Essays on Exchange Rates and Optimal Policy Responses

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Background

1.1 Introduction

Maintaining monetary and financial stability is fundamental to fostering economic progress and improving living standards. The consequences of monetary and financial instability can extend beyond the short term, as demonstrated by Cerra and Saxena, 2008 that a large proportion of output losses associated with financial crises tend to be permanent and irrecoverable. One of the most important lessons policymakers have drawn from past crises, most notably the Global Financial Crisis (GFC), is that monetary stability alone does not necessarily translate and lead to financial stability (Breeden, 2023). Recognising this, policymakers have embraced macroprudential policy as part of their policy mix to safeguard the financial system and mitigate systemic risks. In the aftermath of the GFC, macroprudential policy has been widely adopted in both advanced and emerging market economies. As a result of the widespread implementation of macroprudential policy in many jurisdictions, policymakers now have a better understanding about the effectiveness of the policy and their potential trade-offs.

The main objective of macroprudential policy is to reduce systemic risks that can destabilise the financial system, with one of the key goals being to ensure that financial intermediation activities can remain sound and optimal during both good and bad times. There are two broad categories for macroprudential policy tools, borrower-based and lender-based tools. As the name suggests, the borrower-based tools aim to limit the size of a loan that can be extended to a borrower, which ultimately will contain households total leverage, and, on the flip side, the lender-based tools aim to tighten lending practices and improve banks resilience. Macroprudential policy is needed to maintain financial stability as the drivers of financial cycles are sufficiently different from the business cycles, making monetary policy alone unsuitable to deal with financial cycles (Rünstler, 2016). In particular, driven by animal spirits, borrowers and banks often collectively take on excessive risk during periods of credit expansion and tend to become overly cautious during the downturns.

There is ample and growing empirical and theoretical evidence to suggest the effectiveness of macroprudential policy in preserving financial stability. Among others, the findings of Bruno et al., 2017 and Akinci and Olmstead-Rumsey, 2018 show the effectiveness of macroprudential policy in moderating credit growth and asset prices, which help limit the adverse effect propagating through macrofinancial linkages and, in turn, reduce the negative tail risks of output arising from financial crises. Fernández-Gallardo et al., 2023 argue that tighter macroprudential policy brings benefits by reducing the downside and upside tail risk of future GDP growth, but with a broadly zero effect on the centre of the distribution. Moreover, recent empirical studies that rely on micro data and policy surprises to isolate the effect of the exogenous shock of macroprudential policy on credit growth and asset prices generally find economically and statistically significant effects, especially for borrower-based tools (Gelos, 2023). This is important as credit growth affects both the length of expansions and the amplitude of recessions, as past studies have shown that financial crises and large corrections in asset prices tend to be associated with deeper recessions and slower recoveries (Claessens et al., 2012 and Jordà et al., 2013).

Despite the effectiveness in maintaining financial stability, macroprudential policy also comes with trade-offs or undesired effects that policymakers must be aware of. The main trade-off is that macroprudential policy moderates credit expansion which limits short run economic growth, but it provides stability for the financial system and beneficial for the economy in the long run. Given the trade-off between growth and risk, policymakers must strike a good balance when implementing macroprudential policy, with the objective of achieving an optimal level of credit growth that will allow expansions to last longer, and at the same time avoiding deep recessions (Gadea et al., 2020). That being said, the broad consensus among economists is that the undesirable effects of macroprudential policy are relatively weak and modest. Alam et al., 2019 show that macroprudential policy has a mild impact in dampening the real household consumption. Likewise, Richter et al., 2019 demonstrate that macroprudential policy has substantial effects on credit and house price growth, but modest effects on output and inflation.

More recent studies using country-specific households-level data help to uncover more granular findings and give more insights, in terms of cost and benefit of macroprudential policy. Using data from the Netherlands, a study by van Bekkum et al., 2024 finds that the borrower-based macroprudential policy tool is effective in reducing the total leverage of households and leads to fewer financial distress among affected households. However, affected households experience a reduction in their cash balance as a result of a lower mortgage, generating a short run solvency-liquidity trade-off. The adverse impact on households' liquidity is also being documented by Aastveit et al., 2023, where the study is based on Norweigan tax data, but they found that the effect is more persistent to the extent that macroprudential policy can lead to consumption volatility.

Given the overwhelming evidence that its benefits outweigh the cost, there is an argument for policymakers to use macroprudential policy as the first line of defence against financial imbalances. These findings also advocate for policymakers to take a more lean against the wind approach in protecting the financial system, as the undesirable effects of macroprudential policy have been shown to be insignificant.

1.2 Macroprudential policy in small open economies

To ensure the effectiveness of macroprudential policy in safeguarding the financial system and mitigating systemic risk, there are six principles that can help guide policymakers in implementing any macroprudential policy tool, as outlined by Constâncio, 2017. The six principles are as follows:

1. Macroprudential policy should be preemptive and strongly countercyclical.
2. The concept of the financial cycle is crucial for the rationale of macroprudential policy. It helps assess the position of the economy, predict its development, and appropriately calibrate the use of macroprudential tools.
3. The real estate component is of paramount importance in the financial cycle, underscoring the significance of borrower-based tools.
4. Stress tests of the banking and financial system must have a macroprudential dimension.
5. Macroprudential policy is complementary to monetary policy as both policies share the goal of macro-financial stabilisation through the forward-looking dynamic macro-risk management.
6. Macroprudential policy should reach beyond the banking sector and encompass market-based finance institutions and products.

In the context of small open economies, especially concerning the first principle, it is important to recognise that these economies are not only affected by domestic shocks but are also highly exposed and vulnerable to external shocks that can destabilise the domestic financial system. Consequently, additional macroprudential tools are needed to address these risks. Specifically, macroprudential policy should be designed to mitigate the impact of external forces that can amplify the procyclicality between the domestic financial system and the real sector. This is essential to ensure that macroprudential policy frameworks are comprehensive and capable of reducing systemic risks arising from both domestic and external sources.

Small open economies are particularly susceptible to volatile capital flows. There are domestic and external factors driving capital flows, but Miranda-Agrippino and Rey, 2020 argue that US monetary tightening alone leads to a reduction in a large share of risky asset prices around the world. This is consistent with the findings in Koepke, 2019, in which it is concluded that external factors such as global risk aversion and external interest rates are found to matter the most for portfolio flows. Extensive evidence demonstrates a procyclical relationship between capital flows, domestic financial conditions, and ultimately the real sector. The results of Baskaya et al., 2017 and Kneer and Raabe, 2024 demonstrate that capital inflows boost bank lending to the domestic economy. Asset prices, including house prices, can also be strongly influenced by capital flows as suggested by Tillmann, 2013 and Z. Li et al., 2020. There is also evidence that capital flows affect credit quality, as argued by Cantù et al., 2022, where they find that high capital inflows generally induce weak banks to relax their lending standards. Capital flows also affect exchange rates, which, in turn, will have a direct implication on the net worth of borrowers and lenders through their exposures in foreign assets and foreign liabilities. This captures the financial channel of the exchange rate and it will have a direct impact on both the demand and supply of credit.

In extreme cases, capital flows and exchange rate movements can have a significant detrimental impact on both the financial system and the real sector. Sudden stops reflect the notion of abrupt withdrawal of capital inflows, which has attracted a lot of attention from economists on this topic since the analysis by Calvo, 1998, where in the article it shows that sudden stops in capital flows were observed in both portfolio and foreign direct investment flows. The severity of the impact of sudden stops on real economic activities is well documented, for example, in Mishkin, 1999 and Eichengreen and Gupta, 2016, where they found a significant effect on asset prices, investment, and GDP. The movement of the exchange rate can also affect the real economy through future inflation expectations. In particular, a large depreciation and the expectation of its passing through to domestic inflation can lead to a rise in inflation expectations, which in turn translates into uncertainty about the future path of the economy (Gürkaynak et al., 2023).

The magnitude or severity of the financial channel of the exchange rate or sudden stops is highly dependent on the microstructure of the financial system. The key factor is the vulnerability of the financial system that can be attributed, among others, to the size of foreign borrowing in the financial system, and it can worsen if there is a significant aggregate currency mismatch in the financial system. Currency mismatch refers to a situation where firms and banks have a significant share of their liabilities denominated in foreign currency but most of their assets are denominated in local currency. If the size of the aggregate currency mismatch is large, exchange rate depreciation will have a consequential impact on firms and banks' net worth and dominates the trade channel of the exchange rate, which in turn could destabilise the financial system and will have a direct knock-on effect on the real sector (e.g. Bordo, 2006, Kuruc et al., 2017, and Abbassi and Bräuning, 2023). In addition to currency mismatch, the vulnerability of the financial system can also be due to maturity mismatch in the banking system. Transformation in maturity in the banking system where short-term liability is converted into long-term assets can expose banks to a serious rollover risk and more susceptible to external shocks, especially if banks rely heavily on short-term external funding, which is far less stable compared to the traditional retail deposits (e.g. Drechsler et al., 2018, Kladakis et al., 2022, Jondeau et al., 2024 and Müller et al., 2025). Underdeveloped financial markets can accentuate vulnerability, as withdrawal from external funding cannot be easily replaced with domestic funding.

In addition to macroprudential policy, policymakers in small open economies also rely on capital flow management (CFM) measures to manage risks associated with volatile capital flows and attenuate its direct interlink with domestic financial cycles. CFM is also known as capital controls and its main objective is to limit the free flow of capital. The International Monetary Fund (IMF) recognises that some CFM measures can also be classified as macroprudential policy tools, as long as the CFM measures are used to reduce systemic risk arising from fickle capital flows (IMF, 2022a). In terms of motivation for policymakers to use CFM measures, Binici and Das, 2021 find that domestic overheating and capital flow management were key rationales to tighten inflows, while financial stability and mitigating exchange rate deprecation were key to limit outflows. Although there is evidence that shows the effectiveness of CFM measures in reducing fragility in the financial system and helping manage domestic credit growth (e.g. Forbes et al., 2015 and Wang and Wu, 2021), the implementation of CFM measures also comes with some important trade-offs. Of significance, CFM measures can generate compliance costs, create policy uncertainty, and can impede the development of domestic markets, suggesting the selective and limited use of CFM measures when they are necessary (IMF, 2022b). Table 1.1 below provides a list of some common CFM measures that have been introduced in various countries.

Policymakers also have foreign exchange intervention (FXI) as part of their policy mix to manage and stabilise the exchange rate. FXI is used to reduce the systemic risk that can arise from extreme movement in the exchange rate, which can potentially destabilise the real sector. FXI is particu-

Table 1.1: List of common CFM measures

No.	Type of CFM measures	Example
1	Ban	Limit on offshore investments by individuals and institutions
		Local banks are disallowed to participate in offshore derivative trading
2	Limit on inflow and outflow	A limit on banks' net FX positions
		Limit on nonresident investors can hold on domestic assets
3	Repatriation requirement	Exporters must repatriate export proceeds to local banks
		Conversion of export proceeds into local currency
4	Reserve requirement	A reserve requirement on foreign credit lines and short-term liabilities
5	Stamp duty	Additional duty for foreigners to acquire property
6	Tax	Tax imposed on FX purchases
		Levy on banks' non-deposit foreign-currency liabilities

Source: IMF, 2023a

larly needed when the foreign exchange market dried up and became illiquid, which in turn could lead to extreme exchange rate movement. This is consistent with a survey done by the Bank for International Settlements (BIS) in 2021 that suggests that central banks in emerging markets use FXI primarily to reduce the volatility of the exchange rate, provide liquidity to thin markets and manage speculative activities.[1] Unlike the scheduled monetary policy, FXI is generally implemented on a discretionary basis, responding to the condition in the FX market. Depending on the source of FX pressure and the structure of the FX market, the choice of a central bank to intervene in the spot or derivative markets will determine the efficacy of FXI. FXI is more effective in the futures market if it is more liquid and most of the FX trading is concentrated, but alleviating foreign currency funding shortages is more effective by intervening directly in the FX swaps market. In emerging market economies, FXI is carried out mainly on the offshore spot market.[2]

Past studies have shown that FXI is effective in affecting the level of exchange rate and managing exchange rate volatility, particularly in reducing the pressures from capital flows, especially in the short-term (e.g. Blanchard et al., 2015, Adler et al., 2019 and Vargas-Herrera and Villamizar-Villegas, 2024), which is beneficial to manage the adverse effect from currency mismatch and deanchoring in inflation expectations. However, FXI also comes with some limitations and unintended side effects. First, FXI will limit the effect of the trade channel of the exchange rate through the expenditure switching mechanism. Other notable side effects are that the frequent use of FXI can hinder the development of FX and hedging markets. It can also create a moral hazard problem, as firms and banks have incentives to expand their FX exposures and to rely on the central bank to mitigate any losses, and it can lead to confusion regarding the nominal anchor of central banks (IMF, 2023b).

[1] FX interventions: Insights from a Markets Committee Workshop chaired by Gerardo García López (Bank of Mexico). Published on 17 May 2022.

[2] FX Markets and FX Interventions: Insights from a Markets Committee Workshop chaired by Jwahong Min (Bank of Korea). Published on 14 March 2024.

1.3 Interactions between macroprudential policy, foreign exchange intervention and monetary policy

There is a large interaction and spillovers between macroprudential policy and monetary policy, as both tools operate within the financial system (Martin et al., 2021). The interaction between these two policies means that macroprudential policy can influence the transmission of monetary policy, and vice versa. A study by Altavilla et al., 2020 documents that the effect of expansionary monetary policy on bank lending and lending to riskier borrowers is greater when macroprudential policy is accommodating and is particularly stronger for less-capitalised banks. This is consistent with the findings of Cozzi et al., 2021 that argue that the net worth of banks is more sensitive to monetary policy shocks when their leverage is higher and their assets are more risky. In contrast, higher capital requirements and a more resilient banking system dampen the transmission of monetary policy. Similarly, Garcia Revelo et al., 2020 show that restrictive monetary policy enhances the impact of macroprudential tightening on credit growth.

Monetary policy also has a direct impact on financial stability, mainly propagating through the credit and risk-taking channels. The credit channel captures the traditional mechanism of transmission of monetary policy, where expansionary monetary policy improves the quantity of bank credit, supported by a higher demand and supply of credit (Ciccarelli et al., 2015). However, monetary policy can also affect credit quality, through the risk-taking channel, in which lower interest rates incite banks to lower their lending standards and take more risks. Dell'Ariccia et al., 2017 present evidence of the risk-taking channel of monetary policy for the US banking system, where they show that interest rate policy affects the quality and not just the quantity of bank credit. The risk-taking channel has also been documented in Jiménez et al., 2014 and Whited et al., 2021 to be more prevalent among banks in a low interest rate environment. Unconventional monetary policy tools also have a direct impact on the financial system and bank lending. Karadi and Nakov, 2021 shows that asset purchase policies are effective in stabilising the financial system but reduce the profitability of the banking sector, which, in turn, lengthens the recapitalisation period. In terms of the effect of the monetary policy on the exchange rate, Cañon et al., 2024 find that both conventional and unconventional policy tools have an impact on the tail risk of currencies.

CFM measures and FXI can help complement macroprudential policy to maintain financial stability, especially in the context of managing risk from volatile capital flows and external shocks. Macroprudential policy and CFM measures are found to be effective in mitigating external monetary policy shock, as argued in Takáts and Temesvary, 2021, where they found that tightening of macroprudential policy in the home country will mitigate the negative impact of tighter foreign monetary policy. Depending on the situation, certain shocks are also better suited to be managed by certain measures. For example, Magud and Pienknagura, 2025 shows that FXI is more effective in reducing the depreciation of the large exchange rate compared to the CFM measures, particularly as an immediate response after shocks. Likewise, CFM measures and FXI can also help complement monetary policy to maintain monetary stability. In a case study using Hungary data by Balog et al., 2015, the authors argue that CFM measures to reduce currency and maturity mismatches resulted in the central bank having more room for manoeuvre for monetary policy to focus on its primary objective. This is especially true given that central banks can resort to using a short-term interest rate to ease external pressure on exchange rates.

1.4 Macroprudential policy and financial frictions

Macroprudential policy, together with CFM measures and FXI, changes the dynamics of a financial friction model by directly targeting the amplification mechanisms and vulnerabilities that arise from frictions in the financial system. Financial frictions can arise either from the asset or liability side of the banks' balance sheet. The asset side captures the frictions between banks and their borrowers, and the liability side captures the frictions between banks and their lenders (L. Christiano, 2022). Financial frictions can propagate through the financial accelerator mechanism, as proposed by Bernanke et al., 1999, creating a negative feedback loop between shocks, asset prices, and real economic activities. Meanwhile, Iacoviello, 2005 introduces financial friction through collateral constraints tied to house values. Gertler and Kiyotaki, 2015 build a macroeconomic model with a banking system that allows for liquidity mismatch and bank failures.

In the context of external shock spillover to the domestic economy, R. Banerjee et al., 2016 argue that absent financial friction, international spillovers are minor. However, with frictions in financial intermediation, international spillovers are substantially magnified. Likewise, J. Li, 2018 builds a small open economy model, with access to international capital markets through banks, and sudden stops decrease the supply of banks' credit and increase the domestic interest rate on loans, leading to a fall in production. The existing vulnerability also matters where preexiting conditions can amplify the external shock. Davis et al., 2023 show that when the level of external debt is high, even a small increase in the world's interest rate can eliminate a high-debt equilibrium and the economy experiences a sudden stop.

Countercylical macroprudential policy, together with CFM measures, and FXI can help weaken the financial frictions. These tools, if implemented properly, can help the economy defend itself against both domestic and external shocks. Especially in dealing with global imbalances, Medina and Roldós, 2018 argue that in facing volatilte capital flows, the use of a countercyclical macroprudential instrument by policymakers in addition to the policy rate improves welfare. This is consistent with the empirical findings of Takáts and Temesvary, 2021 and Coman and Lloyd, 2022, which show that macroprudential policy is effective in reducing the spillover effect of external shocks. However, there are still limitations and trade-offs associated with these tools as discussed earlier, which policymakers must be aware of.

1.5 Conclusion

This chapter provides a broad overview of macroprudential policy, especially for small open economies. The following three chapters are a compilation of three different but related papers in the areas of exchange rates and optimal policy responses. What follows is a summary and key findings from the three papers.

The first paper (Chapter 2) entitled **The Interplay Between Domestic Bank Lending, Foreign Interest Rates, and Exchange Rates** examines the impact of exchange rate depreciation on bank loans using data from 16 emerging economies. Based on panel data analysis and the local projection method, I find that depreciation leads to a reduction in bank loans. I also find that the impact is state- and shock-dependent. A greater reliance on foreign funding and depreciation caused by tighter financial conditions in the US leads to a much severe impact on bank loans. Then, I built a dynamic stochastic general equilibrium (DSGE) model with a banking system to explain the amplification mechanism of exchange rate fluctuations on bank loans. First, it occurs when the share of foreign funding by banks is significant, as it directly affects bank lending capacity. Second, in situations where banks face restrictions in obtaining external funding. Third, when banks' profitability is more sensitive to the exchange rate movements. The finding also indicates that the foreign exchange intervention and the countercyclical capital-to-loan ratio can be considered to mitigate the impact, but they come at the expense of some trade-offs.

The second paper (Chapter 3), **LTV, External position, and Exchange rate** studies the effectiveness of macroprudential policy, specifically the loan-to-value (LTV) ratio, 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 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.

The final paper (Chapter 4), **The Impact of Exchange Rate Movements, Volatility, and Intervention: Evidence from Malaysia** attempts to uncover both the trade and the financial channel of the exchange rate. The effectiveness of exchange rate fluctuations in insulating the economy from shocks has been well debated, but remains inconclusive. This paper contributes to this debate by analysing the impact of exchange rate fluctuations on production and bank credit, using micro- and macro-level data from Malaysia. Analysing the data using the local projection method, I show that the effect of exchange rate depreciation on production is expansionary, and production is more responsive when the share of tradable sector is relatively large. In contrast, consistent with the financial channel of the exchange rate, using bank-level data, domestic bank credit reacts negatively to exchange rate depreciation. In addition, I find that bank credit responds differently depending on the volatility level and the initial shock that caused the movement of the exchange rate. Finally, I show that a targeted foreign exchange intervention in reducing the exchange rate volatility is more effective compared to a non-targeted one.

Chapter 2

The Interplay Between Domestic Bank Lending, Foreign Interest Rates, and Exchange Rates

2.1 Introduction

In recent years, many articles have demonstrated the negative impact of exchange rate depreciation on the real economy and credit growth, especially for emerging market economies. This is known as the financial channel of the exchange rate. The detrimental impact of a depreciating exchange rate, transmitted through the financial channel, can partially or entirely neutralise the benefit provided by the trade channel of the exchange rate on the real economy. As a result of the financial channel, most central banks do not allow their exchange rates to be freely determined by market dynamics. This phenomenon was famously coined in Calvo and Reinhart, 2000 as fear of floating, when they discovered that exchange rates do not float freely in emerging economies, although they have adopted the floating exchange rate regime. In contrast, the trade channel is supported by the conventional Mundell-Fleming framework (Mundell, 1961, Fleming, 1962), which proposes that a decrease in the value of domestic currency can enhance the country's trade competitiveness through the expenditure switching mechanism, which consequently helps to stabilise other macroeconomic factors, such as output, consumption, and employment, when the economy is hit by shocks. The net effect of a weaker exchange rate on growth, either expansionary or contractionary, depends on which channel dominates.

Although there are already many articles uncovering the impact of the financial channel of the exchange rate, the discussion on how exchange rate fluctuations affect bank loan growth is relatively scarce, particularly on the non-linear relationship between the two variables. More importantly, most of the discussion on the financial channel of the exchange rate previously focused on the impact originating from foreign liabilities held by domestic firms, as opposed to the exposure of domestic banks, which will be the main discussion of this paper. As long as domestic firms and banks are not fully hedged, they will be exposed to a currency mismatch problem, since their assets and earnings are mostly denominated in domestic currency, but some parts of their liabilities are denominated in foreign currencies. This is particularly important for small open economies, as both domestic firms and banks in small open economies still have a substantial reliance on foreign funding. This paper analyses this topic using both an empirical approach and a dynamic stochastic general equilibrium (DSGE). A key distinctive feature of this paper and its main contribution is that it places greater emphasis on the non-linear relationship between exchange rate and bank loans. The empirical analysis and the DSGE complement each other, where the former aims to establish the relationship, and the latter rationalises the findings. This gives a much broader view of the relationship between exchange rate and bank loans, rather than looking at them in isolation.

Using quarterly data from 16 emerging economies, empirical analysis is performed based on panel data and panel local projection (LP) methods as proposed in Jordà, 2005. The first part of the empirical analysis is to establish the negative relationship between exchange rate movements and bank loan growth. In the second part of the empirical analysis, the paper evaluates whether there is a non-linear relationship between the two variables. The aim is to establish under which conditions the movements of the exchange rate could accentuate its impact on the growth of bank loans. From the perspective of the DSGE framework, the depreciation in the exchange rate that leads to the erosion of bank capital is triggered by an initial shock on the foreign interest rate. The DSGE framework allows me to deepen the analysis, to look closer at how the foreign interest rate and exchange rate affect bank loans, exclusively from the perspective of bank loan supply, and in what circumstances that exchange rate movements could exacerbate the impact on bank loan supply. This underpins the asymmetric relationship between exchange rate movements and bank loans in the model. The DSGE framework also aims to provide some guidance on policy responses that central banks could consider.

The econometric technique to study the non-linearity between exchange rate and bank loans for the panel data analysis follows the approach of Guerrieri and Iacoviello, 2017, where the article investigates the non-linear relationship between house prices and macroeconomic variables. For the panel LP method (LP-OLS), similar approaches in Jordà, 2005 and Ramey and Zubairy, 2018 are used to study the linear and non-linear relationship between exchange rate movements and bank loan growth. Following Jordà et al., 2020, the identification strategy to perform the shock-dependent analysis is carried out with external instrumental variables (LP-IV). The New Keynesian DSGE framework with a banking sector is closely adopted from Gambacorta and Signoretti, 2014, but the model is extended from a closed economy to a small open economy setup, allowing banks to borrow from external sources. The extension to a small open economy is based on Adolfson et al., 2007. The OccBin toolkit proposed in Guerrieri and Iacoviello, 2015 is used to study the impact on bank credit supply and other key macroeconomic variables in a situation where banks face binding restrictions to borrow externally. This is highly relevant and motivated by past findings that show that foreign funds are prone to external shocks and higher funding costs in the home country. Comparison of policy responses includes the foreign exchange intervention (FXI), the loan-to-value (LTV) ratio, and the capital-to-loan (CTL) ratio.

The main findings of this paper are as follows. Empirical evidence suggests that depreciation in the domestic currency will lead to a reduction in the growth of the real bank loan.[1] This result is statistically significant and robust with different model specifications. I also show that there is a non-linear relationship between exchange rate and real bank loan growth, where real bank loan growth experiences a larger contraction when the share of loans in foreign currency provided by foreign banks is high, almost larger, and more sensitive by half compared to when the share of loans in foreign currency is small. I obtain this result based on a panel data analysis and also observe the same asymmetric result based on a panel LP analysis. More importantly, using the US financial conditions index as an instrument to exchange rate movements, I demonstrate that the tightening in the US financial conditions will lead to depreciation in domestic exchange rate, and the impact on real bank loan will be significantly larger and more persistent compared to if the weakness in exchange rate is caused by other factors. The DSGE framework is capable of replicating the empirical results. First, the sensitivity analysis shows that a higher reliance on foreign funding will have a greater negative effect on the supply of bank credit. Second, the financial restrictions facing banks to borrow from external sources lead to a larger contraction in the supply of bank credit and domestic production. Within the same framework, the result shows that banks' profitability and capital can become more sensitive to the movement in exchange rate if banks are exposed to large net open foreign exchange position, which will have a direct knock-on effect on lending capacity of banks. Finally, FXI and the countercyclical CTL ratio are two policy responses that central banks can consider to mitigate the impact of the financial channel of the exchange rate. However, these policies have some trade-offs that policy makers must take into account in their decision-making

[1] Real bank loan growth is deflated by using the headline consumer price index (CPI).

process.

Related literature: This article is mainly related to the discussion on the financial channel of the exchange rate, particularly for small open economies. The findings in the literature show that the main mechanism of propagation of the financial channel of the exchange rate is through foreign liabilities held by domestic borrowers. One of the main sources of foreign liabilities is external borrowing, which, if kept unchecked, could lead to currency or duration mismatch problems and paved the way to a much larger problem. Mishkin, 1999 argues that currency and duration mismatches are two key characteristics that can lead a currency crisis to a full-fledged financial crisis. Even if a full-blown financial crisis is avoided, the impact of the financial channel of the exchange rate could still be significant. Eichengreen et al., 2005 show that countries with net foreign borrowing, which is typically denominated in major currencies, will have currency mismatches in their national balance sheets and negatively affect aggregate wealth when domestic currencies depreciate against the major currencies. Bruno and Shin, 2014 claim that depreciation in the domestic currency leads to a deterioration in the credit risk of local borrowers due to currency mismatch and, as a result, limits bank lending capacity. Carstens, 2019 argues that a combination of a heavy dependence on external borrowing by corporations, together with a large presence of foreign investors in local bond markets, will result in tighter domestic financial conditions when the exchange rate depreciates. Similarly, Kalemli-Özcan et al., 2021 argue that firms operating in countries with net foreign debt will decrease their leverage after depreciation in the domestic currency.

There are many factors at play that will determine the strength of the financial channel of the weaker exchange rate, which exerts a contractionary effect on the real economy. The degree of dependence on foreign funding will have a direct effect on the magnitude of the financial channel, as suggested by Céspedes et al., 2004, which shows that a real depreciation in the domestic currency increases the risk premium for countries with high debt. Similarly, R. N. Banerjee et al., 2020 discover that emerging market economies suffer more from the financial channel, as they rely more on external borrowing to finance their domestic investment activities. Sector-specific exposure to external borrowing also matters, as a large depreciation of the domestic currency and a higher financing cost will have a greater impact on the non-tradable sector compared to the tradable sector (Chui et al., 2016). The intensity of the financial channel also depends on the type of foreign liabilities, either debt or nondebt instruments, as Georgiadis and Zhu, 2021 show that central banks are more concerned with depreciation when foreign liabilities are dominated by debt instruments. In terms of the composition of external liabilities, although they could possibly be denominated in domestic currencies, recent studies suggest that the impact of the financial channel could still be present.

Hofmann et al., 2020 and Hofmann et al., 2022 argue that the effect of foreign funds investing in local assets or lending in the domestic currency will not eliminate currency mismatch, but the risk is now shifting from local borrowers to financially restricted global investors or foreign lenders. Consistent with the degree of dependence on foreign funding, Bruno and Shin, 2023 find that exporters who rely more on dollar-funded bank credit will be more negatively affected in dollar appreciation episodes, which will directly limit the positive impact induced by the trade channel.

Most of the past articles attributed the impact of the financial channel to currency mismatches in the balance sheets of domestic borrowers. Exchange rate depreciation leads to a higher debt repayment obligation on their existing external liabilities, which in turn results in a higher credit risk. The impact will not be uniform across domestic borrowers and will be less severe if earnings are also denominated in foreign currencies. Some of these findings are based on firm-level data and the movement of bond yields to establish the presence of the financial channel, for example, by Bleakley and Cowan, 2008, Kearns and Patel, 2016, and Hofmann et al., 2020. However, the most recent evidence suggests that the supply of credit by banks is also affected by the movements of the exchange rate. Foreign-denominated liabilities on the balance sheet of domestic financial intermediaries could negatively affect bank credit supply due to a weaker bilateral exchange rate against the funding currency. A weaker exchange rate, which usually coincides with monetary tightening in the funding country, will lead to a higher borrowing cost by banks and erodes bank profitability and capital, which in turn reduces the lending capacity of banks.

Empirical works by Argawal, 2019, Beck et al., 2022, and Abbassi and Bräuning, 2023 investigate the relationship between the exchange rate and the supply of bank credit. These articles point to the same result, concluding that banks with net foreign assets will have greater lending capacity when the domestic currency depreciates. However, for banks with net foreign liabilities, their lending capacity will improve as the domestic currency appreciates. There are also papers that develop a DSGE model to study the relationship between exchange rate movements and bank credit supply. The findings in Aoki et al., 2016 show that after depreciation in the domestic currency, banks exposed to foreign currency liabilities will result in a reduction in their intermediation capabilities, leading to a recession. Ferrante and Gornemann, 2022 calibrate their model to replicate a typical Latin American economy and argue that currency devaluation leads to erosion of the net worth of banks, which, in turn, depresses credit supply. These findings are also corroborated by the results in Z. Chen et al., 2021 and Longaric, 2022.

The capacity of a country to absorb exchange rate shocks - that is, its ability to use exchange rate movements as a buffer rather than an amplifier of shocks - depends largely on the size of its foreign exchange reserves and the manner in which the central bank deploys its FXI tools. At a minimum, sufficient foreign reserves are required to cover short-term external liabilities, which is essential for stabilising the exchange rate and curbing speculative behaviour during periods of financial stress (Chiţu et al., 2019). Central banks can employ FXI to counteract excessive exchange rate fluctuations, particularly when liquidity in the foreign exchange market dries up. Research shows that FXI can effectively influence the exchange rate, especially in the short term (e.g., Blanchard et al., 2015 and Adler et al., 2019), which helps mitigate the negative impacts of currency mismatches and the risk of inflation expectations becoming unanchored.

As mentioned before, the key distinctive feature of this paper and its main contribution to the debate compared to past studies is that it gives a greater emphasis on non-linear relationship between exchange rate and bank loans. The results of this paper, from both empirical findings and theoretical model, provide important insight into explaining the differences in the intensity of the impact of exchange rate depreciation on bank loans.

The remainder of the paper is organised as follows. The next section discusses the empirical analysis in more detail, in terms of the framework and identification strategy, and the results provide the motivation for the development of the DSGE model. Section 2.3 gives a detailed explanation of the foundation and specification of the DSGE model. Section 2.4 explains the model parameters and Section 2.5 discusses the results of the model. The final section, Section 2.6, concludes the findings of this paper.

2.2 Empirical analysis

This section presents the econometric framework and the empirical results. The analysis is based on data from 16 emerging market and small open economies, with data covering the period 1Q05 to 4Q22. The countries in my sample contain typical countries that have been studied by many previous papers either in emerging market economies or small open economies literature. The list of countries included in this analysis is as follows; Brazil, Chile, China, Colombia, Czechia, Hungary, India, Indonesia, Israel, South Korea, Malaysia, Mexico, Poland, Russia, South Africa and Thailand. The key variables are real bank loan growth issued by domestic banks, the bilateral exchange rate against the US dollar, real GDP growth, the monetary policy position, and international claims from the consolidated banking statistics of the Bank for International Settlements (BIS).[2] The selection

[2] International claims data captures cross-border claims in any currency plus local claims of foreign affiliates denominated in non-local currencies. These data are used in this article as an indicator of a country's dependence on foreign currency loans.

of countries and the sample period is primarily based on the availability of the data. Most data are taken from databases of multilateral agencies, including the World Bank, the Organisation for Economic Cooperation and Development (OECD), the BIS and the International Monetary Fund (IMF). Some data were taken from CEIC if they are not available from multilateral agency databases. Other variables have been included as controls, such as the US Federal Funds Rate and the Global Economic Policy Uncertainty Index.[3]

2.2.1 A first glace of the data

I start the empirical analysis showing that the bank loan remains the main source of borrowing by households and corporations. The data is based on the BIS total credit statistics. Figure 2.1 shows that the percentage share of bank loans in the total outstanding credit of the nonfinancial sector around the world has increased steadily from 1Q01 to 1Q23. The share in 1Q01 was slightly above 52% and in 1Q23 it rose and was around the 60% level. This trend suggests that analysing the impact of exchange rate movements on bank loans, in addition to from the borrowers' balance sheet perspective, which has been covered extensively in the literature, is necessary and warranted.

Figure 2.1: Percentage share of bank loan from total outstanding credit

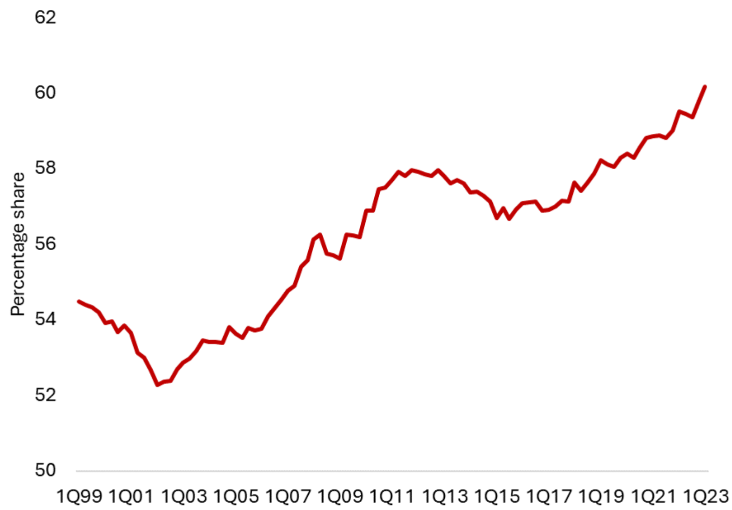

Figure 2.1. Percentage share of bank loan to the non-financial sector from total outstanding credit for all reporting countries, including advanced and emerging economies.

2.2.2 Panel analysis

The use of panel data to study the financial channel of the exchange rate is well established. For example, Bruno and Shin, 2018 find that nonfinancial firms in emerging market economies with

[3] A detailed information about the series is provided in Table A2.1.

US dollar bonds will have their share prices vulnerable during domestic currency depreciation episodes. Nier et al., 2020 suggest that appreciation in domestic currency leads to a positive expansion in the domestic credit gap. Similarly, analysis in Kalemli-Özcan et al., 2021 show that firms that hold foreign currency debt observe a higher net worth when the domestic currency strengthens and subsequently leads to higher borrowing.

