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The interplay between domestic bank lending, foreign interest rates, and exchange rates

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Abstract

I study 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 with some trade-offs.

Keywords: Exchange rate, Loan growth, Foreign funding, Foreign exchange intervention

JEL classification: C33, E51, E58

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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 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

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

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, 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 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 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 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]

2.1 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 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

[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.

[3] A detailed information about the series is provided in Table A1.

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 1: Percentage share of bank loan from total outstanding credit

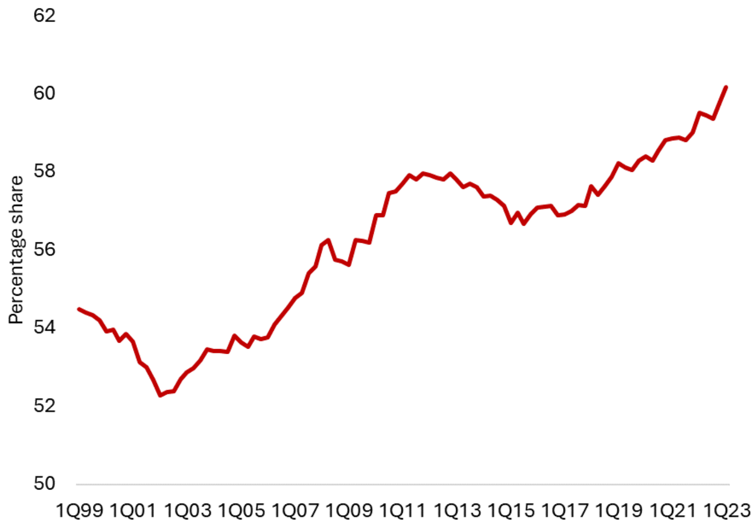

Figure 1. Percentage share of bank loan to the non-financial sector from total outstanding credit for all reporting countries, including advanced and emerging economies.

2.2 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 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.

2.2.1 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 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.

In Table 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

[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: Real bank loans and bilateral US dollar exchange rate

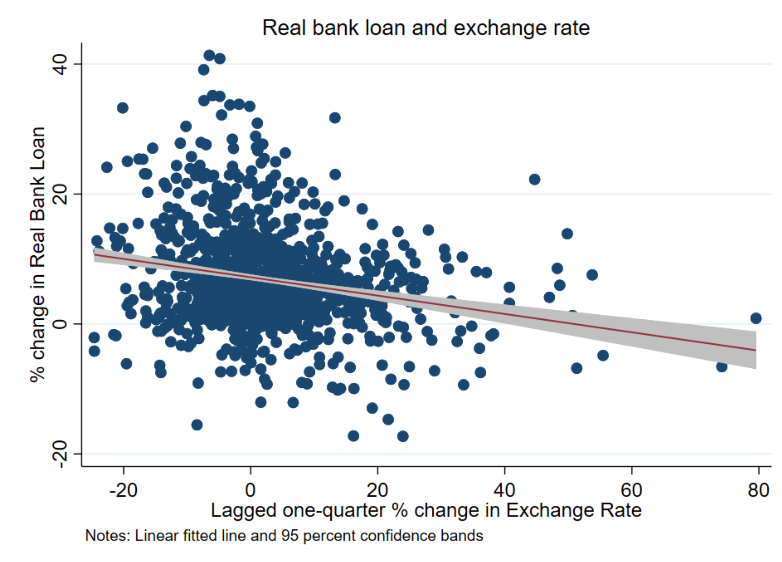

Figure 2. Scatterplot of the annual growth of real bank loans against the annual change of the bilateral US dollar exchange rate.

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.

Table 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.

2.2.2 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 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 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 3 provides an overview of the types of foreign

[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.

liability captured by international claims.

Figure 3: International claims by domestic agents and banks

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

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

Government	
Assets	Liabilities
	FCL (Banks)
	FCL (Non-banks)

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

Figure 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 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 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 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.

[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 4: International claims by counterparty country (Ratio to total domestic bank loan)

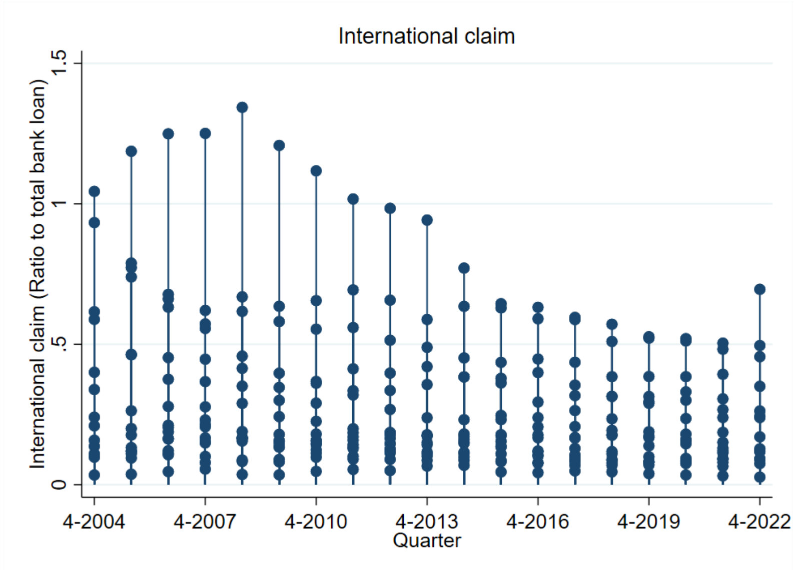

Figure 4. International claims (Ratio to total domestic bank loan) refers to claim on a non-resident or denominated in a foreign currency. International claims comprise cross-border claims in any currency plus local claims of foreign affiliates denominated in non-local currencies. This graph is constructed based on data from the sample of 16 economies.

