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Essays on Capital Flows and Macroprudential Regulation

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Declaration of Authorship

I, Pancras Kafonogo MAYENGO, declare that this thesis titled, "Essays on Capital Flows and Macroprudential Regulation" and the work presented in it are my own. I confirm that:

- This work was done wholly while in candidature for a research degree at this University.
- No part of this thesis has previously been submitted for the award of a degree or any other qualification at this University or any other institution anywhere.
- Where I have consulted the published work of others, I have given acknowledgement and I have given the source.
- Where I use the pronoun "we" in the thesis, I refer to myself and my Supervisor who gave me constructive feedback.

To my mother whom while she struggled for her last breath, she whispered to my ears, "...I love you...!"

UNIVERSITY OF ESSEX

Abstract

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Essays on Capital Flows and Macroprudential Regulation

by Pancras Kafonogo MAYENGO

Capital flows to emerging economies are commonly regarded as volatile and are easily influenced by external shocks. For example, the recent sharp normalization of monetary policy in the U.S. could result in emerging markets experiencing capital flight and domestic exchange rate depreciations. Sharp exchange rate depreciations increase the cost of servicing foreign debt for emerging economies, which often have significant proportions of foreign currency debt. How should central banks and governments in emerging economies respond? We answer this question by proposing macroprudential policies which target the drivers of capital flows in the sectoral destinations of such flows. Unlike the recent literature on macroprudential policies, we show how it is crucial to identify the drivers of capital flows (specifically in sectoral destinations) in order to design policies to mitigate macro-financial risks and financial crises.

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Contents

Chapter 1

Essays on Capital Flows and Macroprudential Regulation

1.1 Non-technical Summary

Capital flows to emerging economies tend to flow in during a boom, while flowing out during a recession. Capital inflows can cause asset prices and the domestic currency to appreciate, while capital outflows can have the opposite effect. Depreciation of the domestic currency increases the cost of servicing foreign debts which are denominated in foreign currency. The cost increases because large quantities of domestic currency would be required to service foreign debt, which may trigger a credit crunch and a collapse of the domestic financial system. Depreciation of the domestic exchange rate is also associated with rising domestic inflation, which works against the macro-stability objectives of a healthy economy. Thus, emerging market economies may benefit from controlling cross-border capital flows.

This view has gained currency, especially since the global financial crisis (Gupta and Masetti, 2018 IMF, 2012 and Bauer et al., 2018). The literature presents a consensus: that capital account measures may enhance the welfare of domestic households. However, not all capital flows have the same effects, and therefore no single policy can control all types of flows.

Normally, capital flows in the form of debt, portfolio and foreign direct investment (FDI) are conducted through private agents. Though individual agents are motivated by self-interest, the consequences of their actions can have pecuniary effects(externalities) on all. This is because capital flows affect asset prices (such as the domestic exchange rate), which affects the economy as a whole. Some components of capital flows, though, create more significant externalities than others, e.g., foreign debt vis-a-vis FDI and portfolio, see Korinek, 2018. Evidently, there is a need for different capital flow measures employing specific flows which target specific sectors.

Much of the focus of the literature has been on analysing capital flows without disaggregating it into its components, see Avdjiev et al., 2017. A few authors, such as Korinek, 2018, have analysed different components of capital flows. But Korinek, 2018 does not analyse the destination impact of capital flows. He concludes that debt matters more than FDI and portfolio, because debt induces higher levels of externalities given an exogenous shock.

The objective of this thesis is to analyse different types of capital flows and to propose specific macroprudential policies. In the first two chapters, we analyse the implications for the domestic economy of FDI (in terms of foreign residential purchases (FRP)) on house prices, while the third chapter analyses the implications to the economy of foreign currency debt. The principal difference between the first two chapters and the third is that the drivers of the capital flows are different. More specifically, in the first two chapters the driver is the domestic house prices encouraging foreign house purchases, while in the third chapter it is the international interest rate differential influencing the demand for foreign debt.

The first chapter develops and estimates a dynamic stochastic general equilibrium (DSGE) model using data from the United States to examine the interaction between foreign purchases of houses and the build-up of house prices. We introduce FRP shock to capture unobserved disturbances that may increase housing demand and house prices. This shock is identified using the dynamic stochastic general equilibrium-vector autoregression (DSGE-VAR) model.

The results suggest that a positive shock to foreign purchases of US housing can significantly increase house prices and output. Furthermore, including the FRP in the model improves the effectiveness of monetary policy in reducing inflation. Thus, policymakers should consider stabilising house prices by monitoring FRP growth, specifically by incorporating the FRP variable in relevant models.

Increased FRP is associated with rising house prices and residential investment, with the converse also true. This argument is consistent with Calvo, 2014, who shows that sudden flows and stoppages of capital negatively affects output and the welfare of domestic households. The results also accord with the findings of Ng and Feng, 2016, Bernanke, Gertler, and Gilchrist, 1999 and Sá and Wieladek, 2015, who show that saving-glut shocks, which capture increased preference for US assets among foreign investors, can increase house prices. In this chapter, we assume that borrowing in international markets is imperfect due to adjustment costs and the exchange rate is normalised to one, ideal conditions for two countries in a currency union. Future research can relax these assumptions and study their implications for monetary policy under different exchange-rate regimes.

However, estimating two large economies has many drawbacks. One of which is the two-way feedback mechanism which makes it impossible to isolate the exact contributions of foreign purchases. For example, the United States could influence foreigners to purchase US houses by implementing quantitative easing and keeping interest rates relatively low to make investments in real assets more attractive. The first chapter of this thesis does not account for this two way mechanism.

In the second chapter, we develop a New Keynesian, small, open-economy DSGE model calibrated to the United Kingdom economy to address these drawbacks. This model rules out the two-way feedback mechanism of two large economies. In addition to attempting to understand the effects of FRP on housing demand and prices in a small open economy, we study how monetary and macroprudential policy can be designed to improve the welfare of domestic households.

We analyse how monetary and macroprudential policies interact to stabilise both the macroeconomy and the financial sectors. In particular, we consider the effects on the small open economy from foreign shocks. Our results demonstrate that foreign interest rates and foreign residential purchase shocks can significantly increase output, consumption of domestic households, and house pricing.

Furthermore, this study suggests that a countercyclical macroprudential policy reacting to output deviations in a model with FRP, coupled with monetary policy targeting inflation, can manage economic booms and maximise welfare better than a model without FRP. However, the findings show that certain combinations of these two policies may improve welfare, but others might do not. More specifically, combinations which improve welfare are those where monetary policy is left to do what it does best (price stability), whereas macroprudential policy should maintain financial stability. But the effectiveness of monetary policy deteriorates when it shifts from targeting inflation to financial stabilisation. This conclusion is deduced after various simulations of monetary policy (inflation targeting) using different parameter values. We find that although the values of consumption equivalent measures change, monetary policy is effective when it is complemented by macroprudential policy, rather than substituting it.

In the first two chapters, we assume that developments related to house prices drive capital inflows in terms of FRP and how the capital flows may affect house prices. But on the other hand, investors who build new houses for sale may borrow abroad to build more houses. While this may increase house supply and help to dampen house prices, it increases the liability of the domestic investors to the foreign economy. Moreover, it does not matter where the external shock originates, whether from the FRP or the debt channel, because both may have negative economic consequences. Hence, there is a need to analyse the foreign credit channel from a different angle, which is the purpose of the third chapter.

In the third chapter, we analyse the drivers of foreign debt on the demand side. Low interest rates on foreign currency mortgages encourage domestic households to borrow more in foreign currency at low interest rates and then invest in the high-yielding domestic housing sector. Initially, foreign currency borrowing increases the supply of foreign currency, which may increase the domestic exchange rate. However, in the long term, domestic currency outflows decrease the domestic exchange rate due to repayment of accumulated foreign debt.

Private foreign debt financing may induce pecuniary externalities when financial frictions, such as collateral constraints, are binding. During financial crises, these binding constraints will amplify financial shocks. This situation may worsen after an exogeneous exchange rate shock that causes foreign currency to appreciate, increasing foreign currency debt. Adverse shocks, such as depreciation of the domestic currency, multiply the burden of paying foreign currency debt, which may result in more private non-performing loans.

What can policymakers do in this situation? The literature proposes both ex ante (macroprudential) regulations and ex post (monetary or fiscal stimulus) measures to respond to systemic financial crises (Chari and Kehoe 2016). With exceptions of Korinek, 2018, no author links optimal regulation to the dynamics of the exchange rate and its effect on balance sheets. This chapter contributes to this literature by analysing the macroeconomic effects of real exchange-rate shocks on a small open economy that holds significant foreign currency debt.

An important contribution to the literature of macroprudential policies is the introduction of financial frictions (e.g., collateral constraints) to foreign currency lending. We analyse the interaction of financial frictions with the exchange rate risk and propose an optimal macroprudential policy. For example, Farhi and Werning, 2016 propose a small open macroeconomic model of optimal policy interventions in international capital markets. However, their main assumption (prominent in many small open economy models) is that the interest rate spread must equal the expected depreciation at equilibrium. However, this assumption holds only if the banker is free from financial frictions, such as borrowing constraints. We show that the presence of collateral constraints in foreign credit channels generates a condition in which the interest rate spread at equilibrium is more than the expected depreciation, implying that the relative ratio is different from a unit, which is a deviation from the UIP condition.

This effect of collateral constraints necessitates government intervention to relax the binding constraints in order to prevent or mitigate the severity of financial crises. The experience of some emerging economies in Eastern and Central Europe, during the most recent crisis shows that countries with significant foreign currency debt (Hungary in particular) have deliberately converted all foreign currency loans into domestic currency to prevent capital flight triggered by adverse exchange rate shocks. The decision to convert foreign currency loans was an ex post intervention to mitigate the adverse impact of depreciation of the domestic exchange rate, which had the potential to cause the financial system to collapse.

For example, the Hungarian forint depreciated by 26% against the euro and even more against the Swiss franc in the first quarter of 2009. Because such depreciation increases the burden for repaying debt, the number of private non-performing loans increased by more than 300 percent from 2007 to 2010 (Vonnák, 2015) increasing the debt-to-GDP ratio. Hungary's experience serves as a reminder for other small open economies to act prudently in order to manage capital flows. Consequently, the following question arises: How to design macroprudential policy to control capital flow and manage exchange rate shocks?

Our answer proposes an optimal macroprudential policy designed to respond to dynamics in exchange rates, and foreign monetary policy shocks. Ex ante, domestic households hold expectations of future exchange rates. If they expect the exchange rate to remain the same, they will borrow more from abroad because the exchange rate on foreign currency debt is lower compared to the domestic currency. Since expectations are involved ex ante, we propose a macroprudential policy that considers the interest rate spread which results from the uncovered interest parity (UIP) condition. We also propose an optimal quantitative restriction, which limits banks to offering foreign currency loans. This aims to discriminate between agents who earn incomes in foreign currency and those who do not, since income earners in foreign currency are less vulnerable to adverse exchange rate shocks as compared to those who do not.

Chapter 2

Housing Market Dynamics: Implications of Foreign Residential Purchases for a Large Open Economy

Abstract

The model consists of two large economies (the US and the RW) that trade with each other. Unlike other open economy models, this model assumes that households in the rest of the world have preferences for domestic housing. We introduce the foreign residential purchase (FRP) shock in order to capture unobserved disturbances that may increase housing demand and house prices. The shock was identified by using the dynamic stochastic general equilibrium-vector autoregression (DSGE-VAR) model. The results of this chapter suggest that a positive shock to the foreign purchase of US housing can significantly increase house prices.

2.1 Introduction

The recent progress in globalisation, which facilitates the free movement of people and capital, increases foreign residential purchases (FRP). To what extent does the foreign purchase of residential property influence housing demand and prices? To what extent do such house purchases by foreigners influence the conduct of monetary policy?

People hold real estate in a foreign country for the purposes of investment, living arrangements, or as a hedge against unforeseen financial adversity. The quality of education and the residence programs are also the main drivers in Canada, the US, the UK and Australia. Though FRP is one type of capital flow (others include debt, portfolio, and FDIs) which is considered by the literature less fragile, like debt flows, it is procyclical, i.e., it increases during economic booms and deceases during recessions. If an economic downturn occurs, a fire sale could happen, which may adversely affect housing prices.

A sharp reduction in housing price decreases household net worth, of which housing is a large component. In the US, for example, housing accounts for more than 40% of total household net worth; and the ratio of mortgages to US GDP is more than 90%. A significant decline in housing prices could lead to negative equity for households with mortgages, which may disrupt their consumption and investment plans. These stylised facts call for deliberate actions by policy makers to study the causes of the rise and fall of house prices in order to avert disruptions such as those that occurred during the global financial crisis of 2007-2009.

A number of papers, including (Iacoviello, 2005) and (Iacoviello and

Neri, 2010), attribute the increased housing prices in the US to the relaxation of borrowing constraints such as the Loan to Value (LTV) ratio. These papers show that collateral effects dramatically increases the response of aggregate demand to housing price shocks. They also show that relaxing borrowing constraints (which increases nominal debt), increases the response of output to inflation shocks. The main policy implication of (Iacoviello, 2005) is that house prices and debt indexation are important in monetary policy trade-offs. However, an obvious policy challenge concerns institutions that lie outside the regulatory parameters of a closed economy. This is because increases in foreign income, interest rates, and the exchange rate may influence prices of domestic assets. For instance, increase in a foreign country's income may induce demand for FRP, which may increase housing prices. (Iacoviello, 2005) rules this important mechanism out, which, we incorporate in this chapter.

On the other hand, papers including ((Bernanke, 2005), (Bernanke, 2010), (King, 2009), ((Sá and Wieladek, 2015) (Mendicino and Punzi, 2014) and (Ferrero, 2015)) attribute increased US housing prices to capital flow. These studies showed that capital flows from emerging economies to the US increase liquidity in that country's financial system and drive down long-term real interest rates, which may reduce the cost of borrowing and encourage a credit boom, and an increase in house prices. Accordingly, the US housing boom was caused by a 'saving glut' from emerging economies, especially the oil exporting countries and the Asian countries. The saving glut reduced the risk-free rate and encouraged investors to allocate a large portion of their worth to high-yielding assets, including sub-prime residential mortgage securities. However, these papers ignore the effects of purchasing domestic houses by foreigners on housing prices.

This chapter will develop and estimate a large open economy model in order to examine the implications of the purchase of residential property by foreigners. A large open-economy model is necessary, because it incorporates mutual influences. That is, the US can influence the international interest rate through expansionary monetary policy, while the rest of the world (RW) can influence the US interest rate through the savings glut. The focus is on whether and how such investment by foreigners influences the transmission of monetary policy.

We develop a New Keynesian (NK) large, open-economy model that is integrated with domestic and international financial markets; in which households in the rest of the world purchase houses in the US. We introduce the FRP shock in order to capture unobserved disturbances that may increase the demand for housing and housing prices. The shock is identified by using the dynamic stochastic general equilibrium-vector autoregression (DSGE-VAR) model. We extend (Punzi, 2013) by introducing real and nominal rigidities in the consumption and labour markets, which enables us to study the transmission of FRP and monetary policy shocks. The addition of these features allows the integration of the housing sector into monetary and inflation disturbances. see (Iacoviello and Neri, 2010).

2.1.1 Related Literature

This chapter recognizes the “savings-glut” hypothesis of (Bernanke, 2005), (Bernanke, 2010) and (King, 2009), who argued that international capital flows can increase interest rates and house prices, thereby creating international imbalances in the current account. This hypothesis has been substantiated by the experience of economies with current account deficits and high growth in house prices. This phenomenon has motivated the investigation of the causality between current accounts and house prices. While some (see e.g., (Laibson and Mollerstrom, 2010) (Punzi, 2013), (Fratzscher, Juvenal, and Sarno, 2010) and (Laibson and Mollerstrom, 2010)) argue that the causality moves from house prices to current accounts, others (e.g.(Bernanke, 2005), (Bernanke, 2010) (King, 2009)) argue the opposite.

According to the first view, an increase in house prices makes foreign housing assets more attractive to foreign housing investors, which can increase the current account deficit. However, in the second view, the direction of causality runs from current account deficits to house prices. This hypothesis is the well-known “savings-glut” hypothesis, which was formerly developed by (Bernanke, 2005) and further discussed by (King, 2009) and (Bernanke, 2010). Taken together, these two hypotheses propose that capital inflows (without specifying a particular type) can potentially affect cross-country differentials in house price inflation. One important departure of this chapter from the savings-glut argument is that as international involvement in the domestic housing market increases, it is incumbent to understand their contributions to business cycles, specifically by examining the specific channels of capital inflows.

This chapter is related to other recent theoretical papers that have analysed the effects of capital inflows on the US housing market, e.g., (Favilukis et al., 2012) and (Adam, Kuang, and Marcet, 2011), who argued that changes in international capital flows have only a small effect on house prices. This chapter differs by directly modelling the foreign purchase of domestic houses in an NK-dynamic stochastic general equilibrium model, which has not been considered in previous studies.

Empirically, this chapter is related to (Caballero and Krishnamurthy, 2009), (Krishnamurthy and Vissing-Jorgensen, 2012) and (Tillmann, 2013), who suggested that capital inflows may influence asset prices. However, most previous empirical studies focused on the effects of capital inflows on interest rates. Here, we study many interactions of macro-variables in general equilibrium, which also can be used to answer important economic questions, such as the effect of foreign housing purchases on house prices, investment, economic growth, income inequality, welfare, interest rates, real wages, and consumption.

In a general equilibrium context (Sá and Wieladek, 2015) and (Mendicino and Punzi, 2014) examined the effects of capital inflows on US house prices. These studies considered (among others) four main domestic shocks: technology, housing preference, housing sector-specific technology and loan-to-value shocks; and two external shocks: foreign preference and foreign interest rates. Although these shocks are standard drivers of business cycles in the housing market literature, they do not consider the implications for the domestic economy of residential purchase by foreigners. To fill this gap in the literature, this chapter embeds these standard shocks with the foreign purchase of domestic housing shocks. Specifically, we add the foreign purchase of domestic housing, which can be interpreted as an increase in the degree of preference of foreigners for domestic houses.

Another closely related empirical study is (Liao et al., 2015), which uses a VAR model to analyse the effects of capital inflows on the demand for housing in emerging markets. This study uses data on foreign purchases of domestic housing to study the effect of foreign liquidity on the real estate market and the ripple effect on the dynamics of house prices. In the present study, we extend this analysis with more comprehensive general equilibrium modelling.

The remainder of this chapter is structured as follows. The next section describes a two-country DSGE model with non-durable goods, housing and collateral constraints. Section 3 discusses the calibration of the model, its theoretical implications and dynamics. Section 4 presents the empirical findings of the DSGE-VAR model. Section 5 offers a conclusion.

2.2 The Model

The domestic economy is composed of patient households, impatient households, and firms that produce consumption goods, C_t and housing H_t. We introduce nominal rigidities into the consumption and the labour markets. Both types of households supply labour to firms and consume non-durable goods and housing (durable goods). While impatient households are borrowers, a fraction $(1 - \eta_h)$ of households are patient (savers) and have access to external borrowing from the RW savers. Borrowers are credit constrained and risky; hence, they need collateral in order to secure their loans. Because the savers are owners of production firms, they receive lump sum profits. Monetary policy shock follows the Taylor rule. A variable with a prime, such as $C_t^{'}$, represents constrained households, while a variable without a prime, such as C_t, represents unconstrained households. Foreign variables are identified by an asterisk $(*)$.

Consistent with other large, open-economy DSGE models, the foreign economy is synonymous with the domestic economy, except that all households are savers who run surplus in their accounts and extend credit to the domestic economy to finance their deficits. Differing from other open economy DSGE models, households in the RW have preferences for domestic houses and domestic demand H_t^F.

2.2.1 Savers

The patient households borrow from the RW b_t^* and lend an amount of b_t to the impatient households. They choose how much to spend on non-durable goods C_t, durable goods, H_t, how much they invest in the production of consumption goods K_{ct-1} and housing K_{ht-1}. They also decide how many hours N_{ct} and N_{ht} they work to produce consumption goods and housing, repsectively. In so doing, they maximise their lifetime discounted utility:

$$E_t\left(\sum_{t=0}^{\infty}\beta^t\left[log\left(C_t-\chi C_{t-1}\right)+\gamma_t logH_t-\nu\frac{\left(N_{ct}^{1+\varphi}+N_{ht}^{1+\varphi}\right)^{\frac{1+\sigma}{1+\varphi}}}{1+\sigma}\right]\right) \tag{2.1}$$

where $\beta \in (0,1)$ is the discounting factor;χ is the measure of habits in consumption; E_t is the mathematical expectation operator; σ is the inverse of the Frisch elasticity of the labour supply; and ν is the scale factor for the labour supply. C_t , H_t and N_t refer to consumption, housing stock and working hours, respectively. The subscripts c and h refer to consumption and the housing sector. γ_t captures shocks to the households' taste in housing services, which evolves according to AR(1) process

$$\gamma_t = \rho_\gamma \gamma_{t-1} + \varepsilon_\gamma$$

subject to the budget constraint:

$$\begin{aligned} C_t + b_t + q_t I_{h,t} + I_{ct} + I_{kht} + \frac{R^*_{t-1} b^*_{t-1}}{\pi^*_t} = & \frac{R_{t-1} b_{t-1}}{\pi_t} + \frac{w_{ct} N_{ct}}{X_{wct}} + T_\pi \\ & + \frac{w_{ht} N_{ht}}{X_{wht}} + r_{ct} K_{ct-1} + r_{ht} K_{ht-1} \\ & + b^*_t - \frac{\xi_b}{2} \left(b^*_t - \overline{b^*_t} \right)^2 \end{aligned} \tag{2.2}$$

The left-hand side of the budget constraint defines the expenditures, where b_t , R_t and q_t are, respectively, the amount saved, the gross return from savings, and the price of housing in units of consumption. The right-hand side defines the sources of income, which include real wages w_t , the return on capital r_t and lump sum profits T_π received from owning firms. X_{wct} and X_{wht} refer to the mark-up cost of the monopolistic competitive firms in labour markets. The housing and capital stocks evolve according to

$$H_t = (1 - \delta_h) H_{t-1} + I_{h,t} - \frac{\xi_h}{2} \left(\frac{H_t - H_{t-1}}{H_{t-1}} \right)^2 \tag{2.3}$$

$$K_{ct} = (1-\delta_k) K_{ct-1} + I_{ct} - \frac{\xi_{ck}}{2}\left(\frac{K_{ct}-K_{ct-1}}{K_{ct-1}}\right)^2 \tag{2.4}$$

$$K_{ht} = (1-\delta_k) K_{ht-1} + I_{kht} - \frac{\xi_{hk}}{2}\left(\frac{K_{ht}-K_{ht-1}}{K_{ht-1}}\right)^2 \tag{2.5}$$

where H_t, K_{ct} and K_{ht} are, respectively, housing stock, capital stock in consumption goods production and capital stock in housing production; δ. is the capital depreciation rate. ξ_h, ξ_{ck} and ξ_{hk} are the coefficients of adjustment costs; I_{ct} and $I_{kh,t}$ indicate the investment in consumption goods and housing production; and I_{ht} is investment in new housing.

Optimal conditions for patient households, that is, the consumption Euler equations and labour supply are summarised below. For brevity, I allocate the first order conditions of other variables to the appendix. I present the version without habit formation; however, introducing habits follows the same procedures. For example the Euler equation becomes $\frac{1}{C_t - hC_{t-1}} + \frac{\beta h}{C_{t+1}-C_t} = \beta E_t\left(\frac{R_t}{\pi_{t+1}(C_{t+1}-hC_t)}\right)$. We can see that as $h = 0$ the equation reduces to the Euler equation: The following equations are respectively the Euler equations for choosing the domestic debt (equation 2.6) and for foreign debt (equation 2.7). Equation 2.8 and 2.9 are the equilibrium labour supply conditions for consumption goods sector and for housing sector, respectively.

$$\frac{1}{C_t} = \beta E_t\left(\frac{R_t}{\pi_{t+1}C_{t+1}}\right) \tag{2.6}$$

$$\frac{1}{C_t}\left(1+\xi_b\left(b_t^* - \overline{b_t^*}\right)\right) = \beta E_t\left(\frac{R_t^*}{\pi_{t+1}^* C_{t+1}}\right) \tag{2.7}$$

$$\frac{w_{ct}}{X_{wct}} = \nu\left(N_{ct}^{\varphi}\right)\left(N_{ct}^{1+\varphi} + N_{ht}^{1+\varphi}\right)^{\frac{1+\sigma}{1+\varphi}-1} C_t \tag{2.8}$$

$$\frac{w_{ht}}{X_{wht}} = \nu \left(N_{ht}^{\varphi}\right) \left(N_{ct}^{1+\varphi} + N_{ht}^{1+\varphi}\right)^{\frac{1+\sigma}{1+\varphi}-1} C_t \tag{2.9}$$

2.2.2 Borrowers

The impatient households borrow b_t from patient households. They choose how much they spend on non-durable goods $C_t^{'}$ and durable goods $H_t^{'}$. They also decide how many hours to work in in the production of consumption goods $N_{ct}^{'}$, and housing sectors $N_{ht}^{'}$. Hence, they maximise their lifetime discounted utility:

$$E_t\left(\sum_{t=0}^{\infty} \beta^{'t}\left[log\left(C_t^{'} - \chi^{'} C_{t-1}^{'}\right) + \gamma_t log H_t^{'} - \nu^{'} \frac{\left(N_{ct}^{'\,1+\varphi} + N_{ht}^{'\,1+\varphi}\right)^{\frac{1+\sigma}{1+\varphi}}}{1+\sigma}\right]\right) \tag{2.10}$$

Subject to the budget constraint,

$$C_t^{'} + q_t I_t^{'} + \frac{R_{t-1} b_{t-1}^{'}}{\pi_t} = \frac{w_{ct}^{'} N_{ct}^{'}}{X_{wct}} + \frac{w_{ht}^{'} N_{ht}^{'}}{X_{wht}} + b_t^{'} \tag{2.11}$$

Where

$$H_t^{'} = (1-\delta_h) H_{t-1}^{'} + I_{h,t}^{'} - \frac{\xi_h}{2}\left(\frac{H_t^{'} - H_{t-1}^{'}}{H_{t-1}^{'}}\right)^2 \tag{2.12}$$

and the borrowing constraint,

$$b_t^{'} \leq m_t E_t\left(\frac{q_{t+1} H_t^{'} \pi_{t+1}}{R_t}\right) \tag{2.13}$$

The above equation is the borrowing constraint, which equates the value of loans to the expected value of collateral. We assume that constrained households use housing stock as collateral in order to secure loans, where m_t indicates the LTV ratio, which also evolves according to the AR(1) process, details of which will follow later in the policy section, $m_t = \rho_m m_{t-1} + \varepsilon_m$.

Optimal conditions for impatient households are as follows:

$$\frac{1}{C_t'} = \beta' E_t \left(\frac{R_t}{\pi_{t+1} C_{t+1}'} \right) + \Gamma_t' \tag{2.14}$$

$$\frac{w_{ct}'}{X_{wct}} = \nu \left(N_{ct}'^{\varphi} \right) \left(N_{ct}'^{1+\varphi} + N_{ht}'^{1+\varphi} \right)^{\frac{1+\sigma}{1+\varphi}-1} C_t' \tag{2.15}$$

$$\frac{w_{ht}'}{X_{wht}} = \nu \left(N_{ht}'^{\varphi} \right) \left(N_{ct}'^{1+\varphi} + N_{ht}'^{1+\varphi} \right)^{\frac{1+\sigma}{1+\varphi}-1} C_t' \tag{2.16}$$

The difference between the Euler equation 2.6 and the Euler equation 2.14 is the binding condition Γ_t', which increases with the borrowing constraint in equation 2.13.

2.2.3 Firms

In this chapter, the model consists of two types of firms: final goods producers and intermediate goods producers. The latter produce a continuum of differentiated goods using capital and labour, and sell them to the final goods producers, who transform them into a final homogeneous good to be sold to households.

Final Goods Producers

In a continuum, final goods producers operate under perfect competitive market assumptions. They transform intermediate goods according to the following production function:

$$Y_t = \left[\int_0^1 y_{i,t}^{\frac{\epsilon-1}{\epsilon}} di \right]^{\frac{\epsilon}{\epsilon-1}}$$

where $\epsilon > 1$ is the elasticity of substitution between intermediate goods. The final goods producer takes its output price P_t and the prices of intermediate goods $p_{i,t}$ as given and chooses Y_t in order to maximise profits. In doing so, the final goods producer solves

$$\max_{Y_t} P_t Y_t - \int_0^1 p_{i,t} y_{i,t} di$$

, subject to the equation above. The resulting optimal conditions yield the input demand of intermediate goods:

$$y_{i,t} = \left(\frac{p_{i,t}}{P_t} \right)^{\epsilon} Y_t$$

where the price index, which relates the price of the final good and the prices of the intermediate goods, is given by,

$$P_t = \left[\int_0^1 p_{i,t}^{1-\epsilon} dz \right]^{\frac{1}{\epsilon-1}}.$$

Intermediate Goods Producer

Intermediate goods producers encounter a two-stage problem: First they choose the optimal amounts of labour and capital to minimise the costs of production; and second, they set the price of their produced goods in order to realise profits.

Stage One. Intermediate firms choose $N_{i,t}$ and $K_{i,t-1}$ in order to maximise profits:

$$\max \frac{Y_t}{X_t} + q_t Y_{ht} - \left[w_{i,t} N_{i,t} + w'_{i,t} N'_{i,t} + r_{i,t} K_{i,t-1} + r_{i,t} K_{i,t-1} \right] \quad (2.17)$$

Where $i \in (c, h)$ stands for consumption and the housing sector, respectively. They maximise profits subject to the consumption goods production function Y_t and housing production $Y_{h,t}$

$$Y_t = \left(A_{ct} N_{ct}{}^{\sigma_y} N'_{ct}{}^{1-\sigma_y} \right)^{1-\alpha_y} K_{ct-1}^{\alpha_y} \quad (2.18)$$

$$Y_{h,t} = \left(A_{ht} N_{ht}{}^{\sigma_h} N'_{ht}{}^{1-\sigma_h} \right)^{1-\alpha_h} K_{ht-1}^{\alpha_h} \quad (2.19)$$

where A_{ct} is the aggregate economy technology(Total Factor Productivity - TFP), and A_{ht} is the housing specific sector production technology, both of which follow AR(1): $A_{j,t}$ for $j \in c, h$ is production technology which follows AR(1), that is,

$$A_{j,t} = \rho_{j,h} A_{j,t-1} + \varepsilon_{j,t}$$

where $\rho_{j,h}$ is the coefficient of autoregression and $\varepsilon_{j,t}$ is the zero mean *i.i.d* innovation to technology. Where α and σ, respectively, measure the output elasticity in terms of the capital (owned by patient households at the end of the period) K_{ct-1} and the labour in unconstrained households N_{ct}.

Stage Two. Intermediate firms set prices following the Calvo (1983) mechanism. It is assumed that in every period, a fraction of θ intermediate firms will not be able to change their prices, whereas $1 - \theta$ will be able to optimise their prices. They solve the optimal reset price $p^*_{i,t}$ by maximising:

$$\sum_{k=0}^{\infty} \theta^k E_t \left\{ \psi_{t,k} \left(\frac{p^*_{i,t}}{P_{t+k}} - \frac{X}{X_{t+k}} \right) y^*_{it+k} \right\} = 0$$

where $\psi_{t,k} = \beta \left(\frac{U'(c_t)}{U'(c_{t+1})} \right)$ is the stochastic discount rate over the interval $[t, t+k]$ for the patient households; and X is the steady state mark-up; and $p^*_{it}\left(Y^*_{t+k}\right)$ is the optimal reset price (output). The aggregate price index P_t in each period is given by:

$$P_t = \left[\theta P_{t-1}^{1-\epsilon} + (1-\theta) \left(P^*_t\right)^{1-\epsilon} \right]^{\frac{1}{1-\epsilon}}$$

By combining this equation with the above two equations and log-linearizing, we can obtain the standard, forward looking aggregate Phillips curve: $\pi_t = \beta E_t \pi_{t+1} - \phi x_t + \eta_{\pi,t}$. We assume that retailers index prices in the previous period with an elasticity δ_π. The extended aggregate Phillips curve becomes:

$$\pi_t - \delta_\pi \pi_{t-1} = \beta E_t \left(\pi_{t+1} - \delta_\pi \pi_t \right) - \phi x_t + \eta_{\pi,t} \tag{2.20}$$

where $\phi = (1-\theta)(1-\beta\theta)\theta$ and $\eta_{\pi,t}$ is the zero mean price mark-up shock such that $\eta_{\pi,t} \sim N(0, \sigma^2_\pi)$:

$$\eta_{\pi,t} = \rho_\eta \eta_{\eta,t-1} + \varepsilon_{\eta,\pi}$$

Wage Setting Behaviour

Wage setting is modelled in the same way. Labour packers/unions (related to retail goods firms) purchase wholesale labour services from households and differentiate labour services before they sell them to wholesale firms. According to (Erceg, Henderson, and Levin, 2000), the labour unions monopolise their own differentiated labour services, which implies they can set their own wage rates. The i^{th} labour union adjusts their new wage rate with a probability of $(1-\theta_w)$ according to the Calvo mechanism. Following the same procedures, we can derive a similar log-linearised wage Phillips curve:

$$w_{ct} - \delta_{wc}\pi_{t-1} = \beta E_t \left(w_{t+1} - \delta_{wc}\pi_t \right) - \phi_{wc} x_t + \eta_{wct} \tag{2.21}$$

where $\phi_{wc} = (1-\theta_{wc})(1-\beta\theta_{wc})\theta_{wc}$. Other variables are defined analogously. The Phillips curves for the other three wages are shown in the Appendix.

Monetary Policy

Monetary policy is conducted via a generalised Taylor rule that reacts to deviations from the steady state of inflation, output, and the interest rate in the previous period:

$$R_t = (R_{t-1})^{\rho R} \left[(\pi_t)^{\rho_\pi} \left(\frac{Y_t}{Y_{t-1}} \right)^{\rho_Y} R \right]^{1-\rho R} \varepsilon_{R,t} \tag{2.22}$$

where $0 \leq \rho R \leq 1$ is the interest rate inertia while $\rho_\pi \geq 1$ and $\rho_Y \geq 0$ are the responses of interest rates to current inflation and output growth, respectively. $\varepsilon_{R,t}$ is the uncorrelated monetary shock with a zero mean, $\varepsilon_{R,t}\ N(0, \sigma_R^2)$.

