BANK NEGARA MALAYSIA
CENTRAL BANK OF MALAYSIA

Bank Negara Malaysia Working Papers
WP2/2026

LTV, External Position, and Exchange Rate

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January 2026

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January 14, 2026

Abstract

This paper studies the impact of the loan-to-value (LTV) ratio for housing loans for countries with different external positions. Using data from 62 countries and measuring volatility in house prices in terms of their absolute annual growth values, the paper documents three novel stylised facts. First, property prices are more volatile for countries with a looser LTV ratio, second, property prices are more stable among countries with net external assets, and third, exchange rates are more volatile for countries with net external liabilities. Motivated by these facts, I develop a dynamic stochastic general equilibrium (DSGE) model with a housing sector and a collateral constraint for borrowers. The model captures two situations, one with net external assets and the other with net external liabilities. The model shows that a looser LTV ratio will lead to much greater volatility in macroeconomic variables when hit by shocks, particularly for a country with net external liabilities. Unsurprisingly, a country with net external liabilities will suffer a larger welfare reduction by deviating from the optimal LTV ratio. In addition, when dealing with external shocks, the exchange rate is not an effective instrument to augment the LTV rule to stabilise macroeconomic variables.

Keywords: Macroprudential, Housing market, LTV, External position, Exchange rate

JEL classification: E32, E58

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1 Introduction

Macroprudential policies are great additions to central banks' toolkits, as the risks managed by central banks are multifaceted. Macroprudential policies are devised as preemptive tools to avoid the boom-and-bust cycle episodes and to protect the financial system from macroeconomic imbalances and disruptions to financial intermediation activities. The close links between the financial and real sectors underscore the importance of preserving financial stability, as any development in the financial system will directly affect the macroeconomic environment. Financial intermediation activities, especially credit demand and supply, will become less effective due to the breakdown of the financial system, causing less support and a suboptimal outcome to promote economic growth (Adrian, 2017). Furthermore, shocks can propagate through vulnerabilities in the financial system and amplify initial shocks, resulting in a much more profound and long-lasting impact on production and employment (Adrian et al., 2019). Thus, disruptions in the financial system will significantly affect central banks' ability to achieve their output and inflation stabilisation mandates. Financial stability can be considered as a prerequisite for price stability, as financial crises will result in impairments in the monetary transmission mechanism (European Central Bank, 2021).

Many articles have documented that the drivers and properties that characterise the financial cycle are sufficiently different compared to the business cycle, as the financial cycle tends to be longer than the business cycle, as suggested in Claessens et al., 2012, Drehmann et al., 2012, and Rünstler and Vlekke, 2016. The different factors driving the financial and business cycles imply that monetary policy alone is insufficient to deal with the financial cycle (Rünstler, 2016). However, unlike monetary policy, which is a blunt instrument, macroprudential policies are more focused on dealing with specific issues. These policies help stabilise the financial system by reducing concentration risks by banks, controlling speculative activities, and managing excessive risk taking activities. This, in turn, will reduce the amplification mechanism of the financial cycle from both demand and supply of credit channels. The role of macroprudential policies to contain the financial cycle also helps to minimise the potential trade-off that monetary policy could face between achieving macroeconomic and financial stability, which will be significant if the objectives are in conflict (Williams, 2016).

Specifically related to the housing market, one of the most widely used macroprudential policies is the loan-to-value (LTV) ratio for housing loans. The LTV ratio limits the maximum amount of housing loans that banks can lend to their customers, as a mechanism to reduce speculative activities, concentration risk, and irrational exuberance in the housing market. This is critical given the significant interlink between credit expansion and house prices. Claessens et al., 2011 show that house prices are strongly procyclical and move in tandem with the financial cycle. Jordà et al., 2016 suggest that the credit and housing booms have preceded many financial crises. Similarly, Claessens et al., 2012 argue that recessions associated with financial disruption episodes, notably house and equity price busts, are often longer and more profound than other types of recession. The Great Recession of 2007-2009 in the US, characterised by a collapse in house prices and a significant deleveraging process, is a classic example of the close links between housing net worth, household debt, and aggregate demand.

In recent years, more evidence and studies have shown the effectiveness of the LTV ratio in containing the growth of household credit and house prices. Using the dynamic stochastic general equilibrium (DSGE) approach with a housing sector and calibrating the models with data from specific countries, many researchers have found the benefits of the implementation of the LTV ratio and highlighted its role in preserving financial stability. The benefits of the LTV ratio that include mitigating a credit boom, managing household debt, and controlling house prices are documented, for example, in Rubio and Carrasco-Gallego, 2017, Chen and Columba, 2016, Rabanal, 2018, and Funke et al., 2018. Moreover, Cokayne et al., 2024 show that the LTV ratio is effective in limiting the riskiest loans, reducing systemic risks by debilitating the house price-leverage spiral, and improving welfare.

Empirical evidence also supports the effectiveness of the LTV ratio in achieving a more resilient financial system. Kuttner and Shim, 2012 argue that macroprudential policies, including the LTV ratio, effectively stabilise credit cycles and house prices. Cerutti et al., 2015 find that the LTV ratio is generally associated with reductions in credit growth expansion. Akinci and Olmstead-Rumsey, 2018 suggest that macroprudential tightening has been associated with lower bank credit growth, weaker housing credit growth, and a more muted appreciation of house prices. They also conclude that macroprudential policies that contain house price appreciation are more effective in an environment where bank financing is significant. Choi et al., 2018 examine the effectiveness of coordinated macroprudential policies, including the LTV ratio, and concluded that the coordinated implementation of macroprudential policies between the main trading partners could help reduce the risks of widespread banking crises. In addition, Belkhir et al., 2020 show that macroprudential policy has a net positive effect on financial stability by reducing the probability of systemic banking crises and Ampudia et al., 2021 find that the resilience of both banks and borrowers improved due to the implementation of macroprudential policies.

This paper contributes to this debate by analysing the effectiveness of the LTV ratio based on the country characteristic. In particular, I examine the impact of the LTV ratio for a small open economy with different external positions within the DSGE small open economy framework. The external position is one of the critical indicators for demonstrating a country's resilience or vulnerability. Evidence shows that countries that rely heavily on external funding are more susceptible to shocks, as discussed, for example, by Eichengreen et al., 2005, Cormun and De Leo, 2020 and Hofmann et al., 2022. Furthermore, the effectiveness of the exchange rate to insulate shocks may differ depending on the external position of the countries, as suggested, for example, by Hofmann et al., 2020 and Banerjee et al., 2020. Beyond the existing findings, three key stylised facts are established, which provide further motivation for this paper. First, property prices are more volatile for countries with a lower LTV, which is most commonly observed with countries with net external liabilities. Secondly, property prices are more stable for countries with net external assets. Third, exchange rates are more volatile for countries with net external liabilities.

Notwithstanding the growing literature on this topic, there is still a wide range of areas that need further investigation. The implementation and practice of macroprudential policies by policymakers seems to be well ahead of the theory. Although the literature in this field has expanded and answered some of the concerns related to the true cost and benefit of macroprudential policies, there are still many unknowns to discover, as argued in Claessens, 2014, Alam et al., 2019, and Filho and Ng, 2023. An area that needs more clarity is how influential and vital macroprudential policies are in stabilising financial and business cycles for small open economies with different fundamentals or characteristics. A better understanding of this issue is paramount as we continue to seek an answer for the optimal implementation of macroprudential policies and, subsequently, how the implementation of these policies will affect households' welfare.

For the modelling strategy, I extend the closed economy housing sector DSGE model of Iacoviello, 2005 to a small open economy set-up, adding foreign lending/borrowing and external trade. The extension to a small open economy is very closely adopted from Adolfson et al., 2007. The New Keynesian DSGE small open economy framework allows me to explore the propagation of domestic and external shocks through the trade and exchange rate channels. I consider two situations, one where a country with external assets and another with external liabilities. The impact of various domestic and foreign shocks on domestic output, domestic credit growth, and foreign lending/borrowing is then examined using both impulse response functions and from a welfare perspective. Finally, motivated by the empirical observation that shows that exchange rate movements are more volatile for countries with net external liabilities, a scenario analysis was performed to study the feasibility of the nominal exchange rate as a countercyclical instrument to augment the LTV ratio.

The main findings are as follows. First, the results show that a looser LTV ratio for a country with net external liabilities compared to a country with net external assets will lead to much larger credit and output growth deviations from their steady states. The welfare analysis that looks for the optimal implementation of the LTV ratio points to the same conclusion, where it shows that a country with net external liability will be much worse off implementing a looser LTV ratio. Although the optimal LTV ratio is identical for both types of countries, the welfare reduction for a country with net external liabilities to deviate from the optimal LTV is much larger compared to a country with net external assets. The loss of social welfare in terms of consumption equivalent can be very significant compared to a country with net external assets. This is mainly due to a much larger welfare loss for borrowers in a country with net external liabilities. One possible explanation is that an extremely loose LTV ratio will lead to overleveraged situations among borrowers, especially for a country with net external liabilities, and shocks together with the movement in interest rate will have the largest impact on their welfare. Third, the result of the scenario analysis shows that the nominal exchange rate is not an effective instrument to augment the LTV rule in stabilising financial and business cycles. As long as a weaker exchange rate leads to an improvement in domestic production through stronger external demand, the loosening of the LTV rule will intensify the procyclicality between domestic borrowing and output. In contrast, a countercyclical LTV rule that moves in the opposite direction of credit growth is more universal and effective in bringing financial stability.

This article is related to different areas of literature. First, it is related to a small open economy framework, featuring a housing market and a borrowing constraint. Although many have also developed models with similar features, for example in Funke et al., 2018, the novel contribution of this paper is to allow borrowers to access external lenders. Second, it is also related to the growing discussion of the effectiveness of the exchange rate in providing stability to domestic production and insulate against shocks. I specifically study the effect of augmenting the LTV rule based on fluctuations in the exchange rate. Finally, the paper seeks to contribute to the literature on the optimal combination of monetary and macroprudential policies used by a small open economy to manage shocks. An example of a paper that also studies the related topic is Filho and Ng, 2023, where the authors examine the role of macroprudential policies on financial volatility and macroeconomic outcomes conditional on various characteristics of the country.

The remainder of the paper is organised as follows. The next section provides motivations for why this topic is essential and must be analysed. I mainly look at the data on the implementation of LTV ratio in countries around the world based on the integrated Macroprudential Policy database developed by the International Monetary Fund (IMF). I supplement it with data from the Bank for International Settlements (BIS) and the World Bank to establish some critical observations to motivate my research. Section 3.3 gives a detailed explanation of the foundation and specification of the model. Section 3.4 explains the model parameters, and Section 3.5 discusses the results in detail. The final section, Section 3.6, concludes the findings of this paper.

2 Motivation

The external position is one of the critical indicators for demonstrating the resilience or vulnerability of countries. The heavy reliance on external funding exposes countries to issues such as currency and maturity mismatches. This remains a crucial issue, given that the Financial Stability Board (FSB), in its report published in 2022, stated that external borrowing by emerging economies remains highly elevated and amounted to USD 5.6 trillion (approximately 30% of GDP) at the end of 2019. More than 80% of this debt was denominated in foreign currencies, mainly in USD (Financial Stability Board, 2022). That is the main reason why I am pursuing this study. Its primary motivation is to show how effective the implementation of the LTV ratio is in taming the financial and output volatilities conditional on the external position. Furthermore, I built a small data set that allows me to learn more about the relationship between the LTV ratio, external positions, house prices, output volatility, and other key macroeconomic variables. The data set contains unbalanced 62 countries' annual data covering advanced and emerging economies. The selection of countries included in this study is based primarily on the availability of data.[1] The data set covers a 15-year period from 2005 to 2020. Information on the implementation of the LTV ratio worldwide comes from the integrated Macroprudential Policy Database of the IMF developed by Alam et al., 2019. The other information on the data set comes from these three sources:

1. IMF's Balance of Payments and International Investment Position Statistics
2. BIS's Residential property price growth (real) year-on-year changes and Credit to GDP gap
3. World Bank's exchange rate and GDP per capita growth

[1]The countries within the sample are listed at the end of the chapter.

Four key observations found from the data set provide additional motivation for my study. The following upcoming subsections discuss these observations, and they are as follows.

2.1 Observation 1: More countries are adopting a tighter LTV rule

Table 1 shows the use of the LTV ratio for all countries in the data set for the years 2005 and 2020, based on their external positions.[2] It shows that the use of a stricter LTV ratio has increased among countries, regardless of their external positions. Of all countries in the data set, the percentage of countries with an LTV ratio of 100% or more has fallen to 37% in 2020 compared to 76% recorded in 2005.[3] In 2020, most countries had an LTV ratio between 70% and 100%, and only seven countries had an LTV ratio below 70%. However, adoption of the LTV ratio below 100% is more prevalent in countries with net external liabilities, where 67% of countries with net external liabilities had an LTV ratio lower than 100%, versus 58% for countries with net external assets. However, countries with net external assets tend to have a much stricter LTV ratio, where 23% of the observation implemented an LTV ratio below 70% compared to only 3% with net external liabilities in 2020. The same pattern of adoption of a tighter LTV ratio in 2020 compared to 2005 is also observed if I look at the data set and dissect it from the perspective of advanced and emerging economies. [4]

2.2 Observation 2: The growth of real residential property prices is more volatile for countries with a lower LTV

In this analysis, I tabulate the absolute annual growth of real residential property prices with the LTV ratio data.[5] The graph on the left-hand side of Figure 1 shows all data points in the data set for the 15-year duration, where each country will have one observation for each year. Meanwhile, the right-hand side chart shows the countries' averages and, in total, contains only 55 data points. The left-hand side chart shows that real residential property prices are generally more volatile, experiencing high appreciation or a significant decline when LTV ratios are loose. The dispersion of real residential property prices is much wider when LTV is loose. The right-hand side chart also suggests that real residential property prices are more volatile when LTV is loose, with Hong Kong being the most notable outlier. This observation is

[2] For year 2005, the international investment position data is not available for Mongolia, Saudi Arabia and Serbia

[3] The LTV focusses mainly on LTV limits on real estate mortgage loans (both residential and commercial.) When a country has no LTV limits, Alam et al., 2019 set the value at 100, where the borrowers can borrow the total amount against the collateral value.

[4] See Table A1 for the data between advanced and emerging economies.

[5] The real residential property price growth data is not available for Argentina, Kuwait, Mongolia, Nigeria, Saudi Arabia, Ukraine and Uruguay.

Table 1: LTV rule implementation in 2005 and 2020

2005			
LTV	Net External Liabilities	Net External Assets	Total
< 70%	1 (2%)	1 (7%)	2 (3%)
70% to < 100%	8 (18%)	4 (29%)	13 (21%)
=> 100%	36 (80%)	9 (64%)	47 (76%)
Total	45	14	59
2020			
LTV	Net External Liabilities	Net External Assets	Total
< 70%	1 (3%)	6 (23%)	7 (11%)
70% < 100%	23 (64%)	9 (35%)	32 (52%)
=> 100%	12 (33%)	11 (42%)	23 (37%)
Total	36	26	62

Source: Author's calculation

consistent with previous empirical findings, for example, of Igan and Kang, 2011, Akinci and Olmstead-Rumsey, 2018, Armstrong et al., 2019 and Richter et al., 2019, in which the authors argue that the LTV ratio is associated with a more muted appreciation of house prices. To remove the possibility of a spurious relationship, I use fixed-effects panel regressions with data available for 55 countries from 2005 to 2020, with real residential property prices (absolute) as the dependent variable, together with LTV, GDP per capita (absolute), lag of unemployment rate (with and without) and annual absolute growth of building permit (with and without) as independent variables. The regression outputs show that LTV is statistically significant at a 1% level in explaining the volatility in real residential property prices.[6] However, the results should be treated with care as they may suffer from omitted variable bias due to limited explanatory variables.

[6] See Table A2 for details of the regression outputs.

