Essays on Macroprudential Policies, Global Financial Spillovers and Immigration

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Abstract

This thesis presents three chapters on assessment of macroprudential policy (Chapter 2 and Chapter 3) and immigration (Chapter 4). Chapter 2 assesses the effectiveness of Macroprudential Policy (MaP) and Unconventional Monetary Policy (UMP) in Emerging Market Economies (EME). We use a New Keynesian DSGE model with financial frictions and banks *á la* Gertler and Karadi (2011). We find that although both policies are effective in dampening the effects of the credit constraint, the welfare gains of households are higher under MaP. Chapter 3 examines the effectiveness of MaPs in fostering financial stability within and across countries also using a New Keynesian two-country DSGE model á la Gertler and Karadi (2011). A key feature of our framework is the cross border bank lending between an EME and an Advanced Economy (AE). We find that capital requirements in AE mitigate financial shocks in both countries. A levy on cross border loans imposed by the EME's central bank dampens the effects of the credit constraint domestically. We also show that coordination of MaPs across countries is highly effective in mitigating financial shocks in both jurisdictions, resulting in substantially higher welfare gains. Chapter 4 discusses the impact of immigration on the labour market and the macroeconomy in the host economy. Using a DSGE model, we extend Canova and Ravn (2000b) and Fusshoeller and Balleer (2017) in two directions by incorporating (i) three skill levels of occupations: high-skilled, medium skilled and low-skilled, and (ii) capital-skill complementarity between physical capital and high-skilled workers. Using the capital-skill complementarity model, we show that under an immigration shock, high-skilled and medium-skilled workers achieve welfare gains and low-skilled workers experience welfare losses. After the shock, the host economy grows faster, investment increases substantially while output per capita decreases slightly.

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Dedication

This thesis is dedicated to my parents Jaime and Josefina, and my siblings Haydee, Janet and Arturo for their unconditional love. I am particularly grateful with my twin sister Haydee, who has been my constant support and counsellor in this journey, to her all my love and deepest admiration. I am thankful to Ben for his patience and the most delightful food we have shared.

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Author's declaration

I declare that this thesis is a presentation of original work and I am the sole author. This work has not previously been presented for an award at this, or any other, University. All sources are acknowledged as References.

A preliminary version of Chapter 2 was presented at the Research Workshop at the Department of Economics and Related Studies, University of York in 2015.

Chapter 3 was presented at different stages at the 24th International Conference: Computing in Economics and Finance, in Milan, June, 2018; at the 17th Annual Conference EEFS 2018 at the University of London, June, 2018; at the Scottish Economic Society Annual Conference in Perth, UK April, 2018; at the White Rose Economics PhD Conference, at the University of Sheffield, April, 2017; at 10th Ruhr Graduate School in Economics, Doctoral Conference in Economics, Technische Universität Dortmund, in Germany, March, 2017; 11th BIGSEM Doctoral Workshop on Economic Theory, at the University of Bielefeld, in Germany, December, 2016; 12th DYNARE CONFERENCE - CEPREMAP, Central Bank of Italy, in Italy, September, 2016, and the Seminar of Financial Stability, Central Bank of Mexico, General Directorate of Financial Stability, in Mexico, September, 2016.

Chapter 1

Introduction

The 2008-09 financial crisis revived the interest in the use of additional tools beyond monetary policy towards ensuring financial stability worldwide. In many countries, Macroprudential Policies (MaPs) became the preferred mechanism towards dampening the systemic risk and limiting macroeconomic costs of financial distress. Although the experience of Advanced Economies (AE) with MaPs is relatively recent in the aftermath of the 2008-09 financial crisis, Emerging Market Economies (EMEs) have been experimenting with these since in the aftermath of the 1990s crises, through the use of both microprudential and macroprudential instruments strengthening their financial system.

In the last ten years, the commitment of central banks to foster financial stability has been more extensive in both EMEs and AEs. In Figure 1.1, we present the mean of the macroprudential index from 2000 to 2013, measuring the number of MaPs in 95 EMEs and AEs.

In AEs, the mean of the macroprudential index was less than one from 2000 to 2006, implying a significant vulnerability of these economies in the 2008-09 financial crisis. Consequently, when the US economy faced the escalating bankruptcies of the big financial institutions, the effects spread significantly more to other AEs. In that period, the US and the UK put in place Unconventional Monetary Policies (UMPs), with both the US Federal Reserve and the Bank of England injecting substantial liquidity into their economies through Quantitative Easing (QE). It was introduced as an alternative tool when the policy rate approached the zero lower bound (in the US and the UK). This largely followed from the scope of the conventional monetary policy reaching its limits because of the low interest rates.