Figure 5: Real bank loan and bilateral US dollar exchange rate

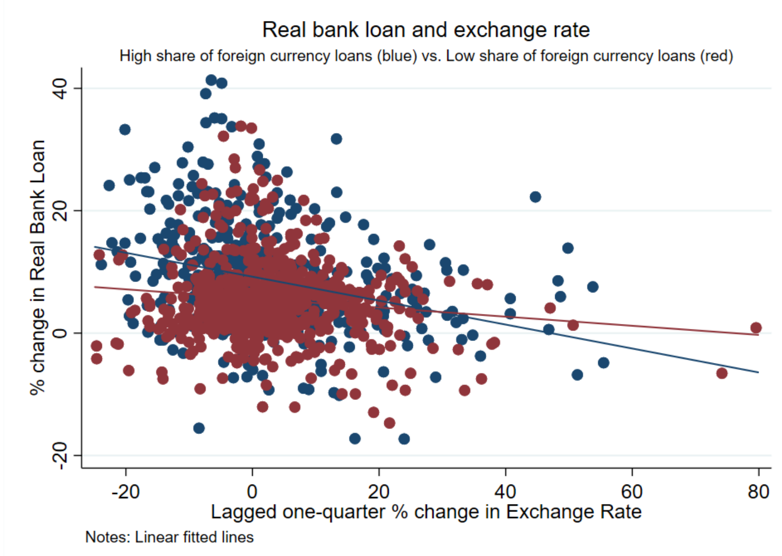

Figure 5. Scatterplot of the annual growth of real bank loans against the annual change of the bilateral US dollar exchange rate.

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 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 6: International claims (% of total domestic bank loan)

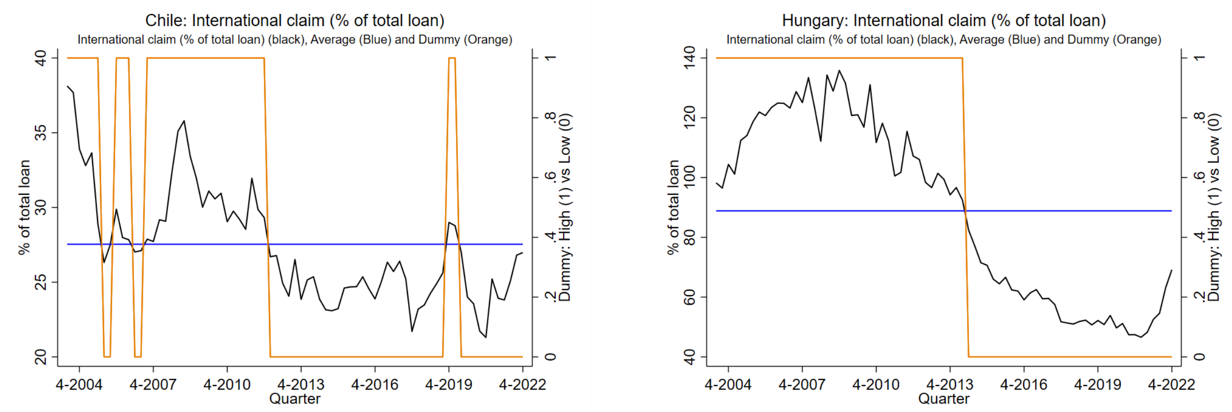

Figure 6. International claims (% of total domestic bank loan) refer to claim on a non-resident or denominated in a foreign currency. International claims comprise cross-border claims in any currency plus local claims of foreign affiliates denominated in non-local currencies.

In Table 2 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 specification shows that real bank loan growth experiences a larger contraction when the share of loans in foreign currency provided

Table 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
$\text{MP}_{i,t}$			-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.

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.

2.3 Panel Local Projection (LP)

2.3.1 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 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 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.

2.3.2 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 state-

Figure 7: Impulse response of Panel LP-OLS (Linear)

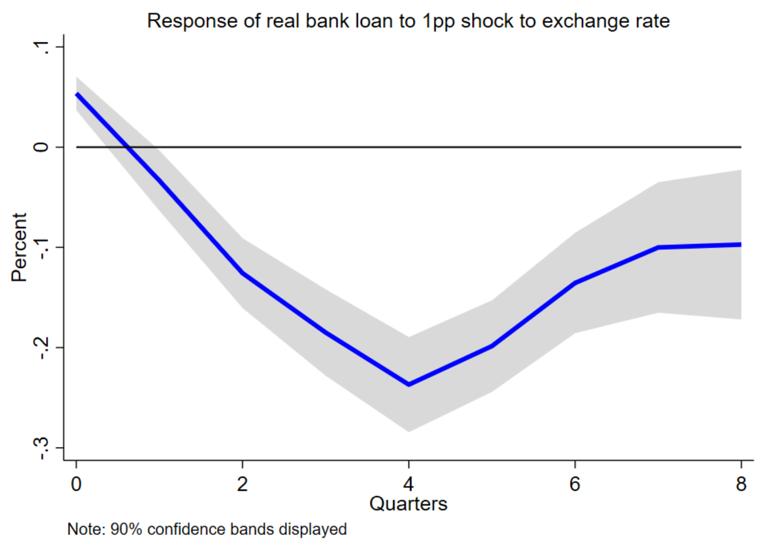

Figure 7. Impulse response of real bank loan growth to a one percentage depreciation of bilateral exchange rate against the US dollar. The grey areas are the 90% confidence bands. The x-axis represents the quarter.

dependent local projection specification is given as follows:

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

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 8 shows the impulse responses of the state-dependent panel LP model, with 90% confidence

Figure 8: Impulse response of Panel LP-OLS (Non-linear)

