi D_t, \tag{17}$$

As with households and entrepreneurs, denoting $m_t^b \equiv \frac{\beta_b C_t^b}{\mathbb{E}_t C_{t+1}^b}$ as the banker's stochastic discount factor, the banker's problem produces the first order conditions for deposits (D_t), foreign borrowing (B_t^f), loan extension to entrepreneurs (L_t), and required reserves (ζ_t) as follows[7]:

$$m_t^b R_t^d = 1 - \varphi\lambda_t^r - \lambda_t^c, \tag{18}$$

$$m_t^b R_t^f = 1 - \lambda_t^c, \tag{19}$$

$$m_t^b \mathbb{E}_t R_{t+1}^l = 1 - (1-\vartheta)\lambda_t^c, \tag{20}$$

$$\lambda_t^r = 1 - m_t^b - \lambda_t^c. \tag{21}$$

Equations 18 and 21 show that reserve requirements decrease both current period benefits and discounted future period costs associated with raising deposits from households. Bankers' behavioural rule for loan extension (20) shows that current period costs are reduced as a result of utility benefits that loan extension provides through relaxing the capital requirement constraint. In contrast, (18) and (19) show that the capital requirement constraint reduces utility benefits from deposits and foreign funds. The first order conditions also show that tight capital requirements increase current period benefits, whilst higher reserve requirements reduce current period benefits.

Through (18), (19), and (20) the evolution of the spreads between interest rates can be described by:

$$m_t^b(R_t^f - R_t^d) = \varphi\lambda_t^r, \tag{22}$$

$$m_t^b(\mathbb{E}_t R_{t+1}^l - R_t^d) = \varphi\lambda_t^r + \vartheta\lambda_t^c, \tag{23}$$

$$m_t^b(\mathbb{E}_t R_{t+1}^l - R_t^f) = \vartheta\lambda_t^c. \tag{24}$$

[7]The multipliers on constraint (16) is denoted as $\Lambda_t^c \equiv \frac{\lambda_t^c}{C_t^b}$ whilst that on (17) is given by $\Lambda_t^r \equiv \frac{\lambda_t^r}{C_t^b}$.

Equation 22 shows that the spread between the returns on foreign funds and deposits is increasing in the tightness of their proximity to the minimum level of required reserves, whilst (23) shows that bankers pass the cost of capital and reserve requirements on to entrepreneurs. Equation 24 indicates that the spread between lending and foreign fund rates is increasing in the tightness of the capital requirement constraint (16).

To ensure that bankers make profits on their loans regardless of the source of their funding requires a binding capital requirement in equilibrium (i.e. $\lambda^c > 0$). When $\lambda^c > 0$, loan extension requires that bankers forgo consumption such that the interest rate on entrepreneur loans is a premium over that of their funding sources[8]. Taking the steady state of (3), (18), and (21), one can solve for λ^c, with the result that $\lambda^c > 0$ so long as

$$\beta_b < \frac{(1-\varphi)\beta_h}{1-\varphi\beta_h}. \tag{25}$$

If condition 25 holds, it will be the case that $R^l > R^f$ and $R^l > R^d$.

Equation 22 shows how reserve requirements exert an asymmetrical influence on the funding markets of bankers – in equilibrium, $R^f > R^d$ so long as $\lambda^r > 0$ and $\varphi > 0$. Taking the steady state of (3), (21), and (22), we have $\lambda^r > 0$ so long as $\beta_h < 1$. Thus, an equilibrium where $R^f > R^d$ will result when reserve requirements are present ($\varphi > 0$) and binding ($\lambda^r > 0$). In equilibrium, household deposits are insufficient to meet bankers' demand for funding. Bankers, therefore, need to incur debts with foreign lenders (i.e., $B^f > 0$) at an interest rate that is higher than that on deposits (i.e., $R^f > R^d$). This implies that D_t and B^f_t are imperfect substitutes, creating a non-trivial role for foreign lenders in the banker's problem which facilitates a spread between the cost of domestic and foreign banker funding sources.

Together, these restrictions on household and banker discount factors and the presence of reserve requirements generate an equilibrium in which bankers generate profits from lending regardless of the source of their funding, and that the cost of domestic funds is lower than that of foreign funds. This equilibrium relationship between interest rates can be summarized as:

$$R^l > R^f > R^d. \tag{26}$$

2.4 Foreign lenders

Risk-neutral foreign lenders can allocate their funds between debt issued either by the rest of the world or by the small open economy's domestic bankers. Debt issued by the rest of the world pays interest of R^w_t, whilst that issued by domestic bankers pays R^f_t. We assume the existence of information asymmetries such that foreign lenders face additional monitoring costs in extending funds to domestic bankers as compared to the rest of the world. These monitoring costs result in a fraction δ_t of the repayment being lost where loans

[8] A binding capital requirement in equilibrium implies that, in equilibrium, banker capital is positive, and so, loan extension is partly financed out of forgone banker consumption.

to domestic bankers are concerned. Thus, for foreign lenders to be indifferent between lending to domestic bankers or the rest of the world, a country risk premium is required over the interest paid on debt issued by the rest of the world.

Formally, foreign lenders will require that the interest rate they receive on domestic banker borrowing be such that, after paying monitoring costs, it equates to the world interest rate:

$$R_t^w = (1 - \delta_t) R_t^f. \tag{27}$$

Where the country risk premium is denoted as $\chi_t \equiv \frac{1}{1-\delta_t}$ such that this risk premium is increasing in the size of monitoring costs. Following Minetti and Peng (2013), the country risk premium is positively related to the external debt to output ratio and the world interest rate. Letting variables without a t subscript denote steady state values, the behavioural rule for χ_t is given by

$$\chi_t = \kappa \left(\frac{B_t^f}{Y_t} / \frac{B^f}{Y} \right)^{\gamma_f} (R_t^w)^{\gamma_w}. \tag{28}$$

Where $\kappa = \frac{R^f}{R^w}$. The parameters γ_f and γ_w capture the degree to which the country risk premium reacts to changes in the external debt to output ratio and the world interest rate.

The world interest rate is assumed to be exogenous and follows an AR(1) process:

$$R_t^w = \rho_w R_{t-1}^w + \varepsilon_t^w, \tag{29}$$

where ρ_w is the autocorrelation coefficient and ε_t^w is a white-noise shock to the world interest rate with a standard deviation of σ_w.

Substituting (28) into (27) and taking logs generates the rule governing the supply of foreign funds:

$$\gamma_f \log(B_t^f) = \log(R_t^f) + \gamma_f \log(Y_t) + \gamma_f \log(\frac{B^f}{Y}) - (1 + \gamma_w) \log(R_t^w) - \log \kappa. \tag{30}$$

(30) shows the supply of foreign funds is positively related to the interest rate received thereon (R_t^f) and domestic fundamentals (Y_t), and negatively related to the world interest rate. Thus, positive shocks to the world interest rate serve to reduce the supply of foreign funds.