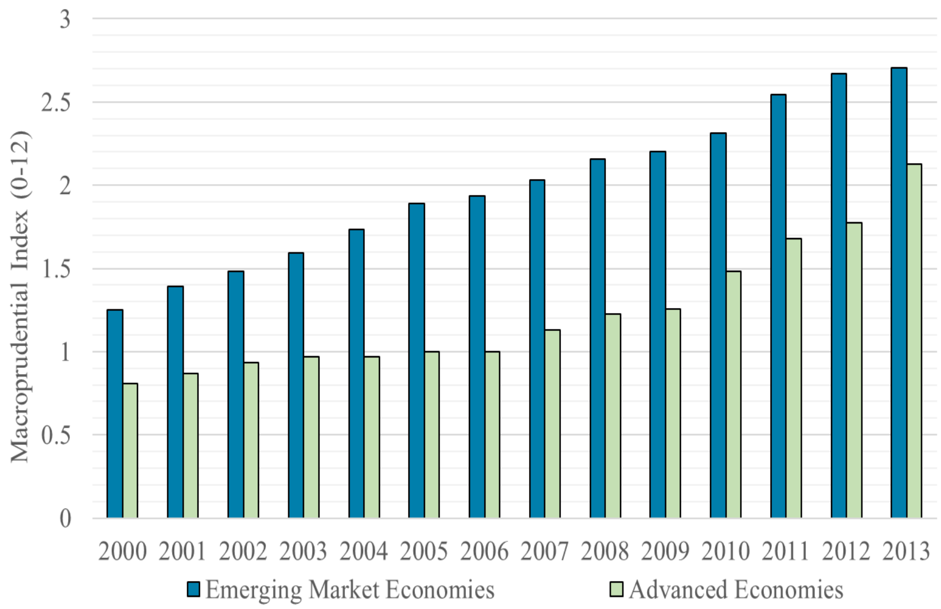

Figure 1.1: Macroprudential Index by Income Group

Source: Author's compilation using data from Cerutti et al. (2016) database including 31 advanced economies and 64 emerging market economies. The macroprudential index is the sum of 12 instruments at most per country, which are Loan To Value Ratio Caps ($LTVCAP$), Debt to Income Ratio (DTI), Dynamic Loans-Loss Provisioning (DP), General Capital Buffer or Requirement (CTC), Leverage Ratio for Banks (LEV), Capital Surcharges on SIFIs ($SIFI$), Limits on Interbank Exposures ($INTER$), Concentration Limits ($CONC$), Limits on Foreign Currency Loans (FC), FX or Countercyclical Reserve Requirements ($RR - REV$), Limits on Domestic Currency Loans (CG) and Levy/Tax on Financial Institutions (TAX).

In contrast to UMP which is an *ex-post* intervention, aiming to recover the economy after the financial crisis, MaPs are enacted to be preventive. MaPs aim is to contain potential risk by addressing externalities such as excess risk-taking, leverage, swing asset prices and excess credit (Galati and Moessner, 2018). One of the lessons from the 2008-09 financial crisis is the understanding of the severe damages caused by the credit-driven financial crises, therefore, the need for MaPs. There has been a significant effort in AEs to enhance the mechanisms to regulate the financial system since 2008, as is clear in Figure 1.1; the mean of the macroprudential index rose to 2.1 in 2013 (i.e. on average AEs had two instruments in place).

Over the years, EMEs have also implemented supplementary MaPs. The 2008-09 financial crisis extended the consensus among central banks and policymakers of all regions to ensure financial regulation. In 2000, on average each EME implemented at least one MaP, while in 2013 the mean of the macroprudential index was 2.7, implying that on average they had in place at least two instruments. These MaPs could address similar intermediate targets or tackle different dimensions of systemic risk.

Clearly, EMEs had been better prepared for the 2008-09 financial crisis with a more extensive tool-kit of MaPs. Moreover, some EMEs also conducted UMP towards dampening the impact of the financial constraint during that period. The case of Brazil is notable, the country successfully faced the international financial contagion and grew at a higher rate than the rest of Latin America.

MaPs adopted by central banks in AEs and EMEs have been distinct. However, both groups of countries have used Concentration Limits (CONC) and Limits on Interbank Exposures (INTER) as the most frequent MaP. In Figure 1.2, we present the percentage use of the twelve MaPs before and after the 2008-09 financial crisis. In the pre-crisis period, EMEs shield the financial system using primarily CONC in 67%, INTER in 28%, Debt To Income (DTI) in 22% and Reserve Requirements (RR-REV) in 20% of the cases.

In the post-crisis period, more EMEs adopted the aforementioned MaPs but also extended their instruments. The Leverage Ratio for Banks (LEV), Limits on Foreign Currency Loans (FC), Levy/Tax on Financial Institutions (TAX), LTV-CAP and DTI became more popular in these economies than before the pre-crisis. The vast set of MaPs in EMEs suggests a stronger financial shield against financial crises. However, the new challenges of the global financial integration demand a more robust tool-kit of MaPs capable of facing: (i) international financial contagion and (ii) global spillovers of foreign policy decisions (both monetary and macroprudential).