Baseline results

This paper provides a new point of view by looking at this topic from the perspective of real bank loan growth. In a panel data regression, I regress the annual growth or year-on-year growth of the real bank loan in the country i in year t, $\Delta^4 RBC_{i,t}$, on the quarterly lagged annual growth of the bilateral exchange rate against the US dollar for country i, $\Delta^4 EXR_{i,t-1}$. Figure 2.2 shows a scatterplot between the two variables, where the y-axis measures the annual growth of the real bank loans and the x-axis measures the annual change of the local currencies against the US dollar. For the annual change in local currencies against the US dollar, a positive denotes depreciation and a negative denotes appreciation. The fitted line of the scatterplot, which contains all data points for all countries in the sample from 1Q05 to 4Q22, suggests a negative relationship between the two variables. The choice to use the bilateral exchange rate against the US dollar instead of the trade weighted exchange rate is guided by the finding in Hofmann et al., 2020 in which the authors argue that the bilateral exchange rate against the US dollar is more relevant to explain the compression of yields or the credit risk premium and macroeconomic variables compared to the trade-weighted exchange rate. I also use a dynamic panel framework to investigate the role of exchange rate movements in influencing the growth of real bank loans.[4] The quarterly lagged annual growth of real GDP, $\Delta^4 RGDP_{i,t-1}$, the monetary policy stance, $MP_{i,t}$, and the global policy uncertainty index, $GEPU_t$, are included as control variables. The baseline setup takes the following form:

$$\Delta^4 RBC_{i,t} = \alpha_i + \gamma_t + \beta_1 \Delta^4 EXR_{i,t-1} + \beta_2 \Delta^4 RBC_{i,t-1} + \delta X_{i,t} + \varepsilon_{i,t}$$

where $\Delta^4 RBC_{i,t}$ is the annual growth of the real bank loans, α_i and γ_t represent country- and time-fixed effects, $\Delta^4 EXR_{i,t-1}$ is the growth of the annual bilateral exchange rate against the US dollar, and $X_{i,t}$ is a vector of additional control variables.

[4] The inclusion of a lagged dependent variable with fixed effects can lead to biases in panels with small time dimensions as proposed by Nickell, 1981. However, given the structure of the data set in this analysis, where the list of countries in my sample, N = 16, and each country consists of 19 years of quarterly observations, T = 76, the Within estimator is expected to be consistent. Judson and Owen, 1999 find that when T = 30, the Within estimator could be biased between 3% and 20% of the true value. However, the Within estimator would still result in an estimate with the correct sign.

Figure 2.2: Real bank loans and bilateral US dollar exchange rate

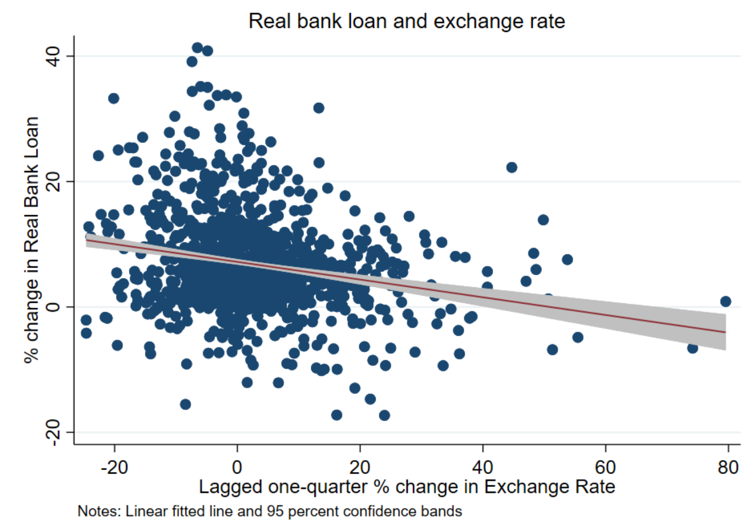

Figure 2.2. Scatterplot of the annual growth of real bank loans against the annual change of the bilateral US dollar exchange rate.

In Table 2.1 I present evidence of a negative relationship between real bank loan growth and the bilateral US dollar exchange rate. I show that real bank loan growth decreases when the domestic currency depreciates against the US dollar. The first specification does not have any control variables and is without time effects. The exchange rate is significantly different from zero with a negative sign, suggesting that depreciation of the domestic currency leads to weaker growth in the real bank loan. The second specification controls for time effects, but still without any other control variables. The result shows that the depreciation of the exchange rate remains statically significant in explaining the growth of real bank loans, but the coefficient is smaller. In the third specification with time effects and control variables, the coefficient of the exchange rate is smaller compared to the first and second specifications, and it remains statistically significant. In the final two specifications, the lagged growth of the real bank loan is included, together with other control variables. We can see that the coefficient of the exchange rate is relatively unchanged compared to the third specification, either with or without the time effects, and it remains statistically significant. The various model specifications suggest that the movement of the bilateral US dollar exchange rate is important in explaining the growth of the real bank loan.

Non-linear relationship

For the study of the non-linear relationship between the exchange rate and the growth of real bank loans, I adopted an approach similar to Guerrieri and Iacoviello, 2017, where the authors used a similar estimation approach to find an asymmetric relationship between house prices and economic

Table 2.1: Real bank loan growth and exchange rate movements

% change in real bank credit to the non-financial sector - domestic currency ($\Delta^4 RBC_{i,t}$)					
$\Delta^4 EXR_{i,t-1}$	-0.1553***	-0.1301***	-0.0980**	-0.0822***	-0.0984***
$\Delta^4 RGDP_{i,t-1}$			0.6683***	0.0873**	0.0307
$\text{MP}_{i,t}$			-0.4603**	-0.2139***	-0.3386***
GEPU_t			-0.0331**	-0.0030**	-0.0038
$\Delta^4 RBC_{i,t-1}$				0.9135***	0.8984***
Specification	1	2	3	4	5
Fixed effects	Yes	Yes	Yes	Yes	Yes
Time effects	No	Yes	Yes	No	Yes
R-squared	0.0617	0.3743	0.4377	0.8958	0.9133
No. obs	1127	1127	1127	1127	1127
Period	1Q05 - 4Q22	1Q05 - 4Q22	1Q05 - 4Q22	1Q05 - 4Q22	1Q05 - 4Q22
No. countries	16	16	16	16	16

Notes: Standard errors are clustered by country code. *, **, *** indicates significance at 90%, 95%, and 99% levels.

activities. The specification to study the non-linearity effect of exchange rate movements on real credit growth takes the following form:

$$\Delta^4 RBC_{i,t} = \alpha_i + \gamma_t + \beta^{High}\psi_{i,t}\Delta^4 EXR_{i,t-1} + \beta^{Low}(1-\psi_{i,t})\Delta^4 EXR_{i,t-1} + \Delta^4 RBC_{i,t-1} + \delta X_{i,t} + \varepsilon_{i,t}$$

where $\Delta^4 RBC_{i,t}$ is the annual growth of real bank loan, α_i and γ_t represent country- and time-fixed effects; and $X_{i,t}$ is a vector of additional control variables. Changes in exchange rate interact with a state-specific indicator variable $\psi_{i,t}$ that takes a value equal to 1 when the share of foreign currency loans is high and equal to 0 when the share of foreign currency loans is low. The aggregated bank loans issued in foreign currencies are based on international claims from BIS counterparty country data. The estimate of the share of foreign currency loans in the banking system is based closely on Hardy, 2019 and is given as follows [5]:

$$\text{\% share of foreign currency loans} = \frac{\text{International claims}}{\text{Total domestic bank loan}} \times 100$$

international claims capture foreign liabilities, exclusively loans from foreign banks and their affiliates, of domestic agents and banks, and will reflect the impact of exchange rate depreciation from the perspective of currency mismatches in the balance sheets of borrowers and banks. However, there are limitations to measuring the size of foreign currency loans purely based on international

[5] In this paper, I do not include the amount of local credit extended in the local currency by foreign banks in the numerator, and the denominator is the total domestic bank loan to the private non-financial sector, instead of total credit to the private non-financial sector as per Hardy, 2019. This is because the focus of this article is to estimate the share of foreign currency loan in the domestic banking system instead of foreign bank reliance.

claims data, since it does not capture foreign liability in the form of foreign currency loans from nonbank creditors and foreign currency deposits in domestic banks. This is especially true since domestic firms and banks also typically raise funds from wholesale markets, where there is a significant presence of nonbank creditors such as large corporations and pension funds. In addition, since international claims capture foreign currency loans in both domestic agents and banks' balance sheets, the result reflects the total impact on bank loans from both demand and supply perspectives. Figure 2.3 provides an overview of the types of foreign liability captured by international claims.

Figure 2.3: International claims by domestic agents and banks

Households		**Firms**	
Assets	Liabilities	Assets	Liabilities
	FCL (Banks)		FCL (Banks)
	FCL (Non-banks)		FCL (Non-banks)

Government		**Banks**	
Assets	Liabilities	Assets	Liabilities
	FCL (Banks)		FCL (Banks)
	FCL (Non-banks)		FCL (Non-banks)
			FC deposits

Figure 2.3. International claims capture cross-border claims in any currency plus local claims of foreign affiliates denominated in non-local currencies in the banking system. International claims do not capture foreign currency loans from non-banks and foreign currency deposits in domestic banks, as highlighted in red font.

The share of foreign currency loans is considered high when it is above the long-term average of a specific country and is classified as low when the share is below the average. Figure 2.4 shows the distribution of the ratio of total foreign currency loans to total domestic bank loans of all countries within the sample in the fourth quarter of 2005 to 2022. The ratio demonstrates a large divergence between the countries in the sample, where the ratio can be as low as 0.1 times and as high as close to 1.4 times.[6] However, the distribution has been markedly narrowing, particularly since 2013, as the size of international claims relative to the total domestic bank loan at the top of the distribution has been in a secular decline trend since 2009.

Figure 2.5 shows a scatterplot between the exchange rate and the growth of real bank loans, where the y-axis measures the annual growth of real bank loans and the x-axis measures the lagged annual change of local currencies against the US dollar. The sample is divided into two groups, where the blue dots are observations when the share of foreign currency loans is high, and the red

[6] The ratio can be above 1 when the loan provided by foreign banks is large relative to the size of total domestic bank loan.

Figure 2.4: International claims by counterparty country (Ratio to total domestic bank loan)

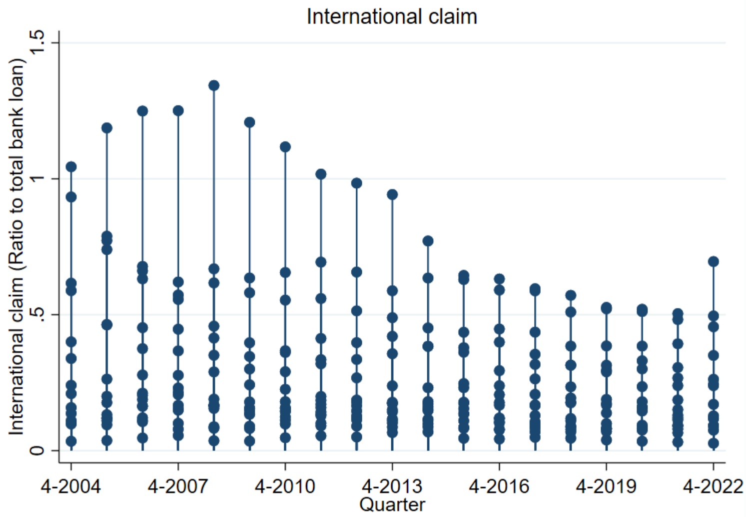

Figure 2.4. International claims (Ratio to total domestic bank loan) refers to claim on a non-resident or denominated in a foreign currency. International claims comprise cross-border claims in any currency plus local claims of foreign affiliates denominated in non-local currencies. This graph is constructed based on data from the sample of 16 economies.

dots are observations when the share of foreign currency loans is low. The blue and red lines are the fitted lines of the respective samples, and we can see that the blue line is steeper compared to the red lines, suggesting that real bank loan growth is more responsive to exchange rate movements when the share of foreign currency loans is high.

Figure 2.5: Real bank loan and bilateral US dollar exchange rate

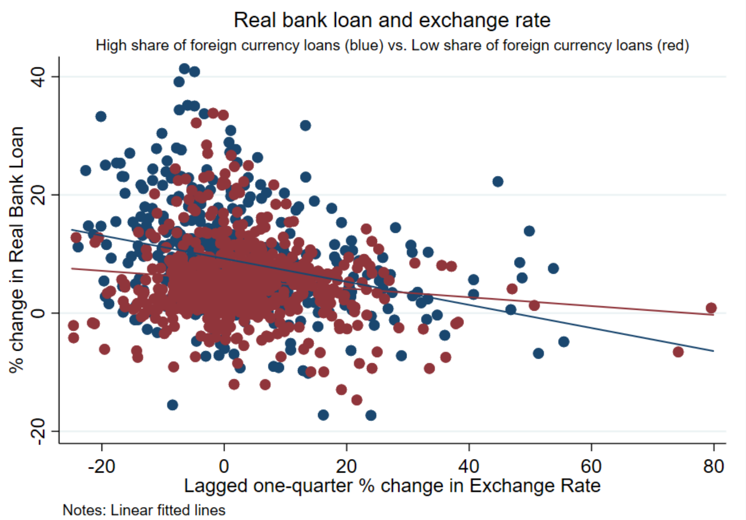

Figure 2.5. Scatterplot of the annual growth of real bank loans against the annual change of the bilateral US dollar exchange rate.

Using this approach, the state of a country, whether in a high or low state of foreign currency loans, can be varied between countries, as the threshold level that defined whether a country in a high or low state is not uniform across countries but instead country specific. Figure 2.6 shows a comparison of two countries in my sample, between Chile and Hungary. For Hungary to be in a high state, the share of foreign currency loans must be above 80%, but the threshold for Chile to be in a high state is much lower, closer to 30%. In terms of timing, Hungary was in the high state from 2004 until 2014, and remained in the low state from 2015 until 2022. However, the pattern is not similar for Chile, where the country was jumping up and down between high and low states throughout the entire duration of the sample period.

Figure 2.6: International claims (% of total domestic bank loan)

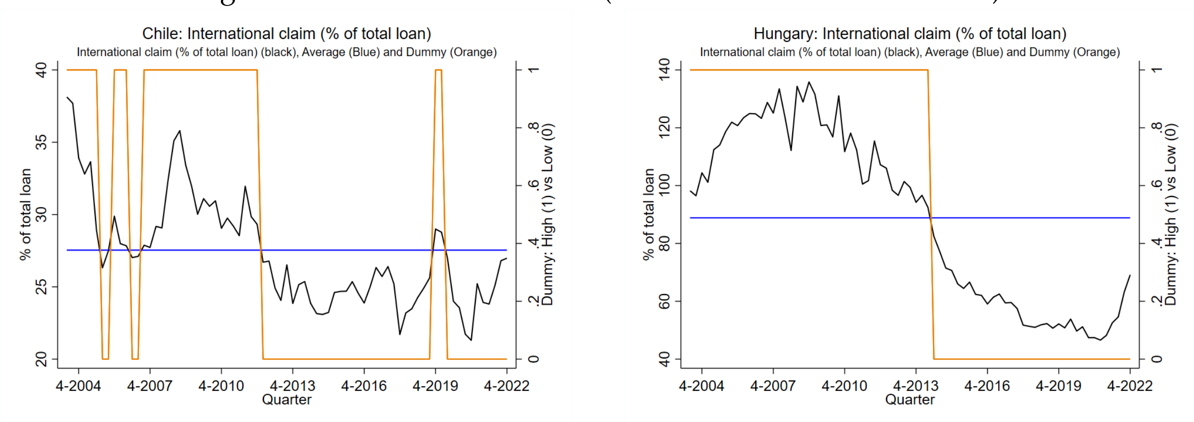

Figure 2.6. International claims (% of total domestic bank loan) refers to claim on a non-resident or denominated in a foreign currency. International claims comprise cross-border claims in any currency plus local claims of foreign affiliates denominated in non-local currencies.

In Table 2.2 I present evidence of a non-linear relationship between real bank loan growth and the bilateral US dollar exchange rate. The growth of real bank loans decreases more after the domestic currency depreciates against the US dollar when the share of foreign currency loans is high. The first specification does not have any control variables and is without time effects. The coefficient for the exchange rate when the share of foreign currency loans is high is larger than when the share of foreign currency loans is low, and both coefficients are significantly different from zero, and both have a negative sign. The second specification controls for time effects, but still without other control variables. The result shows that the exchange rate depreciation remains statically significant in both states in explaining real bank loan growth, but the coefficients are smaller compared to the first specification.

In the third specification with time effects and control variables, the exchange rate coefficients in both states remain statistically significant, and the coefficient when the share of foreign currency loans is high is slightly larger compared to when the share of foreign currency loans is low. In the final two specifications, the lagged growth of the real bank loan is included and the coefficients of the exchange rate for both states remain statistically significant. The result of the fourth specifica-

Table 2.2: Real bank loan growth and exchange rate movements (non-linear)

% change in real bank credit to the non-financial sector - domestic currency ($\Delta^4 RBC_{i,t}$)					
$\Delta^4 EXR^{High}_{i,t-1}$	-0.1946***	-0.1438**	-0.1106*	-0.1051***	-0.1223***
$\Delta^4 EXR^{Low}_{i,t-1}$	-0.1021***	-0.1162**	-0.0900**	-0.0602***	-0.0791***
$\Delta^4 RGDP_{i,t-1}$			0.6658***	0.0859**	0.0273
$\mathrm{MP}_{i,t}$			-0.4801*	-0.2449***	-0.3500***
GEPU_t			-0.0323**	-0.0025**	-0.0035
$\Delta^4 RBC_{i,t-1}$				0.9105***	0.8993***
Specification	1	2	3	4	5
Fixed effects	Yes	Yes	Yes	Yes	Yes
Time effects	No	Yes	Yes	No	Yes
R-squared	0.1238	0.3748	0.4382	0.8973	0.9144
Eq.test (p-val)	0.0578	0.5708	0.6411	0.0320	0.0303
No. obs	1127	1127	1127	1127	1127
Period	1Q05 - 4Q22	1Q05 - 4Q22	1Q05 - 4Q22	1Q05 - 4Q22	1Q05 - 4Q22
No. countries	16	16	16	16	16

Notes: Standard errors are clustered by country code. *, **, *** indicates significance at 90%, 95%, and 99% levels.

tion shows that real bank loan growth experiences a larger contraction when the share of loans in foreign currency provided by nonresident and foreign banks is high, the coefficient is larger and more sensitive by almost half compared to when the share of loans in foreign currency is small to the movement in the exchange rate. Similarly, for the final specification, the sensitivity of real loan growth to the exchange rate is greater when the share of foreign currency loans is high and the difference in coefficients compared to when the share of foreign currency is low remains large. As an additional robustness check for the final two specifications, the equality test for the difference between the coefficients of the low share of foreign currency loans and the coefficient of the high share of foreign currency loans confirms that the difference is significantly greater than zero.[7] The various model specifications suggest that the movement of the bilateral US dollar exchange rate is important in explaining the growth of the real bank loan, and the impact on the real bank loan is greater when the share of foreign currency loans is high.

2.2.3 Panel Local Projection (LP)

Linear Panel LP-OLS

As a robustness check and to validate the result of the panel analysis, as well as to better understand the impact of the movement of the bilateral US dollar exchange rate on the real bank loan, I estimate

[7]The equality tests for coefficients of the exchange rate and its interaction with the state-specific indicator of specifications 4 and 5 are statistically significant at 5% level.

a panel local projection model as in Jordà, 2005. The local projection model projects one period at a time and is more robust to misspecification compared to the structural vector autogregression (SVAR) method. Previous articles from Z. Chen et al., 2021 and Longaric, 2022 also rely on panel local projection or panel VAR to study the financial channel of the exchange rate. I estimate the panel LP-OLS based on the same data set as per the previous panel data analysis, where the data consist of 16 emerging market and small open economies, with quarterly data covering the period 1Q05 to 4Q22. The specification of the panel LP-OLS model, with a three-lag, to study the effect of exchange rate movements on real bank loan growth takes the following form:

$$\Delta^4 RBC_{i,t+h} = \alpha_{i,h} + \psi_h(L) z_{i,t-1} + \beta_h \Delta^4 EXR_{i,t} + \varepsilon_{i,t+h} \qquad \text{for } h = 0, 1, 2, ...,$$

where $\Delta^4 RBC$ is the annual change of real bank loan, z is the vector of control variables, $\psi_h(L)$ is a polynomial in the lag operator, and $\Delta^4 EXR$ is the annual change in bilateral exchange rate. $\alpha_{i,h}$ is vectors of dependent variable-specific panel fixed effects. The vector of control variables contains annual real GDP growth, the monetary policy stance, and the Fed Funds Rate. The construction of impulse response functions reflects the sequence of coefficients β_h estimated in a series of separate regressions for each horizon. The impulse response functions represent the average response of real bank loan growth to a percentage depreciation in the bilateral exchange rate against the US dollar in all countries and times. Figure 2.7 reports the impulse responses of the panel LP-OLS model, with 90% confidence intervals. Standard errors are computed using Driscoll and Kraay, 1998 to account for the possible cross-sectional and temporal dependence in inference. The result shows that a one percent depreciation in the bilateral exchange rate against the US dollar will lead to a reduction in real bank loans, where the largest impact is in quarter four, and it subsides afterwards. The coefficients are statistically significant and the negative impact lasts throughout the forecast period. The results are expected and consistent with the results from the previous results of the panel data analysis.

Non-linear Panel LP-OLS

To estimate the non-linear impact of the exchange rate on real bank loan growth using the LP framework, I follow the approach of Ramey and Zubairy, 2018 and Alpanda et al., 2021. In this paper, the

Figure 2.7: Impulse response of Panel LP-OLS (Linear)

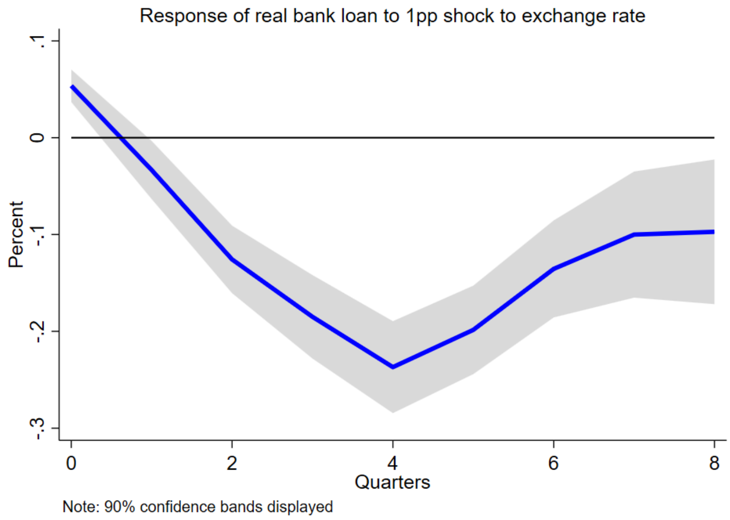

Figure 2.7. Impulse response of real bank loan growth to a one percentage depreciation of bilateral exchange rate against the US dollar. The grey areas are the 90% confidence bands. The x-axis represents the quarter.

state-dependent local projection specification is given as follows:

$$\Delta^4 RBC_{i,t+h} = I_{i,t-1}\left[\alpha_{A,i,h} + \psi_{A,h}(L)z_{i,t-1} + \beta_{A,h}\Delta^4 EXR_{i,t}\right] + (1 - I_{i,t-1})\left[\alpha_{B,i,h} + \psi_{B,h}(L)z_{i,t-1} + \beta_{B,h}\Delta^4 EXR_{i,t}\right] + \varepsilon_{i,t+h}$$

where $\Delta^4 RBC$ is the annual change of real bank loan, z is the vector of control variables, $\psi_h(L)$ is a polynomial in the lag operator, and $\Delta^4 EXR$ is the annual change in bilateral exchange rate. The vector of control variables contains annual real GDP growth, the monetary policy stance, and the Fed Funds Rate. I is a dummy variable that indicates the state of the economy when a shock occurs. I takes the value 1 when the share of foreign currency loans is high and 0 when the share of foreign currency loans is low. The construction of impulse response functions reflects the sequence of coefficients $\beta_{A,h}$ and $\beta_{B,h}$ estimated in a series of separate regressions for each horizon. Impulse response functions represent the average response of real bank loan growth to a percentage depreciation in the bilateral exchange rate against the US dollar in all countries and over time. In this model, coefficients $\beta_{A,h}$ capture the response when the share of foreign currency loans is low, and coefficients $\beta_{B,h}$ capture the response when the share of foreign currency loans is high. The calculation of the standard errors is based on Driscoll and Kraay, 1998.

Figure 2.8 shows the impulse responses of the state-dependent panel LP model, with 90% confidence intervals. The dashed blue line reflects the impulse response of a low share of foreign currency loans, and the solid purple line reflects the impulse response of a high share of foreign currency loans. The result shows that the negative impact of exchange rate depreciation when the share of

Figure 2.8: Impulse response of Panel LP-OLS (Non-linear)

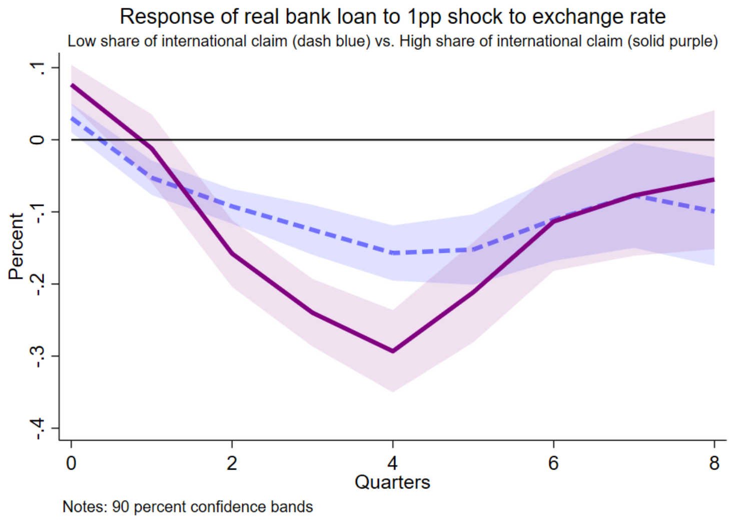

Figure 2.8. Impulse response of real bank loan growth to a one percentage depreciation of bilateral exchange rate against the US dollar. The responses are in cumulative changes in percentage points. The blue and purple areas are the 90% confidence bands. The x-axis represents the quarter.

foreign currency loans is high is greater and more persistent compared to when the share of foreign currency loans is low. The negative impact for both states is statistically significant and lasts for the entire forecast horizon for both states. The results of the state-dependent LP model validate the existence of a non-linear relationship between the exchange rate and real bank loans, as shown in the previous panel data analysis. The coefficients of the LP-OLS models, for both linear and non-linear models, and their significance levels are reported in Table 2.3.

Table 2.3: Panel LP-OLS. Response of real bank loans to exchange rate

Impulse response of real bank loan				
		Non-linear		P-value
At horizon h =	Linear	Low FC share (LS)	High FC share (HS)	LS = HS
0	0.0536***	0.0304**	0.0767***	0.0351
1	-0.0334*	-0.0526***	-0.0119	0.1812
2	-0.1260***	-0.0923***	-0.1580***	0.0302
3	-0.1850***	-0.1250***	-0.2400***	0.0007
4	-0.2370***	-0.1570***	-0.2930***	0.0012
5	-0.1980***	-0.1520***	-0.2110***	0.2985
6	-0.1350***	-0.1110***	-0.1130***	0.9581
7	-0.1000***	-0.0770*	-0.0772	0.9981
8	-0.0972**	-0.0994**	-0.0550	0.4197

Standard errors are based on Driscoll and Kraay, 1998 and *, **, *** indicates significance at 90%, 95%, and 99% levels.

Panel LP-IV

The impact of the exchange rate on the growth of real bank loans could depend not only on the share of foreign currency loans, but also on the source of exchange rate shocks. To investigate this, I analyse exchange rate movements that are caused by the financial conditions in the United States (US). I use the annual change of the US financial conditions index (US FCI) developed by Ajello et al., 2023 as an instrument for the movement in exchange rate. The LP-IV framework is featured in many previous studies, for example, in Jordà et al., 2020, Longaric, 2022, and Carrière-Swallow et al., 2023. The index in Figure 2.9 captures the cumulative effects of unanticipated permanent changes in key financial variables on growth over the next year.[8]

Figure 2.9: US Financial Conditions Index (1-year Lookback Window)

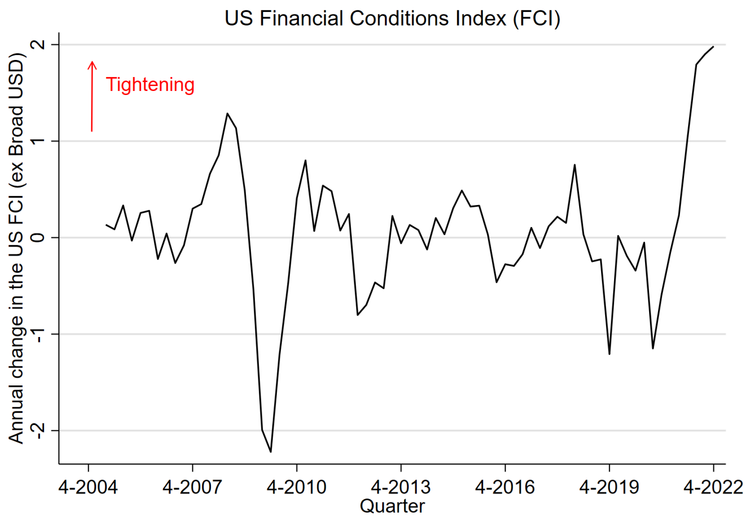

Figure 2.9. Annual change of the US financial conditions index excluding the impact of broad US dollar index.

By construction of the index, which captures the effects of unanticipated changes in key financial variables in the US, the index can be considered to be exogenous to domestic exchange rate movements. Consistent with ample empirical evidence, for example, by Iacoviello and Navarro, 2019 and Akinci and Queraltó, 2021, showing that the higher interest rate in the US will lead to capital outflows and a higher risk premium for emerging market economies, the first-stage regression shows that the tightening of the US financial conditions index by 100 basis points will cause the exchange rate to depreciate by more than 3.0%. The Kleibergen-Paap rk Wald F-statistic and Cragg-Donald Wald F-statistic are well above 10 for the forecast horizon, suggesting that the instrument is

[8]The US FCI aggregates changes in seven financial variables, namely the federal funds rate, the 10-year Treasury yield, the 30-year fixed mortgage rate, the triple-B corporate bond yield, the Dow Jones total stock market index, the Zillow house price index, and the nominal broad dollar index. For the purpose of this study, to ensure consistent and unbiased estimates, the contribution of the nominal broad dollar index to the US FCI has been removed.

strong.[9] The result of the exclusion restriction test also implies that the exclusion restriction assumption holds for all forecast horizon except one.[10] The specification of the panel LP-IV model, with a three-lag, to study the effect of exchange rate movements caused by the US financial conditions on real bank loan growth takes the following form:

$$\Delta^4 RBC_{i,t+h} = \alpha_{i,h} + \psi_h(L)z_{i,t-1} + \beta_h \Delta^4 \widehat{EXR}_{i,t} + \varepsilon_{i,t+h} \qquad \text{for } h = 0, 1, 2, ...,$$

with

$$\Delta^4 EXR_{i,t} = \alpha_i + \psi(L)z_{i,t-1} + \beta^1 \Delta^4 USFCI_t + \varepsilon_{i,t}$$

where the variables are the same as per panel LP-OLS model specification with only one exception in the vector of control variables, in which the Fed Funds Rate is removed. The calculation of the standard errors is based on the bootstrapping method. Figure 2.10 reports the impulse responses of the panel LP-IV model compared to the impulse responses of the panel LP-OLS model. The result shows that a one percent depreciation in the bilateral exchange rate against the US dollar caused by the tightening in the US financial conditions will lead to a much larger and persistent reduction in real bank loans compared to the panel LP-OLS result. At the peak of the impact in quarter 4, the size of the coefficient is more than double that of the average coefficients. The results are consistent and somewhat relatable with previous findings by Forbes et al., 2020 and Carrière-Swallow et al., 2023, which argue that the pass-through effect of the exchange rate to inflation is stronger when the movements of the exchange rate are caused by US monetary policy shocks.

I then estimate the non-linear impact of the exchange rate on real bank loan growth using the panel LP-IV framework. The specification is the same as the panel LP-OLS, but with the US financial conditions index used as an instrument for the contemporaneous exchange rate movements. Figure 2.11 shows the impulse responses of the state-dependent panel LP-IV model, with 90% confidence intervals. The dashed blue line reflects the impulse response of a low share of foreign currency loans, and the solid purple line reflects the impulse response of a high share of foreign currency loans. Consistent with the outcome of the panel LP-OLS, the result shows that the negative impact of exchange rate depreciation when the share of foreign currency loans is high is greater and more persistent compared to when the share of foreign currency loans is low. Similarly to before, the negative impact is statistically significant and lasts for the entire forecast horizon, especially when

[9] See Table A2.2 in the appendix for coefficients and F-statistics of the first-stage regressions.

[10] The exclusion restriction test is done by regressing the errors from the panel LP-OLS with the US financial conditions index. The result shows that the US financial conditions index is not statistically significant in explaining the errors, suggesting that the index does not affect real bank loans through other channels. See Table A2.3 in the appendix for the result of the exclusion restriction test.

Figure 2.10: Impulse response of Panel LP-IV and Panel LP-OLS (Linear)

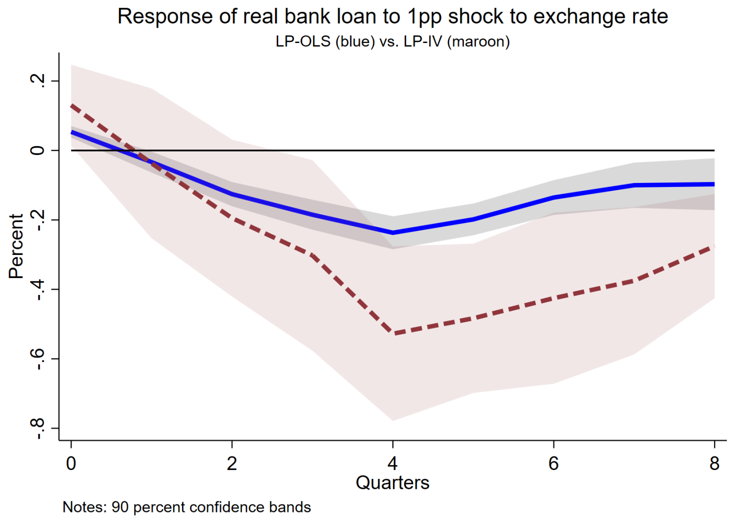

Figure 2.10. Impulse response of real bank loan growth to a one percentage depreciation of bilateral exchange rate against the US dollar. The responses are in cumulative changes in percentage points. The grey and maroon areas are the 90% confidence bands. The x-axis represents the quarter.

the share of foreign currency loans is high. However, the size of the coefficients when the share of foreign currency loans is high can be six times larger compared to when the share of foreign currency loans is low. This is significant given that the panel LP-OLS result only suggests that the impact is only twice as large. The coefficients of the LP-IV models, for both linear and non-linear models, and their significance levels are reported in Table 2.4. As part of a robustness check, the panel LP-OLS and LP-IV have been re-estimated using the total credit outstanding instead of the domestic bank loan, and the results are very consistent with those discussed herein.[11]

Table 2.4: Panel LPs - IV. Response of real bank loans to exchange rate

Impulse response of real bank loan				
		Regime		
At horizon h =	Baseline	Low share (LS)	High share (HS)	P-value (LS = HS)
0	0.1300*	0.1085	0.1976	0.5716
1	-0.0371	-0.0884	0.0624	0.4119
2	-0.1950	-0.2623*	-0.180	0.7933
3	-0.3020*	-0.3261	-0.4964	0.5704
4	-0.5280***	-0.5168***	-0.9651***	0.1922
5	-0.4830***	-0.3286*	-1.1000***	0.0211
6	-0.4250***	-0.1937	-1.1257***	0.0001
7	-0.3750***	-0.1596	-1.0561***	0.0037
8	-0.2760***	-0.1340	-0.7825***	0.0039

Standard errors are based on bootstrapping method and *, **, *** indicates significance at 90%, 95%, and 99% levels.

[11] See Table A2.4 (LP-OLS) and Table A2.5 (LP-IV) in the appendix for impulse response functions of real total credit outstanding.

Figure 2.11: Impulse response of Panel LP-IV (Non-linear)

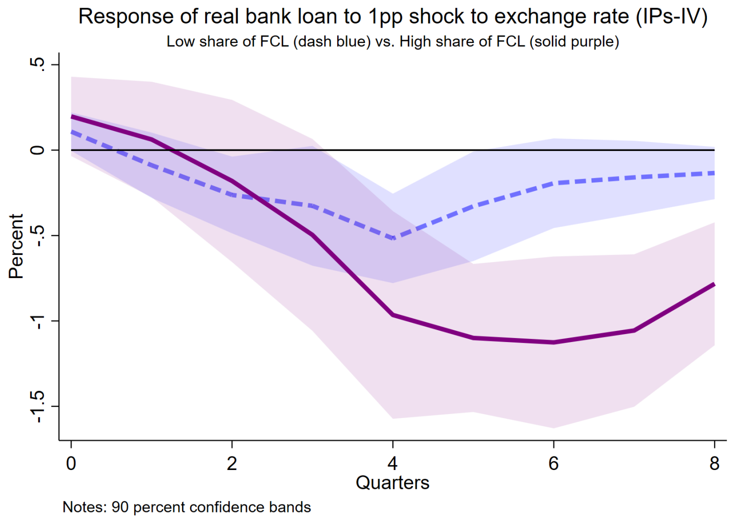

Figure 2.11. Impulse response of real bank loan growth to a one percentage depreciation of bilateral exchange rate against the US dollar. The responses are in cumulative changes in percentage points. The blue and purple areas are the 90% confidence bands. The x-axis represents the quarter.