Figure 1: Real residential property price growth and LTV ratio

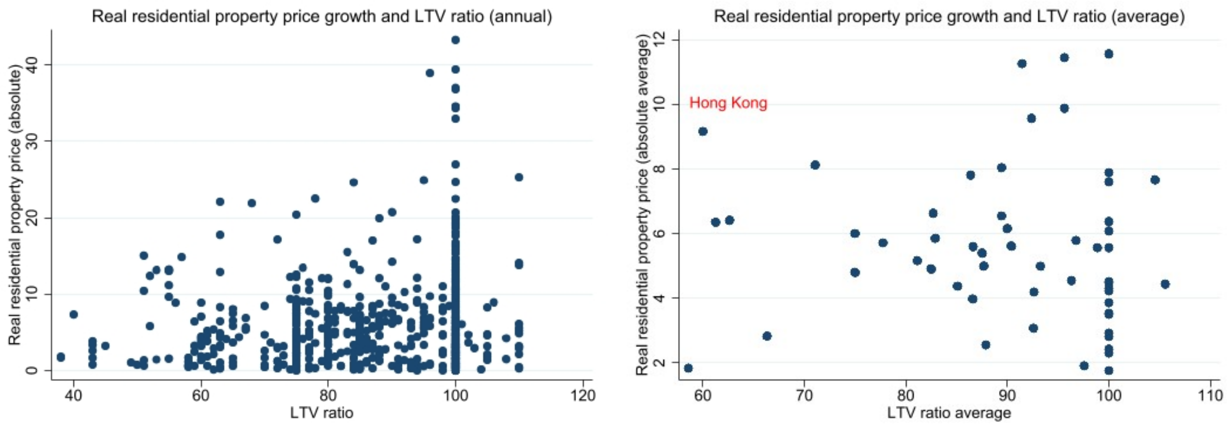

Figure 1. Scatter plots between the absolute growth of real residential property prices and LTV ratio. The y-axis is in terms of the percentage of absolute growth in real residential property prices, and the x-axis is the LTV ratio.

2.3 Observation 3: Real residential property prices are more stable for countries with net external assets

This segment examines the relationship between the growth of real residential property prices and the external position. I divide the growth of real residential property price into two groups: stable and volatile. Stable refers to the growth of real residential property prices between -5% to 5%, and volatile captures the growth of real residential property prices beyond the stable range. Each country will have one data point in each year from 2005 to 2020, and Table 2 summarises the findings. It shows that countries with net external assets typically experience more stable prices for residential properties, with more than two-thirds of the data points falling within the stable range. This compares to only 53% for countries with net external liabilities. Meanwhile, Figure 2 shows the averages of the countries and contains only 55 data points. It shows that the average real residential property price range for countries with net external assets is much tighter, as illustrated by a narrower range of red-dotted data points. The notable outlier is Hong Kong.

2.4 Observation 4: Exchange rates are more volatile for countries with net external liabilities

This segment analyses the relationship between the volatility of the nominal exchange rate and the external position. The volatility of the nominal exchange rate refers to the absolute growth in the bilateral movement of the nominal exchange rate between the home countries against the US dollar.

Table 2: Real residential property price growth and external position

Real residential property price	Net External Liabilities	Net External Assets	Total
-5% to 5%	293 (53%)	180 (67%)	473 (57%)
<-5% and >5%	263 (47%)	87 (33%)	350 (43%)
Total	556	267	823

Source: Author's calculation

Figure 2: Real residential property prices and external position

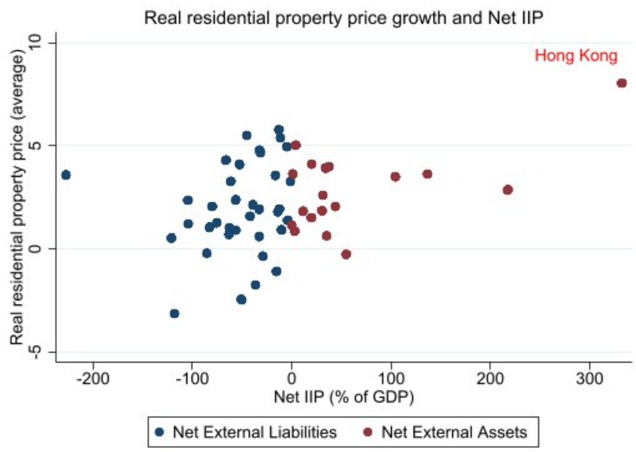

Figure 2. Scatter plot between the growth of real residential property prices and net international investment position. The y-axis represents the percentage growth in real residential property prices, and the x-axis is the net international investment position (% of GDP).

The exchange rate volatilities are clustered into two groups: stable and volatile. Stable refers to the movement of the absolute exchange rate between 0% and 5%, and volatile captures the movement of the absolute exchange rate beyond the stable range. For this analysis, I removed all countries in the Eurozone, Argentina, Hong Kong, Saudi Arabia, Singapore and the United States. All other countries will have one data point in each year from 2005 to 2020, and Table 3 summarises the findings. It shows that countries with net external assets experience more stable exchange rates, with 59% of the data points falling within the stable range. This compares to only 49% for countries with net external liabilities. Meanwhile, Figure 3 shows the averages of the countries and contains only 38 data points. It shows a negative relationship between the volatility of the exchange rate and the external position. To remove the possibility of a spurious relationship, I use fixed effect panel regressions with data for all 38 countries from 2005 - 2020, with exchange rates as the dependent variable and external position and year dummies as independent variables. The regression output shows that the external position is statistically significant at a 1% level in explaining the volatility of the exchange rates.[7] This result is consistent with the findings of other papers, for example, by Gagnon, 1996, Lane and Milesi-Ferretti, 2004, and Hagedorn, 2017, which conclude that the external position is one of the determinants of the movement in the exchange rates.

Table 3: Exchange rates and external position

Exchange rates (Absolute)	Net External Liabilities	Net External Assets	Total
<=5%	213 (49%)	97 (59%)	310 (52%)
>5%	223 (51%)	67 (41%)	290 (48%)
Total	436	164	600

Source: Author's calculation

Figure 3: Exchange rates and external position

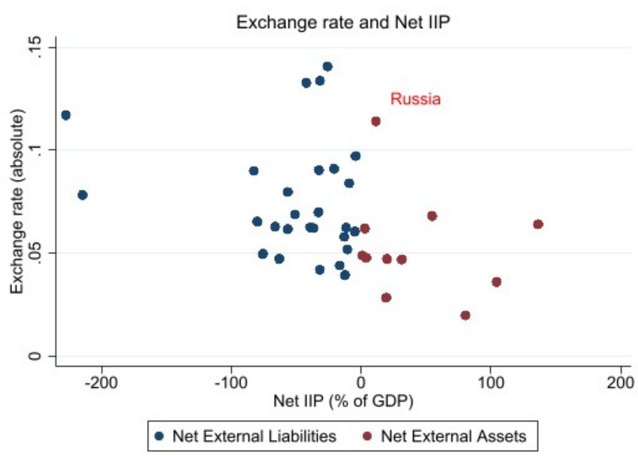

Figure 3. Scatter plot between the absolute growth of nominal exchange rate and net international investment position. The y-axis is in terms of the percentage of absolute growth in the nominal exchange rate, and the x-axis is the net international investment position (% of GDP).

Here are the key takeaways from the four observations, which can be summarised as follows:

1. Regardless of net external position, tighter LTV ratios are more commonly observed now compared than before.

2. Looser LTV is associated with more volatile residential property prices. Using a logit model with fixed effects, the results support Observation 2, which shows that a tighter LTV improves the likelihood of having more stable residential property prices (Table A4).

[7]See Table A3 for details of the regression output.

3. Countries with external assets tend to have more stable exchange rates and residential property prices.

4. Countries with external liabilities tend to have more volatile exchange rates and residential property prices.

This paper aims to study the effectiveness of the LTV ratio conditional on external position, especially from the perspective of the marginal benefit of introducing a tighter LTV rule between countries with net external assets and external liabilities. Apart from the fact that the external position is one of the crucial indicators for demonstrating countries' vulnerability, these key takeaways provide additional motivations to carry out this study. The observations are particularly interesting, as the data show that countries with net external assets tend to have more stable residential property prices, which coincides with the fact that these countries are also the ones that are likely to have tighter LTV ratios as shown in Table 4.

Table 4: Average net external position and LTV ratio (2005 - 2020)

LTV	Net External Liabilities	Net External Assets	Total
< 70%	0 (0%)	5 (24%)	5 (8%)
70% to < 90%	14 (34%)	5 (24%)	19 (31%)
90% to <= 100%	26 (64%)	10 (47%)	36 (58%)
> 100%	1 (2%)	1 (5%)	2 (3%)
Total	41	21	62

Source: Author's calculation

The observations are intriguing and warrant further investigation. In particular, should countries with external liabilities adopt tighter LTV rules? Who will benefit more from a tighter LTV in stabilising the financial and business cycles? Which countries will be worse off deviating from the optimal policy setting? Countries with external assets or external liabilities? In addition, I have also shown that exchange rate movements are more volatile for countries with net external liabilities. This motivates me to explore the benefit of augmenting the LTV rule with the nominal exchange rate for countries with external liabilities. This paper and the model that I developed aim to shed some light on these questions.

3 Model

I develop two identical New Keynesian DSGE models that are similar in all aspects except for their external position. From the modelling perspective, the models can also be seen as a single model with a parameter to determine the state of the economy, either as a country with net external assets or net external liabilities. As a result, both models will start from the same steady-state values, but will generate different impulse response functions depending on their external position. The discount factor for patient households is higher than that for impatient households, leading to positive financial flows in equilibrium, where patient households save and impatient households borrow. The ability of savers to lend domestically and externally captures the concept of a country with net external assets. On the contrary, the flexibility of borrowers to borrow from domestic savers and external lenders reflects the concept of a country with net external liability. First, I explain the model for a country with net assets, followed by minor modifications to the model to reflect a country with net external liabilities.

A country with net external assets

The model is populated by two types of households: patient (that is, savers) and impatient (that is, borrowers). The two types of households work, consume, and accumulate houses. Patient households are unconstrained savers, and impatient households are constrained borrowers. Patient households have a lower discount rate than impatient households to reflect savers' and borrowers' preferences. Patient households can either lend their savings to domestic borrowers or invest them in foreign assets. However, impatient households can only borrow from domestic savers, and the money can be used to finance their consumption spending and accumulate housing stock. Impatient households are constrained borrowers because they need to collateralise their debt repayments. The total amount of loans that impatient households can borrow from patient households is also subject to the LTV rule. The collateralisation of debt repayment and the LTV rule imply that debt repayment in the subsequent period must be within a specific limit of the expected future value of the current stock of houses owned by impatient households. There are also foreign buyers who buy domestic houses in this model.

On the production side, the economy has three types of firms. Firms are involved in producing homogeneous domestic goods, differentiated intermediate goods, or final consumption goods. Firms producing homogeneous domestic goods and final consumption goods operate in perfectly competitive markets, whereas intermediate goods producers operate in a monopolistic competition market. Producers of homogeneous domestic goods purchase intermediate goods and subsequently transform them without cost into homogeneous domestic goods. Producers of final consumption goods require input of homogeneous domestic goods and imported goods, with transformation into final consumption goods carried out at no cost. Producers of homogeneous domestic goods sell their products to producers of final consumption goods and also export them to foreign consumers. However, the production of intermediate and final consumption goods is only for domestic consumption. Intermediate firms require labour from both types of households for their output production.

There are also a federal government and a central bank in this model. Federal government spending in this model is treated as exogenous. The central bank conducts its monetary policy based on the Taylor rule to bring output and inflation to its targets. The aggregate housing stock in this model is fixed, which implies that any development in the housing market will be fully reflected in the movement of house prices. The open economy model also means that any movements in the nominal exchange rate will affect the terms of trade and the balance of payments. Intermediate goods producers are the only source of nominal rigidity in this model, where they can re-optimise their prices based on Calvo friction.

3.1 Households - A country with net external assets

3.1.1 Households - Patient households (unconstrained)

There is a continuum of patient households in the economy. Patient households consume, work, and accumulate houses. The maximisation problem of the representative patient household is given by:

$$\max_{C_t^u, H_t^u, L_t^u, B_t^u, A_t^f} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left(\ln C_t^u + j \ln H_t^u - \frac{(L_t^u)^{\varphi}}{\varphi} \right) \tag{1}$$

subject to the budget constraint

$$S_t A_{t+1}^f + P_t C_t^u + Q_t \left(H_t^u - H_{t-1}^u \right) + B_t^u \leq W_t^u L_t^u + R_{t-1} B_{t-1}^u + S_t \Phi_{t-1} R_{t-1}^f A_t^f + T_t \tag{2}$$

where C_t^u is the current consumption, L_t^u is the labour hours and H_t^u is the number of houses owned by the patient households. $\frac{1}{\varphi-1}$ is the elasticity of the labour supply and $\varphi > 0$. $j > 0$ is the weight of the housing in the utility function. B_t^u is the domestic savings of the patient households or the stock of domestic loans extended to the impatient households, and R_t is the policy rate set by the central bank and also the rate of return for domestic savings. T_t captures transfers and profits to patient households.

S_t is the nominal exchange rate. A_t^f is the stock of foreign assets, R_t^f is the rate of return for foreign assets in foreign currency units, and Φ_t is the term of risk premium. Q_t is house prices, and W_t^u is the wage for patient households.

Dividing the budget constraint by $P_t A_t$, where A_t is the domestic technology, the budget constraint is defined in real terms, and it becomes

$$\frac{S_t A_{t+1}^f}{P_t A_t} + \frac{C_t^u}{A_t} + q_t \left(H_t^u - H_{t-1}^u \right) + b_t^u \leq w_t^u L_t^u + \frac{R_{t-1} b_{t-1}^u A_{t-1}}{\pi_t A_t} + \frac{S_t \Phi_{t-1} R_{t-1}^f A_t^f}{P_t A_t} + \tau_t$$

where $\pi_t = P_t / P_{t-1}$, $q_t = Q_t / P_t A_t$, $b_t^u = B_t^u / P_t A_t$, $w_t^u = W_t^u / P_t A_t$ and $\tau_t = T_t / P_t A_t$. Set $s_t = S_t / S_{t-1}$, $p_t = P_t / P_t^d$, $\bar{\pi}_t = P_t^d / P_{t-1}^d$ and $a_t^f = S_t A_{t+1}^f / P_t^d A_t$, the budget constraint becomes

$$\frac{a_t^f}{p_t} + \frac{C_t^u}{A_t} + q_t \left(H_t^u - H_{t-1}^u \right) + b_t^u \leq w_t^u L_t^u + \frac{R_{t-1} b_{t-1}^u A_{t-1}}{\pi_t A_t} + \frac{s_t \Phi_{t-1} R_{t-1}^f a_{t-1}^f A_{t-1}}{\bar{\pi}_t p_t A_t} + \tau_t$$

Four equations characterise the first order conditions for the patient households:

$$\frac{1}{c_t^u} = \beta E_t \left(\frac{R_t}{\pi_{t+1} c_{t+1}^u \Delta_{t+1}^A} \right) \tag{3}$$

$$w_t^u = \left(L_t^u \right)^{\varphi - 1} c_t^u \tag{4}$$

$$\frac{j}{H_t^u} = \frac{1}{c_t^u} q_t - \beta E_t \frac{1}{c_{t+1}^u} q_{t+1} \tag{5}$$

$$\frac{1}{c_t^u} = \beta E_t \frac{1}{c_{t+1}^u} \frac{s_{t+1} \Phi_t R_t^f p_t}{\bar{\pi}_{t+1} p_{t+1} \Delta_{t+1}^A} \rightarrow \frac{1}{c_t^u} = \beta E_t \frac{1}{c_{t+1}^u} \frac{s_{t+1} \Phi_t R_t^f P_t P_{t+1}^d P_t^d}{P_t^d P_{t+1} P_{t+1}^d \Delta_{t+1}^A} \rightarrow \frac{1}{c_t^u} = \beta E_t \frac{s_{t+1} \Phi_t R_t^f}{c_{t+1}^u \pi_{t+1} \Delta_{t+1}^A} \tag{6}$$

where $c_t^u = C_t^u / A_t$ and $\Delta_{t+1}^A = \frac{A_{t+1}}{A_t}$. Equations (3.3) and (3.4) are the standard Euler and labour supply equations. Equation (3.5) captures patient households' demand for housing. Similar to the Euler equation for domestic assets in (3), Equation (3.6) represents the Euler equation for foreign assets. Δ_{t+1}^A captures the change in domestic technology.