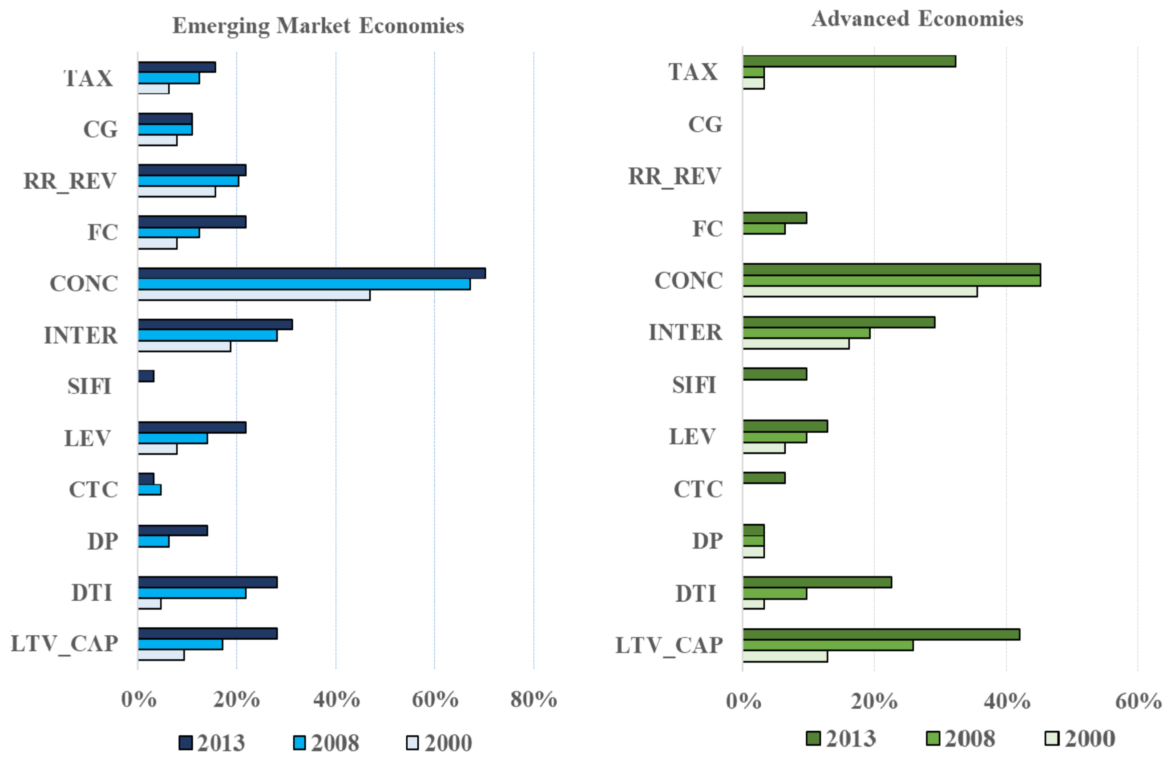

Figure 1.2: Usage of Macroprudential Policies by Income Group

Source: Author' calculation based on Cerutti et al. (2016) database. We calculate the percentage use of each macroprudential instrument per income group in 2000, 2008 and 2013. Macroprudential instruments are Loan To Value Ratio Caps ($LTVCAP$), Debt to Income Ratio (DTI), Dynamic Loans-Loss Provisioning (DP), General Capital Buffer or Requirement (CTC), Leverage Ratio for Banks (LEV), Capital Surcharges on SIFIs ($SIFI$), Limits on Interbank Exposures ($INTER$), Concentration Limits ($CONC$), Limits on Foreign Currency Loans (FC), FX or Countercyclical Reserve Requirements ($RR-REV$), Limits on Domestic Currency Loans (CG) and Levy/Tax on Financial Institutions (TAX).

In the case of AEs, as MaPs, CONC was used in 45%, Loan To Value Ratio Caps (LTV-CAP) in 26% and INTER in 19% before the 2008-09 financial crisis. In 2013, AEs had diversified their set of MaPs, LTV-CAP and INTER rose (significantly) to 42% and 29%, respectively. The use of TAX increased to 32% and DTI to 23%. These developments contribute to extend the set of available instruments to convey financial stability in the advanced world and beyond. Recent empirical evidence emphasises the significant financial spillovers from AEs to EMEs (Goldberg, 2016; Takats and Temesvary, 2017). Both monetary and (potentially) MaP policies are transmitted within jurisdiction but also across countries. These channels of transmission represent new challenges for policymakers. The extent of the MaPs has gone beyond the domestic scenario extending their influence across borders.

Motivated by these issues, Chapter 2 and Chapter 3 are devoted to exploring the effectiveness of MaPs in EMEs. In Chapter 3, we extend the analysis to AEs to examine the implications of coordination of MaPs across countries.

Chapter 2 examines the macroeconomic cost of 'cleaning up afterwards' or 'leaning against the risks', based on the experience of the 2008-09 financial crisis. We focus our attention on UMP versus MaP, both policies mitigate the financial shock but their targets are distinct. The former aims to respond *ex-post* to the slowdown of the economy, while the latter aims to reduce the systemic risk. Many studies have documented the US and the UK experiences with QE. In this chapter, we attempt to cover the case of an EME, and Brazil as a specially compelling case. This is because Brazil combined the use of UMP and MaP, in response to the 2008-09 financial crisis.

The type of policy operated in Brazil to drive the credit expansion can be viewed as similar to the QE implemented by the US and the UK although the circumstances of the limited liquidity in EMEs and AEs were different. While AEs were in the centre of the 2008-09 financial crisis, facing the bankruptcy of banks; EMEs acted to cope with the worsening credit conditions. In both cases, there was a massive injection of public funds to expand credit. In Brazil, state banks received funds to extend new credit lines and provide loans to firms, playing a countercyclical role under tightening credit conditions for private banks. In addition to this, the central bank of Brazil changed the reserve requirements to stimulate credit supply.

Chapter 2 then examines the effectiveness of UMP versus countercyclical capital requirements in Brazil. We use a New Keynesian DSGE model featuring banks *á la* Gertler and Kiyotaki (2010) and Gertler and Karadi (2011). A financial friction limits the banks' ability to build assets (enforcement problem) and there is a clear relation between banks' equity capital and their ability to expand credit. The financial accelerator operates through banks' equity capital, and the demand side is frictionless. Gertler and Karadi (2011) shed light on the transmission mechanism of UMP for the US, we use this framework as a benchmark to our analysis.

Firstly, we calibrate the model for Brazil and explore the financial accelerator mechanism in the face of a total factor productivity shock and a monetary policy shock. Then, we examine a capital quality shock that emulates a financial crisis. Using the latter, we assess the effectiveness of UMP and capital requirements. Finally, we provide a welfare evaluation to support our findings.

Following the monetary policy shock, the rise in the interest rate raises the return of deposits, stimulating the preference for savings. Households substitute present for future consumption leading to a fall in aggregate demand. The cost of the short-term liabilities increases leading to a decline in banks' net worth. The rise in deposits cost narrows the external finance premium since the return on capital remains constant in the first period. The decline in banks' net worth rises the leverage ratio and discourages banks from building assets since the margin of profits per loan is decreasing. Banks aim to face up the constraint of their balance sheets by enhancing the credit market conditions for them. Thus, they increase the cost of credit, pushing up the external finance premium. It dampens the demand for loans from intermediate-good producers. The credit constraint is accentuated because the fall in consumption reduces aggregate demand. This, in turn, results in the amplification of the decline in capital price that further weakens banks' net worth and the banks' balance sheets deepening the fall in investment and output.

In the case of a (negative) total factor productivity shock, the propagation is from the real to the financial sector, reducing asset prices and deteriorating banks' balance sheets that amplify the contraction. The shock is interpreted as an unexpected decrease in productivity that leads to a fall in investment and output. Banks lack of funds reduces credit supply, increasing the external finance premium. The worsened conditions in the credit market amplify the initial drop in investment and output.

We examine the case of a financial crisis using a capital quality shock. The initial decline in the value of capital reduces asset prices and erodes the bank's equity capital. This raises the leverage of banks weakening their balance sheets, shrinking the credit supply from banks to non-financial firms. The demand for assets goes down since credit is more costly, which in turn, further decreases asset prices. Overall, the price of capital declines following the initial shock and also due to the credit market conditions. In addition, the external finance premium increases because leveraged banks impose a higher price on loans, raising the cost of capital and worsening the borrowing conditions facing the non-financial firms, resulting in the decline in investment and output.