However, this traditional approach leaves the housing market untouched. The approach is debated in the literature that it could only explain the real economy but not the financial sector. For this reason, we include house prices Q_t to enable the central bank to effect changes in the financial sector. As can be deduced from the policy rule given below, any deviations in house prices from the steady state can be mitigated by a contractionary policy, hence restricting house price increases.
$R_t = (R_{t-1})^{\rho R} \left[(\pi_t)^{\rho_\pi} \left(\frac{Y_t}{Y_{t-1}} \right)^{\rho_Y} \left(\frac{Q_t}{Q_{t-1}} \right)^{\rho_Q} R \right]^{1-\rho R} \varepsilon_{R,t}$

Financial Deregulation-LTV ratio shock

We set the LTV ratio shock which follows the autoregressive of order one AR(1) process. This shock is translated as the financial liberalisation shock which, if it increases, causes the LTV ratio to increase. As the LTV ratio increases, it enables borrowers to borrow more than before. The literature relates this to a financial liberalisation shock because it reduces frictions in the market. If the ratio is very close to one (1) at maximum, then the financial market is fully liberalised. Hence,

$$m_t = \rho_m m_{t-1} + \varepsilon_{m,t}$$

where m_t is the deviation from its steady state value for the LTV ratio, and ρ_m is the responsiveness of the LTV ratio to changes in the LTV ratio of $(t-1)$; and $\varepsilon_{m,t}$ is the uncorrelated monetary shock with a zero mean, $\varepsilon_{m,t}\ N(0, \sigma_m^2)$

2.2.4 Foreign Economy

The foreign economy is populated by only the patient households. Like (Mendicino and Punzi, 2014), I assume that the household is a saver and extends credit to the domestic economy. The agent owns and rents the capital to firms that produce consumption goods and houses. The agent supplies labour to both sectors.

Savers in Foreign Economy

The foreign utility function is similar to that of domestic savers, except that households in the foreign economy can also own houses internationally.

$$E_t\left(\sum_{t=0}^{\infty}\beta_t^*\left[log\left(C_t^*-\chi^*C_{t-1}^*\right)+\gamma_t^* logH_t^*-\nu^*\frac{\left({N_{ct}^*}^{1+\varphi^*}+{N_{ht}^*}^{1+\varphi^*}\right)^{\frac{1+\sigma^*}{1+\varphi^*}}}{1+\sigma^*}\right]\right) \tag{2.23}$$

Subject to the budget constraint:

$$\begin{aligned} C_t^*+q_t^*I_{ht}^*+q_tH_t^F+I_{ct}^*+I_{kh,t}^*+b_t^* = & \frac{R_{t-1}^*b_{t-1}^*}{\pi_t^*}+\frac{w_{ct}^*N_{ct}^*}{X_t^*}+\frac{w_{ht}^*N_{ht}^*}{X_t^*} \\ & +q_t\left(1-\delta_h^*\right)H_{t-1}^F+r_{ct}^*K_{ct-1}^* \\ & +r_{ht}^*K_{ht-1}^*+T_\pi{}^* \end{aligned} \tag{2.24}$$

where the number of houses purchased in a foreign country H_t^F evolves as:

$$H_t^F=\left(1-\delta_h\right)H_{t-1}^F+\lambda_t$$

where λ_t is the foreign house purchase shock to domestic houses, which evolves as AR(1) where:

$$\lambda_t = (1-\rho_\lambda)\delta_h\overline{H^F} + \rho_\lambda\lambda_{t-1} + \varepsilon_\lambda$$

where $\overline{H^F}$ is the steady state level of housing purchased by foreigners. This configuration is important in order to make the shock evolve around the steady state $\delta_h\overline{H^F}$ which is the equilibrium level in the housing market clearing condition.

Similar to the domestic economy, other variables evolve accordingly:

$$H_t^* = (1-\delta_h^*)\,H_{t-1}^* + I_{ht}^* - \frac{\xi_h^*}{2}\left(\frac{H_t^* - H_{t-1}^*}{H_{t-1}^*}\right)^2 \tag{2.25}$$

$$K_{ct}^* = (1-\delta_k^*)\,K_{ct-1}^* + I_{ct}^* - \frac{\xi_{ck}^*}{2}\left(\frac{K_{ct}^* - K_{ct-1}^*}{K_{ct-1}^*}\right)^2 \tag{2.26}$$

$$K_{ht}^* = (1-\delta_k^*)\,K_{kht-1}^* + I_{kht}^* - \frac{\xi_{hk}^*}{2}\left(\frac{K_{ht}^* - K_{ht-1}^*}{K_{ht-1}^*}\right)^2 \tag{2.27}$$

Firms in Foreign Economy

Firms produce consumption goods and housing. Just like the domestic economy, they are also subject to a technology shock, where $A_{j,t}^*$ for $j \in c, h$ is an AR(1) production technology, that is,

$$A_{j,t}^* = \rho_{j,h}^* A_{j,t-1}^* + \varepsilon_{j,t}^*$$

where $\rho_{j,h}^*$ is the coefficient of autoregression, and $\varepsilon_{j,t}^*$ is a zero mean *i.i.d* innovation in technology. The only assumption that differentiates the two is that firms in the foreign economy operate in a competitive market.

2.2.5 Foreign Monetary Policy

Foreign monetary policy follows a similar Taylor rule fashion as the domestic economy. It reacts to deviations from the steady state of inflation, output, and the interest rate in the previous period:

$$R_t^* = (R_{t-1}^*)^{\rho R} \left[(\pi_t^*)^{\rho_\pi} \left(\frac{Y_t^*}{Y_{t-1}^*} \right)^{\rho_Y} R^* \right]^{1-\rho R} \varepsilon_{R,t}^* \tag{2.28}$$

where ε_R is the uncorrelated monetary shock with a zero mean, $\varepsilon_{R,t}\, N(0, \sigma_R^2)$. In the literature, this setting is the standard for targeting inflation in monetary policy.

2.2.6 Current Account Balance

The current account is defined as the difference between a country's net claims against the rest of the world, that is, the change in its net foreign assets.

$$CA = -\left(b_t^* - \frac{R_{t-1}^* b_{t-1}^*}{\pi_t^*} \right) \tag{2.29}$$

The literature defines the CA in relatively similar fashion, see (Mendicino and Punzi, 2014) and (Punzi, 2013) where $CA_t = Y_t - C_t - C_t' - I_{ct} - I_{ht}$. Equivalently, it is the difference between what the domestic economy saves and what it invests. $CA_t = S_t - I_t$.

2.2.7 The Equilibrium

At equilibrium, all domestic markets clear. Domestic market clearing conditions are:

$$b_t + b_t^{'} = 0 \tag{2.30}$$

$$Y_t + b_t^* = C_t + C_t^{'} + I_{ct} + I_{kht} + \frac{R_{t-1}^* b_{t-1}^*}{\pi_t} \tag{2.31}$$

$$H_t + H_t^{'} + H_t^F - (1 - \delta_h)\left(H_{t-1} + H_{t-1}^{'} + H_{t-1}^F\right) = Y_{h,t} \tag{2.32}$$

Foreign market clearing conditions;

$$Y_t^* + \frac{R_{t-1}^* b_{t-1}^*}{\pi_t} + q_t\left(1 - delta_h^*\right) H_{t-1}^F = C_t^* + q_t H_t^F + I_{ct}^* + I_{ht}^* + b_t^* \tag{2.33}$$

and

$$H_t^* - (1 - \delta_h^*)\, H_{t-1}^* = Y_{h,t}^* \tag{2.34}$$

2.2.8 Exogenous Variables

We consider the following nine exogenous shocks to consumer preferences: γ_t, technology in the consumption good sector; A_{ct}, specific technology process in the housing sector; A_{ht}, the LTV ratio; m_t; the foreign purchase of domestic housing; λ_t, the monetary policy rate; R_t, the cost shock $\eta_{\pi t}$; foreign technology A_{ct}^*; and the foreign housing sector A_{ht}^*. All shocks have zero mean and variance σ_j^2 ,

i.e., $\left[\varepsilon_{\gamma_t}, \varepsilon_{a,ct}, \varepsilon_{a,ht}, \varepsilon_{mt}, \varepsilon_{\lambda_t}, \varepsilon_{R,t}, \varepsilon_{R,t}, \varepsilon_{a,ct}^*, \varepsilon_{a,ht}^*\right] \sim i.i.d\left(0, \Sigma\right)$

2.3 Estimation

2.3.1 Methods and Data

Following (Del Negro and Schorfheide, 2004) and (Del Negro et al., 2007), we use the DSGE-VAR identification methodology. This uses hybrid modelling procedures by combining an unrestricted vector autoregression (VAR) for the data and the VAR implied by the theoretical DSGE model. This methodology is preferred, because it surmounts most of the challenges encountered in the empirical econometric literature regarding the identification of shocks in VARs. A number of identification mechanisms have been widely applied in VARs, including sign restrictions, following the pioneering work of (Uhlig, 2005). [1].

Other common identification mechanisms that are often applied in the VAR literature include the recursive or Cholesky decomposition, short and long run restrictions. Although the recursive approach leads to the just identified model, it is more likely to be criticised than the later because it imposes restrictions without a theoretical foundation; see (Bjørnland, 2009). Despite its shortcomings, the recursive specification is still commonly applied in the literature (including(Christiano, Eichenbaum, and Evans, 1999), (Giannone, Lenza, and Primiceri, 2015), (Bańbura, Giannone, and Lenza, 2015) and (Bruno and Shin, 2015)) to assess the transmission of a monetary policy shock to the economy. Another contentious issue is whether the short and long run restrictions are credible, especially in variables that have no stylised facts, or whose parameters evolve over time. Different from these identification mechanisms, our choice of

[1] see also (Luciani, 2015) for recent applications of sign restrictions

identification mechanism is micro-based, since it derives the restrictions implied by the theoretical DSGE model.

Lag-length and DSGE Prior Weight

The empirical results are based on 3 number of lags and the DSGE-prior-weight equal to 0.9. The MCMC algorithm is based on $500,000$ draws from the respective posterior distribution. The optimal number of lags is chosen by using the computed marginal likelihoods. By default, the algorithm searches between 1 to ∞ lags. Alternatively, the DSGE's prior density could be calibrated by using the formula.[2]. In this case, we deliberately chose three lags and the degree of imposing restrictions from DSGE to the VAR $(dsge - prior - weight(\iota) = 0.9)$. This combination is associated with the highest marginal likelihoods for this model. The DSGE-prior weight of 0.9 is higher than implied by the formula, i.e., that the weight of the DSGE prior should be a positive real number (i.e. $\iota \geq \frac{\varpi p + \varpi}{T}$). In this case, with 9 observables, 3 lags and $T = 150$, the DSGE prior weight $\iota = 0.17$ would be sufficient, at least in principle.

Data

The rows in Table 1 lists the variables for the US during the period 1965Q1-2006Q4. Since the model incorporates nine (9) exogenous shocks, it is a requirement of the DSGE-VAR to include the same number of observables. These include: Real Consumption, Real House Price, Nominal

[2]Normally, the weight of the DSGE prior is calibrated to a positive real number (greater than $\iota \geq \frac{\varpi p + \varpi}{T}$) where ϖ is the number of the observables, and p the number of lags, and T is the number of observations. See (Del Negro and Schorfheide, 2004)

Interest Rate, Real Residential investment, Real Business investment, Inflation, Hours Worked in the Consumption Sector, Hours Worked in the Housing Sector, and Wage inflation in the Consumption Sector. We use the same data set as in (Iacoviello and Neri, 2010). We chose this range of data from the (Iacoviello and Neri, 2010) as the standard benchmark for the present study.

TABLE 2.1: Data for the U.S Covering the period from 1965Q1-2006Q4

Variable name	Variable name
CC	Private Consumption , real
QPI	Res. property prices ,real
RRN	Nominal interest rate
IKH	Real Residential investment, real
IKC	Business investment in Consumption sector, real
CPI	Inflation
HWC	Hours worked in consumption sector
HWH	Hours worked in housing sector
WPI	Wage inflation in consumption sector.

Source: (Iacoviello and Neri, 2010)

Because the objective of this empirical model is to explain business cycle fluctuations around a steady state, all the variables have to be stationary (Dickey Fuller tests are performed to confirm stationarity). One of three processes can be used to make the data stationary: 1) differencing, 2) de-trending, or 3) filtering. In the present case, we log-differenced all the variables, except the short-term interest rate, inflation, and wage inflation, which are demeaned. Consumption and residential investment are divided by the population before the log-transformation. [3] For this reason, we interpreted the results as a percentage of deviation from a steady state level.

[3]In de-trending, it is common to employ the hp-filter by setting the smoothing parameter equal to 1600 for quarterly data.

2.3.2 Calibrated Parameters

In this chapter, both calibrated and estimated parameters are applied. We use Bayesian methods to estimate the structural parameters, including the share of FRP in the total housing stock in the US. We follow (Punzi, 2013) to calibrate the parameters of the model to match the US historical quarterly data from 1965Q1-2006Q4 and the rest of the world. We assume that the RW is running a current account surplus and financing the US current account deficit through different channels of capital inflows, which include buying US assets through government and private financial assets. However, other countries in the RW also had current account deficits and they experienced house price inflation. Nonetheless, at an aggregate level, it is plausible to assume a current account surplus in the RW relative to the US. The RW data are constructed by weighting the values of 23 main trade partners with the US, following (Pesaran, Schuermann, and Smith, 2009).

The model assumes the proportion of constrained households ($\eta_h = 0.4$). However, the literature shows that the proportion of constrained households may be lower than 50% in the US. For example, (Grant, 2007) estimates that the credit constrained households are between 26 percent and 31 percent of households. Given that the study was done in 2007, it is plausible to assume that after a decade, things may have changed. And most probably the proportion of constrained households has increased to about 40 percent. We set the savers' discount parameter β to 0.99 in order to match the average annual interest rate of 4%. The borrower's discounting factor $\beta^{'}$ is set to 0.98. The housing depreciation rate δ_h is set to 1.5%, which is lower than the capital depreciation rate $\delta_{kh} = \delta_{kc}$ of

3.5%. The steady state mark-up is set to 1.2.

TABLE 2.2: Calibrated and Estimated Parameters Values

Calibrated Parameters					
β	discount factor-savers	0.99	m	loan-to-value ratio	0.85
$\beta\prime$	discount factor-borrowers	0.98	ξ_h	adjustment cost-housing	0
δ_h	depreciation-housing	0.015	η	scale factor for labor supply	2
δ_{kh}	depreciation-housing capital	0.035	j	housing weight-utility	0.2
α_y	capital share-goods	0.35	ξ_{kh}	adjustment cost-housing capital	10
σ_h	patient labour share-housing	0.55	ξ_{kc}	adjustment cost-goods capital	10
σ_y	patient labour share-goods	0.45	X	Steady state markup	1.2
δ_{kc}	depreciation-goods capital	0.035			
α_h	capital share-housing	0.15			

Estimated Parameters						
	Prior name	prior [mean, std]	Posterior - HPD interval			
			mode	10%	mean	90%
χ	habit for savers	Beta[0.5, 0.075]	0.39	0.41	0.35	0.46
χ'	habit for borrowers	Beta[0.5, 0.075]	0.45	0.25	0.41	0.47
φ	degree of labor mobility	Beta[0.5, 0.04]	0.50	0.41	0.49	0.59
σ	elasticity of labour supply	Gamm[1.0, 0.05]	0.99	0.83	0.99	1.1
ϖ_1	ratio of F.P in U.S housing	Norm[4.8 ,0.34]	4.85	4.42	4.76	5.23
δ_{wc}	Indexation wages-goods	Beta[0.5, 0.1]	0.50	0.24	0.50	0.67
δ_{wh}	Indexation wages-housing	Beta[0.5, 0.06]	0.49	0.50	0.65	0.81
ρ_{ac}	Persistence - Productivity Shock	Beta[0.8, 0.04]	0.69	0.60	0.66	0.75
$\rho_{\overline{\pi}}$	Persistence - mark-up Shock	Beta[0.8, 0.01]	0.97	0.96	0.97	0.97
ρ_j	Persist. hous. demand shock	Beta[0.8, 0.01]	0.87	0.56	0.63	0.69
ρ_m	Persistence - L.T.V Shock	Beta[0.8, 0.03]	0.96	0.74	0.82	0.92
ρ_λ	Perst.- frgn hs dem. shock	Beta[0.8, 0.01]	0.92	0.99	0.99	0.99
$\rho\pi$	Taylor rule Inflation	Norm[1.5, 0.07]	1.6	1.33	1.47	1.62
ρR	Taylor rule inertia	Beta[0.75, 0.06]	0.15	0.59	0.65	0.71
ρY	Taylor rule output	Norm[0, 0.04]	0.74	0.30	0.39	0.45
θ_π	Calvo price-goods	Beta[0.7, 0.01]	0.92	0.76	0.80	0.83
θ_{wc}	Calvo wages-goods	Beta[0.7, 0.03]	0.67	0.61	0.66	0.73
θ_{wh}	Calvo wages-housing	Beta[0.7, 0.03]	0.67	0.59	0.65	0.70
σ_{ac}	std. technology shock	Invg[0.1, 0.002]	0.03	0.01	0.01	0.02
σ_j	std. housing demand shock	Invg[0.1, 0.01]	0.06	0.13	0.16	0.19
σ_m	std. L.T.V shock	Invg[0.1, 0.002]	0.02	0.11	0.16	0.20
σ_λ	std. Frgn h. Pref. shock	Invg[0.1, 0.002]	0.02	0.02	0.02	0.02
σ_R	std. interest rate shock	Invg[0.02, 0.001]	0.02	0.06	0.13	0.19
σ_{acf}	std. foreign technology shock	Invg[0.1, 0.001]	0.01	0.011	0.012	0.014

The capital shares of the housing sector α_h and the goods sector α_y are 0.15 and 0.35, respectively. The corresponding share of patient households' labour in the housing sector σ_h is set to 0.55, which is slightly higher than the share of the patient households' labour σ_y in the goods sector, 0.45. The scale factor η for the labour supply is 2.

Consistent with the literature on broad monetary DSGE incorporating collateral constraints, we set the domestic housing preference parameter j to 0.2 and the collateral constraint m to 0.85. This ensures the volatility of housing investment relative to GDP of 5%. The housing stock adjustment cost ξ_h is set to zero, and the capital adjustment costs are ξ_{ck} and ξ_{hk}, equal to 10 for both sectors in order to comport the data. The bond adjustment cost ξ_b is relatively low at 0.008. We use the above calibrated parameter values in deriving the "great ratios" below.

Great Ratios

The great ratios are derived by considering a steady state of the variables in their equilibrium and their first order conditions. Capital to output ratio can be linked to parameters as follows:

$$\frac{I_c}{Y} = \delta_{kc} \frac{K_c}{Y}$$

This relation is derived from equation 2.4 for the capital evolution equation. Applying this to equilibrium conditions in equation 2.31, we obtain:

$$\frac{CA}{Y} = 1 + \left(1 - \frac{R^*}{\pi}\right) \frac{b^*}{Y} - \delta_{kc} \frac{K_c}{Y} - \delta_{kh} \frac{K_h}{Y} - \frac{C}{Y} - \frac{C'}{Y}.$$

Using the first order equations A.8 and A.25, we get:

$$\frac{K_c}{Y} = \frac{\beta \alpha_y}{X \left(1 - \beta + \delta_{kc}\right)}.$$

Following the same procedures, we can derive the current account of the foreign economy as:

$$\frac{CA^*}{Y^*} = 1 - \left(1 - \frac{R^*}{\pi}\right)\frac{b^*}{Y^*} - \delta^*_{kc}\frac{K^*_c}{Y^*} - \delta^*_{kh}\frac{K^*_h}{Y^*} - \frac{C^*}{Y^*} + \delta^*_h q H^F$$

.

Using the steady state values of $\frac{K_h}{Y}$, $\frac{C}{Y}$ and $\frac{C^{'}}{Y}$ for the domestic economy, and $\frac{K_h}{Y}$ and $\frac{C}{Y}$ for the foreign economy(whose derivations are not included here for brevity, but they follow the same procedures as the great ratios above.

For brevity purposes, we select few values of great ratios as presented in the table below: Some of these ratios, such as $\frac{b^*}{Y}$ and $\frac{b^*}{Y^*}$ are based on the assumptions used for this model, which do not necessarily relate to a particular country.

$\frac{C}{Y}$	$\frac{C^{'}}{Y}$	$\frac{K_h}{Y}$	$\frac{CA}{Y}$	$\frac{CA^*}{Y^*}$	$\frac{b^*}{Y}$	$\frac{b^*}{Y^*}$
0.5	0.2	2.1	0.25	0.01	0.09	0.01

2.3.3 Prior Distributions

In addition to the calibrated parameters, other parameters are estimated. Table 3.1 reports the prior and posterior distributions. In order to have a standard theoretical base of the priors, we use the priors specified in (Iacoviello and Neri, 2010), except those that were not included in their study.

An alternative method to derive the priors would be to divide the sample into two parts, estimate the parameters in the first sample, and then use them as the priors in the second sample. Both methods are commonly used in the literature, and they yield similar results. However, since our intention is not to invent a new wheel for the US, we find it convenient to use this approach. We also consider that, in order to have proper priors, it is not recommended to use those from the same sample. Because Table 2 elaborates the prior distributions, we concentrate on discussing the empirical results.

2.4 Estimation Results

In this section, we estimate two models: (1) without the FRP variable (baseline), and (2) with the FRP variable. Most of the results presented here are based on the model with the FRP variable, unless otherwise stated, since the log marginal data densities indicate that the FRP model better fitted the data than the model without.

2.4.1 Posterior Distributions

Parameters governing the FRP. The ratio of FRP in the US housing stock (ϖ_1) for ($0 < \varpi_1 < 1$) was calibrated at 7% of the US housing at steady state. This calibration is based on information provided by Knight Frank Property Research of (2015)[4]. The value of (ϖ_1) is very important to understand how the FRP is related to US house prices. Importantly, the higher the ratio, the higher the foreign purchase of domestic housing. This argument is the innovative contribution of this chapter, which distinguishes it from other DSGE studies that assumed (ϖ_1) to be zero.

[4] For example the Knight Frank Property Research of (2015), which reports that a third of new-build sales of above $\$3m$ in New York city alone, are to international buyers. But this may note be indicative of the whole US housing market

Other estimated parameters that are standard in the literature are as follows:

Nominal rigidities: We estimate the standard parameters that define nominal wage and price rigidity. The Calvo parameters $(\theta_\pi, \theta_{wc}, \theta_{wh})$, which encode the probability of not being able to reset prices and wages in the goods and housing sectors, are $(0.8, 0.66)$ and (0.65), respectively. These values comport with the results of similar DSGE studies in the US. The indexation parameters for wages $(\delta_{wc}, \delta_{wh})$ are (0.5) and (0.65), respectively. In this chapter, we assume zero indexation of prices, which comports with the notion that wages are more persistent than prices, and that the labour supply curve is flat.

Real economy parameters: The degree of the habits of the borrowers $(\chi^{'} = 0.41)$ is relatively higher than of the savers $(\chi = 0.35)$. As the literature review revealed, this can be caused by the inability to smooth consumption through saving since borrowers do not own capital. The elasticity of the labour supply (σ) and the degree of labour mobility across sectors (φ) are respectively (0.99) and (0.49), which suggests that the labour supply is elastic. These parameter values are consistent with the range of values reported in the bulk of DSGE literature.

Monetary policy parameters: Monetary policy follows the Taylor rule, where the estimated results show that the interest rate responds to its own lag by the parameters $(\rho R = 0.65)$, inflation rate $(\rho\pi = 1.47)$ and output by $(\rho Y = 0.39)$. These results fall within the range of many DSGE monetary policy models. Other estimated parameters are documented in Table 3.1.

DSGE-VAR IRFs

Foreign Residential Purchase Shock. Figure 2.1 shows how a one standard deviation positive shock in foreign residential purchases causes private consumption and house prices to increase. This is because the foreign purchase of housing not only increases the demand for housing but also increases the net wealth of households, which increases consumption. Consumption increases by 0.2 %, while housing prices rise by 0.4% and then gradually fall, taking a long time to return to the original state. The wealth effect explains why consumption increases following the FRP shock: A positive FRP shock increases household's total wealth for those who own houses, while wealth appreciates given its effect on house prices.

Other variables that respond positively to the FRP shock include real residential investment, hours worked in the housing sector, the nominal interest rate, CPI inflation, and wage inflation in the consumption sector. While the hours worked in the consumption sector, and real business investment decrease. This effect is plausible because of the assumption that consumers are rational and divert resources from the consumption sector to the housing sector, which has a greater yield. These results comport with the predictions of (Sá and Wieladek, 2015), (Ferrero, 2015) and (Mendicino and Punzi, 2014), which indicated a positive relationship between capital inflow and house prices.

Both theoretical the IRF (thick black line) and the empirical IRF (narrow black dashed line) indicate that a positive shock causing the foreign purchase of domestic housing to increase may significantly increase US

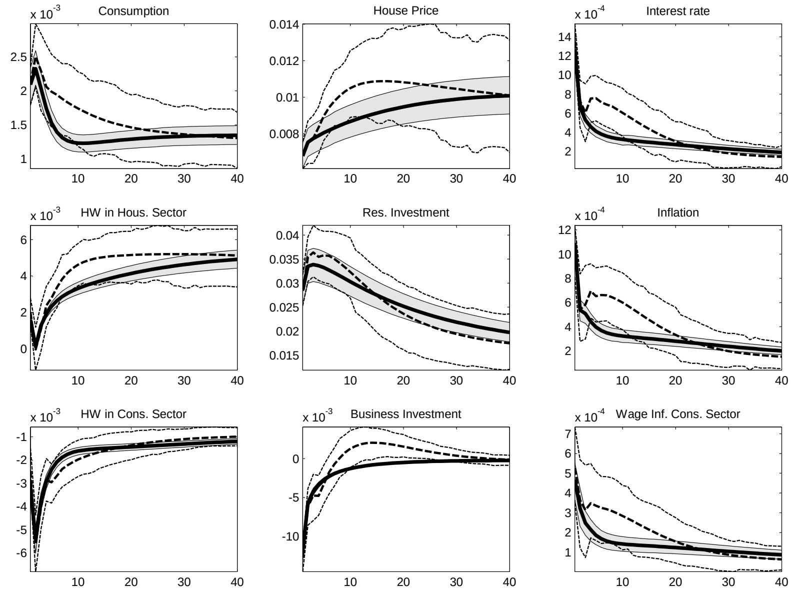


FIGURE 2.1: Impulse Responses to a Foreign Purchase of U.S Housing Shock. *Notes: The thick black line in the middle is the median IRF of the DSGE model.Shaded areas display* 5% *and* 95% *percentiles of the estimated impulse responses. The less thick black dashed line in the middle is the median IRF of the DSGE-VAR model. The thin dashed lines represent the first and ninth posterior deciles of the DSGE-VAR- IRFs.*

house prices. This result confirms the predictions of the savings-glut hypothesis, in which capital flows may increase housing rices; more importantly, it indicates that an increase in the FRP can increase the exposure of the US housing market to foreign business cycles.

These findings suggest that FRP flows may be important in explaining changes in house prices. However, this interpretation is subject to underlying assumptions about the elasticity of housing supply. Therefore a country with an elastic housing supply, such as the US, would experience less persistent effects on house prices following a shock to the FRP, but more persistent effects would be experienced in countries where the supply of housing is more inelastic. [5]

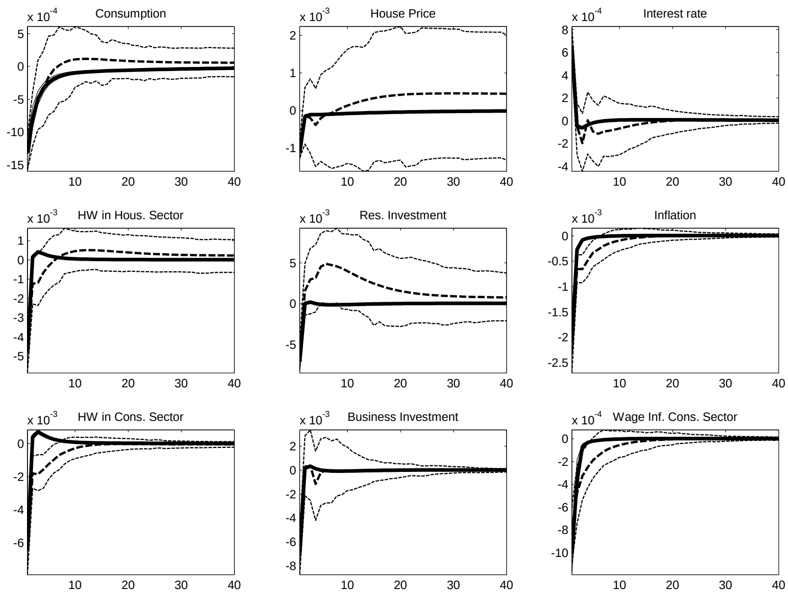


FIGURE 2.2: Impulse Responses to a Contractionary Monetary policy Shock (Model with FRP). *Notes: The thick black line in the middle is the median IRF of the DSGE model.Shaded areas display* 5% *and* 95% *percentiles of the estimated impulse responses. The less thick black dashed line in the middle is the median IRF of the DSGE-VAR model. The thin dashed lines represent the first and ninth posterior deciles of the DSGE-VAR- IRFs.*

Generally, the DSGE model used in the present study fits the data well in terms of the direction of the impact; however, the model did not produce dynamics similar to those of DSGE-VAR IRFs. For example, the latter attain a different level after a shock. Nevertheless, the present model succeeded because it portrayed trends that were in a direction similar to the change in the variables in the foreign house purchase shock in the theoretical model.

[5](Caldera and Johansson, 2013) showed that the housing supply is relatively more elastic in the US and more less elastic in continental European countries and in the UK

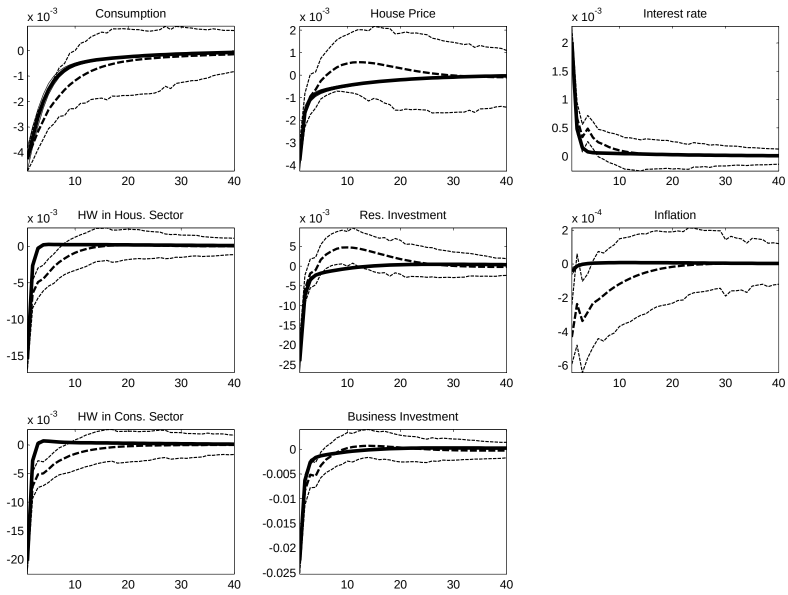


FIGURE 2.3: Impulse Responses to a Contractionary Monetary policy Shock (Baseline Model). *Notes: The thick black line in the middle is the median IRF of the DSGE model.Shaded areas display* 5% *and* 95% *percentiles of the estimated impulse responses. The less thick black dashed line in the middle is the median IRF of the DSGE-VAR model. The thin dashed lines represent the first and ninth posterior deciles of the DSGE-VAR- IRFs.*

Monetary Policy Shock- Figure 2.2 presents the impulse responses for the contractionary monetary policy shock in the model with the FRP variable, and Figure 2.3 reports the impulse responses in the model without the FRP variable. In both cases, an increase in the policy rate caused households to sacrifice current consumption for future consumption, thus reducing demand for goods and housing. This may reduce the CPI, which forces firms to reduce investment in consumption and house production. Consequently, the low demand for labour may cause wages and house prices to decline.

The main difference is how inflation responded to the monetary shock: inflation declined by 0.2 % in the model with the FRP variable, and it decreased by 0.04 % in the model without it. Consumption decreased by 0.15 % in the model with the FRP variable, and it decreased by 0.4 % in the model without it. These results indicate that monetary policy was effective in the model with the FRP variable because higher losses in inflation were associated with fewer losses in consumption.

An important finding is that all the shocks considered in this model imitated previous findings in the DSGE literature. For example, following a technology shock (Figure 5 of the Appendix), consumption, house prices and investment in both sectors increased. Consequently, firms needed fewer workers in both sectors. The interest rate, price inflation, and wage inflation decreased. In the housing sector (Figure 6 of the Appendix) the shock had similar effects, except house prices, which decreased.

In response to financial deregulation, the LTV ratio shock (Figure 7 of the Appendix) relaxed financial constraints, and increased consumption, interest rates, house prices, and wages in the consumption sector. High interest rates increased the cost of investment; hence, firms reduced investment and employment in both sectors. Because the LTV shock and the housing preference shock (Figure 8 of the Appendix) are both demand-side shocks, their effects on the economic variables are relatively similar. Figure 9 of the Appendix reports the impulse responses of price mark-up shock, which increases inflation and the interest rate, while decreasing consumption, because inflation erodes the real incomes of households. As a result, it discourages working hours and investment in both the consumption and housing sector, which decreases wage inflation in the consumption sector.

2.4.2 Variance and Historical Decomposition of House Price

In order to understand how each shock contributed to the forecast error in the variance of house prices, we computed the variance decomposition of all shocks used in the model. Table 2.3 refers to the conditional variance decomposition of some selected shocks.

TABLE 2.3: Conditional Varience Decomposition at Various Horizons

		Model with FRP				Baseline Model			
		Mon-etary	Macro-Prud-ntial	Cons. Goods	Foreg. Res.	Mon-etary	Macro-Prud-ntial	Cons. Goods	Foreg. Res.
Variables	Quarters	Policy	ntial	Technology	Purchase	Policy	ntial	Technology	Purchase
Consumption	1	3.68	7.25	48.99	9.97	18.97	4.03	7.67	-
	10	1.35	4.21	48.35	13.75	6.48	2.12	13.98	-
	100	0.74	2.96	28.97	47.81	2.72	0.88	15.12	-
House Price	1	0.53	2.30	7.51	20.27	6.81	0.34	12.87	-
	10	0.12	0.69	5.24	58.92	1.90	0.27	32.01	-
	100	0.09	0.09	0.73	94.27	0.57	0.10	48.79	-
Interest rate	1	2.07	21.45	25.94	8.73	23.12	25.62	2.34	-
	10	1.08	12.85	25.62	9.51	10.25	10.9	27.88	-
	100	0.71	8.51	17.43	12.22	5.32	5.65	37.45	-
Inflation	1	17.75	7.61	53.65	5.02	0.01	0.00	36.69	-
	10	13.25	6.19	51.17	7.89	0.00	0.00	26.62	-
	100	9.01	4.24	35.10	11.71	0.00	0.00	739.85	-
IKH	1	1.19	13.66	13.34	24.44	14.44	4.70	14.45	-
	10	0.3	3.24	6.44	60.81	5.17	2.37	11.4	-
	100	0.1	1.12	2.13	85.17	2.69	1.24	9.58	-

The Table indicates that the foreign purchase of US housing, and the US technology shock contributed significantly to the variances in the variables more than other the shocks. Of special interest is their long-run contribution to the variances in house prices and inflation. The results indicate that, combined, both shocks contributed to about 30 % of the variances in consumption, house prices, interest rate, inflation, and residential investment in the model with the FRP variable.