2.2.4 Key empirical findings

The paper assesses the relationship between real bank loan growth and the bilateral exchange rate of the US dollar. The key finding of the panel data analysis suggests that real bank loan growth responds negatively to depreciation in the domestic currency against the US dollar. I have also established the fact that there is a non-linear relationship between the two variables, where the effect of a movement in the bilateral US dollar exchange rate on real bank loan growth is more pronounced when the reliance on foreign funding is greater. The relationship between the two variables was also analysed using a panel LPs framework. The results of impulse response functions of the panel LP-OLS corroborate the results produced by the dynamic panel data analysis, and support the evidence that real bank loan growth is more sensitive to the exchange rate movements when the share of foreign currency loans is high. More importantly, the panel LP-IV result suggests that the magnitude of the impact of exchange rate on real bank loan depends not only on the state of the economy, but also on the source of the shock that moves the exchange rate. The weaknesses in the exchange rate caused by the tightening in the US financial conditions are proven to be more severe to real bank loan growth.

To deepen the analysis and have a better understanding of the topic, I develop a small open economy DSGE model. The model will help improve our intuition and allows me to look closer at how the foreign interest rate and exchange rate shocks affect bank loan, particularly through the supply of bank loan, and in what circumstances that exchange rate movements could exacerbate the impact on bank loan supply. The specific areas I would like to address are *(1) How will the degree of dependence on the banking system for foreign funding shape the impact of foreign interest and exchange rate movements on macroeconomic variables? (2) What is the impact of banks facing binding borrowing constraints for foreign funding after a foreign interest shock and a weaker exchange rate? (3) What happens when banks' profits become more sensitive to the movement of the nominal exchange rate? This reflects that banks have net currency mismatches in their balance sheets. (4) Is there a role for FXI, the CTL ratio, an augmented Taylor rule, and an augmented LTV rule to mitigate the impact of the financial channel of the exchange rate in minimising the fluctuation of output and credit growth?* The next section will explain the model in more detail.

2.3 Model

I develop a New Keynesian DSGE model for small open economies with a banking sector. The model is populated by households and entrepreneurs. Households consume and work, while entrepreneurs only care about their consumption. Entrepreneurs produce intermediate goods using capital and labour. The discount factor for households is higher than that for entrepreneurs, leading to positive financial flows in equilibrium, where households save and entrepreneurs borrow. Banks are the financial intermediaries that manage the flow of funds between households and entrepreneurs. Banks operate in a monopolistically competitive market, where banks set the interest rate on loans to entrepreneurs to maximise profit. Banks also target a given level of CTL ratio, which banks will incur a quadratic cost by deviating from the target. One major deviation from Gerali et al., 2010 and Gambacorta and Signoretti, 2014 is that the amount of loans issued by each bank can also be financed through foreign funding, together with the deposit and bank capital. The amount of money that entrepreneurs can borrow depends on the quantity and price of capital they own. The loan amount is also subject to the LTV rule imposed by the central bank. The collateralisation of debt repayment implies that debt repayment in the subsequent periods must be within a specific limit of the expected future value of the current stock of capital owned by entrepreneurs.

On the production side, workers provide their uniform labour services to entrepreneurs. In addition to intermediate goods, there are four other production sectors: monopolistically wholesale goods producers, perfectly competitive final domestic goods producers, perfectly competitive final consumption goods producers, and a capital goods producing sector. Wholesalers purchase intermediate goods from entrepreneurs and subsequently transform them at no cost into wholesale goods. Wholesalers will sell their differentiated output to producers of final domestic goods, which will then be transformed into homogeneous final domestic goods. Transformation into final domestic goods is carried out at no cost. Finally, producers of final domestic goods sell their products to producers of final consumption goods, which also require imported goods in their production. Producers of capital goods are needed to derive a market price for capital. Wholesale goods producers are the only source of nominal rigidity in this model, where they can re-optimise their prices based on Calvo friction. The central bank conducts its monetary policy according to the Taylor rule to achieve stable output and prices. Federal government spending in this model is treated as exogenous.

2.3.1 Households

Households maximise their utility function by choosing consumption and labour hours:

$$\max_{C_t^h, L_t, D_t} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left(\ln C_t^h - \frac{(L_t)^{\varphi}}{\varphi} \right)$$

subject to the budget constraint

$$P_t C_t^h + D_t \leq W_t L_t + (1 + R_{t-1}) D_{t-1} + T_t$$

where C_t^h is the current consumption and L_t is the labour hours. $\frac{1}{\varphi - 1}$ is the elasticity of the labour supply for the wage, and $\varphi > 0$. P_t is the price level and W_t is the wage of the households. D_t is the savings of households in banks, and the rate of return is equal to the policy rate, R_t. T_t captures transfers and profits to patient households. β is the discount factor for households and it is assumed that β is greater than the discount factor for entrepreneurs, $\tilde{\beta}$, so that in steady state households are net savers and entrepreneurs are net borrowers.

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

$$C_t^h + d_t \leq w_t L_t + \frac{(1 + R_{t-1}) d_{t-1}}{\pi_t} + \tau_t \tag{2.1}$$

where $\pi_t = P_t / P_{t-1}$, $d_t = D_t / P_t$, $w_t = W_t / P_t$ and $\tau_t = T_t / P_t$.

Three equations characterise the first order conditions for the households:

$$\frac{\partial \mathbb{L}}{\partial C_t^h} : \frac{1}{C_t^h} = \lambda_t^h \tag{2.2}$$

$$\frac{\partial \mathbb{L}}{\partial d_t} : \lambda_t^h = \beta E_t \lambda_{t+1}^h \left(\frac{1+R_t}{\pi_{t+1}} \right) \tag{2.3}$$

$$\frac{\partial \mathbb{L}}{\partial L_t} : L_t^{\varphi - 1} = \lambda_t^h w_t \tag{2.4}$$

λ_t^h is the Lagrange multiplier on the budget constraint. Equations (2.2) and (2.3) combined will result in the standard Euler equation, and Equation (2.4) is the labour supply condition.

2.3.2 Entrepreneurs

Entrepreneurs only care about their consumption:

$$\max_{C_t^e, L_t, B_t K_t} \mathbb{E}_0 \sum_{t=0}^{\infty} \tilde{\beta}^t \ln C_t^e$$

subject to the budget and borrowing constraints:

$$P_t C_t^e + (1 + R_{t-1}^r) B_{t-1}^d + W_t L_t^d + Q_t^k K_t^d = P_t^e Y_t^e + B_t + Q_t^k (1 - \delta^k) K_{t-1}$$
$$B_t \leq LTV^E \mathbb{E} \left[\frac{Q_{t+1}^k K_t (1 - \delta^k)}{1 + R_t^r} \right]$$

and the production of intermediate goods is produced according to:

$$Y_t^e = A_t K_{t-1}^{\xi} L_t^{1-\xi}$$

where C_t^e is the current consumption of entrepreneurs and L_t is the labour demand. K_t is the capital stock owned by entrepreneurs, Q_t^k is the price of capital, and the capital depreciates at a rate of δ^k. P_t^e is the price level of the intermediate goods that will be sold to retailers, Y_t^e is the production of intermediate goods produced by entrepreneurs. B_t is the amount of loans borrowed by entrepreneurs and R_t^r is the interest rate on bank loans. The maximum amount that entrepreneurs can borrow from banks is subject to the LTV ratio, where $LTV < 1$. The borrowing constraint says that debt repayment in the current period must be within a specific limit of the expected future value of the current stock of capital owned by entrepreneurs. A_t represents the level of technology. $\xi \in$ [0,1] measures the relative size of capital and labour required to produce intermediate goods.

I can re-write the budget and borrowing constraints in real terms by dividing by P_t:

$$C_t^e + \frac{(1 + R_{t-1}^r) b_{t-1}}{\pi_t} + w_t L_t + q_t^k K_t = \frac{Y_t^e}{p_t x_t} + b_t + q_t^k (1 - \delta^k) K_{t-1} \tag{2.5}$$

$$b_t \leq LTV^E \mathbb{E}\left[\frac{q^k_{t+1} K_t (1-\delta^k)\pi_{t+1}}{1+R^r_t}\right] \tag{2.6}$$

where $b_t = B_t/P_t$, $x_t = P^d_t/P^e_t$, and $p_t = P_t/P^d_t$. x_t is the markup and P^d_t is the price level of domestic homogeneous goods.

The first order conditions for this optimisation problem are as follows:

$$\frac{\partial \mathbb{L}}{\partial C^e_t} : \frac{1}{C^e_t} = \lambda^e_t \tag{2.7}$$

$$\frac{\partial \mathbb{L}}{\partial L_t} : w_t p_t = (1-\xi)\frac{A^d_t K^{\xi}_{t-1} L^{-\xi}_t}{x_t} \rightarrow w_t p_t = (1-\xi)\frac{Y^e_t}{x_t L_t} \tag{2.8}$$

$$\frac{\partial \mathbb{L}}{\partial b_t} : \lambda^e_t = \tilde{\beta}_t E_t \lambda^e_{t+1}\left(\frac{1+R^r_t}{\pi_{t+1}}\right) + \omega^e_t(1+R^r_t) \tag{2.9}$$

$$\frac{\partial \mathbb{L}}{\partial K_t} : \omega^e_t LTV^E q^k_{t+1}(1-\delta^k)\pi_{t+1} + \tilde{\beta}\lambda^e_{t+1}(q^k_{t+1}(1-\delta^k) + r^k_t) = \lambda^e_t q^k_t \tag{2.10}$$

$$\frac{\partial Y^e_t}{\partial K_t} : r^k_t = \frac{A_t \xi K^{\xi-1}_{t-1} L^{1-\xi}_t}{x_t}\frac{1}{p_t} \tag{2.11}$$

λ^e_t and ω^e_t are the Lagrange multipliers on the budget and borrowing constraints. Equations (2.7) and (2.9) combined will result in the standard consumption Euler equation. Equation (2.8) is the labour demand condition. Equation (2.10) is the investment Euler equation and Equation (2.11) is the rate of return to capital.

2.3.3 Wholesale goods and final domestic goods

There are continuum of wholesalers indexed by $i \in$ [0,1]. They will purchase intermediate goods, Y^e_t, and subsequently transform them without cost into wholesale goods, $Y_{i,t}$. Then they will sell wholesale goods to a final domestic goods firm at $P^d_{i,t}$. The competitive final domestic goods firm produces output using the following production function:

$$Y_t = \left[\int_0^1 (Y_{i,t})^{\frac{\varepsilon-1}{\varepsilon}} di\right]^{\frac{\varepsilon}{\varepsilon-1}} \tag{2.12}$$

The profit maximisation problem of a final domestic goods producer is given by the following.

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

and profit maximisation leads to the following first order condition

$$Y_{i,t} = Y_t \left(\frac{P_t^d}{P_{i,t}^d}\right)^{\varepsilon} \tag{2.13}$$

By substituting (13) into (12), it defines the following relation between the price level of the final domestic goods, P_t^d, and the price of wholesale goods of i^{th} wholesaler, $P_{i,t}^d$ as follows:

$$\begin{aligned}
Y_t &= \left[\int_0^1 (Y_{i,t})^{\frac{\varepsilon-1}{\varepsilon}} di\right]^{\frac{\varepsilon}{\varepsilon-1}} \\
Y_t &= \left[\int_0^1 \left(Y_t \left(\frac{P_t^d}{P_{i,t}^d}\right)^{\varepsilon}\right)^{\frac{\varepsilon-1}{\varepsilon}} di\right]^{\frac{\varepsilon}{\varepsilon-1}} \qquad (2.14) \\
\Rightarrow P_t^d &= \left(\int_0^1 (P_{i,t}^d)^{(1-\varepsilon)} di\right)^{\frac{1}{1-\varepsilon}}
\end{aligned}$$

2.3.4 Optimal price setting by wholesalers

There are a variety of wholesale goods produced domestically that are distinguishable from each other and are produced by monopolists. This implies that each wholesaler has its own demand function. From (13), 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 wholesale market implies that the i^{th} wholesale monopolist firm can set its price to maximise its profit. However, the setting of prices by wholesalers is subject to Calvo friction. The price stickiness faced by wholesalers is the only source of nominal rigidity in this model. Calvo frictions imply that with probability θ, the i^{th} wholesaler 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} wholesaler′s objective to maximise profit subject to Calvo frictions is given by:

$$\max_{P^d_{i,t}} \mathbb{E}^i_0 \sum_{j=0}^{\infty} \theta^j \left[\Lambda_{t,t+j} \left(\overbrace{P^d_{i,t+j} Y_{i,t+j}}^{\text{Revenue}} - \overbrace{\frac{P^d_{t+j} Y_{i,t+j}}{x_{t+j}}}^{\text{Total cost}} \right) \right]$$

where $\Lambda_{t,t+j}$ is the stochastic discount factor for the payoff. The solution of the i^{th} wholesaler′s profit maximisation problem will lead to

$$\tilde{p}^d_t \equiv \frac{\tilde{P}^d_t}{P^d_t} \equiv \frac{F^1_t}{F^2_t}$$

where

$$F^1_t = \frac{\varepsilon}{\varepsilon - 1}(1 - V)\frac{Y_t}{x_t} + \theta \Lambda_{t,t+j} E_t(\bar{\pi}_{t+1})^{\varepsilon} F^1_{t+1}$$

$$F^2_t = Y_t + \theta \Lambda_{t,t+j} E_t(\bar{\pi}_{t+1})^{\varepsilon - 1} F^2_{t+1}$$

and let $V = \frac{\varepsilon - 1}{\varepsilon}$ to minimise monopoly distortion. From Equation (2.14) I can also express the Calvo equation as

$$P^d_t = \left((1-\theta)(\tilde{P}^d_t)^{1-\varepsilon} + \theta (P^d_{t-1})^{1-\varepsilon}\right)^{\frac{1}{1-\varepsilon}}$$

and divide by P^d_t to get

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

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

$$\tilde{p}^d_t = \left[\frac{1 - \theta\left(\bar{\pi}_t\right)^{\varepsilon - 1}}{1 - \theta}\right]^{\frac{1}{1-\varepsilon}} \tag{2.15}$$

2.3.5 Production of capital goods

Capital goods producers buy undepreciated capital from entrepreneurs and combine it with new investments to increase the stock of effective capital $\bar{x}_t$. The capital will then be sold back to the entrepreneurs. Firms operating in the production of capital goods are owned by households. Producers of capital goods choose $\bar{x}_t$ and i_t so as to maximize

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left(Q^k_t \Delta \bar{x}_t - i_t\right)$$

subject to

$$\bar{x}_t = \bar{x}_{t-1} + \left[1 - \frac{\kappa_i}{2}\left(\frac{i_t}{i_{t-1}} - 1\right)^2\right] i_t \tag{2.16}$$

where κ_i denotes the cost of adjusting capital and i_t is investment in terms of units of final consumption goods in current period. The flow of capital takes the form of

$$\Delta\bar{x}_t = \bar{x}_t - \bar{x}_{t-1} = K_t - (1-\delta)K_{t-1} \tag{2.17}$$

Combining Equations (2.16) and (2.17), the amount of new capital that capital goods producers can produce is given by

$$K_t = (1-\delta)K_{t-1} + \left[1 - \frac{\kappa_i}{2}\left(\frac{i_t}{i_{t-1}} - 1\right)^2\right] i_t$$

The first order condition of this optimisation problem leads to

$$p_t^{inv} = q_t^k \left(1 - \frac{\kappa_i}{2}\left(\frac{i_t}{i_{t-1}} - 1\right)^2 - \kappa_i\left(\frac{i_t}{i_{t-1}} - 1\right)\frac{i_t}{i_{t-1}}\right) + \beta^t \frac{\lambda_{t+1}^h}{\lambda_t^h} q_{t+1}^k \kappa_i \left(\frac{i_{t+1}}{i_t} - 1\right)\left(\frac{i_{t+1}}{i_t}\right)^2 \tag{2.18}$$

where $p_t^{inv} = P_t^{inv}/P_t$ is the price of investment goods.

2.3.6 Production of final consumption goods

The production of final consumption goods purchased by households and entrepreneurs is given by:

$$C_t = \left[(1-\alpha)^{\frac{1}{\eta}}(C_t^d)^{\frac{\eta-1}{\eta}} + \alpha^{\frac{1}{\eta}}(C_t^m)^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}} \tag{2.19}$$

where C_t is the consumption index for households and entrepreneurs, and it consists of final domestic goods, C_t^d, and imported goods, C_t^m. α is the share of imported goods in the production of final consumption goods. η is the substitution elasticity between domestically produced final goods and imported goods, respectively. The maximisation problem for a competitive and representative producer of final consumption goods is given by:

$$\max_{C_t, C_t^d, C_t^m} P_t C_t - P_d^t C_t^d - P_t^m C_t^m$$

subject to the production function. Profit maximisation leads to the following first order conditions:

$$C_t^d : P_t \frac{dC_t}{dC_t^d} = P_t^d \rightarrow C_t^d = (1-\alpha)\left(\frac{P_t}{P_t^d}\right)^{\eta} C_t \tag{2.20}$$

$$C_t^m : P_t \frac{dC_t}{dC_t^m} = P_t^m \rightarrow C_t^m = \alpha \left(\frac{P_t}{P_t^m} \right)^{\eta} C_t \tag{2.21}$$

Substituting the demand functions of Equations (2.20) and (2.21) into the production function of Equation (2.19) gives

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

and divide by P_t^d

$$p_t = \left[(1-\alpha) + \alpha \left(p_t^m\right)^{1-\eta} \right]^{\frac{1}{1-\eta}} \tag{2.22}$$

where $p_t = P_t/P_t^d$ and $p_t^m = P_t^m/P_t^d$. p_t is the final consumption price index.

2.3.7 Banks

As in Gambacorta and Signoretti, 2014, I assume that each bank comprises two units: wholesale and retail branches. The wholesale unit has its own capital K_t^b, collects deposits D_t from households on which it pays the interest rate set by the central bank R_t. Banks also have access to foreign funding that costs R_t^f. The wholesale unit issues wholesale loans B_t to the retail units, which earns the wholesale loan rate R_t^w. Banks have market power, which allows them to charge a constant mark-up on the retail loan rate. A representative bank pays a quadratic cost whenever the ratio of its own capital to loans differs from the target leverage ν. ν can also be interpreted as the CTL ratio imposed on banks by regulators. The maximisation problem for a representative wholesale branch is given by:

$$\max_{\left\{B_t, D_t, A_t^f\right\}} \mathbb{E}_0 \sum_{t=0}^{\infty} \sigma^t \Big[(1+R_t^w)B_t - B_{t+1}\pi_{t+1} - (1+R_t)D_t + D_{t+1}\pi_{t+1} - S_{t+1}\Phi_t(1+R_t^f)A_{t+1}^f$$
$$+ S_{t+1}A_{t+2}^f\pi_{t+1} - \frac{\gamma}{2}\left(\frac{K_t^b}{B_t} - \nu\right)^2 K_t^b + \left(K_{t+1}^b\pi_{t+1} - K_t^b\right) \Big]$$

subject to the balance sheet constraint

$$B_t = D_t + K_t^b + S_t A_{t+1}^f$$

Using the constraint twice, replacing $a_t^f = \frac{S_t A_{t+1}^f}{P_t^d}$, and dividing the objective function by P_t, the objective boils down to

$$\max_{\left\{b_t, d_t, a_t^f\right\}} R_t^w b_t - R_t d_t + \frac{a_t^f}{p_t} - \frac{s_{t+1}\Phi_t a_t^f}{p_t} - \frac{s_{t+1}\Phi_t R_t^f a_t^f}{p_t} - \frac{\gamma}{2}\left(\frac{k_t^b}{b_t} - \nu\right)^2 k_t^b$$

The first order conditions for this optimisation problem are as follows:

$$\frac{\partial \mathbb{L}}{\partial b_t} : R_t^w + \gamma \left(\frac{k_t^b}{b_t} - \nu \right) \left(\frac{k_t^b}{b_t} \right)^2 = 0$$

$$\frac{\partial \mathbb{L}}{\partial d_t} : R_t = 0$$

$$\frac{\partial \mathbb{L}}{\partial a_t^f} : \frac{s_{t+1}\Phi_t}{p_t} + \frac{s_{t+1}\Phi_t R_t^f}{p_t} - \frac{1}{p_t} = 0 \rightarrow s_{t+1}\Phi_t(1 + R_t^f) - 1 = 0$$

For retail loan branches, they operate under a regime of monopolistic competition. The retail branches subscribe to wholesale loans, differentiate them at no cost, and reissue the loans to the final borrowers. Each retail unit fixes the retail loan rate, applying a mark-up on the wholesale loan rate. The markup is constant and additive. The retail lending rate to the final borrowers or entrepreneurs takes the following form:

$$R_t^r = R_t^w + \bar{\mu}^b = R_t - \gamma \left(\frac{k_t^b}{b_t} - \nu \right) \left(\frac{k_t^b}{b_t} \right)^2 + \bar{\mu}^b \tag{2.23}$$

where $\bar{\mu}^b$ is the mark-up, which is constant and additive.

Aggregate banks profits are defined as the sum of retail and wholesale banks' profits for all banks:

$$j_t^B = R_t^r b_t - R_t d_t - \frac{s_{t+1}\Phi_t R_t^f a_t^f}{p_t} - \frac{\gamma}{2} \left(\frac{k_t^b}{b_t} - \nu \right)^2 k_t^b \tag{2.24}$$

and assuming that all bank profits are reinvested in banking activity, aggregate banks capital evolves according to

$$k_t^b = k_{t-1}^b \left(1 - \delta^b \right) + j_{t-1}^B \tag{2.25}$$

where δ^b is a fraction of banks capital consumed in each period. Finally, the optimality condition determines the spread between the domestic borrowing rate and the foreign borrowing rate as follows:

$$1 + R_t = s_{t+1}\Phi_t(1 + R_t^f) \tag{2.26}$$

The selection of loan production based on Gambacorta and Signoretti, 2014 has few limitations and weaknesses, compared to other more complete banking models within the DSGE framework. A more complete version of the model used in this paper is Gerali et al., 2010, where the banking sector operates in a regime of monopolistic competition in both the deposits and loans markets. In this paper, they show that optimality requires setting rates on deposits as a mark-down over the policy rate and that the rates on loans will be set as a mark-up over the marginal cost of funding for banks. As argued in Gerali et al., 2010, a more complete banking model, which reflects more competitive financial intermediation activities, should attenuate the effect of the increased external funding cost and its knock-on effect on output and consumption. On the other hand, a loan production model in Gertler and Kiyotaki, 2010 captures the idea that banks may be restricted not only to obtain funds from depositors, but also to obtain funds from the interbank market. The friction generated in the model depends largely on the ability of the banks to divert assets financed both from depositors and other banks. Incorporating this feature into the model used in this paper may amplify the impulse response functions of variables of interest following shocks.

2.3.8 Inflation

Based on the price index of Equation (2.22), the growth rate of inflation for the final consumption goods is given by:

$$\pi_t \equiv \frac{P_t}{P_{t-1}} = \frac{P_t^d p_t}{P_{t-1}^d p_{t-1}} = \bar{\pi}_t \left[\frac{(1-\alpha) + \alpha \left(p_t^m\right)^{1-\eta}}{(1-\alpha) + \alpha \left(p_{t-1}^m\right)^{1-\eta}} \right]^{\frac{1}{1-\eta}} \tag{2.27}$$

2.3.9 Exchange rate

The real exchange rate is defined by the following:

$$p_t^m = \frac{P_t}{P_t} \frac{P_t^m}{P_t^d} = \frac{P_t}{P_t^d} \frac{P_t^m}{P_t} \Rightarrow p_t^m = p_t \times reals_t \tag{2.28}$$

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 final domestic goods and imported goods. The real exchange rate, $reals_t$, is equal to the price of imported goods in the domestic 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 in 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.

2.3.10 Exports

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

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

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:

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

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

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

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

$$\begin{aligned} 1 &= \frac{S_t P_t^x}{P_t^d} = \frac{P_t S_t P_t^f P_t^x}{P_t^d P_t P_t^f} \\ &= p_t reals_t p_t^x \end{aligned} \tag{2.29}$$

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

$$\frac{reals_t}{reals_{t-1}} = s_t \frac{\pi_t^f}{\pi_t}, s_t \equiv \frac{S_t}{S_{t-1}}, \pi_t^f \equiv \frac{P_t^f}{P_{t-1}^f} \tag{2.30}$$

2.3.11 Balance of Payments

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

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

where the left-hand side of the equation captures outflows, and the right-hand side captures inflows of money to the domestic economy. $S_t A^f_{t+1}$ defines the additional external borrowing by banks in domestic currency units, and $S_t\Phi_{t-1}(1+R^f_{t-1})A^f_t$ captures the repayment of the existing stock of external borrowing in domestic currency units. A^f_t is the net stock of external borrowing in the initial period, t.

Exports and imports in domestic currency units are given by:

- Expenses on imports$_t$ $= S_t P^f_t \alpha \left(\frac{P_t}{P^m_t}\right)^{\eta} C_t + S_t P^f_t \alpha \left(\frac{P_t}{P^m_t}\right)^{\eta} i_t$
- Receipts from exports$_t$ $= S_t P^x_t ex_t$

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

$$S_t\Phi_{t-1}(1+R^f_{t-1})A^f_t + S_t P^f_t \alpha \left(\frac{P_t}{P^m_t}\right)^{\eta} C_t + S_t P^f_t \alpha \left(\frac{P_t}{P^m_t}\right)^{\eta} i_t = S_t P^x_t ex_t + S_t A^f_{t+1}$$

and dividing by P^d_t on both sides

$$\frac{S_t\Phi_{t-1}(1+R^f_{t-1})A^f_t}{P^d_t} + \frac{S_t P^f_t}{P^d_t}\alpha \left(\frac{P_t}{P^m_t}\right)^{\eta} C_t + \frac{S_t P^f_t}{P^d_t}\alpha \left(\frac{P_t}{P^m_t}\right)^{\eta} i_t = \frac{S_t P^x_t}{P^d_t} ex_t + \frac{S_t A^f_{t+1}}{P^d_t}$$

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

$$\frac{s_t\Phi_{t-1}(1+R^f_{t-1})a^f_{t-1}}{\bar{\pi}_t p_t} + p^m_t \alpha \left(\frac{p_t}{p^m_t}\right)^{\eta} C_t + p^m_t \alpha \left(\frac{p_t}{p^m_t}\right)^{\eta} i_t = p_t reals_t p^x_t ex_t + a^f_t \tag{2.31}$$

where $a^f_t = \frac{S_t A^f_{t+1}}{P^d_t}$. And the previous definitions are $p_t \equiv \frac{P_t}{P^d_t}$, $p^m_t \equiv \frac{P^m_t}{P^d_t}$, $\frac{P^m_t}{P_t} \equiv \frac{S_t P^f_t}{P_t}$ and $S_t P^x_t = P^d_t$. Intuitively, a^f_t can be interpreted as the value of net external debt in terms of final domestic goods.

2.3.12 Risk Premium Term

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

$$\Phi_t = \Phi\left(a^f_t, R^f_t, R_t, \tilde{\phi}_t\right) = \exp\left(\tilde{\phi}_a\left(a^f_t - \bar{a}\right) - \tilde{\phi}_s\left(R_t - R^f_t - \left(R - R^f\right)\right) + \tilde{\phi}_t\right) \tag{2.32}$$

where $\tilde{\phi}_a > 0$, $\tilde{\phi}_s > 0$ and $\tilde{\phi}_t \backsim$ mean zero, iid. $\tilde{\phi}_a > 0$ implies if $a^f_t > \bar{a}$, then the cost of external debt in domestic currency units is high and will lead to a reduction in the net external debt, a^f_t, held by banks. On the other hand, if $a_t^f < \bar{a}$, then the cost of external debt is low and will lead to an increase in net foreign funding. $\tilde{\phi}_t$ captures the possibility of a shock to the required return on foreign funding. The term $\tilde{\phi}_s > 0$ is required to adjust for the standard uncovered interest rate parity (UIP) relationship. Modifying 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 proposed by Adolfson et al., 2008.

2.3.13 Final domestic goods market clearing

Let Y_t^* denotes the unweighted integral of gross output across the producers of wholesale goods:

$$\begin{aligned}
Y_t^* &\equiv \int_0^1 Y_{i,t} di \\
&= \int_0^1 A_t K_{i,t}^{\xi} L_{i,t}^{1-\xi} di \\
&= A_t K_t^{\xi} L_t^{(1-\xi)}
\end{aligned}$$

and it leads to

$$Y_t^* = p_t^* Y_t$$

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

$$\begin{aligned}
p_t^* &= \int_0^1 (P_{i,t}^d)^{-\varepsilon} di \\
&= \left[(1-\theta)(\tilde{p}_t^d)^{-\varepsilon} + \theta \frac{\bar{\pi}_t^{\varepsilon}}{p_{t-1}^*}\right]^{-1} \\
&= \left[(1-\theta)\left(\frac{1-\theta(\bar{\pi}_t)^{(\varepsilon-1)}}{1-\theta}\right)^{\frac{\varepsilon}{\varepsilon-1}} + \theta \frac{\bar{\pi}_t^{\varepsilon}}{p_{t-1}^*}\right]^{-1}
\end{aligned} \tag{2.33}$$

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

$$Y_t = \frac{A_t K_t^{\xi} L_t^{(1-\xi)}}{p_t^*} = (C_t^h)^d + (C_t^e)^d + EX_t + G_t$$

where total consumption of final domestic goods by households and entrepreneurs, $(C_t^h)^d + (C_t^e)^d$ $= C_t^d$, equals $(1-\alpha)p_t^{\eta} C_t$. G_t represents spending by the government.

2.3.14 Monetary policy

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

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R}\right)^{\rho_R} E_t\left[\left(\frac{\pi_{t+1}}{\pi^T}\right)^{r_\pi}\left(\frac{Y_{t+1}}{Y}\right)^{r_y}\right]^{1-\rho_R} \varepsilon_{R,t} \tag{2.34}$$

where 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.

2.3.15 Government spending

The model assumes that the government also purchases final 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:

$$\log(G_t) = (1-\rho_g)\eta_g \log Y + \rho_g \log(G_{t-1}) + \varepsilon_{g_t} \tag{2.35}$$

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.

2.3.16 Other equilibrium equations

1. Total consumption

   The total consumption in the economy is equal to the aggregate consumption of households and entrepreneurs.

   $$C_t = C_t^h + C_t^e$$

2. Aggregate inflation, final domestic goods inflation, and inflation target

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

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

2.3.17 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
$$\log((1 + exp(R_t^f)) = (1 - 0.90)\log(1 + exp(R^f)) + 0.90\log(1 + exp(R_{t-1}^f)) + \varepsilon_{R_t^f}$$

4. Risk-premium term
$$\log(\Phi_t) = 0.95\log(\Phi_{t-1}) + \varepsilon_{\Phi_t}$$

2.4 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 households, β, is set at 0.99, calibrated to produce a real interest rate equal to 4.00% annually. The elasticity of the labour supply of households is set at $\varphi - 1 = 0.01$, consistent with Iacoviello, 2005. The discount factor for entrepreneurs, $\tilde{\beta}$, is set at 0.975 as in Iacoviello, 2005. The share of capital in the production function of intermediate goods produced by entrepreneurs, ξ, is set at 0.25, and the capital depreciation rate δ at 0.025, in line with Gerali et al., 2010. I set the steady-state LTV ratio for entrepreneurs at 0.35, consistent with Gerali et al., 2010. The share of imported goods in the production of final consumption goods, α, is set at 0.5, which is the standard calibrated value used for a small open economy. The cost of adjustment for physical investments, κ_i, is set at 8, consistent with Adolfson et al., 2008. The elasticity of the demand for wholesale goods by the final domestic goods producers, ε, is set at 6, which is a widely used value in the literature, implying a mark-up of 1.20 (Gerali et al., 2010).

The substitution elasticity between final domestic goods and imported goods in the production of final consumption goods, η, is set at 1.5. The elasticity of foreign demand for final domestic goods is set at 1.2. These two figures are close to L. J. Christiano et al., 2011. For all parameters related to the banking sector, the figures are consistent with the estimates of Gerali et al., 2010 and Gambacorta and Signoretti, 2014. The target CTL ratio, ν, is set at 0.07, and the parameter for the cost of managing the bank capital position, δ^b, is set at 0.09, to ensure that the ratio of bank capital to total loan is 0.07. The cost of adjusting the bank capital, γ, is equal to 11, and the spread of the bank loan is set at 0.005 or equal to 2.00% annually. The steady state of external funding by banks, η_a, is set at 0.3. This is supported by the Financial Stability Board (FSB) report published in 2022, which states that external borrowing by emerging economies amounted to US 5.6 trillion dollars (approximately 30% of GDP) at the end of 2019. More than 80% of this debt was denominated in foreign currencies, mainly the US dollar (Financial Stability Board, 2022). For the term of risk premium, I use $\tilde{\phi}_a = 0.03$ and $\tilde{\phi}_s = 0.95$, consistent with the literature that places a small value on $\tilde{\phi}_a$ to help find the steady state value of external funding from banks and the value of $\tilde{\phi}_s$ that is suggested in the literature between 0.5 and 1.75. 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 full parameter values used to solve the model are summarised in Table 2.5.

2.5 Results

In this section, I will discuss and analyse the impulse response functions to the variables of interest. Similarly to Aoki et al., 2016 and Ferrante and Gornemann, 2022, to study the impact of movement on the exchange rate, the initial shock to the model will come primarily from a shock of the foreign interest rate. The initial shock to the foreign interest rate then leads to a depreciation in the nominal exchange rate. The analysis starts with the general finding and is followed by three experiments to explain and illustrate in greater detail the impact of the financial channel of the exchange rate. In the final part, I discuss the impact and outcome of some policy responses to mitigate the financial channel of the exchange rate.

2.5.1 General findings

Figure 2.12 shows the impulse response functions to 100 basis points of a temporary increase in the foreign interest rate. An increase in the foreign interest rate leads to a depreciation in the nominal exchange rate. The weakness in the exchange rate results in an expansion of exports, which supports

Table 2.5: Calibrated parameters

Parameter	Value	Description
β	0.99	Savers' discount factor
$\tilde{\beta}$	0.975	Entrepreneurs' discount factor
φ	1.01	$\varphi - 1$ is the labour-supply elasticity
ξ	0.25	Share of capital in the production function
δ	0.025	Depreciation rate of physical capital
LTV	0.35	Loan-to-value ratio for entrepreneurs
α	0.5	Share of imported goods in final consumption goods
η	1.5	Elasticity of substitution between final domestic goods and imported goods
ε	6	Elasticity of demand for wholesale goods
θ	0.75	Calvo parameter, probability of intermediate good firms cannot set prices
κ_i	8	Physical investment adjustment cost
ν	0.07	Target capital to loans or the ratio of capital adequacy
δ^b	0.09	Cost for managing the bank's capital position
γ	11	Bank capital adjustment cost
$\bar{\mu}^b$	0.005	Bank loan spread
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
$\tilde{\phi}_a$	0.03	Weight of net foreign assets in risk term
$\tilde{\phi}_s$	0.95	Weight of interest rate differential in risk term
η_f	1.2	Elasticity of demand for exports
η_a	0.3	Share of external funding by banks
η_g	0.3	Share of government spending

the expansion of domestic output. This captures the trade channel of the exchange rate. As a result of a depreciation in the nominal exchange rate, the price of imported goods increases, which in turn leads to higher inflation. The initial reaction of the central bank is to increase the interest rate in response to a positive expansion in domestic production and higher inflation. However, the expansionary impact of a depreciation in the nominal exchange rate on output turns negative after a few quarters. Banks that were negatively affected by the increase in the cost of their foreign currency liabilities lead to an erosion of their capital and, ultimately, their intermediation capacity. As a consequence, their lending capacity deteriorates and leads to a reduction in loans growth, which, in turn, negatively affects the domestic economy. These responses are in line with the implications of the financial channel. The increase in policy rate becomes less aggressive as the growth of output and inflation stabilise.