Using a capital quality shock, UMP expands credit through the injection of liquidity into the banking sector, easing the credit market conditions and decreasing hence the fall in the price of capital and banks' net worth. The cost of capital and the external finance premium decrease while more public assets extend the credit supply, which enhances the private banks' balance sheets indirectly. Credit market intervention finances investment that would not be funded otherwise, leading to a less severe decline in investment and production. Overall, UMP improves the credit market conditions and de-leverage banks leading to the faster recovery of the economy. Under countercyclical capital requirements, the fall in asset values decreases the requirement of capital, leading to a lower cost of deposits. This mechanism dampens the decline in asset prices, banks' net worth, enhancing the balance sheets of banks. In sum, the financial accelerator mechanism is mitigated to some extent with the implementation of MaP.

Although UMP and countercyclical requirements speed up the recovery, the channels of transmission are different. Under the MaP the economy improves through the enhanced position of banks. Countercyclical capital requirements become less restrictive during the financial crisis allowing the rise in credit supply and production. In contrast, the credit market intervention injects funds to public banks, which conducts the credit expansion providing funds to firms. It alleviates the credit market conditions leading to the improvement of public and private banks. Both policies are welfare improving, however, the improvement in welfare is greater under MaP than UMP. The MaP is an automatic stabiliser for the banking sector. Consequently, the enhancement of the banks' balance sheets is more effective. On the contrary, UMP depends on (i) the injection of funds into the economy and (ii) the transmission channel of public funds to the whole banking system.

Chapter 3 aims to address the challenges of the global financial integration with special reference to the joint use of MaPs in both AEs and EMEs. We explore to what extent central banks can foster financial stability within and across jurisdictions. We examine the potential financial spillovers across countries by implementing MaPs, again in the face of capital quality and monetary policy shocks.

Similar to Chapter 2, we use a New Keynesian two-country DSGE model, we feature banks *á la* Gertler and Kiyotaki (2010) and Gertler and Karadi (2011) and build the cross border bank lending between (global) banks in the AE and the EME. In the model, AE and EME's banks receive deposits from their respective households. AE's banks finance AE's non-financial firms and send cross border loans to EME's banks. Therefore, EME's banks lend to EME's non-financial firms using funds from deposits, their own net worth and the cross border loans. In this framework, the cross border bank lending is a feature that serves as the primary transmission channel for the international propagation of shocks between the AE and EME.

Chapter 3 explores three policy scenarios, in the first case, the AE implements capital requirements. MaP potentially mitigates the shock in its jurisdiction and attenuates global spillovers in the EME. In the second case, the EME is the only economy fostering financial stability. The domestic central bank imposes a levy on cross border loans, and we measure whether this is effective in dampening the effects of shocks in the EME. In the third case, both economies are conducting MaPs (capital requirements in AE and levy on cross border loans in EME).

MaPs respond to either of the two rules: (i) the central bank increases the capital requirements (levy on cross border loans) whenever they observe credit is growing above its steady-state level and (ii) the central bank changes the capital requirements (levy on cross border loans) whenever credit or output are increasing above their steady-state levels.

In the first scenario, under a capital quality or a monetary policy shock in the AE, asset prices fall, raising leverage of AE's banks, weakening their balance sheets. The AE's external finance premium increases, leading to a decline in AE's investment and output. The decline in cross border bank loans propagates the shock to EME's banks and extends the decline in EME's investment and production.

Using MaP in the AE, the central bank dampens the effects of the credit constraint domestically by lowering the decline in AE's assets prices and banks' net worth. It results in lower leverage, enhancing banks' balance sheets and credit supply. Therefore the decline in AE's investment and output is less severe. We also find that cross border loans are more resilient to the shock, capital requirements reduce the effect of the financial shock in the EME. Therefore, EME's output and investment decline significantly less. Capital requirements are more effective in mitigating the shocks when the AE's central bank follows the rule targeting credit and output as indicators.

In the second scenario, the EME's central bank conducts a MaP using a levy on cross border loans. The MaP is highly effective in alleviating the decline in domestic investment and output. The welfare gain for EME's households is more significant under the levy than with capital requirements (implemented by the AE). We find similar results under both the capital quality shock or the monetary policy shock. When the EME's central bank uses a rule with credit and output deviations, the mitigation of the shocks is greater and the welfare gain more significant.

In the third scenario, we explore a coordination of MaPs across countries. AE follows capital requirements and EME imposes a levy on cross border loans. We find that coordination of policies yields the best outcomes for the EME. Cross border loans decline significantly less than under any other MaP implemented individually. Coordination of MaPs is beneficial for both economies. Capital requirements relax the conditions for AE's banks, mitigating the decline in AE's investment and output. It, therefore, strengthens the international credit supply. The levy on cross border loans improves EME banks' balance sheets and stimulates credit supply. We find that EME's households obtain the highest welfare gain under the coordination of MaPs. Regardless of the shock, a coordination of MaPs between AE and EME is broadly effective in mitigating systemic risk across countries.

Chapter 4 is devoted to a different policy issue. In 2017, the OECD estimated that the worldwide migration was 258 million people and two-thirds are high-skilled immigrants, 70% concentrated in four countries, the US, the UK, Canada and Australia. The 2008-09 financial crisis, the national elections in the US and France and the referendum in the UK greater contributed to change the narrative and attitudes towards immigration and the perception of the fiscal burden for the host countries.

Chapter 4 aims to examine and assess the effects of immigration and its dynamics for a host economy with special focus on the labour market and GDP per capita. Our approach is developed from a macroeconomic perspective, and we utilise a DSGE setting to carry out our analysis. Focusing on capital accumulation and skill types, we extend Canova and Ravn (2000b) and Fusshoeller and Balleer (2017) in two directions by incorporating (i) the skill composition of occupations in three levels (high-skilled, medium-skilled and low-skilled workers) and (ii) the capital-skill complementarity between physical capital and high-skilled workers, as proposed by Griliches (1969) and formalised in Krusell et al. (2000). We argue that this is a better framework to explain the immigration impact on countries where the ratio of high-skilled immigrants is significant.