Compared to the baseline model(model without FRP), a particular feature is how monetary policy and financial deregulation contributed to the variances in inflation. The baseline model showed that the contribution of monetary policy and financial deregulation to the variances in inflation was almost zero, suggesting that the model without the FRP variable failed to reflect the dynamics of inflation.

Figure A.1 in the Appendix refers to the historical decomposition of the shocks to house prices. As indicated, from the first quarter to the 50th quarter (i.e., early 1975), foreign purchase of US housing, and domestic housing preference shocks were the main drivers of the upward trend in housing prices. During the period 1975-1990, foreign housing purchases contributed to the decrease of house prices. In the late 1990s, the shock of foreign purchase of US housing was the most significant component of the positive movements of house prices. This may be due to increased global financial integration, enabling capital (i.e., foreign housing purchases) to move across borders faster than before. Canonical models had a difficult time to account for the severity of the feedback effects between financial conditions and the real economy during the financial crisis. This result comports with the historical decomposition results in the literature, (see (Gilchrist and Ortiz, 2009) and (Jermann and Quadrini, 2012)) which deviates from many canonical macroeconomic models by including financial variables.

Figure A.2 and A.3 in the Appendix show respectively, the historical decomposition of the current account and the impulse response function following the shock of foreign housing purchases. In both figures, this shock contributes to the deterioration of the domestic current v/s that of the foreign economy. In the interests of brevity, I do not include the details of all the estimation results, except the selected few, since this would make this thesis voluminous.

2.4.3 Model Comparison

To justify the absolute performance of these competing models (the baseline and the model with the FRP variable) in fitting the data, we compute and compare the marginal data density. Table 2.4 compares the models based on log marginal density, and indicates that the log data densities in the model with the FRP variable $(4,523)$ are relatively higher than in the baseline model without the FRP variable $(3,648)$, implying that adding the FRP variable improves the fit with the data.

TABLE 2.4: Business Cycle Properties of Selected Variables

	Baseline Model	Model with FRP	Log-differenced Data
		StdDev	
Consumption	0.04	0.03	0.01
House Price	0.06	0.2	0.02
Interest Rate	0.01	0.01	0.01
Inflation	0.01	0.01	0.01
IKC	0.11	0.08	0.05
IKH	0.16	0.36	0.10
HWH	0.08	0.11	0.04
HWC	0.11	0.03	0.01
		Correlations	
House Price, Consumption	0.86	0.89	0.48
House price, IKH	0.61	0.95	0.41
		Model Comparison	
Log Marginal Density	4523	3648	-

NOTE: U.S Data Sample Period: 1965:Q1–2006:Q4

However, these general performance criteria do not reveal any particular ability to predict the population moments of the variables in the data sample. We compute the population moments, such as the standard deviations (volatility) and cross correlations, to measure the comovement of some selected variables as presented in Table 4. Regarding the volatility and the cross correlations, no significant difference was found between the two models. However, by using the absolute measure of model performance (the log marginal density), we can conclude that the model with the FRP variable better fitted the data.

2.4.4 Robustness

As a robustness check, we re-estimated the model using two sub-samples: $1965Q1 - 1980Q4$, and $1981Q1 - 2006Q4$. The results changed for the magnitudes of the posterior distributions. This observation is consistent with recent findings in the literature, which estimated time varying parameters. However, there was no significant change in the direction of the reaction to the shocks. For example, the increase in the foreign purchases of housing caused house prices, the interest rate, and inflation rate to increase. Moreover, because the foreign purchase of houses had a positive effect on domestic household wealth, consumption increased accordingly.

Additionally, in both samples, a contractionary monetary policy increasing interest rates led to a decline in consumption, inflation, housing prices, and residential investment. A more striking result was that the foreign residential purchase shock had a greater impact on house prices in the second sub-sample than in the first sub sample. This can be explained by capital flows increasing significantly in the first sample.

2.5 Conclusion

This chapter accounted for the housing market dynamics caused by foreign residential purchases. The chapter addressed the implications for the economy of the foreign purchase of residential property; and whether and how they influence the transmission of monetary policy.

The model consists of two large economies (the US and the RW) that trade with each other and in which households in the RW purchase houses in the US. We introduce the foreign residential purchase (FRP) shock in order to capture unobserved disturbances that may increase housing demand and house prices. The shock was identified by using the dynamic stochastic general equilibrium-vector autoregression (DSGE-VAR) model.

The results of this chapter suggest that a positive shock to the foreign purchase of US housing can significantly increase house prices. Furthermore, including the FRP variable in the model improved the effectiveness of monetary policy in reducing inflation. Using the Bayesian estimation techniques expressed in (Del Negro and Schorfheide, 2004) and (Del Negro et al., 2007), we estimated the proportion of the houses purchased by RW to be higher than 7% at the mode. In this case, a 1% shock to the foreign purchase of US housing significantly increased house prices by 0.4%. Following the shock, consumption and residential investment increased by more than 0.2%, whereas interest rates and inflation increased by less than 0.1%.

Because the positive growth in FRP correlated with increasing house prices and residential investment, the converse could also be true. This argument is consistent with (Calvo, 2014), who demonstrated that sudden flows and stoppages of capital flows were associated with negative effects on output and welfare. The results comport with the evidence in (Ng and Feng, 2016), (Bernanke, 2010) and (Sá and Wieladek, 2015), who show that the savings-glut shock, which captures an increase in the degree of foreign investors' preference for US assets, can increase house prices. Based on these findings, policy makers may consider stabilising house prices by monitoring the growth of the FRP ratio in domestic housing stock. Specifically, this could be done by incorporating the FRP variable into the models.

In this chapter, we assumed that borrowing in the international market is imperfect (due to bond adjustment costs in the international financial market), and that the nominal exchange rate is normalised to one—an ideal condition for two countries in a currency union. A suggestion for future avenues is to relax some of the assumptions and study their implications for monetary policy under different exchange rate regimes.

Appendix A

A.1 Main Equations and Selected DSGE-VAR Figures

Budget constraint of domestic patient households

$$\begin{aligned} C_t + b_t + q_t I_{h,t} + I_{ct} + I_{kht} + \frac{R^*_{t-1} b^*_{t-1}}{\pi^*_t} = & \frac{R_{t-1} b_{t-1}}{\pi_t} + \frac{w_{ct} N_{ct}}{X_t} + \frac{w_{ht} N_{ht}}{X_t} \\ & + r_{ct} K_{ct-1} + r_{ht} K_{ht-1} + T_\pi \\ & + b^*_t - \frac{\xi_b}{2} \left(b^*_t - \overline{b^*_t} \right)^2 \end{aligned} \tag{A.1}$$

Where the housing and capital stocks evolves over time as:

$$H_t = (1 - \delta_h) H_{t-1} + I_{h,t} - \frac{\xi_h}{2} \left(\frac{H_t - H_{t-1}}{H_{t-1}} \right)^2 \tag{A.2}$$

$$K_{ct} = (1 - \delta_k) K_{ct-1} + I_{ct} - \frac{\xi_{ck}}{2} \left(\frac{K_{ct} - K_{ct-1}}{K_{ct-1}} \right)^2 \tag{A.3}$$

$$K_{ht} = (1 - \delta_k) K_{ht-1} + I_{kht} - \frac{\xi_{hk}}{2} \left(\frac{K_{ht} - K_{ht-1}}{K_{ht-1}} \right)^2 \tag{A.4}$$

Optimal conditions for patient households:

Note: For brevity here, I present the version without habit formation. However introducing habits follows the same procedure. For example the Euler equation becomes $\frac{1}{C_t - hC_{t-1}} + \frac{\beta h}{C_{t+1} - C_t} = \beta E_t \left(\frac{R_t}{\pi_{t+1}(C_{t+1} - hC_t)} \right)$. We can see that as $h = 0$ the equation reduces to the Euler equation below:-

$$\frac{1}{C_t} = \beta E_t \left(\frac{R_t}{\pi_{t+1} C_{t+1}} \right) \tag{A.5}$$

$$\frac{1}{C_t} \left(1 + \xi_b \left(b_t^* - \overline{b_t^*} \right) \right) = \beta E_t \left(\frac{R_t^*}{\pi_{t+1}^* C_{t+1}} \right) \tag{A.6}$$

$$\frac{j_t}{H_t} = \frac{q_t}{C_t} \left(1 + \xi_h \left(\frac{H_t}{H_{t-1}} - 1 \right) \right) - \beta E_t \left(\frac{q_{t+1}}{C_{t+1}} \left((1 - \delta_h) + \frac{\xi_h}{2} \left(\frac{H_{t+1}^2}{H_t^2} - 1 \right) \right) \right) \tag{A.7}$$

$$\frac{1}{C_t} \left(1 + \xi_{kc} \left(\frac{K_{ct}}{K_{t-1}} - 1 \right) \right) = \beta E_t \left(\frac{1}{C_{t+1}} \left((1 - \delta_{kc}) + R_{ct} + \frac{\xi_{kc}}{2} \left(\frac{K_{ct+1}^2}{K_{ct}^2} - 1 \right) \right) \right) \tag{A.8}$$

$$\frac{1}{C_t} \left(1 + \xi_{kh} \left(\frac{K_{ht}}{K_{ht-1}} - 1 \right) \right) = \beta E_t \left(\frac{1}{C_{t+1}} \left((1 - \delta_{kh}) + R_{ht} + \frac{\xi_{kh}}{2} \left(\frac{K_{ht+1}^2}{K_{ht}^2} - 1 \right) \right) \right) \tag{A.9}$$

$$\frac{w_{ct}}{X_{wct}} = \nu \left(N_{ct}^{\varphi} \right) \left(N_{ct}^{1+\varphi} + N_{ht}^{1+\varphi} \right)^{\frac{1+\sigma}{1+\varphi} - 1} C_t \tag{A.10}$$

$$\frac{w_{ht}}{X_{wht}} = \nu \left(N_{ht}^{\varphi} \right) \left(N_{ct}^{1+\varphi} + N_{ht}^{1+\varphi} \right)^{\frac{1+\sigma}{1+\varphi} - 1} C_t \tag{A.11}$$

Budget Constraint for Impatient Households:

$$C_t^{'} + q_t H_t^{'} + \frac{R_{t-1} b_{t-1}}{\pi_t} = \frac{w_{ct}^{'} N_{ct}^{'}}{X_t} + \frac{w_{ht}^{'} N_{ht}^{'}}{X_t} + b_t^{'} \tag{A.12}$$

Where

$$H_t^{'} = (1 - \delta_h) H_{t-1}^{'} + I_{h,t}^{'} - \frac{\xi_h}{2} \left(\frac{H_t^{'} - H_{t-1}^{'}}{H_{t-1}^{'}} \right)^2 \tag{A.13}$$

and the borrowing constraint

$$E_t \frac{R_t}{\pi_{t+1}} b_t^{'} = E_t m_t q_{t+1} H_t^{'} \tag{A.14}$$

Optimal conditions for impatient households:

$$\frac{1}{C_t^{'}} = \beta^{'} E_t \left(\frac{R_t}{\pi_{t+1} C_{t+1}^{'}} \right) + \Gamma_t^{'} \tag{A.15}$$

$$\begin{aligned}\frac{j_t^{'}}{H_t^{'}} =& \frac{q_t}{C_t^{'}} \left(1 + \xi_h \left(\frac{H_t}{H_{t-1} - 1} \right) \right) - \beta E_t \left(\frac{q_{t+1}}{C_{t+1}^{'}} \left((1 - \delta_h) + \frac{\xi_h}{2} \left(\frac{H_{t+1}^2}{H_t^2} - 1 \right) \right) \right) \\ & - \Gamma_t^{'} m_t E_t \left(\frac{q_{t+1} \pi_{t+1}}{R_t} \right)\end{aligned} \tag{A.16}$$

$$\frac{w_{ct}^{'}}{X_{wct}} = \nu \left(N_{ct}^{'\ \varphi} \right) \left(N_{ct}^{'\ 1+\varphi} + N_{ht}^{'\ 1+\varphi} \right)^{\frac{1+\sigma}{1+\varphi} - 1} C_t^{'} \tag{A.17}$$

$$\frac{w_{ht}^{'}}{X_{wht}} = \nu \left(N_{ht}^{'\ \varphi} \right) \left(N_{ct}^{'\ 1+\varphi} + N_{ht}^{'\ 1+\varphi} \right)^{\frac{1+\sigma}{1+\varphi} - 1} C_t^{'} \tag{A.18}$$

Firms maximization, wages and pricing mechanism

$$Y_t = \left(A_{ct} N_{ct}^{\sigma_y} N_{ct}^{'\ 1-\sigma_y} \right)^{1-\alpha_y} K_{ct-1}^{\alpha_y} \tag{A.19}$$

$$Y_{h,t} = \left(A_{ht} N_{ht}^{\sigma_h} N_{ht}^{'\ 1-\sigma_h} \right)^{1-\alpha_h} K_{ht-1}^{\alpha_h} \tag{A.20}$$

$$w_{ct} = \frac{1}{X_t} \sigma_y \left(1 - \alpha_y \right) \frac{Y_t}{N_{ct}} \tag{A.21}$$

$$w_{ht} = \sigma_h \left(1 - \alpha_h \right) \frac{q_t Y_{ht}}{N_{ht}} \tag{A.22}$$

$$w_{ct}^{'} = \frac{1}{X_t} \left(1 - \sigma_y \right) \left(1 - \alpha_y \right) \frac{Y_t}{N_{ct}^{'}} \tag{A.23}$$

$$w_{ht}^{'} = \left(1 - \sigma_h \right) \left(1 - \alpha_h \right) \frac{q_t Y_{ht}}{N_{ht}^{'}} \tag{A.24}$$

$$R_{ct} = \frac{1}{X_t} \alpha_y \frac{Y_t}{K_{ct-1}} \tag{A.25}$$

$$R_{ht} = \alpha_h \frac{q_t Y_{ht}}{K_{ht-1}} \tag{A.26}$$

Aggregate Phillips curve relation:

$$\pi_t - \delta_\pi \pi_{t-1} = \beta E_t \left(\pi_{t+1} - \delta_\pi \pi_t \right) - \phi x_t + \eta_{\pi,t} \tag{A.27}$$

where $\phi = (1-\theta)(1-\beta\theta)\theta$ and $\eta_{\pi,t}$ is a zero mean price mark-up shock. Wage Phillips curve of the following form:

$$w_{ct} - \delta_{wc} \pi_{t-1} = \beta E_t \left(w_{ct+1} - \delta_{wc} \pi_t \right) - \phi_{wc} x_t \tag{A.28}$$

$$w_{ht} - \delta_{wh} \pi_{t-1} = \beta E_t \left(w_{ht+1} - \delta_{wh} \pi_t \right) - \phi_{wc} x_t \tag{A.29}$$

$$w'_{ct} - \delta_{wc} \pi_{t-1} = \beta' E_t \left(w'_{ct+1} - \delta_{wc} \pi_t \right) - \phi_{wc} x_t \tag{A.30}$$

$$w_{ht'} - \delta_{wh} \pi_{t-1} = \beta' E_t \left(w'_{ht+1} - \delta_{wh} \pi_t \right) - \phi_{wc} x_t \tag{A.31}$$

where $\phi_{wc} = (1-\theta_{wc})(1-\beta\theta_{wc})\theta_{wc}$ and where $\phi'_{wc} = (1-\theta'_{wc})(1-\beta'\theta'_{wc})\theta'_{wc}$. For simplicity, I assume $\phi_{wc} = \phi_{wh}$ and $\phi'_{wc} = \phi'_{wh}$

Monetary policy

$$R_t = (R_{t-1})^{\rho R} \left[(\pi_t)^{\rho_\pi} \left(\frac{Y_t}{Y_{t-1}} \right)^{\rho_Y} R \right]^{1-\rho R} \varepsilon_{R,t}; \tag{A.32}$$

Foreign Economy

Foreign budget constraint:

$$C_t^* + q_t^* I_{ht}^* + q_t H_t^F + I_{ct}^* + I_{kh,t}^* + b_t^* = \frac{R_{t-1}^* b_{t-1}^*}{\pi_t^*} + \frac{w_{ct}^* N_{ct}^*}{X_t^*} + \frac{w_{ht}^* N_{ht}^*}{X_t^*} + q_t\left(1-\delta_h^*\right) H_{t-1}^F + r_{ct}^* K_{ct-1}^* + r_{ht}^* K_{ht-1}^* + T_\pi{}^* \tag{A.33}$$

$$H_t^* = \left(1-\delta_h^*\right) H_{t-1}^* + I_{h,t}^* - \frac{\xi_h^*}{2}\left(\frac{H_t^* - H_{t-1}^*}{H_{t-1}^*}\right)^2 \tag{A.34}$$

$$K_{ct}^* = \left(1-\delta_k^*\right) K_{ct-1}^* + I_{ct}^* - \frac{\xi_{ck}^*}{2}\left(\frac{K_{ct}^* - K_{ct-1}^*}{K_{ct-1}^*}\right)^2 \tag{A.35}$$

$$K_{ht}^* = \left(1-\delta_k^*\right) K_{kht-1}^* + I_{kht}^* - \frac{\xi_{hk}^*}{2}\left(\frac{K_{ht}^* - K_{ht-1}^*}{K_{ht-1}^*}\right)^2 \tag{A.36}$$

where:

$$H_t^F = \left(1-\delta_h\right) H_{t-1}^F + \lambda_t$$

and

$$\lambda_t = (1-\rho_\lambda)\delta_h \overline{H^F} + \rho_\lambda \lambda_{t-1} + \varepsilon_\lambda$$

Foreign Economy First order conditions are synonymous to the first order conditions of the domestic saver, except that the foreign variables are identifies with an asterisk $(*)$. The main difference is with the equilibrium condition for buying house in a foreign country H_t^F which is:-

$$q_t = \left(1-\delta_h\right) \beta^* \frac{C_t^*}{C_{t+1}^*} q_{t+1} \tag{A.37}$$

$$\frac{1}{C_t^*} = \beta E_t \left(\frac{R_t^*}{\pi_{t+1}^* C_{t+1}^*} \right) \tag{A.38}$$

$$\frac{1}{C_t^*}\left(1 + \xi_b \left(b_t^* - \overline{b_t^*}\right)\right) = \beta E_t \left(\frac{R_t^*}{\pi_{t+1}^* C_{t+1}^*} \right) \tag{A.39}$$

$$\frac{j_t}{H_t^*} = \frac{q_t^*}{C_t^*}\left(1 + \xi_h \left(\frac{H_t}{H_{t-1}} - 1\right)\right) - \beta E_t \left(\frac{q_{t+1}^*}{C_{t+1}^*} \left((1-\delta_h) + \frac{\xi_h}{2}\left(\frac{H_{t+1}^2}{H_t^2} - 1\right)\right)\right) \tag{A.40}$$

$$\frac{1}{C_t^*}\left(1 + \xi_{kc}\left(\frac{K_{ct}^*}{K_{t-1}^*} - 1\right)\right) = \beta E_t \left(\frac{1}{C_{t+1}^*}\left((1-\delta_{kc}) + R_{ct}^* + \frac{\xi_{kc}}{2}\left(\frac{\left(K_{ct+1}^2\right)^*}{\left(K_{ct}^2\right)} - 1\right)\right)\right) \tag{A.41}$$

$$\frac{1}{C_t^*}\left(1 + \xi_{kh}\left(\frac{K_{ht}^*}{K_{ht-1}^*} - 1\right)\right) = \beta E_t \left(\frac{1}{C_{t+1}^*}\left((1-\delta_{kh}) + R_{ht} + \frac{\xi_{kh}}{2}\left(\frac{\left(K_{ht+1}^2\right)^*}{\left(K_{ht}^2\right)} - 1\right)\right)\right) \tag{A.42}$$

$$\frac{w_{ct}^*}{X_{wct}^*} = \nu \left((N_{ct}^*)^{\varphi} \right) \left((N_{ct}^*)^{1+\varphi} + (N_{ht}^*)^{1+\varphi} \right)^{\frac{1+\sigma}{1+\varphi} - 1} C_t^* \tag{A.43}$$

$$\frac{w_{ht}^*}{X_{wht}^*} = \nu \left(N_{ht}^{*\,\varphi} \right) \left((N_{ct}{}^*)^{1+\varphi} + (N_{ht}^*)^{1+\varphi} \right)^{\frac{1+\sigma}{1+\varphi} - 1} C_t^* \tag{A.44}$$

Current Account

$$CA = \left(b_{t-1}^* - \frac{R_{t-1}^* b_{t-1}^*}{\pi_t^*} \right) + Y - C_t - C_t^{'} - I_{ct} - I_{ht} \tag{A.45}$$

Real interest rate (Fisher equation)

$$rn_t = rr_t + \pi_{t+1} \tag{A.46}$$

and the foreign current account equation

$$CA^* = -\left(b_{t-1}^* - \frac{R_{t-1}^* b_{t-1}^*}{\pi_t^*} \right) + Y^* - C_t^* - I_{ct}^* - I_{ht}^* \tag{A.47}$$

Domestic market clearing conditions:

$$b_t + b_t^{'} = 0 \tag{A.48}$$

$$Y_t + b_t^* = C_t + C_t^{'} + I_{ct} + I_{kht} + \frac{R_{t-1}^* b_{t-1}^*}{\pi_t} \tag{A.49}$$

$$H_t + H_t^{'} + H_t^F - (1-\delta_h)\left(H_{t-1} + H_{t-1}^{'} + H_{t-1}^F\right) = Y_{h,t} \tag{A.50}$$

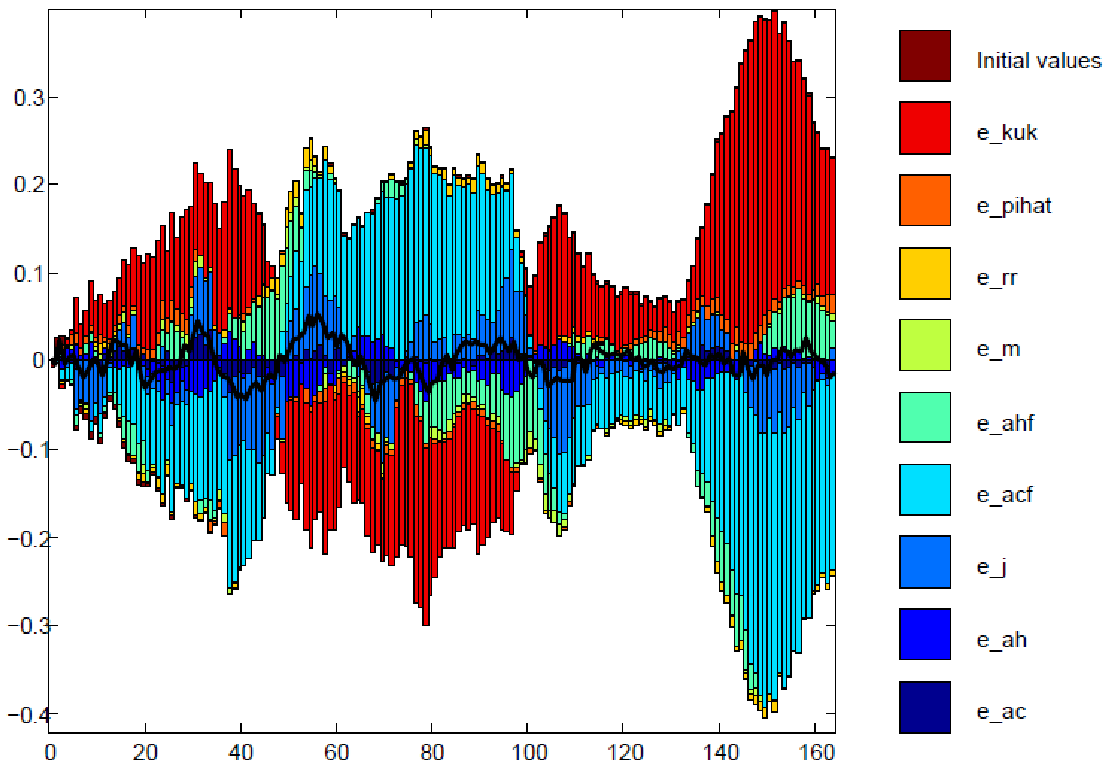
Foreign market clearing conditions;

$$Y_t^* + \frac{R_{t-1}^* b_{t-1}^*}{\pi_t} + q_t\left(1 - delta_h^*\right) H_{t-1}^F = C_t^* + q_t H_t^F + I_{ct}^* + I_{ht}^* + b_t^* \tag{A.51}$$

and

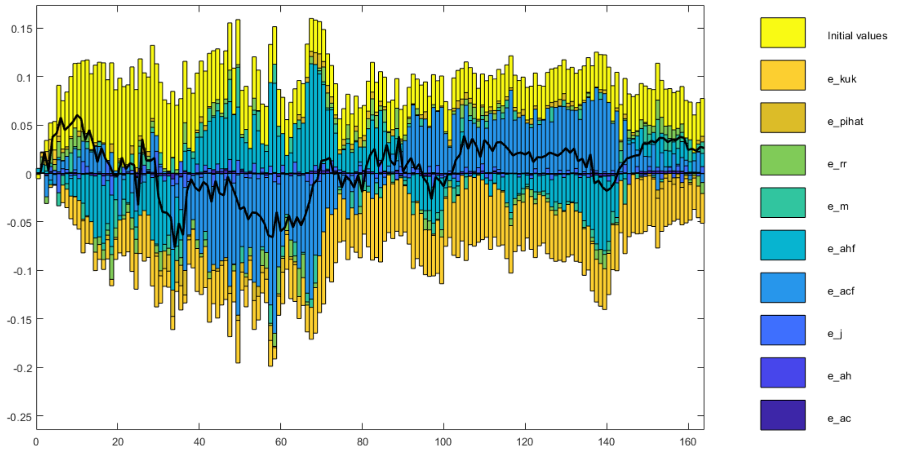
$$H_t^* - (1-\delta_h^*)\, H_{t-1}^* = Y_{h,t}^* \tag{A.52}$$

FIGURE A.1: Historical Decomposition of House Price



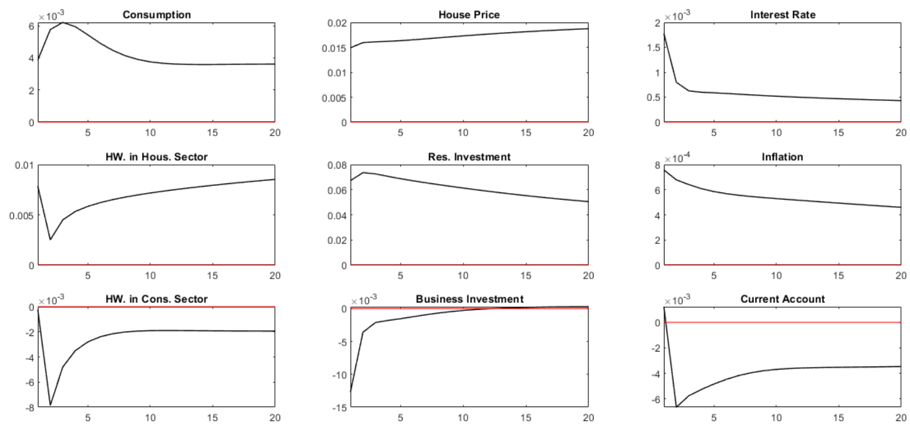
Notes: e_{kuk}, e_{pihat}, e_{rr}, e_{ahf}, e_{acf}, e_m, e_j, e_{ah}, *and* e_{ac} *are respectively the foreign purchase of U.S housing shock, cost shock, monetary policy shock, foreign housing technology shock, aggregate technology shock, financial easing shock, domestic house preference shock and domestic housing and aggregate technology shock. The solid black line shows the quarterly growth rate in real house price, expressed in percentage deviations from the model's steady state (Sample period: 1965:Q1–2006:Q4). The coloured bars show the estimated contributions of the various shocks*

FIGURE A.2: Historical Decomposition of Current Account



Notes: $e_{kuk}, e_{pihat}, e_{rr}, e_{ahf}, e_{acf}, e_m, e_j, e_{ah}$, and e_{ac} are respectively the foreign purchase of U.S housing shock, cost shock, monetary policy shock, foreign housing technology shock, aggregate technology shock, financial easing shock, domestic house preference shock and domestic housing and aggregate technology shock. The solid black line shows the quarterly growth rate in current account, expressed in percentage deviations from the model's steady state. The coloured bars show the estimated contributions of the various shocks.

FIGURE A.3: Theoretical Impulse Responses to Foreign Housing Purchase Shock



Notes: The Foreign Purchase Shock contributes to the deterioration of the current Account.

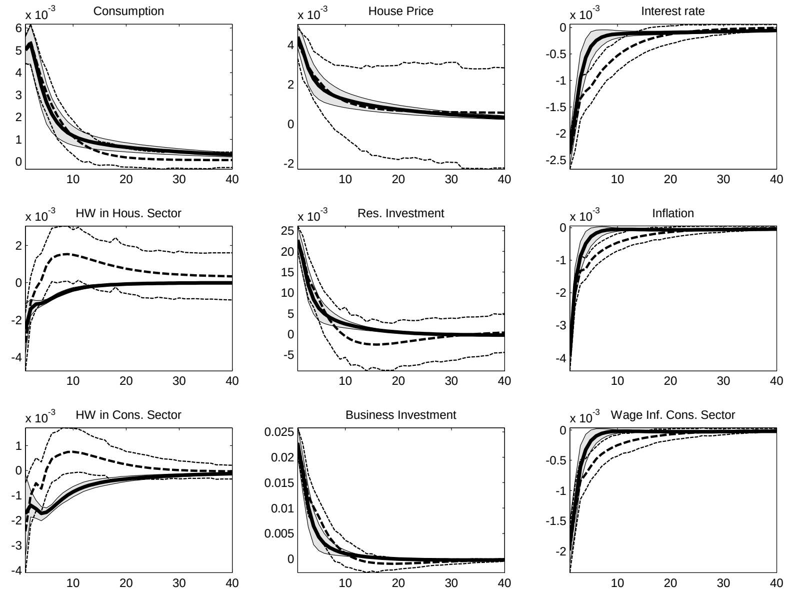


FIGURE A.4: Impulse Responses to Aggregate Technology Shock in US

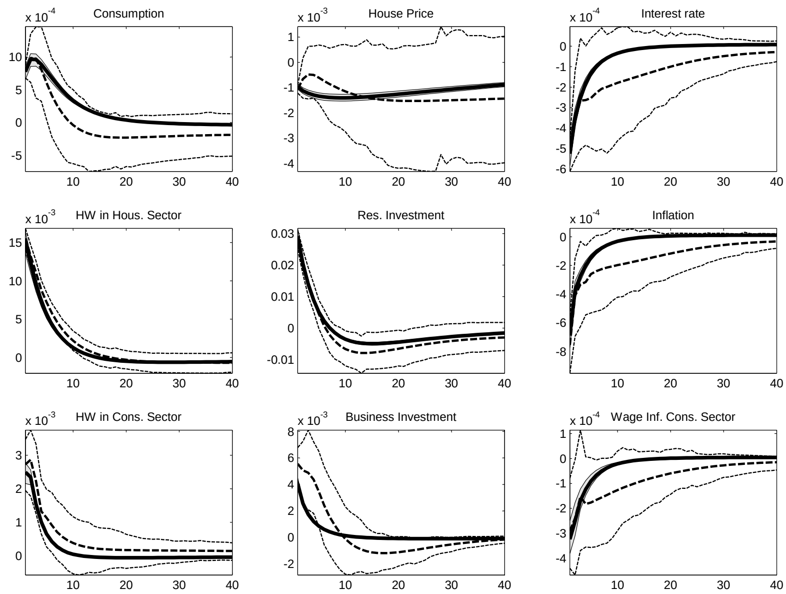


FIGURE A.5: Impulse Responses to US Housing Technology Shock

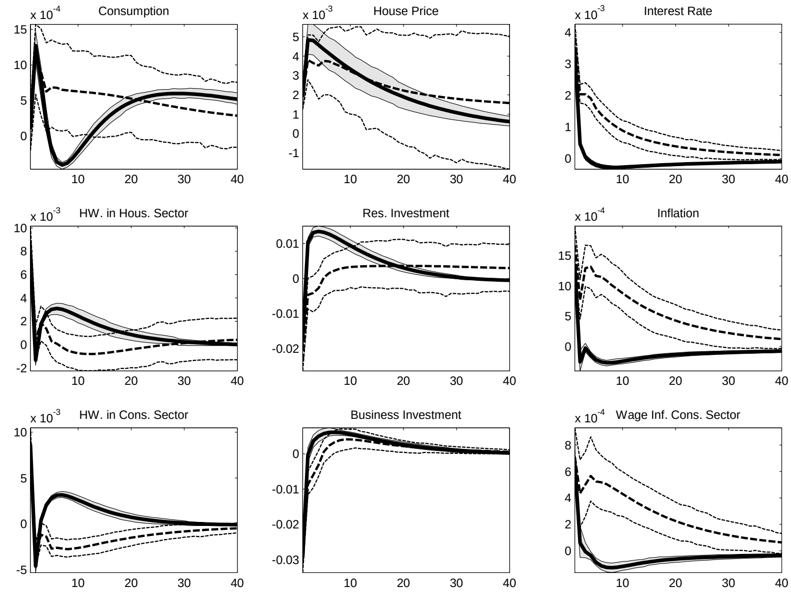


FIGURE A.6: Impulse Responses to a Macroprudential Policy Shock

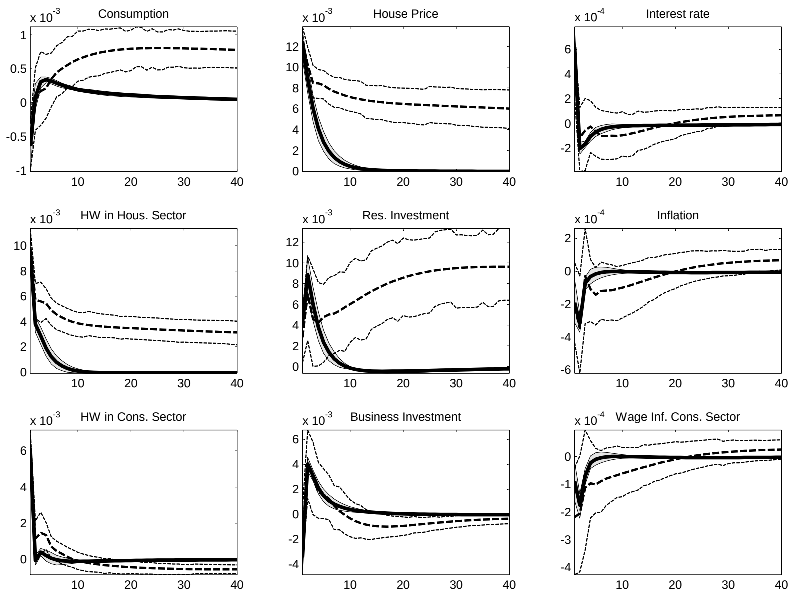


FIGURE A.7: Impulse Responses to the US Housing Preference Shock

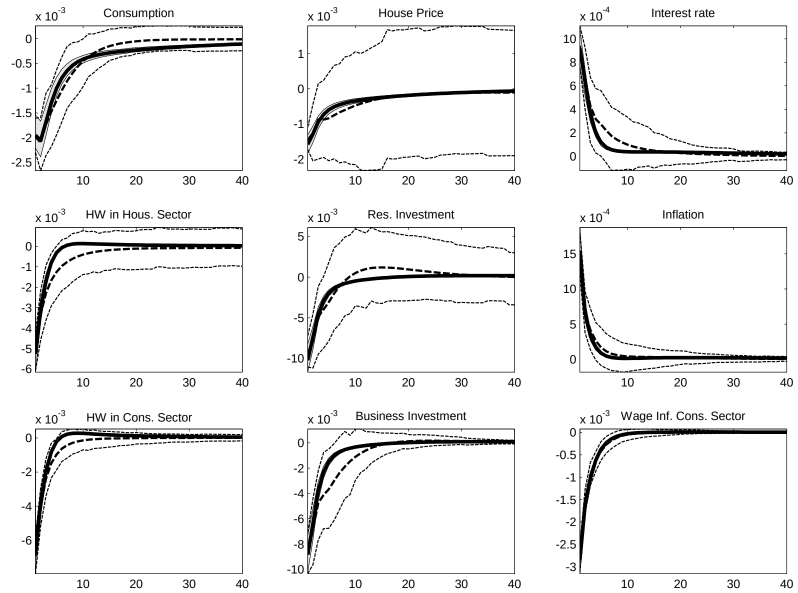


FIGURE A.8: Impulse Responses to the US Cost Shock

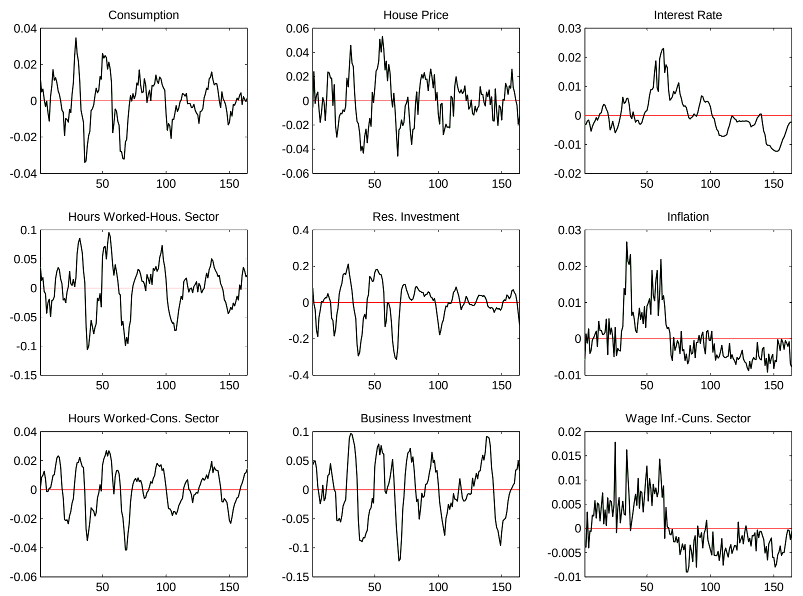


FIGURE A.9: Smoothed Variables for Empirical Estimation of the DSGE-VAR.