2.5 Macroprudential regimes and social welfare

To assess the welfare costs associated with each macroprudential instrument, we follow Rubio and Carrasco-Gallego (2014) and numerically evaluate social welfare derived in each case. With household (ω_t^h), entrepreneur (ω_t^e), and banker (ω_t^b) welfare given as

$$\omega_t^h = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta_h^t \left[\log(C_t^h) + j\log(H_t^h) + \tau\log(1-N_t)\right], \tag{31}$$

$$\omega_t^e = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta_e^t \left[\log(C_t^e)\right], \tag{32}$$

$$\omega_t^b = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta_b^t \left[\log(C_t^b)\right], \tag{33}$$

social welfare can be defined as the weighted sum of individual welfares:

$$\omega_t = (1-\beta_h)\omega_t^h + (1-\beta_e)\omega_t^e + (1-\beta_b)\omega_t^b. \tag{34}$$

Weighting each agent's welfare by their respective discount factors ensures that all groups receive the same level of utility from a constant consumption stream.

2.6 Market Clearing

Market clearing is given by the following conditions:

$$1 = H_t^e + H_t^h, \tag{35}$$

$$Y_t = C_t^h + C_t^e + C_t^b + R_{t-1}^f B_{t-1}^f - B_t^f, \tag{36}$$

$$T_t = \zeta_t - \zeta_{t-1}. \tag{37}$$

Equation 35 is a simple normalization for housing as in Angelini et al. (2014) whilst equation 36 is the aggregate resource constraint. To close the model, (37) shows we assume that changes in reserves are financed entirely out of lump-sum taxes (or subsidies). Since there is no trade in this model, the current account balance is given by equation (38):

$$CA_t = B_{t-1}^f - B_t^f. \tag{38}$$

3 Calibration

Table 1 contains the model parameters for the generic small open economy. The values for $\beta_h = 0.985$, $\beta_b = 0.945$, and $\beta_e = 0.94$ are standard and ensure that both the banker's capital requirement and the entrepreneur's collateral constraint are binding. As in the small open economy of Minetti and Peng (2013), $j = 0.3$ sees that households and entrepreneurs split the total stock of real estate equally in the steady state. Setting $\tau = 2$ as per Iacoviello (2015) sees households devote roughly a third of their time to labour. We follow Iacoviello (2005), Aguiar and Gopinath (2007), and Minetti and Peng (2013) in calibrating $\alpha = 0.4$, which corresponds to labour's share in output being 0.6.

The baseline calibrations for each macroprudential instrument are as follows. Minimum capital requirements for bankers are set at 10%, which is in line with the minimum total capital plus conservation buffer as per Basel III (BIS, 2010). The reserve requirements ratio $\varphi = 0.1$ is as per Agénor et al. (2014). For LTV regulation, we calibrate $\nu_e = 0.75$, in line with the cross country evidence presented in IMF (2011).

Table 1: Calibration of model parameters.

Parameter	Symbol	Value
Household discount factor	β_h	0.985
Entrepreneur discount factor	β_e	0.94
Banker discount factor	β_b	0.945
Household real estate preference	j	0.3
Household labour supply parameter	τ	2
Real estate share in production	α	0.4
Loan-to-value ratio for entrepreneurs	ν_e	0.75
Capital to assets ratio	ϑ	0.1
Reserve requirement	φ	0.1
Country risk premium sensitivity to R_t^w	γ_w	0.85
Country risk premium sensitivity to $\frac{B_t^f}{Y_t}$	γ_f	0.05
AR(1) coefficient on R_t^w	ρ_w	0.85
Standard deviation of ε_t^w	σ_w	0.01

We calibrate the parameters relating to the country risk premium, (28), with reference to empirical evidence on the determinants of emerging market sovereign spreads. This literature indicates a high degree of heterogeneity between emerging markets in their experience of foreign interest rate shocks; however, in general the findings indicate that $\gamma_w > 0$ and $\gamma_f > 0$.[9] We calibrate $\gamma_w = 0.85$ to match Minetti & Peng's 2013 estimates for a variant of (28). This value also concurs with the empirical analysis of Eichengreen and Mody (1998) as well as that of Arora and Cerisola (2001). In the case of the sensitivity of the country risk premium to external debt levels, we set $\gamma_f = 0.05$ to ensure that positive shocks to the world interest rate increases the country risk premium. This calibration is in line with the estimates of Bellas and Papaioannou (2010) and Dell'Erba et al. (2013) where these authors estimate that a 1 p.p. increase in the external debt-to-GDP ratio of emerging markets is associated with a 0.03–0.05 p.p. increase in their country spread. It is worth noting that although changes to the calibration of γ_w and γ_f affect the results quantitatively, they bear no influence qualitatively. In evidence, figure 7 plots the impact of a foreign interest rate shock across alternative calibrations for γ_f and γ_w.[10] Finally, we calibrate the AR(1) parameter on the world interest rate shock as $\rho_w = 0.85$ with a standard deviation of $\sigma_w = 0.01$.

[9] See Eichengreen and Mody (1998), Arora and Cerisola (2001), Ferrucci (2003), and Ahmed et al. (2017) for evidence on the highly heterogeneous experience that emerging markets have with foreign interest rate shocks.

[10] Uribe and Yue (2006) find that, in small open economy models, the optimal parameter values that govern external debt accumulation depend on the model structure. In simplified settings such as that presented here, the values needed to match the impulse response functions generated by a VAR can be quite large. For instance, in the absence of capital adjustment costs, Uribe and Yue (2006) find that $\gamma_f = 0.95$ is needed to minimize the distance between their model and a VAR's impulse response functions.

3.1 Comparing the effectiveness of macroprudential instruments

To analyse and compare the effectiveness of the macroprudential instruments in our model, we deploy each instrument across a variety of regulatory calibrations as per table 2. We contrast the baseline macroprudential calibration to both strict and easy regulatory regimes. Strict macroprudential regimes are defined by higher capital or reserve requirements (relative to the baseline) or lower LTV requirements (relative to the baseline). The converse holds under an easy macroprudential regime, where capital and reserve requirements are lower, and LTV requirements are higher than the baseline calibration.

Table 2: Calibration of alternative macroprudential regimes.

Parameter	Symbol	Baseline	Strict	Easy
Loan-to-value ratio	ν_e	0.75	0.7	0.8
Capital to assets ratio	ϑ	0.1	0.15	0.05
Reserve requirement	φ	0.1	0.15	0.05

Table 2's ad-hoc specification of the different macroprudential regimes is consistent with a setup where the financial frictions always bind and a desire to conduct a comparison of different macroprudential instruments. Previous studies have made use of rules-based macroprudential instruments and optimized policy parameters to study the effectiveness of these instruments in limiting the frequency with which financial frictions bind, or to assess the merits of including a financial stability objective to monetary policy.[11] Since the entirety of this analysis occurs in a state where the financial frictions bind, modelling the macroprudential instruments as endogenous rules that reduce the frequency of such states is of little interest. Similarly, our interest in comparing different macroprudential instruments to one another negates the benefits of calculating optimal values for ν_e, ϑ, and φ. In this regard, calculating optimal policy parameters would only affect the baseline level of the model's macroprudential calibration with no effect on the ad-hoc nature of the analysis. Nevertheless, the baseline calibration for each macroprudential instrument is in line with that advocated by international regulatory bodies (BIS, 2010; Lim et al., 2011).