We explore a transitory and a gradual immigration shock and analyse the dynamics of the host economy in a capital accumulation model (baseline) and a capital-skill complementarity model. We find that using the baseline model, high-skilled workers are better off with the transitory immigration shock relative to their steady-state consumption. Medium-skilled workers experience a decline in their wages and income, but their welfare improves in the long run. Low-skilled workers experience a small welfare loss. Using the capital-skill complementarity model, we find that the effects are more favourable for the host economy. High-skilled workers experience similar welfare gains compared to the baseline model. However, the welfare loss of low-skilled workers decreases significantly. The economy grows faster, output per capita falls notably less. The results suggest that under the capital-skill complementarity model, the economy absorbs the immigration shock faster, the expansion favours the demand for workers and the effects on wages along the distribution are more even.

Finally, we compare both models, setting the same transitory immigration shock and assuming the downgrading of immigrants is zero. In the case of the baseline model, high-skilled and medium-skilled workers are worse off because there is a significant share of immigrants looking for jobs in the high-skilled and medium-skilled occupations. In contrast, low-skilled workers have welfare gains since the share of immigrants searching a job in low-skilled occupations is low.

In the case of the capital-skill complementarity model, the welfare loss of high-skilled workers is smaller than in the baseline model. Medium-skilled and low-skilled workers perceive greater welfare gains than in the baseline model. Therefore, all skill levels are better off compared to the baseline model. Our results suggest that the competition for jobs in the high-skilled occupations is stronger, when immigrants work in occupations matching their educational qualification. In the aggregate level, output and investment per capita grow faster than in any other case.

Chapter 2

Unconventional Monetary Policies versus Macroprudential Policies

2.1 Introduction

The 2008-09 financial crisis revived the 'lean' versus 'clean' debate regarding the response to the asset price bubbles. The collapse of the financial markets led to a sharp contraction in the US, which then spread to other countries. The US Federal Reserve responded to the financial crisis using UMP through Quantitative Easing (QE).

There is emerged a consensus among central bankers and the academia regarding the MaPs as an effective mechanism towards dampening the procyclicality of the financial system, leading to explosion of work on this issues. For example, Brzoza-Brzezina et al. (2013, 2014) and Angeloni and Faia (2013) evaluate a set of MaPs for the Euro Area. For the US, existing work includes Gertler and Karadi (2011), Gertler et al. (2012), Ozkan and Unsal (2014), Benes and Kumhof (2015) and Tavman (2015). Regarding Latin America Aguirre and Blanco (2015) assess capital requirements in Argentina, Areosa and Arrigoni (2013) evaluate the use of reserve requirements in Brazil, Carrillo et al. (2015) and Cuadra and Nuguer (2016) explore a set of MaPs in Mexico, and Garcia Cicco et al. (2017) conduct a comprehensive analysis on MaPs for four Latin American economies.

Linking the strands, we contribute to this debate by comparing the effectiveness of UMP versus MaP. In the aftermath of the 2008-09 financial crisis the US, the UK and some Latin American economies like Brazil implemented credit market intervention aimed to 'clean' after the event. In contrast, MaPs aim at the prevention of systemic risk and the contention of financial bubbles by 'leaning' against the risks. Brazil is a compelling case as it combined the use of UMP and MaP in response to the 2008-09 financial crisis. Also notably, Brazil grew at a substantially higher rate than the rest of Latin America during this period.

This chapter examines the scope of UMP versus MaPs as response to a financial crisis. We present the dynamics of the model -calibrated with Brazilian data- under a credit market intervention and its effectiveness to speed up economic recovery. As an alternative policy option, we consider MaP in the form of countercyclical capital requirements. We use a New Keynesian DSGE model *á la* Gertler and Kiyotaki (2010) and Gertler and Karadi (2011). We examine the financial accelerator mechanism by exploring the implications of a total factor productivity shock, a monetary policy shock and a capital quality shock, the latter mimicking a global financial crisis.

Our findings indicate that a capital quality shock leads to a drop in asset prices, worsens the balance sheets of banks, increases the cost of capital and reduces credit supply. Overall, it amplifies the contraction in investment and output. This financial crisis experiment illustrates the channel of transmission from the financial sector through the real side of the economy. We compare the responses of shocks between a model without banks and a model with banks featured *á la* Gertler and Kiyotaki (2010) and Gertler and Karadi (2011).

We explore a monetary policy shock and a productivity innovation. In the first case, the rise in the interest rate weakens the balance sheets of banks, pushing up banks liabilities and the external finance premium. It results in a higher cost of borrowing, a decline in investment and output. In the case of the total factor productivity shock, the propagation occurs from the real to the financial sector, reducing asset prices and deteriorating banks' balance sheets that amplify the contraction.

In the model, the link between physical capital and assets plays a crucial role in the channel of transmission. Any shock to the value of capital deteriorates the banks' balance sheets triggering the financial accelerator mechanism, even in the face of a productivity shock. In this scenario, the shock starts in the real side of the economy and ends there amplifying the effect through banks. In contrast, financial shocks affect banks' balance sheets directly, but the propagation reaches the real economy through the credit market.

Finally, the credit intervention policy through public banks finances additional investment and ease the credit market conditions. We find that the decline in investment and output are both smaller with credit market intervention. The central bank would also be able to dampen the credit constraint in the economy by using countercyclical capital requirements. Our analysis shows that the MaP enhances banks' balance sheets, reduces the leverage of banks and stimulates credit supply. Overall the drop in investment and output are also smaller with capital requirements.

Although both policies speed up the recovery, the channel of transmission is different. Under the MaP the economy improves through the position of banks since the countercyclical capital requirements become more flexible during the financial crisis, allowing a rise in the supply of credit and production. In contrast, the credit market intervention injects funds to public banks, which conducts the credit expansion providing funds to firms. It alleviates the credit market conditions and leads to the improvement of public and private banks.