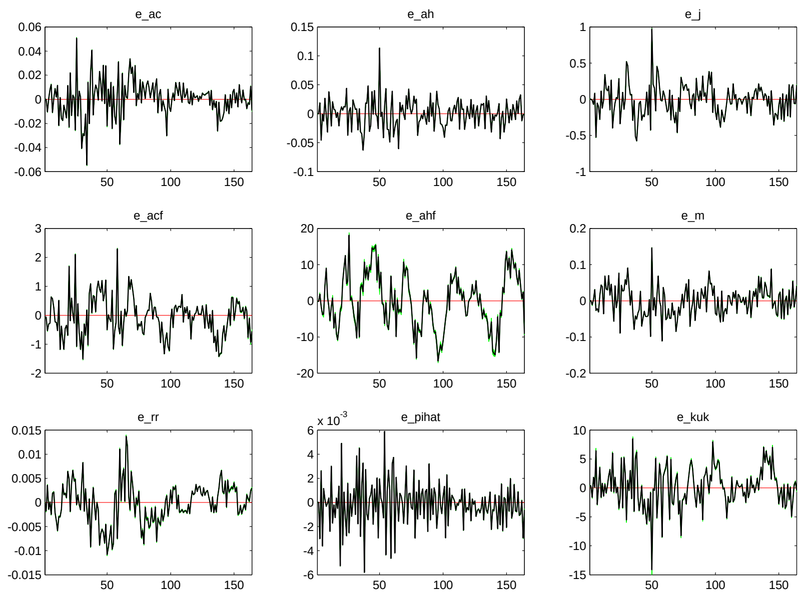


FIGURE A.10: Smoothed Shocks for Empirical Estimation of the DSGE-VAR.

Chapter 3

Housing Market Dynamics: Implications of Foreign Residential Purchases for a Small Open Economy

Abstract

In this chapter we study the effect of capital flows (specifically, foreign residential purchases (FRP) on the housing market in a SOE. We use a calibrated dynamic stochastic general equilibrium (DSGE) model to analyse the effect of foreign-originated shocks on the dynamics of the housing market. We investigate whether (FRP) and the foreign interest rate can affect housing demand and price of housing. Our findings show that foreign interest rates and FRP can significantly increase output, consumption, house prices, and domestic credit. And furthermore, a countercyclical macroprudential policy that reacts to the deviations in output, coupled with a monetary policy that targets inflation, can stabilize the economy. We also found that some combinations of macroprudential and monetary policies improve welfare, whereas others do not.

3.1 Introduction

In the large economy model with two nations, discussed in Chapter One, since both nations can affect each other, it is difficult to rule out any mutual effects of economic shocks. This makes it difficult to identify the main source of economic shocks. To overcome this problem, in this chapter we consider a small, open-economy (SOE) model. In this model, a small economy, that is not able to set the terms of trade (i.e., it takes price as give)interacts with the rest of the world (RW). However, this usually refers to financial markets where it is assumed that the domestic economy takes the world interest rate as given.

This model is relevant for an emerging economy which receives a lot of capital flows (in the form of debt, portfolio, and FDIs) but is not able to affect international interest rates and exchange rate. Because these terms are determined by external factors, they can adversely affect domestic variables. For example, capital inflows cause domestic asset prices to appreciate, whereas a reversal implies the opposite. Thus, this chapter will investigate how capital flows, specifically FRP, affect the housing market in a small open economy? How can a SOE attenuate any domestic disruption?

In small, open economies which are highly leveraged by housing, more than half the households own residential property, with net housing wealth varying between approximating the GDP up three times the GDP [1]. In such a scenario, given a weakening housing market, the wealth

[1] Ng and Feng, 2016 notes that, according to the Hong Kong Census and Statistics Department, the home ownership rate in Hong Kong was 51.2 % and the ratio of net housing wealth to GDP was 3.2. For comparison, in 2010 the ratio was 2.1 for Canada and 1.8 for the US

of most households would decrease significantly, reducing their subsequent consumption and investment. The current literature, however, does not account for the increasing proportion of domestic housing under foreign ownership. If significant enough, this might be another window through which global business cycles can affect the housing sector of the SOE.

On average, almost 10 % of new-build sales (in £1m+) in Greater London are to non-UK residents[2]. However, we acknowledge that the 10% figure cannot be indicative of the U.K market, nor is it calibrated from the our model. While this figure is relatively small, the scene changes dramatically when considering particularly concentrated market centres such as central London[3] For example, Knight Frank Property Research reports that, during the period 2011-2013, almost 69 % of central London new-build purchases were made by foreign buyers [4]. Thus the preponderant question becomes: to what extent do foreign residential purchases (FRP) affect housing demand and prices? And to what extent does this pose a challenge to monetary policy?

In this chapter, we develop a New Keynesian – dynamic stochastic general equilibrium (DSGE) model in order to study the effects of foreign shocks on the domestic housing market of a SOE. We analyse how monetary and macroprudential policies interact to maintain stability in both its macroeconomy and its financial sector. For the policy simulation,

[2] Knight Frank Property Research(2015) provides housing market analysis of London specifically, though these figures do not cover the UK as a whole, but they indicate the trend of one of the most important housing market centres in the UK

[3]Similarly, about a third of new-build sales of above \$3m in New York go to international buyers.

[4]although this falls to 49 % if we remove foreigner residents of the UK

we develop a SOE model that integrates domestic and international financial markets. We allow domestic savers to borrow from foreigners and to extend loans to impatient households.

We assume no borrowing constraints (which we will relax in the third chapter) in the foreign credit channel. Domestic borrowing is subject to collateral constraints such as the loan to value (L.T.V) ratio, which creates one of the important channels through which financial shocks are propagated to the real economy. Foreign households invest in the domestic housing sector by purchasing new houses. The flow of funds towards foreign purchase of houses is then subject to a shock, which evolves according to autoregressive of order one (AR (1)). A positive shock to FRP causes foreigners to demand more domestic houses. This may increase house prices, and hence, the value of the collateral. This may therefore encourage credit booms, which can increase domestic inflation.

Our model incorporates the main transmission mechanisms, such as the credit channel through which shocks from the financial sector are transmitted to the macroeconomy in a closed economy, as modelled in the standard literature on financial frictions (e.g., Iacoviello, 2005; Iacoviello and Neri, 2010; Monacelli, 2009; Liu, Wang, and Zha, 2013). We borrow from this literature by introducing standard domestic shocks, such as aggregate technology, sector-specific technology, housing preferences, cost-push inflation, and financial deregulation shock (captured by the LTV ratio). We also introduce external shocks such as foreign interest rates and foreign purchase of domestic housing. Our choice of selecting foreign interest rates as the main driver of external shocks is consistent with the literature on small, open economies (e.g., Schmitt-Grohé and

Uribe, 2003 and Gali and Monacelli, 2005). However, we extend this literature by including the effect of the FRP shock, monetary and macro-prudential policies, and their effects on consumer welfare.

3.1.1 Related Literature

This chapter is also related to papers that analyse the interaction between housing market dynamics and the macroeconomy of a small open economy; more specifically, how shocks to foreign variables can affect the domestic variables, which include: the world interest rate shocks, terms of trade, international capital flows, foreign housing preferences, foreign demand, and news shocks. Papers which analyse one or more of these variables include Bao et al. (2009), Tomura, 2010, Hu and Zhang (2011), Funke and Paetz (2013), Schmitt-Grohé and Uribe, 2012 and Ng and Feng, 2016.

An important finding from these papers is that contemporaneous shocks to foreign variables can significantly explain the varying degrees of volatility of domestic house prices in small, open economies (anywhere from 90% variability to around 10% variability). For example, Ng and Feng, 2016 and (the references therein) found that external shocks and news shocks are a major driver of real house prices and housing investment in small open economies. The impulse response analysis of Ng and Feng, 2016 further suggests that the instantaneous responses of real house prices to external shocks are at least two times larger than responses to domestic shocks. Their findings highlight the relative importance of the spill-over effects of exogenous external shocks on the domestic housing market of a SOE.

Ng and Feng, 2016 assumes that housing in a small open economy is only owned by domestic households. One important feature overlooked in this literature, however (and which is the main ingredient of our chapter), is the direct investment by foreigners in purchasing domestic houses in a SOE, and another potential mechanism through which international shocks can be transmitted.

A distinctive feature of our study, therefore, is the presence of foreign buyers in the domestic housing market. We assume that the newly-built domestic houses are bought by both domestic households (savers and borrowers) and foreigners. The aggregate number of houses bought by foreigners in period $(t+1)$ is equal to the houses remaining after depreciation in period (t) plus the amount of capital they invest in new houses in period (t). This capital is determined by exogenous shocks, which may increase demand, house prices, and the net worth of households who produce houses.

FRP inflows can have various effects. On the one hand, they may bid up house prices. High house prices may attract high wages in the housing sector, which may concentrate resources in this sector at the expense of other sectors. This may result in unbalanced reallocation of resources across sectors, thus potentially leading to economic instability. On the other hand, increasing house prices attract foreign capital inflows, which may appreciate the domestic currency, making domestic goods less attractive globally. Under these circumstances, policy makers must consider trade policies such as currency devaluation. Although devaluation may bring temporary relief, it is not often desirable, because of its association with high inflation. This in turn, may necessitate punitive contractionary monetary measures (high interest rates), which may not be feasible for some economies with a growth perspective, thus contributing to monetary policy ineffectiveness.

To overcome such policy ineffectiveness, a considerable number of studies have investigated how prudent regulatory policies can complement monetary policy in order to stabilise house prices. These macroprudential policies include loan-to-value, debt-to-income, or bank capital requirements, in order control excessive increases in domestic credit, thus attenuating housing demand and price increases. While these measures ostensibly are effective, they are less useful in stabilising housing if the source of the boom is foreign. Canova et al., 2015 emphasizes that to understand the consequences of these prudential policies, one needs to know the type of shock and its originating sector.

Meanwhile, Aoki, Benigno, and Kiyotaki, 2015 shows that monetary policy complemented by macroprudential policy (e.g., a cyclical tax on foreign currency borrowing by banks) can enhance welfare. In his study Aoki, Benigno, and Kiyotaki, 2015 suggests how policy may be designed to stabilise the economy when exposed to foreign shocks, but unlike our study, his does not analyse the housing market explicitly.

The remainder of this chapter is structured as follows. The next section describes a small open economy – a DSGE model with non-durable goods and housing and collateral constraints. Section 3 discusses the calibration of the model, its theoretical implications and its dynamics. Section 4 presents the welfare analysis of different policy-making processes. Section 5 concludes.

3.2 The Model

3.2.1 Households

The domestic economy is composed of patient households, impatient households, and firms that produce consumption goods C_t^d, (superscript d stands for domestic) and housing H_t, where we introduce nominal rigidities into consumption, and the labour market. Both types of households supply labour to firms and consume non-durable goods and housing (durable goods). While impatient households are borrowers, a fraction (η_h) of households are patient (savers) and have access to external borrowing from the RW savers.

Borrowers are credit-constrained and risky; hence, they need collateral in order to secure their loans. Because savers are owners of production firms, they receive lump sum profits. In order to evaluate the effect of policies, we introduce the government sector, which determines the monetary policy and macroprudential policy. A variable with a prime, such as $C_t^{'}$, represents constrained households, while a variable without a prime, such as C_t, represents unconstrained households. Foreign variables are identified by an asterisk $(*)$.

The foreign economy variables, e.g., the foreign interest rate, price, debt and output, are exogenous. Unlike in other small open economy DSGE models, here, households in the RW have preference for domestic houses and demand H_t^F for the domestic economy, which is also determined outside the model.

Savers

The patient households borrow from the RW b_t^* and lend b_t to the impatient households. Patient households choose their spending on non-durable goods C_t, durable goods, H_t; and how much they invest in the production of consumption goods K_{ct-1} and housing K_{ht-1}. They also decide how many hours N_{ct} and N_{ht} they work to produce consumption goods and housing. In so doing, they maximise the lifetime discounted utility:

$$E_t\left(\sum_{t=0}^{\infty}\beta^t\left[log\left(C_t-\chi C_{t-1}\right)+\gamma_t logH_t-\nu\frac{\left(N_{ct}^{\frac{1}{\varphi+1}}+N_{ht}^{\frac{1}{\varphi+1}}\right)^{\frac{(1+\sigma)}{\varphi+1}}}{1+\sigma}\right]\right) \tag{3.1}$$

where $\beta\in(0,1)$ is the discounting factor; χ is the measure of habits in consumption; E_t is the mathematical expectation operator and σ is the inverse of the Frisch elasticity of labour supply; ν is the scale factor for the labour supply. C_t, H_t; and N_t stand for consumption, housing stock, and working hours, respectively. The subscripts c and h refer to consumption, and the housing sector. γ_t captures shocks to the households' taste in housing services, which evolves according to AR(1) process, subject to the budget constraint:

$$\begin{aligned}C_t+b_t+q_tI_{h,t}+I_{ct}+I_{kht}+S_t\frac{\xi_R R_{t-1}^*b_{t-1}^*}{\pi_t^*}=&\frac{R_{t-1}b_{t-1}}{\pi_t}+\frac{w_{ct}N_{ct}}{X_{wct}}+T_\pi\\&+\frac{w_{ht}N_{ht}}{X_{wht}}+r_{ct}K_{ct-1}+r_{ht}K_{ht-1}\\&+S_tb_t^*-\frac{\xi_b}{2}\left(b_t^*-\overline{b_t^*}\right)^2\end{aligned} \tag{3.2}$$

The left-hand side of the budget constraint defines the expenditures, where b_t , R_t and q_t are, respectively, the savings, the gross return from savings, and the price of housing. $\overline{b_t^*}$ is the steady state level of foreign debt, while ξ_b is the coefficient of adjustment costs. $I_{h,t}$,I_{ct} and I_{kht} refer to consumption of new housing, investment in consumption, and the housing sector. S_t is the nominal exchange rate. The right-hand side defines the sources of income, which include the receipts from savings net of inflation π_t, the real wages w_t , the return on capital $r_{i,t}$ multiplied by the respective level of capital $K_{i,t-1}$ for $i \in c, h$ - consumption and housing sectors, while T_π is the lump sum profit received from owning firms. X_{wct} and X_{wht} is the mark-up (inverse of marginal cost) of the monopolistic competitive firms in labour markets.

The final consumption good C_t for the patient households is a composite of domestic produced goods C_t^d purchased at price P_t^d and foreign produced goods C_t^m purchased at price P_t^m

$$C_t = \left[(1-\omega)^{\frac{1}{\eta_c}} \left(C_t^d \right)^{\frac{\eta_c - 1}{\eta_c}} + \omega^{\frac{1}{\eta_c}} \left(C_t^m \right)^{\frac{\eta_c - 1}{\eta_c}} \right]^{\frac{\eta_c}{\eta_c - 1}}$$

where η_c is the elasticity of substitution between domestic and foreign goods. The combination of these prices leads to the aggregate consumer price relation:

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

profit maximization rules lead to choose

$$C_t^d = (1-\omega)\left(\frac{P_t^d}{P_t}\right)^{-\eta_c} C_t$$

and

$$C_t^m = \omega\left(\frac{P_t^m}{P_t}\right)^{-\eta_c} C_t$$

At the same time, the foreign demand for domestic goods is EX_t (which is domestic exports). However, the variable EX is not exogenous: It is part of the home resource constraint; and it is part of aggregate foreign demand Y_t^*, that is,

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

where P_t^x and P_t^* are price of domestic exports and foreign goods prices respectively; while η_f is the elasticity of substitution between domestic exports and foreign goods.

Borrowers

The impatient households borrow b_t from the patient ones. They choose how much to spend on non-durable goods $C_t^{'}$ and durable goods $H_t^{'}$. They also decide how many hours $N_{ct}^{'}$ and $N_{ht}^{'}$ to work in the production of consumption goods and housing, respectively. Hence, they maximise their lifetime discounted utility:

$$E_t\left(\sum_{t=0}^{\infty}\beta^{'t}\left[log\left(C_t^{'}-\chi^{'}C_{t-1}^{'}\right)+\gamma_t logH_t^{'}-\nu^{'}\frac{\left(N_{ct}^{'\frac{1}{\varphi+1}}+N_{ht}^{'\frac{1}{\varphi+1}}\right)^{\frac{(1+\sigma)}{\varphi+1}}}{1+\sigma}\right]\right) \tag{3.3}$$

Subject to the budget constraint:

$$C_t^{'} + q_t I_t^{'} + \frac{R_{t-1} b_{t-1}^{'}}{\pi_t} = \frac{w_{ct}^{'} N_{ct}^{'}}{X_{wct}} + \frac{w_{ht}^{'} N_{ht}^{'}}{X_{wht}} + b_t^{'} \tag{3.4}$$

and the borrowing constraint:

$$b_t^{'} \leq m_t E_t \left(\frac{q_{t+1} H_t^{'} \pi_{t+1}}{R_t} \right) \tag{3.5}$$

The above equation is the borrowing constraint, which equates the value of loans to the expected value of collateral. We assume that constrained households use housing stock as collateral in order to secure loans. m_t is the LTV ratio, which also evolves according to the AR(1) process.

$$m_t = \rho_m m_{t-1} + \varepsilon_m$$

3.2.2 Firms

In this chapter, the model economy consists of two types of firms: final goods producers and intermediate goods producers. The later produces a continuum of differentiated goods using capital and labour, which they sell to the final goods producers, who transform them into a homogeneous good to be sold to households.

Final Goods Producers

The final goods producers operate under perfect competitive market assumptions. They transform intermediate goods according to the following production function:

$$Y_t = \left[\int_0^1 y_{i,t}^{\frac{\epsilon-1}{\epsilon}} di \right]^{\frac{\epsilon}{\epsilon-1}}$$

where $\epsilon > 1$ is the elasticity of substitution among intermediate goods. The final goods producer takes its output price P_t and the prices of intermediate goods $p_{i,t}$ as given and chooses Y_t in order to maximise profits. In doing so, the final goods producer solves

$$\max_{Y_t} P_t Y_t - \int_0^1 p_{i,t} y_{i,t} di$$

, subject to the equation above. The resulting optimal conditions yield the input demand of intermediate goods:

$$y_{i,t} = \left(\frac{p_{i,t}}{P_t} \right)^{\epsilon} Y_t$$

where the price index, which relates the price of the final good and the prices of the intermediate goods, is given by:

$$P_t = \left[\int_0^1 p_{i,t}^{1-\epsilon} dz \right]^{\frac{1}{\epsilon-1}}$$

Intermediate Goods Producer

Intermediate goods producers have a two-stage objective: (1) they choose the optimal amounts of labour and capital to minimise the costs of production; and (2) they set the price of their produced goods in order to realise positive profits subject to a mark-up X_t (i.e., inverse of marginal cost) of the monopolistic competitive firms.

The first-stage objective. Intermediate firms choose $N_{i,t}$ and $K_{i,t-1}$ in order to maximise profits:

$$\max \frac{Y_t}{X_t} + q_t Y_{ht} - \left[w_{i,t} N_{i,t} + w'_{i,t} N'_{i,t} + r_{i,t} K_{i,t-1} + r_{i,t} K_{i,t-1} \right] \tag{3.6}$$

For $i \in (c, h)$ for the consumption and housing sectors, respectively. They maximise the profits subject to the consumption goods production function Y_t and the housing production $Y_{h,t}$

$$Y_t = \left(A_{ct} N_{ct}{}^{\sigma_y} N'_{ct}{}^{1-\sigma_y} \right)^{1-\alpha_y} K^{\alpha_y}_{ct-1} \tag{3.7}$$

$$Y_{h,t} = \left(A_{ht} N_{ht}{}^{\sigma_h} N'_{ht}{}^{1-\sigma_h} \right)^{1-\alpha_h} K^{\alpha_h}_{ht-1} \tag{3.8}$$

Where A_{ct} is the aggregate economy (Total Factor Productivity - TFP) technology, while A_{ht} is the housing sector production technology, both of which follow AR(1), that is,

$$A_{j,t} = \rho_{j,h} A_{j,t-1} + \varepsilon_{j,t}$$

for $j \in c, h$ where $\rho_{j,h}$ is the coefficient of autoregression and $\varepsilon_{j,t}$ is the zero mean *i.i.d* innovation to technology. where α and σ, respectively, measure the output elasticity in terms of the capital (owned by patient households at the end of the period) K_{ct-1} and the labour in unconstrained households N_{ct}.

The housing and capital stocks evolve according to:

$$H_t = (1-\delta_h) H_{t-1} + I_{h,t} - \frac{\xi_h}{2}\left(\frac{H_t - H_{t-1}}{H_{t-1}}\right)^2 \tag{3.9}$$

$$K_{ct} = (1-\delta_k) K_{ct-1} + I_{ct} - \frac{\xi_{ck}}{2}\left(\frac{K_{ct} - K_{ct-1}}{K_{ct-1}}\right)^2 \tag{3.10}$$

$$K_{ht} = (1-\delta_k) K_{ht-1} + I_{kht} - \frac{\xi_{hk}}{2}\left(\frac{K_{ht} - K_{ht-1}}{K_{ht-1}}\right)^2 \tag{3.11}$$

where H_t, K_{ct} and K_{ht} respectively are housing stock, capital stock in consumption production goods firms and capital stock in housing production. δ. refers to the depreciation rate of the capital. ξ_h, ξ_{ck} and ξ_{hk} are the coefficients of the respective adjustment costs, whereas I_{ct} and $I_{kh,t}$ indicate the investment in consumption goods and housing production and I_{ht} is investment in new housing.

The second-stage objective. Intermediate firms set prices following the Calvo (1983) mechanism. It is assumed that firms set prices in the producer's (home) currency when exporting which leads to full exchange rate pass-through. In every period, a fraction of θ intermediate firms will not be able to change their prices, whereas $1-\theta$ will be able to optimise their prices. They solve the optimal reset price $p^*_{i,t}$ by maximising:

$$\sum_{k=0}^{\infty} \theta^k E_t \left\{ \psi_{t,k} \left(\frac{p^*_{i,t}}{P_{t+k}} - \frac{X}{X_{t+k}} \right) y^*_{it+k} \right\} = 0$$

where $\psi_{t,k} = \beta\left(\frac{U'(c_t)}{U'(c_{t+1})}\right)$ is the stochastic discount rate over the interval $[t, t+k]$ for the patient households, and X is the steady state mark-up and $p^*_{it}\left(Y^*_{t+k}\right)$ is the optimal reset price (output). The aggregate price index P_t in each period is given by:

$$P_t = \left[\theta P_{t-1}^{1-\epsilon} + (1-\theta)\left(P_t^*\right)^{1-\epsilon}\right]^{\frac{1}{1-\epsilon}}$$

By combining this equation with the above two equations and log-linearising, we can obtain the standard forward-looking aggregate Phillips curve: $\pi_t = \beta E_t \pi_{t+1} - \phi x_t + \eta_{\pi,t}$. We assume that retailers index prices in the previous periods with an elasticity δ_π. The extended aggregate Phillips curve becomes:

$$\pi_t - \delta_\pi \pi_{t-1} = \beta E_t\left(\pi_{t+1} - \delta_\pi \pi_t\right) - \phi x_t + \eta_{\pi,t} \tag{3.12}$$

where $\phi = (1-\theta)(1-\beta\theta)\theta$ and $\eta_{\pi,t}$ is the zero mean price mark-up shock such that $\eta_{\pi,t} \sim N(0, \sigma_\pi^2)$:

$$\eta_{\pi,t} = \rho_\eta \eta_{\eta,t-1} + \varepsilon_{\eta,\pi}$$

Wage Setting Behaviour

Wage setting is modelled in the same way. Labour packers/unions (related to retail goods firms) purchase wholesale labour services from households and differentiate labour services before they sell them to wholesale firms. According to Erceg, Henderson, and Levin, 2000, the labour unions monopolise their own differentiated labour services, which implies that they can set their own wage rates. The i^{th} labour union adjusts their new wage rate with a probability of $(1-\theta_w)$ according to the Calvo mechanism. Following the same procedures, we can derive a similar log-linearised wage Phillips curve in the following form:

$$w_{ct} - \delta_{wc}\pi_{t-1} = \beta E_t \left(w_{t+1} - \delta_{wc}\pi_t\right) - \phi_{wc}x_t + \eta_{wct} \tag{3.13}$$

where $\phi_{wc} = (1-\theta_{wc})(1-\beta\theta_{wc})\theta_{wc}$. Other variables are defined analogously. The Phillips curves for the other three wages are shown in the Appendix.

Monetary Policy

Monetary policy is conducted via a generalised Taylor rule that reacts to inflation, output, the interest rate in the previous period, and house prices:

$$R_t = (R_{t-1})^{\rho R} \left[(\pi_t)^{\rho_\pi} \left(\frac{Y_t}{Y_{t-1}} \right)^{\rho_Y} R \right]^{1-\rho R} \varepsilon_{R,t} \tag{3.14}$$

where $0 \leq \rho R \leq 1$ is the interest rate inertia while $\rho_\pi \geq 1$ and $\rho_Y \geq 0$ are the responses of interest rates to current inflation and output growth, respectively. $\varepsilon_{R,t}$ is the uncorrelated monetary shock with a zero mean, $\varepsilon_{R,t}\ N(0, \sigma_R^2)$.

However, this traditional set-up leaves the housing market untouched. This approach is debated in the literature because it could only affect the real economy but not the financial sector. For this reason, we include housing price Q_t to enable the central bank to effect changes in the financial sector. As can be deduced from the policy rule given below, any deviations in housing prices from the steady state can be mitigated by a contractionary policy, hence restricting house-price increases in the economy. $R_t = (R_{t-1})^{\rho R} \left[(\pi_t)^{\rho_\pi} \left(\frac{Y_t}{Y_{t-1}} \right)^{\rho_Y} \left(\frac{Q_t}{Q_{t-1}} \right)^{\rho_Q} R \right]^{1-\rho R} \varepsilon_{R,t}$

Macroprudential Policy

We set the LTV macroprudential policy rule m_t, which reacts to volatilities in house prices and foreign holdings of domestic real estate. Here it is intended that higher deviations from the steady state values in house prices and the FRP, will lower the LTV ratio. This effect is important, because it restricts credit in the economy and avoids credit booms that might be fuelled by a high influx of foreign real estate investment.

$$\frac{m_t}{\overline{m}} = \left(\frac{m_{t-1}}{\overline{m}} \right)^{\rho_m^{mp}} \left(\frac{q_t}{\overline{q}} \right)^{-\rho_q^{mp}} \left(\frac{Y_t}{\overline{Y}} \right)^{-\rho_y^{mp}} \left(\frac{H_t^F}{\overline{H}} \right)^{-\rho_{hf}^{mp}} e^{\varepsilon_{m,t}} \tag{3.15}$$

where m_t is the deviation from its steady state value for the LTV ratio, and $\rho_m^{mp}, \rho_q^{mp}, \rho_y^{mp}, \rho_{hf}^{mp}$ are the responsiveness of the LTV to changes in LTV in period $(t-1)$ house prices, output, and FRP.

3.2.3 Foreign Economy

Foreign variables evolve exogenously in this model. These include the foreign demand Y_t^*, foreign housing purchase H_t^F and the foreign interest rate R_t^*. Unlike in other open economy DSGE models, households in the RW have a preference for domestic houses and domestic demand H_t^F. See Adolfson et al., 2007 for a similar way of closing a small open economy model.

3.2.4 Current Account Balance

The current account is defined as the difference between the net claims of a country against the rest of the world, i.e., the change in its net foreign assets.

$$CA = -S_t \left(b_t^* - \frac{R_{t-1}^* b_{t-1}^*}{\pi_t^*} \right) \tag{3.16}$$

where $CA_t = Y_t - C_t^d - C_t^{'} - I_{ct} - I_{ht}$. Equivalently, it is the difference between what the domestic economy saves and what it invests. $CA_t = S_t - I_t$.

3.2.5 The Equilibrium

At equilibrium, domestic financial market clears

$$b_t + b_t^{'} = 0$$

Domestic goods market clears

$$Y_t = C_t^d + C_t^{'} + I_{ct} + I_{kht} + EX_t - C_t^m$$

Domestic housing market clears

$$H_t + H_t^{'} + H_t^F - (1 - \delta_h) \left(H_{t-1} + H_{t-1}^{'} + H_{t-1}^F \right) = Y_{h,t}$$

where the number of houses purchased by foreign country H_t^F evolves as

$$H_t^F = (1 - \delta_h) H_{t-1}^F + \lambda_t$$

where λ_t is the foreign purchase shock, which evolves as AR(1) where

$$\lambda_t = (1 - \rho_\lambda)\delta_h \overline{H^F} + \rho_\lambda \lambda_{t-1} + \varepsilon_\lambda$$

where $\overline{H^F}$ is the steady state level of housing purchased by foreigners. This configuration is important in order to make the shock evolve around the steady state $\delta_h \overline{H^F}$, which is the equilibrium level in the housing market clearing condition.

Balance of Payments implies

$$S_t b_t^* + S_t P_t^* EX_t = S_t \frac{R_{t-1}^* b_{t-1}^*}{\pi_t^*} + S_t P_t^m \omega_c \left(\frac{P_t^m}{P_t}\right)^{-\eta_c} C_t$$

Foreign market clearing conditions imply;

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

where foreign interest rate also evolves exogenously as

$$R_t^* = \rho_{R^*} R_{t-1}^* + \varepsilon_{R^*}$$

3.2.6 Exogenous Variables

We consider two exogenous processes to foreign interest rate R_t^* and foreign residential purchases λ_t. We also consider six additional domestic exogenous processes: technology in the consumption goods sector, A_{ct}, specific technology process in the housing sector, A_{ht}, the financial easing (LTV) ratio m_t,consumer preferences γ_t, the monetary policy rate R_t, and the cost shock $\eta_{\pi t}$. All shocks have zero mean and variance σ_j^2 i.e

$[\varepsilon_{R^*}, \varepsilon_{\lambda}, \varepsilon_{a,ct}, \varepsilon_{a,ht}, \varepsilon_{mt}, \varepsilon_{\gamma_t}, \varepsilon_{R,t}, \varepsilon_{\pi,t}] \sim i.i.d\,(0, \Sigma)$.

3.3 Simulation

3.3.1 Calibrated Parameter Values

We calibrate the parameters of the model to match the UK economy. However, these numerical examples may not be precise estimates, because of the problem we face in trying to find exact parameters that simulate the UK economy. Unless it is stated otherwise, we borrow heavily from the parameter values used (and justified) by Lubik and Schorfheide, 2007, Andreasen, 2012, DiCecio and Nelson, 2007 and Villa and Yang, 2011, which are DSGE papers specifically addressing the U.K economy. Where the parameter values are not found in these papers, we use parameters from the DSGE literature of the Euro area, which include Smets and Wouters, 2003 Monacelli, 2009, Adolfson et al., 2014, Brzoza-Brzezina, Kolasa, and Makarski, 2015a, Rubio, 2014 , Calza, Monacelli, and Stracca, 2013 and Sy, 2016. Our assumption here is that developed countries share some features very closely. Specifically, the U.K economy might share similar features with France and Germany due to similar level of technology.