With the macroprudential calibration as per table 2, switching between regimes entails a standardized 5 percentage point (p.p.) increase or decrease relative to the baseline. We exploit the standardized nature of these changes in regulation to compare the effects of LTV, capital, and reserve requirements to one another. For instance, if $\mathbf{X}_i^s$ is a vector containing the dynamics of variable X obtained under the strict regime of instrument i, instrument equality would imply that

$$\mathbf{X}_{LTV}^s = \mathbf{X}_{Capital}^s = \mathbf{X}_{Reserve}^s, \tag{39}$$

$$\mathbf{X}_{LTV}^e = \mathbf{X}_{Capital}^e = \mathbf{X}_{Reserve}^e. \tag{40}$$

Where vector $\mathbf{X}_i^e$ contains variable X's dynamics under the easy regime of instrument i. If both equations 39 and 40 hold, the analysis indicates that a 5 p.p. change in capital requirements has the same effect on X

[11] Bianchi and Mendoza (2013), Akinci and Queralto (2014), and Cesa-Bianchi and Rebucci (2017) study the ability of macroprudential policy to limit the frequency with which financial frictions bind. Mendicino and Punzi (2014), Rubio and Carrasco-Gallego (2014), and Bailliu et al. (2015) study optimal macroprudential and monetary policy.

as a 5 p.p. change in LTV or reserve requirements.

The ad-hoc specification also afford an assessment of the returns to scale associated with each instrument. For an instrument to exhibit constant returns to scale, the quantitative impact of moving from the baseline to the strict regime must be the same as moving from the baseline to the easy regime, but of the opposite sign. For example, LTV regulation will exhibit constant returns to scale if

$$\frac{|\mathbf{X}^{s}_{LTV}|}{|\mathbf{X}_{Baseline}|} = \frac{|\mathbf{X}^{e}_{LTV}|}{|\mathbf{X}_{Baseline}|}, \tag{41}$$

where vector $\mathbf{X}_{Baseline}$ contains variable X's dynamics under the baseline regime. Alternatively, decreasing returns to scale imply that the impact of macroprudential instruments decline as the regulatory regime moves from an easy to a strict calibration. In this case, the impact of moving from the easy to baseline regime would be greater than the impact of moving from the baseline to the strict regime.

4 A macroprudential response to foreign interest rate shocks

Positive foreign interest rate shocks increase the country risk premium as per equation 28, and reduce the supply of foreign financing. This increase in banker funding costs realizes higher domestic borrowing costs which impacts negatively on entrepreneur credit ceilings through their collateral constraint. In turn, lower credit extension to entrepreneurs tightens the banker's capital and reserve requirements, realizing additional increases in domestic borrowing costs and further declines in the banker's access to foreign funds. These dynamics culminate in a downward spiral in asset prices and credit extension, which see positive foreign interest rate shocks impart a persistent negative effect on both the financial sector and real economy.[12]

Macroprudential regulation can mitigate the negative effects of foreign interest rate shocks by limiting the vicious feedback that the shock induces between asset prices and credit extension. To illustrate this shock attenuation property, we discuss the different transmission channels of each of our macroprudential instruments and plot the impulse response functions obtained under each instrument and regime. Next, we assess whether there is a trade-off between financial stability and macroeconomic stability in the deployment of each instrument following a positive foreign interest rate shock and elaborate on these findings by comparing the effectiveness and returns to scale of each macroprudential instrument. Taken together, this analysis identifies which instrument(s) are best suited to respond to the negative effects of positive foreign interest rate shocks.

4.1 LTV regulation

The dynamic interaction between credit ceilings and asset prices afforded by constraint 8 underpins the magnitude and persistence of the negative effects associated with foreign interest rate shocks. This interaction between the real and financial sector is governed by the entrepreneur's first order condition for real estate

[12] The dynamics of the baseline model are in line with those in the small open economy literature (e.g., Neumeyer and Perri, 2005; Minetti and Peng, 2013).

holdings:

$$q_t = m_t^e \left(\frac{\alpha \mathbb{E}_t Y_{t+1}}{H_t^e} + \mathbb{E}_t q_{t+1} \right) + \nu_e \lambda_t^e \mathbb{E}_t q_{t+1}. \tag{42}$$

In (42) the marginal value of credit to the entrepreneur, λ_t^e, provides the link between credit markets and the behaviour of asset prices. Thus, in order to mitigate the negative effects of foreign interest rate shocks, regulation should either reduce the interaction between credit and real estate markets, or reduce the marginal value of credit to the entrepreneur.

Changes to LTV regulation (ν_e) can affect the downward spiral in loans and asset prices through the influence that this instrument has on the interaction between credit and real estate markets (λ_t^e and q_t). To illustrate, figure 1 compares the impulse response functions (IRFs) for select variables under the strict, baseline, and easy LTV regimes as per table 2. In the baseline regime, a positive foreign interest rate shock causes an increase in interest rate spreads, a reduction in entrepreneurial loans and foreign funds, as well as lower output, consumption, and asset (real estate) price growth.[13]