The chapter is organised into five sections. The second section describes the model. The third part explains the calibration and provides some sensitivity analysis. The fourth section presents and discusses the financial accelerator mechanism and the policies of economic recovery in Brazil. The last section concludes.

2.2 Model

We use a monetary New Keynesian model for a closed economy. It features banks *á la* Gertler and Kiyotaki (2010) and Gertler and Karadi (2011), and quadratic menu costs á la Rotemberg (1982). There are six agents in the economy: households, intermediate-good producers, final-good producers, capital producers, banks and the central bank.

2.2.1 Households

There is a continuum of identical households, which have within their members workers and bankers. Households consume goods, save money in banks they do not own, and supply labour. They receive the free-risk interest rate in return for their savings, wages for the labour supply and earnings for managing a bank. The latter is only transferred to households at the end of the banks lifetime.

A fraction *1-f* of household members are workers and the fraction f are bankers, and they perfectly insure each other. Every period, a banker stays as a banker with probability θ independently of her history while a banker becomes a worker with probability $1-\theta$. The average survival time for a banker in any given period is $\frac{1}{1-\theta}$. It implies banks have a finite horizon ensuring they cannot fund all investments with their capital. At the beginning of the period, the new bankers receive the ω fraction as *starting funds* from their households. Similarly, the exiting bankers transfer back any earnings to their households.

A representative household maximises expected discounted utility with preferences represented by

$$maxE_t \sum_{t=0}^{\infty} \beta^t \left[lnC_t + \chi ln(1-L_t)\right] \tag{2.1}$$

where E_t is the expectation operator at time t, $\beta \in (0,1)$ is the discount factor, $\chi > 0$ is the relative weight of labour, C_t is consumption, L_t is labour and $1-L_t$ leisure.[1]

The budget constraint facing the representative households is

$$C_t = \frac{W_t}{P_t}L_t + \Pi_t + \frac{R_t}{P_t}D_t - \frac{D_{t+1}}{P_t} - \frac{T_t}{P_t} \tag{2.2}$$

where D_{t+1} is the total quantity of short term debt, R_t is the gross nominal return, W_t

[1]For simplicity, we use the utility function of Faia and Monacelli (2007) and the model preserves the same dynamics than Gertler and Kiyotaki (2010) and Gertler and Karadi (2011).

is the nominal wage, Π_t is the real profits from firms and banks, T_t is nominal lump-sum tax and P_t the prices.

Households solve a maximization problem of their discounted expected utility subject to the budget constraint. They choose $\{C_t, L_t, D_{t+1}\}$ and the first order conditions for consumption, labour and deposits are as follow

$$\varrho_t = \frac{1}{C_t} \tag{2.3}$$

$$\varrho_t \frac{W_t}{P_t} = \frac{\chi}{1 - L_t} \tag{2.4}$$

$$\varrho_t = \beta R_{t+1} \frac{P_t}{P_{t+1}} E_t \left[\varrho_{t+1}\right] \tag{2.5}$$

where equation (2.3) defines the Lagrange multiplier, ϱ_t as the marginal utility of consuming an additional unit of income at time t. Equation (2.4) is the labour supply and shows that the marginal rate of substitution between consumption and leisure is equal to the real wage. Equation (2.5) describes that the marginal utility from consuming one unit of income in time t is equal to the discounted marginal utility from consuming the gross income saved for future consumption. We arrange equation (2.5) to obtain the Euler equation for consumption so we take expectations in both sides and define $\Lambda_{t,t+1} = \beta \frac{\varrho_{t+1}}{\varrho_t}$ as the real stochastic discount factor over the time t and $t+1$.

$$E_t \left[\Lambda_{t,t+1} \frac{R_{t+1}}{\pi_{t+1}}\right] = 1 \tag{2.6}$$

2.2.2 Banks

Our model follows closely Gertler and Kiyotaki (2010) in its specification of the financial sector. Banks finance long-term investment by their equity and the short term liabilities obtained from households. Since they have a finite horizon, they cannot finance non-financial firms without the financial intermediation. In this framework, θ is the probability that a banker stays as a banker next period, independently of its history and $1 - \theta$ is the probability a banker becomes a worker next period. In that case, all present earnings are transferred back to her household. Similarly, new banks receive the starting funds denoted by ω, a fraction of the total assets.

The balance sheet of an individual bank is as follows

$$Q_t s_t = n_t + d_t \tag{2.7}$$

where s_t denotes assets, Q_t is the relative price of each asset, n_t is the real net worth and d_t the amount of deposits.

Over time the equity capital of a bank evolves as the difference between earnings on assets and the interest payments for the short-term liabilities

$$n_t = R_{k,t} Q_{t-1} s_{t-1} - R_t d_{t-1} \frac{1}{\pi_t} \tag{2.8}$$

where $R_{k,t}$ is the return on loans to intermediate-good firms, R_t is the return on deposits from period $t-1$ to t and π_t the inflation rate. Using equation (2.8), we re-express the equity capital accumulation then any growth in equity capital depends on the value of assets and the external finance premium $\left[R_{k,t} - \frac{R_t}{\pi_t}\right]$.

$$n_t = Q_{t-1} s_{t-1} \left[R_{k,t} - \frac{R_t}{\pi_t}\right] + \frac{R_t}{\pi_t} n_{t-1} \tag{2.9}$$

One of the crucial features of Gertler and Kiyotaki (2010) and Gertler and Karadi (2011) framework is the imperfect capital markets, so banks earn a return on assets greater than the riskless return they pay for deposits. It induces banks to expand their assets by borrowing additional short-term debt. The gap between the return on capital $R_{k,t}$ and the real interest rate on deposits R_t is defined as external finance premium, where $\Lambda_{t,t+1}$ is the real stochastic discount factor over the time t and $t+1$.

$$E_t \Lambda_{t,t+1} \left[R_{k,t+1} - R_{t+1} \frac{1}{\pi_{t+1}}\right] \geq 0 \tag{2.10}$$