Figure 2.13 shows the impulse response functions to a negative shock in the bank capital. The erosion in bank capital results instantaneously in reduction in bank loan, as bank's lending capacity is adversely affected. However, a shock in bank capital leads to a depreciation in the nominal exchange rate, which helps to support export growth. However, the positive impact on domestic production is proven to be short-lived, as the expansion in foreign demand is not large enough to

Figure 2.12: Impulse responses to the foreign interest rate shock

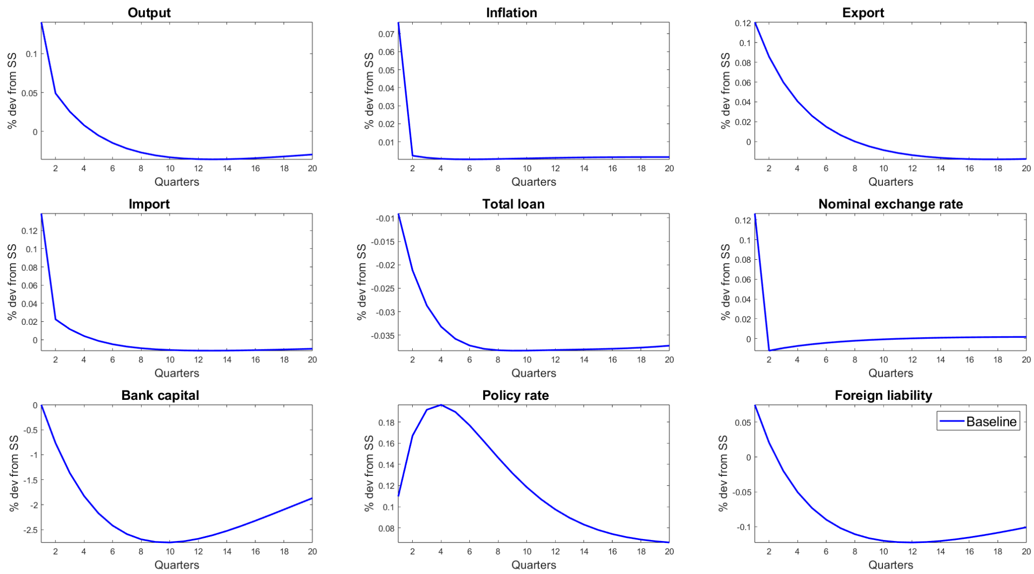

Figure 2.12. Impulse responses to the foreign interest rate shock, $\varepsilon_{R_t^f} = 0.0025$. The unit on the y-axis is in terms of percentage points deviation from the steady state.

offset the negative impact of the reduction in bank capital. Furthermore, higher inflation as a result of higher import prices limits the central bank's ability to reduce the interest rate and becomes less accommodating to support economic growth.

Figure 2.13: Impulse responses to the bank capital shock

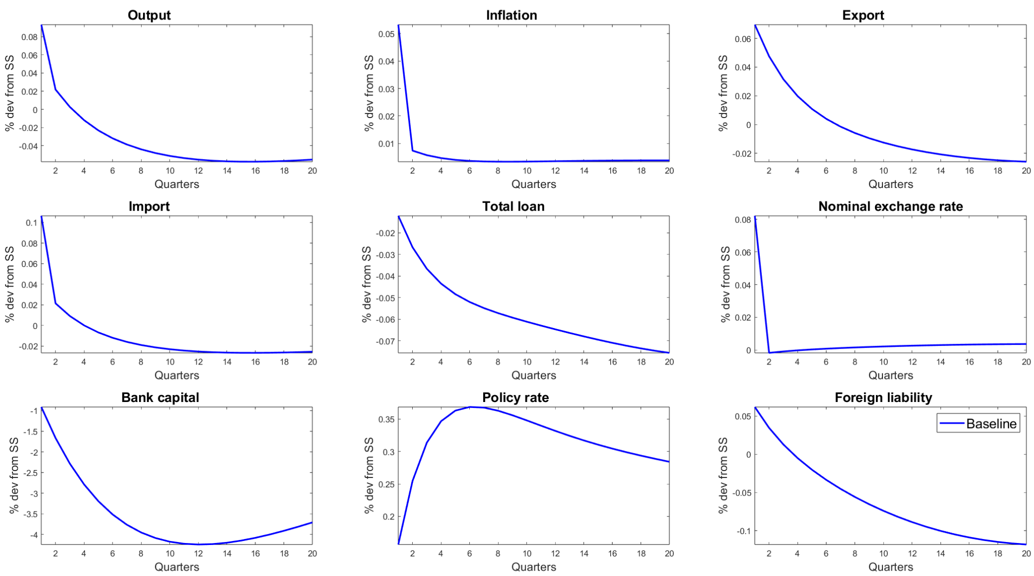

Figure 2.13. Impulse responses to the bank capital shock, $\varepsilon_{K_t^b} = 0.01$. The unit on the y-axis is in terms of percentage points deviation from the steady state.

2.5.2 Sensitivity analysis on the size of foreign liabilities

In this part, I will perform a sensitivity analysis based on the size of the foreign liabilities of banks, in terms of their share relative to domestic production (i.e. % of GDP). I compare the size of η_a between 0.2, 0.3 and 0.4. This exercise is related to the first question that I intend to address in the framework of the DSGE model, which is *How will the degree of dependence on the banking system for foreign funding shape the impact of foreign interest and exchange rate movements on macroeconomic variables?* Figure 2.14 shows the impulse response function to a temporary increase of 100 basis points in the foreign interest rate, with various degrees of exposure of banks to foreign funding. Since the change in parameter η_a will result in different steady state levels, the comparison of impulse response functions is shown in terms of the deviation from the steady state levels, instead of the normal percentage points deviation from the steady state. The baseline case refers to a situation in which the share of foreign funding, η_a, is set at 0.3. The shock will lead to a reduction in the banks loan and a deterioration in the banks capital. The greatest impact on bank loan and capital is observed when η_a is set at 0.4. In particular, the impact on banks' capital will begin to become acute from time $t + 2$ onwards, when a clear divergence begins to emerge, as banks' profits begin to be negatively affected from time $t + 1$. This explains why the impact of foreign interest rate shock is more pronounced when the exposure of banks to foreign funding is set at 0.4, as the increase in the cost of external funding will be greater as η_a increases. The result clearly shows that the strength of the cost of external borrowing depends directly on the size of the external borrowing by banks, where the higher the reliance on foreign funding, the stronger the contractionary effects on domestic bank loan.

2.5.3 Banks with a foreign funding constraint

In the second experiment, I intend to address the second question that the framework of the DSGE model allows me to analyse, which is *What is the impact of banks facing binding borrowing constraints for foreign funding after a foreign interest shock and a weaker exchange rate?* This is a legitimate and relevant question that we need to better understand given that many studies have shown that emerging economies are prone to sudden stop in foreign funding, especially during episodes of exchange rate depreciation and external shocks. Haas and Horen, 2012 show evidences that cross border lending by international banks to emerging economies was significantly reduced during the global financial crisis in the 2007-2009 period. The finding is also supported by Barajas et al., 2020, which argues that shocks in US dollar funding costs during the COVID-19 crisis have led to financial stress in the home economies of global non-US banks and their domestic financial systems, particularly in emerging

Figure 2.14: Sensitivity analysis on the size of η_a

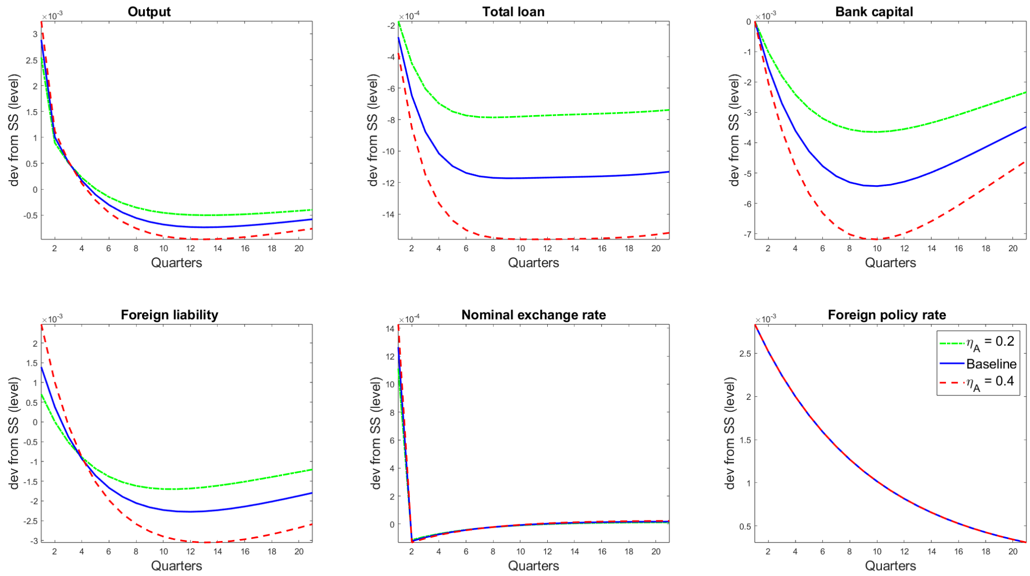

Figure 2.14. Impulse responses to the foreign interest rate shock, $\varepsilon_{R_t^f} = 0.0025$. The unit on the y-axis is in terms of deviation from the steady state level.

economies. Similarly, Davis et al., 2023 suggest that a depreciation in the domestic currency in a situation where the level of external debt is high could lead to a sudden stop in foreign funding.

To deal with the problem of binding constraints that banks face occasionally, I rely on the OccBin toolkit introduced by Guerrieri and Iacoviello, 2015. The toolkit adapts a first-order perturbation approach and applies it in a piecewise fashion to solve dynamic models with occasionally binding constraints. With the toolkit, one can distinguish situations where banks are not constrained and they can borrow externally without any problem; and situations where banks are constrained and faced with some binding limitations on how much they can fund externally. Figure 2.15 shows the impulse response function to an increase of 250 basis points in the foreign interest rate. Solid blue lines represent the response during normal times when banks are without the foreign funding constraint, and dashed red lines denote the response when banks face the foreign funding constraint. In this exercise, the constraints faced by banks result in them not being able to increase the share of foreign funding beyond the steady-state level which is equivalent to 30% of GDP despite the depreciation in the exchange rate. The foreign funding constrain binds when the foreign interest rate increase by more than 250 basis points, which is consistent with empirical findings which suggest large reversal of capital outflows typically happen during large increase in US monetary policy.[12]

[12]In order to solve the problem with occasionally binding constraint in Dynare, I have set the balance sheet constraint of banks as $S_t A^f_{t+1} = 0.618254$, compared to the baseline scenario of $B_t = D_t + K^b_t + S_t A^f_{t+1}$. This will result in not allowing the level of foreign funding to exceed the steady-state level despite the depreciation of the exchange rate. As a result of the funding constraint, it leads to a reduction in banks' foreign funding by more compared to the baseline

As a result of the foreign funding constraint, the positive impact on output as a result of the improvement in exports due to the depreciation of domestic currency is almost entirely diminished compared to the baseline scenario, as banks' lending capacity is severely affected. This exercise shows that when banks face funding constraints, it would amplify the financial channel of the exchange rate and could possibly completely offset the trade channel effect.

Figure 2.15: Occasionally binding constraint of banks

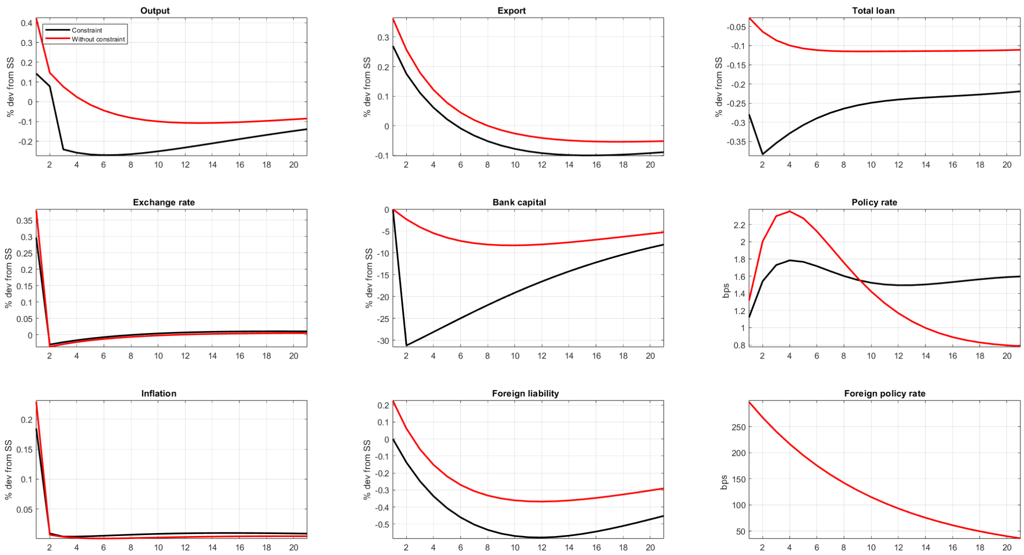

Figure 2.15. Impulse responses to the foreign interest rate shock, $\varepsilon_{R_t^f} = 0.0075$. The unit on the y-axis is in terms of percentage points and basis points deviation from the steady state.

2.5.4 Banks' profit sensitivity to the exchange rate

The third experiment will address the issue of *What happens when banks' profits become more sensitive to the movement of the nominal exchange rate? This reflects that banks have net currency mismatches in their balance sheets.* Exchange rate fluctuations affect banks through direct and indirect channels (Popper, 1996). The direct effect comes as a result of banks' exposure to assets or liabilities with payment streams denominated in foreign currency. Meanwhile, the indirect effect refers to banks' exposure to currency risk even without assets or liabilities that are denominated in foreign currencies on their balance sheet. For example, a reduction in profitability in importers who are negatively affected by the depreciation in the exchange rate will directly affect their ability to service their debts. The direct effect of the exchange rate on banks' profitability remains a key source of risk that banks face and have to manage, given their sizeable exposure to foreign currencies-denominated liabilities,

scenario.

particularly in emerging economies. Of significance, in many economies in Latin America, the share of deposits in the US dollar in the banking system has remained above 25% for the past two decades (Ferrante and Gornemann, 2022). There is also evidence to support the view that derivative market and hedging activities have also made banks more vulnerable to exchange rate fluctuations. Kloks et al., 2023 find that for a given currency in the FX swaps and forwards market, the interbank positions between banks of different nationalities are net to zero by market clearing. However, the aggregate banking sector of a given country is still exposed to a net open FX position. This is corroborated by the finding of Abbassi and Bräuning, 2023, which finds that hedging activities have led banks to have net currency mismatches in their balance sheets.

In this experiment, I would make a minor adjustment to the baseline model to reflect that banks are becoming more sensitive to exchange rate fluctuations. The aim of the minor adjustment is to amplify the impact of the movement of the nominal exchange rate on banks' profitability. To achieve that, a new parameter, η^s, is added to the equation of bank profits. With the minor adjustment, Equation (2.24) now becomes

$$j_t^B = R_t^r b_t - R_t d_t - \frac{s_{t+1}^{\eta^s} \Phi_t R_t^f a_t^f}{p_t} - \frac{\theta}{2}\left(\frac{k_t^b}{b_t} - \nu\right)^2 k_t^b \tag{2.36}$$

where η^s essentially captures banks' net foreign exchange open position, with $\eta^s > 1$ reflecting banks' hedging position or a smaller net open foreign exchange position against the foreign currency, and $\eta^s < 1$ reflecting the unhedged or a bigger net long foreign exchange position against the foreign currency. The net hedging position implies that banks will generate a smaller loss when the domestic currency depreciates compared to the foreign currency. In contrast, banks will make a larger profit with a net long foreign exchange position when the domestic currency strengthens against the foreign currency. The new parameter will either naturalise or amplify the impact on bank profitability and bank capital after a shock on the foreign interest rate and movement in the nominal exchange rate.

Figure 2.16 shows the impulse response function to an increase of 100 basis points in the foreign interest rate. Solid blue lines represent the baseline model, dotted red lines denote a scenario in which banks have a larger net foreign exchange position, and dashed green lines capture a scenario in which banks have a smaller net foreign exchange position. We can see that a foreign interest rate shock and a depreciation in the domestic currency will result in the least severe impact on output in the scenario where banks have a smaller net foreign exchange position. Since banks with a hedging position will be making a smaller loss when the domestic currency depreciates, it partially offsets the adverse impact on banks' capital as a result of higher foreign funding cost. As a result, the negative impact on banks' lending capacity is mitigated, which, in turn, helps to support domestic economic activity. On the flip side, the impact on output is much worse when banks have a larger net foreign exchange position compared to the baseline model, as the negative impact on banks' capital following the rise in higher foreign funding cost is amplified by the additional loss due to banks' net open foreign exchange position. The result shows that the financial channel of the exchange rate is larger and will become more significant when banks' profits are tightly correlated with the exchange rate fluctuations.

Figure 2.16: Banks' sensitivity to the exchange rate

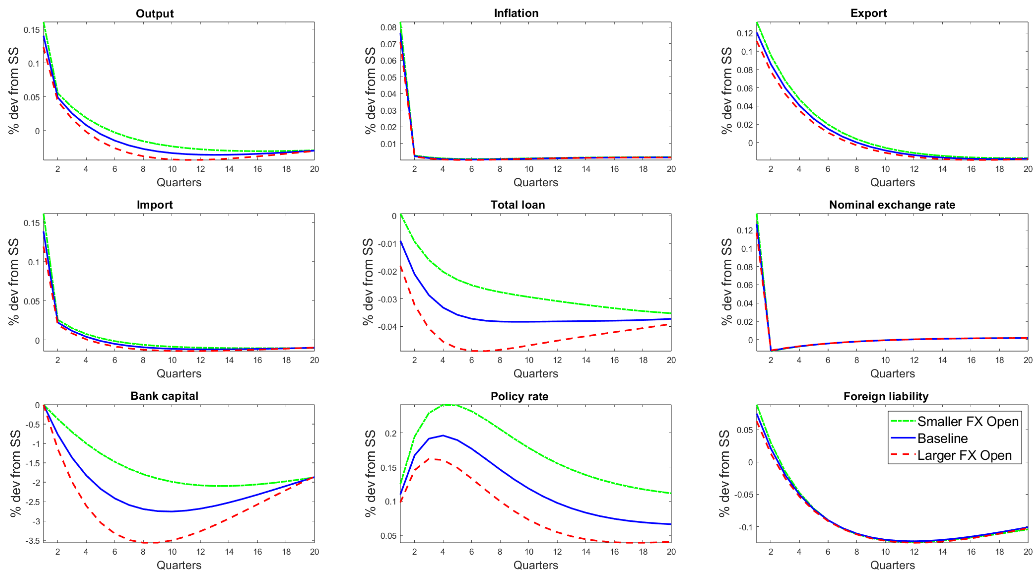

Figure 2.16. Impulse responses to the foreign interest rate shock, $\varepsilon_{R_t^f} = 0.0025$. The unit on the y-axis is in terms of percentage points deviation from the steady state.

2.5.5 Evaluation on policy responses

This part analyses the effectiveness of policy responses to soften the negative impact of depreciation on domestic currency. This remains an important topic and related to one of the areas that the DSGE framework allows me to address, that is, *Is there a role for FXI, CTL ratio, an augmented Taylor rule, and an augmented LTV rule to mitigate the impact of the financial channel of the exchange rate in minimising the fluctuation of output and credit growth?* In this part, three policy responses by the central bank are analysed and compared alongside the traditional Taylor rule, and the objective is to find the policy response that could be implemented to stabilise output and loans growth, and to minimise the adverse impact of exchange rate depreciation.

The first policy response that the central bank could implement is the FXI. When faced with a foreign interest rate shock that leads to a reduction in external borrowing by banks and puts some downward pressure on the domestic currency, the central bank will step in and intervene in the foreign exchange market by buying the domestic currency. The implementation of FXI to reduce the depreciation in the domestic currency will also lead to a reduction in the central bank's foreign reserve. The central bank's rule on FXI is closely adopted from Castillo and Medina, 2021 and is given as follows:

$$\frac{FXI_t}{FXI} = \left(\frac{FXI_{t-1}}{FXI}\right)^{\rho_F} \left(\left(\frac{R_t^f}{R^f}\right)^{\theta_{Rf}}\right)^{1-\rho_F} \tag{2.37}$$

where FXI is the foreign exchange reserve in the steady state, ρ_F is the persistence term of the stock of foreign exchange reserve and θ_{Rf} is a feedback parameter on the foreign interest rate, which governs the intensity of FXI to the movement in foreign interest rate. The FXI rule is designed so that the central bank will only react and intervene in foreign exchange when there is a shock to the foreign interest rate. The negative coefficient of the feedback parameter, θ^{Rf}, means that the central bank will only come in to moderate the appreciation or depreciation of the domestic currency.

The second policy response is a combination of the augmented Taylor rule and the augmented LTV rule. Changes in both rules are intended to make the policy response more countercyclical and more responsive to fluctuations in the exchange rate. The augmented Taylor rule and the augmented LTV rule take the following forms:

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

and

$$LTV = 0.35 * \left(\frac{s_t}{s}\right)^{\phi_s}$$

where $r_s > 0$ implies that the central bank will increase the policy rate in response to the depreciation in domestic currency. Similarly, $\phi_s > 0$ means that the LTV rule will be relaxed when the exchange rate depreciates, which will make the borrowers less strained by the LTV rule.

The final policy response that this article evaluates is the countercyclical CTL ratio, ν. Similarly to the second policy response, the aim of the countercyclical CTL ratio is to make banks more flexible in managing their capital and loans following the foreign interest rate shocks. The countercyclical CTL ratio, ν, resembles Filho and Ng, 2023 and is given as follows:

$$\nu = 0.07 * \left(\frac{b_t}{b}\right)^{\phi_\nu}$$

where $\phi_\nu > 0$ implies that the target CTL ratio imposed by the central bank will be relaxed and should improve banks' lending capacity. Table 2.6 summarises the parameters of the alternative policy responses. The feedback parameter on the foreign interest rate, θ_{Rf}, for the FXI policy is consistent with Castillo and Medina, 2021, and the feedback parameter on the CTL ratio, ϕ_ν, is consistent with Filho and Ng, 2023.

Table 2.6: Parameters for alternative policy responses

Parameter	Value	Description
θ_{Rf}	-1.5	Foreign exchange intervention, feedback parameter on the foreign interest rate
ρ_F	0.90	Foreign exchange intervention, persistence parameter
r_s	0.15	Taylor rule, exchange rate parameter
ϕ_s	0.50	LTV rule, exchange rate parameter
ϕ_ν	10	Capital-to-loan ratio, aggregate loan parameter

Figure 2.17 and Table 2.7 show the impulse response function to an increase of 100 basis points in the foreign interest rate. The impulse response functions generated by the three different policy responses are compared with the scenario in which the banks have a larger net foreign exchange position, as shown in Figure 2.15. The solid blue lines represent the baseline policy response, the dotted red lines denote the FXI, the dashed green lines are for the combination of the augmented Taylor rule and the augmented LTV rule, and the plus sign makers demonstrate the countercyclical CTL ratio.

First, the impulse response functions of the output seem to experience the least fluctuations under the FXI policy regime. Direct intervention by the central bank to moderate the depreciation of the exchange rate has resulted in limiting the transmission of exchange rate depreciation to the domestic economy, through a much smaller impact from both the trade and the financial channels. This is evidenced by the smallest gain in exports and the least severe impact to banks' capital under the FXI policy regime. Second, in terms of stabilising loans growth, the countercyclical CTL ratio is the most effective policy response compared to other policy responses. However, stabilisation in loans growth comes at the expense of banks' capital position, where banks' capital deteriorated the most compared to other policy responses. Third, the impulse response functions of output and loans growth between the baseline model and the combination of the augmented Taylor rule and the augmented LTV rule seem almost identical. This suggests that modifying both rules by making them more sensitive to exchange rate movements does not lead to a better outcome. The overall result of this exercise demonstrates that there are policy responses that can help to moderate the negative impact of the depreciation in the domestic currency, but they also come with some trade-off that we need to be aware of.

Figure 2.17: Policy responses by the central bank

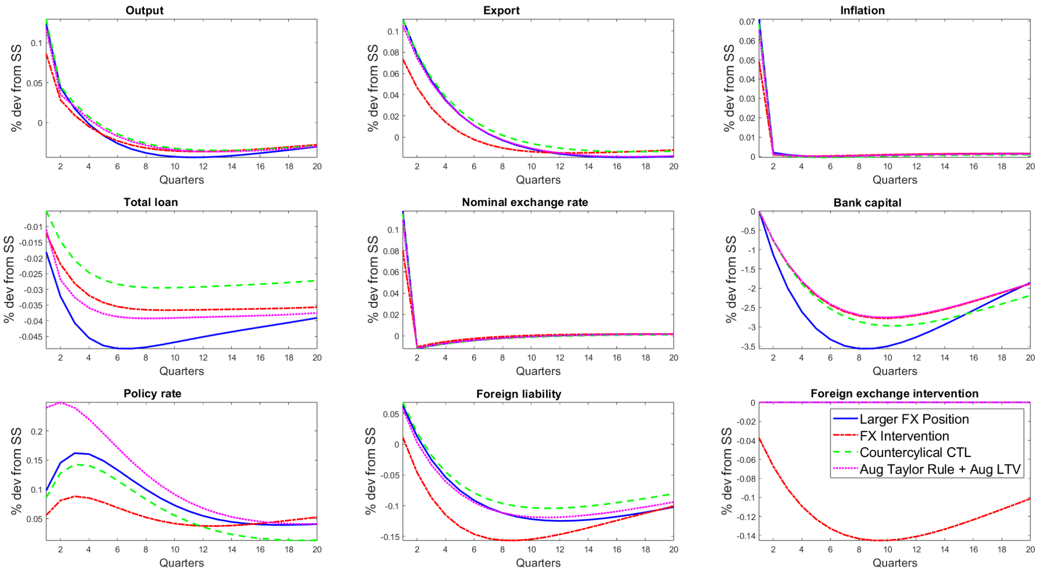

Figure 2.17. Impulse responses to the foreign interest rate shock, $\varepsilon_{R_t^f} = 0.0025$. The unit on the y-axis is in terms of percentage points deviation from the steady state.

Welfare analysis of the various policy responses

In this part, I quantify the welfare costs for each policy regime. The welfare analysis follows a similar approach to that taken by Rubio and Carrasco-Gallego, 2015 and Mendicino and Pescatori, 2005, where the welfare analysis is evaluated in terms of units of consumption equivalents. The welfare evaluation captures change in welfare only within the model domain and does not capture other potential frictions, such as loan default or other extreme cases, such as bankruptcy or sudden stop. The welfare analysis is performed using a second-order approximation to the structural equations. Individual welfare for households and entrepreneurs is represented by their maximisation problem given by:

$$W_t^h \equiv E_0 \sum_{t=0}^{\infty} \beta^t \left(\ln C_t^h - \frac{(L_t)^{\varphi}}{\varphi} \right) \tag{2.38}$$

and

$$W_t^e \equiv E_0 \sum_{t=0}^{\infty} \widetilde{\beta}^t \left(\ln C_t^e \right) \tag{2.39}$$

Table 2.7: Impulse response functions of various policy responses

Output				
Period	Larger FX position	FX intervention	Countercyclical CTL	Aug Taylor Rule and Aug LTV
1	0.123294126	0.086121202	0.129250001	0.117045059
5	-0.015967368	-0.015416525	-0.005178996	-0.008095029
10	-0.042720971	-0.035454449	-0.032130099	-0.034100344
15	-0.039897987	-0.034136792	-0.034109868	-0.035554334
20	-0.030120386	-0.027665909	-0.02890386	-0.029919947
Total loan				
Period	Larger FX position	FX intervention	Countercyclical CTL	Aug Taylor Rule and Aug LTV
1	-0.018099153	-0.012244225	-0.005042923	-0.010979837
5	-0.047901477	-0.034213313	-0.027010603	-0.037764635
10	-0.046860348	-0.036616364	-0.029466704	-0.039109942
15	-0.042783361	-0.036268799	-0.028559491	-0.038482556
20	-0.039087561	-0.035670373	-0.027209528	-0.037498167
Bank capital				
Period	Larger FX position	FX intervention	Countercyclical CTL	Aug Taylor Rule and Aug LTV
1	0	0	0	0
5	-3.043530255	-2.183544611	-2.535182989	-2.163132853
10	-3.501992219	-2.779261093	-2.972239459	-2.755734011
15	-2.758522149	-2.44890117	-2.714192826	-2.432569355
20	-1.854973567	-1.883559704	-2.185680336	-1.876027942
Foreign liability				
Period	Larger FX position	FX intervention	Countercyclical CTL	Aug Taylor Rule and Aug LTV
1	0.062954832	0.01103695	0.068386833	0.057813539
5	-0.075288441	-0.134397288	-0.065055351	-0.080524012
10	-0.121986816	-0.154763832	-0.103430192	-0.118543044
15	-0.120896796	-0.130216965	-0.09817169	-0.112573781
20	-0.102279718	-0.100765333	-0.080601745	-0.094181504

and social welfare is defined as a weighted sum of the individual welfare of households and entrepreneurs represented as follows:

$$W_t = (1-\beta)W_t^h + (1-\widetilde{\beta})W_t^e \tag{2.40}$$

Social welfare that is evaluated when the LTV^E ratio is set at 0.34 is used as benchmark, and the comparison of welfare gain or loss based on different policy regimes is made when the LTV^E ratio is set between 0.34 to 0.50. Welfare changes are defined in terms of units of consumption equivalents compared to the traditional Taylor rule. When there is a welfare loss, consumption equivalent measures the share of lifetime consumption that households are willing to give up to obtain the benefits of the LTV ratio at 0.34. 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 0.34. The derivation of welfare gain or loss is defined as:

$$CE = \exp\left[W^{LTV^E} - W^{LTV^E=0.34}\right] - 1 \tag{2.41}$$

Table 2.8 summarises the welfare gains and losses for given LTV^E ratios under different policy regimes compared to the traditional Taylor rule regime. Welfare analysis suggests that there will be welfare gains from the implementation of the augmented Taylor rule and FXI policy in response to the foreign interest rate shock and exchange rate depreciation. The FXI policy, in particular, can improve welfare by 0.004 of consumption units compared to the traditional Taylor rule regime if the LTV ratio is set at 0.50. The augmented Taylor rule can also improve welfare, but the magnitude is smaller compared to the FXI policy. In contrast, the countercyclical CTL ratio does not improve welfare even though it stabilises loan growth more effectively. This is due to the fact that borrowing constraint is always binding, which stabilisation in loan supply leads to higher borrowing among entrepreneurs, and their welfare will be affected adversely with a looser LTV ratio.

Table 2.8: Welfare analysis under the various policy regimes

Welfare gains / losses for different values of LTV^E				
	LTV^E level			
Policy type	0.35	0.40	0.45	0.50
Traditional TR and Countercylical CTL	-0.0002	-0.0007	-0.0011	-0.0013
Traditional TR and FXI	0.0002	0.0012	0.0025	0.0040
Adjusted TR with ER	0.0001	0.0007	0.0015	0.0025

Note: The welfare loss is compared against the benchmark LTV^E level of 0.34 and calculated on the basis of a foreign interest rate shock $\varepsilon_{R_t^f} = 0.0025$.

2.6 Extension

2.6.1 Foreign lenders

To have a more complete analysis on the impact of exchange rate movement on external funding, in this section, I study the changes in risk premium of foreign lenders' home country on the supply of external funding. This extension can be considered as a simplified version compared to a full-blown two-country DSGE model, where the aim is to capture the impact on external funding following risk premium shocks that originate from the lenders' home country. This extension aims to replicate the findings in Bruno and Shin, 2023 that show that appreciation in the US dollar leads to a decrease in US dollar funding. Similarly, in this exercise, I show that exchange rate appreciation in the lender's home country leads to a reduction in external funding, and on the other hand, exchange rate depreciation in lenders' home country leads to a greater supply of external funding.

In this simplified exercise, foreign lenders care only about their consumption and can save either domestically or provide external funding. The maximisation problem of representative foreign lenders is given by the following.

$$\max_{C_t^f, A_t^f, D_t^f} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta_f^t \left(\ln C_t^f \right) \tag{2.42}$$

subject to the budget constraint

$$P_t^f C_t^f + S_t^f B_{t+1}^f + D_t^f \leq S_t^f \Phi_{t-1}^f (1 + R_{t-1}^f) B_t^f + (1 + R_{t-1}^{fd}) D_{t-1}^f \tag{2.43}$$

where C_t^f is the current consumption, D_t^f is the domestic savings and B_t^f is the external funding. $S_t^f = \frac{1}{S_t}$ 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 setting $b_t^f = \frac{S_t^f B_{t+1}^f}{P_t^f}$ and $d_t^f = \frac{D_t^f}{P_t^f}$, it becomes

$$C_t^f + b_t^f + d_t^f \leq \frac{s_t^f \Phi_{t-1}^f (1 + R_{t-1}^f) b_{t-1}^f}{\pi_t^f} + \frac{(1 + R_{t-1}^f) d_{t-1}^f}{\pi_t^f} \tag{2.44}$$

Three equations characterise the first-order conditions for foreign lenders:

$$\frac{\partial \mathbb{L}}{\partial C_t^f} : \frac{1}{C_t^f} = \lambda_t^f \tag{2.45}$$

$$\frac{\partial \mathbb{L}}{\partial b_t^f} : \lambda_t^f = \beta_f E_t \lambda_{t+1}^f \frac{s_{t+1}^f \Phi_t^f (1 + R_t^f)}{\pi_{t+1}^f} \tag{2.46}$$

$$\frac{\partial \mathbb{L}}{\partial d_t^f} : \lambda_t^f = \beta_f E_t \lambda_{t+1}^f \frac{(1 + R_t^f)}{\pi_{t+1}^f} \tag{2.47}$$

where λ_t^f is the Lagrangian multiplier for the budget constraint of foreign lenders. Figure 2.18 shows the impulse response function of a risk premium shock in the home country of foreign lenders, where the red line shows a positive shock that leads to appreciation in the exchange rate, and the blue line reflects a negative shock. Following appreciation in the exchange rate of the home country of foreign lenders, it reduces the return of external funding. As a result, the supply of external funding drops, subsequently leading to a reduction in bank loans. In contrast, depreciation in the exchange rate of the home country of foreign lenders leads to an improvement in the supply of external funding, subsequently leading to an increase in bank loans. This exercise shows that exchange rate movement that originates from the lender's home country is important in explaining the external funding dynamics, especially from the supply of external funding perspective.

Figure 2.18: Foreign lender's home country: Risk premium shock

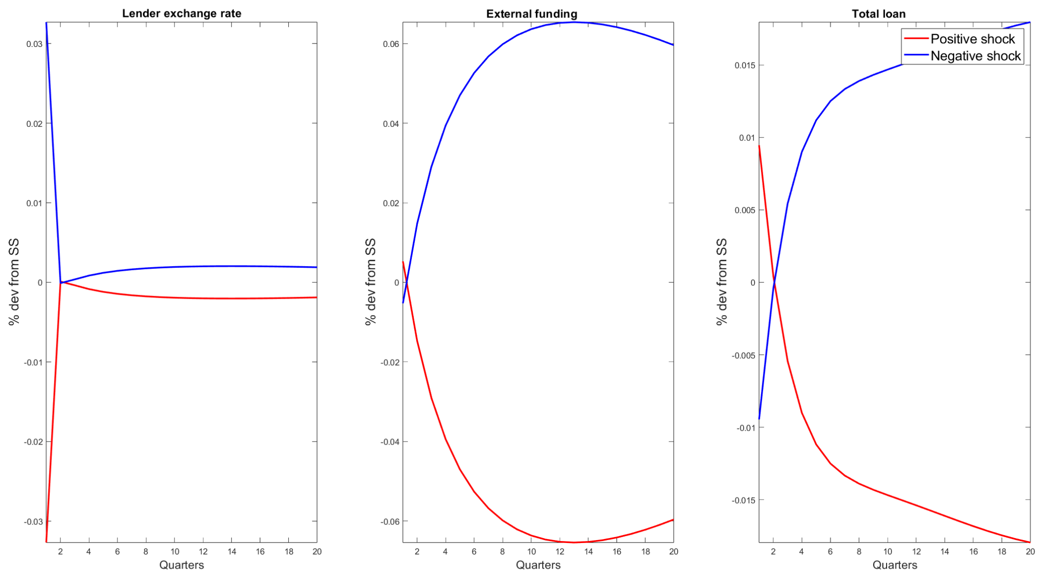

Figure 2.18. Impulse responses to the foreign risk premium shock, Φ_t^f. The unit on the y-axis is in terms of percentage points deviation from the steady state.