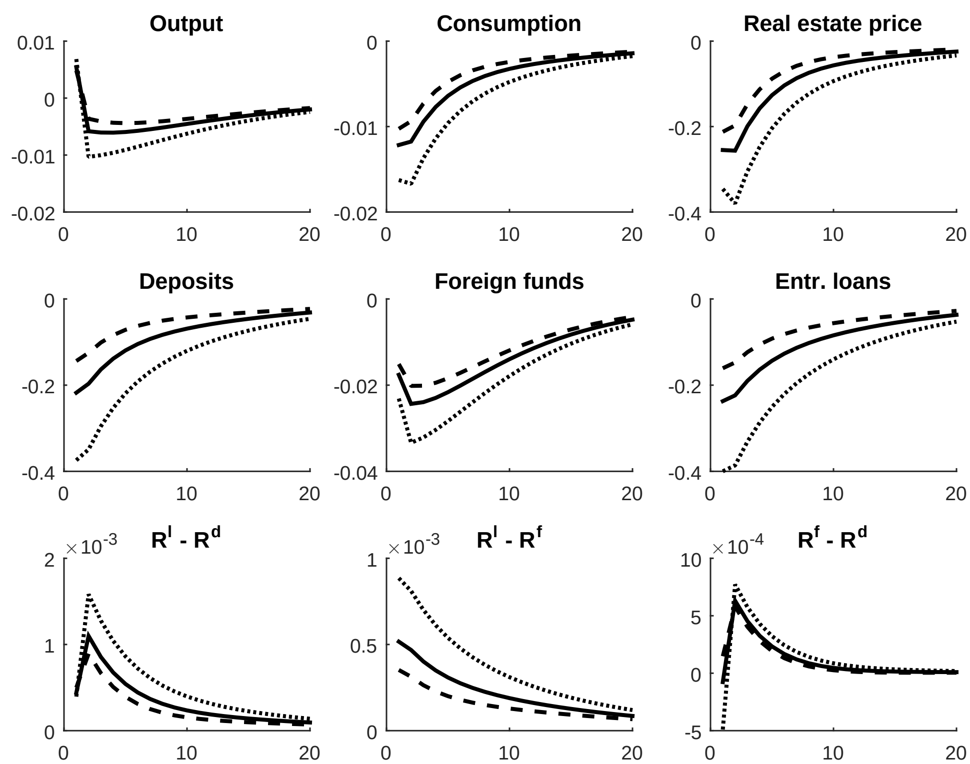

Figure 1: Impulse response functions following a positive shock to R_t^w for different LTV regimes as per table 2. Solid line: baseline calibration; Dashed line: strict LTV regime; Dotted line: easy LTV regime.

As per (42), a strict LTV regime reduces the feedback between credit and asset markets such that the effects of foreign interest rate shocks are attenuated under a strict (as opposed to baseline) regime. Shock attenuation under the strict regime results from lower entrepreneur demand for real estate. When the strict

[13] The figure plots aggregate consumption, defined as $C_t = C_t^h + C_t^e + C_t^b$.

LTV regime is imposed, an additional unit of real estate affords access to less loan credit, and since the entrepreneur's marginal value of credit (λ_t^e) is unaffected by LTV regulation, this translates into a demand for real estate that is both lower and less sensitive to foreign interest rate shocks than under the baseline. Under an easy regime, the opposite occurs, where (42) serves to enhance entrepreneur demand for real estate and the feedback between credit and asset markets relative to the baseline. This holds across all variables: the strict LTV regime attenuates the impact of foreign interest rate shocks relative to the baseline whilst the easy regime sees that their impact is amplified relative to the baseline.

4.2 Capital requirements

Whilst LTV regulation proffers attenuation benefits by reducing the entrepreneur's demand for real estate, capital requirements can influence (42) by targeting the entrepreneur's demand for credit. The banker's first order condition for loans shows that the capital requirement (ϑ) can affect the marginal value of credit to the entrepreneur, $\lambda_t^e = \frac{1}{R_{t+1}^l} - m_t^e$, through its influence over the interest rate on entrepreneur loans[14]:

$$m_t^b \mathbb{E}_t R_{t+1}^l = 1 - (1 - \vartheta)\lambda_t^c. \tag{43}$$

Where λ_t^c gives the marginal value of liquidity to bankers.

The stricter the capital requirement, the larger the fraction of loans that need to be financed with capital, and because raising capital entails a consumption cost for bankers, higher capital requirements increases the interest rate that bankers charge to entrepreneurs.[15] Through (11), higher interest rates reduce the marginal value of credit to entrepreneurs. This lowers their demand for credit and reduces feedback between credit and asset markets as per (42). Figure 2 confirms this narrative and shows that the strict capital regime reduces the impact of foreign interest rate shocks on real and financial aggregates (top and middle rows). The opposite occurs when the easy regime is imposed, and so the dynamics of these variables are amplified relative to the baseline.

A comparison across figures 1 and 2 shows that although strict LTV regulation and capital requirements exhibit similar shock attenuation properties for the quantitative macroeconomic variables of the model, these two instruments have different effects on interest rate spreads. This disparity illustrates the different transmission channels of LTV and capital requirements. Specifically, where changes in LTV regulation are initially transmitted through real estate markets, changes in capital requirements are initially transmitted through interest rates. This difference between the transmission channels of LTV and capital requirements is illustrated by the differential response of the interest rate spreads in figures 1 and 2.

Using the relationship between interest rate spreads as given by equations 22 to 24, we can decompose the impact of capital requirements on interest rate spreads into two parts. The first part reflects the impact of capital requirements on the feedback between asset and credit markets in (42) through its influence over the marginal value of credit to the entrepreneur and is illustrated by $R^f - R^d$. The second part reflects

[14] $\lambda_t^e = \frac{1}{R_{t+1}^l} - m_t^e$ is derived from the entrepreneur's first order condition for loans, (11).

[15] Bank capital is generated out of banker's consumption.

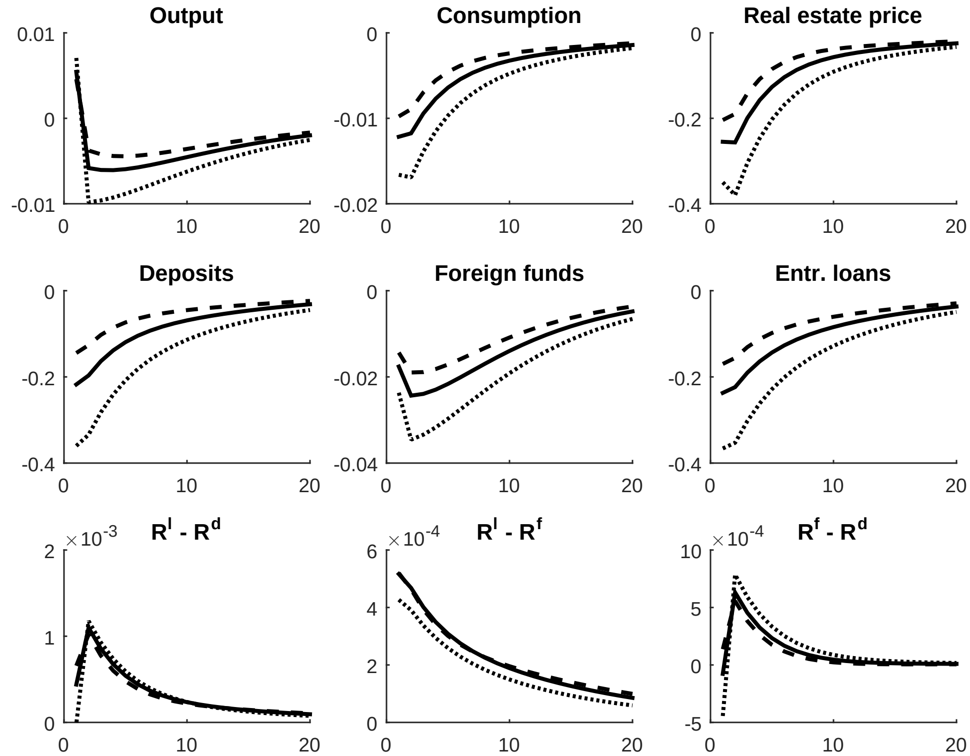

Figure 2: Impulse response functions following a positive shock to R_t^w for different capital requirement regimes as per table 2. Solid line: baseline calibration; Dashed line: strict capital requirement regime; Dotted line: easy capital requirement regime.