It pays for the bank to accumulate assets and borrow funds from households as long as the external finance premium is positive. To limit the ability of the bank to build assets indefinitely, Gertler and Karadi (2011) introduce a moral hazard enforcement problem between banks and households. We assume at the beginning of every period, banks may divert a λ fraction of their assets $Q_t s_t$ in the form of bonuses or dividends. If households would claim their funds, they could only recover the fraction $1-\lambda$ of assets and it would force banks into bankruptcy. Thus, it is too costly for depositors to recover the diverted funds and they are willing to supply funds to banks when they do not expect a moral hazard behaviour. Therefore, households save deposits in banks as long as the present value on future profits of banks is higher than the earnings from diverting funds as below.

$$V_t\left(s_t,d_t\right)\geq\lambda Q_t s_t \tag{2.11}$$

The ability of building assets from banks depends on the λ fraction and that the constraint always binds. When $\lambda\Rightarrow 1$ there is a tight borrowing constraint for banks and they obtain less deposits. However, for a $\lambda\Rightarrow 0$ banks have higher accumulation of assets.

At the end of each period an individual bank maximises the present value of its future dividends when it exists in the market. It is defined θ is the probability of surviving in the next period and $\Lambda_{t,t+i}$ the real stochastic discount factor the banker applies at t to earnings at $t+i$.

$$V_t = maxE_t\sum_{i=1}^{\infty}\left(1-\theta\right)\left(\theta\right)^{i-1}\Lambda_{t,t+i}n_{t+i} \tag{2.12}$$

The maximisation problem of an individual bank is subject to the incentive constraint from equation (2.11). To solve the maximisation problem of the individual bank we write the value function as a Bellman equation

$$V_t\left(s_{t-1},d_{t-1}\right)=E_{t-1}\Lambda_{t-1,t}\left\{\left(1-\theta\right)n_t+\theta\left[\max_{s_t,d_t}\;V_t\left(s_t,d_t\right)\right]\right\} \tag{2.13}$$

$$V_t\left(s_t,d_t\right)\geq\lambda Q_t s_t$$

To solve the maximisation problem, we guess and verify the value function of the individual bank. The algebra is explained in detail in Appendix A.1.1. We assume that the functional form of the value function is linear in assets s_t and deposits d_t same as Gertler and Kiyotaki (2010). We define ν_s and ν_d as the time-varying marginal values of assets and deposits.

$$V_t(s_t, d_t) = \nu_{s,t}s_t - \nu_{d,t}d_t \tag{2.14}$$

The first order conditions respect to assets, deposits and the Lagrange multiplier are as follow

$$\nu_{s,t} - \lambda_{lm,t}(\lambda Q_t - \nu_{s,t}) = 0 \tag{2.15}$$

$$-\nu_{d,t} - \lambda_{lm,t}\nu_{d,t} = 0 \tag{2.16}$$

$$\lambda Q_t s_t - \nu_{s,t}s_t + \nu_{d,t}d_t = 0 \tag{2.17}$$

Using equation (2.17) and the balance sheet of the individual bank $d_t = Q_t s_t - n_t$ we obtain

$$Q_t s_t [\lambda - \mu_t] = \nu_{d,t}n_t \tag{2.18}$$

where μ_t is the excess value of assets over deposits.

$$\mu_t = \frac{\nu_{s,t}}{Q_t} - \nu_{d,t} \tag{2.19}$$

We define ϕ_t as the leverage ratio of banks that is the ratio of assets to equity capital from equation (2.18).

$$\phi_t = \frac{\nu_{d,t}}{\lambda - \mu_t} \tag{2.20}$$

Note that the leverage ratio is a countercyclical variable since it decreases in λ. It is because the ability of banks to accumulate assets is lower. On the contrary, the excess value of assets over deposits μ_t, co-moves with the leverage ratio so it is a procyclical variable.

$$Q_t s_t = \phi_t n_t \tag{2.21}$$

Equation 2.21 illustrates the transmission mechanism underlying the financial accelerator. Asset values are directly determined by two elements, equity capital and leverage ratio. When banks' net worth decreases due to, for example a capital quality shock, it impacts credit supply to non-financial firms. The lower value of assets and holding constant equity capital, the value of the intermediary assets depends on the leverage ratio. It is influenced by the diverting fund's rate λ, and the excess value of assets over deposits μ_t, in other words, for the external finance premium. The tighter borrowing constraint limits the expansion of the credit supply of banks. In this case, the ratio between assets and net worth is lower because banks are more restricted to build new assets.

Next, we verify the functional form of the value function and obtain equations for assets s_t, deposits d_t and the excess marginal value of assets over deposits μ_t. To satisfy the conjecture, equation (2.22) is the marginal value of assets and equation (2.23) the cost of holding deposits. Note that is easier to observe the relationship between the finance premium and the excess value of assets over deposits from equation (2.24).

$$\nu_{s,t} = E_t \Lambda_{t,t+1} \Omega_{t+1} R_{k,t+1} Q_t \tag{2.22}$$

$$\nu_{d,t} = E_t \Lambda_{t,t+1} \Omega_{t+1} R_{t+1} \frac{1}{\pi_{t+1}} \tag{2.23}$$

$$\mu_t = E_t \Lambda_{t,t+1} \Omega_{t+1} \left(R_{k,t+1} - R_{t+1} \frac{1}{\pi_{t+1}} \right) \tag{2.24}$$

The three equations depend on the shadow value of net worth Ω_t, expressed in (2.25). The first term of the equation is the probability of exiting the banking sector and the second term is the marginal value of an extra unit of net worth conditional to the survival rate.

$$\Omega_t = (1 - \theta) + \theta \left(\mu_{s,t} \phi_t + \nu_{d,t} \right) \tag{2.25}$$

To determine the aggregate variables, we sum across individual banks since they are homogeneous. The total equity capital depends on the equity capital on existing banks $N_{e,t}$ plus the equity capital on new banks $N_{n,t}$ at time t. $N_{e,t}$ is given by the difference between their earnings for assets and payments for liabilities, while $N_{n,t}$ is equal to the starting funds, a fraction of the assets in period $t-1$.

$$N_{e,t} = \theta \left[R_{k,t} Q_{t-1} S_{t-1} - \frac{1}{\pi_t} R_t D_{t-1} \right] \tag{2.26}$$

$$N_{n,t} = \omega R_{k,t} Q_{t-1} S_{t-1} \tag{2.27}$$

The equation of motion for the total net worth is as follows

$$N_t = (\theta + \omega) R_{k,t} Q_{t-1} S_{t-1} - \theta \frac{1}{\pi_t} R_t D_{t-1} \tag{2.28}$$

2.2.3 Non-financial Firms

In the economy, there are three types of firms: capital producers, final-good producers and intermediate-good producers. The first two operate in a competitive market whereas the last one does it in a market with monopolistic competition, where we set nominal rigidities using Rotemberg (1982) contracts.