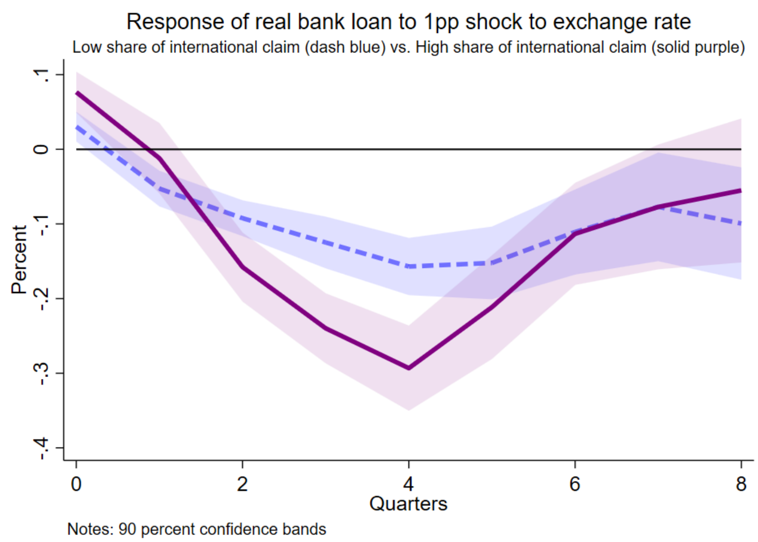

Figure 8. Impulse response of real bank loan growth to a one percentage depreciation of bilateral exchange rate against the US dollar. The responses are in cumulative changes in percentage points. The blue and purple areas are the 90% confidence bands. The x-axis represents the quarter.

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 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 3.

2.3.3 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

Table 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.

in Figure 9 captures the cumulative effects of unanticipated permanent changes in key financial variables on growth over the next year.[8]

Figure 9: US Financial Conditions Index (1-year Lookback Window)

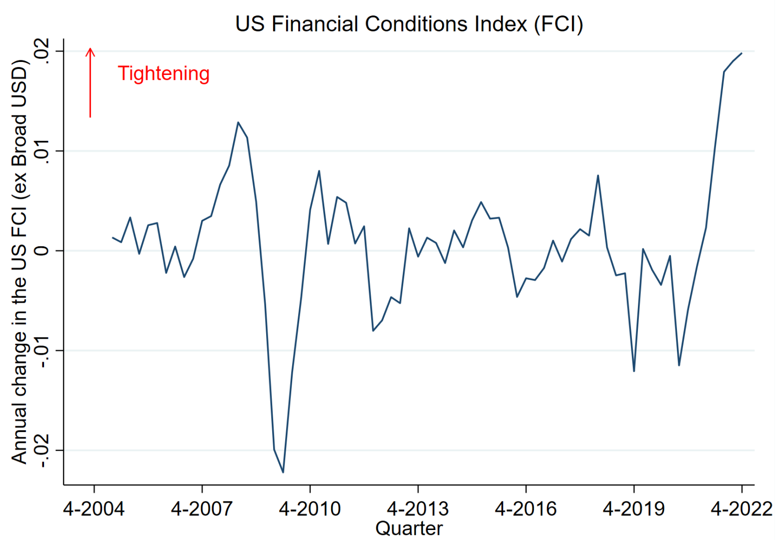

Figure 9. Annual change of the US financial conditions index excluding the impact of broad US dollar index.

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.

[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.

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 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 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 11

[9] See Table A2 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 A3 in the appendix for the result of the exclusion restriction test.

Figure 10: Impulse response of Panel LP-IV and Panel LP-OLS (Linear)

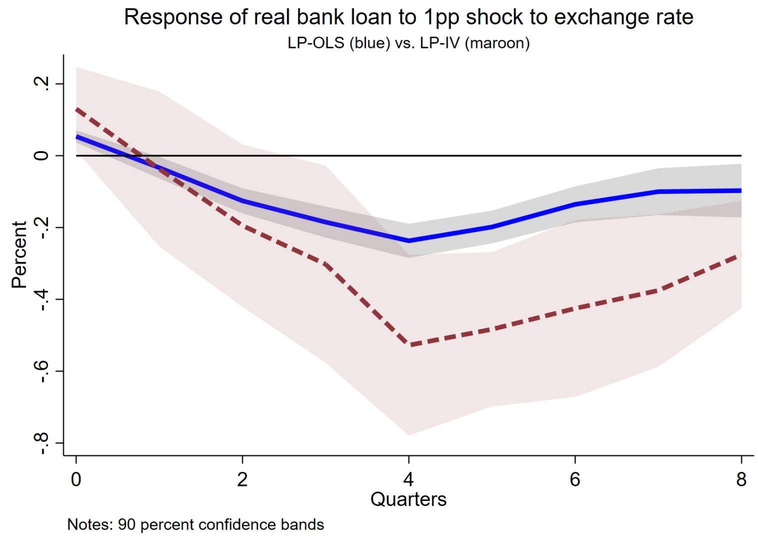

Figure 10. Impulse response of real bank loan growth to a one percentage depreciation of bilateral exchange rate against the US dollar. The responses are in cumulative changes in percentage points. The grey and maroon areas are the 90% confidence bands. The x-axis represents the quarter.

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 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 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]

[11] See Table A4 (LP-OLS) and Table A5 (LP-IV) in the appendix for impulse response functions of real total credit outstanding.