The model contains a smaller proportion of constrained households $(1 - \eta_h) = 0.4$ vis-à-vis unconstrained households $(\eta_h = 0.6)$.We set the savers' discount parameter β to 0.99 in order to match the average annual interest rate of 4%. The borrowers' discounting factor $\beta^{'}$ is set to 0.98. The housing depreciation rate δ_h is set to 1.5%, which is lower than the capital depreciation rate $\delta_{kh} = \delta_{kc}$ of 3.5%. The steady state mark-up is set to 2. We set the elasticity of substitution between domestic and foreign consumption goods at η_c equal to 0.9, while the elasticity of demand for exports as a function of the relative price paid by foreigners is η_f is 1.5; see Thirlwall, 2012. The degree of openness ω is set to 0.3, which implies that almost 70% of the final consumption is produced domestically; see World Bank data for exports of goods and services (% of GDP). The elasticity of labour supply σ is set to 1, while the degree of labour mobility across sectors is 0.5.

TABLE 3.1: Calibrated and Estimated Parameters Values

Calibrated Parameters					
β	discount factor-savers	0.99	m	loan-to-value ratio	0.85
β'	discount factor-borrowers	0.98	ξ_h	adjustment cost-housing	0
δ_h	depreciation-housing	0.014	η	scale factor for labor supply	2
δ_{kh}	depreciation-housing capital	0.035	j	housing weight-utility	0.1
α_y	capital share-goods	0.35	ξ_{kh}	adjustment cost-housing capital	7
σ_h	patient labour share-housing	0.55	ξ_{kc}	adjustment cost-goods capital	7
σ_y	patient labour share-goods	0.45	X	Steady state markup	4
δ_{kc}	depreciation-goods capital	0.035	ω	foreign content in consumption	0.3
α_h	capital share-housing	0.15	η_c, η_f	domestic elasticity-consumption	0.9
σ	elasticity of labour supply	1	φ	degree of labor mobility	0.5
η_h	proportion of savers in population	0.6	$1-\eta_h$	proportion of borrowers in population	0.4
ρ	Smoothing coefficient in Taylor rule	0.6	ρ_π	Response to Inflation in Taylor rule	1.3
ρ_Y	Response to output in Taylor rule	0.13	ρ_q	Response to house price in Taylor rule	0.13

The capital shares of the housing sector α_h and the goods sector α_y are 0.15 and 0.35, respectively. The corresponding share of patient households' labour in output in the housing sector σ_h is set to 0.55, which is slightly higher than the share of the patient households' labour σ_y in the goods sector 0.45. The scale factor η for the labour supply is 2.

Consistent with the literature on broad monetary DSGE incorporating collateral constraints for the euro area, we set the steady state values of domestic housing preference parameter j to 0.1, e.g., Rubio, 2014, and the collateral constraint m equal to 0.85. The housing stock adjustment cost ξ_h is set to zero, and the capital adjustment costs are ξ_{ck} and ξ_{hk}, equal to 7 for both sectors in order to mimic the data. The bond adjustment cost ξ_b is relatively low at 0.001. The remaining parameters such as the response of monetary policy to output growth and inflation are standard in the literature. We set the smoothing coefficient in the Taylor rule $\rho = 0.6$, the response to inflation in Taylor rule $\rho_{\pi=1.3}$ and the response to output in Taylor rule $\rho_Y = 0.13$.

3.3.2 Dynamics of the Model

Figure 3.1 reports the impulse responses to a positive 1% shock to the foreign interest rate for the imperfect capital mobility model(due to bond adjustment costs) where the domestic interest rate is fixed to the foreign interest rate; and domestic prices are completely flexible(continuous black line), and sticky (dashed red line). The shock generates an increase in the foreign interest rate and an appreciation of the foreign exchange rate through the uncovered interest parity condition. Because the appreciation of foreign currency implies a depreciation of domestic currency, the current account balance increases, generating an increase in output initially for the first couple of quarters before it starts to decline.

Inflation and the interest rate increase too, which induces patient households to save more, while impatient households increase their consumption, but not to the same degree as to offset the effect of patient households on aggregate consumption, which remains negative as a result. Because both foreign and domestic interest rates increase the cost of borrowing, foreign debt and domestic debt decrease as well. An increase in the foreign interest rate also generates a decrease in house prices and residential investment.

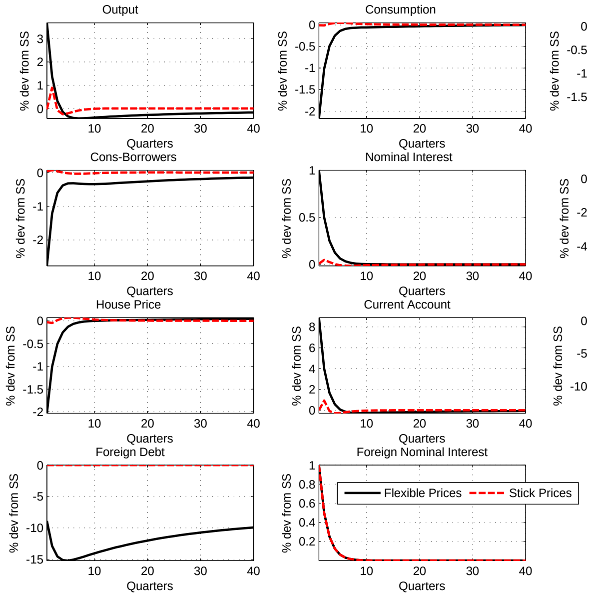


FIGURE 3.1: Impulse Responses to a 1% Foreign Interest Rate Shock

Of particular importance is that a completely flexible price economy suffers the most from the foreign interest rate shock. While direction of the responses of the variables in both model economies is the same, the flexible price model overestimates the impacts of the shock. In particular, it generates a significant reaction in output, consumption, nominal interest rate, house prices, and domestic credit. This has an important policy implication: the domestic credit growth which may result from a decrease in the foreign interest rate shock may increase the financial sector instability, necessitating prudential policies in order to curb credit growth and maintain a sound financial system.

Some of the prudential measures that have been advocated in the literature are the LTV ratio, loan to income (LTI) ratios, and the capital requirement ratios that restrict the amount of credit to the value of the collateral. Other scholars propose a cyclical tax on foreign borrowing. In this chapter, we analyse the former approach, i.e., a dynamic macroprudential policy which reacts to the deviations from their steady state levels of output, house prices, and the FRP variable.

Figure 3.2 reports the impulse responses to a positive 1% shock on aggregate technology for the perfect capital mobility model, where the domestic interest rate is fixed to the foreign interest rate; and domestic prices are completely flexible(continuous black line) and sticky (dashed red line). Following the technology shock, output and consumption increase. Because the aggregate technology is a supply shock, it generates a decrease in inflation and interest rates, which encourages both domestic and foreign borrowing. Meanwhile, the shock generates an increase in house prices, which (similar to capital price appreciation) attracts foreign investors and appreciates the domestic real exchange rate. As a result, the current account deteriorates, but as we mentioned earlier, the flexible economy model suffers more from this shock. Because of this feature of flexible price model which is revealed in all the shocks as shown in Figure 3.1 and 3.2; and for clarity of the graphs, we think it is more realistic to focus our main analysis on the sticky price model through most of the remaining sections.

Figure 3.3 reports the impulse responses to a positive 1% shock on FRP. As foreign purchase of domestic houses is a demand shock, it generates increased house prices, inflation and interest rates. Increasing interest rates cause patient households to smooth their consumption by saving more, while impatient households increase their consumption and borrowing. An increasing interest rate encourages savers to increase

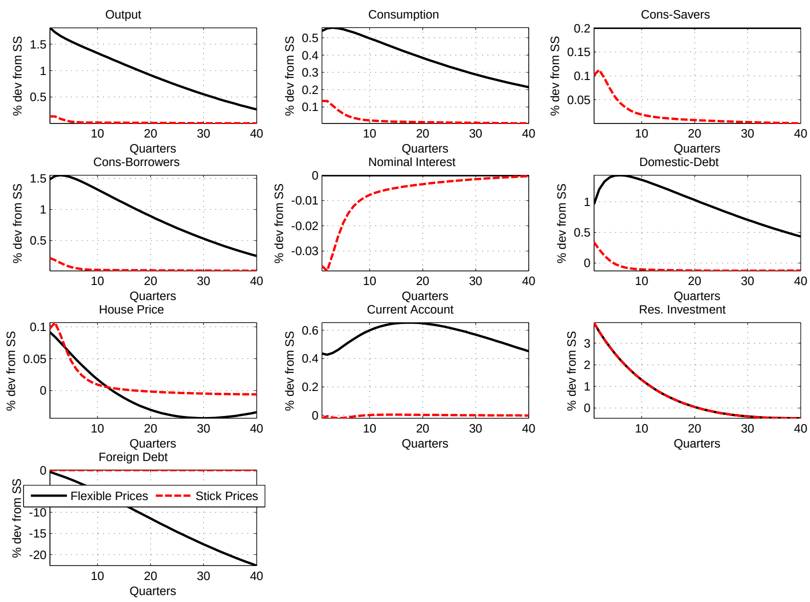


FIGURE 3.2: Impulse Responses to a 1% TFP shock

their foreign debt and extend more credit to domestic borrowers. Meanwhile, an increasing interest rate generates appreciation of the exchange rate (through the uncovered interest-rate parity), which decreases the current account. As a result of increasing house prices, residential investment increases, which in turn, generates increased output.

Figure 3.4 reports the impulse responses to a positive 1% shock on the quarterly nominal interest rate, which increases the domestic interest rate, thereby attracting more capital inflows and causing the capital account to increase. In order to maintain the balance of payments, the increase in the capital account causes the current account to decrease, leading to a decrease in output and consumption for savers and borrowers. The decrease in consumption reduces the aggregate demand, leading to a decrease in house prices and inflation. Because their incomes decrease,

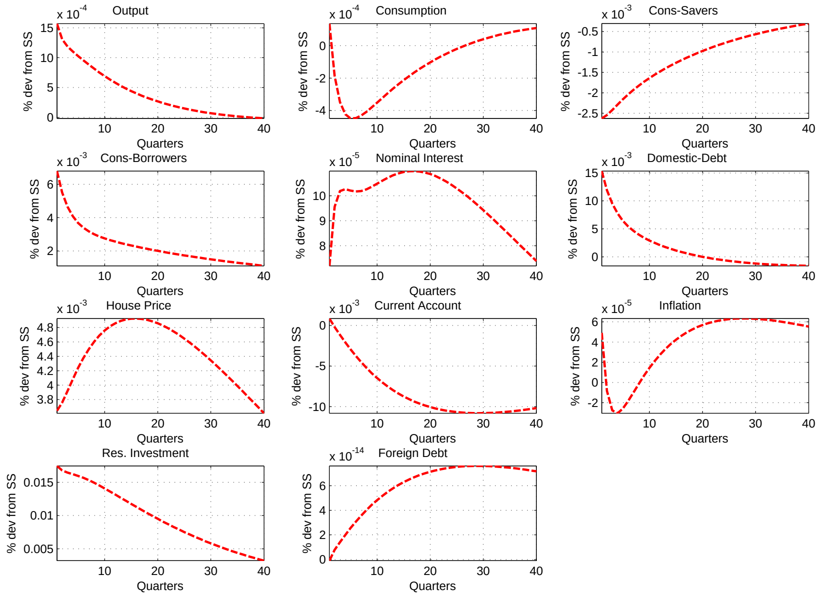


FIGURE 3.3: Impulse Responses to a a 1% Foreign Purchase of U.K Housing Shock.

their residential investment decline, together with domestic and foreign borrowing capacity.

Figure 3.5 reports the impulse responses to a 1% positive specific housing sector technology shock, which also increases output and consumption; while inflation and the nominal interest rate decline, similar to the aggregate technology shock. However, unlike the aggregate shock, the specific housing sector technology shock generates a decrease in house prices, causing capital outflow and a depreciation of the real exchange rate, which improves the current account. At the same time, residential investment increases, while both domestic and foreign debts initially decrease, before increasing thereafter.

Figure 3.6 reports the impulse responses to a 1% positive financial

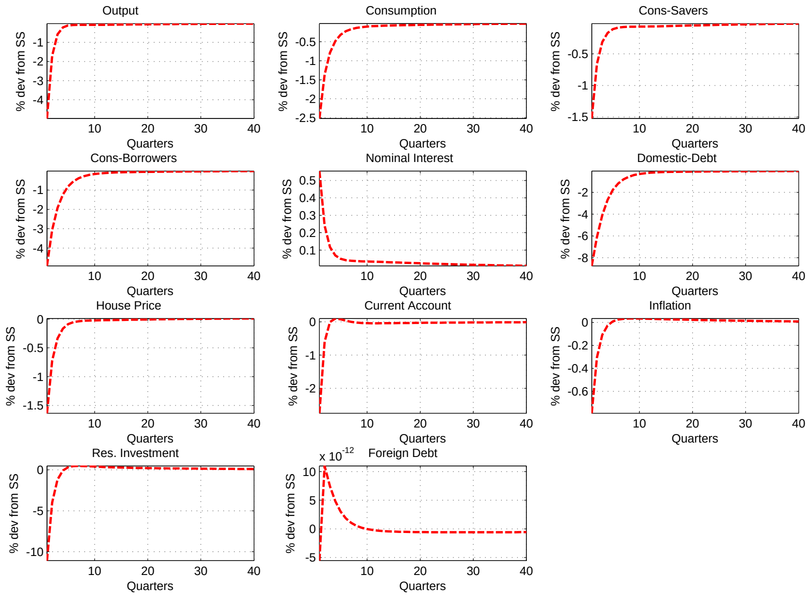


FIGURE 3.4: Impulse Responses to a 1% Nominal Interest Rate Shock

deregulation (LTV ratio) shock, while Figure 3.7 reports the impulse responses of a positive 1% shock to housing demand. As both shocks are demand shocks, they generate similar effects, i.e., an increase in domestic and foreign debt, hence a credit boom. As the credit boom increases the purchasing power of the households, it generates an increase in house prices and inflation. Also, as the level of leverage increases, this raises the level of risk, thus increasing the interest rate.

A higher interest rate induces patient households to postpone their current consumption by saving more, while impatient households increase their current consumption at a higher rate vis-a-vis patient households. This makes aggregate consumption positive. An increasing interest rate coupled with increasing house prices causes capital inflow,

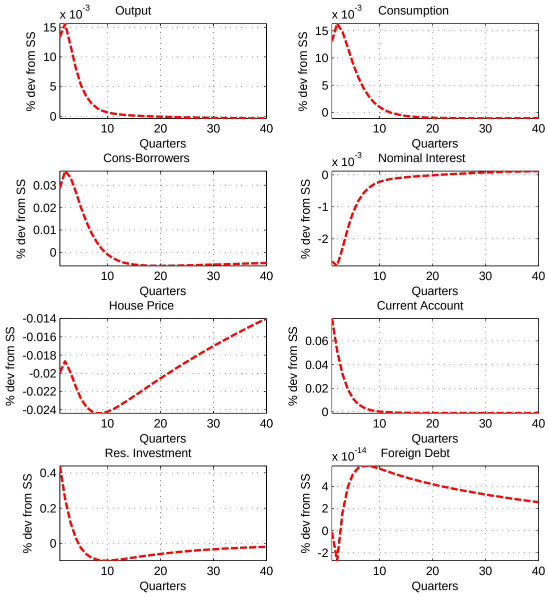


FIGURE 3.5: Impulse Responses to a 1% Housing Technology Shock.

which causes the current account balance to decrease (because of the appreciation of the domestic exchange rate effect).

Figure 3.8 reports the impulse responses to a positive 1% mark-up shock which increases inflation and the interest rate. An increasing interest rate causes exchange-rate appreciation, which causes the current account position to deteriorate. As a result, output and consumption decrease. Because households have low incomes, they decrease their domestic and foreign borrowing, which decreases their housing demand, thus decreasing house prices and discouraging residential investment.

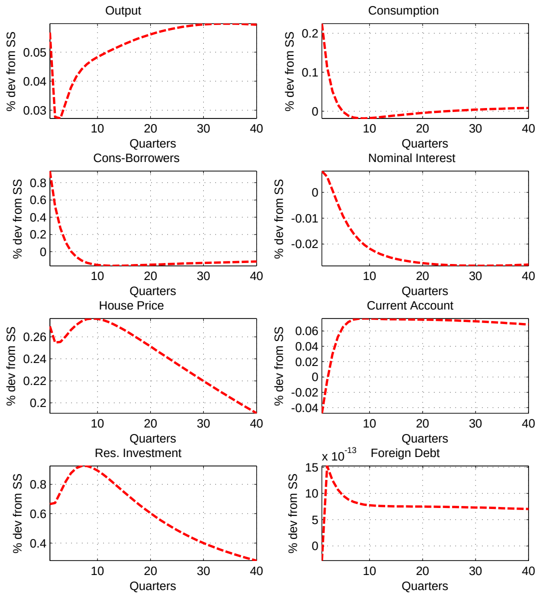


FIGURE 3.6: Impulse Responses to a 1% Financial Easing (L.T.V) Shock

3.4 Welfare Analysis

In order to evaluate how macroprudential policy can be used to stabilize the financial sector, in our model we start by calculating welfare implied by monetary policy, followed by welfare implied by macroprudential policy. This is done by summing the losses and gains which the policy may cause to consumption, output or employment. Welfare is a standard way in the literature through which policy makers evaluate the effects of a policy action. In this section, we closely follow Schmitt-Grohé and Uribe, 2004 and Faia and Monacelli, 2007 to derive the consumption equivalent measure of welfare, which is a common measure in recent DSGE models. We use this approach because it accounts for both the transitional dynamics and the long-run effects of a policy change. Thus,

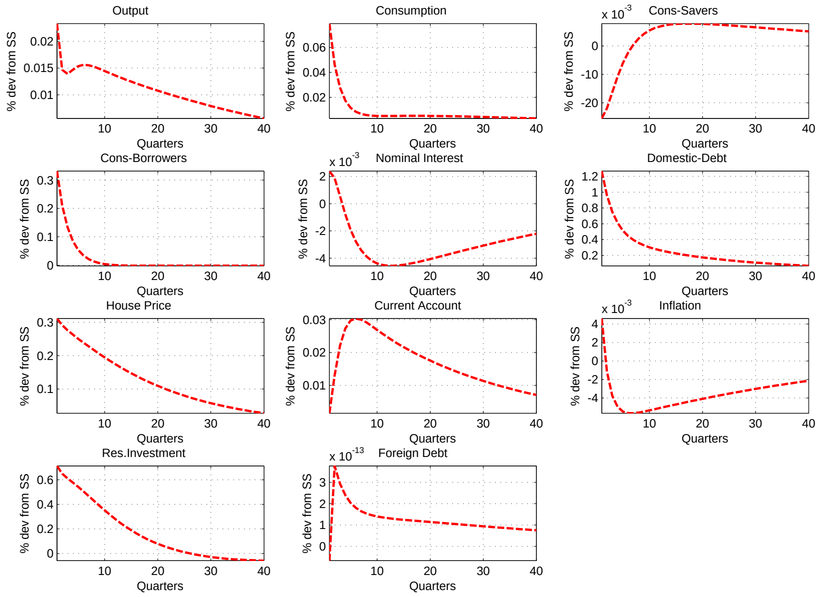


FIGURE 3.7: Impulse Responses to a 1% Housing Demand Shock

we measure welfare as the discounted sum of all future streams of instantaneous utility as:

$$W_t^{MP} = E_t \left\{ \sum_{t=0}^{\infty} \beta U \left(C_t, L_t, H_t \right) \right\}$$

$$W_t^{\prime MP} = E_t \left\{ \sum_{t=0}^{\infty} \beta^{\prime} U \left(C_t^{\prime}, L_t^{\prime}, H_t^{\prime} \right) \right\}$$

where W_t^{MP} and $W_t^{\prime MP}$ are the respective welfare measures of monetary policy for savers and borrowers, which can be expressed in a recursive form as:

$$W_t^{MP} = U \left(C_t, L_t, H_t \right) + \beta E_t W_{t+1}^{MP} \tag{3.17}$$

$$W_t^{\prime MP} = U \left(C_t^{\prime}, L_t^{\prime}, H_t^{\prime} \right) + \beta^{\prime} E_t W_{t+1}^{\prime MP} \tag{3.18}$$

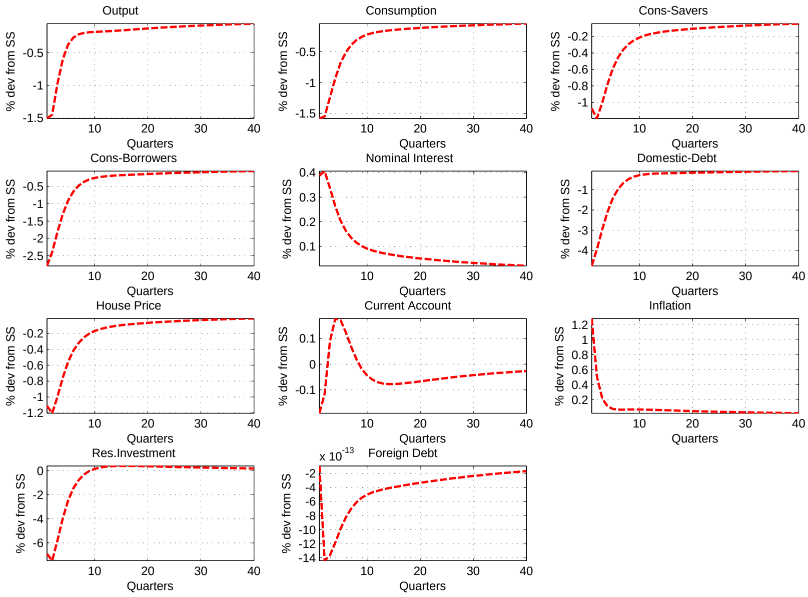


FIGURE 3.8: Impulse Responses to a 1% Price Markup Shock

Following from the above, we compute social welfare SW_t as the weighted sum of the welfare of both types of households(savers and borrowers), which is given as:

$$SW_t = \Theta_H W_t + \Theta_H^{'} W_t^{'} \tag{3.19}$$

where $\Theta_H = (\eta_h)$ and $\Theta_H^{'} = (1 - \eta_h)$. This procedure of weighting the welfare of the two groups to (η_h)– their proportions in the population – is necessary to ensure that both groups receive the same level of consumption from a constant flow; see Mendicino and Punzi, 2014 for an elaboration and Lambertini, Mendicino, and Punzi, 2013 for a discussion on alternative weighting criteria.

Referring to equation (14), monetary policy (following the Taylor rule) may respond to deviation from the steady state of inflation - TR1, inflation and output - TR2 or inflation, output and house price - TR3. Likewise, macroprudential policy (MPP1, MPP2, MPP3) follows equation (15), where it may react to deviations of previous LTV - MPP1, house prices - MPP2, and or output - MPP3.

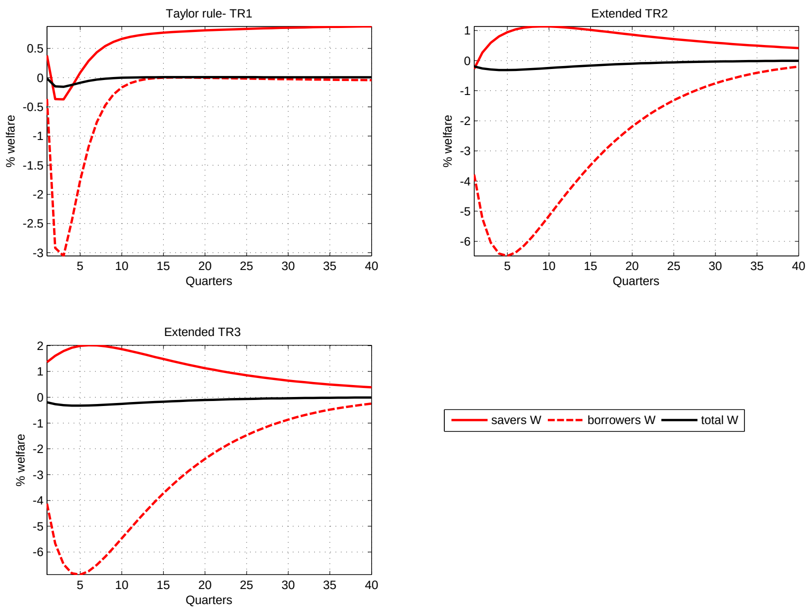


FIGURE 3.9: Impulse Responses to a 1% Macroprudential Policy Shock-MPP3

Figure 3.9 simulates welfare for savers and borrowers over time following a macroprudential shock (MPP3). Our MPP3 allows the macroprudential policy to react to deviations in output, house prices and FRP. As indicated in the Figure, welfare for borrowers (dotted red line) suffers the most, while welfare for savers (red line) gains the most under the extended Taylor rule TR2 and TR3, where the welfare of savers increases by more than 1% while that of borrowers decreases by more than 4% after the shock. However, social welfare, which is the weighted average of the two (black line), decreases following the macroprudential policy, and for almost 20 quarters it remains below the steady state level before converging back to the original state.

Thereafter, and to have an economic intuition of the implications of the welfare on average, we calculate the second order approximation of welfare W_t^{MPP} and $W_t'^{MPP}$ implied by macroprudential policy. Then we compare the two policies in terms of a compensating measure ξ which is the additional proportion of consumption required to equate W_t^{MP} to W_t^{MPP} and $W_t'^{MP}$ to $W_t'^{MPP}$, respectively. Thus, ξ is the opportunity cost of consumption that households are willing to incur in order to obtain the benefits of macroprudential policy. A higher and positive value implies a higher welfare gain and vice versa. Hence, using this condition, we derive the following consumption equivalent measure:

$$\xi = exp[\eta_h(W_t^{MPP} - W_t^{MP})] - 1 \tag{3.20}$$

$$\xi' = exp[(1-\eta_h)(W_t'^{MPP} - W_t'^{MP}] - 1 \tag{3.21}$$

Where the total consumption equivalent measure $\Gamma = \xi + \xi'$

Table 2 reports the consumption equivalent measure of welfare for different combinations of monetary policy (TR1, TR2, TR3). Our baseline is the combination of TR1 and MPP1, where the monetary policy is inflation targeting only, (Response to inflation in the Taylor rule) $(\rho_\pi = 1.3)$while macroprudential policy responds only to the LTV ratio in $(t-1)$ by $(\rho_m = 0.5)$. This combination generates no consumption equivalency welfare, implying that society is indifferent whether to accept the macroprudential policy or not. Note that while these values are randomly selected for the purposes of simulation, they fall within the range of the common policy parameter values widely used by the monetary DSGE literature.

TABLE 3.2: Consumption Equivalent Measure of Welfare-Flexible Prices

	MPP 1$(\rho_m^{mp} = 0.5)$	**MPP 2** $(\rho_y^{mp} = 0.08)$	**MPP 3** $(\rho_q^{mp} = 0.4)$
TR 1 $(\rho_\pi = 1.3)$	0.0	12.73	12.43
TR 2 $(\rho_\pi = 1.3, \rho_y = 0.13)$	00.75	12.62	12.33
TR 3 $(\rho_\pi = 1.3, \rho_y = 0.13, \rho_q = 0.13)$	-1.94	12.64	12.36

Combining the inflation targeting TR1 $(\rho_\pi = 1.3)$ and macroprudential policy MPP2, which reacts to the deviations of output from its steady state by $(\rho_y^{mp} = 0.08)$, generates the highest consumption equivalent measure of all the combinations in our study. On the other hand, the extended Taylor rule TR3 coupled with MP1 generates the lowest consumption equivalent measure (-1.94).

Finally, as a robustness check, we conducted several simulation exercises using different parameter values. We found that the values of consumption equivalent measures change, but the implied conclusion of this chapter is maintained: i.e., monetary policy is effective when complemented by macroprudential policy. In other words, monetary policy may perform better if it is left to do what it does best (price stability), while macroprudential policy should maintain financial stability.

TABLE 3.3: Consumption Equivalent Measure of Welfare-Flexible Prices

	MPP 1$(\rho_m^{mp} = 0.5)$	**MPP 2** $(\rho_y^{mp} = 0.08)$	**MPP 3** $(\rho_q^{mp} = 0.4)$
TR 1 $(\rho_\pi = 1.3)$	0.0	0.0	0.0
TR 2 $(\rho_\pi = 1.3, \rho_y = 0.13)$	-0.52	1638	2269
TR 3 $(\rho_\pi = 1.3, \rho_y = 0.13, \rho_q = 0.13)$	22.9	12.64	233980

3.5 Conclusion

In this chapter, we analysed how monetary and macroprudential policies interact to stabilize both the macroeconomic and financial sectors. In particular, we considered the implications for the small open economy of foreign shocks such as foreign interest rates and foreign residential purchases. We found that these shocks can generate significant increases in output, consumption, house prices and domestic credit. Our study further revealed that while certain combinations of the two policies may improve welfare, others do not. In our case, a countercyclical macroprudential policy which reacts to deviations in output, coupled with a monetary policy which is inflation targeting can bring the most stability to the economy.

A distinctive feature of our study is the presence of foreign buyers in the domestic housing market. Newly built domestic houses are bought by both domestic households (savers and borrowers) and foreign buyers. Houses bought by foreigners in period $(t+1)$ are equal to the houses remaining after depreciation in period (t) plus the amount of capital foreigners invest in new houses in period (t). This capital is determined by the exogenous shock which may increase demand, house prices, and the house producers' net worth. In an economy where the proportion of FRP is significantly large, models which disregard this feature of the housing market may lead to erroneous conclusions and policy recommendations.

Although our model incorporates this important feature of a small open economy, it does not account for other important channels of international capital flows (portfolios and equity) and how such flows may affect the domestic economy. This is an avenue for future work.