2.7 Conclusion

In this paper, the impact of exchange rate fluctuations and a higher foreign interest rate on bank loan growth is evaluated from both an empirical and a theoretical perspective. From an empirical analysis perspective, based on data from emerging markets and small open economies, I find that depreciation in domestic currency leads to a contractionary effect on real bank loan growth. Furthermore, the results demonstrate that the intensity of the negative impact on real bank loan growth is greater when the share of loan provided in foreign currencies is high. Moreover, I show that the factor that causes the movement in the exchange rate also matters in explaining its impact on real bank loan growth. The depreciation in exchange rate driven by the tightening in the US financial conditions will have a much more severe impact on real bank loans. This suggests that the impact of exchange rate on real bank loans is non-linear, where it is highly dependent on the state of the economy and the source of the shock. These results underscore the role of exchange rate movements in explaining real bank loan growth. I also develop a small open economy DSGE model with banks that are accessible to foreign funding. In the model, the impact on output and bank loan after a foreign interest rate shock, which then leads to depreciation in the domestic currency, is more significant when the share of foreign funding is larger. Furthermore, the negative impact can be amplified if the initial shock leads banks to face some restrictions in securing foreign funding, or if banks profit are more sensitive to the exchange rate movements. In order to mitigate the negative impact, the introduction of FXI and countercylical CTL can help to improve stabilising output and loan growth compared to the traditional Taylor rule. I have also shown that FXI policy is welfare enhancing. However, the benefits of this policy also come with some trade-offs that need to be taken into consideration. In terms of scope for future work, there are few main limitations that can be focused on to improve this paper. First, employ a more complete banking model to capture all the possible channels in which loan productions will be affected by exchange rate movements. Secondly and related to the first point, use a two-country DSGE model to capture domestic and international risk premia. With a more comprehensive banking framework, this paper can be extended to study the trade-off between monetary and macroprudential policy for both short- and long-term analysis.

2.8 Table A2.1 - A2.5

Table A2.1: Data Information

No.	Series	Source
1	Domestic banks loans to the non-financial private sector	BIS
2	International claims by immediate counterparty country	BIS
3	Bilateral exchange rates against the US dollar	BIS
4	Annual real GDP growth	OECD, IMF, CEIC
5	Annual inflation growth	World Bank
6	Central bank policy rates	BIS
7	US Federal Funds Rate	Federal Reserve, Wu and Xia, 2016
8	Global Economic Policy Uncertainty Index	Economic Policy Uncertainty
9	US financial conditions index	Federal Reserve, Ajello et al., 2023

Note: Most real GDP data are sourced from the OECD, except for three countries. Real GDP data for Thailand are taken from the IMF. The real GDP data for China and Malaysia are taken from CEIC data.

Table A2.2: First-stage Coefficients Table

At horizon h =	Coefficient	Cragg-Donald Wald F statistic	Kleibergen-Paap Wald rk F-statistic
0	3.0894***	76.22	11.91
1	3.4232***	85.98	13.89
2	3.7023***	88.10	14.04
3	4.1139***	95.18	14.25
4	4.1606***	95.22	14.07
5	4.1690***	92.64	13.74
6	4.1007***	87.33	13.15
7	4.2464***	94.05	14.69
8	4.4976***	102.48	17.38

Standard errors are based on Driscoll and Kraay, 1998 and *, **, *** indicates significance at 90%, 95%, and 99% levels.

Source: Author's calculation.

Table A2.3: Exclusion Restriction Test Result			
At horizon h =	Coefficient	p-value	R-squared
0	0.0879	0.609	0.0009
1	-0.0896	0.722	0.0004
2	-0.1874	0.559	0.0010
3	-0.2327	0.501	0.0010
4	-0.6349	0.136	0.0065
5	-0.6412	0.283	0.0058
6	-0.6980	0.310	0.0064
7	-0.7136	0.337	0.0064
8	-0.5038	0.525	0.0031

Standard errors are based on Driscoll and Kraay, 1998 and *, **, *** indicates significance at 90%, 95%, and 99% levels.

Source: Author's calculation.

Table A2.4: Impulse response of real total credit outstanding (LP-OLS)				
		Non-linear		P-value
At horizon h =	Linear	Low FC share (LS)	High FC share (HS)	LS = HS
0	0.1027***	0.0817***	0.1218***	0.1321
1	0.0206	-0.0141	0.0483	0.0590
2	-0.0911***	-0.0856***	-0.1115**	0.4604
3	-0.1421***	-0.1211***	-0.1856***	0.0534
4	-0.2311***	-0.1942***	-0.2727***	0.0768
5	-0.2067***	-0.2044***	-0.2018***	0.9615
6	-0.1227***	-0.1382***	-0.0910**	0.2854
7	-0.1046***	-0.0961*	-0.0877**	0.8525
8	-0.1013**	-0.1146**	-0.0652	0.3382

Standard errors are based on Driscoll and Kraay, 1998 and *, **, *** indicates significance at 90%, 95%, and 99% levels.

Source: Author's calculation

Table A2.5: Impulse response of real total credit outstanding (LP-IV)				
		Non-linear		P-value
At horizon h =	Linear	Low FC share (LS)	High FC share (HS)	LS = HS
0	0.1326***	0.1304***	0.1911	0.6194
1	-0.0191	-0.0785	0.1385	0.2474
2	-0.1555	-0.2562***	-0.0174	0.1053
3	-0.2220**	-0.3560***	-0.2070*	0.3522
4	-0.4191***	-0.5459***	-0.5573***	0.9634
5	-0.4111***	-0.4005*	-0.7404***	0.2918
6	-0.3539*	-0.2260	-0.8148**	0.1101
7	-0.3775*	-0.1848	-0.9587***	0.0321
8	-0.3412**	-0.1962	-0.8330***	0.0281

Standard errors are based on Driscoll and Kraay, 1998 and *, **, *** indicates significance at 90%, 95%, and 99% levels.

Source: Author's calculation

Chapter 3

LTV, External Position, and Exchange Rate

3.1 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, J. 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 R. N. 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.

3.2 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

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

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

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.

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

Table 3.1 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]

3.2.2 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

[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 A3.1 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 3.1: 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

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 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 A3.2 for details of the regression outputs.

Figure 3.1: Real residential property price growth and LTV ratio

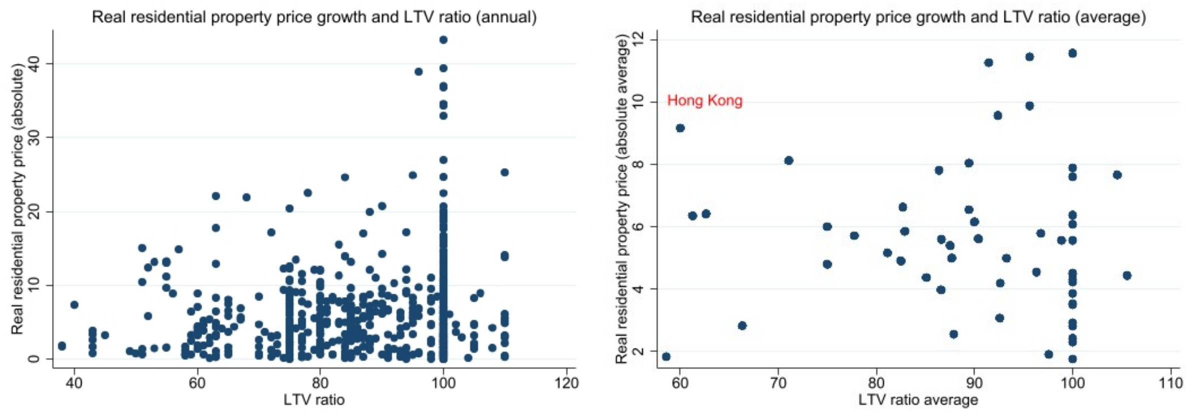

Figure 3.1. Scatter plots between the absolute growth of real residential property prices and LTV ratio. The y-axis is in terms of the percentage of absolute growth in real residential property prices, and the x-axis is the LTV ratio.

3.2.3 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 3.2 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 3.2 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.

Table 3.2: 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 3.2: Real residential property prices and external position

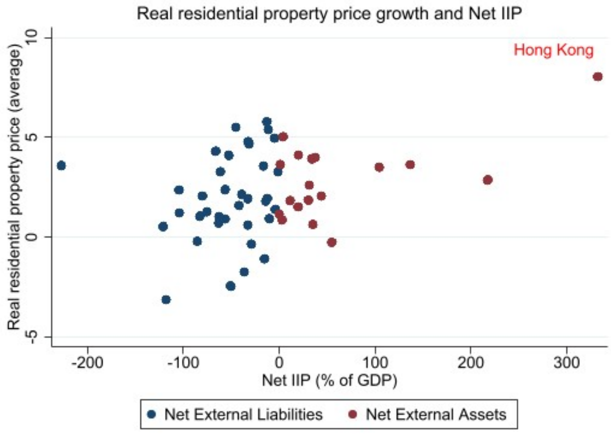

Figure 3.2. Scatter plot between the growth of real residential property prices and net international investment position. The y-axis represents the percentage growth in real residential property prices, and the x-axis is the net international investment position (% of GDP).

3.2.4 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. 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 3.3 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 3.3 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

[7] See Table A3.3 for details of the regression output.

position is one of the determinants of the movement in the exchange rates.

Table 3.3: 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 3.3: Exchange rates and external position

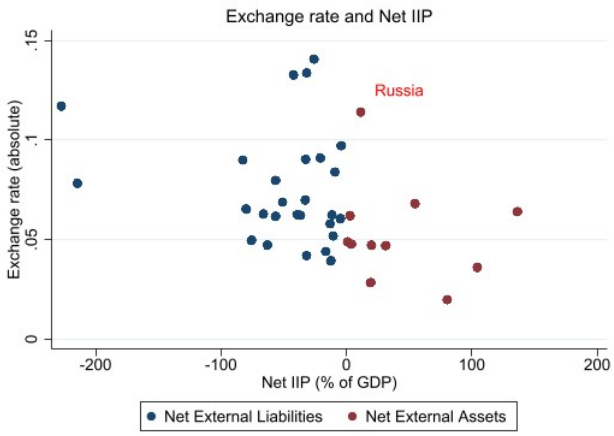

Figure 3.3. Scatter plot between the absolute growth of nominal exchange rate and net international investment position. The y-axis is in terms of the percentage of absolute growth in the nominal exchange rate, and the x-axis is the net international investment position (% of GDP).

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 A3.4).

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 3.4.

Table 3.4: 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.

3.3 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.

3.3.1 Households - A country with net external assets

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:

$$\max_{C_t^u, H_t^u, L_t^u, B_t^u, A_t^f} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left(\ln C_t^u + j \ln H_t^u - \frac{(L_t^u)^{\varphi}}{\varphi} \right) \tag{3.1}$$

subject to the budget constraint

$$S_t A_{t+1}^f + P_t C_t^u + Q_t \left(H_t^u - H_{t-1}^u \right) + B_t^u \leq W_t^u L_t^u + R_{t-1} B_{t-1}^u + S_t \Phi_{t-1} R_{t-1}^f A_t^f + T_t \tag{3.2}$$

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:

$$\frac{1}{c_t^u} = \beta E_t\left(\frac{R_t}{\pi_{t+1} c_{t+1}^u \Delta_{t+1}^A}\right) \tag{3.3}$$

$$w_t^u = (L_t^u)^{\varphi-1} c_t^u \tag{3.4}$$

$$\frac{j}{H_t^u} = \frac{1}{c_t^u} q_t - \beta E_t \frac{1}{c_{t+1}^u} q_{t+1} \tag{3.5}$$

$$\frac{1}{c_t^u} = \beta E_t \frac{1}{c_{t+1}^u} \frac{s_{t+1}\Phi_t R_t^f p_t}{\bar{\pi}_{t+1} p_{t+1} \Delta_{t+1}^A} \rightarrow \frac{1}{c_t^u} = \beta E_t \frac{1}{c_{t+1}^u} \frac{s_{t+1}\Phi_t R_t^f P_t P_{t+1}^d P_t^d}{P_t^d P_{t+1} P_{t+1}^d \Delta_{t+1}^A} \rightarrow \frac{1}{c_t^u} = \beta E_t \frac{s_{t+1}\Phi_t R_t^f}{c_{t+1}^u \pi_{t+1} \Delta_{t+1}^A} \tag{3.6}$$

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.

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

$$\max_{C_t^c, H_t^c, L_t^c, B_t^c} \mathbb{E}_0 \sum_{t=0}^{\infty} \widetilde{\beta}^t \left(\ln C_t^c + j \ln H_t^c - \frac{(L_t^c)^{\varphi}}{\varphi}\right) \tag{3.7}$$

subject to the budget constraint

$$P_t C_t^c + Q_t\left(H_t^c - H_{t-1}^c\right) + R_{t-1} B_{t-1}^c + \leq W_t^c L_t^c + B_t^c \tag{3.8}$$

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

$$R_t B_t^c \leq LTV E_t Q_{t+1} H_t^c \tag{3.9}$$

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:

$$\frac{1}{c_t^c} = \widetilde{\beta} E_t \left(\frac{R_t}{\pi_{t+1} c_{t+1}^c \Delta_{t+1}^A} \right) + \Omega_t' R_t \tag{3.10}$$

$$w_t^c = \left(L_t^c\right)^{\varphi - 1} c_t^c \tag{3.11}$$

$$\frac{j}{H_t^c} = \frac{q_t}{c_t^c} - \widetilde{\beta} E_t \frac{q_{t+1}}{c_{t+1}^c} - \Omega_t' LTV E_t \pi_{t+1} q_{t+1} \Delta_{t+1}^A \tag{3.12}$$

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.

3.3.2 Foreign buyers

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

$$\max_{C_t^f, H_t^f, B_t^f} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^{*t} \left(\ln C_t^f + j^f S_t^f \ln H_t^f \right) \tag{3.13}$$

subject to the budget constraint

$$P_t^f C_t^f + \frac{P_t^f}{P_t A_t} S_t^f Q_t \left(H_t^f - \Phi_{t-1}^f H_{t-1}^f \right) + B_t^f \leq R_{t-1}^f B_{t-1}^f \tag{3.14}$$

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:

$$\frac{1}{C_t^f} = \lambda_t^f \tag{3.15}$$

$$\lambda_t^f = \beta^* E_t \lambda_{t+1}^f \frac{R_t^f}{\pi_{t+1}^f} \tag{3.16}$$

$$\frac{j^f S_t^f}{H_t^f} = \lambda_t^f S_t^f q_t - \beta^* E_t \lambda_{t+1}^f S_{t+1}^f q_{t+1} \Phi_t^f \rightarrow \frac{j^f}{H_t^f} = \lambda_t^f q_t - \beta^* E_t \lambda_{t+1}^f s_{t+1}^f q_{t+1} \Phi_t^f \tag{3.17}$$

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.

3.3.3 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.

$$Y_t = \left[\int_0^1 Y_{i,t}^{\frac{\varepsilon-1}{\varepsilon}} di \right]^{\frac{\varepsilon}{\varepsilon-1}} \tag{3.18}$$

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

$$Y_{i,t} = Y_t \left(\frac{P_t^d}{P_{i,t}^d} \right)^{\varepsilon} \tag{3.19}$$

3.3.4 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:

$$\begin{aligned}
Y_t &= \left[\int_0^1 Y_{i,t}^{\frac{\varepsilon-1}{\varepsilon}}\,di\right]^{\frac{\varepsilon}{\varepsilon-1}} \\
Y_t &= \left[\int_0^1 \left(Y_t\left(\frac{P_t^d}{P_{i,t}^d}\right)^{\varepsilon}\right)^{\frac{\varepsilon-1}{\varepsilon}} di\right]^{\frac{\varepsilon}{\varepsilon-1}} \\
\Rightarrow P_t^d &= \left(\int_0^1 (P_{i,t}^d)^{(1-\varepsilon)} di\right)^{\frac{1}{1-\varepsilon}}
\end{aligned} \tag{3.20}$$

3.3.5 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:

$$L_t^u : W_t^u = X_t A_t \gamma \left(L_t^u\right)^{\gamma-1} \left(L_t^c\right)^{(1-\gamma)} \tag{3.21}$$

$$L_t^c : W_t^c = X_t A_t (1-\gamma) \left(L_t^u\right)^{\gamma} \left(L_t^c\right)^{-\gamma} \tag{3.22}$$

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, $P_{i,t}$.

3.3.6 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

$$K_t = \frac{\varepsilon}{\varepsilon - 1}(1 - V)\frac{y_t}{c_t^u}x_t + \beta\theta E_t \bar{\pi}_{t+1}^{\varepsilon} K_{t+1} \tag{3.23}$$

$$F_t = \frac{y_t}{c_t^u} + \beta\theta E_t \bar{\pi}_{t+1}^{\varepsilon-1} F_{t+1} \tag{3.24}$$

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,

$$\tilde{p}_t = \left[\frac{1-\theta\left(\bar{\pi}_t\right)^{\varepsilon-1}}{1-\theta}\right]^{\frac{1}{1-\varepsilon}} \tag{3.25}$$

3.3.7 Production of final consumption goods

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

$$C_t = \left[(1-\alpha)^{\frac{1}{\eta}}(C_t^d)^{\frac{\eta-1}{\eta}} + \alpha^{\frac{1}{\eta}}\left(C_t^m\right)^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}} \tag{3.26}$$

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:

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

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:

$$\frac{\partial \mathbb{L}}{\partial C_t^m} : P_t \frac{dC_t}{dC_t^m} = P_t^m \to C_t^m = \alpha \left(\frac{P_t}{P_t^m} \right)^\eta C_t \tag{3.27}$$

$$\frac{\partial \mathbb{L}}{\partial C_t^d} : P_t \frac{dC_t}{dC_t^d} = P_t^d \to C_t^d = (1-\alpha) \left(\frac{P_t}{P_t^d} \right)^\eta C_t \tag{3.28}$$

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

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

which becomes

$$p_t = \left[(1-\alpha) + \alpha \left(p_t^m\right)^{1-\eta} \right]^{\frac{1}{1-\eta}} \tag{3.29}$$

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.

3.3.8 Real exchange rate and inflation

The real exchange rate is defined by the following:

$$p_t^m = \frac{P_t}{P_t} \frac{P_t^m}{P_t^d} = \frac{P_t}{P_t^d} \frac{P_t^m}{P_t} \Rightarrow p_t^m = p_t \times reals_t \tag{3.30}$$

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:

$$\pi_t \equiv \frac{P_t}{P_{t-1}} = \frac{P_t^d p_t}{P_{t-1}^d p_{t-1}} = \bar{\pi}_t \left[\frac{(1-\alpha) + \alpha \left(p_t^m\right)^{1-\eta}}{(1-\alpha) + \alpha \left(p_{t-1}^m\right)^{1-\eta}} \right]^{\frac{1}{1-\eta}} \tag{3.31}$$

3.3.9 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:

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

3.3.10 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

$$\begin{aligned} 1 &= \frac{S_t P_t^x}{P_t^d} = \frac{P_t S_t P_t^f P_t^x}{P_t^d P_t P_t^f} \\ &= p_t reals_t p_t^x \end{aligned} \tag{3.32}$$

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

$$\frac{reals_t}{reals_{t-1}} = s_t \frac{\pi_t^f}{\pi_t}, s_t \equiv \frac{S_t}{S_{t-1}}, \pi_t^f \equiv \frac{P_t^f}{P_{t-1}^f} \tag{3.33}$$

3.3.11 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

$$
\begin{aligned}
p_t^* &= \int_0^1 P_{i,t}^{-\varepsilon} di \\
&= \left[(1-\theta)\tilde{p}_t^{-\varepsilon} + \theta \frac{\bar{\pi}_t^\varepsilon}{p_{t-1}^*}\right]^{-1} \\
&= \left[(1-\theta)\left(\frac{1-\theta\bar{\pi}_t^{(\varepsilon-1)}}{1-\theta}\right)^{\frac{\varepsilon}{\varepsilon-1}} + \theta \frac{\bar{\pi}_t^\varepsilon}{p_{t-1}^*}\right]^{-1}
\end{aligned}
\tag{3.34}
$$

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:

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

or

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

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:

$$y_t = p_t^*(L_t^u)^\gamma (L_t^c)^{1-\gamma} = (1-\alpha)(p_t)^\eta c_t + ex_t + g_t \tag{3.35}$$

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

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:

$$a_t^f + p_t^m \alpha \left(\frac{p_t}{p_t^m}\right)^\eta c_t = p_t real s_t p_t^x ex_t + \frac{s_t R_{t-1}^f \Phi_{t-1} a_{t-1}^f}{\bar{\pi}_t \Delta_t^A} \tag{3.36}$$

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.

3.3.13 Risk Premium Term - A country with net external assets

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

$$\Phi_t = \Phi\left(a_t^f, R_t^f, R_t, \tilde{\phi}_t\right) = \exp\left(-\tilde{\phi}_a\left(a_t^f - \bar{a}\right) - \tilde{\phi}_s\left(R_t - R_t^f - \left(R - R^f\right)\right) + \tilde{\phi}_t\right) \tag{3.37}$$

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).

3.3.14 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:

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R}\right)^{\rho_R} E_t\left[\left(\frac{\pi_{t+1}}{\bar{\pi}}\right)^{r_\pi}\left(\frac{y_{t+1}}{y}\right)^{r_y}\right]^{1-\rho_R} \varepsilon_{R,t} \tag{3.38}$$

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.

3.3.15 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:

$$\log(g_t) = (1 - \rho_g)\eta_g \log y + \rho_g \log(g_{t-1}) + \varepsilon_{g_t} \tag{3.39}$$

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.

3.3.16 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:

$$H_t^u + H_t^c + H_t^f = \bar{H} \tag{3.40}$$

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.

3.3.17 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.

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

3.3.18 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.

3.3.19 Households - A country with net external liabilities

Households - Patient households (unconstrained)

Patient households maximise their utility by choosing:

$$\max_{C_t^u, H_t^u, L_t^u, B_t^u} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left(\ln C_t^u + j \ln H_t^u - \frac{(L_t^u)^{\varphi}}{\varphi} \right) \tag{3.41}$$

subject to the budget constraint

$$P_t C_t^u + Q_t \left(H_t^u - H_{t-1}^u \right) + B_t^u \leq W_t^u L_t^u + R_{t-1} B_{t-1}^u + T_t \tag{3.42}$$

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:

$$\frac{1}{c_t^u} = \beta E_t \left(\frac{R_t}{\pi_{t+1} c_{t+1}^u \Delta_{t+1}^A} \right) \tag{3.43}$$

$$w_t^u = (L_t^u)^{\varphi - 1} c_t^u \tag{3.44}$$

$$\frac{j}{H_t^u} = \frac{q_t}{c_t^u} - \beta E_t \frac{q_{t+1}}{c_{t+1}^u} \tag{3.45}$$

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.

Households - Impatient households (constrained)

Impatient households maximise their utility by choosing:

$$\max_{C_t^c, H_t^c, L_t^c, B_t^c, B_t^f} \mathbb{E}_0 \sum_{t=0}^{\infty} \widetilde{\beta}^t \left(\ln C_t^c + j \ln H_t^c - \frac{(L_t^c)^{\varphi}}{\varphi} \right) \tag{3.46}$$

subject to the budget constraint

$$P_t C_t^c + Q_t \left(H_t^c - H_{t-1}^c \right) + R_{t-1} B_{t-1}^c + S_t \Phi_{t-1} R_{t-1}^f B_t^f \leq W_t^c L_t^c + B_t^c + S_t B_{t+1}^f \tag{3.47}$$

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 $b_t^f = S_t B_{t+1}^f / P_t^d A_t$, the budget constraint becomes

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

The maximisation problem is also subject to the borrowing constraint:

$$R_t B_t^c + S_t \Phi_{t-1} R_{t-1}^f B_t^f \leq LTV E_t Q_{t+1} H_t^c \tag{3.48}$$

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 $b_t^f = S_t B_{t+1}^f / P_t^d A_t$, the borrowing constraint becomes

$$R_t b_t^c \leq LTV E_t \pi_{t+1} q_{t+1} H_t^c \Delta_{t+1}^A - \frac{s_t \Phi_{t-1} R_{t-1}^f b_{t-1}^f A_{t-1}}{\bar{\pi}_t p_t A_t}$$

Four equations characterise the first order conditions for impatient households:

$$\frac{1}{c_t^c} = \widetilde{\beta} E_t \left(\frac{R_t}{\pi_{t+1} c_{t+1}^c \Delta_{t+1}^A} \right) + \Omega_t' R_t \tag{3.49}$$

$$w_t^c = (L_t^c)^{\varphi - 1} c_t^c \tag{3.50}$$

$$\frac{j}{H_t^c} = \frac{q_t}{c_t^c} - \widetilde{\beta} E_t \frac{q_{t+1}}{c_{t+1}^c} - \Omega_t' LTV E_t \pi_{t+1} q_{t+1} \Delta_{t+1}^A \tag{3.51}$$

$$\frac{1}{c_t^c} = \widetilde{\beta} \frac{s_{t+1} \Phi_t R_t^f}{c_{t+1}^c \pi_{t+1} \Delta_{t+1}^A} + \Omega_{t+1}' \frac{s_{t+1} \Phi_t R_t^f}{\pi_{t+1} \Delta_{t+1}^A} \tag{3.52}$$

where Ω_t' is the Lagrangian multiplier for the borrowing constraint of impatient households, and $c_t^c = C_t^c / A_t$. Equations (3.49) 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.

3.3.20 Balance of Payments - A country with net external liabilities

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

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

where the left-hand side captures outflows, and the right-hand side reflects the inflow of money into the domestic economy. $S_t B_{t+1}^f$ defines the additional net foreign liabilities in domestic currency units and $S_t [\Phi_{t-1} R_{t-1}^f] A_t^f$ 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:

$$\frac{s_t R_{t-1}^f \Phi_{t-1} b_{t-1}^f}{\bar{\pi}_t \Delta_t^A} + p_t^m \alpha \left(\frac{p_t}{p_t^m} \right)^\eta c_t = p_t real s_t p_t^x ex_t + b_t^f \tag{3.53}$$

where $b_t^f = \frac{S_t B_{t+1}^f}{P_t^d A_t}$

3.3.21 Risk term - A country with net external liabilities

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

$$\Phi_t = \Phi\left(b_t^f, R_t^f, R_t, \tilde{\phi}_t\right) = \exp\left(\tilde{\phi}_b\left(b_t^f - \bar{b}\right) - \tilde{\phi}_s\left(R_t - R_t^f - \left(R - R^f\right)\right) + \tilde{\phi}_t\right) \tag{3.54}$$

where $\tilde{\phi}_b > 0$, and it implies that if $b_t^f > \bar{b}$, then the cost of foreign liabilities in domestic currency units is high and will lead to a reduction in net foreign liabilities, b_t^f, held by domestic residents. On the other hand, if $b_t^f < \bar{b}$, 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.

3.4 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 L. J. 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 3.5.

Table 3.5: 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

3.5 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.

3.5.1 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.

General findings

Figure 3.4 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).

The impulse response functions in Figure 3.5 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.

Figure 3.4: Foreign interest rate shock

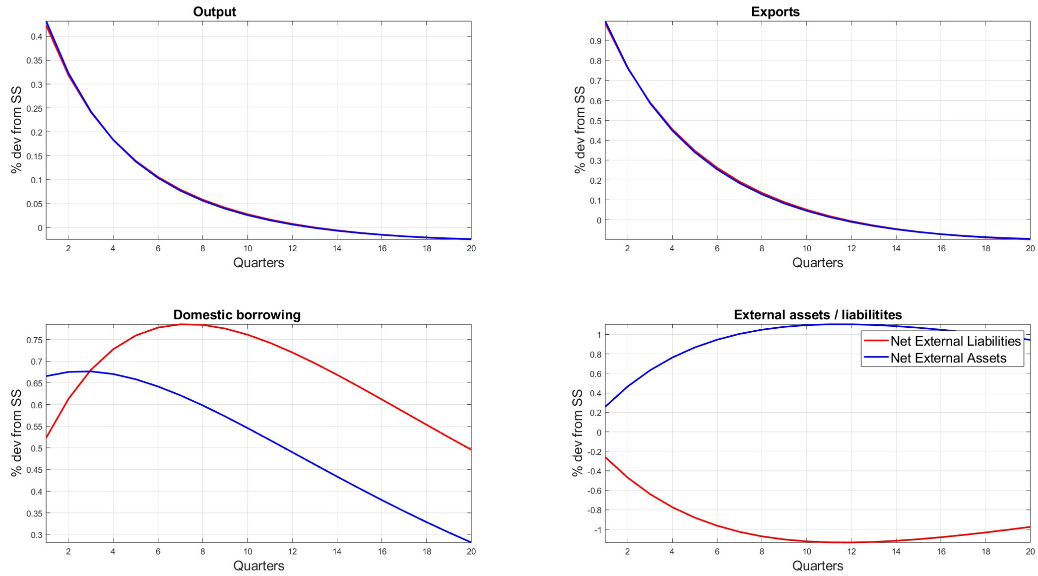

Figure 3.4. Impulse responses to the foreign interest rate shock, $\varepsilon_{R_t^f} = 0.0025$. The unit on the y-axis is in terms of percentage points deviation from the steady state.

Figure 3.5: Monetary policy shock

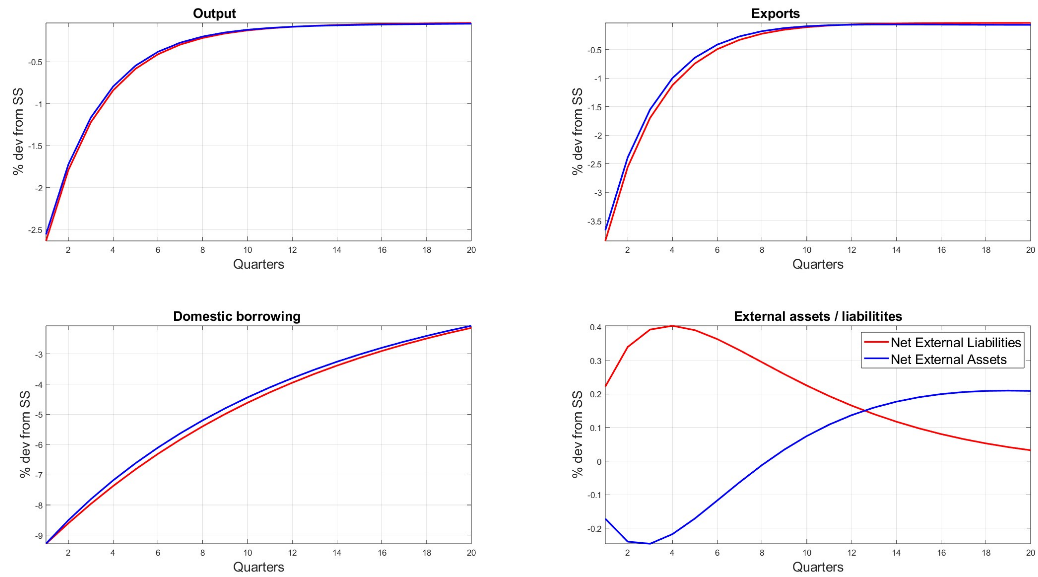

Figure 3.5. Impulse responses to the monetary policy shock, $\varepsilon_{R_t} = 0.0025$. The unit on the y-axis is in terms of percentage points deviation from the steady state.

The 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 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 3.6, 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.

Figure 3.6: Risk premium shock

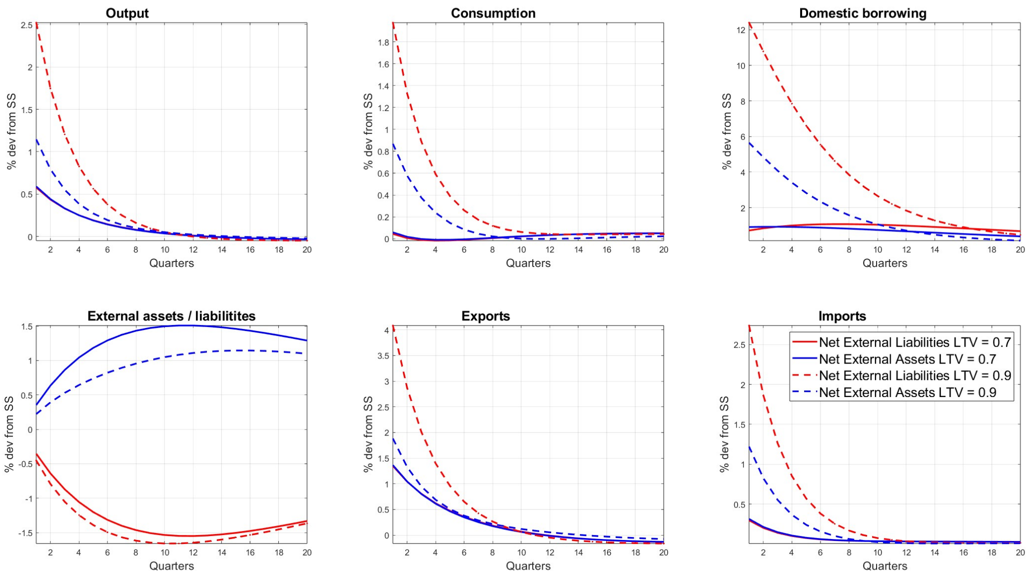

Figure 3.6. Impulse responses to a risk premium shock, $\varepsilon_{\Phi_t} = 0.001$. The unit on the y-axis is in terms of percentage points deviation from the steady state. The solid lines are the baseline model, and the dotted lines are the alternative.

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 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 3.7 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 3.7: Foreign interest rate shock

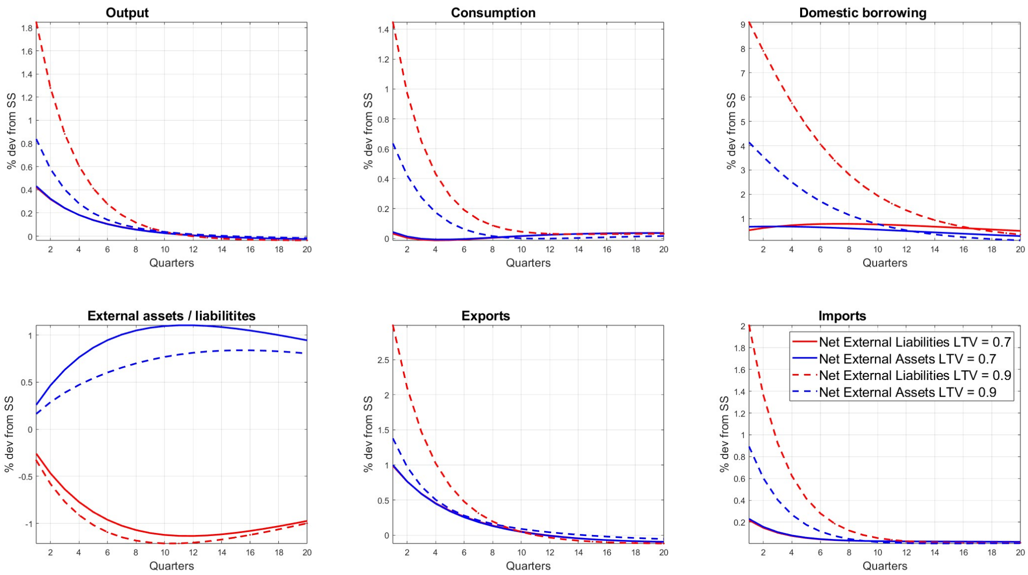

Figure 3.7. Impulse responses to the foreign interest rate shock, $\varepsilon_{R_t^f} = 0.0025$. The unit on the y-axis is in terms of percentage deviation from the steady state. The solid lines are the baseline model, and the dotted lines are the alternative.

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 3.8 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.

Figure 3.8: Foreign demand shock

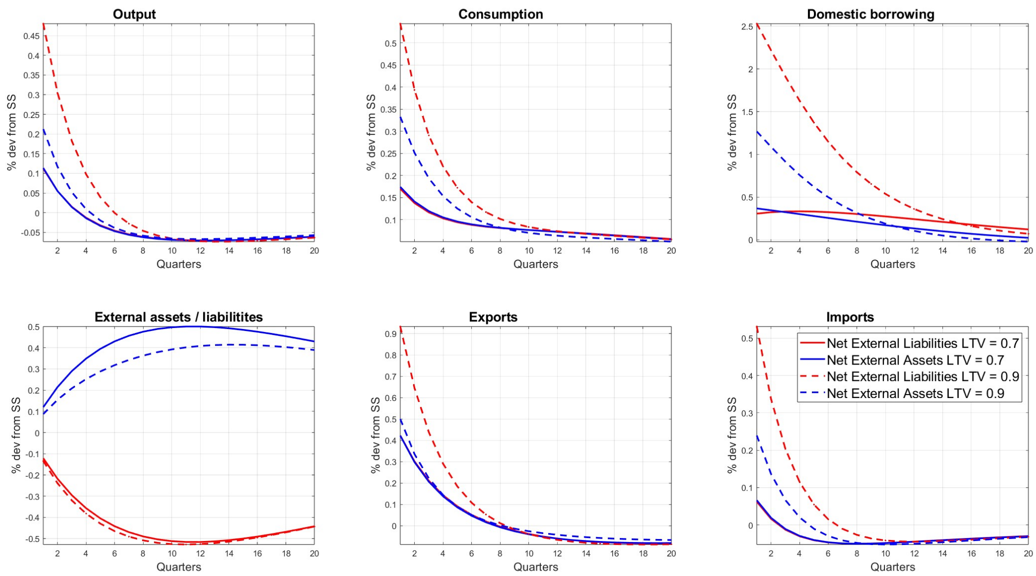

Figure 3.8. Impulse responses to a foreign demand shock, $\varepsilon_{Y_t^f} = 0.01$. The unit on the y-axis is in terms of percentage points deviation from the steady state. The solid lines are the baseline model and the dotted lines are the alternative.