the influence that capital requirements have on the sensitivity of the banker's consumption stream and is illustrated by $R^l - R^f$. In turn, the dynamics of $R^l - R^d$ can be seen as an amalgamation of these two forces.[16] Thus, on the one hand, a strict capital regime attenuates the behaviour of domestic spreads ($R^l - R^d$) through its ability to limit the feedback between asset and credit markets in (42). On the other hand, a strict capital requirement regime amplifies the behaviour of domestic spreads by increasing the sensitivity of banker consumption to foreign interest rate shocks. As a result of these two opposing forces, changes in the capital requirement regime have a more muted effect on domestic interest rate spreads as compared to changes in LTV regulation. Nevertheless, the dynamics of $R^l - R^d$ shows a marginal attenuation of domestic spread dynamics under strict capital requirements.

4.3 Reserve requirements

The attenuation benefits of reserve requirements also result from their influence over the cost of loan finance to entrepreneurs; however this instrument imparts less influence over interest rates than capital requirements. The comparative inefficiency of reserve requirements stems from the fact that this instrument does not directly affect the interest rate on loans, rather it has direct bearing over the marginal value of liquidity to

[16]Equation 23 shows that the loan-deposit spread ($R^l - R^d$) depends on both capital and reserve requirements whilst (24) shows that the loan-foreign fund spread ($R^l - R^f$) depends solely on capital requirements. Lastly, equation 22 shows that the foreign fund-deposit spread ($R^f - R^d$) depends solely on reserve requirements.

bankers, λ_t^c, which in turn affects R_{t+1}^l. Using equations 18 and 21, we can solve for λ_t^c as:

$$\lambda_t^c = 1 - (R_t^d - \varphi)\frac{m_t^b}{1-\varphi}. \tag{44}$$

Equation 44 shows that the marginal value of liquidity to the banker is given by the extra consumption that borrowing affords, net of repayment obligations.

As per (43), reserve requirements (φ) can attenuate the impact of foreign interest rate shocks if they decrease the marginal value of liquidity to bankers. Changes in reserve requirements exert two opposing effects on the marginal value of liquidity. On the one hand, stricter reserve requirements increase the marginal value of liquidity by reducing the interest rate on deposits (see equation 18). On the other hand, because the reserve requirement is financed with deposits, stricter regimes tighten the banker's capital requirement which serves to decrease their marginal value of liquidity.[17] Because of these two opposing effects, changes in reserve requirements will have a more muted impact on R_{t+1}^l than capital requirements.[18]

The transmission of reserve requirements illustrates how different macroprudential instruments can influence one another. Previous analyses on the effects of reserve requirements focus on the liquidity benefits provided by this instrument and study it in isolation of capital requirements (see e.g., Glocker and Towbin, 2012; Agénor and da Silva, 2014). This analysis shows that capital and reserve requirements interact such that the influence of reserve requirements on loan interest rates is reduced relative to a scenario where reserve requirements are applied in isolation of capital requirements. Note that the impact of the capital requirement on the effectiveness of reserve requirements works in one direction: the presence of a reserve requirement does not affect the ability of capital requirements to influence interest rates. Furthermore, this interaction between capital and reserve requirements is predicated on the assumption that the capital requirement is binding. In this model, if the capital requirement does not bind, λ_t^c disappears from equation 43 and reserve requirements have no effect on loan interest rates or the feedback between asset and credit markets.

Figure 3 reveals that, as a result of the two opposing effects that reserve requirements have on the marginal value of liquidity to bankers, this instrument delivers smaller and less persistent attenuation benefits as compared to LTV and capital requirements. Strict reserve requirements reduce the contemporaneous impact of the shock on aggregate consumption, asset prices, and entrepreneur loans, whilst output and household deposits are almost invariant to changes in the reserve requirement regime.[19]

The analysis above provides the rationale for a macroprudential response to foreign interest rate shocks and is illustrative of the subtle differences and interactions between macroprudential instruments. For instance, even though changes to demand side regulation (LTV) are transmitted through real estate demand whilst changes supply side regulation (capital and reserve requirements) are transmitted through interest

[17] The capital requirement tightens because higher reserve requirements increase the share of deposits on the banker's balance sheet with no effect on the level of banker capital.

[18] Specifically, a 1 p.p. increase/decrease in reserve requirements will increase/decrease the interest rate on loans by less than a 1 p.p. increase/decrease in capital requirements.

[19] Although graphically extremely similar, the policy and transition functions upon which the impulse responses for output and deposits basically show a very small attenuation benefit for the strict regime and a very small amplification of the shock for the easy regime.

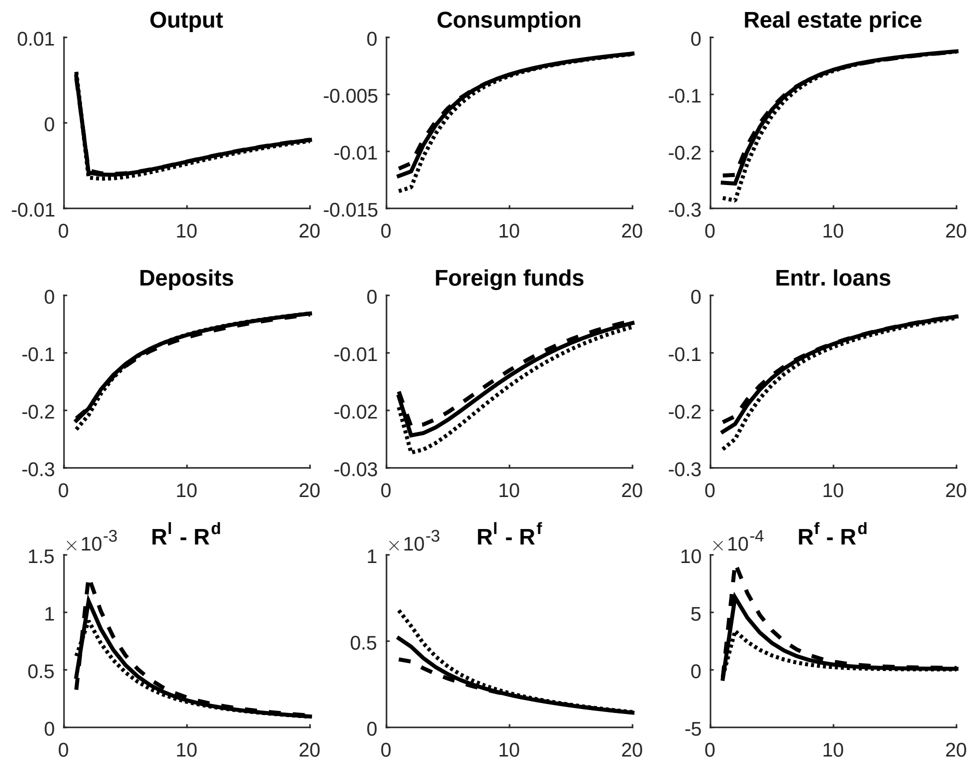

Figure 3: Impulse response functions following a positive shock to R_t^w for different reserve requirement regimes as per table 2. Solid line: baseline calibration; Dashed line: strict reserve requirement regime; Dotted line: easy reserve requirement regime.