Figure 11: Impulse response of Panel LP-IV (Non-linear)

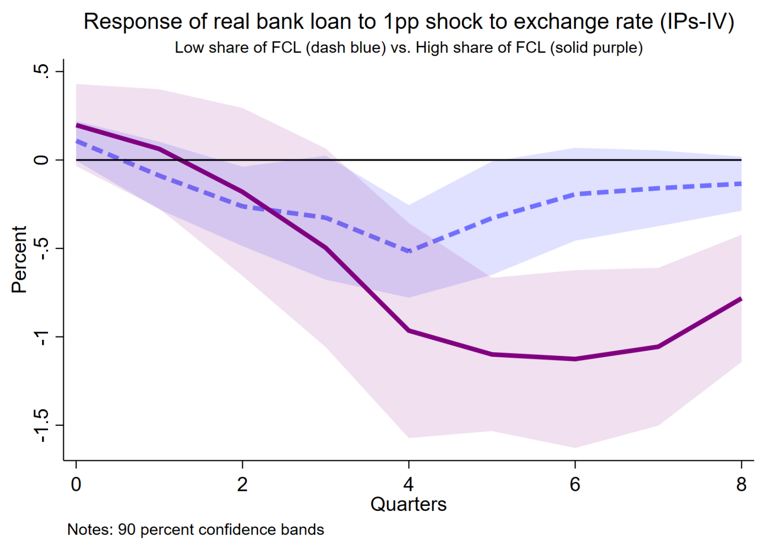

Figure 11. Impulse response of real bank loan growth to a one percentage depreciation of bilateral exchange rate against the US dollar. The responses are in cumulative changes in percentage points. The blue and purple areas are the 90% confidence bands. The x-axis represents the quarter.

Table 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.

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.

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.

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

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

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:

$$\frac{\partial \mathbb{L}}{\partial C_t^h} : \frac{1}{C_t^h} = \lambda_t^h \tag{2}$$

$$\frac{\partial \mathbb{L}}{\partial d_t} : \lambda_t^h = \beta E_t \lambda_{t+1}^h \left(\frac{1+R_t}{\pi_{t+1}} \right) \tag{3}$$

$$\frac{\partial \mathbb{L}}{\partial L_t} : L_t^{\varphi-1} = \lambda_t^h w_t \tag{4}$$

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.

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:

$$C_t^e + \frac{(1+R_{t-1}^r)b_{t-1}}{\pi_t} + w_t L_t + q_t^k K_t = \frac{Y_t^e}{p_t x_t} + b_t + q_t^k(1-\delta^k)K_{t-1} \tag{5}$$

$$b_t \leq LTV^E \mathbb{E}\left[\frac{q_{t+1}^k K_t (1-\delta^k)\pi_{t+1}}{1+R_t^r}\right] \tag{6}$$

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

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

$$\frac{\partial \mathbb{L}}{\partial C_t^e} : \frac{1}{C_t^e} = \lambda_t^e \tag{7}$$

$$\frac{\partial \mathbb{L}}{\partial L_t} : w_t p_t = (1-\xi)\frac{A_t^d K_{t-1}^{\xi} L_t^{-\xi}}{x_t} \rightarrow w_t p_t = (1-\xi)\frac{Y_t^e}{x_t L_t} \tag{8}$$

$$\frac{\partial \mathbb{L}}{\partial b_t} : \lambda_t^e = \tilde{\beta}_t E_t \lambda_{t+1}^e \left(\frac{1+R_t^r}{\pi_{t+1}}\right) + \omega_t^e (1+R_t^r) \tag{9}$$

$$\frac{\partial \mathbb{L}}{\partial K_t} : \omega_t^e LTV^E q_{t+1}^k (1-\delta^k)\pi_{t+1} + \tilde{\beta}\lambda_{t+1}^e (q_{t+1}^k (1-\delta^k) + r_t^k) = \lambda_t^e q_t^k \tag{10}$$

$$\frac{\partial Y_t^e}{\partial K_t} : r_t^k = \frac{A_t \xi K_{t-1}^{\xi-1} L_t^{1-\xi}}{x_t} \frac{1}{p_t} \tag{11}$$

λ_t^e and ω_t^e 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.

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_t^e, 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 $P_{i,t}^d$. The competitive final domestic goods firm produces output using the following production function:

$$Y_t = \left[\int_0^1 (Y_{i,t})^{\frac{\varepsilon-1}{\varepsilon}} di \right]^{\frac{\varepsilon}{\varepsilon-1}} \tag{12}$$

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

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

and profit maximisation leads to the following first order condition

$$Y_{i,t} = Y_t \left(\frac{P_t^d}{P_{i,t}^d} \right)^{\varepsilon} \tag{13}$$

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:

$$
\begin{aligned}
Y_t &= \left[\int_0^1 (Y_{i,t})^{\frac{\varepsilon-1}{\varepsilon}} di\right]^{\frac{\varepsilon}{\varepsilon-1}} \\
Y_t &= \left[\int_0^1 \left(Y_t\left(\frac{P_t^d}{P_{i,t}^d}\right)^{\varepsilon}\right)^{\frac{\varepsilon-1}{\varepsilon}} di\right]^{\frac{\varepsilon}{\varepsilon-1}} \\
\Rightarrow P_t^d &= \left(\int_0^1 (P_{i,t}^d)^{(1-\varepsilon)} di\right)^{\frac{1}{1-\varepsilon}}
\end{aligned} \tag{14}
$$

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:

$$
\max_{P_{i,t}^d} \mathbb{E}_0^i \sum_{j=0}^{\infty} \theta^j \left[\Lambda_{t,t+j}\left(\overbrace{P_{i,t+j}^d Y_{i,t+j}}^{\text{Revenue}} - \overbrace{\frac{P_{t+j}^d Y_{i,t+j}}{x_{t+j}}}^{\text{Total cost}}\right)\right]
$$