Relaxation in the LTV ratio to 0.9 results in a much more significant deviation from the steady state 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 3.9 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 3.9: Domestic technology shock

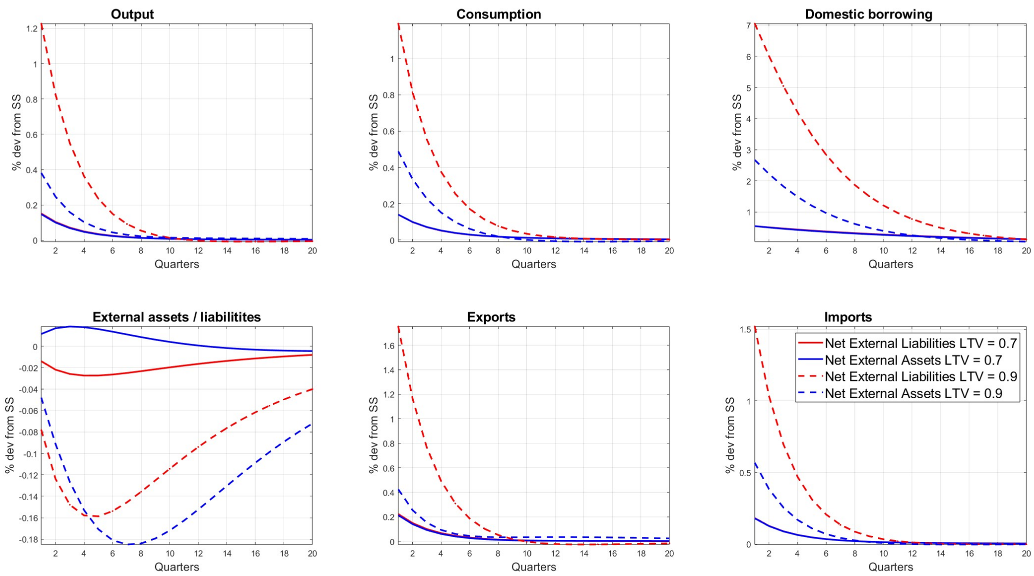

Figure 9. Impulse responses to a domestic technology shock, $\varepsilon_{\Delta_t^A} = 0.001$. The unit on the y-axis is in terms of percentage points deviation from the steady state. The solid lines are the baseline model, and the dotted lines are the alternative.

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.

Variance decomposition

This subsection provides a variance decomposition analysis to understand the relative importance of all four shocks that I have discussed earlier in explaining the dynamics of the model and the impulse response functions. I have normalised the size of all shocks that will give the same impact on output in period 1. The variance decomposition analysis shows that external lending or external borrowing is significantly influenced by the foreign interest rate and the domestic risk premium. Meanwhile, domestic borrowing is mainly driven by the domestic technology shock and foreign demand.

3.5.2 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:

$$W_{u,t} \equiv E_0 \sum_{t=0}^{\infty} \beta^t \left(\ln C_t^u + j \ln H_t^u - \frac{(L_t^u)^{\varphi}}{\varphi} \right) \tag{3.55}$$

Table 3.6: Variance decomposition

Net external assets					
		LTV = 0.7			
Period	Variable	ε_{Φ_t}	$\varepsilon_{R_t^f}$	$\varepsilon_{Y_t^f}$	$\varepsilon_{\Delta_t^A}$
1	Output	0.25	0.25	0.25	0.25
	Consumption	0.27	0.02	0.73	0.02
	Domestic borrowing	0.55	0.07	0.32	0.07
	External assets / liabilities	0.04	0.19	0.61	0.19
	Exports	0.08	0.20	0.52	0.20
	Imports	0.63	0.12	0.14	0.12
10	Output	0.21	0.25	0.30	0.25
	Consumption	0.16	0.00	0.84	0.00
	Domestic borrowing	0.35	0.14	0.37	0.14
	External assets / liabilities	0.01	0.20	0.60	0.20
	Exports	0.07	0.23	0.48	0.23
	Imports	0.53	0.10	0.28	0.10

Net external liabilities					
		LTV = 0.7			
Period	Variable	ε_{Φ_t}	$\varepsilon_{R_t^f}$	$\varepsilon_{Y_t^f}$	$\varepsilon_{\Delta_t^A}$
1	Output	0.25	0.25	0.25	0.25
	Consumption	0.27	0.03	0.72	0.03
	Domestic borrowing	0.48	0.08	0.36	0.08
	External assets / liabilities	0.00	0.20	0.61	0.20
	Exports	0.08	0.20	0.52	0.20
	Imports	0.62	0.12	0.14	0.12
10	Output	0.21	0.25	0.30	0.25
	Consumption	0.17	0.00	0.83	0.00
	Domestic borrowing	0.42	0.12	0.33	0.12
	External assets / liabilities	0.00	0.20	0.60	0.20
	Exports	0.07	0.23	0.48	0.23
	Imports	0.54	0.10	0.27	0.10

and

$$W_{c,t} \equiv E_0 \sum_{t=0}^{\infty} \widetilde{\beta}^t \left(\ln C_t^c + j \ln H_t^c - \frac{(L_t^c)^{\varphi}}{\varphi} \right) \tag{3.56}$$

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

$$W_t = (1-\beta)W_{u,t} + (1-\widetilde{\beta})W_{c,t} \tag{3.57}$$

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:

$$CE_u = \exp\left[(1-\beta)(W_u^{LTV} - W_u^{LTV=0.3})\right] - 1 \tag{3.58}$$

$$CE_c = \exp\left[(1-\widetilde{\beta})(W_c^{LTV} - W_c^{LTV=0.3})\right] - 1 \tag{3.59}$$

and social welfare is defined as:

$$CE = \exp\left[(W^{LTV} - W^{LTV=0.3})\right] - 1 \tag{3.60}$$

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.

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 3.10. 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.

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 3.11. 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,

Figure 3.10: Welfare - Foreign demand shock

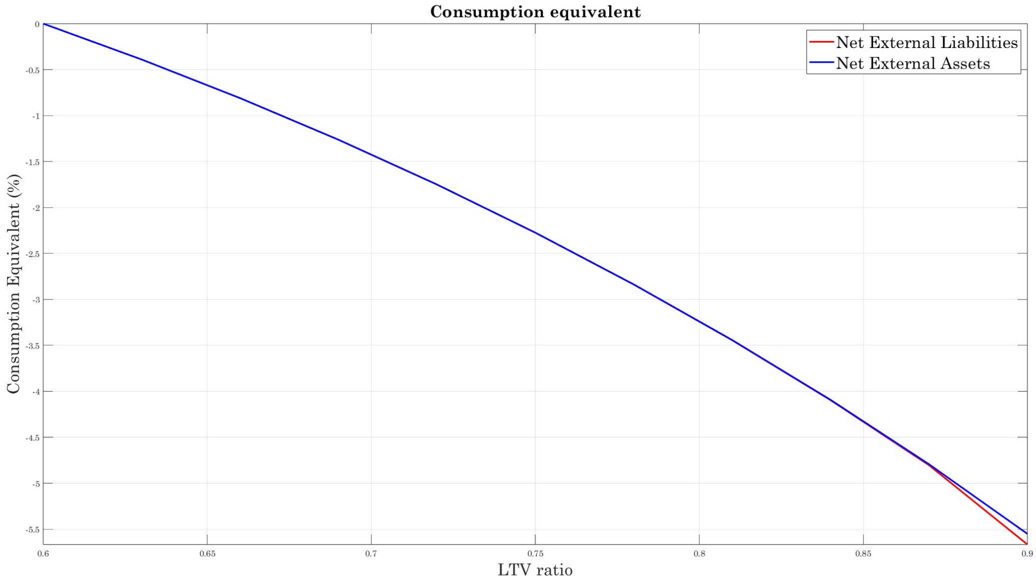

Figure 3.10. The figure shows welfare in terms of consumption equivalent over a range of LTV ratios following a foreign demand shock, $\varepsilon_{Y_t^f} = 0.01$. The unit on the y-axis is in terms of consumption equivalent (CE) from the benchmark economy. The blue line is for a country with net external assets, and the red line is for a country with net external liabilities.

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.

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 3.12. 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.

Figure 3.11: Welfare - Domestic technology shock

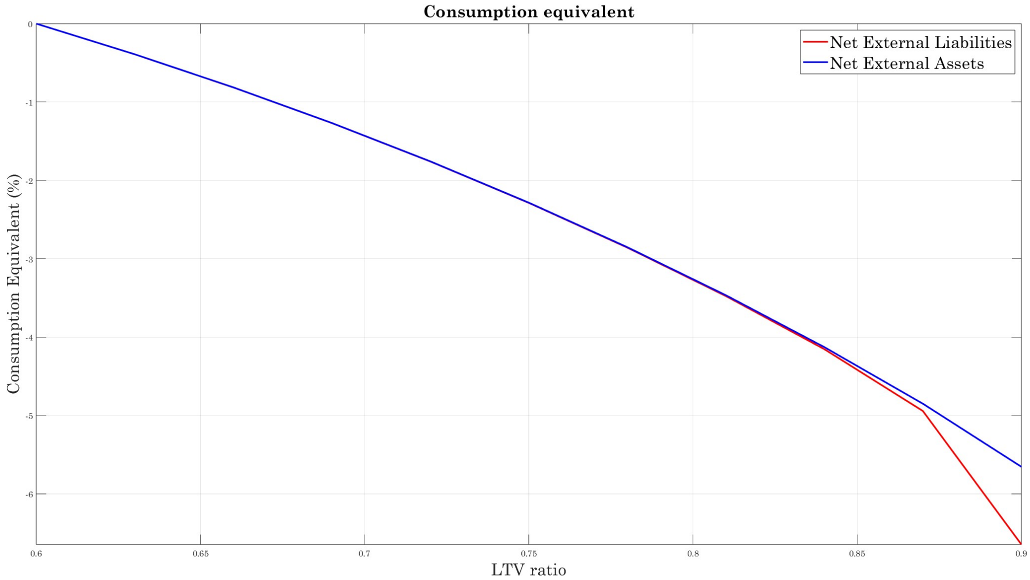

Figure 3.11. The figure shows welfare in terms of consumption equivalent over a range of LTV ratios following a domestic technology shock, $\varepsilon_{\Delta_t^A} = 0.0001$. The unit on the y-axis is in terms of consumption equivalent (CE) from the benchmark economy. The blue line is for a country with net external assets, and the red line is for a country with net external liabilities.

Figure 3.12: Welfare - Foreign interest rate shock

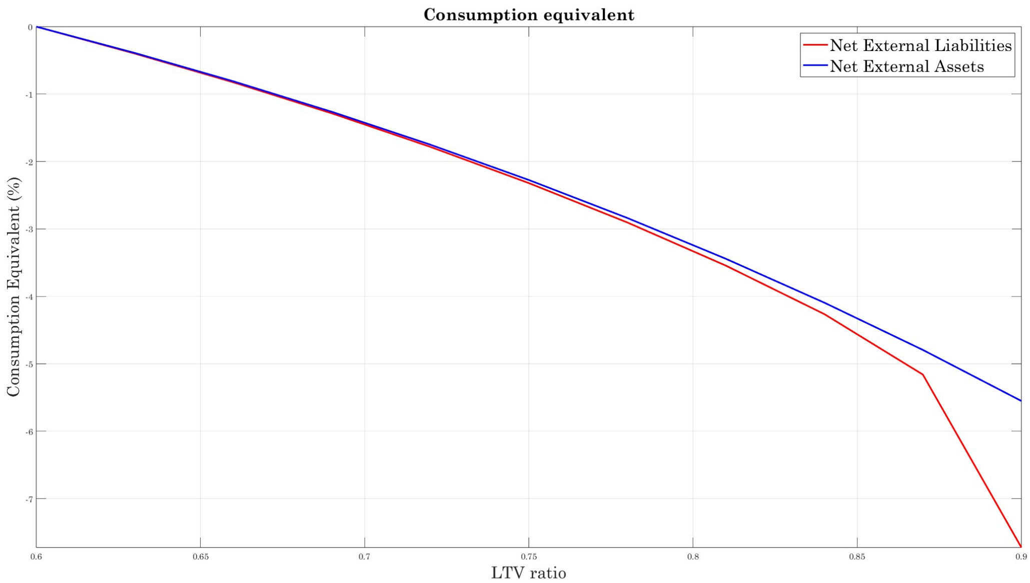

Figure 3.12. The figure shows welfare in terms of consumption equivalent over a range of LTV ratios following a foreign interest rate shock, $\varepsilon_{R_t^f} = 0.0025$. The unit on the y-axis is in terms of consumption equivalent (CE) from the benchmark economy. The blue line is for a country with net external assets, and the red line is for a country with net external liabilities.

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 they set the ratio at 0.9 and deviate from their optimal LTV ratios for various magnitudes of the shocks. Table 3.7 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.

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

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

Fixed LTV rule : $LTV = 0.7$

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

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 effec-

Table 3.7: 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

tive in stabilising credit growth and output compared to the credit growth augmented LTV rule. The reason being is that 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, 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.

Augmented LTV - Foreign interest rate shock

Figure 3.13 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 3.13: Augmented LTV - Foreign interest rate shock

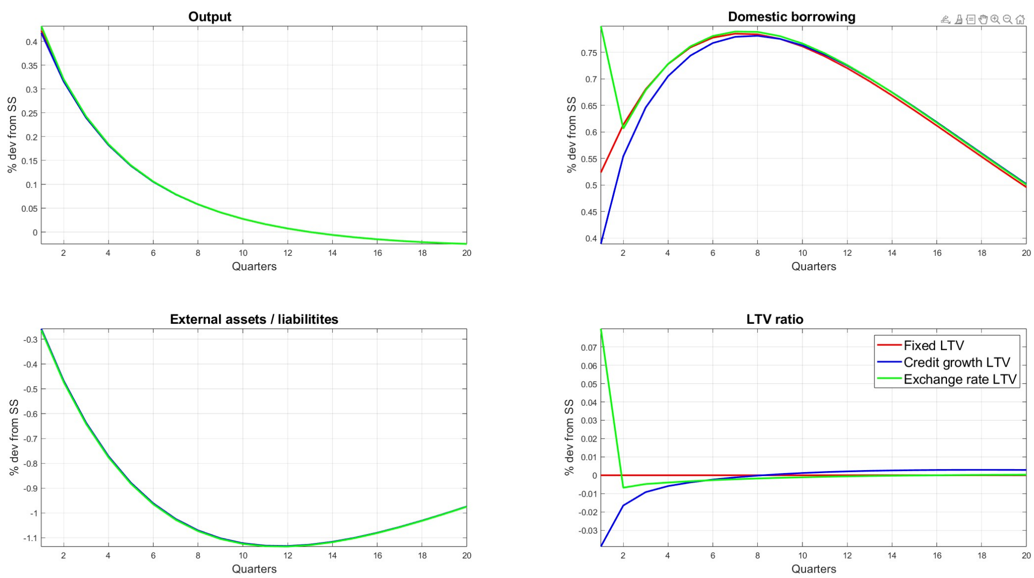

Figure 3.13. Impulse responses to the foreign interest rate shock, $\varepsilon_{R_t^f} = 0.0025$. The unit on the y-axis is in terms of percentage points deviation from the steady state. The red line represents a fixed LTV rule, the blue line represents a credit growth augmented LTV rule, and the green line represents a nominal exchange rate augmented LTV rule.

Augmented LTV - Foreign demand shock

The impulse response functions in Figure 3.14 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 3.14: Augmented LTV - Foreign demand shock

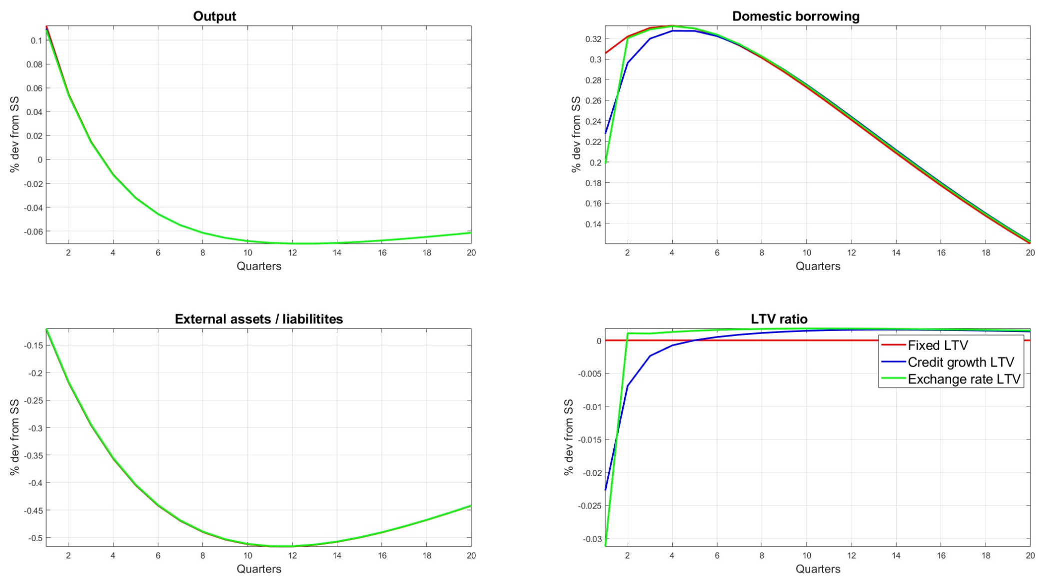

Figure 3.14. Impulse responses to a foreign demand shock, $\varepsilon_{Y_t^f} = 0.01$. The unit on the y-axis is in terms of percentage deviation from the steady state. The red line represents a fixed LTV rule, the blue line represents a credit growth augmented LTV rule, and the green line represents a nominal exchange rate augmented LTV rule.

3.6 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.

3.7 Table A3.1 - A3.3

Table A3.1

	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 A3.2

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 A3.3

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 A3.4

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.

Chapter 4

The Impact of Exchange Rate Movements, Volatility and Intervention: Evidence from Malaysia

4.1 Introduction

The role of the exchange rate as the first line of defence and shock absorber in response to shocks depends on which channel dominates, the trade channel, or the financial channel. The trade channel helps to stabilise macroeconomic variables through the expenditure switching mechanism, supported by the conventional Mundell-Fleming framework (Mundell, 1961, Fleming, 1962). However, the financial channel of the exchange rate, which reflects the deterioration of domestic balance sheets due to the presence of unhedged external liabilities, will have a contractionary effect on economic activity, as argued in Eichengreen et al., 2005, Bruno and Shin, 2014 and R. N. Banerjee et al., 2020. These two channels compensate for each other, since exchange rate depreciation makes domestic production more competitive, but at the same time it also tightens domestic financial conditions.

This paper contributes to this debate by evaluating the impact of exchange rate fluctuations on domestic production and bank credit based on micro- and macro-level data from Malaysia. The notable movement in the exchange rate over the past years, where it has depreciated around 50% against the US dollar since its peak in 2012, makes Malaysia an interesting case study, especially given its high degree of openness in both the financial system and trade with the rest of the world.[1] The high degree of openness is critical to unravel the passthrough effect of exchange rate fluctu-

[1] In Southeast Asia region, Malaysia is ranked second to Singapre for the capital account openness according to Chinn-Ito index, with trade to GDP ratio exceeding 100%.

ation in both the real and financial sectors. Although this paper focusses on Malaysia, the results remain relevant and applicable for other countries as well, especially for countries that share similar characteristics or are in a similar stage of development with Malaysia. A dedicated discussion on the effectiveness of policy response to manage exchange rate volatility and capital flows makes this paper relevant to policymakers in other countries as well, to give them a broader perspective in dealing with the same issues in their countries.

The paper employs the local projection method proposed in Jordà, 2005, but extends the framework to include both state- and shock-dependent analyses. The main objective of the paper is to examine the links between exchange rate fluctuations and their volatility on domestic production and bank credit. I also study the effectiveness of the foreign exchange intervention (FXI) in reducing the volatility of the bilateral exchange rate of the Malaysian ringgit (MYR) against the US dollar and the behaviour of Bank Negara Malaysia (the central bank of Malaysia) in dealing with capital flows. Specifically, the paper aims to shed some light on the following questions. First, what is the impact of exchange rate movements on domestic production? Does the impact depend on the size of the tradable sector? Second, what is the impact of exchange rate movement on bank credit? To what extent does the impact of exchange rate movements on bank credit depend on the volatility of the exchange rate and the nature of the shock? Third, how effective is the FXI in moderating the volatility of the exchange rate in Malaysia? And finally, how responsive is the FXI to the movement of capital flows in Malaysia?

This topic remains highly relevant, especially for policymakers, given that there are a myriad of factors that influence the intensity of both the trade and financial channels of the exchange rate. For the trade channel, among the key ones, the responsiveness of domestic economic activity to the movement of the exchange rate depends on the share of the tradable sector (Rodrik, 2008). The strength of the trade channel is also subject to the level of passthrough to export and import prices, as well as the nature of tradable goods (Kearns and Patel, 2016). For the financial channel, the important factor is the degree of dependency on foreign funding, where greater reliance on foreign funding will make domestic balance sheets more vulnerable to exchange rate depreciation, as suggested in Céspedes et al., 2004. Other significant factors that have an important influence on the financial channel include the type of foreign liabilities, debt or non-debt instruments (Georgiadis and Zhu, 2021), and the composition of external liabilities in local or foreign currencies, as shown in Bruno and Shin, 2023.

The initial trigger that causes the fluctuations in exchange rate is also important in how the macroeconomic variables respond subsequently. Associated with the financial channel of the exchange rate, the deterioration in the domestic financial condition after the exchange rate depreciation has been shown to be worse if it is caused by a higher interest rate in the United States, as it leads to greater losses in the balance sheets of domestic borrowers (Iacoviello and Navarro, 2019, S. Banerjee and Mohanty, 2021 and Akinci and Queraltó, 2021). In contrast, exchange rate fluctuations will help stabilise domestic economic activities when the economy is hit by terms of trade shocks, as argued in Broda, 2004 and Carrière-Swallow et al., 2021. Furthermore, previous studies have also shown that the inflation response to changes in the exchange rate is not linear and highly depends on the driver that moves the exchange rate (Forbes et al., 2018 and Carrière-Swallow et al., 2023).

The impact of exchange rate fluctuations on economic activities also depends greatly on the level of volatility of the exchange rate. Heightened exchange rate volatility could create unnecessary uncertainties, which could lead to monetary and financial instabilities, which, in turn, could complicate firms' operating and investment decisions. The volatility of exchange rates has been shown to have an adverse impact on key macroeconomic variables, including productivity, trade flow, investment, and employment, as argued in Aghion et al., 2009, Caglayan and Torres, 2008, Vieira and MacDonald, 2016, Zmami and Ben-Salha, 2015, and Barguellil et al., 2018.[2] The role of the exchange rate as a shock absorber will diminish in the presence of extreme volatility, as the fluctuation in the exchange rate itself becomes a source of real volatility (Gadanecz and Mehrotra, 2013).[3] Based on these findings, it is safe to argue that extreme volatility of the exchange rate could potentially neutralise the positive effect of the trade channel or intensify the negative impact of the financial channel of the exchange rate.

In order to ensure an orderly adjustment of the exchange rate and reduce its volatility, central banks, especially in emerging markets, have accumulated foreign reserves and relied on FXI when necessary. A survey by the Bank for International Settlements (BIS) in 2021 suggests that central banks in emerging markets use FXI primarily to reduce exchange rate volatility, provide liquidity to thin markets, and manage speculative activities.[4] In addition to these reasons, FXI has also been used as a toolkit to manage capital flows, which is essential during stress periods, particularly for countries with a large presence of foreign investors. From a broader point of view, especially in dealing with many challenges, FXI is considered an important toolkit in central banks' policy mix to achieve both financial and monetary stabilities.

The analysis in this paper covers the period of August 2005 to December 2023, a period in which

[2]Aghion et al., 2009 find that the negative relationship between the volatility of the exchange rate and productivity growth depends critically on the level of financial development of a country.

[3]Overshooting behaviour in the exchange rate market could destabilise economic activities if it leads to a sudden stop in capital flows, a balance of payments crisis or exacerbate the impact of structural vulnerabilities in the economy.

[4]FX interventions: Insights from a Markets Committee Workshop chaired by Gerardo García López (Bank of Mexico). Published on 17 May 2022.

the Malaysian authority adopts a managed floating exchange rate regime following the adoption of a pegged exchange rate regime that took place from late 1998 to June 2005.[5] The study is based on publicly available micro- and macro-level data and empirical investigation is performed mainly using the local projection method (LP-OLS). In addition to the baseline linear estimates, the paper also evaluates the non-linear effect of the exchange rate on both domestic production and bank credit in Malaysia. The aim is to establish under which conditions the movement of the exchange rate could accentuate the trade and financial channels on domestic production and bank credit. Furthermore, to obtain more precise estimates of impulse responses, instrumental variables are employed within the local projection framework (LP-IV). The LP-IV framework allows for investigation of the initial trigger that causes fluctuations in the exchange rate and its subsequent impact on bank credit. In this paper, I consider two initial triggers, terms of trade shock and the US financial conditions shock.

The findings of this paper can be summarised as follows. First, the depreciation of the MYR against the US dollar will have a positive medium-term impact on domestic production. The effect is more significant when the size of the tradable sector is relatively larger, suggesting that the impact of the trade channel in Malaysia remains significant. Second, consistent with the financial channel of the exchange rate, I show that a weaker exchange rate will result in declining real bank credit growth. The severity of the negative impact is more pronounced during the extreme volatility period of the exchange rate. Furthermore, estimated using external instruments, the impact of exchange rate depreciation on real bank credit is shock-dependent. The shock-dependent analysis indicates that the effect of exchange rate depreciation on real bank credit is insignificant when the exchange rate fluctuations are triggered by the terms of trade shock, but the impact is much more severe and persistent compared to the baseline estimates if it is caused by the US financial conditions shock. This result suggests that the exchange rate adjustment helps to stabilise the economy when hit by the terms of trade shock, but the exchange rate shock-absorbing role is not evidenced following the tightening in US financial conditions. The result is consistent and corroborates the risk-taking mechanism proposed in Bruno and Shin, 2015, in which tighter financial conditions in the US not only lead to deterioration of the balance sheets of borrowers and the banks' lending capacity, but also negatively affect market participants' willingness to take on additional risk exposure. I also show that FXI is effective in reducing volatility in the exchange rate market, but the potency of FXI is much more significant and lasts longer during the extreme global uncertainty period. Although the results are expected and seem trivial, the results help policymakers to have a broader view on this issue, especially given the relatively active use of FXI in Malaysia. Finally, I

[5] The Malaysian riggit was pegged at 3.80 against the US dollar from September 1998 until June 2005. This decision to fix the currency was made mainly to stabilise it in the aftermath of the Asian financial crisis.

find that the central bank via its FXI operation is very responsive to the movement in capital flows.

The remainder of the paper is organised as follows. Section 4.2 explains the background of the Malaysian economy and describes the datasets as well as the empirical specifications used for the study. Section 4.3 discusses the impact of exchange rate fluctuations on domestic production based on macro-level data, in which the short-run restriction is imposed within the local projection framework. In Section 4.4, I study the relationship between the exchange rate and bank credit based on bank-level data, to examine the financial channel of the exchange rate. Section 4.5 studies the effectiveness of FXI in mitigating the volatility of the exchange rate and the link between FXI and capital flows. The final section, Section 4.6, concludes the findings of this paper.

4.2 Background of the Malaysian economy

In July 2005, Malaysia started to adopt a managed floating exchange rate regime, about seven years after the authority decided to fix the currency against the US dollar at MYR3.80 per dollar. In the initial period after the decision to float the currency, the MYR was on an appreciation trend against the US dollar, supported mainly by aggressive monetary easing in major economies and strong capital inflows into the country after the global financial crisis. However, the decision of the US Federal Reserve to adjust the pace of its monetary easing in 2013 led to capital outflows from emerging market economies, including Malaysia (Figure 4.1). This was the beginning of a depreciation trend of the MYR against the US dollar. The currency was also affected by other external and domestic factors since then, and the exchange rate stood at the end of December 2023 at MYR4.59 per dollar.[6] Episodes of significant movement of the exchange rate have also usually been accompanied by an increase in volatility. Volatility in this paper is measured using the monthly standard deviation of the change in daily movement in the bilateral exchange rate against the US dollar. Increasing volatility episodes were observed particularly during the global financial crisis, the taper tantrum, and the Covid-19 crisis (Figure 4.2). An interesting observation is that high volatility does not always happen when the exchange rate is depreciating against the US dollar. The increase in volatility is recorded on both ends; it also occurred when the exchange rate is strengthening against the US dollar (Figure 4.3).

The focus of Bank Negara Malaysia since migrated to the managed floating exchange rate regime has been to ensure that exchange rate movements remain orderly and will not be a factor that could

[6]The currency has been affected by factors like (1) the significant movements in commodity prices given the significant share of commodities related industries in the country and (2) the increased in political and policy uncertainties due to the change in government in 2018, the first time since Malaysia gained its independence in 1957.

Figure 4.1: Exchange rate

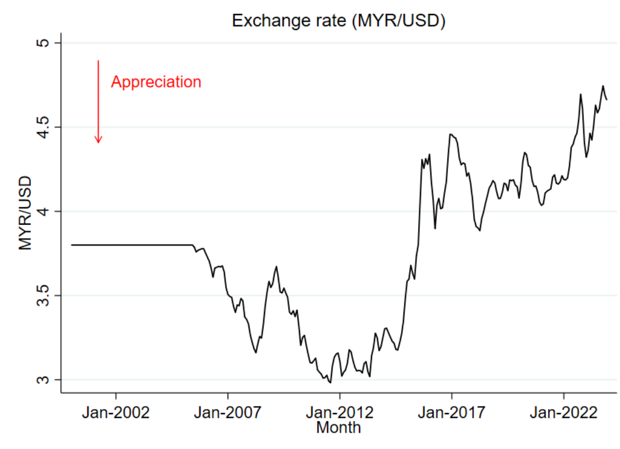

Figure 4.1. The bilateral exchange rate of MYS against the US dollar.

Figure 4.2: Exchange rate volatility

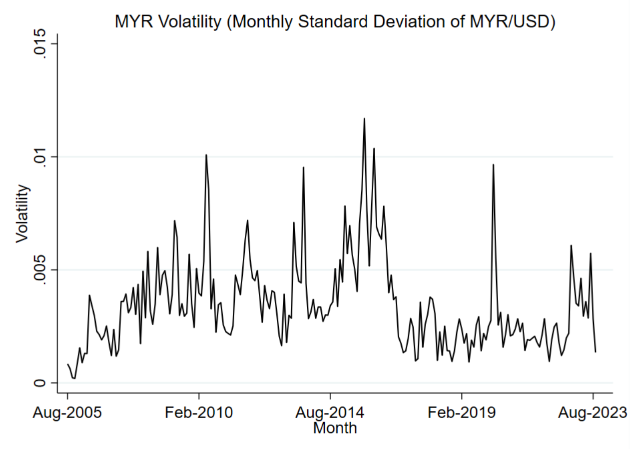

Figure 4.2. The monthly standard deviation of the change in daily movement of MYR against the US dollar.

Figure 4.3: Volatility vs appreciation/depreciation

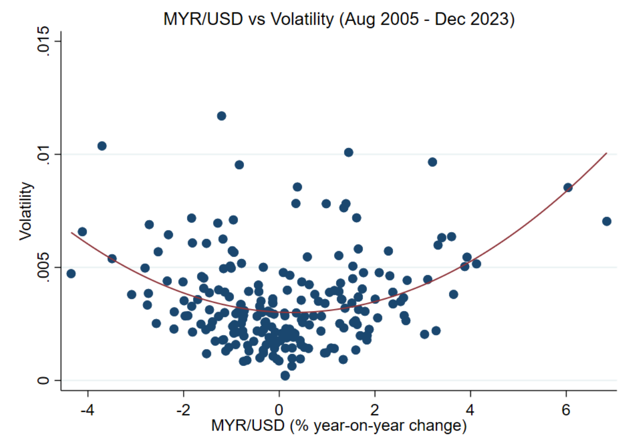

Figure 4.3. Positive (negative) on the x-axis denotes depreciation (appreciation) against the US dollar.

Figure 4.4: Foreign exchange intervention

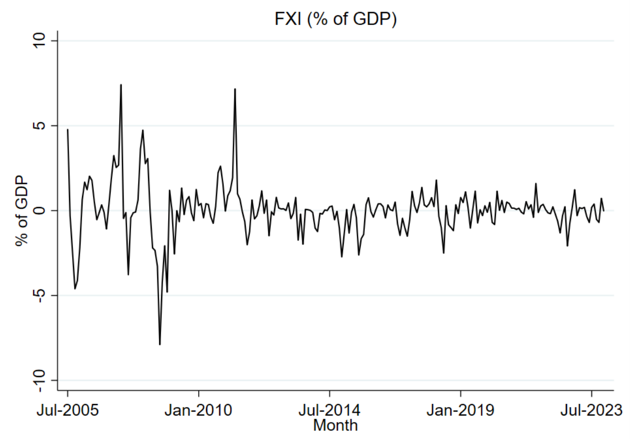

Figure 4.4. Broad monthly FXI as percentage of GDP from 2005 until 2023.

destabilise domestic economic activities (Aziz, 2013). Initially, FXI was extensively used to stabilise the currency, but the growing domestic foreign exchange market, supported by gradual liberalisation in the foreign exchange market, has led to a reduction in the deployment of FXI by Bank Negara Malaysia over time.[7] Like many other central banks, Bank Negara Malaysia does not publish the FXI data, but the estimated size of the monthly FXI as a percentage of GDP calculated by Adler et al., 2021 has shown a significant reduction since 2005 (Figure 4.4).[8] This coincides with the decline

[7]The Malaysian foreign exchange market has increased from an average daily transaction volume of USD 2.3 billion in 2005 to USD 11.3 billion in 2021. These figures are reported in the report entitled Foreign exchange markets in Asia-Pacific. A report by a study group established by the Asian Consultative Council of the Bank for International Settlements published in October 2022.

[8]This paper uses the estimate of broad FXI which encompasses both the spot and derivative transactions as estimated by Adler et al., 2021 using data reported by Bank Negara Malaysia.

in the degree of exchange rate management in Malaysia, from a value of 1 that represents a fixed exchange rate regime against the US dollar in June 2005 to 0.2-0.3 at the end of 2023 (Figure 4.5).[9]

Figure 4.5: Exchange rate management

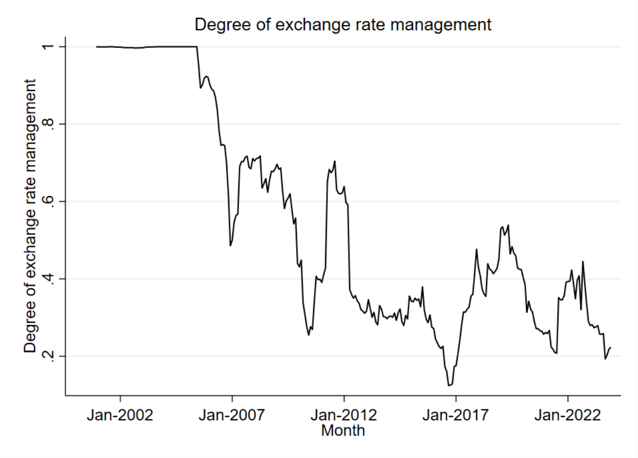

Figure 4.5. Degree of exchange rate management for MYR against the US dollar.

Figure 4.6: FXI in selected Asian countries

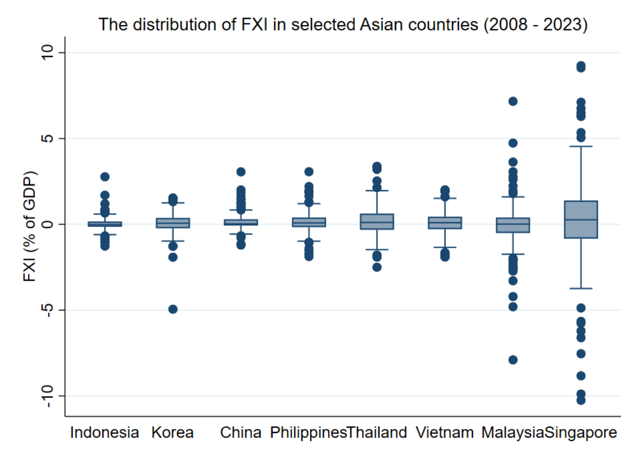

Figure 4.6. The monthly FXI as percentage of GDP in selected Asian countries.