Appendix B

B.1 Main Equations of the Model

Budget constraint of patient households:

$$C_t + b_t + q_t I_{h,t} + I_{ct} + I_{kht} + S_t \frac{\xi_R R^*_{t-1} b^*_{t-1}}{\pi^*_t} = \frac{R_{t-1} b_{t-1}}{\pi_t} + \frac{w_{ct} N_{ct}}{X_{wct}} + \frac{w_{ht} N_{ht}}{X_{wht}} + r_{ct} K_{ct-1} + r_{ht} K_{ht-1} + T_\pi + s_t b^*_t - \frac{\xi_b}{2}\left(b^*_t - \overline{b^*_t}\right)^2 \tag{B.1}$$

Where the housing and capital stocks evolves over time as:

$$H_t = (1-\delta_h) H_{t-1} + I_{h,t} - \frac{\xi_h}{2}\left(\frac{H_t - H_{t-1}}{H_{t-1}}\right)^2 \tag{B.2}$$

$$K_{ct} = (1-\delta_k) K_{ct-1} + I_{ct} - \frac{\xi_{ck}}{2}\left(\frac{K_{ct} - K_{ct-1}}{K_{ct-1}}\right)^2 \tag{B.3}$$

$$K_{ht} = (1-\delta_k) K_{ht-1} + I_{kht} - \frac{\xi_{hk}}{2}\left(\frac{K_{ht} - K_{ht-1}}{K_{ht-1}}\right)^2 \tag{B.4}$$

Optimal conditions for patient households:

Note: For brevity here, I present here the optimal conditions for the model without adjustment costs and habit formation. However introducing them is straight forward. For example the Euler equation with habits becomes $\frac{1}{C_t - hC_{t-1}} + \frac{\beta h}{C_{t+1} - C_t} = \beta E_t \left(\frac{R_t}{\pi_{t+1}(C_{t+1} - hC_t)}\right)$. We can see that as $h = 0$ and $\xi_{\cdot} = 0$ the equation reduces to the Euler equation below. Other equations follow the same procedures.

$$\frac{1}{C_t} = \beta E_t \left(\frac{R_t}{\pi_{t+1} C_{t+1}} \right) \tag{B.5}$$

$$\frac{S_t}{C_t} = \beta E_t \left(\frac{\chi_{t+1} s_{t+1}}{C_{t+1}} \right) \left(\frac{R_t^*}{\pi_{t+1}^*} \right) \tag{B.6}$$

$$\frac{\gamma_t}{H_t} = \frac{q_t}{C_t} - \beta E_t \left(\frac{q_{t+1}}{C_{t+1}} [1 - \delta_h] \right) \tag{B.7}$$

$$\frac{1}{C_t} = \beta E_t \left(\frac{1}{C_{t+1}} (1 - \delta_{kc} + R_{ct}) \right) \tag{B.8}$$

$$\frac{1}{C_t} = \beta E_t \left(\frac{1}{C_{t+1}} [1 - \delta_{kh} + R_{ht}] \right) \tag{B.9}$$

$$\frac{w_{ct}}{X_{wct}} = \nu \left(N_{ct}^{\varphi} \right) \left(N_{ct}^{1+\varphi} + N_{ht}^{1+\varphi} \right)^{\frac{1+\sigma}{1+\varphi} - 1} C_t \tag{B.10}$$

$$\frac{w_{ht}}{X_{wht}} = \nu \left(N_{ht}^{\varphi} \right) \left(N_{ct}^{1+\varphi} + N_{ht}^{1+\varphi} \right)^{\frac{1+\sigma}{1+\varphi} - 1} C_t \tag{B.11}$$

$$C_t = \left[(1 - \omega)^{\frac{1}{\eta_c}} \left(C_t^d \right)^{\frac{\eta_c - 1}{\eta_c}} + \omega^{\frac{1}{\eta_c}} \left(C_t^m \right)^{\frac{\eta_c - 1}{\eta_c}} \right]^{\frac{\eta_c}{\eta_c - 1}}$$

$$C_t^d = (1 - \omega) \left(\frac{P_t^d}{P_t} \right)^{-\eta_c} C_t$$

$$C_t^m = \omega \left(\frac{P_t^m}{P_t} \right)^{-\eta_c} C_t$$

Using equations (21) and (22) we can derive the UIP condition

$$\frac{R_t}{\pi_t} = \chi_{t+1} \frac{R_t^*}{\pi_t^*} \frac{S_{t+1}}{S_t}$$

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

Budget Constraint for Impatient Households:

$$C_t^{'} + q_t H_t^{'} + \frac{R_{t-1} b_{t-1}}{\pi_t} = \frac{w_{ct}^{'} N_{ct}^{'}}{X_{wct}} + \frac{w_{ht}^{'} N_{ht}^{'}}{X_{wht}} + b_t^{'} \tag{B.12}$$

Where

$$H_t^{'} = (1 - \delta_h) H_{t-1}^{'} + I_{h,t}^{'} - \frac{\xi_h}{2} \left(\frac{H_t^{'} - H_{t-1}^{'}}{H_{t-1}^{'}} \right)^2 \tag{B.13}$$

and the borrowing constraint

$$E_t \frac{R_t}{\pi_{t+1}} b_t^{'} = E_t m_t q_{t+1} H_t^{'} \tag{B.14}$$

Optimal conditions for impatient households:

$$\frac{1}{C_t^{'}} = \beta^{'} E_t \left(\frac{R_t}{\pi_{t+1} C_{t+1}^{'}} \right) + \Gamma_t^{'} \tag{B.15}$$

$$\frac{\gamma_t^{'}}{H_t^{'}} = \frac{q_t}{C_t^{'}} - \beta E_t \left(\frac{q_{t+1}}{C_{t+1}^{'}} (1 - \delta_h) \right) - \Gamma_t^{'} m_t E_t \left(\frac{q_{t+1} \pi_{t+1}}{R_t} \right) \tag{B.16}$$

$$\frac{w_{ct}^{'}}{X_{wct}} = \nu \left(N_{ct}^{'\,\varphi} \right) \left(N_{ct}^{'\,1+\varphi} + N_{ht}^{'\,1+\varphi} \right)^{\frac{1+\sigma}{1+\varphi} - 1} C_t^{'} \tag{B.17}$$

$$\frac{w_{ht}^{'}}{X_{wht}} = \nu \left(N_{ht}^{'\,\varphi} \right) \left(N_{ct}^{'\,1+\varphi} + N_{ht}^{'\,1+\varphi} \right)^{\frac{1+\sigma}{1+\varphi} - 1} C_t^{'} \tag{B.18}$$

Firms maximization, wages and pricing mechanism

$$Y_t = \left(A_{ct} N_{ct}{}^{\sigma_y} N_{ct}^{'\,1-\sigma_y} \right)^{1-\alpha_y} K_{ct-1}^{\alpha_y} \tag{B.19}$$

$$Y_{h,t} = \left(A_{ht} N_{ht}{}^{\sigma_h} N_{ht}^{'\,1-\sigma_h} \right)^{1-\alpha_h} K_{ht-1}^{\alpha_h} \tag{B.20}$$

$$w_{ct} = \frac{1}{X_t} \sigma_y (1 - \alpha_y) \frac{Y_t}{N_{ct}} \tag{B.21}$$

$$w_{ht} = \sigma_h (1-\alpha_h) \frac{q_t Y_{ht}}{N_{ht}} \tag{B.22}$$

$$w^{'}_{ct} = \frac{1}{X_t} \left(1-\sigma_y\right) \left(1-\alpha_y\right) \frac{Y_t}{N^{'}_{ct}} \tag{B.23}$$

$$w^{'}_{ht} = (1-\sigma_h) (1-\alpha_h) \frac{q_t Y_{ht}}{N^{'}_{ht}} \tag{B.24}$$

$$R_{ct} = \frac{1}{X_t} \alpha_y \frac{Y_t}{K_{ct-1}} \tag{B.25}$$

$$R_{ht} = \alpha_h \frac{q_t Y_{ht}}{K_{ht-1}} \tag{B.26}$$

Aggregate Phillips curve relation:

$$\pi_t - \delta_\pi \pi_{t-1} = \beta E_t \left(\pi_{t+1} - \delta_\pi \pi_t\right) - \phi x_t + \eta_{\pi,t} \tag{B.27}$$

where $\phi = (1-\theta)(1-\beta\theta)\theta$ and $\eta_{\pi,t}$ is a zero mean price mark-up shock. Wage Phillips curve of the following form:

$$w_{ct} - \delta_{wc} \pi_{t-1} = \beta E_t \left(w_{ct+1} - \delta_{wc} \pi_t\right) - \phi_{wc} x_t + \eta_{wc,t} \tag{B.28}$$

$$w_{ht} - \delta_{wh} \pi_{t-1} = \beta E_t \left(w_{ht+1} - \delta_{wh} \pi_t\right) - \phi_{wc} x_t + \eta_{wh,t} \tag{B.29}$$

$$w^{'}_{ct} - \delta_{wc} \pi_{t-1} = \beta^{'} E_t \left(w^{'}_{ct+1} - \delta_{wc} \pi_t\right) - \phi_{wc} x_t + \eta_{wc^{'},t} \tag{B.30}$$

$$w_{ht^{'}} - \delta_{wh} \pi_{t-1} = \beta^{'} E_t \left(w^{'}_{ht+1} - \delta_{wh} \pi_t\right) - \phi_{wc} x_t + \eta_{wh^{'},t} \tag{B.31}$$

where $\phi_{wc} = (1-\theta_{wc})(1-\beta\theta_{wc})\theta_{wc}$ and where $\phi^{'}_{wc} = (1-\theta^{'}_{wc})(1-\beta^{'}\theta^{'}_{wc})\theta^{'}_{wc}$. For simplicity, I assume $\phi_{wc} = \phi_{wh}$ and $\phi^{'}_{wc} = \phi^{'}_{wh}$
Monetary policy

$$R_t = (R_{t-1})^{\rho R} \left[(\pi_t)^{\rho_\pi} \left(\frac{Y_t}{Y_{t-1}}\right)^{\rho_Y} R\right]^{1-\rho R} \varepsilon_{R,t}; \tag{B.32}$$

Current Account

$$CA = -S_t \left(b_t^* - \frac{R_{t-1}^* b_{t-1}^*}{\pi_t^*} \right) \tag{B.33}$$

Real interest rate (Fisher equation)

$$rn_t = rr_t + \pi_{t+1} \tag{B.34}$$

Domestic market clearing conditions:

$$b_t + b_t^{'} = 0$$

$$H_t + H_t^{'} + H_t^F - (1 - \delta_h) \left(H_{t-1} + H_{t-1}^{'} + H_{t-1}^F \right) = Y_{h,t}$$

$$Y_t = C_t^d + C_t^{'} + I_{ct} + I_{kht} + EX_t - C_t^m$$

$$S_t b_t^* + S_t P_t^* EX_t = S_t \frac{R_{t-1}^* b_{t-1}^*}{\pi_t^*} + S_t P_t^m \omega_c \left(\frac{P_t^m}{P_t} \right)^{-\eta_c} C_t$$

$$H_t^F = (1 - \delta_h) H_{t-1}^F + \lambda_t$$

$$\lambda_t = (1 - \rho_\lambda) \delta_h \overline{H^F} + \rho_\lambda \lambda_{t-1} + \varepsilon_\lambda$$

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

$$R_t^* = \rho_{R^*} R_{t-1}^* + \varepsilon_{R^*}$$

Chapter 4

Foreign Mortgage Borrowing, Interest Rate Differentials and Macroprudential Policies

Abstract

In the first two chapters, we assumed that house prices drive capital inflows in terms of FRP and how the later may affect the house price. But on the other hand, investors who build new houses for sale may borrow abroad. While this may increase housing supply and help to dampen house price, the vulnerability of domestic economy due to foreign debt is increased. Regardless in which channel the external shock originates, the FRP or the debt channel, both may have negative economic consequences. Hence, there is a need to analyse the foreign credit channel from a different angle, which is the purpose of this chapter. Specifically, we ask: How can macroprudential policy be designed ex ante to curb capital flows due to exchange rate shocks?

4.1 Introduction

After the global financial crisis(GFC), the debate is no longer about whether governments may intervene in financial markets, but how best to do so. Such interventions are conducted through macroprudential policies aimed at curbing capital flows or capital flights to mitigate the severity of financial crises. Macroprudential policies are either ex ante sets of taxes and quantitative restrictions or ex post interventions that involve a monetary or fiscal stimulus.

Macroprudential policies are justified based on pecuniary externalities as in Bianchi and Mendoza, 2018. In this chapter, pecuniary externalities are defined as arising from private agents' decisions on foreign debt financing, particularly those who borrow in foreign currency with expectations [1] that the exchange rate will remain favourable. However, when the exchange rate increases, such expectations can be belied by an unforeseen exogenous shock, causing interest payments on foreign debt to devalue the domestic currency. This situation may affect capital outflows, causing further adverse effects on exchange rates; and financial constraints may be tightened in response to the adverse effects on the balance sheet. Hence, domestic inflation would increase, affecting all agents in the domestic economy. These costs are not internalised by private agents, which justifies governmental interventions to correct market imperfections in the exchange rate channel.

The shock caused by adverse exchange rates may pose a financial

[1] Preceding the most financial crisis (2007-2009), official data showed that interest rates on foreign currency debt were relatively low, and expectations were so high that some EU members, such as Hungary, would have liked to have joined the Euro area. Such motives induced domestic households to borrow in foreign currency at low interest rates and then invest in the high-yielding domestic housing sector.

risk to the banking sector in countries with mortgages that are heavily denominated in a foreign currency. This is because depreciation increases the debt repayment burden and thus the number of private nonperforming loans (NPL), increasing the private debt-to-GDP ratio. NPLs may increase the risk to the banking sector, which may reduce the ability of banks to offer loans to the private sector, thus potentially sparking a credit crunch that is transmitted to the real sector through reductions in output and employment. For example, when the Hungarian forint depreciated by 26% in the first quarter of 2009 against the euro (and even more against the Swiss franc), the debt-to-GDP ratio almost doubled. To avoid capital flight and a credit crunch, the Hungarian government converted all Foreign Currency Loans (FCLs) into Hungarian currency. This leads us to ask: How can macroprudential policy be designed ex ante to curb capital flows due to exchange rate shocks?

A significant contribution to the literature on the analysis of the interactions between pecuniary externalities and the exchange rate channel was made by Korinek, 2018. They demonstrated that domestic agents subject to collateral constraints trade a broad set of financial claims with international investors. Their study uniquely linked the value of collateral with the country's real exchange rate. Hence, when the real exchange rate depreciates, the borrowing capacity of domestic agents is reduced, and international investors may remove their funds from the domestic economy. The depreciation of domestic currency has a contractionary effect whenever the collateral constraints are binding.

To study the macroprudential policies on the carry trade, we extend the linking of pecuniary externalities to the value of the exchange rate, but we relax some basic assumptions. Korinek, 2018 used homogeneous representative agents in a domestic economy; however, we analyse heterogeneous agents using a small open-economy model in the spirit of Kiyotaki and Moore, 1997, with bankers who borrow internationally, but lend domestically. Here the bankers are financial intermediaries between the foreign economy and the domestic borrowers. Borrowers in the domestic economy borrow in both domestic and foreign currency-denominated loans. This setting enables us to design macroprudential policies to address the carry trade motives of financial intermediaries who borrow in foreign currencies and invest in high-yielding domestic assets. In this chapter, the assumptions are justified, because households do not borrow directly from abroad; instead, banks borrow on their behalf.

We also differ from Korinek, 2018, who differentiated between diverse types of capital flows: debt, FDIs and portfolios; whereas we analyse only debt flows, because debt holds a significant proportion of capital flows in carry trades [2] In the literature, FCLs are considered more volatile than other flows. We contribute to this literature by proposing how governments may intervene optimally in financial markets.

A crucial assumption of this chapter is the presence of financial frictions, such as collateral constraints, in the international credit channel, which contravenes the well-known uncovered interest parity (UIP). The

[2] In Eastern and Central Europe, several emerging economies that experienced the most recent financial crisis had a large portion of their mortgage debt denominated in foreign currencies. Official data showed that loans to the non-banking sector were on average above 20% of the GDP in Austria, where 20% of the loans were denominated in foreign currency. In Poland (ECB,2017 – The Opinion on foreign exchange-linked loans), the ECB showed that loans denominated in foreign currency accounted for almost 40% of all outstanding housing loans and 24% of all outstanding loans to households in January 2017.

UIP postulates that the interest differential between two countries ought to be equal to the expected depreciation of the exchange rate. It is equivalent to saying that the relative ratio of the interest rates would equal one (1), although this is true only if there are no financial constraints. If the financial constraints are binding, then the interest rate differential equals the expected depreciation of the exchange rate plus a wedge, which depends on the binding constraint. Ideally, this wedge is represented by the expected interest rate ratio $\mathbf{E_t}\left[\psi_{t+1}\right]$. This ratio becomes one when the UIP holds and when there are no financial frictions in the international credit channel. However, this chapter assumes that the expected interest rate ratio $\mathbf{E_t}\left[\psi_{t+1}\right]$ is different from a unit, in order to account for the effect of the binding borrowing constraints in the model.

We propose an optimal tax, τ_t^b first, followed by an optimal quantitative restriction, ξ_t. The τ_t^b tax is designed to respond to all dynamics in the exchange rate, or to the foreign monetary policy shock. This response is justified because it reacts to the expected interest rate ratio that encapsulates the two dynamics: $\mathbf{E_t}\left[\psi_{t+1}\right]$. The expected interest rate ratio is a function of the expected depreciation $\mathbf{E_t}\left[\frac{e_{t+1}^e}{e_t}\right]$ (where e_t is the real exchange rate expressed in domestic real currency over foreign real currency and e_{t+1}^e is the expected real exchange rate), and the interest rate spread between the foreign interest rate, R_t^{bf}, and the domestic interest rate, R_t^{ed}, that is, $\mathbf{E_t}\left[\psi_{t+1}\right] = \mathbf{E_t}\left[\frac{e_{t+1}^e}{e_t}\right]\frac{R_t^{bf}}{R_t^{ed}}$.

The interest rate ratio $\mathbf{E_t}\left[\psi_{t+1}\right]$ will capture the expectations of agents ex ante, which may induce them to commit more foreign loans during good times. We assume that agents understand how the economic model works and they use this knowledge to build rational expectations. In doing so, they make use of all available information to build rational expectations of future exchange rate e^e_{t+1}. That is $e^e_{t+1} = \mathbf{E_t}\left[e^{\eta_{t+1}}_{t+1}/\Omega_t\right]$, where $\mathbf{E_t}$ is the expectation operator, Ω_t is the set of all available information, while η_{t+1} refers to the exchange rate shock, which is exogenous to the domestic economy. In the period t, agents use all available information to form an expectation of the future exchange rate. If the exogenous shock is $\eta_{t+1} = 0$, then agents form perfect expectations; otherwise, if $\eta_{t+1} > 0$, agents form incorrect expectations, they might experience financial distress depending on the severity of the shock. The problem is that optimistic expectations do not materialise ex post.

In the baseline ($\eta_{t+1} = 0$), if the expected interest rate ratio $\mathbf{E_t}\left[\psi_{t+1}\right]$ decreases (i.e., the domestic currency appreciates), it prompts the government to impose an optimal tax τ^b_t to discourage private borrowers from obtaining foreign currency loans during the economic boom. It also prevents crashes in the financial market during recessions. In the scenario case, if the government perceives ($\eta_{t+1} > 0$), it may impose a higher tax than in the baseline case. In contrast, when the interest rate ratio $\mathbf{E_t}\left[\psi_{t+1}\right]$ increases (i.e., the domestic currency depreciates), it suggests that the government will decrease taxes for private agents in international financial markets in order to help them repay foreign currency debt. This is because collateral constraints are not binding when the domestic currency appreciates, which may encourage more borrowing.

The government may also enforce regulation ξ_t, which restricts banks from offering foreign currency loans above a certain percent of total loans. For example, $\xi_t = 0.3$ implies that the borrower is allowed to hold only

30 percent of foreign currency debt in their total loan portfolio. This number is exogenously determined by the government to discriminate between those who earn incomes in foreign currency and those who do not. It may be a function of the rating of a country's creditworthiness, which is based on the ability to earn foreign currency; general economic management; structural policies; and policies for social inclusion, equity and public-sector management and institutions. This regulation minimises the impact of an exchange risk because it reduces the demand for foreign currency loans, which may help to improve the resiliency of the domestic currency against foreign currency shocks. In this chapter, we demonstrate that the restriction can be set optimally by responding to the social price of the restrictions constraint.

4.1.1 Related Literature

This chapter is related to a growing literature that analyses market outcomes resulting from the interactions between financial frictions and private agents' optimal financing decisions. These interactions may produce inefficient market outcomes, that in turn call for preventive governmental intervention or curative policies to curb capital flows or capital flights before or after a financial crisis. Based on Jeanne and Korinek, 2013, we divide the literature on macroprudential policy into two groups (1) the emphasis on ex ante interventions; see Benigno et al., 2016, Benigno et al., 2013, Bianchi, 2011 and Bianchi and Mendoza, 2018; (2) the analysis of ex post crisis mitigation. This includes Bianchi, 2016, Fornaro, 2015, Ottonello, 2015 and Korinek, 2018. The present chapter relies on the first group but differs slightly by linking the adverse effects of balance sheets to the depreciation of the exchange rate.

One important feature of all studies on macroprudential policies in the literature is the justification of governmental intervention based on pecuniary externalities arising from financial constraints. These studies assume that governmental intervention is based on pecuniary externalities that arise from limitations to the risk-sharing capacity of domestic agents; see Caballero and Krishnamurthy, 2001 and Caballero and Krishnamurthy, 2003. This chapter differs in several aspects: First, building on Korinek, 2018, we model pecuniary externalities that arise from changes in the value of collateral, capturing the effects of balance sheets. In Korinek, 2018, the value of the collateral is directly linked to the real exchange rate.

In this chapter, we build on his assumption, but differentiate between agents, according to the work of Kiyotaki and Moore, 1997, where the banker can access foreign credit markets, while the entrepreneur cannot. The objective is to model popular incentives that induce agents to borrow in low-interest rate currencies and invest in high-interest rate currencies, so-called 'carry trades'. The is because households do not borrow directly from abroad; instead, banks do so on their behalf. Whereas Korinek, 2018 emphasised preventive policies, we model both optimal preventive restrictions and ex ante macroprudential optimal policies in a carry trade environment.

In another strand of the literature, macroprudential policies are based on aggregate demand externalities in the presence of nominal price stickiness, e.g., Jeanne and Korinek, 2010, Bianchi, 2011, Mendoza and Bianchi, 2015, Farhi and Werning, 2016 and Schmitt-Grohé and Uribe, 2016. These studies proposed a Pigouvian tax be imposed on debt so that borrowers internalise the externalities caused by their borrowing during good times. However, these studies did not address the carry trade specifically. Furthermore, they assumed that the domestic economy consists of only net borrowers or savers; did not link the collateral directly to the real exchange rate.

We extend this literature by introducing the features of financial frictions (e.g., collateral constraints) in foreign currency lending, and their interactions with the exchange rate risk or the foreign monetary shock. For example, Farhi and Werning, 2016 proposed a small open macroeconomic model of optimal policy interventions in international capital markets. However, their main assumption (which is prominent in many small, open economy models) was that the interest rate spread must equal the expected depreciation at equilibrium. However, this assumption holds only if the banker is free from financial frictions, such as borrowing constraints. We show that the presence of collateral constraints in the foreign credit channel causes the interest rate spread at equilibrium to be more than the expected depreciation, implying that the relative ratio is different from one, which contravenes the UIP.

This chapter is similar to other macroeconomic models used to study the transmission of financial shocks from the banking sector to the real sector, propagated through different sets of financial frictions. In particular, this chapter is similar to Iacoviello, 2015, who modelled financial business cycles between savers and borrowers who are intermediated by banks. In their study, default shocks were modelled in a closed economy, whereas we analyse exchange rate shocks in a small open economy.

We contribute to the literature of macroprudential policies by proposing an optimal tax τ_t^b, which is designed to respond ex ante to all dynamics in the expected exchange rate or the foreign monetary policy shock. We also propose an optimal quantitative restriction ξ_t, which is designed to restrict banks from offering foreign currency loans beyond a certain proportion of foreign debt. The optimal rule of this restriction is ξ_1 moves in the opposite direction from the Lagrange multiplier of the restriction constraint κ_t. For example, an increase in κ_t implies a reduction in ξ_1, which tightens the regulation, allowing less foreign currency debt, whereas relaxing κ has the opposite effect.

Closely related studies in the literature on the carry trade and the macroeconomic implications of currency mismatch are Jakucionyte and Wijnbergen, 2017, Garcia-Barragan and Liu, 2017 and Brzoza-Brzezina, Kolasa, and Makarski, 2015b. While Jakucionyte and Wijnbergen, 2017 analysed the macroeconomic consequences of shifting the exchange rate risk from borrowers to banks, Brzoza-Brzezina, Kolasa, and Makarski, 2015b analysed the effects of foreign currency borrowing on economic policy and agents' welfare. Their results demonstrated that a significant volume of foreign currency loans weakened the transmission of monetary policy more than macroprudential policy. In a similar DSGE analysis, Garcia-Barragan and Liu, 2017 proposed a capital control measure that restricts banks to financing only a fraction of the gap between foreign currency loans and foreign currency deposits (denominated in foreign currency). The authors concluded that restrictive capital-control policy weakens the negative effects of foreign exchange risk and foreign monetary policy shock. However, their study did not consider the optimal policy, which is the focus of the present chapter.

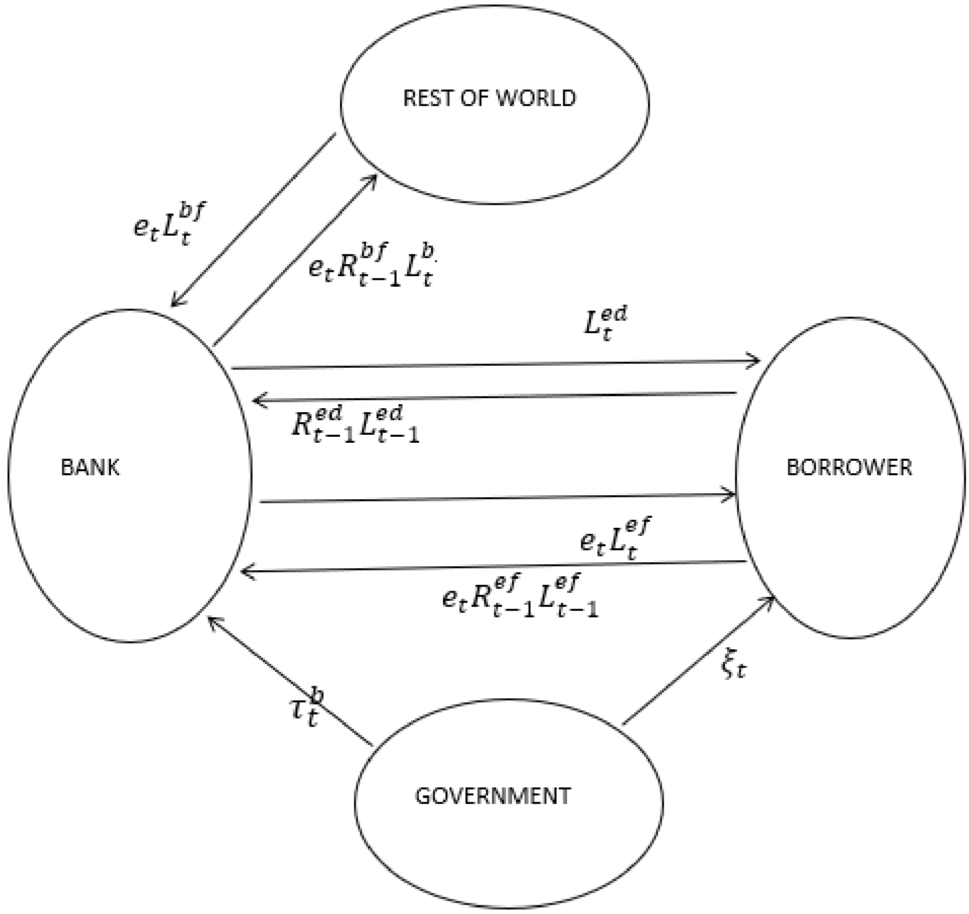
This chapter is organised as follows: Section 2 presents a theoretical macroeconomic model in three periods aimed at savers, borrowers and the social planner; Section 3 presents the analysis of policy responses; Section 4 concludes.

4.2 Model

The model used in this chapter focuses on the macroeconomic consequences of foreign exchange rate shocks for a domestic economy which has a significant proportion of loans denominated in foreign currency. We build a three-period model in the spirit of the model developed in Kiyotaki and Moore, 1997. The model has two types of agents: (1) borrowers or entrepreneurs, and (2) financial intermediaries, which we call bankers. The bankers borrow from international credit markets and save in domestic currency through lending to entrepreneurs in both domestic and foreign currencies.

Figure 4.1 depicts the flow of funds from the rest of the world (RW) to entrepreneurs in the domestic economy through the financial intermediary. The banker on the left-hand side raises funds from the RW, L_t^{bf}, which they then use to lend to the domestic borrowers on the right-hand side of the Figure. The borrower can either request a domestic L_t^{ed} or a dollar denominated loan, L_t^{ef}. The rate of interest to be paid at the end of one period is R_t^{ed} on a domestic currency loan, and R_t^{ef}, which the domestic borrower pays on the dollar debt. The banker also pays interest at the rate R_t^{bf} on the funds raised from the RW. Both the dollar debt and

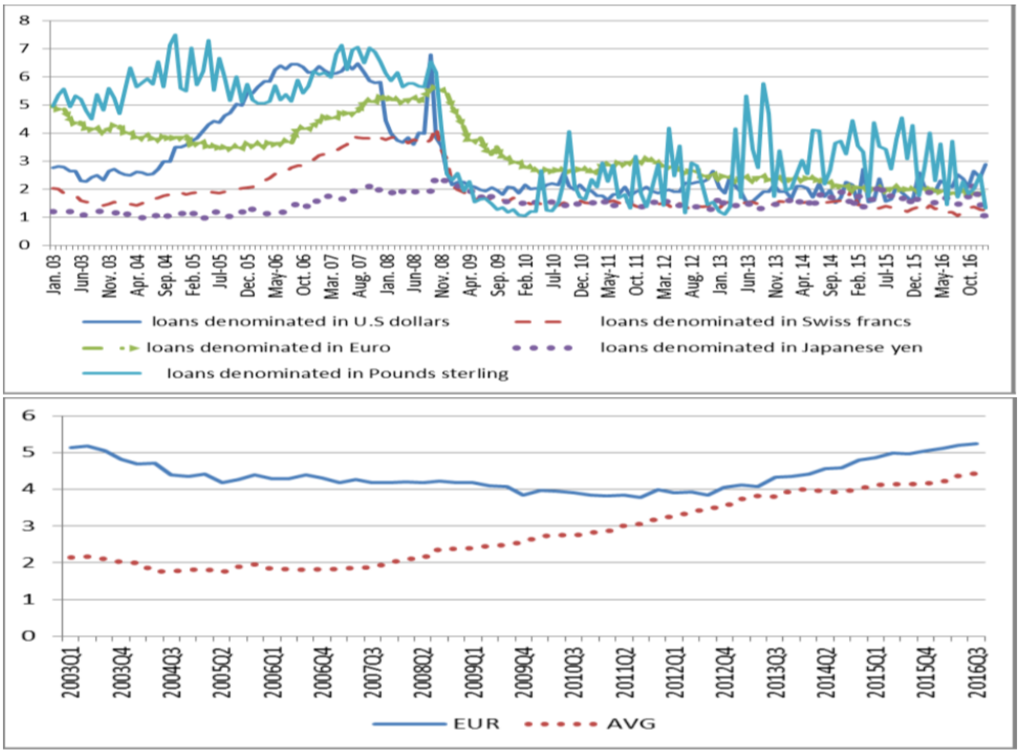
FIGURE 4.1: Flow of Funds



any international funds are subject to real exchange rates e_t, which may change at any time subject to an exogenous shock in the foreign economy. In order for the banker to be motivated to borrow funds from the RW, we assume that this condition holds: $R_t^{ed} > R_t^{ef} > R_t^{bf}$. Intuitively, the banker must obtain more from lending to domestic borrowers than they pay to foreign lenders. In this case, banks finance their activities by borrowing (L_t^{bf}) from foreign banks, where e_t is the real exchange rate. They then lend to entrepreneurs in both domestic and foreign denominations L_t^{ed}, L_t^{ef} to fund the production of goods.

Empirical evidence indicates that interest rates for foreign currency loans were on average lower than the loans denominated in Euro before the GFC. This applies for Swiss and Japanese interest rates from Jan 2003 to Dec 2017 and to loans denominated in U.S dollars only from April 2009. Lending rates for the Pound Sterling are too volatile to indicate a clear pattern. The foreign currency interest rates were relatively high preceding the crisis, but they after the crisis.

FIGURE 4.2: Lending rates in Austria



Source:Oesterreichische Nationalbank (OeNB) and own calculations .

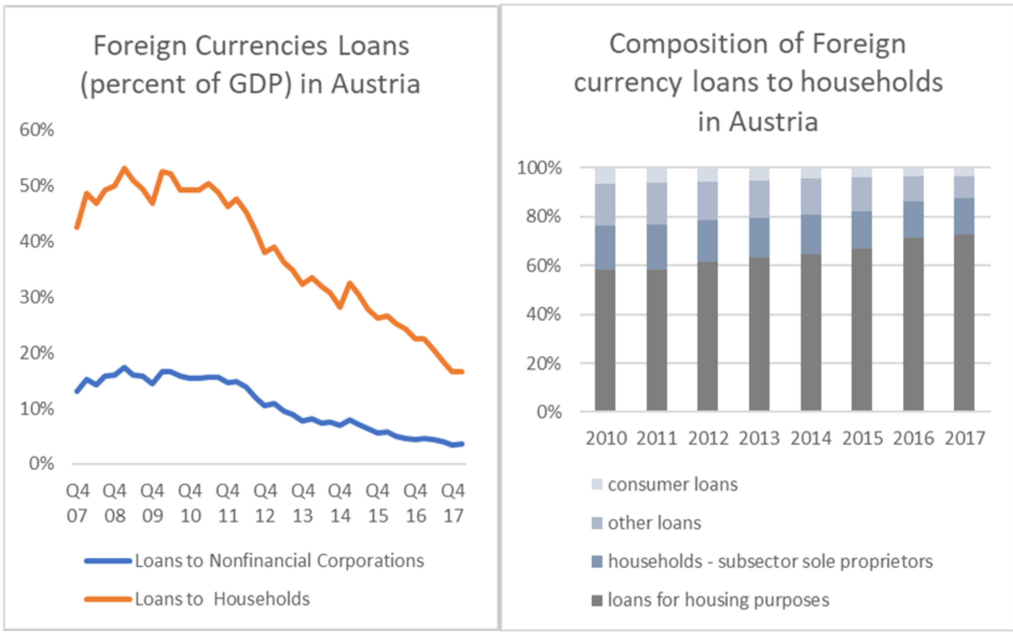
Before the GFC, the interest rate differentials were very high compared to after (see Figure 4.2). During the period leading to GFC, foreign mortgage debt was high (not shown in the Figure for brevity reasons). The literature associates the increase of the interest rate differential with increased foreign currency mortgages. Another factor associated with the increase in foreign currency lending is the expectations of the stability of the real exchange rate that agents had, assuming some EU nations would soon be joining the euro area. These two motives inculcated domestic households with carry trade activities where they borrowed in foreign currency at a low interest rate and invested in the highly yielding domestic housing.

Traditionally carry trade activities were dominated by large financial institutions and leveraged institutions, such as hedge funds (see Keloharju and Niskanen, 2001, Clark and Judge, 2008 and Allayannis, Brown, and Klapper, 2003). But more recently the literature shows that households are becoming even more important players in carry trade activities. In most cases, foreign currency loans are mortgage linked. In Poland, the ECB indicates that loans denominated in foreign currency accounted for almost 40% of all outstanding housing loans and 24% of all outstanding loans to households in January 2017.

In Austria, loans to non-financial corporation amounted to 4% of GDP while loans to households were 17% of GDP by the first quarter of 2018, (Figure 4.3). Loans for housing purposes account for almost 70% of foreign currency loans to households in Austria, followed by sub-sector sole proprietors which account for 15%, other loans-10% and consumer loans-5%, Figure 4.3. These statistics conform the survey by Christian Beer, Steven Ongena, Marcel Peter (2010) which reported that 13% of households had their housing loans denominated in foreign currency, mostly Swiss franc.

The ECB Financial Stability Review of June 2010 noted that foreign currency borrowing can create risks for financial stability through its

FIGURE 4.3: Foreign Currency Loans and Composition



Source:Oesterreichische Nationalbank (OeNB) and own calculations .

linkage with the exchange rate. A significant depreciation of the local currency may translate into an increase in the local-currency value of outstanding debt. Consequently, this could lead to increased debt-servicing costs of domestic borrowers (for non-hedged loans). If the exchange rate shock is sufficiently large, this could aggravate default risk, which would then pose a systemic financial stability risk.

In addition, significant non-performing loans can reduce banks earnings, via a significant decrease in interest income, and an increase in provisioning. This can also create funding risk for banks, as the inflows of funds that are available to banks for repayment of their own liabilities could decrease significantly.

On the contrary, a domestic currency appreciation may positively affect the net wealth of borrowers in foreign currency, which can then increase demand for new foreign currency loans. This may happen especially with a persistently wide interest rate differential in domestic currency loans, vis-à-vis foreign currency loans. This, in turn, can increase aggregate demand, potentially increasing the risk of overheating the economy.

The government intervenes in the markets by implementing two regulatory policies: a macroprudential tax τ_t^b and a regulation on foreign currency loans ξ_t^b. Other regulations may be applied to the bank (which is not the focus of this analysis), such as capital requirements. [3]

Agent $i \in (e, b)$ lives for three periods $t = 1, 2, 3$. The agent derives utility from consuming two types of goods: a homogeneous consumption good $\left(C_t^i\right)$ that serves as a numeraire; and housing, which is a capital good $\left(H_t^i\right)$. The economy is endowed with consumption goods $\left(Y_t^{ic}\right)$ and housing $\left(Y_t^{ih}\right)$. The superscripts (c) and (h) represent the consumption and housing of each agent $i \in (e, b)$.

Each agent maximises the separable utility function:

$$U^i = \max_{\{C_t^i, L_t^{id}, L_t^{if}, H_t^i\}} \mathbf{E_t} \left[\sum_{t=1}^{3} \beta^{i^t} \left[u^i \left(C_t^i \right) + v^i \left(H_t^i \right) \right] \right] \tag{4.1}$$

where $u^i\left(C_t^i\right) = log\left(C_t^i\right)$ and $v^i\left(H_t^i\right) = \gamma log\left(H_t^i\right)$ for $i \in (e, b)$. The utility function $\left(U^i\right)$ is concave and is twice differentiable, satisfying the Inada conditions. $\mathbf{E_t}$ is the expectation operator and β^i $i \in (e, b)$ is the

[3]We refer the reader to Garcia-Barragan and Liu, 2017 for a rigorous analysis of various restrictions on the banking sector, including risk weights of loans denominated in domestic and foreign currencies, and on the gap between foreign currency-denominated loans and deposits.

subjective discount factor. We assume that savers are more patient than borrowers, implying that $\beta^b > \beta^e$. For brevity, in each section we only outline the first-order conditions with respect to the agents. Detailed information on calculations of the derivations are included in the Appendix.