3.1.2 Households - Impatient households (constrained)

There is a continuum of impatient households in the economy. Impatient households consume, work, and accumulate houses. The discount factor for impatient households, $\widetilde{\beta}$, is lower than that of the patient households, β. The maximisation problem of the representative impatient households is given by

$$\max_{C_t^c, H_t^c, L_t^c, B_t^c} \mathbb{E}_0 \sum_{t=0}^{\infty} \widetilde{\beta}^t \left(\ln C_t^c + j \ln H_t^c - \frac{(L_t^c)^\varphi}{\varphi} \right) \tag{7}$$

subject to the budget constraint

$$P_t C_t^c + Q_t \left(H_t^c - H_{t-1}^c \right) + R_{t-1} B_{t-1}^c + \leq W_t^c L_t^c + B_t^c \tag{8}$$

where C_t^c is the current consumption, L_t^c is the labour hours and H_t^c is the number of houses owned by the impatient households. W_t^c is the wage for impatient households and B_t^c is the amount borrowed from patient households.

Dividing the budget constraint by $P_t A_t$, and it becomes

$$\frac{C_t^c}{A_t} + q_t \left(H_t^c - H_{t-1}^c \right) + \frac{R_{t-1} b_{t-1}^c A_{t-1}}{\pi_t A_t} \leq w_t^c L_t^c + b_t^c$$

where $b_t^c = B_t^c / P_t A_t$ and $w_t^c = W_t^c / P_t A_t$. The maximisation problem is also subject to the following borrowing constraint

$$R_t B_t^c \leq LTV E_t Q_{t+1} H_t^c \tag{9}$$

where the maximum amount that impatient households can borrow from domestic savers is subject to the LTV ratio, where $LTV < 1$. The borrowing constraint implies that the debt repayment in the current period must be within a specific limit of the expected future value of the current stock of houses owned by impatient households. Dividing the borrowing constraint by $P_t A_t$, and it becomes

$$R_t b_t^c \leq LTV E_t \pi_{t+1} q_{t+1} H_t^c \Delta_{t+1}^A$$

Three equations characterise the first order conditions for impatient households:

$$\frac{1}{c_t^c} = \widetilde{\beta} E_t \left(\frac{R_t}{\pi_{t+1} c_{t+1}^c \Delta_{t+1}^A} \right) + \Omega_t' R_t \tag{10}$$

$$w_t^c = (L_t^c)^{\varphi - 1}\, c_t^c \tag{11}$$

$$\frac{j}{H_t^c} = \frac{q_t}{c_t^c} - \widetilde{\beta} E_t \frac{q_{t+1}}{c_{t+1}^c} - \Omega_t' LTV E_t \pi_{t+1} q_{t+1} \Delta_{t+1}^A \tag{12}$$

where Ω_t' is the Lagrangian multiplier for the borrowing constraint of impatient households, and $c_t^c = C_t^c / A_t$. Equations (3.10) and (3.11) are the standard Euler and labour supply equations for impatient households. Equation (3.12) captures the demand for housing by impatient households, taking into account the additional borrowing constraint imposed on them.

3.2 Foreign buyers

Foreign investors can also purchase houses. The maximisation problem of representative foreign investors is given by the following.

$$\max_{C_t^f, H_t^f, B_t^f} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^{*t} \left(\ln C_t^f + j^f S_t^f \ln H_t^f \right) \tag{13}$$

subject to the budget constraint

$$P_t^f C_t^f + \frac{P_t^f}{P_t A_t} S_t^f Q_t \left(H_t^f - \Phi_{t-1}^f H_{t-1}^f \right) + B_t^f \leq R_{t-1}^f B_{t-1}^f \tag{14}$$

where C_t^f is the current consumption and H_t^f is the number of houses owned by foreign investors. $j^f > 0$ is the weight of the housing in the utility function. B_t^f is the savings of foreign investors and R_t^f is the rate of return on the savings. $S_t^f = \frac{1}{S_t}$ is the nominal exchange rate and $\Phi_t^f = \frac{1}{\Phi_t}$ is the term of risk premium.

Dividing the budget constraint by P_t^f, and it becomes

$$C_t^f + S_t^f q_t \left(H_t^f - \Phi_{t-1}^f H_{t-1}^f \right) + b_t^f \leq \frac{R_{t-1}^f b_{t-1}^f}{\pi_t^f}$$

Three equations characterise the first order conditions for foreign investors:

$$\frac{1}{C_t^f} = \lambda_t^f \tag{15}$$

$$\lambda_t^f = \beta^* E_t \lambda_{t+1}^f \frac{R_t^f}{\pi_{t+1}^f} \tag{16}$$

$$\frac{j^f S_t^f}{H_t^f} = \lambda_t^f S_t^f q_t - \beta^* E_t \lambda_{t+1}^f S_{t+1}^f q_{t+1} \Phi_t^f \rightarrow \frac{j^f}{H_t^f} = \lambda_t^f q_t - \beta^* E_t \lambda_{t+1}^f s_{t+1}^f q_{t+1} \Phi_t^f \tag{17}$$

where λ_t^f is the Lagrangian multiplier for the budget constraint of foreign investors. Combining all three equations, the optimal reaction of foreign investors to house prices and the rate of return for foreign assets is given as follows.

$$q_t = \frac{j^f}{H_t^f \lambda_t^f} + \frac{\beta^* E_t \lambda_{t+1}^f s_{t+1}^f q_{t+1} \Phi_t^f}{\lambda_t^f} \rightarrow q_t = \frac{j^f C_t^f}{H_t^f} + \frac{\pi_{t+1}^f s_{t+1}^f q_{t+1} \Phi_t^f}{R_t^f}$$

where the first part of the equation captures the ratio of marginal utilities of housing and consumption for foreign investors. This approach is similar to Rabanal, 2018.

3.3 Production of the homogeneous domestic goods

Producers of the homogeneous domestic goods purchase intermediate goods as input and subsequently transform them without costs into homogeneous domestic goods. Homogeneous domestic goods are a composite of a continuum of i differentiated intermediate goods and are produced using the following production function.

$$Y_t = \left[\int_0^1 Y_{i,t}^{\frac{\varepsilon-1}{\varepsilon}} di \right]^{\frac{\varepsilon}{\varepsilon-1}} \tag{18}$$

where $Y_{i,t}$ denotes differentiated intermediate goods and ε reflects their degree of substitutability. A competitive and representative firm produces homogeneous domestic goods and takes the output price of homogeneous domestic goods, P_t^d, and the price of the inputs, $P_{i,t}^d$ as given. The profit maximisation problem of the representative homogeneous domestic good producer is given by the following.

$$P_t^d Y_t - \int_0^1 P_{i,t}^d Y_{i,t} dj$$
$$\text{subject to } Y_t = \left[\int_0^1 Y_{i,t}^{\frac{\varepsilon-1}{\varepsilon}} di \right]^{\frac{\varepsilon}{\varepsilon-1}}$$

Profit maximisation leads to the following first order condition

$$Y_{i,t} = Y_t \left(\frac{P_t^d}{P_{i,t}^d} \right)^{\varepsilon} \tag{19}$$

3.4 Production of intermediate goods

There are a variety of differentiated intermediate goods produced domestically. Intermediate goods are required as the only input to produce homogeneous domestic goods. In this model, firms only need labour to produce intermediate goods. The production of each intermediate good by the i^{th} intermediate producer, $Y_{i,t}$, depends on the level of domestic technology and requires the supply of labour from both patient and impatient households as follows:

$$Y_{i,t} = A_t \left(L_{i,t}^u\right)^{\gamma} \left(L_{i,t}^c\right)^{(1-\gamma)}$$

where $\gamma \in [0,1]$ measures the relative size of each group in terms of labour required to produce intermediate goods. This implies that patient and impatient households are needed to produce intermediate goods that are not perfectly substitutable. γ is treated as static among all intermediate goods producers in this model. A_t represents technology and the change in technology, $log(\Delta_t^A) = log(A_t - A_{t-1})$, follows an autoregressive process:

$$\Delta_t^A = \rho_A \Delta_{t-1}^A + \varepsilon_{\Delta_t^A}$$

where ρ_A captures the persistence of a domestic technology shock. By substituting (14) into (13), it defines the relationship between the price level of homogeneous domestic goods, P_t^d, and the price of the intermediate good of the i^{th} intermediate producer, $P_{i,t}^d$ as follows:

$$\begin{aligned} Y_t &= \left[\int_0^1 Y_{i,t}^{\frac{\varepsilon-1}{\varepsilon}} di \right]^{\frac{\varepsilon}{\varepsilon-1}} \\ Y_t &= \left[\int_0^1 \left(Y_t \left(\frac{P_t^d}{P_{i,t}^d} \right)^{\varepsilon} \right)^{\frac{\varepsilon-1}{\varepsilon}} di \right]^{\frac{\varepsilon}{\varepsilon-1}} \\ \Rightarrow P_t^d &= \left(\int_0^1 (P_{i,t}^d)^{(1-\varepsilon)} di \right)^{\frac{1}{1-\varepsilon}} \end{aligned} \tag{20}$$

3.5 Labour demand by intermediate goods producers

Intermediate producers demand labour as the only input required to produce outputs. The labour demand for patient and impatient households by the i^{th} intermediate producer is given by the following minimisation problem:

$$\min_{L_{i,t}^{u},L_{i,t}^{c}} W_t^u L_{i,t}^u + W_t^c L_{i,t}^c$$

subject to the production function

$$Y_{i,t} = A_t \left(L_{i,t}^u\right)^{\gamma} \left(L_{i,t}^c\right)^{(1-\gamma)}$$

The standard first order conditions of this minimisation problem for all the intermediate producers are as follows:

$$L_t^u : W_t^u = X_t A_t \gamma \left(L_t^u\right)^{\gamma-1} \left(L_t^c\right)^{(1-\gamma)} \tag{21}$$

$$L_t^c : W_t^c = X_t A_t (1-\gamma) \left(L_t^u\right)^{\gamma} \left(L_t^c\right)^{-\gamma} \tag{22}$$

Divide both equations by $P_t A_t$ into both sides, and they become

$$w_t^u = x_t \gamma \left(L_t^u\right)^{\gamma-1} \left(L_t^c\right)^{(1-\gamma)}$$

$$w_t^c = x_t (1-\gamma) \left(L_t^u\right)^{\gamma} \left(L_t^c\right)^{-\gamma}$$

where $x_t = X_t/P_t$ is the Lagrangian multiplier for the minimisation problem, and it can be interpreted as the real marginal cost. When $\gamma < 1$, cost minimisation by the i^{th} intermediate good producer leads it to equate the relative wage of its patient and impatient households' inputs with their corresponding relative marginal productivities:

$$\frac{w_t^u}{w_t^c} = \frac{\gamma}{1-\gamma} \frac{L_t^c}{L_t^u}$$

which implies that the ratio of labour required for the patient and impatient households will be uniform across intermediate good producers, regardless of the price of intermediate good imposed by the i^{th} intermediate producer, $P_{i,t}$.

3.6 Optimal price setting by intermediate goods producers

There are a variety of intermediate goods produced domestically. Intermediate goods are distinguishable from each other and are produced by monopolists. This implies that each intermediate good producer has its demand function. From Equation (3.19), the demand curve for i^{th} monopolist can be expressed as:

$$Y_{i,t} = Y_t \left(\frac{P_t^d}{P_{i,t}^d} \right)^{\varepsilon}$$

The monopolistic structure for the intermediate goods market implies that i^{th} monopolist firm can set its price to maximise its profit. However, the setting of prices by intermediate producers is subject to Calvo friction. The price stickiness faced by intermediate producers is the only source of nominal rigidity in this model. Calvo frictions imply that with probability θ, the i^{th} intermediate good firm cannot re-optimise its price, which is defined as follows:

$$P_{i,t}^d = \begin{cases} \tilde{P}_t^d & \text{with probability } 1-\theta \\ P_{i,t-1}^d & \text{with probability } \theta \end{cases}$$

i^{th} intermediate good firm's objective to maximise profit subject to Calvo frictions is given by:

$$E_t^i \sum_{j=0}^{\infty} \beta^j \lambda_{t+j} \left[\overbrace{P_{i,t+j}^d Y_{i,t+j}}^{\text{Revenue}} - \overbrace{P_{t+j}^d x_{t+j} Y_{i,t+j}}^{\text{Total cost}} \right]$$

where λ_{t+j} is the Lagrange multiplier on the patient household budget constraint. The left term of the equation, $P_{i,t+j}Y_{i,t+j}$, is revenue, and the right term, $P_{t+j}^d x_{t+j} Y_{i,t+j}$, captures the total cost for the intermediate producer i^{th}. The solution of i^{th} intermediate good firm's profit maximisation problem will lead to

$$\tilde{p}_t^d \equiv \frac{\tilde{P}_t^d}{P_t^d} \equiv \frac{K_t}{F_t}$$

where

$$K_t = \frac{\varepsilon}{\varepsilon - 1}(1-V)\frac{y_t}{c_t^u} x_t + \beta\theta E_t \bar{\pi}_{t+1}^{\varepsilon} K_{t+1} \tag{23}$$

$$F_t = \frac{y_t}{c_t^u} + \beta\theta E_t \bar{\pi}_{t+1}^{\varepsilon-1} F_{t+1} \tag{24}$$

in which $y_t = Y_t/A_t$ and let $V = \frac{\varepsilon-1}{\varepsilon}$ to minimise monopoly distortion.

From the optimal price setting as per Equation (3.20), I can also express the Calvo equation as

$$P_t^d = \left((1-\theta)\tilde{P}_t^{1-\varepsilon} + \theta(P_{t-1}^d)^1 - \varepsilon\right)^{\frac{1}{1-\varepsilon}}$$

and divide by P_t^d to get

$$1 = \left((1-\theta)\tilde{p}_t^{1-\varepsilon} + \theta\left(\frac{1}{\bar{\pi}_t}\right)^{1-\varepsilon}\right)^{\frac{1}{1-\varepsilon}}$$

where $\tilde{p}_t$ is the relative price of the marginal price setter. It follows, then,

$$\tilde{p}_t = \left[\frac{1-\theta\left(\bar{\pi}_t\right)^{\varepsilon-1}}{1-\theta}\right]^{\frac{1}{1-\varepsilon}} \tag{25}$$

3.7 Production of final consumption goods

Final consumption goods purchased by both types of households are produced by representative and competitive firms given by:

$$C_t = \left[(1-\alpha)^{\frac{1}{\eta}}(C_t^d)^{\frac{\eta-1}{\eta}} + \alpha^{\frac{1}{\eta}}\left(C_t^m\right)^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}} \tag{26}$$

where C_t is the final consumption good. The production of final consumption goods consists of input from domestic production and imported goods. The homogeneous domestic goods, C_t^d, represent domestic inputs and, C_t^m, represent imported inputs from abroad. η is the substitution elasticity between domestic and foreign inputs. α is the share of foreign goods required to produce the final consumption goods.