rates and credit demand, both can deliver similar shock benefits. Indeed, (8) implies that credit and real estate markets are in fact different sides of the same coin, and thus, measures aimed at the real estate market can be substituted for those aimed at the credit market. That being said, the analysis of reserve requirements shows that different supply side instruments can interact even though they have different transmission channels. As a result, the quantitative impact and comparative effectiveness of supply side macroprudential measures can vary across instruments.

4.4 Macroeconomic and financial stability across instruments and regimes

The simultaneity of business and financial cycles imply that macroprudential efforts can be complimentary to macroeconomic stability objectives (Borio, 2014; Smets, 2014). To assess whether macroprudential regulation can address both financial stability and macroeconomic stability concerns, we plot the change in the steady state standard deviation of output ($\Delta\sigma_Y$) and asset prices ($\Delta\sigma_q$) or loans ($\Delta\sigma_L$) for each instrument across the different regulatory regimes. In this case, $\Delta\sigma_Y$ serves as a measure of macroeconomic stability whilst the use of $\Delta\sigma_q$ and $\Delta\sigma_L$ as measures of financial stability is motivated with reference to their role in the financial cycle (see e.g., Galati and Moessner, 2013; Kuttner and Shim, 2016) .

In line with Angelini et al. (2014), figure 4 illustrates that macroprudential regulation complements both financial and macroeconomic stability. This figure shows that, for each instrument, the standard deviation

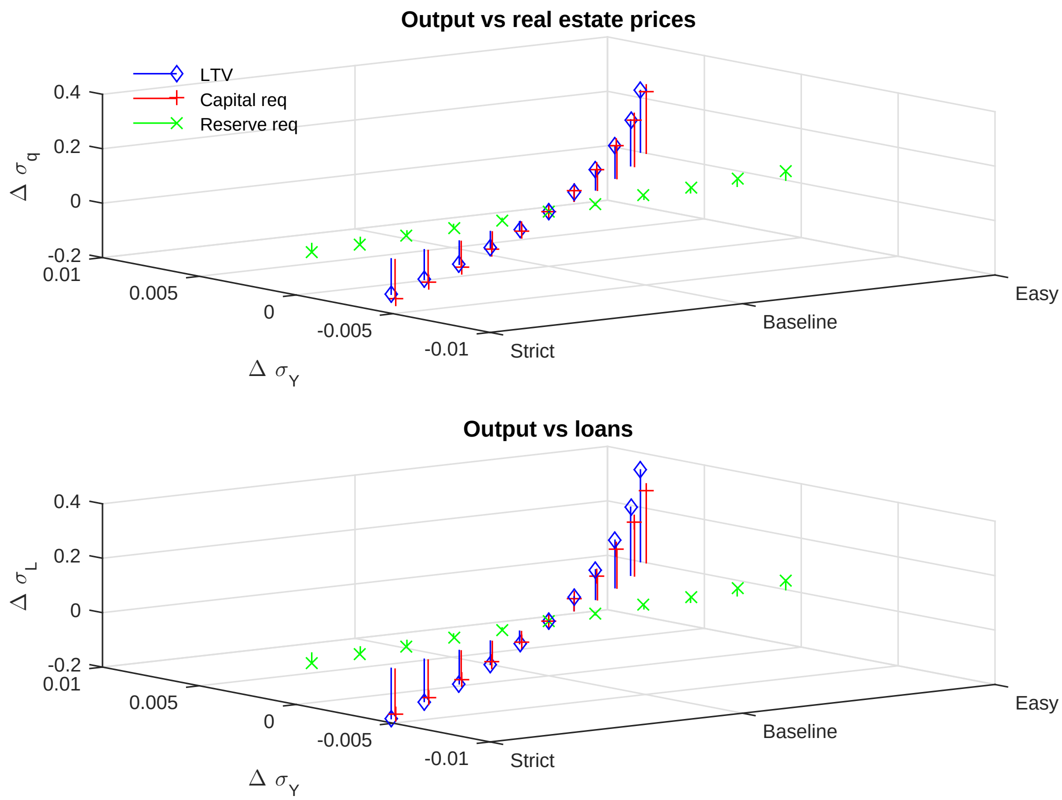

Figure 4: Trade-off between macroeconomic and financial stability across instruments and regimes. X-axis: macroprudential regimes, easy to strict. Y-axis: change in the standard deviation of output. Z-axis: change in the standard deviation of asset prices or loans. Top panel plots standard deviation of output vs. standard deviation of real estate prices. Bottom panel plots standard deviation of output vs. standard deviation of loans.

of output and asset prices (top panel) or output and loans (bottom panel) increases when we move from a strict to an easy regime. Therefore, stricter macroprudential regimes increase macroeconomic and financial stability, whilst easier regimes reduce macroeconomic and financial stability. Nevertheless, the size of the change in σ_Y, σ_q, and σ_L across regulatory regimes shows that although each instrument is able to foster both financial and macoreconomic stability, macroprudential regulation is more effective on the financial stability front. As per the IRF analysis, reserve requirements have a very small impact on the volatility of these three variables whilst LTV and capital requirements generate larger effects on variable volatility.[20]

Although strict LTV and capital requirements deliver similar macroeconomic and financial stability benefits, the bottom panel of figure 4 indicates that moving from the baseline to the strict LTV regime realizes a marginally larger decrease in the volatility of loans than when moving from the baseline to the easy capital regime. Thus, in line with the different transmission mechanisms of LTV and capital requirements, these two instruments may impart different effects on different variables. Looking at the shape of the curves in figure 4, one can see that there may be decreasing returns to scale in LTV and capital requirements whereas reserve requirements exhibit constant returns to scale. Decreasing returns to scale in LTV and capital requirements is evidenced by the decline in the gradient of the LTV and capital requirement curves as we move from the

[20]These findings are echoed by the steady state standard deviation of aggregate consumption, deposits, and foreign funds.

easy to the strict regime. Here, figure 4 shows that as authorities increase the strictness of LTV and capital requirements, the reductions in the standard deviations of output, asset price, and loans become smaller.