Figure 4.7: Exchange rate management

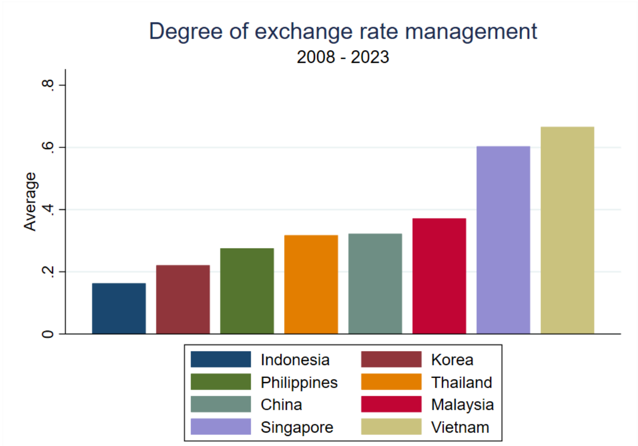

Figure 4.7. Degree of exchange rate management against the US dollar in selected Asian countries.

Figure 4.8: Capital account openness

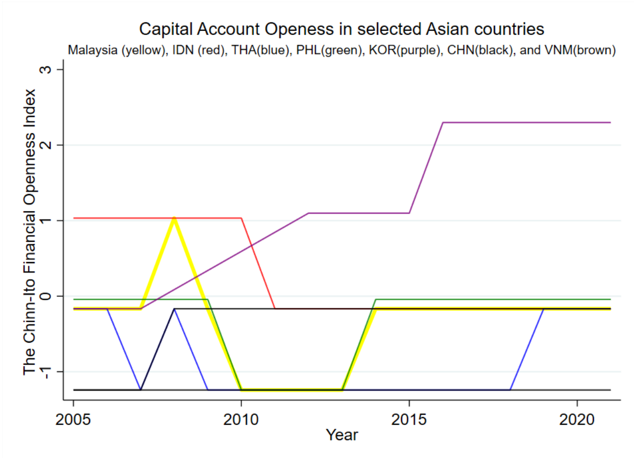

Figure 4.8. The degree of capital account openness in selected Asian countries.

However, despite the reduction in the magnitude of FXI since 2005, Bank Negara Malaysia remains one of the most active central banks in the foreign exchange market compared to other neighbouring countries in the region. In terms of the size of FXI between 2008 and 2023, measured by its aggregate intervention and distribution, Malaysia is ahead of all other countries except Singapore (Figure 4.6). Unlike many countries including Malaysia, where monetary policy is established by adjusting the policy interest rate, the Monetary Authority of Singapore is very active in the foreign exchange market due to its monetary policy operating framework, which is focused on managing

[9] The computation of the degree of exchange rate management followed Adler et al., 2021 and is defined as Standard deviation of FXI / (Standard devition of FXI + Standard deviation of MYRUSD).

the Singapore dollar against a basket of currencies. This is the main reason for the large FXI in Singapore. Similarly, the degree of exchange rate management between 2008 and 2023 suggests that Malaysia is higher than many countries in the region (Figure 4.7).[10] This is despite the fact that other countries in the region have a more liberal and greater openness in their capital accounts (Figure 4.8).[11]

The Malaysian economy is very open and well integrated in the global economy, with trade as a percentage of GDP exceeding 100% in recent decades (Figure 4.9). The manufacturing sector has been rapidly growing, making Malaysia one of the important countries in the global electronic and electrical (E&E) supply chain and the sixth global leader in semiconductor exports.[12] However, despite the growing manufacturing industry, commodity exports remain large and a significant contributor to export earnings in Malaysia. The share of commodities exports is around 20% in total merchandise exports in 2022 and 2023, mainly supported by petroleum-related products, palm oil, and liquefied natural gas (LNG). As a net commodity exporter country, the movement in global commodity prices has a significant bearing on the exchange rate, as a reflection of the change in Malaysia's terms of trade. This can be clearly seen from the strong comovement of the MYR against the US dollar with global commodity prices (Figure 4.10).[13]

Figure 4.9: Trade (% of GDP)

Figure 4.9. Malaysia's trade as percentage of GDP from 3Q05 to 4Q23.

Figure 4.10: MYR/USD vs oil prices

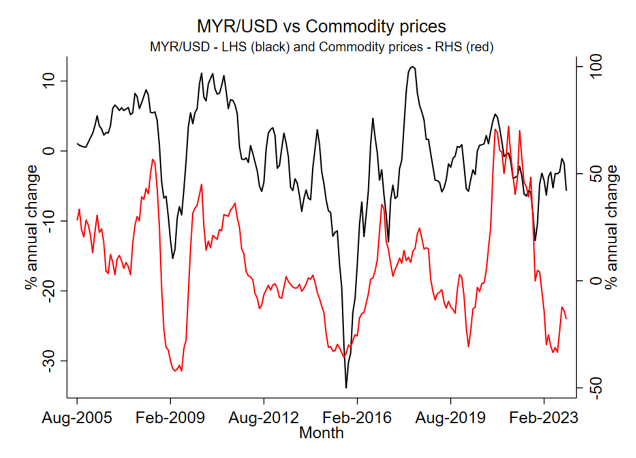

Figure 4.10. Positive (negative) on the x-axis denotes appreciation/higher (depreciation/lower).

[10] The high degree of exchange rate management in Vietnam is due to their exchange rate regime, which is crawling peg, where the currency is adjusted periodically in small amounts at a fixed rate.

[11] The estimations of a country's degree of capital account openness is based on the Chinn-Ito index. The index was originally introduced by Chinn and Ito (Journal of Development Economics, 2006), but has been updated to 2021. The score of 2.30 reflects the most financially open countries, and the score for the least financially open countries is -1.93.

[12] Malaysia also represent 7% of global semiconductor trade and 13% of global chip assembly, testing and packaging activities. For more information, see the Malaysia External Trade Development Corporation (MATRADE) press release entitled The Sky is not The Limit for Malaysia's E&E Trade published on 20 May 2024.

[13] Extracted from the International Monetary Fund (IMF) Primary Commodity Prices database. All Commodity Price Index, 2016 = 100, includes both Fuel and Non-Fuel Price Indices.

Malaysian banks are mainly funded by domestic deposits, with recent data showing a relatively small share of foreign funding of around 8% of total funding, where the majority comes in the form of interbank borrowings. In terms of the exposure of banks to foreign exchange risk, net open positions of FX remained stable around 5% of total capital over the past years, where banks actively use FX swaps, forwards and options to manage their net open positions.[14] This funding structure was the result of reforming the banking system after the Asian financial crises, to ensure that banks are more resilient to shocks and less susceptible to sudden capital flow reversals. The central bank imposed a number of prudential regulations on banks to minimise the risk of currency and maturity mismatches with regard to banks' exposure to exchange rate risk. For example, banks are required to continuously assess their aggregate foreign currency liquidity needs and diversify their funding sources to avoid overreliance on any particular source or tenor for funding. In managing their FX exposure, central bank does not allowed banks and institutional investors to participate in the offshore non-deliverable forward (NDF) markets primarily to minimise speculative activities. Instead, the central bank in 2016 introduced the dynamic hedging programme, as an alternative to NDF markets, to provide market access to institutional investors who wish to actively manage the FX exposures of their ringgit assets. This is critical given that Malaysia's bond market is one of the largest in the region and has attracted a lot of interest from foreign investors.

4.2.1 Data and empirical specifications

This section discusses the use of data and empirical specifications in this paper. For the analysis to estimate the impact of exchange rate fluctuations on domestic production, the sample contains monthly macro-level data covering the period of August 2005 until December 2023. The variables are the industrial production index, bilateral exchange rate of MYR against the US dollar, gross merchandise export, the domestic stock market index, credit to GDP, the index of global commodity prices, and the index of world industrial production. The first four variables are taken from Bank Negara Malaysia and CEIC. The monthly credit to GDP is extrapolated from the quarterly credit to GDP data published by the BIS.[15] The global commodity price is based on the IMF Primary Commodity Prices database, and the monthly index of world industrial production is estimated in Baumeister and Hamilton, 2019. In addition to the baseline model, this paper also considers a state-dependent variable to identify under which circumstances domestic production becomes more responsive to exchange rate fluctuations. In a robustness exercise, this paper uses quarterly

[14] Bank Negara Malaysia's Financial Stability Review 2nd Half 2024

[15] The data uses in this paper is BIS' credit from all sectors to non financial sector at market value, percentage of GDP, adjusted for breaks.

GDP and the same control variables to analyse the impact of exchange rate fluctuations on domestic economic activities.

For the second part of the analysis, to study the impact of exchange rate fluctuations on bank credit, the sample contains quarterly micro- and macro-level data covering the period of 3Q05 until 4Q23. The bank-level data are sourced from the LSEG Datastream, where the article compiles the data set of the eight largest publicly listed domestic banks in Malaysia. The eight banks are Affin Bank, Alliance Bank Malaysia, AMMB Holdings, Bank Islam Malaysia, CIMB Group Holdings, Hong Leong Financial Group, Malayan Banking, Malaysia Building Society, Public Bank, and RHB Bank. The data set consists of net loans, profit, deposit, and level of equity of all respective banks. The aggregate bank credit of these eight banks represent more than 70% of the total outstanding credit from all sectors to the private non-financial sector in Malaysia. In addition to bank-level data, control variables include GDP growth, monetary policy stance, capital flows, and real house prices. The first three variables are taken from CEIC, and real house prices are sourced from BIS.[16] This article also studies state- and shock-dependent variables to discover the different sensitivity of bank credit to exchange rate fluctuations. The shock-dependent analysis is performed via external instruments. The aim is to study how bank credit reacts differently to the initial triggers that caused fluctuations in exchange rates. The analysis considers two types of shock and is performed based on the quarterly oil supply news shock developed in Känzig, 2021 and the US financial conditions index estimated in Ajello et al., 2023. These two series represent the terms of trade shock and the US financial conditions shock.

The final part of the analysis focusses on the effectiveness of FXI in reducing exchange rate volatility and the responsiveness of FXI to the movement of capital flows. These analyses use monthly data, and the monthly capital flows data for the Malaysian bond market are taken from CEIC. In terms of the model specifications for all the above analyses, the baseline linear LP-OLS model follows Jordà, 2005, with state- and shock-dependent specifications closely adopted from Alpanda et al., 2021 and Carrière-Swallow et al., 2023, respectively. The shock-dependent study is performed using the news oil supply shock and the US financial conditions index as external instrument variables within the LP-IV framework.

[16]The data uses in this paper is BIS' Malaysia - Selected residential property prices, Real, Index, 2010 = 100.

4.3 Exchange rate and production

In this section, I describe the empirical framework for analysing the impact of exchange rate fluctuations on domestic production, followed by the discussion on the empirical results. First, I describe the methodology for linear estimation and its result. Then I discuss the state-dependent analysis, to study the non-linearities in the transmission of exchange rate on domestic production. A robustness exercise concludes the discussion of this section.

4.3.1 Baseline model

To study the impact of exchange rate fluctuations on domestic production, I estimate a local projection model proposed in Jordà, 2005. Based on monthly data covering the period August 2005 to December 2023, the specification of the local projection model, with a three-lag, takes the following form:

$$\Delta y_{t+h} = \alpha_h + \psi_h(L) z_t + \beta_h \Delta ER_{t-1} + \varepsilon_{t+h} \qquad \text{for } h = 0, 1, 2, ..., \tag{4.1}$$

where Δy is the annual change in industrial production index, z is the vector of control variables, $\psi_h(L)$ is a polynomial in the lag operator, and ΔER is the annual change in bilateral exchange rate. α is a contstant. The vector of control variables contains the real export growth, the growth of the stock market index, the annual change in the percentage of credit to GDP, the annual growth of price of global commodities, the monetary policy stance, and the annual growth of the index of world industrial production.[17] The construction of impulse response functions reflects the sequence of coefficients β_h estimated in a series of separate regressions for each horizon, and it represents the average response of domestic production growth to a percentage depreciation in the bilateral exchange rate against the US dollar. For the identification strategy, I imposed short-run restrictions within the local projection framework, which implies that the effect of exchange rate fluctuations on the industrial production index comes with a lag. The paper uses the Newey-West correction for the estimations of standard errors to fix the serial correlation in the error terms induced by the successive leading of the dependent variable.

Figure 4.11 reports the impulse responses of the local projection model for the next 15 months from the time the shock hits, with one standard error confidence intervals. The result shows that a one percent depreciation in the bilateral exchange rate against the US dollar will initially lead to a reduction in domestic production, but will have a positive impact afterwards, especially from

[17] Real export growth is deflated by using the quarterly export deflator.

month 9 and beyond. However, the responses are only statistically significant for month 9. The results of a positive delay response of domestic production are consistent with previous findings in Ibrahim and Mohd Amin, 2005 and Raghavan and Athanasopoulos, 2019. They find that the depreciation of the exchange rate in Malaysia leads to a positive delay effect on domestic production based on structural VAR models. They attributed their results to an inelastic demand to respond immediately to exchange rate adjustments, which negatively affects the trade balance. However, a gradual improvement in the trade balance as a result of the adjustment in export and import demand supports an expansion in domestic production.

Figure 4.11: Impulse response of LP-OLS (Monthly)

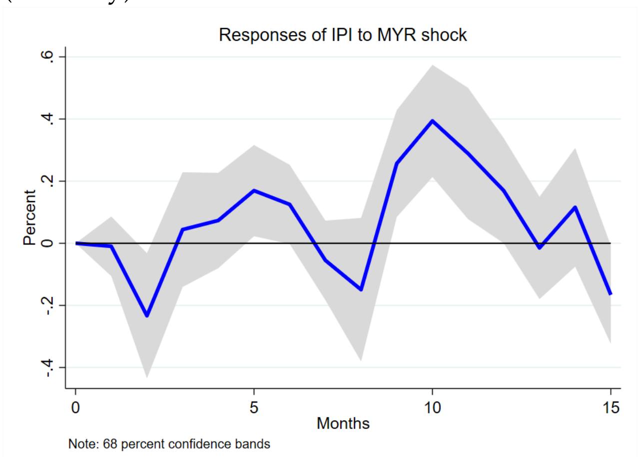

Figure 4.11. Impulse response of domestic production to a one percentage depreciation of MYR against the US dollar.

Figure 4.12: Monthly gross exports (% of GDP)

Figure 4.12. Gross exports as percentage of GDP from August 2005 until December 2023.

4.3.2 State-dependent analysis

The linear specification in Equation (4.1) can be extended to a non-linear setting which allows for a state-dependent analysis, similar to the approaches in Ramey and Zubairy, 2018 and Alpanda et al., 2021. In comparison to regime-switching structural VAR, the state-dependent local projection method is simple to implement and does not require one to take a stand on the duration of a given state or on the mechanism that triggers the transition between states. In this section, the state-dependent local projection specification is given as follows:

$$\begin{aligned}\Delta y_{t+h} = & I_t\left[\alpha_{A,h} + \psi_{A,h}(L)z_t + \beta_{A,h}\Delta ER_{t-1}\right] \\ & + (1-I_t)\left[\alpha_{B,h} + \psi_{B,h}(L)z_t + \beta_{B,h}\Delta ER_{t-1}\right] + \varepsilon_{t+h}\end{aligned} \tag{4.2}$$

where Δy is the annual change in industrial production index, z is the vector of control variables, $\psi_h(L)$ is a polynomial in the lag operator, and ΔER is the annual change in bilateral exchange rate.

The vector of control variables contains the real export growth, the growth of the stock market index, the annual change in the percentage of credit to GDP, the annual growth of price of global commodities, the monetary policy stance, and the annual growth of the index of world industrial production. I is a dummy variable that indicates the state of the economy when the shock hits. The construction of impulse response functions reflects the sequence of coefficients $\beta_{A,h}$ and $\beta_{B,h}$ estimated in a series of separate regressions for each horizon, where they represent the average effects of the exchange rate depreciation conditional on the state of the economy. Similar to before, I imposed short-run restrictions in the local projection framework, implying that the effect of exchange rate fluctuations on the industrial production index comes with a lag. The standard errors are estimated by using the Newey-West correction method.

In this state-dependent analysis, I am interested in studying the effect of exchange rate fluctuations on domestic production depending on the size of the tradable sector. The size of the tradable sector is represented by the share of gross monthly exports to GDP as shown in Figure 4.12. I distinguish the periods of high and low share of the tradable sector depending on whether the share is above or below the median. The median value of gross exports as a percentage of GDP during the period is 6.6%. In this setup, the dummy variable I takes a value of 1 during a high share of tradable goods and takes a value of 0 during a low share of tradable goods. Figure 4.13 shows the impulse responses of the state-dependent local projection model, with one standard error confidence intervals. The dashed blue line reflects the impulse response of a low share of the tradable sector, and the solid purple line reflects the impulse response of a high share of the tradable sector. The result shows that domestic production is more sensitive to fluctuations in exchange rates when the share of the tradable sector is large. In particular, the positive impact from exchange rate depreciation happens much quicker and last longer compared to when the share of tradable sector is small. The result suggests that the impact of the trade channel in Malaysia remains significant. The coefficients for both linear and non-linear models and their significance levels are reported in Table A4.1.

4.3.3 Robustness check

As a robustness check, I have re-estimated the linear specification in Equation (4.1) using quarterly data. Instead of using the industrial production index, I replace the dependent variable with quarterly data of annual GDP growth. The other specifications, which include short-run restrictions, control variables, and the estimation of standard errors, remain the same as previously discussed. Figure 4.14 reports the impulse responses of the local projection model for the next six quarters from the time the shock hits, with one standard error confidence intervals. The result shows that a one

Figure 4.13: Impulse response of LP-OLS (Non-lin)

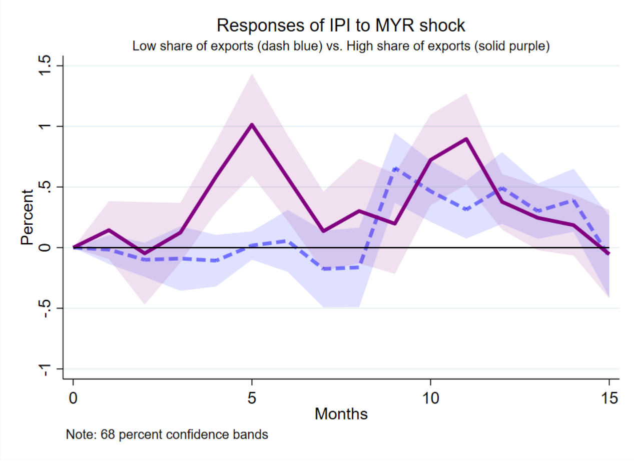

Figure 4.13. Non-linear impulse response of IPI to a one percentage depreciation of MYR againts the US dollar.

Figure 4.14: Impulse response of LP-OLS (Quarterly)

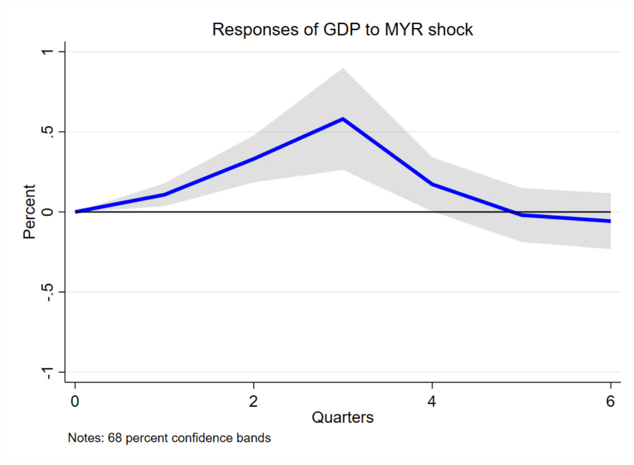

Figure 4.14. Impulse response of GDP to a one percentage depreciation of MYR against the US dollar.

percent depreciation in the bilateral exchange rate leads to an improvement in domestic production, especially in quarters 2 and 3, which are statistically significant at 1% and 5% levels. The positive impact diminishes from quarter 4 onwards. The results roughly mimic the results estimated using the monthly data, where the positive impact peaks on month 10, and the impact diminishes afterwards. This finding indicates that the impact of the trade channel in Malaysia remains significant and more dominant compared to the financial channel of the exchange rate.

4.4 Exchange rate and bank credit

In this section, I describe the empirical framework for analysing the impact of exchange rate fluctuations on real bank credit and the results. The baseline linear analysis is presented first, which is then followed by state- and shock-dependent analyses.

4.4.1 Baseline model

To study the impact of exchange rate fluctuations on real bank credit, I estimate a panel local projection model based on quarterly data covering the period 1Q05 to 4Q23. The specification of the panel local projection model, with a three-lag, takes the following form:

$$\Delta y_{i,t+h} = \alpha_{i,h} + \psi_h(L) z_{i,t-1} + \beta_h \Delta ER_t + \varepsilon_{i,t+h} \qquad \text{for } h = 0, 1, 2, ..., \tag{4.3}$$

where Δy is the annual change in real bank credit of domestic banks in Malaysia, z is the vector of control variables, $\psi_h(L)$ is a polynomial in the lag operator, and ΔER is the annual change in bilateral exchange rate.[18] $\alpha_{i,h}$ is a bank fixed effect, which captures time invariant bank heterogeneity, such as number of employment, geographical presence etc. For the identification strategy, I follow Longaric, 2022 and Carrière-Swallow et al., 2023, where the vector of control variables are known prior to the exchange rate shock. This identification setup is critical for the shock dependent analysis that will be discussed later. The vector of control variables contains the real GDP growth, the monetary policy stance, capital flows, real house prices, and banks' specific variables. Banks' data include real profit, real deposit, and level of real equity.[19] The construction of impulse response functions reflects the sequence of coefficients β_h, and the impulse response functions represent the average response of real bank loan growth to a percentage depreciation in the bilateral exchange rate against the US dollar. Standard errors are clustered at the bank level.

Figure 4.15 reports the impulse responses of the local projection model for the eight quarters from the time the shock hits, with one standard error confidence intervals. The result shows that a one percent depreciation in the bilateral exchange rate against the US dollar will initially lead to an immediate positive response in real bank credit, but the impact turns negative from the first quarter onwards. The negative impact will peak in quarter four and become smaller from there onwards. The results are consistent with the presence of the financial channel of the exchange rate, where depreciation leads to both deterioration in the balance sheets of domestic borrowers and reduction in domestic banks' lending capacity. The coefficients for the linear models and their significance levels are reported in Table A4.2.

Figure 4.15: Impulse response of panel LP-OLS

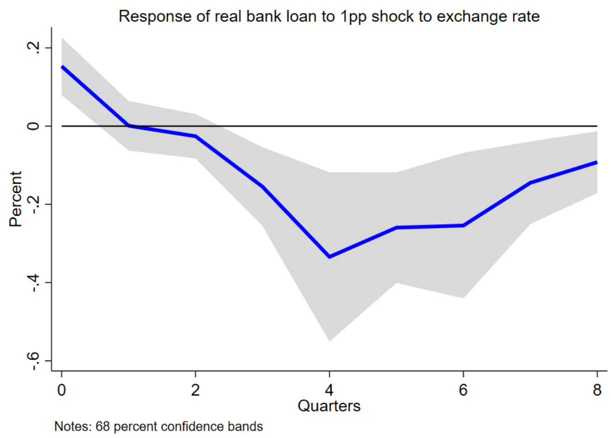

Figure 4.15. Impulse response of real bank credit to a one percentage depreciation of MYR againts the US dollar.

[18]Real bank credit growth is deflated by using the quarterly consumer price index (CPI).
[19]Real bank profit, real bank deposit and level of real equity are deflated by using the quarterly CPI.

4.4.2 State-dependent analysis

The linear specification in Equation (4.3) can also be extended to a non-linear setting which allows for state-dependent analysis. In this section, the analysis focuses on the impact of exchange rate volatility on real bank credit. This is motivated by previous findings based on data from other countries, which show the adverse impact of extreme exchange rate volatility on various macrovariables. The analysis aims to explore the relationship between the volatility of the exchange rate and real bank credit and under what circumstances that volatility of the exchange rate could intensify the financial channel of the exchange rate. The state-dependent panel local projection specification is given as follows:

$$\begin{aligned}\Delta y_{i,t+h} =& F(x_{t-1})\left[\alpha_{A,i,h} + \psi_{A,h}(L)z_{i,t-1} + \beta_{A,h}\Delta ER_t\right] \\ &+ (1 - F(x_{t-1}))\left[\alpha_{B,i,h} + \psi_{B,h}(L)z_{i,t-1} + \beta_{B,h}\Delta ER_t\right] + \varepsilon_{i,t+h}\end{aligned} \tag{4.4}$$

where Δy is the annual change in real bank credit of domestic banks in Malaysia, z is the vector of control variables, $\psi_h(L)$ is a polynomial in the lag operator, where the vector of control variables are known prior to the exchange rate shock. ΔER is the annual change in bilateral exchange rate. The vector of control variables contains the real GDP growth, the monetary policy stance, capital flows, real house prices, and banks' specific variables. Banks' data include real profit, real deposit, and level of real equity. The construction of impulse response functions reflects the sequence of coefficients $\beta_{A,h}$ and $\beta_{B,h}$ estimated in a series of separate regressions for each horizon, where they represent the average effects of the exchange rate depreciation conditional on the state of the economy. Similarly, standard errors are clustered at the bank level.

In terms of model specification, the model closely follows the smooth transition local projection model employed in Tenreyro and Thwaites, 2016. $F(x_{t-1})$ is a smooth increasing function of an indicator of the state of the economy x_t, either in a low or high volatility state, and the logistic function is given as follows:

$$F(x_t) = \frac{exp\left(\theta\frac{(x_t-c)}{\sigma_x}\right)}{1 + exp\left(\theta\frac{(x_t-c)}{\sigma_x}\right)} \tag{4.5}$$

where c is the threshold level and controls what proportion of the sample the economy spends in either state and σ_x is the standard deviation of the state variable x. θ determines how the economy switches from a low to high volatility state depending on x_t. The measurement of the volatility of the exchange rate, x_t, is the quarterly average of the monthly standard deviation of the change in the daily movement of the MYR against the US dollar, as reported in Figure 4.2. I follow Tenreyro and Thwaites, 2016 and set θ = 3 to give an intermediate degree of intensity to the state switching.

For c, two values are explored, the median and the 75th percentile of volatility of the exchange rate. Figure 4.16 plots the transition variables during the sample period. The solid red line represents c as the median and the dashed blue line represents c as the 75th percentile, where 0 reflects the low volatility state and 1 reflects the high volatility state. The frequency of the solid red line to be in the high volatility state is higher compared to the dashed blue line precisely because the threshold level is lower compared to the 75th percentile.

Figure 4.16: Smooth transition pattern

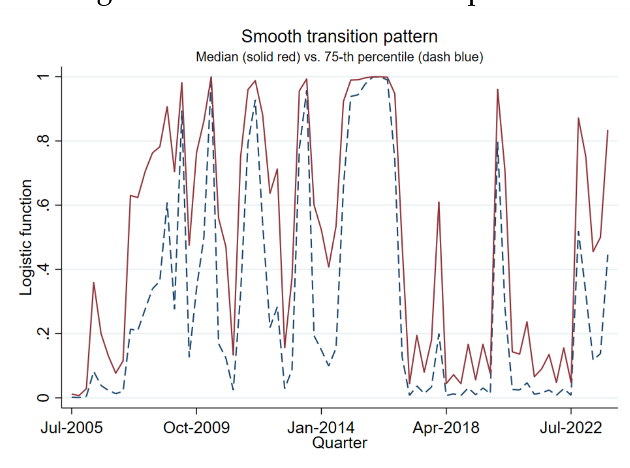

Figure 4.16. Smooth transition pattern of state switching from low to high volatility state. 0 reflects the low volatility state and 1 reflects the high volatility state.

In terms of the underlying factors that are important in explaining the volatility of the exchange rate, I estimated a measure of the volatility spillover using the generalised decomposition of the variance of the forecast error based on the VARs proposed by Diebold and Yilmaz, 2012. Based on four external and two domestic variables, I found that the gross directional volatility spillovers from others to the exchange rate market is 11.95%, in which 70% of the variance of the forecast error from others to the exchange rate can be attributed to external factors.[20] This is not surprising given the integration of Malaysia with the global economy and financial markets.

Figures 4.17 and 4.18 show the impulse responses of the state-dependent panel local projection model, with one standard error confidence intervals. The dashed blue line reflects the impulse response of a low-volatility state, and the solid purple line reflects the impulse response of a high-volatility state. The only difference between the two figures is that Figure 4.17 shows the results when using the median value as the threshold level, and Figure 4.18 is based on the 75th percentile. The impulse responses in the low- and high-volatility states in Figure 4.17 are broadly

[20]The variables are S&P 500, 10-year US Treasury bond yield, the broad US dollar index, Brent crude oil price, domestic stock market index and 10-year Malaysian government bond yield. The annualised daily percent standard deviation is calculated based on daily opening and closing prices, using data from June 2005 to December 2023. The result of the volatility spillover is reported in Table A4.2.

similar, both in terms of direction and intensity. This suggests that the sensitivity of real bank credit to exchange rate volatility is quite similar when I split the sample at the median level. However, impulse responses in low- and high-volatility states determined using the 75th percentile value as the threshold shown in Figure 4.18 suggest that high exchange rate volatility exacerbates the impact of exchange rate depreciation on real bank credit. The adverse impact on real bank credit in high volatility state is more severe and statistically significant compared to those in low volatility state. Based on the results, there is evidence to show that extreme volatility of the exchange rate will result in the intensification of the financial channel of the exchange rate, which in turn could potentially lead to a worse impact on real economy activities. The coefficients for the non-linear model using the 75th percentile value as the threshold and their significance levels are reported in Table A4.3.

Figure 4.17: Impulse response of panel LP-OLS (Non-linear - Median)

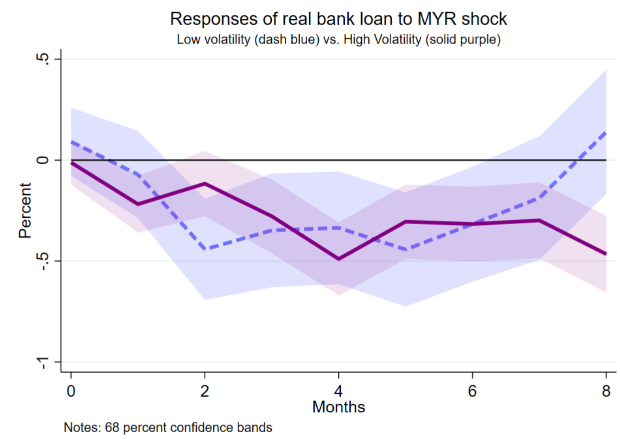

Figure 4.17. Non-linear impulse response of real bank credit to a one percentage depreciation of MYR against the US dollar.

Figure 4.18: Impulse response of panel LP-OLS (Non-linear - 75th percentile)

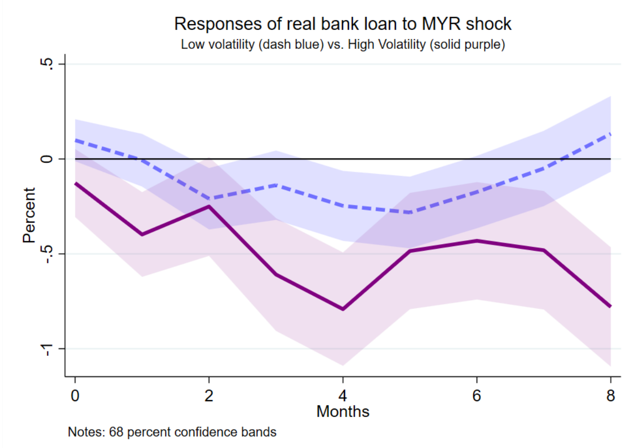

Figure 4.18. Non-linear impulse response of real bank credit to a one percentage depreciation of MYR against the US dollar.

4.4.3 Shock-dependent analysis

The impact of the exchange rate on the growth of real bank credit could also depend on the initial trigger that leads to fluctuations in the exchange rate. The analysis in this section attempts to shed some light on under what circumstances that exchange rate will play its role as a shock absorber versus a shock amplifier. In particular, in this section I consider two different initial external triggers of the exchange rate fluctuations, firstly, the terms of trade shock, and secondly, the US financial conditions shock. These two shocks are highly relevant to Malaysia given the size of trade and the significant presence of foreign investors in the domestic bond market.[21] This is also consistent

[21] Foreign holdings in the domestic bond market (% of GDP) at the end of 2023 was around 15%. The highest level of foreign holdings on the domestic bond market was around 25% in 2013.

with my previous finding, based on the framework Diebold and Yilmaz, 2012, which shows that external factors are important in explaining the volatility of the exchange rate. To investigate this, I analyse the movements of exchange rates caused by the development in the global oil market and financial conditions in the US. In terms of the identification strategy, I use the oil supply news shock developed by Känzig, 2021 (Figure 4.19) and the US financial conditions index (US FCI) estimated by Ajello et al., 2023 (Figure 4.20) as instruments within the panel LP-IV framework. The LP-IV framework is featured in many previous studies, for example, in Jordà et al., 2020 and Carrière-Swallow et al., 2023. By construction, both the oil supply news shock and the US FCI are exogenous to domestic exchange rate movements, which is critical to identify the impact of these two shocks propagating through exchange rate fluctuations on real bank credit.[22] The oil supply news shock captures the news shock about the future oil supply driven by the announcements of the Organisation of Petroleum Exporting Countries (OPEC), and the US FCI reflects the effects of unanticipated changes in key financial variables on growth in the US.

Figure 4.19: Oil Supply News Shock

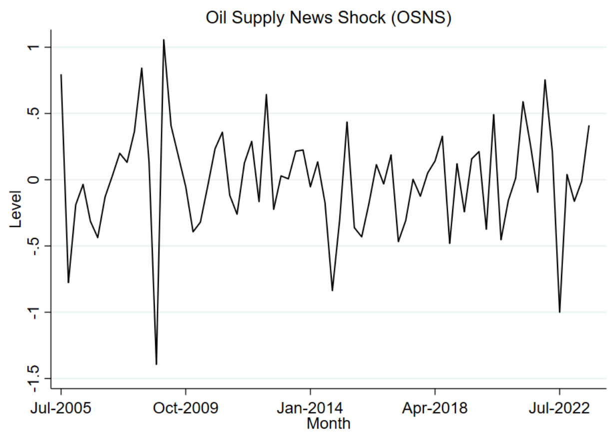

Figure 4.19. Oil supply news shock. Positive (negative) denotes decrease (increase) in oil supply.

Figure 4.20: US Financial Conditions Index

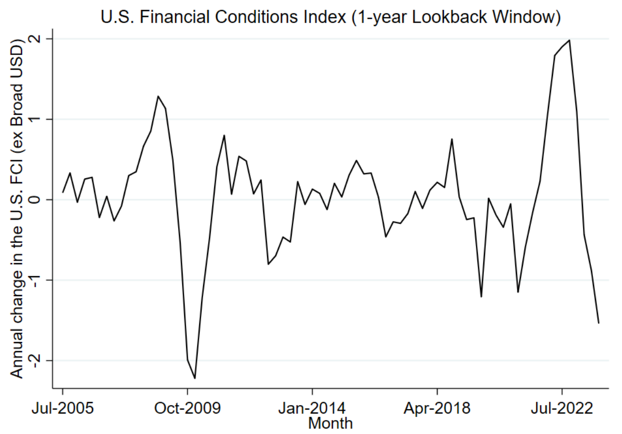

Figure 4.20. Annual change of the US financial conditions index excluding the impact of broad US dollar index.

Using oil supply news as an instrument, the first-stage regression result shows that oil supply news leads to appreciation of the exchange rate, where an increase in oil supply news shock by one point will lead to an appreciation of around one percent in the domestic currency. This is consistent with the findings of Känzig, 2021 arguing that oil supply news results in an immediate increase in global oil prices, which in turn will help improve Malaysia's terms of trade. The Kleibergen-Paap rk Wald F-statistic is well above 10, suggesting that the instrument is a strong instrument. For the US

[22]The US FCI aggregates changes in seven financial variables, namely the federal funds rate, the 10-year Treasury yield, the 30-year fixed mortgage rate, the triple-B corporate bond yield, the Dow Jones total stock market index, the Zillow house price index, and the nominal broad dollar index. For the purpose of this study, to ensure consistent and unbiased estimates, the contribution of the nominal broad dollar index to the US FCI has been removed.