The profit maximisation problem by the competitive and representative firm producing the final consumption goods is given by:

$$\max_{P_t} P_tC_t - P_t^mC_t^m - P_t^dC_t^d$$
$$\text{subject to} \quad C_t = \left[(1-\alpha)^{\frac{1}{\eta}}(C_t^d)^{\frac{\eta-1}{\eta}} + \alpha^{\frac{1}{\eta}}\left(C_t^m\right)^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}}$$

where P_t is the price of final consumption good, P_t^m is the price of imported goods, and P_t^d is the price of homogeneous domestic goods. The optimal allocation of any given expenditure within each category of goods yields the following demand functions:

$$\frac{\partial \mathbb{L}}{\partial C_t^m} : P_t \frac{dC_t}{dC_t^m} = P_t^m \to C_t^m = \alpha \left(\frac{P_t}{P_t^m} \right)^\eta C_t \tag{27}$$

$$\frac{\partial \mathbb{L}}{\partial C_t^d} : P_t \frac{dC_t}{dC_t^d} = P_t^d \to C_t^d = (1-\alpha) \left(\frac{P_t}{P_t^d} \right)^\eta C_t \tag{28}$$

Substituting the demand functions of (3.27) and (3.28) into the production function (3.26) gives

$$P_t = \left[(1-\alpha)(P_t^d)^{1-\eta} + \alpha\, (P_t^m)^{1-\eta} \right]^{\frac{1}{1-\eta}}$$

which becomes

$$p_t = \left[(1-\alpha) + \alpha\, (p_t^m)^{1-\eta} \right]^{\frac{1}{1-\eta}} \tag{29}$$

where $p_t \equiv \frac{P_t}{P_t^d}$ and $p_t^m \equiv \frac{P_t^m}{P_t^d}$. p_t is also known as the final consumption price index.

3.8 Real exchange rate and inflation

The real exchange rate is defined by the following:

$$p_t^m = \frac{P_t}{P_t} \frac{P_t^m}{P_t^d} = \frac{P_t}{P_t^d} \frac{P_t^m}{P_t} \Rightarrow p_t^m = p_t \times reals_t \tag{30}$$

where $reals_t \equiv \frac{P_t^m}{P_t} \equiv \frac{S_t P_t^f}{P_t}$ is the real exchange rate. This equation governs the relationship between the prices of domestic and imported goods. The real exchange rate, $reals_t$, is equal to the price of imported goods in local currency, $S_t P_t^f$, relative to the price of the final consumption goods, P_t. This implies that a decrease in the price of final consumption goods, P_t, or a depreciation of the nominal exchange rate, S_t, or higher prices of foreign goods in foreign currency units, P_t^f, will lead to a weakness in the real exchange rate.

From the price index as per Equation (3.29), I can define the final consumption goods inflation and homogeneous domestic goods inflation growth rates as follows:

$$\pi_t \equiv \frac{P_t}{P_{t-1}} = \frac{P_t^d p_t}{P_{t-1}^d p_{t-1}} = \bar{\pi}_t \left[\frac{(1-\alpha) + \alpha\, (p_t^m)^{1-\eta}}{(1-\alpha) + \alpha \left(p_{t-1}^m\right)^{1-\eta}} \right]^{\frac{1}{1-\eta}} \tag{31}$$

3.9 Exports

Homogeneous domestic goods are also exported to foreign consumers. The total demand by foreigners for domestic exports takes on the following form:

$$\frac{EX_t}{A_t} = ex_t = \left(\frac{P_t^x}{P_t^f}\right)^{-\eta_f} Y_t^f = (p_t^x)^{-\eta_f} Y_t^f$$

where Y_t^f is foreign demand, P_t^f is foreign currency price of foreign goods and P_t^X is an index of export prices in foreign currency. η_f is the elasticity of the demand of foreign consumers for domestic exports. The effective terms of trade that captures the movement of the relative prices of export prices and homogeneous foreign goods prices is given by:

$$p_t^x = \frac{P_t^x}{P_t^f}$$

3.10 Rate of depreciation and foreign inflation

Competition between homogeneous domestic goods producers and foreign producers will lead to the index of export prices in a domestic currency equal to the marginal cost. This leads the index of export prices in a domestic currency to equal the price of the homogeneous domestic final goods, defined as:

$$S_t P_t^x = P_t^d$$

By dividing both sides by P_t^d, the relationship becomes

$$\begin{aligned} 1 &= \frac{S_t P_t^x}{P_t^d} = \frac{P_t S_t P_t^f P_t^x}{P_t^d P_t P_t^f} \\ &= p_t reals_t p_t^x \end{aligned} \tag{32}$$

and the growth rates of the real exchange rate, nominal exchange rate and foreign inflation are given by:

$$\frac{reals_t}{reals_{t-1}} = s_t \frac{\pi_t^f}{\pi_t}, s_t \equiv \frac{S_t}{S_{t-1}}, \pi_t^f \equiv \frac{P_t^f}{P_{t-1}^f} \tag{33}$$

3.11 Homogeneous domestic goods market clearing

Let Y_t^* denote the unweighted integral of gross output across the producers of intermediate goods:

$$\begin{aligned} Y_t^* &\equiv \int_0^1 Y_{i,t} di \\ &= \int_0^1 A_t \left(L_{i,t}^u\right)^\gamma \left(L_{i,t}^c\right)^{1-\gamma} di \\ &= A_t \left(L_t^u\right)^\gamma \left(L_t^c\right)^{(1-\gamma)} \end{aligned}$$

An alternative representation of Y_t^* makes use of the demand curve, as per Equation (3.20):

$$Y_t^* = Y_t \int_0^1 \left(\frac{P_{i,t}}{P_t}\right)^{-\varepsilon} di = Y_t P_t^\varepsilon \int_0^1 P_{i,t}^{-\varepsilon} di = Y_t P_t^\varepsilon (P_t^*)^{-\varepsilon}$$

This leads to

$$Y_t = p_t^* Y_t^* \Rightarrow Y_t = p_t^* A_t \left(L_t^u\right)^\gamma \left(L_t^c\right)^{(1-\gamma)} \Rightarrow Y_t = p_t^* \left(l_t^u\right)^\gamma \left(l_t^c\right)^{(1-\gamma)}$$

where $p_t^* = \left(\frac{P_t^*}{P_t}\right)^\varepsilon$. Here, $P_t^* \leq 1$ measures the output lost due to price dispersion. From Equation (3.25), p_t^* can be defined as

$$\begin{aligned} p_t^* &= \int_0^1 P_{i,t}^{-\varepsilon} di \\ &= \left[(1-\theta)\tilde{p}_t^{-\varepsilon} + \theta \frac{\bar{\pi}_t^\varepsilon}{p_{t-1}^*}\right]^{-1} \\ &= \left[(1-\theta)\left(\frac{1-\theta\bar{\pi}_t^{(\varepsilon-1)}}{1-\theta}\right)^{\frac{\varepsilon}{\varepsilon-1}} + \theta \frac{\bar{\pi}_t^\varepsilon}{p_{t-1}^*}\right]^{-1} \end{aligned} \tag{34}$$

Clearing in the homogeneous domestic goods market leads to the production of homogeneous domestic goods, Y_t, equals to the absorption of homogeneous domestic goods, defined as:

$$Y_t = p_t^* A_t \left(L_t^u\right)^\gamma \left(L_t^c\right)^{(1-\gamma)} = \left(C_t^u\right)^d + \left(C_t^c\right)^d + EX_t + G_t$$

or

$$y_t = p_t^* \left(L_t^u\right)^\gamma \left(L_t^c\right)^{(1-\gamma)} = \left(c_t^u\right)^d + \left(c_t^c\right)^d + ex_t + g_t$$

where $ex_t = EX_t/A_t$ and $g_t = G_t/A_t$. The total consumption of homogeneous domestic goods by patients and impatient households, $c_t = c_t^u + c_t^c$, is equal to $(1-\alpha)(p_t)^\eta c_t$. g_t represents spending by the government. ex_t is exports of homogeneous domestic goods. Substituting out the expression for consumption of the homogeneous domestic goods by households, the equation becomes:

$$y_t = p_t^*(L_t^u)^\gamma (L_t^c)^{1-\gamma} = (1-\alpha)\,(p_t)^\eta\, c_t + ex_t + g_t \tag{35}$$

3.12 Balance of Payments - A country with net external assets

Equality of international flows relating to trade in goods and financial assets is defined by:

$$S_t A_{t+1}^f + \text{expenses on imports}_t = \text{receipts from exports}_t + S_t \Phi_{t-1} R_{t-1}^f A_t^f$$

where the left-hand side of the equation captures outflows, and the right-hand side captures inflows of money to the domestic economy. $S_t A_{t+1}^f$ defines the acquisition of new net foreign assets in domestic currency units and $S_t \Phi_{t-1} R_{t-1}^f A_t^f$ captures receipts from the existing stock of net foreign assets in domestic currency units. A_t^f is the net stock of foreign assets in the initial period t.

Exports and imports in domestic currency units are given by:

- Expenses on imports$_t = S_t P_t^f \alpha \left(\frac{P_t}{P_t^m}\right)^\eta C_t$
- Receipts from exports$_t = S_t P_t^x EX_t$

Incorporating the expression for exports and imports in domestic currency units, the equation for the balance of payment can be defined as

$$S_t A_{t+1}^f + S_t P_t^f \alpha \left(\frac{P_t}{P_t^m}\right)^\eta C_t = S_t P_t^x EX_t + S_t \Phi_{t-1} R_{t-1}^f A_t^f$$

and dividing by $P_t^d A_t$ on both sides

$$\frac{S_t A_{t+1}^f}{P_t^d A_t} + \frac{S_t P_t^f}{P_t^d} \alpha \left(\frac{P_t}{P_t^m}\right)^\eta c_t = \frac{S_t P_t^x}{P_t^d} ex_t + \frac{S_t R_{t-1}^f \Phi_{t-1} A_t^f}{P_t^d A_t}$$

the final expression for the balance of payment is given by:

$$a_t^f + p_t^m \alpha \left(\frac{p_t}{p_t^m}\right)^\eta c_t = p_t reals_t p_t^x ex_t + \frac{s_t R_{t-1}^f \Phi_{t-1} a_{t-1}^f}{\bar{\pi}_t \Delta_t^A} \tag{36}$$

where $a_t^f = \frac{S_t A_{t+1}^f}{P_t^d A_t}$. And the previous definitions are $p_t \equiv \frac{P_t}{P_t^d}$, $p_t^m \equiv \frac{P_t^m}{P_t^d}$, $\frac{P_t^m}{P_t} \equiv \frac{S_t P_t^f}{P_t}$ and $S_t P_t^x = P_t^d$. Intuitively, a_t^f can be interpreted as a value of net foreign assets in terms of homogeneous domestic goods.

3.13 Risk Premium Term - A country with net external assets

The risk term that governs the movement of the nominal exchange rate is given by:

$$\Phi_t = \Phi\left(a_t^f, R_t^f, R_t, \tilde{\phi}_t\right) = \exp\left(-\tilde{\phi}_a\left(a_t^f - \bar{a}\right) - \tilde{\phi}_s\left(R_t - R_t^f - \left(R - R^f\right)\right) + \tilde{\phi}_t\right) \tag{37}$$

where $\tilde{\phi}_a > 0$, $\tilde{\phi}_s > 0$ and $\tilde{\phi}_t \backsim$ mean zero, iid. $\tilde{\phi}_a > 0$ implies if $a_t^f > \bar{a}$, then the return on foreign assets in domestic currency units is low and will lead to a reduction in net foreign assets a_t^f, held by domestic residents. On the other hand, if $a_t^f < \bar{a}$, then the return on foreign assets is high and will lead to an increase in net foreign assets. $\tilde{\phi}_t$ captures the possibility of a shock to the required return on domestic assets. The term $\tilde{\phi}_s > 0$ is required to adjust for the standard uncovered interest parity (UIP) relationship. The adjustment will lead to a higher domestic nominal interest rate, leading to an increase in the rate of return required for people to hold domestic assets. Under the standard UIP, which implies $\tilde{\phi}_s = 0$, a higher domestic nominal interest rate and expected appreciation of the currency represent a double boost in the return on domestic assets. However, the scenario in which investors increase their holding of domestic assets due to higher domestic nominal interest rates is not empirically observed. Therefore, modification of the UIP condition allows for a negative correlation between the risk premium and the expected change in the nominal exchange rate, and will increase the persistence in the real exchange rate, which has an empirical advantage compared to the standard UIP specification (Adolfson et al., 2008).

3.14 Monetary policy - Taylor rule

The central bank operates policy according to a Taylor-type rule. The central bank reacts to changes in aggregate inflation and the growth rate of output as follows:

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R}\right)^{\rho_R} E_t\left[\left(\frac{\pi_{t+1}}{\bar{\pi}}\right)^{r_\pi}\left(\frac{y_{t+1}}{y}\right)^{r_y}\right]^{1-\rho_R} \varepsilon_{R,t} \tag{38}$$

where $y_t = Y_t/A_t$ and ρ_R is a smoothing parameter, and a bigger ρ_R means changes in nominal interest rate will become more persistent. r_π is the weight given to minimise the expected deviation of inflation from its target and satisfies the Taylor principle when $r_\pi > 1$. r_y is the weight given to minimise the expected deviation of the output from its target.

3.15 Government spending

The model assumes that the government also purchases homogeneous domestic goods. However, the government does not spend its money on imported goods. The exogenous process of government spending in this model is defined as follows:

$$\log(g_t) = (1-\rho_g)\eta_g \log y + \rho_g \log(g_{t-1}) + \varepsilon_{g_t} \tag{39}$$

where ρ_g reflects the persistence of policy-induced changes in the fiscal policy, and η_g captures the size or ratio of government spending to domestic production.

3.16 Housing market

The total number of houses is fixed in this model. The total units of houses available for patient and impatient households to own is given by:

$$H_t^u + H_t^c + H_t^f = \bar{H} \tag{40}$$

In this model, any developments in the housing market will not alter domestic output directly, as domestic production only accounts for the production of domestic homogeneous output goods. However, any developments in the housing market, which will affect house prices, could still indirectly affect domestic production through a knock-on effect on consumption.

3.17 Other equilibrium equations

1. Total labour supply

   The total supply of labour in the economy is equal to the aggregation of the supply of labour from patient and impatient households.

$$l_t = l_t^u + l_t^c$$

2. Total consumption

   The total domestic consumption in the economy is equal to the aggregate consumption of patients and impatient households.

$$c_t = c_t^u + c_t^c$$

3. Total savings and borrowing in the domestic economy

   Aggregate lending from patient households equals aggregate borrowing from impatient households.

$$b_t^c = b_t^u$$

4. Aggregate inflation, homogeneous domestic inflation, and inflation target

   In equilibrium, aggregate inflation is equal to homogeneous domestic inflation and the inflation target of the central bank.

$$\pi = \bar{\pi} = \pi^T$$

3.18 Foreign sector and risk term

The model assumes that foreign inflation, foreign demand, and interest rate are determined exogenously. The risk term shock is also given exogenously in this model. All exogenous processes for the foreign sector and the risk term follow an AR(1) process given by:

1. Foreign inflation

$$\log(\pi_t^f) = (1 - 0.95)\log(\pi^f) + 0.95\log(\pi_{t-1}^f) + \varepsilon_{\pi_t^f}$$

2. Foreign demand

$$\log(Y_t^f) = (1 - 0.95)\log(Y^f) + 0.95\log(Y_{t-1}^f) + \varepsilon_{Y_t^f}$$

3. Foreign interest rate

$$\log(R_t^f) = (1 - 0.95)\log(R^f) + 0.95\log(R_{t-1}^f) + \varepsilon_{R_t^f}$$

4. Risk premium term

$$\log(\Phi_t) = 0.95\log(\Phi_{t-1}) + \varepsilon_{\Phi_t}$$

A country with net external liabilities

The model for a country with net external liabilities is very similar to that of a country with net external assets, except for the equations of the household problem, the balance of payments, and the term of risk premium. Similarly to before, there are two types of households: patient and impatient. However, patient households can only save domestically, but impatient households can borrow from both domestic savers and foreign lenders. The total amount of loans that impatient households can borrow from patient households and foreign lenders is also subject to the LTV rule. Meanwhile, the balance of payments and risk premium term equations need a minor adjustment to reflect external borrowing instead of external savings. The rest of the model is analogous to a country with net external assets.