Agents face the following budget constraint:

$$C_t^i + Q_t H_t^i + L_t^{id} + \mathbf{E_t}\left[e_{t+1}^e \frac{L_{t+1}^{if}}{R_t^{bf}}\right] = Y_t^{ci} + Q_t Y_t^{hi} + e_t L_t^{if}$$

On the left side of the budget constraint are expenses on consumption goods C_t^i and housing H_t^i, which are bought at the respective market price Q_t, where e_{t+1}^e is the expected exchange rate in period t. That is, $e_{t+1}^e = \mathbf{E_t}\left[e_{t+1}^{\eta_{t+1}}/\Omega_t\right]$, where Ω_t is the set of all available information, while η_{t+1} refers to exchange rate shock, exogenous to the domestic economy. We associate η_{t+1} with the real exchange rate e_{t+1}.

$\mathbf{E_t}\left[e_{t+1}^{\eta} \frac{L_{t+1}^{if}}{R_t^f}\right]$ are the repayments on foreign debt that agents expect to make in period $t+1$. In period t, agents use all available information to form (rational) expectations of the future exchange rate. If the variable $\eta_t = 0$, then agents form perfect expectations; otherwise, if $\eta_t > 0$, agents form incorrect expectations, and they might experience financial distress depending on the severity of the shock. To simplify the notations, we drop the superscript η_{t+1}, but we acknowledge that the real exchange rate in $t+1$ is subject to the exogenous shock η_{t+1}. Y_t^{cb} and $Q_t Y_t^{hi}$ are endowments of consumption goods and housing, respectively. L_t^f is the foreign debt multiplied by the real exchange rate e_t. In the following sections, we explain in detail the features of different types of agents.

4.2.1 Bank Optimisation Problem

The banker maximises the discounted utility equation 4.1 subject to the following budget constraints:

$$C_1^b + Q_1 H_1^b + L_1^{ed} + e_1 L_1^{ef} = Y_1^{cb} + Q_1 Y_1^{hb} + e_1 L_1^{bf} \tag{4.2}$$

$$C_2^b + Q_2 H_2^b + e_2 R_1^{bf} L_1^{bf} + L_2^{ed} + e_2 L_2^{ef} = Y_2^{cb} + Q_2 Y_2^{hb} + Q_2 H_1^b + R_1^{ed} L_1^{ed} + e_2 R_1^{ef} L_1^{ef} + e_2 L_2^{bf} \tag{4.3}$$

$$C_3^b + Q_3 H_3^b + e_3 R_2^{bf} L_2^{bf} = Y_3^{cb} + Q_3 Y_3^{hb} + Q_3 H_2^b + R_2^{ed} L_2^{ed} + e_3 R_2^{ef} L_2^{ef} \tag{4.4}$$

$$e_1 L_1^{bf} \leq m^b \left(Q_1 H_1^b \right) \tag{4.5}$$

$$e_2 L_2^{bf} \leq m^b \left(Q_2 H_2^b \right) \tag{4.6}$$

Equation 4.2 is the banker's budget constraint in the first period. The banker buys consumption goods C_1^b and housing H_1^b sold at market price Q_1. The banker lends L_1^{ed} in the domestic currency to entrepreneurs, and L_1^{ef} in the foreign currency. L_1^{ef} is multiplied by the real exchange rate $e_1 \equiv \frac{E_1 P_1^*}{P_1}$, where E_1 is the nominal exchange rate and P_1 and P_1^* are the respective consumer prices in the domestic and foreign economies. Because we assume no inflation in the foreign economy, $P_1^* = P^* = 1$. The superscripts d and f represent domestic and foreign sources, respectively. The banker finances the expenses with endowments of consumption goods Y_1^{cb} and housing goods Y_1^{bh} , which are valued at the respective market prices, and borrows L_1^{bf} from foreigners.

Equation 4.3 represents the banker's expenses in period $t = 2$ on consumption goods C_2^b and housing H_2^b sold at price Q_2. The banker pays for the foreign debt contracted in the first period at the interest rate R_1^{bf}.

In addition, the banker lends to entrepreneurs the domestic currency-denominated loans L_2^{ed} and the foreign currency-denominated loans L_2^{ef}. These expenses are financed by endowments Y_2^{cb}, $Q_2 Y_2^{bh}$, the new foreign debt L_2^{bf}, the interest receipts, and the income from selling the houses bought in the first period $Q_2 H_1^b$.

At time $t = 3$, the banker buys the consumption goods C_3^b and H_3^b at the price Q_3 and pays for the loans borrowed in the second period. The banker neither lends nor borrows, because the banker will not exist in the fourth period to pay for the loans contracted in the third period. This assumption satisfies the "no Ponzi game" condition. The banker finances the consumption using the income from endowments Y_3^{cb}, $Q_3 Y_3^{bh}$, the income from the interest receipts, and from sale of the houses bought in the second period. We assume that the housing depreciates completely after the third period.

The corresponding first-order conditions yield the following equations:[4]

$$C_1^b: \qquad \lambda_1^b = \frac{1}{C_1^b} \tag{4.7}$$

$$C_2^b: \qquad \lambda_2^b = \frac{1}{C_2^b} \tag{4.8}$$

$$C_3^b: \qquad \lambda_3^b = \frac{1}{C_3^b} \tag{4.9}$$

$$L_1^{bf}: \qquad \lambda_1^b = \beta^b \lambda_2^b \frac{e_2}{e_1} R_1^{bf} + \mu_1^b \tag{4.10}$$

$$H_1^b: \qquad \lambda_1^b = \frac{\gamma}{Q_1 H_1^b} + \beta^b \lambda_2^b \left(\frac{Q_2}{Q_1}\right) + \mu_1^b m^b \tag{4.11}$$

$$L_1^{ed}, L_1^{ef}: \qquad R_1^{ed} = \frac{e_2}{e_1} R_1^{ef} \tag{4.12}$$

[4]We present here a summary of the first-order conditions. See Appendix C.0.1 for full details of the first-order conditions.

Equations 4.7 to 4.9 show the first-order conditions for choosing consumption in the three periods, where the banker equates the marginal cost of consumption on the left-hand side to the marginal benefit of consumption on the right. Equation 4.10 is the first-order condition for choosing L_1^{bf}, and equation 4.11 is the first-order condition for choosing housing in the first period. These conditions can be combined to show how exchange rates relate to real variables:

$$C_1^b = \frac{1}{\mu_1^b}\left(1 - \psi_2^b\right) \tag{4.13}$$

where $\psi_2^b = \frac{\frac{e_2}{e_1} R_1^{bf}}{R_1^{ed}} > 0$ is the expected interest rate ratio, which shows the extent of the appreciation or depreciation of the domestic currency against the foreign currency. If $\psi_2 < 1$, it indicates that the domestic currency is appreciating; and the converse is true if $\psi_2 > 1$. In contrast, a given level of $\mu_1^b > 0$ implies that the borrowing constraints are binding.

Equation 4.13 indicates that the consumption of goods moves in the opposite direction from the expected interest rate ratio ψ_2, which means that increasing (decreasing) ψ_2 decreases (increases) the consumption of goods. This is plausible, because the depreciation of the domestic currency increases payments towards foreign debt and reduces the income remaining for the consumption of goods. For the banker to choose a positive level of the consumption of goods, that is, $C_1^b > 0$ for $\mu_1^b > 0$, the changes in the expected interest rate ratio, ψ_2, must be less than one, that is, $\psi_2^b < 1$.

Equation 4.13 shows that consumption in the first period increased with the appreciation of the domestic currency, whereas depreciation decreased consumption in the first period.

4.2.2 Entrepreneur Optimisation Problem

The entrepreneur maximises the discounted utility equation 4.1 subject to the following constraints:

$$C_1^e + Q_1 H_1^e = Y_1^{ce} + Q_1 Y_1^{he} + L_1^{ed} + e_1 L_1^{ef} \tag{4.14}$$

$$C_2^e + Q_2 H_2^e + R_1^{ed} L_1^{ed} + e_2 R_1^{ef} L_1^{ef} = Y_2^{ce} + Q_2 Y_2^{he} + Q_2 H_1^e + L_2^{ed} + e_2 L_2^{ef} \tag{4.15}$$

$$C_3^e + Q_3 H_3^e + R_2^{ed} L_2^{ed} + e_3 R_2^{ef} L_2^{ef} = Y_3^{ce} + Q_3 Y_3^{he} + Q_3 H_2^e \tag{4.16}$$

$$L_1^{ed} + e_1 L_1^{ef} \leq m^e \left(Q_1 H_1^e\right) \tag{4.17}$$

$$L_2^{ed} + e_2 L_2^{ef} \leq m^e \left(Q_2 H_2^e\right) \tag{4.18}$$

At period $t = 1$, the entrepreneur buys consumption goods C_1^e and housing $\left(H_1^e\right)$, which are sold at the price Q_1. The entrepreneur finances the purchases using endowments Y_1^{ce}, $Q_1 Y_1^{eh}$, and domestic and foreign-currency denominated loans L_1^{ed} and L_1^{ef} , respectively.

At time $t = 2$, the entrepreneur buys consumption goods C_2^e and housing H_2^e , which are sold at price Q_2, and pays for the loans contracted in the first period at the interest rates of R_1^{ed} and R_1^{ef} on domestic and foreign-currency denominated loans, respectively. These expenses are financed by endowment incomes Y_2^{ce}, $Q_2 Y_2^{eh}$ and newly contracted domestic and foreign currency-denominated loans L_2^{ed} and L_2^{ef} respectively, as well as the income obtained from selling the houses bought in the first period $Q_2 H_1^e$.

At time $t = 3$, the entrepreneur buys the consumption goods C_3^e and H_3^e at the market price Q_3 and pays for the loans borrowed in the second period. The entrepreneur does not borrow, because the entrepreneur will not exist in the fourth period. This assumption satisfies the "no Ponzi game" condition. The entrepreneur finances consumption using income from his/her consumption endowment Y_3^{ec}, housing endowment income $Q_3 Y_3^{eh}$; and sells the houses bought in the second period, $Q_3 H_2^e$. It is assumed that the housing depreciates completely after the third period.

The corresponding first-order conditions yield the following equations:

$$\lambda_1^e = \frac{1}{C_1^e} \tag{4.19}$$

$$\lambda_2^e = \frac{1}{C_2^e} \tag{4.20}$$

$$\lambda_3^e = \frac{1}{C_3^e} \tag{4.21}$$

$$\lambda_1^e = \lambda_1^e \beta^e R_1^{ed} + \mu_1^e \tag{4.22}$$

$$\frac{1}{C_1^e} = \frac{\gamma}{Q_1 H_1^e} + \frac{\beta^b}{C_2^e}\left(\frac{Q_2}{Q_1}\right) + \mu_1^e m^e \tag{4.23}$$

$$R_1^{ed} = \frac{e_2}{e_1} R_1^{ef} \tag{4.24}$$

Equation 4.22 is the Euler condition of the constrained borrower who equates the marginal cost of borrowing today to the discounted marginal cost of borrowing tomorrow, in addition to a factor that determines the binding constraints. If $\mu_1^e > 0$, it implies that the borrowing constraints are binding; hence, the marginal cost in the first period increases according to the binding constraints. Condition 4.23 shows how house prices in time $(t+1)$ are determined.

Condition 4.24 is the no arbitrage condition: the UIP condition, which shows that at equilibrium the domestic interest rate R_1^{ed} is determined by the foreign interest rate R_1^{ef} , multiplied by the changes in the expected exchange rate.

4.2.3 Market clearing

The clearing condition requires that the housing bought in any period equals the housing endowment for $i \in \{e, b\}$. That is,

$$H_t^i = Y_t^{ih}. \tag{4.25}$$

By including this condition in the budget constraints of the entrepreneurs and the bankers, we obtain the social resource constraints, which are explained in the following section.

4.2.4 Central Planner Optimization

The central planner (social planner) chooses $\{C_t^e, L_t^{ed}, L_t^{ef}\}$ and the house price $\{Q_t\}$ for $t \in (1, 2, 3)$ to maximise the utility function 4.1, subject to the following budget constraints: [5]

$$C_1^e + C_1^b = Y_1^{ce} + Y_1^{cb} + e_1 L_1^{bf} \tag{4.26}$$

$$C_2^e + C_2^b + e_2 R_1^{bf} L_1^{bf} = Y_2^{cb} + Y_2^{ce} + Q_2 H_1^b + Q_2 H_1^e + e_2 L_2^{bf} \tag{4.27}$$

$$C_3^e + C_3^b + e_3 R_2^{bf} L_2^{bf} = Y_3^{cb} + Y_3^{ce} + Q_3 H_2^e + Q_3 H_2^b \tag{4.28}$$

$$e_1 L_1^{bf} \leq m_1^p Q_1 H_1^e \tag{4.29}$$

$$e_2 L_2^{bf} \leq m_2^p Q_2 H_2^e \tag{4.30}$$

The following equation combines the banker's first-order conditions:

$$\frac{1}{C_1^b} = \frac{\gamma}{Q_1 H_1^b} + \frac{\beta^b}{C_2^b}\left(\frac{Q_2}{Q_1}\right) + \mu_1^b m^b \tag{4.31}$$

$$\frac{1}{C_2^b} = \frac{\gamma}{Q_2 H_2^b} + \frac{\beta^b}{C_3^b}\left(\frac{Q_3}{Q_2}\right) + \mu_2^b m^b \tag{4.32}$$

$$\frac{1}{C_3^b} = \frac{\gamma}{Q_3 H_3^b} \tag{4.33}$$

[5] This comes after taking into account that, at state level, housing is equal to house endowment $\{H_t^i = Y_t^{ih}\}$

Equations 4.26 to 4.28 are the budget constraints on the agent in time $t = 1, 2, 3$. Equations 4.29 and 4.30 are the borrowing constraints that restrict foreign debt to a certain proportion of the value of collateral in the first and the second periods. Equations 4.31 to 4.33 are the Euler equations for housing in the first-order conditions of the competitive equilibrium. These conditions serve as implementability constraints on the social planner. Hence, the social planner is constrained to choose the house price that is consistent with the competitive equilibrium. In this case, the central planner chooses the house price that clears the decentralised markets.

Calling λ_t^p the Lagrange multiplier assigned to the budget constraints, μ_t^p the Lagrangian assigned to the borrowing constraints and Γ_t^p the Lagrangian assigned to the implementability constraint for t=1,2,3. The first-order conditions of the social planner are summarised as follows:

$$\lambda_1^p = \frac{1}{C_1^b} + \Gamma_1^p \frac{Q_1}{(C_1^b)^2} \tag{4.34}$$

$$\lambda_2^p = \frac{1}{C_2^b} + \Gamma_2^p \frac{Q_2}{(C_2^b)^2} \tag{4.35}$$

$$\lambda_3^p = \frac{1}{C_3^b} + \Gamma_3^p \frac{Q_3}{(C_3^b)^2} \tag{4.36}$$

$$\lambda_1^p = \beta^p \lambda_2^p \frac{e_2}{e_1} R_1^{bf} + \mu^p \tag{4.37}$$

$$\mu_1^p m_1^p H_1^e = \Gamma_1^p \left(\frac{1}{{Q_1}^2 H_1^e} + \frac{\beta^b}{C_2^b} \frac{Q_2}{{Q_1}^2} \right) \tag{4.38}$$

On the left-hand side of the first-order conditions of the equations 4.34 to 4.37 are the marginal costs of borrowing, which equal the shadow value of the wealth of the social planner. On the right-hand side are the marginal benefits, which are composed of the marginal utilities of consumption $\frac{1}{C_t^b}$ for t=1,2,3, and the product of the implementability conditions Γ_t^p and the value of houses Q_t adjusted to the diminishing marginal utility of consumption $\frac{1}{C_t^{b2}}$ for t=1,2,3. Equation 4.38 shows that the second component on the right-hand side holds when the collateral conditions are binding, that is, $\mu_t^p > 0 \Rightarrow \Gamma_t > 0$. The optimal choices of the planner are maximised when all the equilibrium conditions are satisfied.

Comparing Central Planner and Competitive Equilibria

For the social planner, the shadow wealth of borrowing in the three periods is represented by the Lagrange multiplier λ_t^p for t = 1,2,3 in equations 4.34 to 4.36 . The comparison of the shadow wealth of the social planner with that of the private agents in the decentralised equilibrium indicates that the social planner's shadow value of wealth for t= 1,2,3 was higher than the private agents' by the term $\Gamma_t^p \frac{Q_t}{(C_t^e)^2} > 0 \Leftrightarrow \left\{\Gamma_t^p > 0\right\}$. Thus, the difference holds when $\Gamma_t^p > 0$, that is, when the borrowing constraints are binding for the social planner because of the equation 4.38, which shows $\Gamma_t^p > 0 \Leftrightarrow \mu_t^p > 0$. If the constraints are binding, social planners consider how increasing consumption goods might affect housing and house prices. The mechanism is as follows:

For example, by increasing C_1^b in 4.34, the entire term $\Gamma_1^p \frac{Q_1}{(C_1^b)^2}$ will decline, which implies that Q_1 must increase to maintain the system's balance. Intuitively, by increasing consumable goods at an increasing rate, the marginal utility of consumable goods is decreased. This may cause the social planner to substitute consumable goods for housing, which may increase the demand for housing and house prices, because the supply of housing is highly inelastic in the short term. In this case, the planner equates the social marginal cost with the marginal benefit, plus the effect of the consumption of goods on house prices. Hence, the marginal cost to the social planner is higher than that of the decentralised equilibrium, which is referred to as "pecuniary externality" in the literature (see Dávila and Korinek, 2017).

This result is plausible because social planners acknowledge that increasing demand for one good might affect the price of the other (recall that this model assumes only two goods: houses and consumable goods), a feature that private agents in a decentralised market do not take into account. However, the difference between the equilibrium of the banker and the social planner holds true only if the borrowing constraints are binding: $\left\{\Gamma_t^b > 0\right\} \Leftrightarrow \left\{\mu_t^b > 0\right\}$.

In equation 4.37, the social cost of the planner moves in the same direction as the exchange rate. Hence, a shock that causes the exchange rate to increase may increase the social marginal cost through its effect on the discounted cost of foreign borrowing in future, which is represented by equation 4.37. Intuitively, the debt burden increases because of the increase in the foreign exchange rate against the domestic currency, which reduces a country's creditworthiness. This effect may be multiplied through the borrowing constraints represented in equations 4.29 and 4.30.

4.3 Regulating Foreign Currency Debt

In this section, we analyse two policy tools for controlling the adverse effects of a foreign exchange rate shock: (1) the macroprudential tax $\tau_t \in (0,1)$ on the foreign interest payments made by private agents, to discourage agents from borrowing in foreign currency and evade the burden associated with exchange rate shocks; (2) a restriction limiting the quantum of foreign loans.

4.3.1 Macroprudential Tax

The optimal tax level can be obtained if the equilibria conditions of the banker and the social planner are equalised. This can be done by equating the Euler equation of the private agent's equilibrium with the social planner's Euler equation. The private agent's Euler equation regulated by a tax τ_1 is: $\lambda_1^b = \beta^b \lambda_2^b \frac{e_2}{e_1} R_1^{bf} (1+\tau_1) + \mu^p$. And, that of the social planner is represented by equation 4.37, $\lambda_1^p = \beta^b \lambda_2^p \frac{e_2}{e_1} R_1^{bf} + \mu^p$, where τ_t is the tax. These two equations can be combined to obtain the optimal tax, which makes the two Euler equations the same:

$$\tau_1^b = \frac{\theta_1}{\psi_2} + \phi_1 \tag{4.39}$$

where $\psi_2 = \frac{\frac{e_2}{e_1} R_1^{bf}}{R_1^{ed}}$ is the expected interest rate ratio adjusted for the exchange rate. $\theta_1 = \left(\frac{\mu^p}{\lambda_1^p} - \frac{\mu_1^p}{\beta^b \lambda_2^p R_1^{ed}} \right)$ is the slope between the tax and the expected interest rate ratio and $\phi_1 = \frac{\beta^b \lambda_2^p R_1^{ed}}{\lambda_1^p} - 1$ is the intercept of the line. This is the value of the tax when there is no change in ψ_2. The intercept term ϕ_1 is the level of tax, which is different from zero, and which the government may keep because it does not depend on changes in the exchange rate. The slope is a combination of collateral binding conditions, the expected house price, and the discounted marginal utility of consumable goods(see the Appendix at the end of this chapter for details on the derivations).

Equation 4.39 shows a negative relationship between the tax τ_1^b and the expected interest rate ratio ψ_2. Recall that the expected interest rate ratio is defined as $\left(\psi_2 = \frac{\frac{e_2}{e_1} R_1^{bf}}{R_1^{ed}}\right)$. Increasing ψ_2 depreciates the domestic exchange rate, whereas decreasing ψ_2 appreciates the domestic exchange rate. The aim of the interest rate ratio $\mathbf{E_t}\left[\psi_2\right]$ is to capture the expectations of agents ex ante, which may induce them to commit more foreign loans during good times. If the expectation on the interest rate ratio $\mathbf{E_1}\left[\psi_2\right]$ decreases(which is translated as the appreciation of domestic currency), it causes the government to impose an optimal tax τ_1^b in order to discourage private borrowers from committing to foreign currency loans during the boom and prevent a financial market crash during recessions. For this reason, Equation 4.39 indicates that the government taxes bankers when the exchange rate appreciates, and it reduces taxes on them when the exchange rate depreciates.

In contrast, the government may give a macroprudential subsidy $s_t \in (0,1)$, which has a sign opposite to the tax τ_t when the exchange rates are not favourable. Subsidisation may occur during the recession when domestic exchange rate depreciation causes the weakening of the financial system. To avoid financial collapse, the government must intervene by subsidising borrowers to help bear the cost of foreign currency debt payments. This subsidy may be offered in order to relax the binding constraints of borrowing. For this reason, both taxes and subsidies are designed to react to all changes caused by expected exchange rates and foreign monetary policy shocks.

4.3.2 Restriction of Foreign Debt

Instead of charging a tax or subsidy, the government may decide to impose a restriction ξ_t, which is set exogenously to limit the demand for foreign currency loans to a certain percentage of the loan portfolio, which may attenuate the impact of the exchange rate risk. Assume the entrepreneurs do not earn income in foreign currency, but they borrow in foreign currency. The government may want to restrict the amount of foreign currency they can borrow. How can this be done optimally? Consider the representative entrepreneur who combines loans denominated in domestic and foreign currency into an aggregated loan portfolio L_t,

$$L_t = L_t^{ed} + e_t L_t^{ef} \tag{4.40}$$

The government may restrict banks from lending foreign currency loans beyond a certain threshold:

$$\frac{e_t L_t^{ef}}{L_t} \leq \xi_t. \tag{4.41}$$

where $\xi_t \in (0,1)$ is a regulation variable that caps the proportion of foreign currency in the total loan portfolio at a certain level. e_t and L_t^{ef} are the real exchange rate and the foreign currency loans extended to the entrepreneur, respectively. How is the optimal level determined?

The banks maximise the discounted utility equation (4.1) by choosing how much to spend on non-durable goods C_t^b, housing H_t^b, how much to borrow from the RW L_t^{bf} and how much to lend in domestic L_t^{ef} and foreign currency L_t^{ed} subject to budget constraints:

$$C_1^b + Q_1 H_1^b + L_1^{ed} + e_1 L_1^{ef} = Y_1^{cb} + Q_1 Y_1^{hb} + e_1 L_1^{bf} \tag{4.42}$$

$$C_2^b + Q_2 H_2^b + e_2 R_1^{bf} L_1^{bf} + L_2^{ed} + e_2 L_2^{ef} = Y_2^{cb} + Q_2 Y_2^{hb} + Q_2 H_1^b + R_1^{ed} L_1^{ed} + e_2 R_1^{ef} L_1^{ef} + e_2 L_2^{bf} \tag{4.43}$$

$$C_3^b + Q_3 H_3^b + e_3 R_2^{bf} L_2^{bf} = Y_3^{cb} + Q_3 Y_3^{hb} + Q_3 H_2^b + R_2^{ed} L_2^{ed} + e_3 R_2^{ef} L_2^{ef} \tag{4.44}$$

$$e_1 L_1^{bf} \leq m^b \left(Q_1 H_1^b \right) \tag{4.45}$$

$$e_2 L_2^{bf} \leq m^b \left(Q_2 H_2^b \right) \tag{4.46}$$

$$e_1 L_1^{ef} \leq \frac{\xi}{1-\xi} L_1^{ed} \tag{4.47}$$

$$e_2 L_2^{ef} \leq \frac{\xi}{1-\xi} L_2^{ed} \tag{4.48}$$

To determine the optimal setting of the regulation, we follow the same process that we conducted in section 4.3.1 to determine the optimal macroprudential subsidy and tax. We start by deriving a regulated equilibrium with $\xi_t \in (0, 1)$ and equate it with the social planner's equilibrium in section 4.2.4 in order to determine the optimal level of $\xi_t \in (0, 1)$. The regulated banker maximisation problem is the same as in section 4.2.1, but with the addition of the restriction $\xi_t \in (0, 1)$ in equation 4.41. The details of the maximisation problem are provided in the Appendix. For brevity, we present the results of the derived optimal restriction as follows:

$$\xi_1 = \frac{\Upsilon_1}{\Upsilon_1 + \kappa_1} \tag{4.49}$$

where κ_t is the Lagrange multiplier in the regulation constraint in equation 4.47 for $t = 1$. $\Upsilon_1 = \Theta_1 (\psi_2 - 1) + \mu_1^p$, whereas $\Theta_1 = \beta^b R_1^{ed} \lambda_2^p$. The expected interest rate ratio ψ_2 is defined as in earlier sections . Equation 4.49 shows that ξ_1 moves in the opposite direction from κ_t. For example, an increase in κ_t implies a reduction in ξ_1 , which tightens the regulation, allowing less foreign currency debt, whereas relaxing κ has the opposite effect.

This restriction may be used to complement other financial policies that are designed to prevent or minimise the effects of crises. Many scholars have advocated the use of collateral constraints, but most of the assets that are used as collateral are valued at market prices, which may be diluted heavily by the crisis itself. Hence, other regulations may be justified, such as ξ_t , which determines the overall creditworthiness of the borrower and does not depend on market prices of collateral.

Under what conditions would a policy maker prefer one or the other?

The tax policy aims to create additional "implicit costs" for banks in order to discourage them from holding foreign currency liabilities and assets on their balance sheets, in order to decrease the supply of foreign currency loans. However, there are some circumstances where the tax (which is an automatic stabilizer) cannot work effectively. The ECB Financial Stability Review of June 2010, documents several reasons which may make the automatic stabilizers less effective. These include circumstances when:

(i) the differential between interest rates on loans in domestic currency and those on loans in foreign currency are persistently wide which encourage demand for foreign currency loans;

(ii) given a shortage of domestic (local currency) savings, and intense bank competition necessitated the supply of foreign currency loans; and

(iii) there is a significant presence of foreign-owned banks in the domestic economy.

This may increase the opportunities for banks to circumvent such measures. Under such circumstances, banks may partially shift the foreign currency loans to the balance sheets of parent banks or to affiliated non-bank financial intermediaries, which are outside the scope of responsibility of national authorities. To overcome these challenges, a necessary condition (which may not be sufficient) is to limit the amount of foreign currency loans.

4.4 Conclusion

In this chapter, we analysed the macroeconomic implications of real exchange rate shocks for a small open economy that holds a significant proportion of foreign currency debt. Adverse shocks, such as the depreciation of the domestic currency, increase the burden of paying the foreign currency debt, which may increase the number of private, non-performing loans.

Private foreign debt financing may induce pecuniary externalities in which financial frictions, such as collateral constraints, are binding. During a financial crisis, these binding constraints can amplify financial shocks. This effect calls for governmental intervention to relax the binding constraints to prevent or mitigate the severity of a financial crisis. Experience has shown that some countries with a significant proportion of foreign currency debt had to convert all foreign currency loans into domestic currencies. This was done to prevent capital flight, which was triggered by the adverse exchange rate shocks. The main question is: How can an optimal macroprudential policy be designed to control capital flows and capital flight due to adverse exchange rate shocks?

Most previous studies that analysed macroprudential policies linked pecuniary externalities with the limitations to the capacity of risk sharing by domestic agents. Other studies examined macroprudential policies through analysing aggregate demand externalities in the presence of price stickiness. In the present study, we analysed pecuniary externalities that arise from changes in the value of collateral, which are linked to the exchange rate, thus capturing the effects of the balance sheet.

We propose the optimal tax τ_t^b, designed to respond to all dynamics in the exchange rate and the foreign monetary policy shock; and the optimal quantitative restriction ξ_t for agents who do not earn their incomes in foreign currency. This restricts banks to offering foreign currency loans up to a certain percentage of their total loan portfolio. Many scholars have advocated the use of collateral constraints, but most of the assets that are used as collateral are valued at market prices, which may be diluted heavily by the crisis itself. The regulation proposed in this chapter is preferred since it is determined independently of the prices of the collaterals.

Appendix C

C.0.1 Bank Optimisation

The representative banker maximise the discounted utility by choosing how much to spend on non-durable goods C_t^b, housing H_t^b and decide how much to lend in domestic currency L_t^{ed} and foreign currency L_t^{ef}. The banker raises funds from international financial markets L_t^{bf}. The maximization problem is as follows:

$$\max_{\{C_t^b, L_t^{ed}, L_t^{ef}, H_t^b\}} \{lnC_1^b + \beta^b lnC_2^b + {\beta^b}^2 lnC_3^b + \gamma lnH_1^b + \beta^b \gamma lnH_2^b + {\beta^b}^2 \gamma lnH_3^b\} \tag{C.1}$$

subject to budget constraints:

$$C_1^b + Q_1 H_1^b + L_1^{ed} + e_1 L_1^{ef} = Y_1^{cb} + Q_1 Y_1^{hb} + e_1 L_1^{bf} \tag{C.2}$$

$$C_2^b + Q_2 H_2^b + e_2 R_1^{bf} L_1^{bf} + L_2^{ed} + e_2 L_2^{ef} = Y_2^{cb} + Q_2 Y_2^{hb} + Q_2 H_1^b + R_1^{ed} L_1^{ed} + e_2 R_1^{ef} L_1^{ef} + e_2 L_2^{bf} \tag{C.3}$$

$$C_3^b + Q_3 H_3^b + e_3 R_2^{bf} L_2^{bf} = Y_3^{cb} + Q_3 Y_3^{hb} + Q_3 H_2^b + R_2^{ed} L_2^{ed} + e_3 R_2^{ef} L_2^{ef} \tag{C.4}$$

$$e_1 L_1^{bf} \leq m^b \left(Q_1 H_1^b \right) \tag{C.5}$$

$$e_2 L_2^{bf} \leq m^b \left(Q_2 H_2^b \right) \tag{C.6}$$

Formally,

$$\begin{aligned}
\mathcal{L} = & \max_{\{C_t^b, L_t^{ed}, L_t^{ef}, H_t^b\}} \{lnC_1^b + \beta^b lnC_2^b + \beta^{b^2} lnC_3^b + \gamma lnH_1^b + \beta^b \gamma lnH_2^b + \beta^{b^2} \gamma lnH_3^b\} \\
& - \lambda_1^b \left[C_1^b + Q_1 H_1^b + L_1^{ed} + e_1 L_1^{ef} - \left(Y_1^{cb} + Q_1 Y_1^{hb} + e_1 L_1^{bf}\right)\right] \\
& - \beta^b \lambda_2^b \left[C_2^b + Q_2 H_2^b + e_2 R_1^{bf} L_1^{bf} + L_2^{ed} + e_2 L_2^{ef}\right] \\
& + \beta^b \lambda_2^b \left[\left(Y_2^{cb} + Q_2 Y_2^{hb} + Q_2 H_1^b + R_1^{ed} L_1^{ed} + e_2 R_1^{ef} L_1^{ef} + e_2 L_2^{bf}\right)\right] \\
& - \beta^{b^2} \lambda_3^b \left[C_3^b + Q_3 H_3^b + e_3 R_2^{bf} L_2^{bf} - \left(Y_3^{cb} + Q_3 Y_3^{hb} + Q_3 H_2^b + R_2^{ed} L_2^{ed} + e_3 R_2^{ef} L_2^{ef}\right)\right] \\
& - \mu_1^b \left[e_1 L_1^{bf} - m^b \left(Q_1 H_1^b\right)\right] \\
& - \beta^b \mu_2^b \left[e_2 L_2^{bf} - m^b \left(Q_2 H_2^b\right)\right]
\end{aligned} \tag{C.7}$$

The first order conditions are as follows:

$$C_1^b: \qquad \lambda_1^b = \frac{1}{C_1^b} \tag{C.8}$$

$$C_2^b: \qquad \lambda_2^b = \frac{1}{C_2^b} \tag{C.9}$$

$$C_3^b: \qquad \lambda_b^e = \frac{1}{C_3^b} \tag{C.10}$$

$$H_1^b: \qquad \frac{\gamma}{H_1^b} = \lambda_1^b Q_1 - \beta^b \lambda_2^b Q_2 - \mu^b m^b Q_1 \tag{C.11}$$

$$H_2^b: \qquad \frac{\gamma}{H_2^b} = \lambda_2^b Q_2 - \beta^b \lambda_3^b Q_3 - \mu^b m^b Q_2 \tag{C.12}$$

$$H_3^b: \qquad \frac{\gamma}{H_2^e} = \lambda_3^b Q_3 \tag{C.13}$$

$$L_1^{ed}: \qquad \lambda_1^e = \beta^e \lambda_2^e R_1^{ed} \tag{C.14}$$

$$L_2^{ed}: \qquad \lambda_2^e = \beta^e \lambda_3^e R_1^{ed} \tag{C.15}$$

$$L_1^{ef}: \qquad \lambda_1^e = \beta^e \lambda_2^e \frac{e_2}{e_1} R_1^{ef} \tag{C.16}$$

$$L_2^{ef}: \qquad \lambda_2^e = \beta^e \lambda_3^e \frac{e_2}{e_1} R_1^{ef} \tag{C.17}$$

$$L_1^{bf}: \qquad \lambda_1^b = \beta^b \lambda_2^b \frac{e_2}{e_1} R_1^{bf} + \mu^b \tag{C.18}$$

$$L_2^{bf}: \qquad \lambda_2^b = \beta^b \lambda_3^b \frac{e_3}{e_2} R_2^{bf} + \mu^b \tag{C.19}$$