FCI, the first stage regression shows that tightening of the index by 100 basis points will cause the exchange rate to depreciate between 1.4% and 2.9%. The result is consistent with the risk taking and portfolio balance channels, where the tightening in US FCI will lead to capital outflows, especially from emerging market economies, as well as depreciation in their domestic currencies. Likewise, the Kleibergen-Paap rk Wald F-statistic is well above 10, suggesting that the instrument is a strong instrument. The coefficients and F-statistics of the first-stage regressions are presented in Table A4.4 and Table A4.5. The specification of the two stages panel LP-IV model, with a three-lag, to study the effect of exchange rate movement caused by the terms of trade shock and the global financial condition shock takes the following form:

$$\Delta y_{i,t+h} = \alpha_{i,h} + \psi_h(L)z_{i,t-1} + \beta_h \widehat{\Delta ER_t} + \varepsilon_{i,t+h} \qquad \text{for } h = 0, 1, 2, ..., \tag{4.6}$$

with

$$\Delta ER_t = \alpha_i + \psi(L)z_{i,t-1} + \beta^1 Instrument + \varepsilon_t \tag{4.7}$$

where $\widehat{\Delta ER_t}$ are the estimates from the first stage regressions, produced from Equation (4.7). Figure 4.21 reports the impulse responses of the panel LP-IV model from the estimated exchange rate fluctuations based on oil supply news shock compared to the impulse responses of the panel LP-OLS model, with one standard error confidence intervals. The solid blue line reflects the impulse response of the panel LP-IV model, and the dashed purple line reflects the impulse response of the panel LP-OLS model. Unlike the results from the panel LP-OLS model, a depreciation in exchange rate caused by the terms of trade shock, represented by the drop in global oil prices, does not lead to a decline in real bank credit. The point estimates are always above the results from the panel LP-OLS, although they are insignificantly different from zero at all horizons. Meanwhile, Figure 4.22 reports the impulse responses of the panel LP-IV model from the estimated exchange rate fluctuations based on US FCI compared to the impulse responses of the panel LP-OLS model, with one standard error confidence intervals. Similarly to before, the solid blue line reflects the impulse response of the panel LP-IV model, and the dashed purple line reflects the impulse response of the panel LP-OLS model. The results of the panel LP-IV show that the impact of exchange rate depreciation on real bank credit is much worse, where the point estimates are more than twice larger than the estimates of the panel LP-OLS model at all horizons. The results are also more statistically significant compared to the panel LP-OLS model. The coefficients for both LP-IV models and their significance levels are reported in Table A4.5.

The results of the panel LP-OLS and panel LP-IV models suggest that the impact of the exchange

Figure 4.21: Impulse response of panel LP-IV (Oil Supply News Shock)

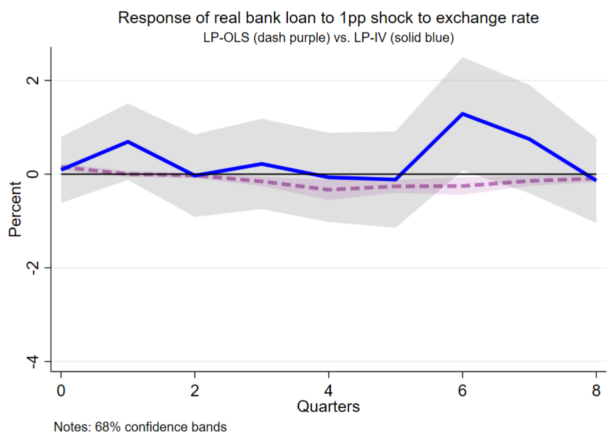

Figure 4.22: Impulse response of panel LP-IV (US Financial Conditions Index)

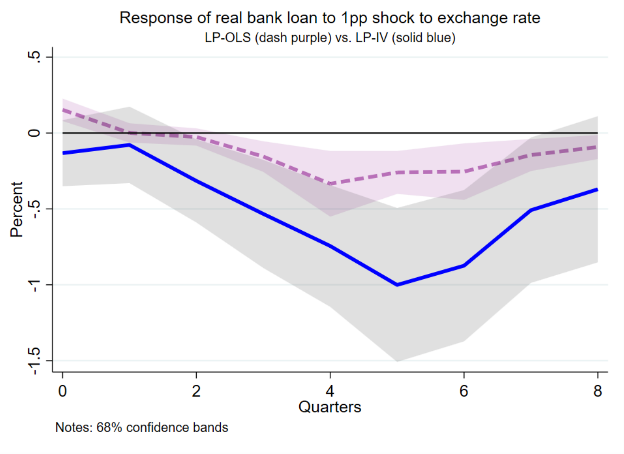

Figure 4.21. Impulse response of real bank credit to a one percentage depreciation of MYR against the US dollar.

Figure 4.22. Impulse response of real bank credit to a one percentage depreciation of MYR against the US dollar.

rate on real bank credit depends significantly on the initial shock that triggers the fluctuation in the exchange rate. The evidence is consistent with previous findings. The flexible exchange rate has been shown to be effective in insulating terms of trade shock, as argued in Broda, 2004 and Carrière-Swallow et al., 2021. In addition, depreciation in the exchange rate coupled with a higher interest rate in the US leads to a larger adverse effect for emerging market economies, due to much tighter domestic financial conditions as documented in Iacoviello and Navarro, 2019 and S. Banerjee and Mohanty, 2021. The result suggests that the exchange rate adjustment helps to stabilise the economy when hit by the terms of trade shock, but the exchange rate shock-absorbing role is not evidenced following the tightening in US financial conditions. The result is consistent with the risk-taking mechanism proposed in Borio and Zhu, 2012 and Bruno and Shin, 2015, in which tighter financial conditions in the US not only lead to deterioration of the balance sheets of borrowers and the banks' lending capacity, but also negatively affect market participants' willingness to take on additional risk exposure. More importantly, the panel LP-IV result indicates that the sign and magnitude of the impact of exchange rate on real bank loan depends not only on the state of the economy, but also on the source of the shock that moves the exchange rate.

4.4.4 Interactions of exchange rate and prudential policy

The impact of the exchange rate on the growth of real bank credit may also be influenced by the prudential policy imposed by the central bank. In order to estimate the impact of prudential policy, I extend the baseline specification in Equation (4.3) as follows:

$$\Delta y_{i,t+h} = \alpha_{i,h} + \psi_h(L)z_{i,t-1} + \beta_h \Delta ER_t + \beta_h^{pru}(\Delta ER_t \times Pru_{t-1}) + \varepsilon_{i,t+h} \tag{4.8}$$

where the coefficient of the interaction term, β_h^{pru}, where positive reflects the effectiveness of tighter prudential policy to mitigate the effect of the financial channel of the exchange rate, and negative indicates that tighter prudential policy does not mitigate the effect of the financial channel of the exchange rate on real bank credit. The econometric approach and the interpretation of the interaction term are very similar to Coman and Lloyd, 2022. Pru_{t-1} represents a cumulative prudential policy stance, developed by Cerutti et al., 2017, where higher positive values reflect a tighter prudential policy stance and lower negative values reflect a looser prudential policy stance. Throughout 1Q05 to 4Q23, the prudential policy stance in Malaysia ranged from -2 to 7, where the tightest period was observed during 2013 to 2015. The decision to use a lagged indicator of prudential policy is mainly to prevent the possibility that the coefficients capture endogenous responses of Malaysian policymakers to exchange rate movements. Table 4.1 reports the coefficient values of the interaction term, where the results show that the interaction coefficient turns positive from quarter 4 onwards. This suggests that additional tightening of prudential policy in the face of 1% percentage of depreciation helps mitigate the financial channel of exchange rate on real bank credit on average by 0.07 percentage points from quarter 4 to quarter 8.

Table 4.1: Exchange rate and prudential policy

Interaction term: $\beta_h^{pru}(\Delta ER_t \times Pru_{t-1})$	
At horizon h =	Coefficient
0	-0.0208
1	-0.0206
2	-0.0477*
3	0.0268
4	0.0860
5	0.0560*
6	0.0998
7	0.0792*
8	0.0733**

Note: Standard errors are clustered at the bank level (robust) and *, **, *** indicates significance at 90%, 95%, and 99% levels.

4.5 Foreign exchange intervention (FXI), volatility and capital flows

As stated above, a survey by BIS in 2021 revealed that among the main objectives of the implementation of FXI by central banks in emerging markets are to reduce the volatility of the exchange rate and to provide liquidity to thin markets. As such, the first part of this section analyses the effectiveness of Bank Negara Malaysia in using the FXI to mitigate volatility in the foreign exchange market. In the second part, the article studies the responses of the central bank, in terms of FXI, to the movement of capital flows in Malaysia.

4.5.1 FXI and volatility

To capture both the uncertainty elements and the liquidity level in the foreign exchange market, this section uses a new measure of exchange rate volatility. Following the same method in Diebold and Yilmaz, 2012, I estimate the daily variance using high and low exchange rates as follows:

$$\sigma_t^2 = 0.361\left[\mathbf{ln}(ER_t^{high}) - \mathbf{ln}(ER_t^{low})\right]^2 \tag{4.9}$$

where ER_t^{high} and ER_t^{low} are the highest and lowest quotes for the exchange rate on day t. The corresponding estimate of the annualised daily percent standard deviation is

$$\sigma^2 = 100\sqrt{365 \times \sigma_t^2} \tag{4.10}$$

and I take the monthly average of the daily standard deviation to represent the monthly exchange rate volatility. This volatility measurement is more reflective of the liquidity condition in the foreign exchange market, as it uses the highest and lowest daily quotes. Increasing volatility episodes were observed particularly during major events. Figure 4.23 reports the new volatility measure on the red line compared to the monthly standard deviation of the change in daily movement on the black line, as reported earlier in Figure 4.2. Overall, both measurements of volatility move in the same direction, but in some situations the magnitudes of movement are different.

Using the new measure of volatility, I estimate a local projection model based on monthly data from January 2008 to December 2023 to study the effectiveness of the FXI to tame volatility in the foreign exchange market. The specification of the local projection model, with a four-lag is consistent with Equation (4.3), which takes the following form:

$$VOL_{t+h} = \alpha_h + \psi_h(L)z_{t-1} + \beta_h FXI_t + \varepsilon_{t+h} \qquad \text{for } h = 0, 1, 2, ..., \tag{4.11}$$

Figure 4.23: Exchange rate volatility (High-Low)

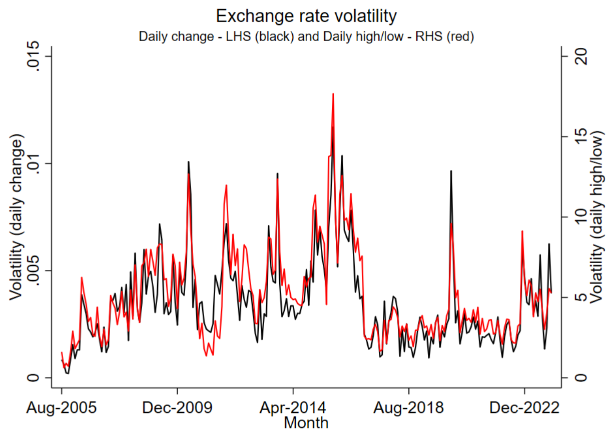

Figure 4.23. Exchange rate volatility based on the change in daily movement (black) and the difference in daily high and low (red).

where VOL is the volatility in the foreign exchange market, z is the vector of control variables, $\psi_h(L)$ is a polynomial in the lag operator, and FXI is the absolute size of the foreign exchange intervention (% of GDP). α is a constant. The use of absolute size of FXI means that it captures the effect of FXI in reducing the volatility of the exchange rate in both episodes of purchases and sales of foreign exchange reserves. For the identification strategy, the vector of control variables is known prior to the FXI shock. The vector of control variables contains the absolute monthly change in the index of the stock market, $KLCI$, the absolute monthly change in the index of global commodity prices, $COMM$, the absolute monthly change in foreign holdings in the debt market, FH, and the CBOE Volatility Index, VIX. Figure 4.24 reports the average effects of FXI on the volatility of the exchange rate with one standard error confidence intervals. Interestingly, the point estimates show that FXI does not lead to a reduction in the volatility of the exchange rate. The point estimates suggest that the effect of FXI is almost statistically indifferent to zero and is not economically significant in reducing the volatility for the entire forecast period.

Regardless of the baseline linear result, will the impact of FXI to reduce exchange rate volatility be more effective if the central bank changes its FXI strategy and becomes more targeted? This is a pertinent issue in Malaysia, as the central bank seems to be active in the foreign exchange market even during the low volatility period. Figure 4.25 shows the FXI distribution during the high- and low-volatility periods. I classified the high volatility period when the exchange rate volatility is above its median and vice versa. The distribution shows that the magnitude of FXI is comparable in both periods, suggesting that the central bank is very active in the exchange rate market even during the period that is relatively calmer. The distribution suggests that the central bank tends to accumulate its foreign reserve during the low volatility period and uses its foreign reserve when

Figure 4.24: Impulse response of LP-OLS (Volatility and FXI)

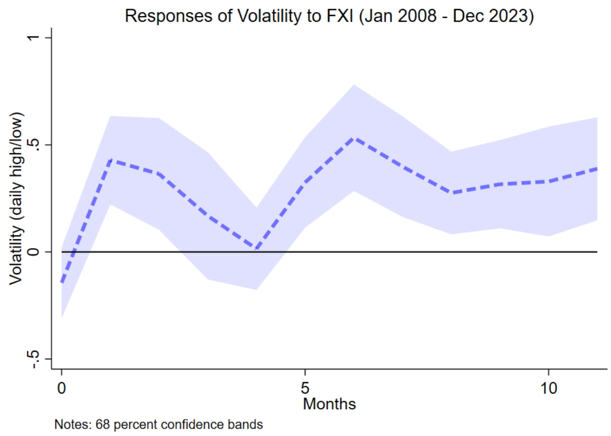

Figure 4.24. Impulse response of exchange rate volatility to FXI (% of GDP).

volatility is high. Although it is rational for the central bank to accumulate its foreign reserve during the low volatility period, a significant deployment of foreign reserves is also observed during the same period. The details in Table 4.2, where I provide statistics of the magnitude of FXI during both periods, irrespective of the sign of FXI, show that the implementation of FXI is very identical in both periods.

Figure 4.25: Distribution of FXI (% of GDP)

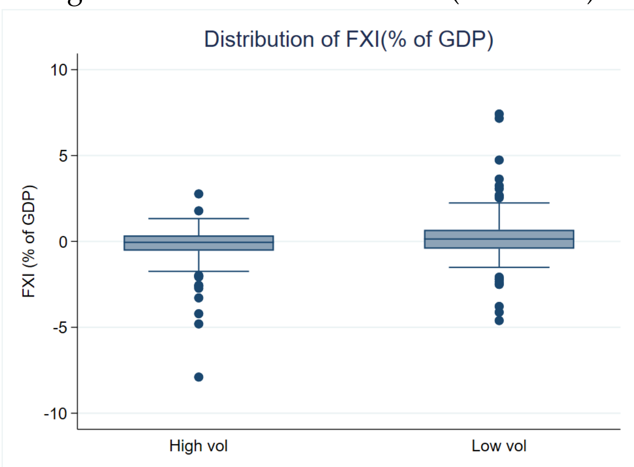

Figure 4.25. Distribution of FXI (% of GDP) in high and low volatility periods.

Table 4.2: FXI from August 2005 until December 2023

Volatility	No. observation	Average size (% of GDP)	Std. dev	Min (% of GDP)	Max (% of GDP)
High vol	110	0.78	1.10	0.002	7.90
Low vol	111	1.08	1.34	0.033	7.42

I extend the linear specification in Equation (4.10) to a non-linear setting, where the aim is to estimate the impact of FXI during periods of extreme global uncertainty and relative stability. I use the World Uncertainty Index (WUI) developed by Ahir et al., 2022 to capture the uncertainty at the global level, which has a significant bearing on the volatility of the exchange rate.[23] I define the extreme global uncertainty period as when the WUI is above its 75th percentile threshold. In the non-linear setting as per Equation (4.11), the dummy variable I takes the value 1 when the WUI is above its 75th percentile threshold and 0 otherwise.

$$VOL_{t+h} = I_{t-1}\left[\alpha_{A,h} + \psi_{A,h}(L)z_{t-1} + \beta_{A,h}FXI_t\right] + (1 - I_{t-1})\left[\alpha_{B,h} + \psi_{B,h}(L)z_{t-1} + \beta_{B,h}FXI_t\right] + \varepsilon_{t+h} \tag{4.12}$$

The construction of impulse response functions reflects the sequence of coefficients $\beta_{A,h}$ and $\beta_{B,h}$ estimated in a series of separate regressions for each horizon, where they represent the average effects of the FXI depending on the state of the economy, either during extreme global uncertainty or during stable global periods. Figure 4.26 shows the non-linear impulse responses function with one standard error confidence intervals, where the solid purple line reflects the impulse response of exchange rate volatility to FXI during an extreme global uncertainty period, and the dashed blue line reflects the impulse response for a stable period. The impact of FXI during the extreme global uncertainty period, as shown by the point estimates, is more effective in reducing the volatility of the exchange rate compared to its impact during the stable period. At the peak of the impact of FXI, the volatility of the exchange rate will be reduced by more than 50% of its standard deviation, compared to the economically insignificant impact during the stable period. This shows that if Bank Negara Malaysia's main goal is to reduce the volatility of exchange rate, the central bank needs to be more targeted in its FXI strategy by deploying its resources more during uncertain times, especially in a situation where the central bank also wants to preserve its foreign reserves. The coefficients for both linear and non-linear models and their significance levels are reported in Table A7.

To complement the finding based on the local projection method, I also investigated the effectiveness of FXI in reducing the volatility of the exchange rate using OLS analysis. The OLS analysis is done based on the same data set as per the previous non-linear local projection analysis. The results presented in Table 4.3 show that in model specifications 3 and 4, where the control variables are included, FXI is statistically and economically significant in managing the volatility of the exchange rate. More importantly, the potency of FXI is much greater during the extreme global uncertainty period, as shown in model specification 4. The variable FXI_t^{HU} that captures the interaction of FXI

[23] A result of Wald test with four lags suggests that WUI does Granger-cause exchange rate volatility, but not the other way around.

Figure 4.26: Impulse response of non-linear LP-OLS (Volatility and FXI)

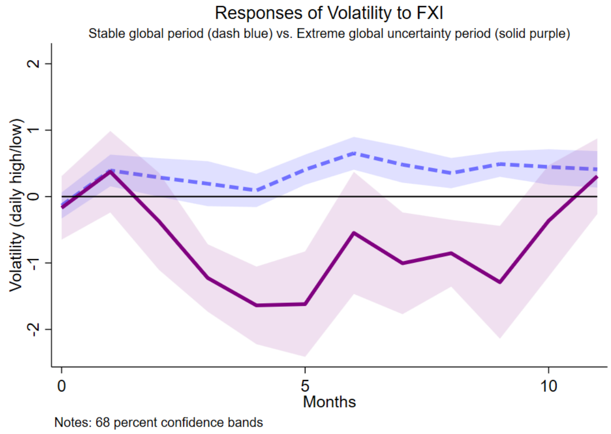

Figure 4.26. Impulse response of exchange rate volatility to FXI (% of GDP).

during the extreme global uncertainty period suggests that the effect of FXI to reduce the volatility of the exchange rate is more than triple compared to the stable period, as captured by FXI_t^{LU}. The equality test also shows that the statistical difference between the two coefficients is greater than zero at the 10% level. The result of the panel data analysis underscores again the importance of the need for the central bank to be more selective in managing its foreign exchange reserves.

Table 4.3: Volatility and FXI

	$\mathbf{VOL}_t$, $(2008 - 2023)$			
FXI_t	-0.0481		-0.4090***	
FXI_t^{HU}		-0.9218		-1.1633**
FXI_t^{LU}		-0.0626		-0.3628**
FH_t			0.8856***	0.8864***
KLCI_t			0.0850	0.0823
COMM_t			-0.0010	0.0058
VIX_t			0.0419*	0.0394**
VOL_{t-1}			0.7318***	0.7323***
Specification	1	2	3	4
Adj R-squared	-0.0049	0.0129	0.6149	0.6159
Equality test		0.1931		0.0786
No. obs	192	192	191	191
Period	Jan'08 - Dec'23	Jan'08 - Dec'23	Feb'08 - Dec'23	Feb'08 - Dec'23

Note: HAC standard errors. *, **, *** indicates significance at 90%, 95%, and 99% levels.

4.5.2 FXI and capital flows

The growing domestic debt market and the investment-grade credit rating given to Malaysian sovereign bonds make it attractive for foreign investors to come and invest in Malaysia, especially for global investors who want to have exposure in emerging market economies. This is reflected in the large presence of foreign investors in the Malaysian bond market, where they held close to 15% of GDP worth of domestic bonds in December 2023 (Figure 4.27). The highest level of foreign holdings on the debt market was recorded in 2013, where the number exceeded 25% of GDP, supported by the monetary easing of the major central banks in response to the global financial crisis. In terms of the size of the monthly capital flows, there are instances of capital flows as large as 4% of GDP that flow into and out of the country. The extremely erratic nature of capital flows can destabilise the domestic financial market, which in turn could lead to negative effects on the real sector. And every time there are massive capital flows, the central bank always intervenes and uses the FXI as shown by the strong positive linear relationship between the two variables in the scatterplot in Figure 4.28.

Figure 4.27: Foreign holdings in bond market

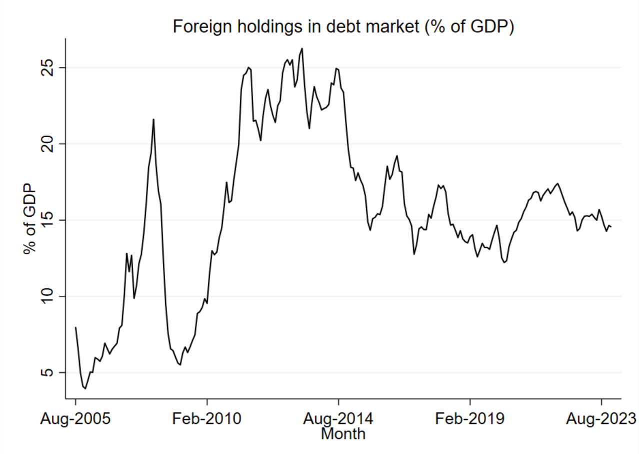

Figure 4.27. Foreign holdings in domestic bond market (% of GDP).

Figure 4.28: FXI and capital flows

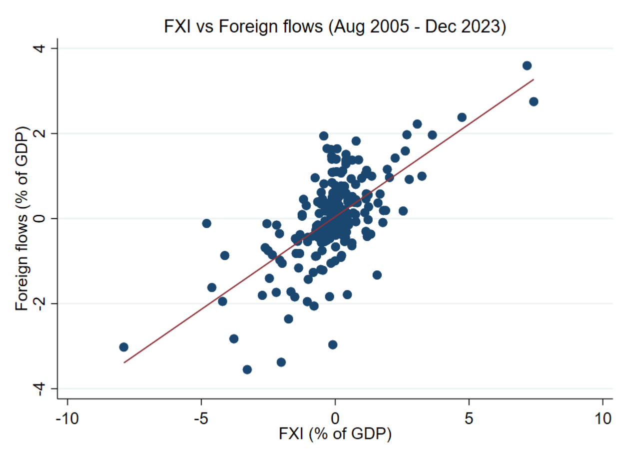

Figure 4.28. Scatterplot between FXI and capital flows into bond market (% of GDP).

Against this background, in this section, this paper analyses the central bank's reaction function to foreign portfolio flows in the domestic bond market. The analysis is based on monthly data from August 2005 to December 2023. The specification of the local projection model, with a three-lag is consistent with Equation (4.3) and Equation (4.10), which takes the following form:

$$FXI_{t+h} = \alpha_h + \psi_h(L)z_{t-1} + \beta_h FH_t + \varepsilon_{t+h} \qquad \text{for } h = 0, 1, 2, ..., \tag{4.13}$$

where FXI is the foreign exchange intervention (% of GDP) by the central bank, z is the vector of control variables, $\psi_h(L)$ is a polynomial in the lag operator, and FH is the size of capital flows (% of GDP). α is a constant. The vector of control variables contains the monthly change in the index of the stock market, the monthly change in the index of global commodity prices, and the monthly change in the bilateral exchange rate against the US dollar. Standard errors are estimated by using the Newey-West correction method. Figure 4.29 reports the average effects of capital flows on FXI with one standard error confidence intervals. Point estimates indicate that 1% of GDP worth of movement in capital flows will lead to an almost identical response by the central bank via the FXI, where the size of FXI will also be close to 1% of GDP. This suggests that the central bank is very sensitive to the movement of capital flows.

Figure 4.29: Impulse response of LP-OLS (FXI and capital flows)

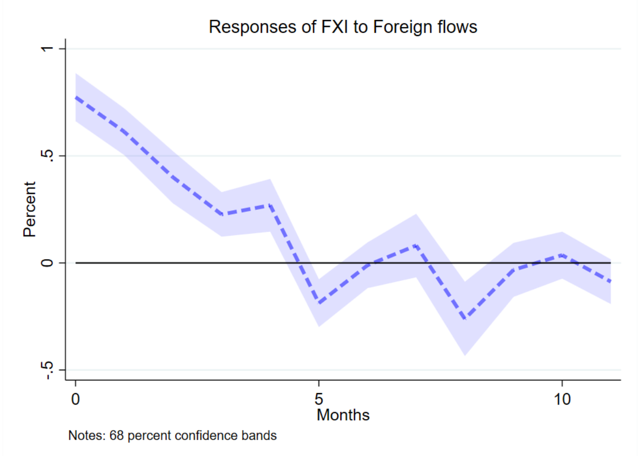

Figure 4.29. Impulse response of FXI to capital flows (% of GDP).

Figure 4.30: Impulse response of non-linear LP-OLS (FXI and capital flows)

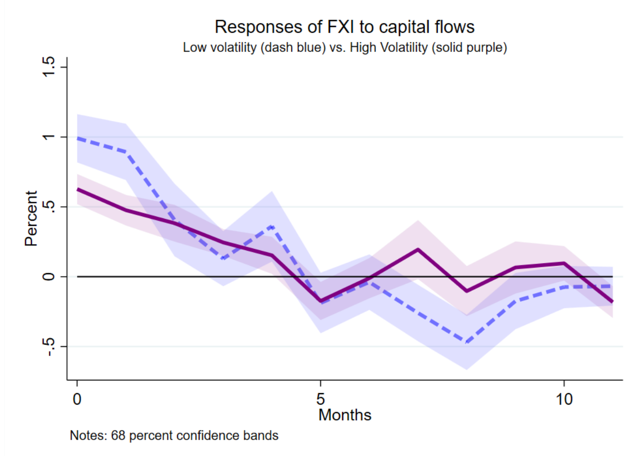

Figure 4.30. Non-linear impulse response of FXI to capital flows (% of GDP).

I extend the analysis by asking whether the sensitivity depends on the prevailing level of volatility in the exchange rate market? Was the central bank more active in facilitating capital flows during the high volatility period? To answer this question, I extend the linear specification in Equation (4.12) to a non-linear specification, with an aim to estimate the central bank responsiveness during high and low volatility periods. The volatility in this analysis is estimated using the highest and lowest daily quotes. Figure 4.30 reports the non-linear impulse responses function with one standard error confidence intervals, where the solid purple line shows the response of FXI to capital flows during a high volatility period, and the dashed blue line shows the response during a low volatility period. It is interesting to observe that the central bank is more responsive to capital flows during the low volatility period, where the size of the FXI is almost 50% larger in the first month compared to the response during the high volatility period. One possible explanation is that the decision to use the FXI may depend not just on looking at the exchange rate volatility, but perhaps on the overall condition of financial market, which warrants further investigation. The coefficients for both linear and non-linear models and their significance levels are reported in Table A4.7.

4.6 Conclusion

In this paper, using data from Malaysia, the impact of exchange rate fluctuations on domestic production and bank credit is analysed. First, I show that domestic production responds positively to exchange rate depreciation, but with some lag. The positive impact varies depending on the size of the tradable sector, where the impact is larger and more persistent the larger the size of the tradable sector. This suggests that the trade channel of the export rate remains significant for the Malaysian economy. Second, the results show that bank credit reacts negatively to exchange rate depreciation, consistent with the financial channel of the exchange rate. However, the response of bank credit is both state- and shock-dependent. The impact is severe when depreciation is accompanied by significant exchange rate volatility. The severity of the impact also depends on the shock that moves the exchange rate. The impact of exchange rate fluctuations caused by terms of trade shocks on bank credit is insignificant, but the impact is significantly larger if exchange rate fluctuations are triggered by shocks in US financial conditions.

As a response to high exchange rate volatility, my analysis suggests that FXI is effective in reducing the volatility of the exchange rate during the extreme global uncertainty period. However, the potency of FXI as a tool to reduce volatility is weak when used in a stable global period. I also find that the central bank through its FXI operation is very sensitive to the movement in capital flows, where the size of FXI is comparable to the size of capital flows. This is driven by the erratic nature of capital flows, the size of which could be extremely large, especially during uncertain times. However, I also document that FXI has also been widely used during a relatively calmer period to facilitate capital flows. These results indicate that the use of FXI should be more targeted and primarily deployed during the uncertain period, particularly when the central bank wants to preserve its foreign reserves.

Finally, this paper has some limitations, and addressing them will validate the main findings of this paper. First, extract the exogenous movements in the exchange rate, to remove any endogeneity problem. This will complement the LP-IV findings. This is similar to the approach taken in Leiva-Leon et al., 2023. Second, the analysis in this paper uses monthly and quarterly data, which should also be complemented with daily data given the volatile and erratic move in the exchange rate. Third, in state-dependent analysis, finding an alternative to exchange rate volatility will eliminate any endogeneity concern between exchange rate volatility and exchange rate movements.

4.7 Table A4.1 - A4.8

Table A4.1: Impulse response of domestic production (LP-OLS)

		Non-linear		P-value
At horizon h =	Linear	Low Tradable (LT)	High Tradable (HT)	LT = HT
2	-0.2330	-0.1000	-0.0472	0.9052
4	0.0734	-0.1080	0.5870**	0.0642
5	0.1690	0.0178	1.0140**	0.0234
6	0.1250	0.0557	0.5750*	0.2271
8	-0.1490	-0.1630	0.3020	0.4108
10	0.3940**	0.4650*	0.7240*	0.5739
12	0.1690	0.4920*	0.3780	0.7412
14	0.1160	0.3910	0.1860	0.5687

Standard errors are computed using Newey-West correction method and *, **, *** indicates significance at 90%, 95%, and 99% levels.

Table A4.2: Volatility spillover table

	S%P 500	10-yr Treasury	USD Index	Brent	Bursa Malaysia	10-yr MGS	MYR/USD
MYR/USD	1.93	1.45	4.86	0.32	1.63	1.75	88.05

Table A4.3: Impulse response of real bank credit (LP-OLS)				
		Non-linear (75th percentile)		P-value
At horizon h =	Linear	Low Volatility (LV)	High Volatility (HV)	LV = HV
0	0.1530*	0.0990	-0.1270	0.3282
1	0.0010	-0.0066	-0.3980*	0.1757
2	-0.0259	-0.2090	-0.2500	0.9034
3	-0.1550	-0.1380	-0.6090**	0.2220
4	-0.3340	-0.2470	-0.7910***	0.1601
5	-0.2600*	-0.2820	-0.4850	0.6094
6	-0.2540	-0.1740	-0.4310	0.5219
7	-0.1450	-0.0496	-0.4810	0.2981
8	-0.0920	0.1330	-0.7800**	0.0290

Standard errors are computed using Newey-West correction method and *, **, *** indicates significance at 90%, 95%, and 99% levels.

Table A4.4: First-stage Coefficients Table - Oil Supply News Shock		
At horizon h =	Coefficient	Kleibergen-Paap Wald rk F-statistic
0	-1.0581***	26.73
1	-1.0581***	26.73
2	-1.0921***	27.25
3	-1.05007***	24.14
4	-1.0186***	23.49
5	-1.0479***	24.80
6	-1.0814***	19.62
7	-1.12589**	21.90
8	-1.4193***	36.46

Standard errors are clustered at the bank level (robust) and *, **, *** indicates significance at 90%, 95%, and 99% levels.

Table A4.5: First-stage Coefficients Table - US Financial Conditions Index		
At horizon h =	Coefficient	Kleibergen-Paap Wald rk F-statistic
0	1.4446***	77.84
1	1.6558***	88.89
2	1.7460***	91.80
3	2.1373***	131.48
4	2.0893***	125.31
5	2.1290***	119.51
6	2.4730***	119.59
7	2.8463***	56.22
8	2.7910***	56.34

Standard errors are clustered at the bank level (robust) and *, **, *** indicates significance at 90%, 95%, and 99% levels.

Table A4.6: Impulse response of real bank credit (LP-IV)			
At horizon h =	LP-OLS	LP-IV Oil Supply News Shock	LP-IV US Financial Conditions Index
0	0.1530*	0.0915	-0.1330
1	0.0010	0.6920	-0.0781
2	-0.0259	-0.0320	-0.3150
3	-0.1550	0.2180	-0.5330
4	-0.3340	-0.0689	-0.7440*
5	-0.2600*	-0.1150	-1.0010**
6	-0.2540	1.2880	-0.8740*
7	-0.1450	0.7490	-0.5080
8	-0.0920	-0.1380	-0.3700

Standard errors are clustered at the bank level (robust) and *, **, *** indicates significance at 90%, 95%, and 99% levels.

Table A4.7: Impulse response of volatility (LP-OLS)

			Non-linear	P-value
At horizon h =	Linear	Stable (LU)	Extreme Uncertainty (HU)	LU = HU
0	-0.144	-0.134	-0.170	0.9444
1	0.429**	0.393	0.374	0.9771
2	0.364	0.289	-0.373	0.3962
3	0.169	0.194	-1.225**	0.0196
4	0.0146	0.0924	-1.639***	0.0084
5	0.325	0.405*	-1.619**	0.0158
6	0.534**	0.652***	-0.547	0.2090
7	0.399*	0.481*	-1.005	0.0589
8	0.275	0.354	-0.853*	0.0297

Standard errors are computed using Newey-West correction method and *, **, *** indicates significance at 90%, 95%, and 99% levels.

Table A4.8: Impulse response of FXI (LP-OLS)

		Non-linear		P-value
At horizon h =	Linear	Low Volatility (LV)	High Volatility (HV)	LV = HV
0	0.7740***	0.9910***	0.6270***	0.0755
1	0.6130***	0.8940***	0.4760***	0.0698
2	0.4000**	0.4060	0.383**	0.9362
3	0.2270*	0.1290	0.245*	0.5944
4	0.2690*	0.3610	0.1530	0.5059
5	-0.1880	-0.1880	-0.1740	0.9585
6	-0.0108	-0.0388	-0.0106	0.8913
7	0.0814	-0.2600	0.1940	0.1056
8	-0.2610	-0.4700*	-0.1030	0.0804

Standard errors are computed using Newey-West correction method and *, **, *** indicates significance at 90%, 95%, and 99% levels.

Chapter 5

Concluding Remarks

This thesis compiles three papers that explore the role and impact of exchange rate movements, as well as optimal policy responses to mitigate their effects. The findings of Chapter 2 and Chapter 4 highlight the dual role of exchange rates through the trade and financial channels. On one hand, a weaker exchange rate can enhance economic competitiveness, potentially stimulating growth. However, it can also exert contractionary effects, which, in extreme cases, may destabilise the economy, as evidenced by past studies. The results of this research underscore that the magnitude of these contractionary effects is highly dependent on the state of the economy at the time of the shock and the underlying source of the exchange rate movement.

In addressing optimal policy responses, this thesis demonstrates that policymakers have several tools at their disposal to mitigate the contractionary effects of exchange rate fluctuations. However, these tools come with inherent trade-offs, and their effectiveness largely depends on the manner and context in which they are implemented. This is a central theme in Chapter 3, which examines the effectiveness of LTV policies across countries with differing characteristics. The findings reveal that the opportunity cost of LTV policies in terms of output and credit growth volatility is particularly pronounced for countries with net external liabilities, suggesting that country characteristics matter when it comes to policy interventions.

Looking ahead, my goal is to expand this research by enriching existing models to incorporate additional policy dimensions. For example, I plan to investigate the role of fiscal policy in counteracting the financial channel of exchange rate movements. Beyond this, I intend to explore the effectiveness of asset purchase programmes in stabilising financial systems, particularly within the context of small open economies. These future directions seek to deepen our understanding of policy tools and their implications for economic stability in an increasingly interconnected global economy. Thank you.

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