3.19 Households - A country with net external liabilities

3.19.1 Households - Patient households (unconstrained)

Patient households maximise their utility by choosing:

$$\max_{C_t^u, H_t^u, L_t^u, B_t^u} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left(\ln C_t^u + j \ln H_t^u - \frac{(L_t^u)^\varphi}{\varphi} \right) \tag{41}$$

subject to the budget constraint

$$P_t C_t^u + Q_t \left(H_t^u - H_{t-1}^u \right) + B_t^u \leq W_t^u L_t^u + R_{t-1} B_{t-1}^u + T_t \tag{42}$$

where C_t^u is the current consumption, L_t^u is the labour hours and H_t^u is the number of houses owned by the patient households. $\frac{1}{\varphi - 1}$ is the elasticity of the labour supply and $\varphi > 0$. $j > 0$ is the weight of the housing in the utility function. B_t^u is the domestic savings of the patient households or the stock of domestic loans extended to the impatient households, and R_t is the policy rate set by the central bank and also the rate of return for domestic savings. T_t captures transfers and profits to patient households. S_t is the nominal exchange rate. Q_t is house prices, and W_t^u is the wage for patient households.

Dividing the budget constraint by $P_t A_t$, the budget constraint is defined in real terms, and it becomes

$$\frac{C_t^u}{A_t} + q_t \left(H_t^u - H_{t-1}^u \right) + b_t^u \leq w_t^u L_t^u + \frac{R_{t-1} b_{t-1}^u A_{t-1}}{\pi_t A_t} + \tau_t$$

where $\pi_t = P_t / P_{t-1}$, $q_t = Q_t / P_t A_t$, $b_t^u = B_t^u / P_t A_t$, $w_t^u = W_t^u / P_t A_t$, and $\tau_t = T_t / P_t A_t$.

Three equations characterise the first order conditions for the patient households:

$$\frac{1}{c_t^u} = \beta E_t \left(\frac{R_t}{\pi_{t+1} c_{t+1}^u \Delta_{t+1}^A} \right) \tag{43}$$

$$w_t^u = \left(L_t^u\right)^{\varphi - 1} c_t^u \tag{44}$$

$$\frac{j}{H_t^u} = \frac{q_t}{c_t^u} - \beta E_t \frac{q_{t+1}}{c_{t+1}^u} \tag{45}$$

where $c_t^u = C_t^u / A_t$ and $\Delta_{t+1}^A = \frac{A_{t+1}}{A_t}$. Equations (3.43) and (3.44) are the standard Euler and labour supply equations. Equation (3.45) captures patient households' demand for housing.

3.19.2 Households - Impatient households (constrained)

Impatient households maximise their utility by choosing:

$$\max_{C_t^c, H_t^c, L_t^c, B_t^c, B_t^f} \mathbb{E}_0 \sum_{t=0}^{\infty} \widetilde{\beta}^t \left(\ln C_t^c + j \ln H_t^c - \frac{\left(L_t^c\right)^{\varphi}}{\varphi} \right) \tag{46}$$

subject to the budget constraint

$$P_t C_t^c + Q_t \left(H_t^c - H_{t-1}^c\right) + R_{t-1} B_{t-1}^c + S_t \Phi_{t-1} R_{t-1}^f B_t^f \leq W_t^c L_t^c + B_t^c + S_t B_{t+1}^f \tag{47}$$

where C_t^c is the current consumption, L_t^c is the labour hours and H_t^c is the number of houses owned by the patient households. W_t^c is the wage for impatient households, B_t^c is the amount borrowed from patient households, and B_t^f is the external borrowing. The discount factor for impatient households, $\widetilde{\beta}$, is smaller than that of patient households, β.

Dividing the budget constraint by $P_t A_t$, the budget constraint becomes

$$\frac{C_t^c}{A_t} + q_t \left(H_t^c - H_{t-1}^c\right) + \frac{R_{t-1} b_{t-1}^c A_{t-1}}{\pi_t A_t} + \frac{S_t \Phi_{t-1} R_{t-1}^f B_t^f}{P_t A_t} \leq w_t^c L_t^c + b_t^c + \frac{S_t B_{t+1}^f}{P_t A_t}$$

where $\pi_t = P_t / P_{t-1}$, $q_t = Q_t / P_t A_t$, $b_t^c = B_t^c / P_t A_t$, and $w_t^c = W_t^c / P_t A_t$. Set $s_t = S_t / S_{t-1}$ and $b_t^f =$

$S_t B^f_{t+1}/P^d_t A_t$, the budget constraint becomes

$$C^c_t + q_t\left(H^c_t - H^c_{t-1}\right) + \frac{R_{t-1} b^c_{t-1} A_{t-1}}{\pi_t A_t} + \frac{s_t \Phi_{t-1} R^f_{t-1} b^f_{t-1} A_{t-1}}{\bar{\pi} p_t A_t} \leq w^c_t L^c_t + b^c_t + \frac{b^f_t}{p_t}$$

The maximisation problem is also subject to the borrowing constraint:

$$R_t B^c_t + S_t \Phi_{t-1} R^f_{t-1} B^f_t \leq LTV\, E_t Q_{t+1} H^c_t \tag{48}$$

where the maximum amount that impatient households can borrow from domestic savers and foreign lenders is subject to the LTV rule, where $LTV < 1$. Divide both sides by $P_t A_t$ and replace $b^f_t = S_t B^f_{t+1}/P^d_t A_t$, the borrowing constraint becomes

$$R_t b^c_t \leq LTV\, E_t \pi_{t+1} q_{t+1} H^c_t \Delta^A_{t+1} - \frac{s_t \Phi_{t-1} R^f_{t-1} b^f_{t-1} A_{t-1}}{\bar{\pi}_t p_t A_t}$$

Four equations characterise the first order conditions for impatient households:

$$\frac{1}{c^c_t} = \widetilde{\beta} E_t \left(\frac{R_t}{\pi_{t+1} c^c_{t+1} \Delta^A_{t+1}} \right) + \Omega'_t R_t \tag{49}$$

$$w^c_t = \left(L^c_t\right)^{\varphi - 1} c^c_t \tag{50}$$

$$\frac{j}{H^c_t} = \frac{q_t}{c^c_t} - \widetilde{\beta} E_t \frac{q_{t+1}}{c^c_{t+1}} - \Omega'_t LTV\, E_t \pi_{t+1} q_{t+1} \Delta^A_{t+1} \tag{51}$$

$$\frac{1}{c^c_t} = \widetilde{\beta} \frac{s_{t+1} \Phi_t R^f_t}{c^c_{t+1} \pi_{t+1} \Delta^A_{t+1}} + \Omega'_{t+1} \frac{s_{t+1} \Phi_t R^f_t}{\pi_{t+1} \Delta^A_{t+1}} \tag{52}$$

where Ω'_t is the Lagrangian multiplier for the borrowing constraint of impatient households, and $c^c_t = C^c_t/A_t$. Equations (3.49) and (3.50) are the standard Euler and labour supply equations for impatient households. Equation (3.51) captures impatient households' demand for housing, taking into account the additional borrowing constraint imposed on them. Equation (3.52) is the Euler equation for foreign borrowing.

3.20 Balance of Payments - A country with net external liabilities

Equality of international flows relating to trade in goods and financial assets is defined by:

$$S_t\Phi_{t-1}R^f_{t-1}B^f_t + \text{expenses on imports}_t = \text{receipts from exports}_t + S_tB^f_{t+1}$$

where the left-hand side captures outflows, and the right-hand side reflects the inflow of money into the domestic economy. $S_tB^f_{t+1}$ defines the additional net foreign liabilities in domestic currency units and $S_t[\Phi_{t-1}R^f_{t-1}]A^f_t$ captures the repayment of debt from the existing stock of net foreign liabilities in domestic currency units.

Following the same step as before, the final expression of the balance of payments is given by:

$$\frac{s_tR^f_{t-1}\Phi_{t-1}b^f_{t-1}}{\bar{\pi}_t\Delta^A_t} + p^m_t\alpha\left(\frac{p_t}{p^m_t}\right)^\eta c_t = p_t reals_tp^x_tex_t + b^f_t \tag{53}$$

where $b^f_t = \frac{S_tB^f_{t+1}}{P^d_tA_t}$

3.21 Risk term - A country with net external liabilities

The risk term that governs the movement of the nominal exchange rate is given by:

$$\Phi_t = \Phi\left(b^f_t, R^f_t, R_t, \tilde{\phi}_t\right) = \exp\left(\tilde{\phi}_b\left(b^f_t - \bar{b}\right) - \tilde{\phi}_s\left(R_t - R^f_t - \left(R - R^f\right)\right) + \tilde{\phi}_t\right) \tag{54}$$

where $\tilde{\phi}_b > 0$, and it implies that if $b^f_t > \bar{b}$, then the cost of foreign liabilities in domestic currency units is high and will lead to a reduction in net foreign liabilities, b^f_t, held by domestic residents. On the other hand, if $b^f_t < \bar{b}$, then the cost of foreign liabilities is low and will lead to an increase in net foreign liabilities. The other specifications remain the same as before.

4 Model's parameters

Since this article aims to provide a general framework for a small open economy, I calibrate this model with standard parameters that previous studies have applied. The discount factor for patient households, β, is set at 0.99, which is calibrated to produce a real interest rate equal to 4.00% annually. In line with Iacoviello, 2005, the discount factor for impatient households, $\tilde{\beta}$, is set at 0.98. The weight of the housing on the utility function of the households, j, is set to 0.3. This is consistent with the relative share of housing in total expenditure found in some small open economies, which varies between 0.22 and 0.33 (Ng and Feng, 2016). The elasticity of the labour supply of households is set at $\varphi - 1 = 1$, consitent with Rubio, 2014. The LTV ratio is set to 0.70, which is the typical value that can be found in many small open economies (Ng and Feng, 2016). The share of the labour income for the patient households, γ, is set to 0.7 (Rubio, 2014). The elasticity of the demand for intermediate goods by homogeneous domestic goods producers, ε, is set to 6. The share of imported goods in the production of final goods, α, is set to 0.4. These two figures are consistent with Funke et al., 2018. The substitution elasticity between domestic homogeneous and foreign goods in the production of final consumption goods is set at 1.2, and the foreign demand elasticity for domestic homogeneous goods is set at 1.5, where these two figures are consistent with Christiano et al., 2011. For the risk premium term, I use $\tilde{\phi}_a = 0.03$ and $\tilde{\phi}_s = 0.7$, consistent with the literature that places a small value on $\tilde{\phi}_a$ to help find the steady-state value for external assets/liabilities. For the Taylor rule parameters, r_π and r_y are set to 1.5 and 0.15, respectively, which are the standard calibrated values in the Taylor rule literature. ρ_R is set to 0.90, as widely found in the literature. The probability of not changing prices, θ, is set to 0.75, which implies that prices change every four quarters on average. The share of government expenditures of GDP, η_g, is set at 0.30. The full calibrated values are shown in Table 5.

Table 5: Calibrated parameters

Parameter	Value	Description
A	1	Aggregate domestic technology
π^T	1.0	Steady state gross inflation target
α	0.4	Share of imported goods in final consumption
β	0.99	Savers' discount factor
$\tilde{\beta}$	0.98	Borrowers' discount factor
j	0.3	Weight of housing on the utility function
φ	2	$\varphi - 1$ is the labour-supply elasticity
LTV	0.7	Loan-to-value ratio
γ	0.7	Savers' labour income share
θ	0.75	Calvo parameter, probability of intermediate good firms cannot set prices
r_π	1.5	Taylor Rule, inflation parameter
r_y	0.15	Taylor Rule, output parameter
ρ_R	0.9	Taylor Rule, interest rate smoothing parameter
η	1.2	Elasticity of substitution between foreign and final goods
$\tilde{\phi}_a$	0.03	Weight of net foreign assets in risk term
$\tilde{\phi}_s$	0.7	Weight of interest rate differential in risk term
η_f	1.5	Elasticity of demand for exports
ε	6	Elasticity of demand for domestic intermediate goods
η_g	0.3	Steady state of the share of government expenditure over GDP
η_a	0	Steady state of external assets/liabilities

5 Results

In this section, I will discuss impulse response functions following multiple shocks that originate from both domestic and external shocks. The welfare analysis will follow the discussion. Subsequently, I compare the impulse response functions with different LTV rules for a country with net external liabilities. Specifically, I augment the LTV rule with the nominal exchange rate to explore its effectiveness as a countercyclical instrument when dealing with external shocks.

5.1 Impulse response functions (IRFs)

The analysis will begin with some general findings of the model and then look at the effectiveness of the LTV ratio to contain the financial and business cycles. To study the effectiveness of the LTV ratio based on countries' net external positions, I will experiment by loosening the LTV ratio to 0.9 from 0.7 in the baseline model and comparing the impulse response functions for both types of countries.

5.1.1 General findings

Figure 4 compares the impact of 100 basis point foreign interest rate positive shocks on a country with external assets and external liabilities. The blue line represents a country with net external assets, and the red line represents a country with net external liabilities. A foreign interest rate shock in both countries will result in a nominal exchange rate depreciation, leading to higher domestic production following positive export expansion. For a country with net external liabilities, an increase in foreign borrowing costs leads to a reduction in foreign borrowing. In contrast, for a country with net external assets, a higher return on foreign investment leads to an increase in savings in foreign assets. Domestic borrowing reacts positively in both countries, but the expansion is larger for a country with net external liabilities, as it is more economical for impatient households to borrow domestically.

However, the positive impact on output is marginally smaller for a country with net external liabilities than for a country with net external assets. This is expected because a country with net external assets will benefit fully from the nominal exchange rate depreciation through the trade channel without any negative trade-off coming from the financial channel. For a country with net external liabilities, a foreign interest rate shock and the nominal exchange rate depreciation will lead to higher debt repayment of its external borrowing. This is defined as the financial channel of exchange rate movements, which will partially offset the positive impact of the weaker exchange rate that comes from the trade channel. This result is consistent with previous findings in the exchange rate literature. Kearns and Patel, 2016 finds that the financial channel leads to a tightening in domestic financial conditions, which, in turn, partially offsets the trade channel for emerging market economies. Similarly, the financial channel can potentially work in the opposite direction to the trade channel since it operates through the liability side of the country's external balance sheet (Avdjiev et al., 2019).

Figure 4: Foreign interest rate shock

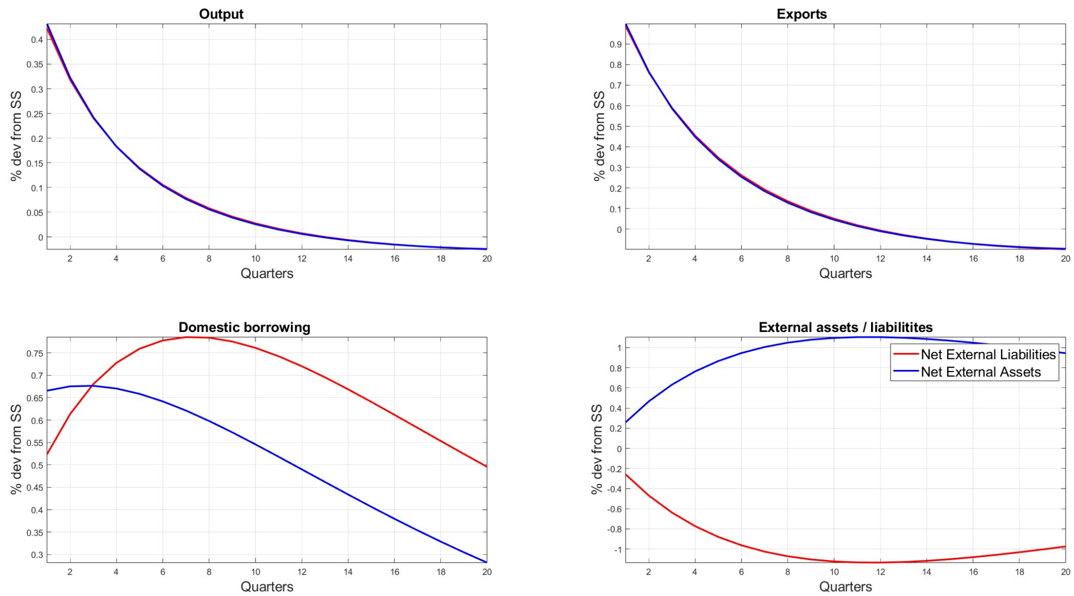

Figure 4. Impulse responses to the foreign interest rate shock, $\varepsilon_{R_t^f} = 0.0025$. The unit on the y-axis is in terms of percentage points deviation from the steady state.