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

$$
\tilde{p}_t^d \equiv \frac{\tilde{P}_t^d}{P_t^d} \equiv \frac{F_t^1}{F_t^2}
$$

where

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

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

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

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

and divide by P_t^d to get

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

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

$$\tilde{p}_t^d = \left[\frac{1 - \theta\left(\bar{\pi}_t\right)^{\varepsilon-1}}{1-\theta}\right]^{\frac{1}{1-\varepsilon}} \tag{15}$$

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

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

subject to

$$\bar{x}_t = \bar{x}_{t-1} + \left[1 - \frac{\kappa_i}{2}\left(\frac{i_t}{i_{t-1}} - 1\right)^2\right] i_t \tag{16}$$

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

$$\Delta\bar{x}_t = \bar{x}_t - \bar{x}_{t-1} = K_t - (1-\delta)K_{t-1} \tag{17}$$

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

$$p_t^{inv} = q_t^k \left(1 - \frac{\kappa_i}{2}\left(\frac{i_t}{i_{t-1}} - 1\right)^2 - \kappa_i \left(\frac{i_t}{i_{t-1}} - 1\right)\frac{i_t}{i_{t-1}}\right) + \beta^t \frac{\lambda_{t+1}^h}{\lambda_t^h} q_{t+1}^k \kappa_i \left(\frac{i_{t+1}}{i_t} - 1\right)\left(\frac{i_{t+1}}{i_t}\right)^2 \quad (18)$$

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

3.6 Production of final consumption goods

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

$$C_t = \left[(1-\alpha)^{\frac{1}{\eta}} (C_t^d)^{\frac{\eta-1}{\eta}} + \alpha^{\frac{1}{\eta}} (C_t^m)^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}} \quad (19)$$

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:

$$C_t^d : P_t \frac{dC_t}{dC_t^d} = P_t^d \rightarrow C_t^d = (1-\alpha)\left(\frac{P_t}{P_t^d}\right)^\eta C_t \quad (20)$$

$$C_t^m : P_t \frac{dC_t}{dC_t^m} = P_t^m \rightarrow C_t^m = \alpha\left(\frac{P_t}{P_t^m}\right)^\eta C_t \quad (21)$$

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

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

and divide by P_t^d

$$p_t = \left[(1-\alpha) + \alpha\,(p_t^m)^{1-\eta}\right]^{\frac{1}{1-\eta}} \tag{22}$$

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.

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:

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

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:

$$R_t^r = R_t^w + \bar{\mu}^b = R_t - \gamma \left(\frac{k_t^b}{b_t} - \nu \right) \left(\frac{k_t^b}{b_t} \right)^2 + \bar{\mu}^b \tag{23}$$

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:

$$j_t^B = R_t^r b_t - R_t d_t - \frac{s_{t+1}\Phi_t R_t^f a_t^f}{p_t} - \frac{\gamma}{2} \left(\frac{k_t^b}{b_t} - \nu \right)^2 k_t^b \tag{24}$$

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

$$k_t^b = k_{t-1}^b \left(1 - \delta^b \right) + j_{t-1}^B \tag{25}$$

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:

$$1 + R_t = s_{t+1}\Phi_t(1 + R_t^f) \tag{26}$$

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.

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:

$$\pi_t \equiv \frac{P_t}{P_{t-1}} = \frac{P_t^d p_t}{P_{t-1}^d p_{t-1}} = \bar{\pi}_t \left[\frac{(1-\alpha) + \alpha \left(p_t^m\right)^{1-\eta}}{(1-\alpha) + \alpha \left(p_{t-1}^m\right)^{1-\eta}} \right]^{\frac{1}{1-\eta}} \tag{27}$$

3.9 Exchange rate

The real exchange rate is defined by the following:

$$p_t^m = \frac{P_t}{P_t} \frac{P_t^m}{P_t^d} = \frac{P_t}{P_t^d} \frac{P_t^m}{P_t} \Rightarrow p_t^m = p_t \times reals_t \tag{28}$$

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.

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

$$\begin{aligned} 1 &= \frac{S_t P_t^x}{P_t^d} = \frac{P_t S_t P_t^f P_t^x}{P_t^d P_t P_t^f} \\ &= p_t reals_t p_t^x \end{aligned} \tag{29}$$

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

$$\frac{reals_t}{reals_{t-1}} = s_t \frac{\pi_t^f}{\pi_t}, s_t \equiv \frac{S_t}{S_{t-1}}, \pi_t^f \equiv \frac{P_t^f}{P_{t-1}^f} \tag{30}$$

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:

$$\frac{s_t \Phi_{t-1}(1+R^f_{t-1})a^f_{t-1}}{\bar{\pi}_t p_t} + p^m_t \alpha \left(\frac{p_t}{p^m_t}\right)^\eta C_t + p^m_t \alpha \left(\frac{p_t}{p^m_t}\right)^\eta i_t = p_t reals_t p^x_t ex_t + a^f_t \tag{31}$$

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.

3.12 Risk Premium Term

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

$$\Phi_t = \Phi\left(a^f_t, R^f_t, R_t, \tilde{\phi}_t\right) = \exp\left(\tilde{\phi}_a\left(a^f_t - \bar{a}\right) - \tilde{\phi}_s\left(R_t - R^f_t - \left(R - R^f\right)\right) + \tilde{\phi}_t\right) \tag{32}$$

where $\tilde{\phi}_a > 0$, $\tilde{\phi}_s > 0$ and $\tilde{\phi}_t \backsim$ mean zero, iid. $\tilde{\phi}_a > 0$ implies if $a_t^f > \bar{a}$, then the cost of external debt in domestic currency units is high and will lead to a reduction in the net external debt, a_t^f, 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.