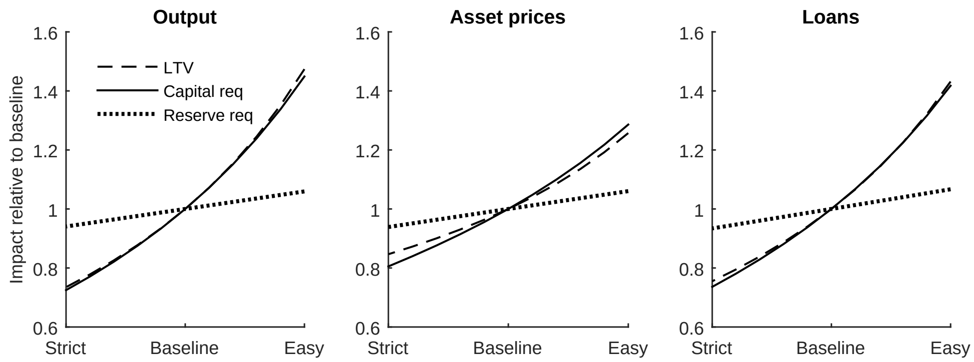

Figure 5: Macroprudential instrument effectiveness. Values larger than 1 indicate shock amplification relative to the baseline. Values smaller than 1 indicate shock attenuation relative to the baseline.

To get a better illustration of each instrument's influence over the financial and business cycle, figure 5 shows how the impact of the shock on output, asset prices, and loans varies across macroprudential instruments and regimes. We divide the absolute value of the contemporaneous response of each variable under each instrument-regime pair by the absolute value of its contemporaneous response under the baseline. Thus, in figure 5, values larger than one indicate cycle amplification relative to the baseline whilst values smaller than one are associated with cycle attenuation relative to the baseline.

This exercise reveals that LTV and capital requirements have very similar effects on output and loans, but differ in their impact on asset prices. Thus, the desirability of different macroprudential instruments depend on the objectives of the regulator. In this regard, figure 5 indicates that strict capital requirements may be more effective than strict LTV regulation when authorities seek to lean against the financial cycle. On the other hand, when authorities are interested in stimulating the financial cycle, easy LTV regulation is more productive than easy capital requirements. This insight is evidenced by the fact that strict LTV regulation has a smaller attenuation effect on asset prices than strict capital requirements, and easy LTV regulation has a smaller amplification effect on asset prices than easy capital requirements. In addition, the attenuating effect of strict LTV regulation on output and loans is marginally smaller than strict capital requirements, but the amplification effect of easy LTV regulation on output and loans is marginally larger than that of easy capital requirements. Within instruments, figure 5 reveals that both capital and LTV regulation exert the most influence over output, marginally less influence over loans, and the least influence over asset prices. In contrast, reserve requirements impart the same influence over output, asset prices, and loans.

Figure 5 is also indicative of decreasing returns to scale in LTV regulation and capital requirements. For instance in response to a 5 p.p. increase (strict) in capital requirements, the decline in asset prices following the foreign interest rate shock is approximately 20 p.p. smaller than under the baseline. In contrast, when capital requirements are decreased by 5 p.p. (easy), the decline in asset prices is approximately 30 p.p. larger than under the baseline. As a result, authorities are able to realize larger macroeconomic and financial stability gains through LTV regulation and capital requirements when moving from the easy to the baseline regime, than when moving from the baseline to the strict regime. In contrast, the gradient of the reserve requirement curve in figure 5 remains constant regardless of the target variable, indicating that when changing reserve requirements, authorities can impart a small, but predictable influence over both the financial and business cycle.

Together, figures 4 and 5 indicate that following a positive foreign interest rate shock, macroeconomic and financial stability concerns are aligned: stricter policy can enhance both financial and macroeconomic stability. This result is in keeping with Claessens et al. (2012) and Antonakakis et al. (2015) where the findings of these studies indicate that the link between the financial and business cycle strengthens during times of distress. As per Dees (2016), the strengthening of this link during times of distress implies that the international transmission of financial shocks on the business cycle can be large, providing scope for welfare improvement through macroprudential regulation.[21]

This analysis shows that capital and LTV regulation proffer the most productive means with which to address the negative consequences of foreign interest rate shocks. As per the discussion of their different transmission channels, these two instruments work on different sides of the same coin: capital requirements reduce entrepreneur demand for credit whilst LTV regulation reduces the entrepreneur's demand for real estate (collateral assets). This difference in transmission mechanism sees that capital requirements are more effective in leaning against the financial and business cycle, whilst LTV regulation is more effective in stimulating said cycles. However the difference between these two instruments is marginal, indicating toward their substitutability.

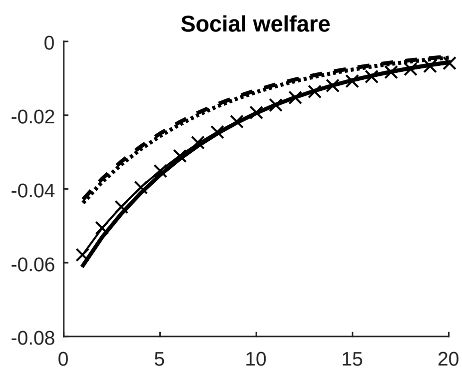

Figure 6: Impulse response functions of social welfare following a positive shock to R_t^w for different macroprudential instruments under the strict regime of table 2. Solid line: baseline calibration; Dashed line: strict LTV regime; Dotted line: strict capital requirement regime; Crossed line: strict reserve requirement regime.

The similarity of social welfare dynamics under the strict LTV and capital regimes as per figure 6 reiterates the substitutability of these instruments when dealing with foreign interest rate shocks.[22] Although the contemporaneous shock attenuation benefits of the capital requirement are marginally larger than that of LTV regulation, the disparity diminishes quickly. Looking at the effect of the strict reserve requirement

[21] The shock is manifest in the foreign economy, where international transmission occurs through the country risk premium, equation 28.

[22] Social welfare is defined by equation 34. We focus on the strict regime as it attenuates the impact of the foreign interest rate shock.

regime on social welfare, the small and temporary attenuation benefits associated with this instrument points to its effectiveness as a supplement to existing LTV or capital requirement measures.

5 Conclusion

Although there is ample theoretical and empirical evidence on the benefits of macroprudential regulation to economic outcomes, not much is known about the comparative effectiveness of the various macroprudential instruments available to authorities. This paper contributes to our understanding of a subset of these instruments through the design a generic small open economy with banking and foreign borrowing where capital requirements, reserve requirements, and LTV regulation coexist. To compare these instruments, we subject the model to a positive foreign interest rate shock that increases the country risk premium with negative consequences for credit extension, asset prices, and output. We find that these macroprudential instruments can attenuate the impact of a positive foreign interest rate shock, and that a strict regulatory regime outperforms a baseline and an easy regime in this regard. We study the transmission channels of these three instruments and show that although capital and LTV regulation are imposed on different sides of the credit market, they are substitutable. This analysis of the transmission channels of reserve requirements indicate that capital requirements interacts with this instrument so as to negate the attenuation benefits of reserve requirements. As a result of this instrument interaction, the effects of reserve requirements diminish quite rapidly, indicating that this instrument should be used to supplement existing LTV and capital requirements. The analysis also shows that financial stability concerns are complimentary to macroeconomic stability concerns following a positive foreign interest rate shock and that the desirability of different macroprudential instruments depend on the objectives of the regulator. In this regard, capital requirements seem most effective at leaning against the financial cycle whilst LTV regulation is most effective at stimulating the financial cycle. Lastly, the results indicate that that LTV and capital requirements may exhibit decreasing returns to scale.