C.0.2 Entrepreneur Optimisation

The entrepreneur choose $C_t^e, L_t^{ed}, L_t^{ef}, H_t^e$ for $t = 1,2,3$ to maximise the utility given by equation (4.1). Formally,

$$\max_{\{C_t^e, L_t^{ef}, H_t^e\}} \left(lnC_1^e + \beta^e lnC_2^e + \beta^{e2} lnC_3^e + \gamma lnH_1^e + \beta^e \gamma lnH_2^e + \beta^{e2} \gamma lnH_3^e \right) \tag{C.20}$$

Subject to:

$$C_1^e + Q_1 H_1^e = Y_1^{ce} + Q_1 Y_1^{he} + L_1^{ed} + e_1 L_1^{ef} \tag{C.21}$$

$$C_2^e + Q_2 H_2^e + R_1^{ed} L_1^{ed} + e_2 R_1^{ef} L_1^{ef} = Y_2^{ce} + Q_2 Y_2^{he} + Q_2 H_1^e + L_2^{ed} + e_2 L_2^{ef} \tag{C.22}$$

$$C_3^e + Q_3 H_3^e + R_2^{ed} L_2^{ed} + e_3 R_2^{ef} L_2^{ef} = Y_3^{ce} + Q_3 Y_3^{he} + Q_3 H_2^e \tag{C.23}$$

$$L_1^{ed} + e_1 L_1^{ef} \leq m^e \left(Q_1 H_1^e \right) \tag{C.24}$$

$$L_2^{ed} + e_2 L_2^{ef} \leq m^e \left(Q_2 H_2^e \right) \tag{C.25}$$

$$C_1^e: \qquad \lambda_1^e = \frac{1}{C_1^e} \tag{C.26}$$

$$C_2^e: \qquad \lambda_2^e = \frac{1}{C_2^e} \tag{C.27}$$

$$C_3^e: \qquad \lambda_3^e = \frac{1}{C_3^e} \tag{C.28}$$

$$H_1^e: \qquad \frac{\gamma}{H_1^e} = \lambda_1^e Q_1 - \beta^b \lambda_2^e Q_2 - \mu_2^e m^e Q_1 \tag{C.29}$$

$$H_2^e: \qquad \frac{\gamma}{H_2^e} = \lambda_2^e Q_2 - \beta^e \lambda_3^e Q_3 - \mu_2^e m^e Q_2 \tag{C.30}$$

$$H_3^e: \qquad \frac{\gamma}{H_3^e} = \lambda_3^e Q_3 \tag{C.31}$$

$$L_1^{ed}: \qquad \lambda_1^e = \lambda_2^e \beta^e \frac{e_2}{e_1} R_1^{ed} + \mu_1^e \tag{C.32}$$

$$L_2^{ed}: \qquad \lambda_2^e = \lambda_3^e \beta^e \frac{e_3}{e_2} R_2^{ed} + \mu_2^e \tag{C.33}$$

$$L_1^{ef}: \qquad \lambda_1^e = \lambda_2^e \beta^e \frac{e_2}{e_1} R_1^{ef} + \mu_1^e \tag{C.34}$$

$$L_2^{ef}: \qquad \lambda_2^e = \lambda_3^e \beta^e \frac{e_3}{e_2} R_2^{ef} + \mu_2^e \tag{C.35}$$

C.0.3 Central Planner Optimization

$$C_1^e + C_1^b = Y_1^{ce} + Y_1^{cb} + e_1 L_1^{bf} \tag{C.36}$$

$$C_2^e + C_2^b + e_2 R_1^{bf} L_1^{bf} = Y_2^{cb} + Y_2^{ce} + Q_2 H_1^b + Q_2 H_1^e + e_2 L_2^{bf} \tag{C.37}$$

$$C_3^e + C_3^b + e_3 R_2^{bf} L_2^{bf} = Y_3^{cb} + Y_3^{ce} + Q_3 H_2^e + +Q_3 H_2^b \tag{C.38}$$

$$e_2 R_1^{bf} L_1^{bf} \leq m_1^p Q_1 H_1^e \tag{C.39}$$

$$e_3 R_2^{bf} L_2^{bf} \leq m_2^p Q_2 H_2^e \tag{C.40}$$

$$\frac{1}{C_1^b} = \frac{\gamma}{Q_1 H_1^b} + \frac{\beta^b}{C_2^b}\left(\frac{Q_2}{Q_1}\right) + \mu_1^b m^b \tag{C.41}$$

$$\frac{1}{C_2^b} = \frac{\gamma}{Q_2 H_2^b} + \frac{\beta^b}{C_3^b}\left(\frac{Q_3}{Q_2}\right) + \mu_2^b m^b \tag{C.42}$$

$$\frac{1}{C_3^b} = \frac{\gamma}{Q_3 H_3^b} \tag{C.43}$$

$$\begin{aligned}
\mathcal{L} = \max_{\{C_t^e, L_t^{ef}, H_t^e\}} & \{lnC_1^e + \beta^e lnC_2^e + \beta^{e2} lnC_3^e + \gamma lnH_1^e + \beta^e \gamma lnH_2^e + \beta^{e2} \gamma lnH_2^e\} \\
& - \lambda_1^p \left[C_1^e + C_1^b - \left(Y_1^{ce} + Y_1^{cb} + e_1 L_1^{bf}\right)\right] \\
& - \beta^e \lambda_2^p \left[C_2^e + C_2^b + e_2 R_1^{bf} L_1^{bf} - \left(Y_2^{cb} + Y_2^{ce} + Q_2 H_1^b + Q_2 H_1^e + e_2 L_2^{bf}\right)\right] \\
& - \beta^{e2} \lambda_3^p \left[C_3^e + C_3^b + e_3 R_2^{bf} L_2^{bf} - \left(Y_3^{cb} + Y_3^{ce} + Q_3 H_2^e + Q_3 H_2^b\right)\right] \\
& - \mu_1^p \left[e_2 R_1^{bf} L_1^{bf} - m_1^p Q_1 H_1^e\right] \\
& - \beta^p \mu_2^p \left[e_3 R_2^{bf} L_2^{bf} - m_2^p Q_2 H_2^e\right] \\
& + \Gamma_1^p \left[\frac{1}{C_1^b} - \left(\frac{\gamma}{Q_1 H_1^b} + \frac{\beta^b}{C_2^b}\left(\frac{Q_2}{Q_1}\right) + \mu_1^b m^b\right)\right] \\
& + \beta^e \Gamma_2^p \left[\frac{1}{C_2^b} - \left(\frac{\gamma}{Q_2 H_2^b} + \frac{\beta^b}{C_3^b}\left(\frac{Q_3}{Q_2}\right) + \mu_2^b m^b\right)\right] \\
& + \beta^{e2} \Gamma_3^p \left[\frac{1}{C_3^b} - \left(\frac{\gamma}{Q_3 H_3^b}\right)\right]
\end{aligned} \tag{C.44}$$

$$C_1^b: \qquad \lambda_1^p = \frac{1}{C_1^b} + \Gamma_1^p \frac{Q_1}{\left(C_1^b\right)^2} \tag{C.45}$$

$$C_2^b: \qquad \lambda_2^p = \frac{1}{C_2^b} + \Gamma_2^p \frac{Q_2}{\left(C_2^b\right)^2} \tag{C.46}$$

$$C_3^b: \qquad \lambda_3^p = \frac{1}{C_3^b} + \Gamma_3^p \frac{Q_3}{\left(C_3^b\right)^2} \tag{C.47}$$

$$C_1^e: \qquad \lambda_1^p = \frac{1}{C_1^e} \tag{C.48}$$

$$C_2^e: \qquad \lambda_2^p = \frac{1}{C_2^e} \tag{C.49}$$

$$C_3^e: \qquad \lambda_3^p = \frac{1}{C_3^e} \tag{C.50}$$

$$Q_1: \qquad \mu_1^p m_1^p H_1^e = \Gamma_1^p \left(\frac{1}{{Q_1}^2 H_1^e} + \frac{\beta^b}{C_2^b} \frac{Q_2}{{Q_1}^2} \right) \tag{C.51}$$

$$Q_2: \qquad \lambda_2^p m_2^p H_2^e = \frac{\beta^e \Gamma_2^p \beta^b Q_3}{C_3^b {Q_2}^2} - \frac{\beta^b \Gamma_1^p}{C_2^e Q_1} - \beta^e \lambda_2 Q_2 \left(H_1^e + H_1^b \right) \tag{C.52}$$

$$Q_3: \qquad \beta^{e2} \lambda_2^p \left(H_2^e + H_2^b \right) = \frac{\beta^e \Gamma_2^p \beta^b Q_3}{C_3^b {Q_2}^2} + \frac{\beta^e \Gamma_2^p \beta^p}{C_3^e Q_2} \tag{C.53}$$

$$L_1^{ef}: \qquad \lambda_1^p = \beta^e \lambda_2^p \frac{e_2}{e_1} R_1^{ef} + \mu^p \tag{C.54}$$

$$L_2^{bf}: \qquad \lambda_2^p = \beta^e \lambda_3^p \frac{e_3}{e_2} R_2^{bf} + \mu^p \tag{C.55}$$

C.0.4 Macroprudential Policy Derivation

The two Euler equations of the planner and the regulated competitive equilibrium are as follows:

$$\lambda_1^p = \beta^b \lambda_2^p \frac{e_2}{e_1} R_1^{bf} + \mu^p \tag{C.56}$$

$$\lambda_1^b = \beta^b \lambda_2^b \frac{e_2}{e_1} R_1^{bf} (1+\tau_1) + \mu^p \tag{C.57}$$

In order to bring in the domestic interest rate R_1^{ed}, I replace $(\lambda_1^b = \beta^b \lambda_2^b R_1^{ed})$[1] into equation C.57 and after rearranging the two equations become:

$$1 = \frac{\beta^b \lambda_2^p \frac{e_2}{e_1} R_1^{bf} + \mu^p}{\lambda_1^p}, and$$

$$1 = \frac{\beta^b \lambda_2^b \frac{e_2}{e_1} R_1^{bf} (1+\tau_1) + \mu^p}{\beta^b \lambda_2^b R_1^{ed}}$$

which implies

$$\frac{\beta^b \lambda_2^b}{\beta^b \lambda_2^b} \frac{\frac{e_2}{e_1} R_1^{bf}}{R_1^{ed}} (1+\tau_1) + \frac{\mu_1^p}{\beta^b \lambda_2^p R_1^{ed}} = \frac{\beta^b \lambda_2^p \frac{e_2}{e_1} R_1^{bf}}{\lambda_1^p} + \frac{\mu^p}{\lambda_1^p}$$

putting $\psi_2^b = \frac{\frac{e_2}{e_1} R_1^{bf}}{R_1^{ed}}$, the above equation can be written as;

$$\psi_2 (1+\tau_1) + \frac{\mu_1^p}{\beta^b \lambda_2^p R_1^{ed}} = \frac{\beta^b \lambda_2^p \frac{e_2}{e_1} R_1^{bf}}{\lambda_1^p} + \frac{\mu^p}{\lambda_1^p}$$

$$\psi_2 (1+\tau_1) = \frac{\beta^b \lambda_2^p \frac{e_2}{e_1} R_1^{bf}}{\lambda_1^p} + \frac{\mu^p}{\lambda_1^p} - \frac{\mu_1^p}{\beta^b \lambda_2^p R_1^{ed}}$$

$$\psi_2 + \psi_2 \tau_1 = \frac{\beta^b \lambda_2^p \frac{e_2}{e_1} R_1^{bf}}{\lambda_1^p} + \frac{\mu^p}{\lambda_1^p} - \frac{\mu_1^p}{\beta^b \lambda_2^p R_1^{ed}}$$

[1] This is the first order condition of the regulated banker when choosing how much L_1^{ed} to save in the domestic credit market.

$$\psi_2\tau_1 = \psi_2\frac{\beta^b\lambda_2^p R_1^{ed}}{\lambda_1^p} - \psi_2 + \frac{\mu^p}{\lambda_1^p} - \frac{\mu_1^p}{\beta^b\lambda_2^p R_1^{ed}}$$

$$\tau_1 = \frac{\beta^b\lambda_2^p R_1^{ed}}{\lambda_1^p} - 1 + \frac{1}{\psi_2}\left(\frac{\mu^p}{\lambda_1^p} - \frac{\mu_1^p}{\beta^b\lambda_2^p R_1^{ed}}\right)$$

$$\tau_1 = \frac{\theta_1}{\psi_2} + \phi_1$$

where $\theta_1 = \left(\frac{\mu^p}{\lambda_1^p} - \frac{\mu_1^p}{\beta^b\lambda_2^p R_1^{ed}}\right)$ and $\phi_1 = \frac{\beta^b\lambda_2^p R_1^{ed}}{\lambda_1^p} - 1$

C.0.5 Restricting Foreign Debt

The bank maximise the discounted utility by choosing how much to spend on non-durable goods C_t^b, housing H_t^b and decide how much to borrow from the rest of the world L_t^{bf} and how much to lend in domestic and foreign currency L_t^{ef} and L_t^{ed} as follows:

$$\max_{\{C_t^b, L_t^{bf}, L_t^{ed}, L_t^{ef}, H_t^b\}} \{lnC_1^b + \beta^e lnC_2^b + \beta^{b^2} lnC_3^b + \gamma lnH_1^b + \beta^b\gamma lnH_2^b + \beta^{b^2}\gamma lnH_3^b\} \tag{C.58}$$

subject to budget constraints:

$$C_1^b + Q_1 H_1^b + L_1^{ed} + e_1 L_1^{ef} = Y_1^{cb} + Q_1 Y_1^{hb} + e_1 L_1^{bf} \tag{C.59}$$

$$C_2^b + Q_2 H_2^b + e_2 R_1^{bf} L_1^{bf} + L_2^{ed} + e_2 L_2^{ef} = Y_2^{cb} + Q_2 Y_2^{hb} + Q_2 H_1^b + R_1^{ed} L_1^{ed} + e_2 R_1^{ef} L_1^{ef} + e_2 L_2^{bf} \tag{C.60}$$

$$C_3^b + Q_3 H_3^b + e_3 R_2^{bf} L_2^{bf} = Y_3^{cb} + Q_3 Y_3^{hb} + Q_3 H_2^b + R_2^{ed} L_2^{ed} + e_3 R_2^{ef} L_2^{ef} \tag{C.61}$$

$$e_1 L_1^{bf} \leq m^b \left(Q_1 H_1^b \right) \tag{C.62}$$

$$e_2 L_2^{bf} \leq m^b \left(Q_2 H_2^b \right) \tag{C.63}$$

$$e_1 L_1^{ef} \leq \frac{\xi}{1-\xi} L_1^{ed} \tag{C.64}$$

$$e_2 L_2^{ef} \leq \frac{\xi}{1-\xi} L_2^{ed} \tag{C.65}$$

Formally,

$$\begin{aligned}
\mathcal{L} = & \max_{\{C_t^e, L_t^{ef}, H_t^e\}} \{lnC_1^e + \beta^e lnC_2^e + {\beta^b}^2 lnC_3^e + \gamma lnH_1^e + \beta^e \gamma lnH_2^e + {\beta^b}^2 \gamma lnH_3^b\} \\
& - \lambda_1^b \left[C_1^b + Q_1 H_1^b + L_1^{ed} + e_1 L_1^{ef} - \left(Y_1^{cb} + Q_1 Y_1^{hb} + e_1 L_1^{bf} \right) \right] \\
& - \beta^b \lambda_2^b \left[C_2^b + Q_2 H_2^b + e_2 R_1^{bf} L_1^{bf} + L_2^{ed} + e_2 L_2^{ef} \right] \\
& + \beta^b \lambda_2^b \left[\left(Y_2^{cb} + Q_2 Y_2^{hb} + Q_2 H_1^b + R_1^{ed} L_1^{ed} + e_2 R_1^{ef} L_1^{ef} + e_2 L_2^{bf} \right) \right] \\
& - {\beta^b}^2 \lambda_3^b \left[C_3^b + Q_3 H_3^b + e_3 R_2^{bf} L_2^{bf} - \left(Y_3^{cb} + Q_3 Y_3^{hb} + Q_3 H_2^b + R_2^{ed} L_2^{ed} + e_3 R_2^{ef} L_2^{ef} \right) \right] \\
& + \mu_1^b \left[e_1 L_1^{bf} - m^b \left(Q_1 H_1^b \right) \right] \\
& + \beta^b \mu_2^b \left[e_2 L_2^{bf} - m^b \left(Q_2 H_2^b \right) \right] \\
& - \kappa_1 \left[e_1 L_1^{ef} - \frac{\xi}{1-\xi} L_1^{ed} \right] \\
& - \beta^b \kappa_2 \left[e_2 L_2^{ef} - \frac{\xi}{1-\xi} L_2^{ed} \right]
\end{aligned}$$

$$C_1^b: \qquad \lambda_1^b = \frac{1}{C_1^b} \tag{C.66}$$

$$C_2^b: \qquad \lambda_2^b = \frac{1}{C_2^b} \tag{C.67}$$

$$C_3^b: \qquad \lambda_b^e = \frac{1}{C_3^b} \tag{C.68}$$

$$H_1^b: \qquad \frac{\gamma}{H_1^b} = \lambda_1^b Q_1 - \beta^b \lambda_2^b Q_2 - \mu^b m^b Q_1 \tag{C.69}$$

$$H_2^b: \qquad \frac{\gamma}{H_2^b} = \lambda_2^b Q_2 - \beta^b \lambda_3^b Q_3 - \mu^b m^b Q_2 \tag{C.70}$$

$$H_3^b: \qquad \frac{\gamma}{H_2^e} = \lambda_3^b Q_3 \tag{C.71}$$

$$L_1^{ed}: \qquad \lambda_1^e = \beta^e \lambda_2^e R_1^{ed} + \frac{\xi}{1-\xi}\kappa_1 \tag{C.72}$$

$$L_2^{ed}: \qquad \lambda_2^e = \beta^e \lambda_3^e R_1^{ed} + \frac{\xi}{1-\xi}\kappa_2 \tag{C.73}$$

$$L_1^{ef}: \qquad \lambda_1^e = \beta^e \lambda_2^e \frac{e_2}{e_1} R_1^{ef} - \kappa_1 \tag{C.74}$$

$$L_2^{ef}: \qquad \lambda_2^e = \beta^e \lambda_3^e \frac{e_2}{e_1} R_1^{ef} - \kappa_2 \tag{C.75}$$

$$L_1^{bf}: \qquad \lambda_1^b = \beta^b \lambda_2^b \frac{e_2}{e_1} R_1^{bf} + \mu^b \tag{C.76}$$

$$L_2^{bf}: \qquad \lambda_2^b = \beta^b \lambda_3^b \frac{e_3}{e_2} R_2^{bf} + \mu^b \tag{C.77}$$

Optimal Restriction on Foreign Debt

The two Euler equations of the regulated equilibrium C.74 and that of the central planner equilibrium, 4.37 are as follows:

$$\lambda_1^e = \beta^e \lambda_2^e R_1^{ed} + \frac{\xi}{1-\xi}\kappa_1 \tag{C.78}$$

$$\lambda_1^p = \beta^b \lambda_2^p \frac{e_2}{e_1} R_1^{bf} + \mu^p \tag{C.79}$$

Combining the two equations, we get

$$\beta^e \lambda_2^e R_1^{ed} + \frac{\xi}{1-\xi}\kappa_1 = \beta^b \lambda_2^p \frac{e_2}{e_1} R_1^{bf} + \mu^p$$

$$\frac{\xi}{1-\xi}\kappa_1 = \beta^b \lambda_2^p \left(\frac{e_2}{e_1} R_1^{bf} - R_1^{ed}\right) + \mu^p$$

$$\frac{\xi}{1-\xi}\kappa_1 = \beta^b \lambda_2^p R_1^{ed} \left(\frac{\frac{e_2}{e_1} R_1^{bf}}{R_1^{ed}} - 1\right) + \mu^p$$

$$\frac{\xi}{1-\xi}\kappa_1 = \Theta\left(\psi_2 - 1\right) + \mu^p$$

where $\Theta_1 = \beta^b R_1^{ed} \lambda_2^p$ and the expected interest rate ratio ψ_2 is defined as $\left(\psi_2 = \frac{\frac{e_2}{e_1} R_1^{bf}}{R_1^{ed}}\right)$. The last equation may be simplified by making ξ_1 the subject of the formula as:

$$\xi_1 = \frac{\Upsilon_1}{\Upsilon_1 + \kappa_1} \tag{C.80}$$

where $\Upsilon_1 = \Theta_1\left(\psi_2 - 1\right) + \mu_1^p$.

Bibliography

Adam, Klaus, Pei Kuang, and Albert Marcet (2011). "House price booms and the current account". In: *NBER Macroeconomics Annual 2011, Volume 26*. University of Chicago Press, pp. 77–122.

Adolfson, Malin et al. (2007). "Bayesian estimation of an open economy DSGE model with incomplete pass-through". In: *Journal of International Economics* 72.2, pp. 481–511.

Adolfson, Malin et al. (2014). "Monetary policy trade-offs in an estimated open-economy DSGE model". In: *Journal of Economic Dynamics and Control* 42, pp. 33–49.

Allayannis, George, Gregory W Brown, and Leora F Klapper (2003). "Capital structure and financial risk: Evidence from foreign debt use in East Asia". In: *The Journal of Finance* 58.6, pp. 2667–2710.

Andreasen, Martin M (2012). "An estimated DSGE model: Explaining variation in nominal term premia, real term premia, and inflation risk premia". In: *European Economic Review* 56.8, pp. 1656–1674.

Aoki, Kosuke, Gianluca Benigno, and Nobuhiro Kiyotaki (2015). "Monetary and Financial Policies in Emerging Markets". In:

Avdjiev, Stefan et al. (2017). *Gross capital flows by banks, corporates and sovereigns*. Tech. rep. National Bureau of Economic Research.

Bańbura, Marta, Domenico Giannone, and Michele Lenza (2015). "Conditional forecasts and scenario analysis with vector autoregressions for large cross-sections". In: *International Journal of Forecasting*.

Bauer, Gregory et al. (2018). "The Global Financial Cycle, Monetary Policies, and Macroprudential Regulations in Small, Open Economies". In: *Canadian Public Policy* 44.2, pp. 81–99.

Benigno, Gianluca et al. (2013). "Financial crises and macro-prudential policies". In: *Journal of International Economics* 89.2, pp. 453–470.

— (2016). "Optimal capital controls and real exchange rate policies: A pecuniary externality perspective". In: *Journal of Monetary Economics* 84, pp. 147–165.

Bernanke, Ben (2005). *The global saving glut and the US current account deficit*. Tech. rep. Board of Governors of the Federal Reserve System (US).

— (2010). *Monetary policy and the housing bubble: speech at the Annual Meeting of the American Economic Association, Atlanta, Georgia*.

Bernanke, Ben S, Mark Gertler, and Simon Gilchrist (1999). "The financial accelerator in a quantitative business cycle framework". In: *Handbook of macroeconomics* 1, pp. 1341–1393.

Bianchi, Javier (2011). "Overborrowing and Systemic Externalities in the Business Cycle". In: *The American Economic Review* 101.7, p. 3400.

— (2016). "Efficient bailouts?" In: *American Economic Review* 106.12, pp. 3607–59.

Bianchi, Javier and Enrique G Mendoza (2018). "Optimal time-consistent macroprudential policy". In: *Journal of Political Economy* 126.2, pp. 588–634.

Bjørnland, Hilde C (2009). "Monetary policy and exchange rate overshooting: Dornbusch was right after all". In: *Journal of International Economics* 79.1, pp. 64–77.

Bruno, Valentina and Hyun Song Shin (2015). "Capital flows and the risk-taking channel of monetary policy". In: *Journal of Monetary Economics* 71, pp. 119–132.

Brzoza-Brzezina, Michał, Marcin Kolasa, and Krzysztof Makarski (2015a). "Macroprudential policy and imbalances in the euro area". In: *Journal of International Money and Finance* 51, pp. 137–154.

Brzoza-Brzezina, Michal, Marcin Kolasa, and Krzysztof Makarski (2015b). "Monetary and macroprudential policy with foreign currency loans". In:

Caballero, Ricardo J and Arvind Krishnamurthy (2001). "International and domestic collateral constraints in a model of emerging market crises". In: *Journal of monetary Economics* 48.3, pp. 513–548.

— (2003). "Excessive dollar debt: Financial development and underinsurance". In: *The Journal of Finance* 58.2, pp. 867–893.

— (2009). "Global imbalances and financial fragility". In: *American Economic Review* 99.2, pp. 584–88.

Caldera, Aida and sa Johansson (2013). "The price responsiveness of housing supply in OECD countries". In: *Journal of Housing Economics* 22.3, pp. 231–249.

Calvo, Guillermo A (2014). "Sudden Stop and Sudden Flood of Foreign Direct Investment: Inverse Bank Run, Output, and Welfare Distribution". In: *The Scandinavian Journal of Economics* 116.1, pp. 5–19.

Calza, Alessandro, Tommaso Monacelli, and Livio Stracca (2013). "Housing finance and monetary policy". In: *Journal of the European Economic Association* 11.s1, pp. 101–122.

Canova, Fabio et al. (2015). "The Domestic and the International Effects of Financial Disturbances!" In:

Christiano, Lawrence J, Martin Eichenbaum, and Charles L Evans (1999). "Monetary policy shocks: What have we learned and to what end?" In: *Handbook of macroeconomics* 1, pp. 65–148.

Clark, Ephraim and Amrit Judge (2008). "The determinants of foreign currency hedging: does foreign currency debt induce a bias?" In: *European Financial Management* 14.3, pp. 445–469.

Dávila, Eduardo and Anton Korinek (2017). "Pecuniary Externalities in Economies with Financial Frictions". In: *The Review of Economic Studies*, rdx010.

Del Negro, Marco and Frank Schorfheide (2004). "Priors from general equilibrium models for VARs". In: *International Economic Review* 45.2, pp. 643–673.

Del Negro, Marco et al. (2007). "On the fit of new Keynesian models". In: *Journal of Business & Economic Statistics* 25.2, pp. 123–143.

DiCecio, Riccardo and Edward Nelson (2007). "An Estimated DSGE Model for the United Kingdom". In: *FEDERAL RESERVE BANK OF ST. LOUIS REVIEW* 89.4, pp. 215–31.

Erceg, Christopher J, Dale W Henderson, and Andrew T Levin (2000). "Optimal monetary policy with staggered wage and price contracts". In: *Journal of monetary Economics* 46.2, pp. 281–313.

Faia, Ester and Tommaso Monacelli (2007). "Optimal interest rate rules, asset prices, and credit frictions". In: *Journal of Economic Dynamics and control* 31.10, pp. 3228–3254.

Farhi, Emmanuel and Iván Werning (2016). "A theory of macroprudential policies in the presence of nominal rigidities". In: *Econometrica* 84.5, pp. 1645–1704.

Favilukis, Jack et al. (2012). "International capital flows and house prices: Theory and evidence". In: *Housing and the financial crisis*. University of Chicago Press, pp. 235–299.

Ferrero, Andrea (2015). "House price booms, current account deficits, and low interest rates". In: *Journal of Money, Credit and Banking* 47.S1, pp. 261–293.

Fornaro, Luca (2015). "Financial crises and exchange rate policy". In: *Journal of International Economics* 95.2, pp. 202–215.

Fratzscher, Marcel, Luciana Juvenal, and Lucio Sarno (2010). "Asset prices, exchange rates and the current account". In: *European Economic Review* 54.5, pp. 643–658.

Gali, Jordi and Tommaso Monacelli (2005). "Monetary policy and exchange rate volatility in a small open economy". In: *The Review of Economic Studies* 72.3, pp. 707–734.

Garcia-Barragan, Fernando and Guangling Liu (2017). *Capital controls and foreign currency denomination*. Tech. rep. Economic Research Southern Africa.

Giannone, Domenico, Michele Lenza, and Giorgio E Primiceri (2015). "Prior selection for vector autoregressions". In: *Review of Economics and Statistics* 97.2, pp. 436–451.

Gilchrist, Simon and Alberto Ortiz (2009). “Credit risk and the macroeconomy: Evidence from an estimated dsge model”. In:

Grant, Charles (2007). “Estimating credit constraints among US households”. In: *Oxford Economic Papers* 59.4, pp. 583–605.

Gupta, Poonam and Oliver Masetti (2018). *Capital flow measures: structural or cyclical policy tools?*

Iacoviello, Matteo (2005). “House prices, borrowing constraints, and monetary policy in the business cycle”. In: *The American economic review* 95.3, pp. 739–764.

— (2015). “Financial business cycles”. In: *Review of Economic Dynamics* 18.1, pp. 140–163.

Iacoviello, Matteo and Stefano Neri (2010). “Housing Market Spillovers: Evidence from an Estimated DSGE Model”. In: *American Economic Journal: Macroeconomics* 2.2, pp. 125–164.

IMF, International Monetary Fund (2012). “The Liberalization and Management of Capital Flows–An Institutional View”. In: *Staff Note*.

Jakucionyte, Egle and Sweder van Wijnbergen (2017). *Debt Overhang and the Macroeconomics of Carry Trade*. Tech. rep. CEPR Discussion Papers.

Jeanne, Olivier and Anton Korinek (2010). “Excessive Volatility in Capital Flows: A Pigouvian Taxation Approach”. In: *The American Economic Review* 100.2, pp. 403–407.

— (2013). *Macroprudential regulation versus mopping up after the crash*. Tech. rep. National Bureau of Economic Research.

Jermann, Urban and Vincenzo Quadrini (2012). “Macroeconomic effects of financial shocks”. In: *American Economic Review* 102.1, pp. 238–71.

Keloharju, Matti and Mervi Niskanen (2001). "Why do firms raise foreign currency denominated debt? Evidence from Finland". In: *European Financial Management* 7.4, pp. 481–496.

King, Mervin (2009). "Speech given by Mervyn King". In: *Governor of the Bank of England, the CBI dinner, Nottingham, January* 20.

Kiyotaki, Nobuhiro, John Moore, et al. (1997). "Credit chains". In: *Journal of Political Economy* 105.21, pp. 211–248.

Korinek, Anton (2018). "Regulating capital flows to emerging markets: An externality view". In: *Journal of International Economics* 111, pp. 61–80.

Krishnamurthy, Arvind and Annette Vissing-Jorgensen (2012). "The aggregate demand for treasury debt". In: *Journal of Political Economy* 120.2, pp. 233–267.

Laibson, David and Johanna Mollerstrom (2010). "Capital flows, consumption booms and asset bubbles: A behavioural alternative to the savings glut hypothesis". In: *The Economic Journal* 120.544, pp. 354–374.

Lambertini, Luisa, Caterina Mendicino, and Maria Teresa Punzi (2013). "Leaning against boom–bust cycles in credit and housing prices". In: *Journal of Economic Dynamics and Control* 37.8, pp. 1500–1522.

Liao, Wen-Chi et al. (2015). "Foreign liquidity to real estate market: Ripple effect and housing price dynamics". In: *Urban Studies* 52.1, pp. 138–158.

Liu, Zheng, Pengfei Wang, and Tao Zha (2013). "Land-price dynamics and macroeconomic fluctuations". In: *Econometrica* 81.3, pp. 1147–1184.

Lubik, Thomas A and Frank Schorfheide (2007). "Do central banks respond to exchange rate movements? A structural investigation". In: *Journal of Monetary Economics* 54.4, pp. 1069–1087.

Luciani, Matteo (2015). "Monetary policy and the housing market: A structural factor analysis". In: *Journal of applied econometrics* 30.2, pp. 199–218.

Mendicino, Caterina and Maria Teresa Punzi (2014). "House prices, capital inflows and macroprudential policy". In: *Journal of Banking & Finance* 49, pp. 337–355.

Mendoza, Enrique, Javier Bianchi, et al. (2015). "Optimal time-consistent macroprudential policy". In: *2015 Meeting Papers*. 289. Society for Economic Dynamics.

Monacelli, Tommaso (2009). "New Keynesian models, durable goods, and collateral constraints". In: *Journal of Monetary Economics* 56.2, pp. 242–254.

Ng, Eric CY and Ning Feng (2016). "Housing market dynamics in a small open economy: do external and news shocks matter?" In: *Journal of International Money and Finance*.

Ottonello, Pablo (2015). "Optimal exchange rate policy under collateral constraints and wage rigidity". In: *manuscript, Columbia University*.

Pesaran, M Hashem, Til Schuermann, and L Vanessa Smith (2009). "Forecasting economic and financial variables with global VARs". In: *International Journal of Forecasting* 25.4, pp. 642–675.

Punzi, Maria Teresa (2013). "Housing market and current account imbalances in the international economy". In: *Review of International Economics* 21.4, pp. 601–613.

Rubio, Margarita (2014). "Housing-market heterogeneity in a monetary union". In: *Journal of International Money and Finance* 40, pp. 163–184.

Sá, Filipa and Tomasz Wieladek (2015). "Capital inflows and the US housing boom". In: *Journal of Money, Credit and Banking* 47.S1, pp. 221–256.

Schmitt-Grohé, Stephanie and Martın Uribe (2003). "Closing small open economy models". In: *Journal of international Economics* 61.1, pp. 163–185.

Schmitt-Grohé, Stephanie and Martın Uribe (2004). "Solving dynamic general equilibrium models using a second-order approximation to the policy function". In: *Journal of economic dynamics and control* 28.4, pp. 755–775.

Schmitt-Grohé, Stephanie and Martin Uribe (2012). "What's news in business cycles". In: *Econometrica* 80.6, pp. 2733–2764.

Schmitt-Grohé, Stephanie and Martín Uribe (2016). "Downward nominal wage rigidity, currency pegs, and involuntary unemployment". In: *Journal of Political Economy* 124.5, pp. 1466–1514.

Smets, Frank and Raf Wouters (2003). "An estimated dynamic stochastic general equilibrium model of the euro area". In: *Journal of the European economic association* 1.5, pp. 1123–1175.

Sy, Mouhamadou (2016). "Overborrowing and Balance of Payments Imbalances in a Monetary Union". In: *Review of International Economics* 24.1, pp. 67–98.

Thirlwall, Anthony Philip (2012). "Balance of payments constrained growth models: history and overview". In: *Models of Balance of Payments Constrained Growth*. Springer, pp. 11–49.

Tillmann, Peter (2013). "Capital inflows and asset prices: Evidence from emerging Asia". In: *Journal of Banking & Finance* 37.3, pp. 717–729.

Tomura, Hajime (2010). "International capital flows and expectation-driven boom–bust cycles in the housing market". In: *Journal of Economic Dynamics and Control* 34.10, pp. 1993–2009.

Uhlig, Harald (2005). "What are the effects of monetary policy on output? Results from an agnostic identification procedure". In: *Journal of Monetary Economics* 52.2, pp. 381–419.

Villa, Stefania and Jing Yang (2011). "Financial intermediaries in an estimated DSGE model for the United Kingdom". In:

Vonnák, Dzsamila (2015). *Decomposing the riskiness of corporate foreign currency lending: The case of Hungary*. Tech. rep. IEHAS Discussion Papers.