The impulse response functions in Figure 5 are for the monetary policy shock. The impact of a 100 basis point temporary increase in the nominal interest rate causes output to decline. The negative impact on a country with net external liabilities is slightly larger compared to a country with net external assets. The shock leads to a reduction in aggregate income, resulting in a decrease in domestic borrowing in both countries. A country with net external liabilities increases its foreign borrowing as the cost of domestic borrowing becomes more expensive. In contrast, a country with net external assets reduces its foreign lending as the return on domestic lending increases.

5.1.2 The effectiveness of LTV ratio

To gain some insight into the effectiveness of the LTV ratio for countries with different external positions, I simulate the impulse responses of the baseline model where the LTV ratio is set at 0.7 and compare

Figure 5: Monetary policy shock

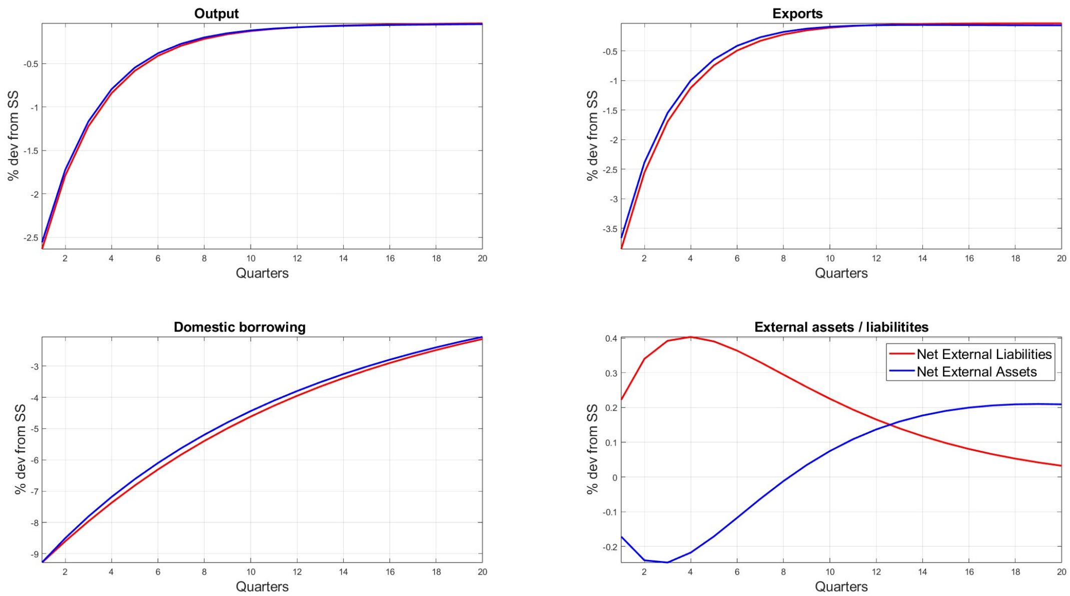

Figure 5. Impulse responses to the monetary policy shock, $\varepsilon_{R_t} = 0.0025$. The unit on the y-axis is in terms of percentage points deviation from the steady state.

the impulse responses with the LTV ratio at 0.9. The impulse responses of the benchmark model are represented by the solid line, where blue belongs to a country with net external assets and red belongs to a country with net external liabilities. The dotted line represents impulse responses when the LTV ratio is set to 0.9. In this part, four shocks are considered, a risk premium shock, a foreign interest rate shock, a foreign demand shock, and a domestic technology shock.

Risk premium shock

A shock on the risk premium of a country leads to depreciation in the nominal exchange rate. A weaker exchange rate results in a positive expansion of domestic output as exports react positively, following an improvement in the terms of trade. As shown in Figure 6, under the baseline model, the impact of a shock on the risk term on domestic production is slightly greater for a country with net external assets. For a country with net external liabilities, under the baseline model, the initial impact on domestic borrowing and consumption is smaller compared to a country with net external assets.

Relaxation in the LTV ratio to 0.9 results in a much more significant deviation from the steady state for all the variables, as shown by the dotted lines. However, the deviation is more prominent for a country with net external liabilities. For a country with net external liabilities, the relaxation in the LTV

Figure 6: Risk premium shock

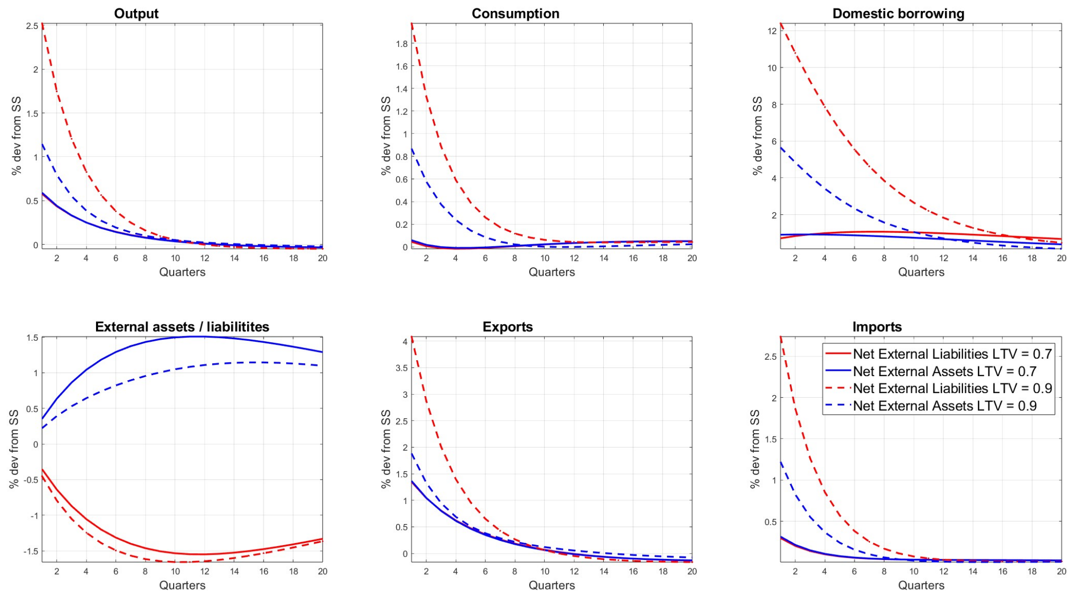

Figure 6. Impulse responses to a risk premium shock, $\varepsilon_{\Phi_t} = 0.001$. The unit on the y-axis is in terms of percentage points deviation from the steady state. The solid lines are the baseline model, and the dotted lines are the alternative.

ratio leads to a significant increase in domestic borrowing, which partly substitutes foreign borrowing as the cost of external borrowing becomes more expensive following the weakness in the exchange rate. The increase in consumption for a country with net external liabilities is also supported by lower external debt repayment due to a reduction in foreign borrowing. However, for a country with net external assets, the weaker exchange rate improves the return on external lending by savers and induces more cross-border lending.

Foreign interest rate shock

The impulse response functions in Figure 7 show the impact of 100 basis point positive foreign interest rate shocks. An increase in foreign interest rate leads to a depreciation in the nominal exchange rate, leading to a higher growth in export and domestic output. Under the baseline model, the impact of a foreign interest rate shock on domestic output is slightly greater for a country with net external assets. This is expected as a higher foreign interest rate leads to a more binding borrowing constraint for a country with net external liabilities as the debt repayment of external borrowing increases. Consistent with a risk premium shock, the initial impact on domestic borrowing and consumption is smaller for a country with net external liabilities compared to a country with net external assets.

Figure 7: Foreign interest rate shock

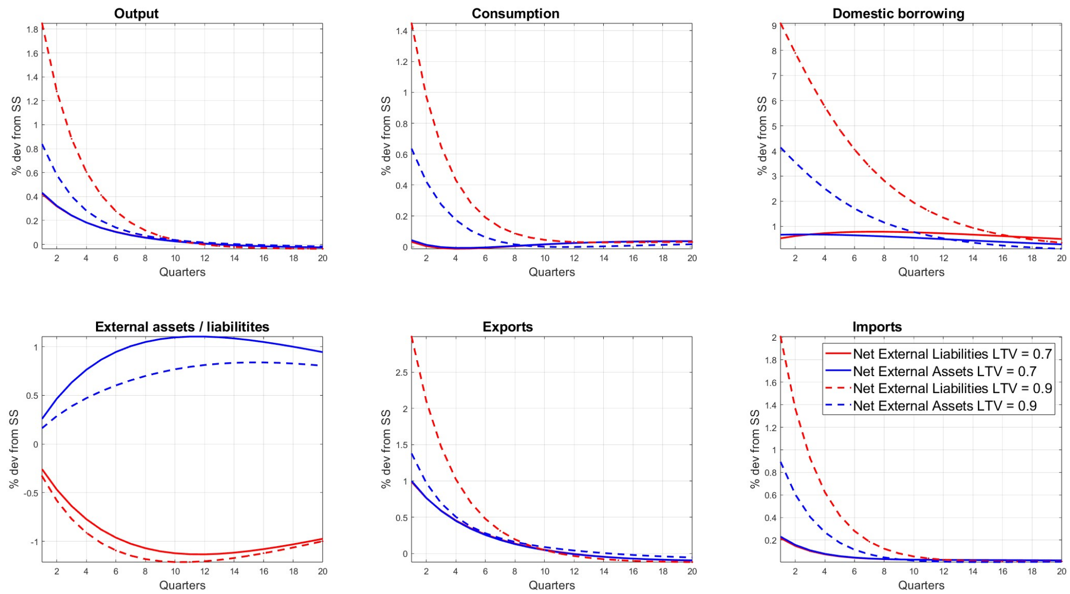

Figure 7. Impulse responses to the foreign interest rate shock, $\varepsilon_{R_t^f} = 0.0025$. The unit on the y-axis is in terms of percentage deviation from the steady state. The solid lines are the baseline model, and the dotted lines are the alternative.

Similarly to before, the relaxation in the LTV ratio to 0.9 results in a much more significant deviation from the steady state for all the variables, as shown by the dotted lines. Likewise, the deviation is much larger for a country with net external liabilities. For a country with net external liabilities, the relaxation in the LTV ratio leads to a much significant increase in domestic borrowing, which partly substitutes foreign lending, as a higher foreign interest rate results in the cost of external borrowing becoming more expensive. For a country with net external assets, there is an increase in foreign lending as a result of a higher rate of return on external lending.

Foreign demand shock

The impulse response functions in Figure 8 show the impact of a foreign demand shock. In the baseline model, the increase in foreign demand leads to a positive expansion of export and domestic production. The increase in output leads the central bank to raise the interest rate, which induces savers to increase their saving today and consume more tomorrow. At the same time, borrowers acquire more houses and also consume more as their borrowing constraint relaxes. On the production side, the increase in output is mainly driven by a higher labour supply by savers.

Relaxation in the LTV ratio to 0.9 results in a much more significant deviation from the steady state

Figure 8: Foreign demand shock

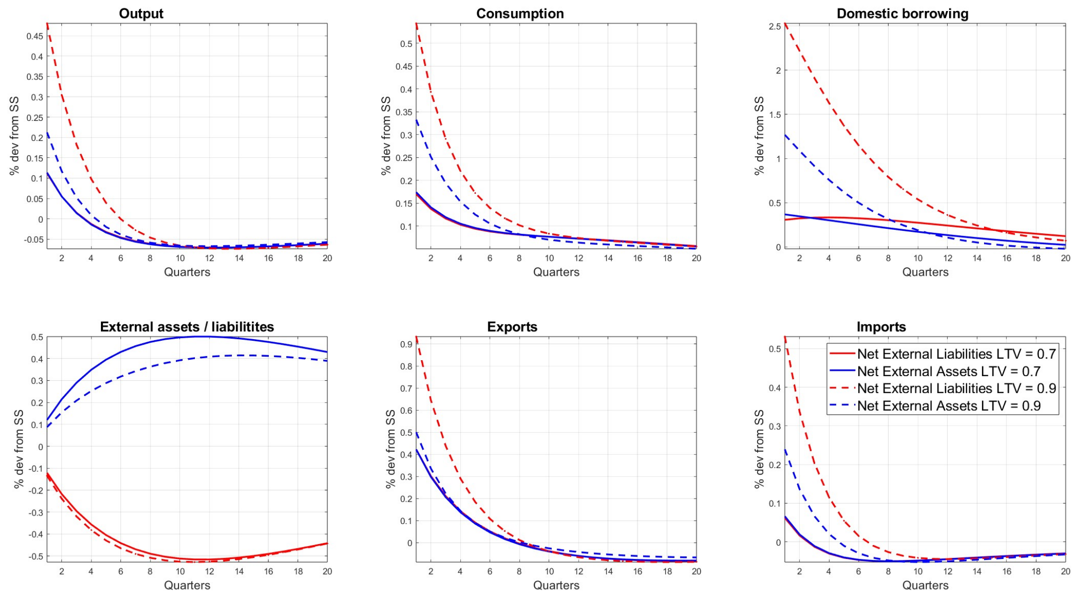

Figure 8. Impulse responses to a foreign demand shock, $\varepsilon_{Y_t^f} = 0.01$. The unit on the y-axis is in terms of percentage points deviation from the steady state. The solid lines are the baseline model and the dotted lines are the alternative.

for all variables, as shown by the dotted lines. The impact on output, domestic borrowing, and aggregate consumption of a country with net external liabilities is much more significant than that of a country with net external assets. The explanation behind this observation is as follows. For a country with net external liabilities, given the relaxation in the borrowing constraint as domestic output increases lead to an increase in savers' aggregate income, as well as an appreciation in the nominal exchange rate, it results in additional domestic lending to borrowers. Furthermore, higher collateral values due to higher housing prices lead borrowers to increase their leverage level. This is reflected in the higher consumption level and the increase in the housing stock among the borrowers. However, for a country with net external assets, not all the increase in savers' aggregate income is consumed domestically, as reflected in higher external lending.

Domestic technology shock

The impulse response functions in Figure 9 illustrate the impact of a domestic technology shock. Under the baseline model, the increase in domestic technology leads to a positive expansion in domestic production, supported by both increased consumption and exports. Like before, the increase in output prompts the central bank to increase the interest rate, which induces savers to save more domestically.

Borrowers acquire more houses and also consume more as their borrowing constraint relaxes. On the production side, the increase in output is mainly driven by a higher labour supply by savers.

Figure 9: Domestic technology shock

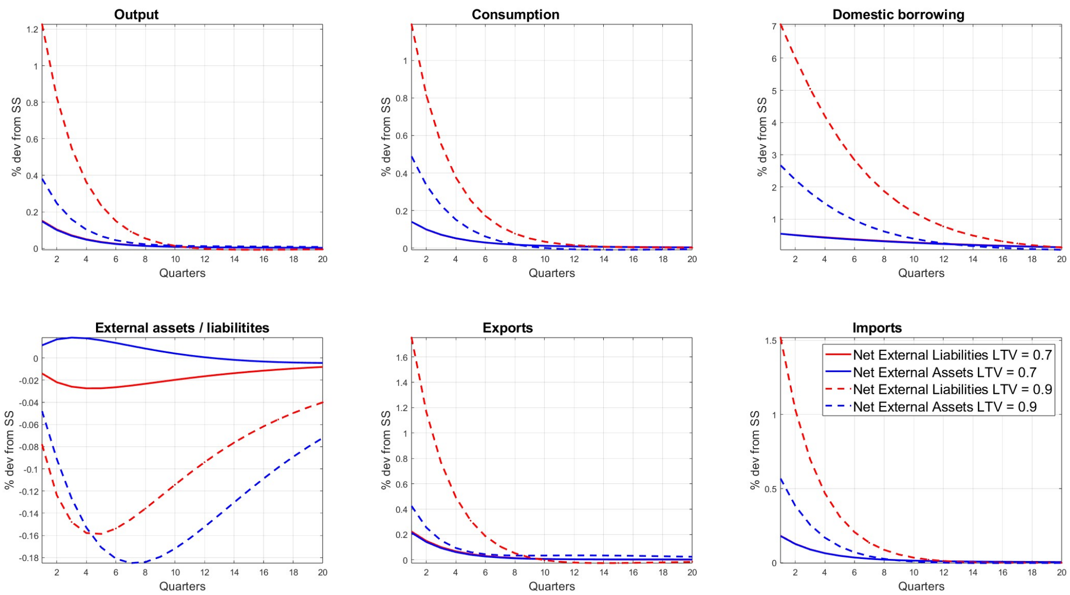

Figure 9. Impulse responses to a domestic technology shock, $\varepsilon_{\Delta_t^A} = 0.001$. The unit on the y-axis is in terms of percentage points deviation from the steady state. The solid lines are the baseline model, and the dotted lines are the alternative.