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

$$\begin{aligned} p_t^* &= \int_0^1 (P_{i,t}^d)^{-\varepsilon} di \\ &= \left[(1-\theta)(\tilde{p}_t^d)^{-\varepsilon} + \theta \frac{\bar{\pi}_t^{\varepsilon}}{p_{t-1}^*}\right]^{-1} \\ &= \left[(1-\theta)\left(\frac{1-\theta(\bar{\pi}_t)^{(\varepsilon-1)}}{1-\theta}\right)^{\frac{\varepsilon}{\varepsilon-1}} + \theta \frac{\bar{\pi}_t^{\varepsilon}}{p_{t-1}^*}\right]^{-1} \end{aligned} \tag{33}$$

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.

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:

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R}\right)^{\rho_R} E_t\left[\left(\frac{\pi_{t+1}}{\pi^T}\right)^{r_\pi}\left(\frac{Y_{t+1}}{Y}\right)^{r_y}\right]^{1-\rho_R} \varepsilon_{R,t} \tag{34}$$

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.

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:

$$\log(G_t) = (1-\rho_g)\eta_g \log Y + \rho_g \log(G_{t-1}) + \varepsilon_{g_t} \tag{35}$$

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.

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.

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

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

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

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 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 5.

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.

Table 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

5.1 General findings

Figure 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 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 12: Impulse responses to the foreign interest rate shock

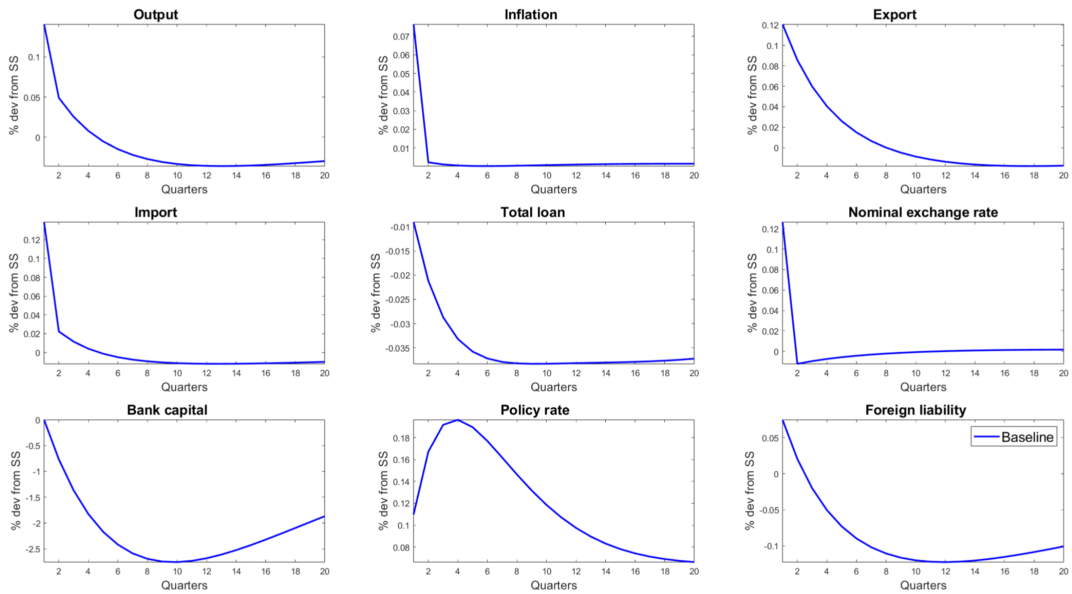

Figure 2.12. Impulse responses to the foreign interest rate shock, $\varepsilon_{R_t^f} = 0.0025$. The unit on the y-axis is in terms of percentage points deviation from the steady state.

Figure 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 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.

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

Figure 13: Impulse responses to the bank capital shock

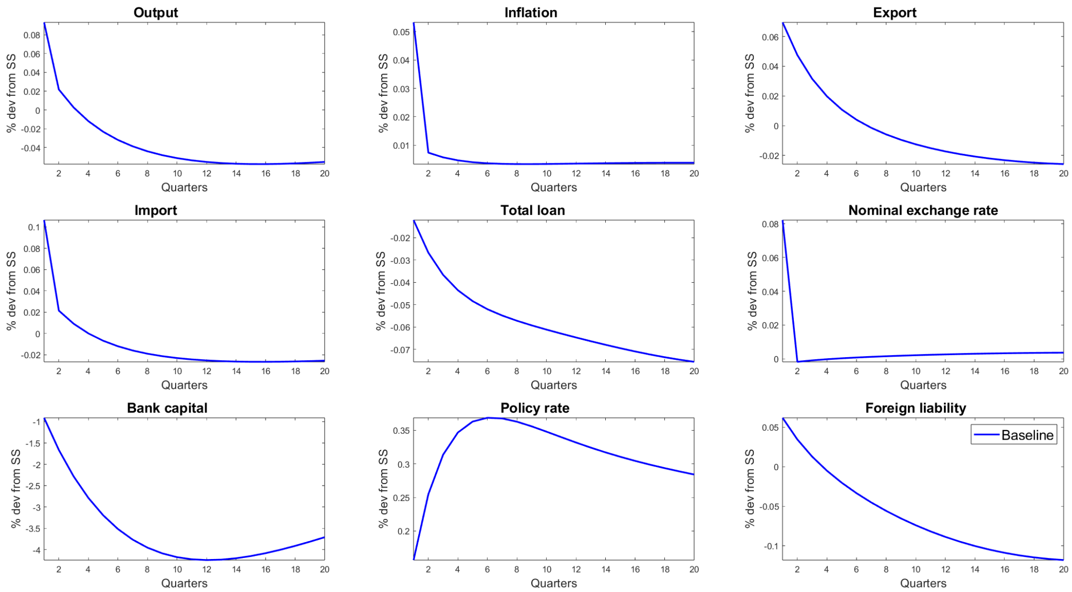

Figure 13. Impulse responses to the bank capital shock, $\varepsilon_{K_t^b} = 0.01$. The unit on the y-axis is in terms of percentage points deviation from the steady state.