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A Model equations

A.1 Households

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta_h^t \left\{ \log(C_t^h) + j \log(H_t^h) + \tau \log(1 - N_t) \right\} \tag{45}$$

$$C_t^h + D_t + q_t(H_t^h - H_{t-1}^h) + T_t = R_{t-1}^d D_{t-1} + W_t N_t \tag{46}$$

$$1 = m_t^h R_t^d \tag{47}$$

$$q_t = \frac{jC_t^h}{H_t^h} + m_t^h \mathbb{E}_t q_{t+1} \tag{48}$$

$$W_t = \frac{\tau C_t^h}{1 - N_t} \tag{49}$$

A.2 Entrepreneurs

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta_e^t \{log(C_t^e)\} \tag{50}$$

$$C_t^e + q_t(H_t^e - H_{t-1}^e) + R_t^l L_{t-1} + W_t N_t = Y_t + L_t \tag{51}$$

$$\mathbb{E}_t R_{t+1}^l L_t \leq \nu_e \mathbb{E}_t q_{t+1} H_t^e \tag{52}$$

$$Y_t = (H_{t-1}^e)^{\alpha}(N_t)^{1-\alpha} \tag{53}$$

$$q_t = m_t^e \left(\frac{\alpha \mathbb{E}_t Y_{t+1}}{H_t^e} + \mathbb{E}_t q_{t+1} \right) + \nu_e \lambda_t^e \mathbb{E}_t q_{t+1} \tag{54}$$

$$1 = (m_t^e + \lambda_t^e)\mathbb{E}_t R_{t+1}^l \tag{55}$$

$$W_t = \frac{(1-\alpha)Y_t}{N_t} \tag{56}$$

A.3 Bankers

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta_b^t \left\{\log(C_t^b)\right\} \tag{57}$$

$$C_t^b + L_t + R_{t-1}^d D_{t-1} + R_{t-1}^f B_{t-1}^f + \zeta_t = D_t + B_t^f + R_t^l L_{t-1} + \zeta_{t-1} \tag{58}$$

$$D_t + B_t^f \leq (1-\vartheta)L_t + \zeta_t \tag{59}$$

$$\zeta_t \geq \varphi D_t \tag{60}$$

$$m_t^b R_t^d = 1 - \varphi \lambda_t^r - \lambda_t^c \tag{61}$$

$$m_t^b R_t^f = 1 - \lambda_t^c \tag{62}$$

$$m_t^b \mathbb{E}_t R_{t+1}^l = 1 - (1-\vartheta)\lambda_t^c \tag{63}$$

$$\lambda_t^r = 1 - m_t^b - \lambda_t^c \tag{64}$$

A.4 Foreign lenders

$$R_t^w = (1-\delta_t)R_t^f \tag{65}$$

$$\chi_t = \kappa \left(\frac{B_t^f}{Y_t} / \frac{B^f}{Y} \right)^{\gamma_f} (R_t^w)^{\gamma_w} \tag{66}$$

$$R_t^w = \rho_w R_{t-1}^w + \varepsilon_t^w \tag{67}$$

A.5 Market clearing

$$1 = H_t^h + H_t^e \tag{68}$$

$$Y_t = C_t^h + C_t^e + C_t^b + R_{t-1}^f B_{t-1}^f - B_t^f \tag{69}$$

$$CA_t = B_{t-1}^f - B_t^f \tag{70}$$

$$T_t = \zeta_t - \zeta_{t-1} \tag{71}$$

B Model sensitivity to changes in country risk premium parameters

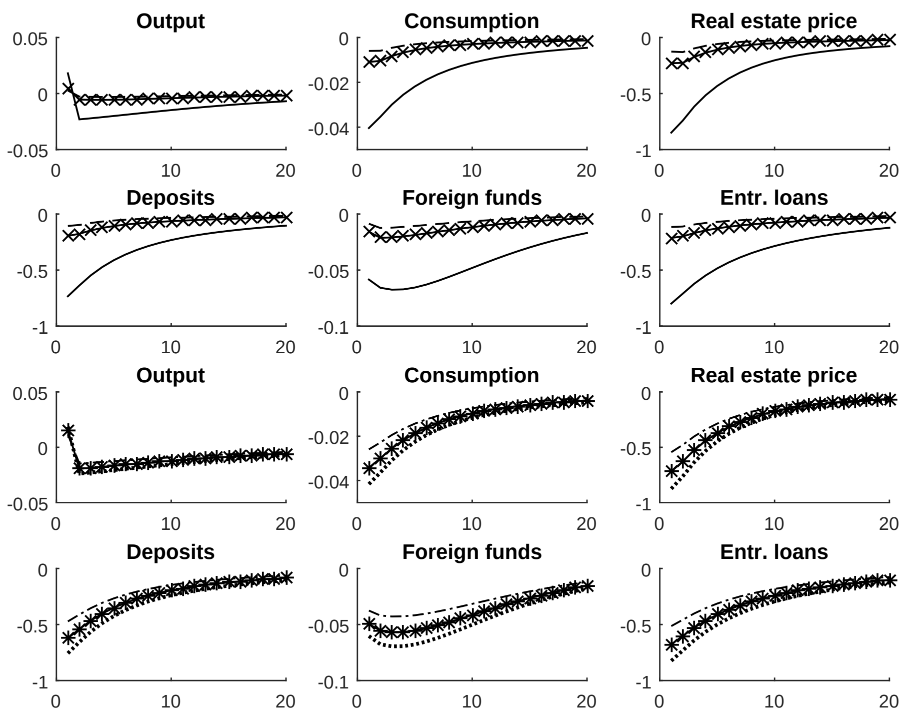

Figure 7: Impulse response functions following a positive shock to R_t^w for different calibrations of γ_f and γ_w. Dashed line: $\gamma_f = 0.85$ and $\gamma_w = 0.85$. Crossed line: $\gamma_f = 0.45$ and $\gamma_w = 0.85$. Solid line: $\gamma_f = 0.05$ and $\gamma_w = 0.85$. Dotted line: $\gamma_f = 0.05$ and $\gamma_w = 0.85$. Star line: $\gamma_f = 0.05$ and $\gamma_w = 0.45$. Dash-dot line: $\gamma_f = 0.05$ and $\gamma_w = 0.05$.