Relaxation in the LTV ratio to 0.9 results in a much more significant deviation from the steady state for all the variables, as shown by the dotted lines. Similarly to a foreign demand shock, the impacts on output, domestic borrowing, and aggregate consumption for a country with net external liabilities are much more significant than those with net external assets. The explanation behind this observation is very consistent with what we have seen for the foreign demand shock and is as follows. For a country with net external liabilities, the increase in savers' aggregate income, which then leads to additional domestic lending to borrowers, is consumed entirely domestically, as reflected in improvement in consumption and higher housing stock among the borrowers. Higher borrowing is also the result of improved collateral values. However, the impact for a country with net external assets is smaller due to a stronger performance of the nominal exchange rate, as a result of a higher domestic interest rate, leading to some repatriation of external assets. This supports the domestic currency, which in turn leads to a smaller expansion in exports.

5.2 Welfare analysis

This section analyses the social welfare of LTV implementation, with the aim of finding the optimal LTV ratio that maximises social welfare for countries with net external assets and net external liabilities. The impulse response function shows that a tighter LTV can help reduce households' debt, limiting volatility in households' consumption when shocks hit the economy. However, at the same time, a tighter LTV ratio reduces the number of houses owned by the borrowers. As a result, borrowers could potentially be worse off if they preferred to have a higher housing stock over a higher level of consumption. One way to address this problem is through a welfare function that considers consumption, housing stock accumulation, and labour supply for both households in the economy.

The welfare analysis in this paper is adapted from a similar approach taken by Rubio and Carrasco-Gallego, 2015 and Mendicino and Pescatori, 2005, where it captures welfare only within the model domain and does not capture other potential impacts, such as loan default or other extreme cases, such as bankruptcy. To find the optimal LTV and analyse the welfare implications of the different LTV ratios, I solve the model using a second-order approximation to the structural equations and then evaluate welfare using this solution. The individual welfare for savers and borrowers is represented by their maximisation problem given by:

$$W_{u,t} \equiv E_0 \sum_{t=0}^{\infty} \beta^t \left(\ln C_t^u + j \ln H_t^u - \frac{(L_t^u)^{\varphi}}{\varphi} \right) \tag{55}$$

and

$$W_{c,t} \equiv E_0 \sum_{t=0}^{\infty} \widetilde{\beta}^t \left(\ln C_t^c + j \ln H_t^c - \frac{(L_t^c)^{\varphi}}{\varphi} \right) \tag{56}$$

and social welfare is defined as a weighted sum of the individual welfare of savers and borrowers represented as follows:

$$W_t = (1-\beta) W_{u,t} + (1-\widetilde{\beta}) W_{c,t} \tag{57}$$

where each agent's welfare is weighted by its discount factor so that savers and borrowers receive the same level of utility from a constant consumption stream. Following Rubio and Carrasco-Gallego (2015), I present welfare changes in terms of consumption equivalent. Social welfare that is evaluated when the LTV ratio is set at 0.6 is used as a benchmark. The alternative and comparison with the social welfare benchmark is made when the LTV ratio is set between 0.6 and 0.9. The welfare of the benchmark economy, if it is higher than the alternative scenarios, represents a welfare gain. Similarly, if it is lower than the alternative scenarios, it reflects a welfare loss. When there is a welfare loss, consumption equivalent measures the share of consumption that households are willing to give up to obtain the benefits of the LTV ratio at 0.6. Likewise, when there is a welfare gain, it measures how much households need to be compensated for them to be willing to remain in the economy where the LTV ratio is at 0.6. The derivation of the welfare benefits in terms of the consumption equivalent units for savers and borrowers is given as follows:

$$CE_u = \exp\left[(1-\beta)(W_u^{LTV} - W_u^{LTV=0.3})\right] - 1 \tag{58}$$

$$CE_c = \exp\left[(1-\widetilde{\beta})(W_c^{LTV} - W_c^{LTV=0.3})\right] - 1 \tag{59}$$

and social welfare is defined as:

$$CE = \exp\left[(W^{LTV} - W^{LTV=0.3})\right] - 1 \tag{60}$$

where W^{LTV} is the welfare corresponding to the utility function of the agent for any given LTV ratio, which increases with higher consumption and house ownership, but decreases with more hours of labour supply. In this welfare analysis, three different shocks are considered, namely the foreign demand shock, the domestic technology shock, and the foreign interest rate shock. Regardless of the external position, there is a trade-off between the welfare of savers and borrowers. Consistent with the findings in Rubio, 2014, as the LTV ratio gets looser, the welfare of borrowers decreases, but the welfare of savers increases. That said, the welfare analysis looking for the optimal implementation of the LTV ratio points to the same conclusion as the impulse response functions suggest. A country with net external liabilities will be worse off deviating from the optional LTV ratio. Although the optimal LTV ratio is similar for both types of countries, the welfare reduction for a country with net external liabilities to deviate from the optimal LTV and implement a looser LTV ratio is much larger compared to a country with net external assets. The welfare loss in terms of consumption equivalent in certain circumstances can be notably greater compared to a country with net external assets. This is mainly due to a much larger welfare loss for borrowers in a country with net external liabilities. One possible explanation is that a loose LTV ratio will lead to overleveraged situations among borrowers, especially for a country with net external liabilities, due to the fact that borrowing constraints are always binding and they have access to external lenders. As argued in Rubio, 2014, even a small change in the LTV ratio can lead to a very large change in borrowing. As a result, shocks and subsequent movement in interest rate will have the largest impact on their welfare. The result is robust to various magnitudes of the initial shock. A detailed welfare analysis will be discussed next, followed by a robustness analysis based on different sizes of the initial shock.

5.2.1 Welfare analysis - foreign demand shock

This welfare analysis analyses the impact on welfare following a shock in foreign demand. The optimal LTV ratios for a country with net external liabilities and a country with net external assets is 0.60, as shown in Figure 10. The welfare reduction for a country with net external liabilities that deviate from the optimal LTV ratio to a looser LTV ratio is slightly larger than that of a country with net external assets that deviate. Regarding the welfare loss measured in consumption equivalent, for a country with net external assets, households are willing to give up 5.5% of lifetime consumption to remain in the economy, with the LTV ratio set at 0.60 compared to the LTV ratio at 0.9. Welfare loss is marginally smaller than a situation where households are willing to give up 5.7% of lifetime consumption to remain in the economy, with the LTV ratio set at 0.60 compared to the LTV ratio at 0.9 for a country with net external liabilities.

5.2.2 Welfare analysis - domestic technology shock

This welfare analysis analyses the impact on welfare following a technological shock. The optimal LTV ratios for a country with net external liabilities and a country with net external assets are similar at 0.6, as shown in Figure 11. Like before, the welfare reduction for a country with net external liabilities deviating from the optimal LTV ratio to a looser LTV ratio is much more significant compared to a country with net external assets to deviate. For a country with net external assets, the welfare loss measured in consumption equivalent is as follows; households are willing to give up close to 5.6% of lifetime consumption to remain in the economy, with the LTV ratio set at 0.60 compared to the LTV ratio at 0.9. Welfare loss is notably smaller compared to a situation where households are willing to give up more than 6.6% of lifetime consumption to remain in the economy, with the LTV ratio set at 0.60 compared to the LTV ratio at 0.9 for a country with net external liabilities.

Figure 10: Welfare - Foreign demand shock

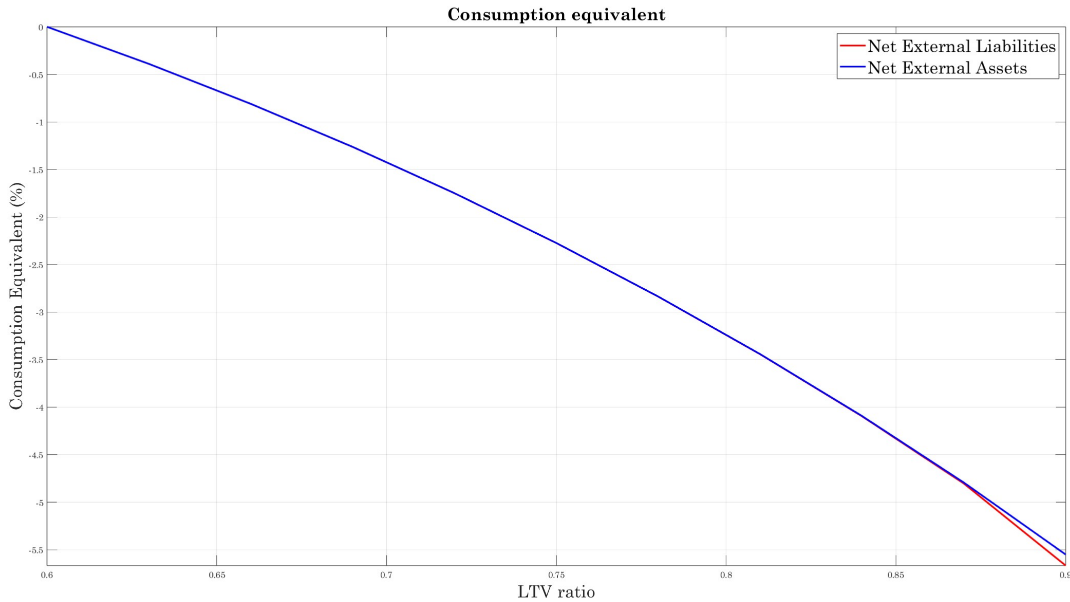

Figure 10. The figure shows welfare in terms of consumption equivalent over a range of LTV ratios following a foreign demand shock, $\varepsilon_{Y_t^f} = 0.01$. The unit on the y-axis is in terms of consumption equivalent (CE) from the benchmark economy. The blue line is for a country with net external assets, and the red line is for a country with net external liabilities.

5.2.3 Welfare analysis - foreign interest rate shock

This welfare analysis analyses the impact on welfare following a shock of foreign interest. The optimal LTV ratios for a country with net external liabilities and a country with net external liabilities are identical at 0.60 as shown in Figure 12. Similarly to before, the welfare reduction for a country with net external liabilities deviating from the optimal LTV ratio to a looser LTV ratio is larger than that of a country with net external assets to deviate. The loss in welfare measured in consumption equivalent for a country with net external assets to set the LTV ratio at 0.9 compared to 0.60 is estimated at 5.5% of lifetime consumption. This is much smaller compared to 7.7% of lifetime consumption that households are willing to give up to remain in the economy, with the LTV ratio set at 0.60 compared to the LTV ratio at 0.9 for a country with net external liabilities.

5.2.4 Welfare analysis - robustness check

In this part, I check the robustness of the results of the welfare analysis by changing the size of the shock. This is an important step in validating the above findings and ensuring that the results are valid for different magnitudes of the shocks. I compare the size of welfare reduction for both economies if

Figure 11: Welfare - Domestic technology shock

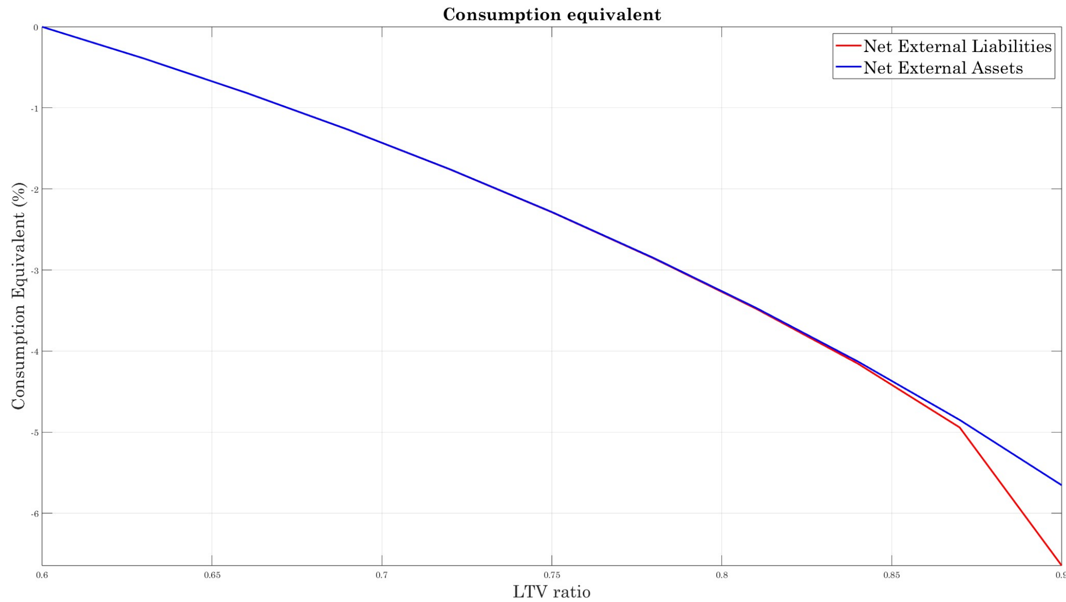

Figure 11. The figure shows welfare in terms of consumption equivalent over a range of LTV ratios following a domestic technology shock, $\varepsilon_{\Delta_t^A} = 0.0001$. The unit on the y-axis is in terms of consumption equivalent (CE) from the benchmark economy. The blue line is for a country with net external assets, and the red line is for a country with net external liabilities.

they set the ratio at 0.9 and deviate from their optimal LTV ratios for various magnitudes of the shocks. Table 7 summarises the change in welfare for a country with net external assets and a country with net external liabilities following a deviation from the optimal LTV ratio for the three different shocks. The result indicates that regardless of the size of the shocks, the welfare loss for a country with net external liabilities to deviate from the optimal LTV is always bigger and more significant compared to a country with net external assets.