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.

Figure 14: Sensitivity analysis on the size of η_a

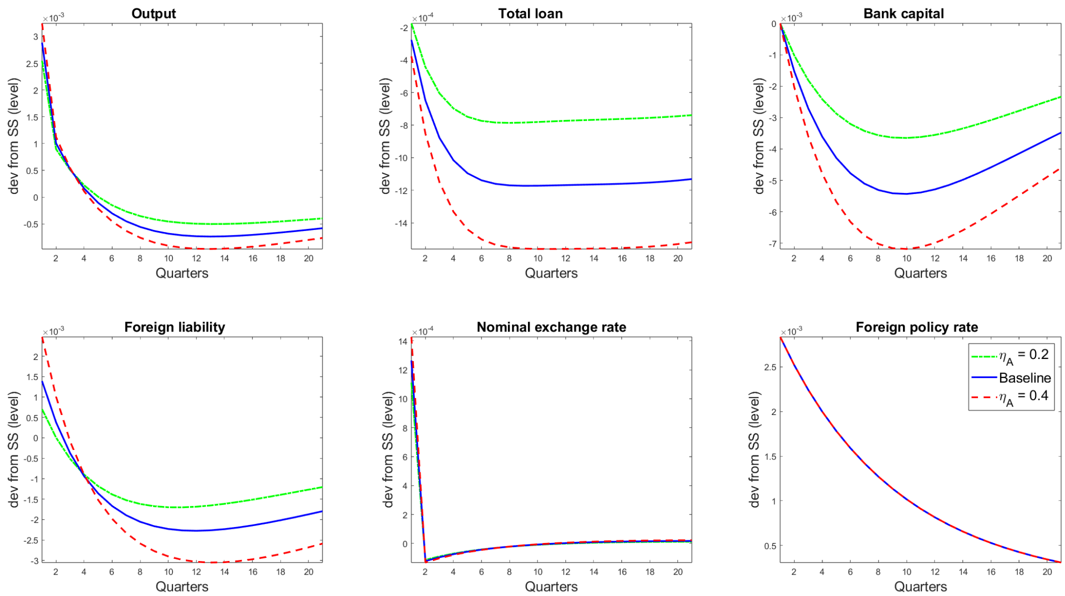

Figure 14. Impulse responses to the foreign interest rate shock, $\varepsilon_{R_t^f} = 0.0025$. The unit on the y-axis is in terms of deviation from the steady state level.

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 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 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] 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.

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, particularly in emerging

[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 scenario.

Figure 15: Occasionally binding constraint of banks

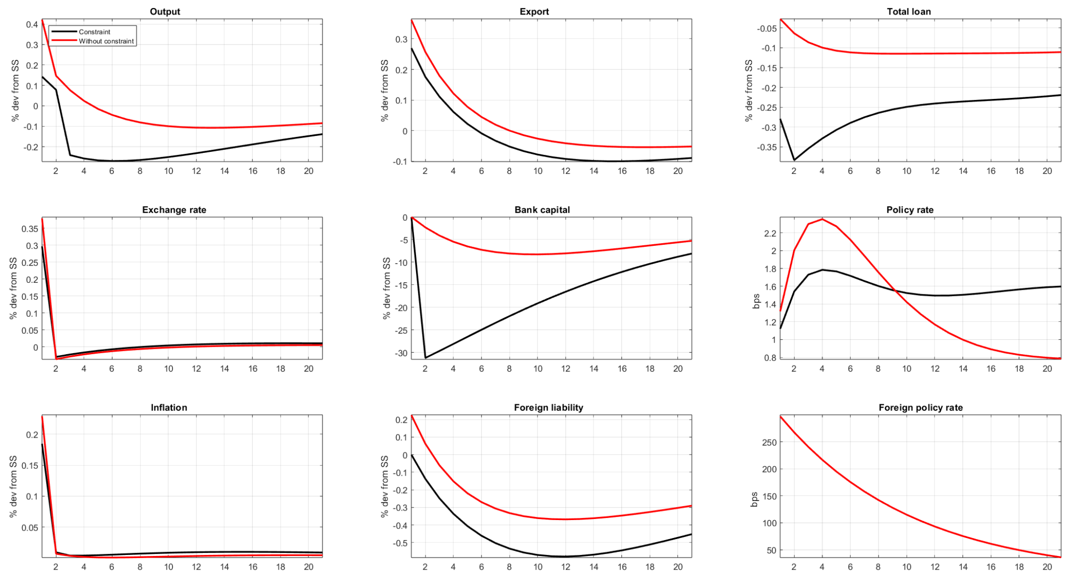

Figure 15. Impulse responses to the foreign interest rate shock, $\varepsilon_{R_t^f} = 0.0075$. The unit on the y-axis is in terms of percentage points and basis points deviation from the steady state.

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

$$j_t^B = R_t^r b_t - R_t d_t - \frac{s_{t+1}^{\eta^s} \Phi_t R_t^f a_t^f}{p_t} - \frac{\theta}{2} \left(\frac{k_t^b}{b_t} - \nu \right)^2 k_t^b \tag{36}$$

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 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.

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.

Figure 16: Banks' sensitivity to the exchange rate

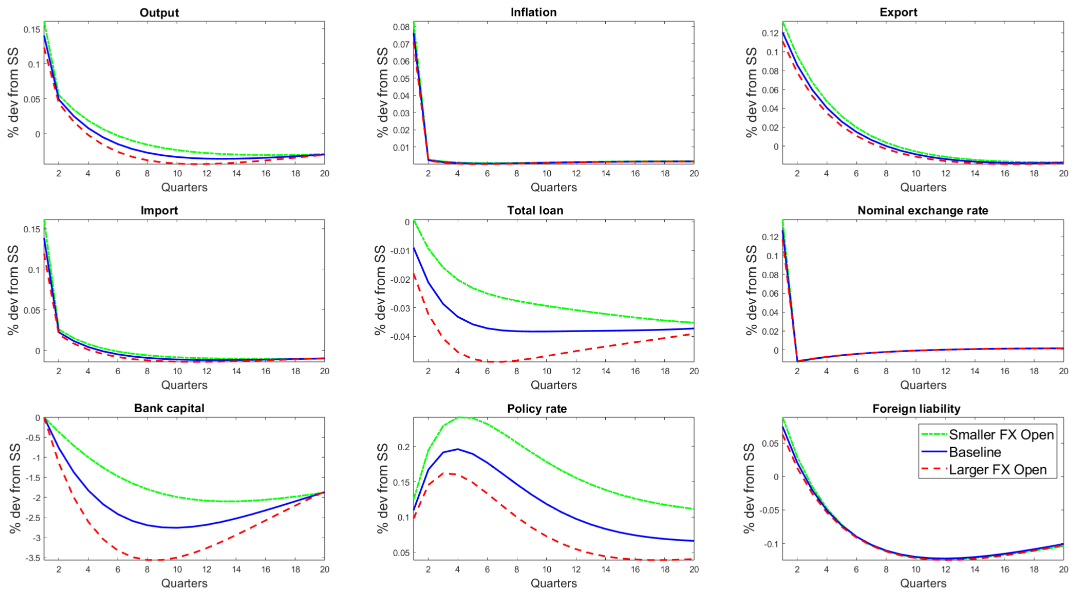

Figure 16. Impulse responses to the foreign interest rate shock, $\varepsilon_{R_t^f} = 0.0025$. The unit on the y-axis is in terms of percentage points deviation from the steady state.

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:

$$\frac{FXI_t}{FXI} = \left(\frac{FXI_{t-1}}{FXI}\right)^{\rho_F} \left(\left(\frac{R_t^f}{R^f}\right)^{\theta_{Rf}}\right)^{1-\rho_F} \tag{37}$$

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 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 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 17 and Table 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 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.

5.5.1 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:

$$W_t^h \equiv E_0 \sum_{t=0}^{\infty} \beta^t \left(\ln C_t^h - \frac{(L_t)^\varphi}{\varphi} \right) \tag{38}$$

Figure 17: Policy responses by the central bank

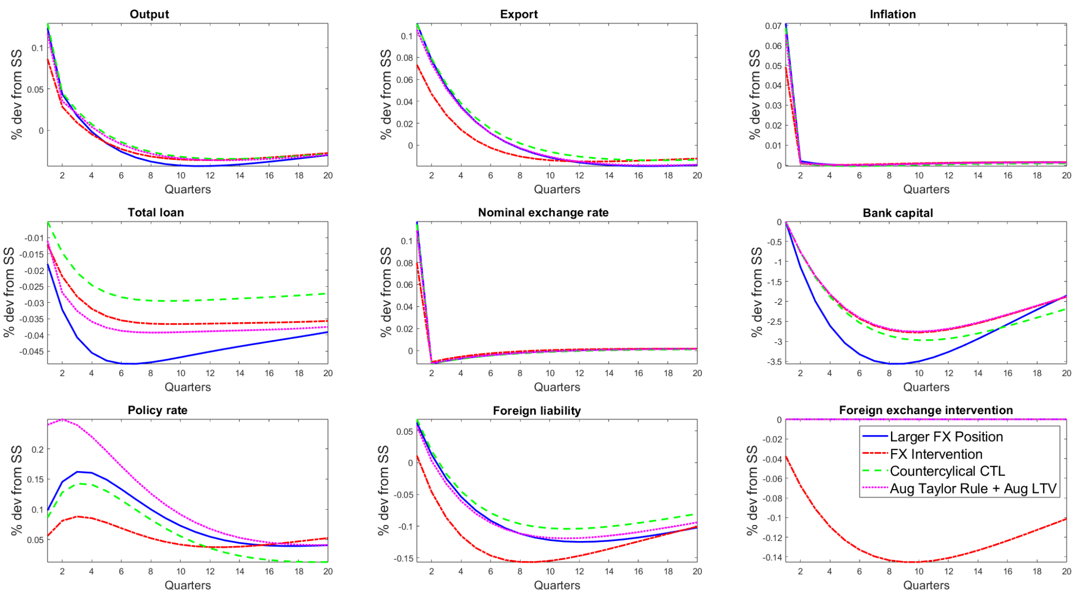

Figure 2.17. Impulse responses to the foreign interest rate shock, $\varepsilon_{R_t^f} = 0.0025$. The unit on the y-axis is in terms of percentage points deviation from the steady state.

and

$$W_t^e \equiv E_0 \sum_{t=0}^{\infty} \widetilde{\beta}^t \left(\ln C_t^e\right) \tag{39}$$

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

$$W_t = (1-\beta)W_t^h + (1-\widetilde{\beta})W_t^e \tag{40}$$

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:

$$CE = \exp\left[W^{LTV^E} - W^{LTV^E=0.34}\right] - 1 \tag{41}$$

Table 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

Table 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 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 $\varepsilon_{R_t^f} = 0.0025$.

6 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.

7 Table A1 - A5

Table A1: 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: 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 A3: 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 A4: 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 A5: 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

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