5.3 Extension

Motivated by the empirical observation discussed in Section 3.2, which shows that exchange rate movements are more volatile for countries with net external liabilities, the benefit of modifying the rule of the LTV ratio with the nominal exchange rate for countries with external liabilities is studied next. The main motivation of this analysis is to examine whether the nominal exchange rate is a good candidate for a countercyclical instrument to stabilise credit growth and output when the economy faces external shocks. There are two other rules for the LTV ratios that are compared together with the nominal exchange rate augmented LTV rule. The other two rules are a fixed LTV rule and a credit growth

Figure 12: Welfare - Foreign interest rate shock

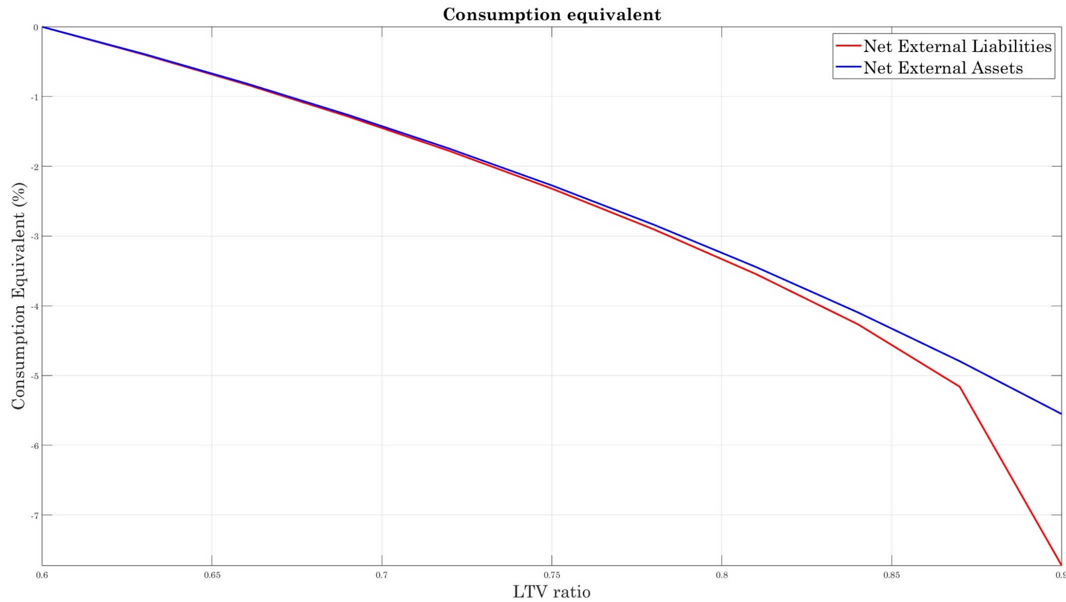

Figure 12. The figure shows welfare in terms of consumption equivalent over a range of LTV ratios following a foreign interest rate shock, $\varepsilon_{R^f_t} = 0.0025$. The unit on the y-axis is in terms of consumption equivalent (CE) from the benchmark economy. The blue line is for a country with net external assets, and the red line is for a country with net external liabilities.

augmented LTV rule. The three types of LTV rules are defined as follows:

$$\text{Augmented LTV ratio rule - Nominal exchange rate} : LTV = 0.7 * (s_t)^{\phi_S}$$

$$\text{Fixed LTV rule} : LTV = 0.7$$

$$\text{Augmented LTV rule - Credit growth} : LTV = 0.7 * \left(\frac{bc_t}{bc_{t-1}}\right)^{-\phi_B}$$

where I set $\phi_S = 0.1$ and $\phi_B = 0.1$. The nominal exchange rate augmented LTV rule implies that the LTV ratio will be relaxed when the nominal exchange rate depreciates. Similarly, the LTV ratio will be tightened as the nominal exchange rate appreciates. The intuition behind this rule is that the borrowing constraint will become less binding for a country with net external liabilities when the exchange rate depreciates and becomes more binding when the exchange rate appreciates. Meanwhile, a credit growth augmented LTV rule implies that the LTV ratio will be relaxed when the credit growth contracts, and the LTV ratio will be tightened when the credit growth expands. The result shows that the nominal exchange rate as an instrument to augment the LTV is not as effective in stabilising credit growth and output compared to the credit growth augmented LTV rule. The reason being is that as long as a weaker

Table 6: Welfare analysis - robustness check

Foreign demand shock		
Size of the initial shock, $\varepsilon_{Y_t^f}$	Net External Liabilities (Optimal LTV)	Net External Assets (Optimal LTV)
0.010	-5.7%	-5.5%
	(0.60)	(0.60)
0.030	-6.8%	-5.8%
	(0.60)	(0.60)
0.050	-9.0%	-6.2%
	(0.60)	(0.60)
Technological shock		
Size of the initial shock, $\varepsilon_{\Delta_t^A}$	Net External Liabilities (Optimal LTV)	Net External Assets (Optimal LTV)
0.0001	-6.6%	-5.6%
	(0.60)	(0.60)
0.0002	-9.9%	-6.0%
	(0.60)	(0.60)
0.0003	-15.1%	-6.7%
	(0.60)	(0.60)
Foreign interest rate shock		
Size of the initial shock, $\varepsilon_{R_t^f}$	Net External Liabilities (Optimal LTV)	Net External Assets (Optimal LTV)
0.0025	-7.7%	-5.5%
	(0.60)	(0.60)
0.0050	-14.0%	-7.1%
	(0.60)	(0.60)
0.0075	-23.6%	-9.0%
	(0.60)	(0.60)

Note: Welfare loss is measured by the reduction in lifetime consumption in terms of consumption equivalent after a departure from the optimal LTV ratio to the LTV ratio of 0.9.
Source: Author's calculation

exchange rate leads to an improvement in domestic production through stronger external demand, the loosening of the LTV rule will intensify the procyclicality between domestic borrowing and output. In contrast, an augmented LTV that moves in the opposite direction of credit growth is effective in bringing financial and output stability. A more thorough explanation of the results will follow.

5.3.1 Augmented LTV - Foreign interest rate shock

Figure 13 shows the impulse response functions for output, domestic borrowing, external liabilities, and the change in the LTV ratio following a foreign interest rate shock for the three different LTV rules. The red line represents a fixed LTV rule, the blue line represents a credit growth augmented LTV rule, and the green line represents a nominal exchange rate augmented LTV rule. The impulse response functions show that the impact on output and external liabilities for all three LTV rules is very similar. However, the initial impact of domestic borrowing varies. The nominal exchange rate augmented LTV rule seems to be least effective in stabilising domestic credit growth compared to the fixed LTV and augmented credit growth LTV rules. The intuition behind this is that the nominal exchange rate augmented LTV relaxes the borrowing constraint, which more than offsets the tightening effect of a depreciation in the exchange rate on the borrowing capacity of the borrowers. As a result, it has a greater impact on domestic credit growth.

Figure 13: Augmented LTV - Foreign interest rate shock

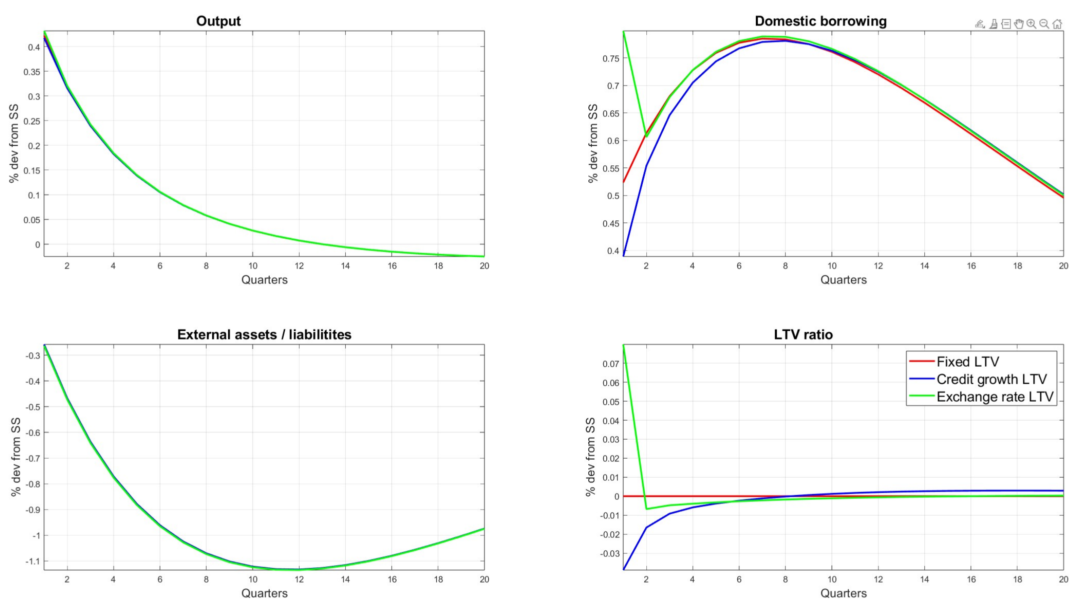

Figure 13. Impulse responses to the foreign interest rate shock, $\varepsilon_{R_t^f} = 0.0025$. The unit on the y-axis is in terms of percentage points deviation from the steady state. The red line represents a fixed LTV rule, the blue line represents a credit growth augmented LTV rule, and the green line represents a nominal exchange rate augmented LTV rule.

5.3.2 Augmented LTV - Foreign demand shock

The impulse response functions in Figure 14 illustrate the impact of a foreign demand shock on production, domestic borrowing, external liabilities, and the LTV ratio under the three different LTV rules. Similarly to what we have seen before, the impulse response functions show that the impact on output and external liabilities for all three LTV rules is very similar. However, the initial impact of domestic borrowing varies. The credit growth augmented LTV rule and nominal exchange rate augmented LTV rules seem to be effective in stabilising domestic credit growth compared to the fixed LTV. The explanation of why the nominal exchange rate augmented LTV is effective goes as follows. An appreciation in the exchange rate following a foreign demand shock loosens the borrowing capacity of the borrowers; however, it has been more than offset by the tightening in the nominal exchange rate augmented LTV, resulting in domestic credit growth reacting very closely with the credit growth augmented LTV rule.

Figure 14: Augmented LTV - Foreign demand shock

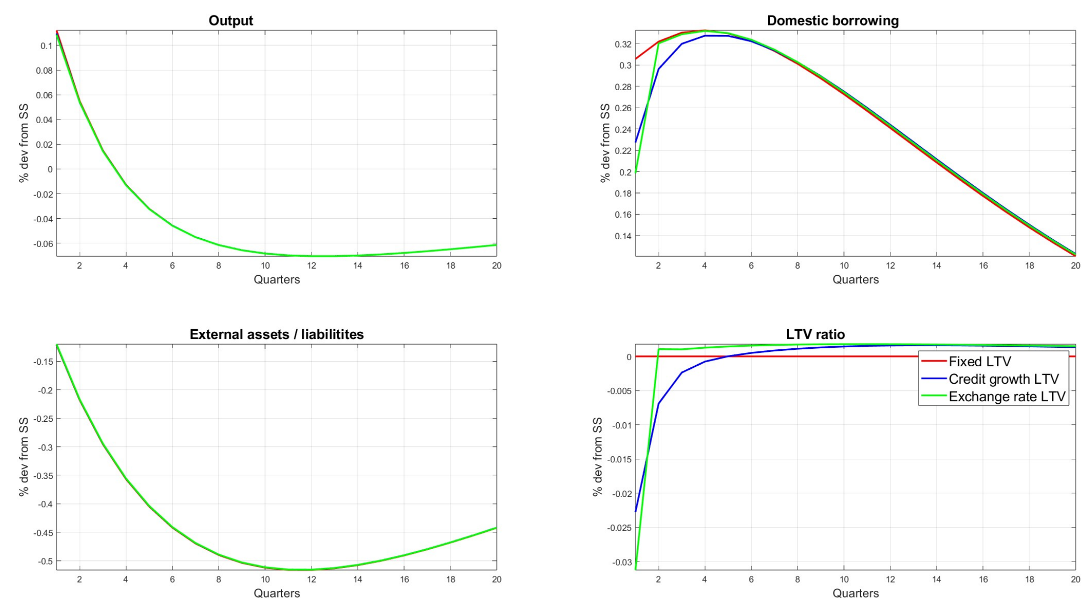

Figure 14. Impulse responses to a foreign demand shock, $\varepsilon_{Y_t^f} = 0.01$. The unit on the y-axis is in terms of percentage deviation from the steady state. The red line represents a fixed LTV rule, the blue line represents a credit growth augmented LTV rule, and the green line represents a nominal exchange rate augmented LTV rule.

6 Conclusion

I analyse the effectiveness of the LTV ratio in containing the financial and business cycles for countries with different external positions. Two situations are considered, one where a country with external assets, and another is a country with external liabilities. The external position that remains a crucial macroeconomic variable reflecting a country's resilience, primarily for an emerging economy, is the reason why I undertake this study. I also construct a small data set and the observations gathered from the data set provide additional reasoning for the importance of this study. In particular, even though house prices are more volatile for countries with net external liabilities, tighter LTV ratios are more commonly observed among countries with net external assets.

From the impulse response functions, I find that a looser LTV ratio for countries with external liabilities will lead to much bigger credit and output growth deviations from their steady states. I can safely conclude from the findings that the implementation of a looser LTV ratio, which in this paper is defined as setting the LTV ratio at 0.9 compared to 0.7 as in the baseline model, will result in more volatile financial and business cycles for a country with net external liabilities.

In addition, I also study the impact of the implementation of the LTV ratio on welfare. Welfare analysis allows me to find the optimal LTV ratios that maximise social welfare for both countries, which allows me to estimate the welfare gain or loss if a country decides to deviate from the optimal LTV ratio implementation. The welfare analysis points to the same conclusion from the impulse response functions. Although the optimal LTV ratio is identical for both types of countries, the welfare loss for a country with external liabilities to deviate from the optimal LTV is larger compared to countries with external assets.

Finally, I also explore the benefit of augmenting the LTV with the nominal exchange rate for countries with external liabilities. This is motivated by one of the empirical observations that shows that exchange rate movements are more volatile for countries with net external liabilities. I examine the model with external shocks and the result shows that augmenting the LTV ratio based on the movement of the nominal exchange rate may not necessarily be a good idea. In contrast, a countercyclical LTV that moves in the opposite direction of credit growth is much more universal and effective in stabilising credit growth and output.

There are few limitations in this paper that provide scope for future research. First, in the empirical part, to include more variables in the regressions to reduce the risk of omitted variable bias. Secondly, the introduction of banks will help to properly capture the effect of the financial channel of the exchange rate by incorporating the impact of exchange rate depreciation on lenders' balance sheet. Third, to properly study the role of foreign buyers, a two-country DSGE model is more suited, where the impact of foreign buyers on domestic housing market will be endogenously determined by factors in both domestic and foreign countries.

List of countries

Argentina, Australia, Austria, Belgium, Brazil, Bulgaria, Canada, Chile, China, Colombia, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hong Kong, Hungary, Iceland, India, Indonesia, Ireland, Israel, Italy, Japan, Korea, Kuwait, Latvia, Lithuania, Luxembourg, Malaysia, Malta, Mexico, Mongolia, Netherlands, New Zealand, Nigeria, Norway, Peru, Philippines, Poland, Portugal, Romania, Russia, Saudi Arabia, Serbia, Singapore, Slovak Republic, Slovenia, South Africa, Spain, Sweden, Switzerland, Thailand, Turkiye, Ukraine, United Kingdom, United States, Uruguay.

7 Table A1 - A3

Table A1

	2005		
LTV	Advanced Economies	Emerging Economies	Total
< 70%	0 (0%)	2 (6%)	2 (3%)
70% to < 100%	6 (25%)	6 (17%)	12 (21%)
=> 100%	18 (75%)	27 (77%)	45 (76%)
Total	24	35	59
	2020		
LTV	Advanced Economies	Emerging Economies	Total
< 70%	3 (11%)	4 (11%)	7 (11%)
70% to < 100%	15 (56%)	17 (49%)	32 (52%)
=> 100%	9 (33%)	14 (40%)	23 (37%)
Total	27	35	62

Source: Alam et al. (2019)

Table A2

Fixed effects regression Dependent: Real residential property prices (absolute)			
GDP per capita (absolute)	0.683*** (0.1832)	0.628*** (0.1702)	0.5275*** (0.1882)
LTV	0.103*** (0.0353)	0.1154*** (0.0371)	0.1401* (0.0731)
Unemployment rate (-1)		-0.1897* (0.1076)	-0.2171* (0.1106)
Building permit (absolute) (-1)			0.0253** (0.0093)
R-squared (within)	0.1175	0.1276	0.1278
No. observations	826	789	477
No. groups	55	55	38
Time effects	No	No	No

Robust standard errors are reported in parentheses. *, **, *** indicates significance at 90%, 95%, and 99% level, respectively.

Table A3

Fixed effects regression Dependent: Exchange rate (absolute)	
External position	-0.0001*** (0.00003)
R-squared (within)	0.2839
No. observations	600
No. groups	38
Time effects	Yes

Robust standard errors are reported in parentheses. *, **, *** indicates significance at 90%, 95%, and 99% level, respectively.

Table A4

Fixed-effects logistic regression		
Dependent: Volatile residential property prices (<-5% and >5%)		
LTV	0.0187* (0.0102)	0.0267** (0.0113)
GDP per capita (absolute)	0.0921*** (0.0353)	0.0755** (0.0372)
Unemployment rate (-1)		-0.0997*** (0.0341)
No. observations	810	756
No. groups	54	54
Time effects	No	No

Standard errors are reported in parentheses. *, **, *** indicates significance at 90%, 95%, and 99% level, respectively.

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