2.2.3.1 Capital Producers

Capital producers play a crucial role in the model since variations in the price of capital drive the financial accelerator, as set out by Bernanke et al. (1999). In Gertler and Kiyotaki (2010) and Gertler and Karadi (2011) the price of capital becomes endogenous. Capital producers operate in a perfectly competitive market, purchase investment goods and transform them into new capital. They also refurbish obsolete capital acquired from intermediate-good producers at the end of each period. The new and repaired capital is sold to the intermediate good producers at the end of the time t. This capital will be used in production in the next period and its price per unit is Q_t.

Capital producers incur quadratic investment adjustment costs $S_t^k(X_t)$ per unit of investment to produce new capital and repair the obsolete capital. Investment adjustment cost are defined as $S_t^k(X_t) = \Phi_X (X_t - 1)^2$ where $X_t = \frac{I_t}{I_{t-1}}$ and $\Phi_X > 0$ is the adjustment cost parameter.

Capital producers maximise their expected discounted profits choosing I_t.

$$maxE_t \sum_{t=0}^{\infty} \Lambda_{t,t+1} \{Q_t[1 - S^k(X_t)I_t] - I_t\} \tag{2.29}$$

The optimality condition yields the following Q-investment relation for capital goods.

$$Q_t \left(1 - S^k(X_t) - X_t S^{k'}(X_t)\right) + E_t \left[\Lambda_{t,t+1} Q_{t+1} S^{k'}(X_{t+1}) X_{t+1}^2\right] = 1 \tag{2.30}$$

The aggregate capital stock for time $t+1$ is given by the following equation

$$K_{t+1} = I_t \left[1 - S_t^k(X_t)\right] + (1-\delta)K_t \tag{2.31}$$

where δ denotes the depreciation rate of capital. We present the maximisation problem in detail in Appendix A.1.2.

2.2.3.2 Final Goods Producers

Final-good producers operate in a competitive market, they combine the different varieties of goods $Y_t(i)$ from the i intermediate-good producers. They repackage these varieties and obtain a homogeneous compound final good that is sold at the competitive price P_t.

$$Y_t = \left[\int_0^1 Y_t(i)^{\frac{\varepsilon-1}{\varepsilon}} di\right]^{\frac{\varepsilon}{\varepsilon-1}} \tag{2.32}$$

where Y_t is the aggregated output of the retailers in period t and $Y_t(i)$ is the output of the i intermediate good producer. The elasticity of substitution between varieties is expressed by ε, the more it approaches to the unit $\varepsilon \to 1$, the closer to perfect substitutes. We assume imperfect substitution among varieties so intermediate-good producers have some power to set prices and $\varepsilon > 1$. Final-good producers maximise with zero profits condition. Therefore, the maximisation problem is given by

$$P_tY_t(i) - \int_0^1 P_tY_t(i)di \tag{2.33}$$

subject to

$$Y_t(i) = \left[\int_0^1 Y_t(i)^{\frac{\varepsilon-1}{\varepsilon}} di\right]^{\frac{\varepsilon}{\varepsilon-1}} \tag{2.34}$$

It yields the demand for good i

$$Y_t(i) = \left(\frac{P_t(i)}{P_t}\right)^{-\varepsilon} Y_t \tag{2.35}$$

2.2.3.3 Intermediate Good Producers

Our economy have a large number of intermediate-good producers indexed by i and each of them produce the variety $Y_t(i)$. They combine capital and labour and operate with return to scale

$$Y_{H,t}(i) = A_tK_t(i)^{\alpha}L_t(i)^{1-\alpha} \tag{2.36}$$

where α is the share of capital and A_t denotes an exogenous and stochastic total factor productivity shock that follows an AR(1) process, the persistence parameter is $0 < \gamma_A < 1$ and $\epsilon_{A,t}$ is distributed as $\epsilon_{A,t} \sim N(0, \sigma_A)$.

$$A_t = A_{t-1}^{\gamma_A} e^{\epsilon_{A,t}} \tag{2.37}$$

Intermediate-good producers operate as monopolistic competitors and face Rotemberg(1982) quadratic menu costs and they adjust prices by

$$\frac{\varphi}{2}\left[\frac{P_t(i)}{P_{t-1}(i)} - 1\right]^2 \tag{2.38}$$

where φ denotes the price stickiness and prices are flexible when φ is equal to zero. Intermediate-good producers set the optimal price level by maximising their present discounted real profits

$$maxE_t \sum_{t=0}^{\infty} \beta^t \left[\frac{P_t(i)}{P_t} Y_t(i) - \frac{W_t}{P_t} L_t(i) - Q_t R_{k,t} K_t(i) - \frac{\varphi}{2} \left[\frac{P_t(i)}{P_{t-1}(i)} - 1 \right]^2 Y_t \right]$$

subject to

$$Y_t(i) = \left(\frac{P_t(i)}{P_t} \right)^{-\varepsilon} Y_t$$

$$Y_t(i) = A_t K_t(i)^{\alpha} L_t(i)^{1-\alpha}$$

Intermediate-good producers take identical decisions then the aggregate level is defined by adding over i, the optimal price is as follows

$$rmc_t = \frac{\varepsilon - 1}{\varepsilon} + \frac{\varphi}{\varepsilon} \pi_t (\pi_t - 1) - \frac{\varphi}{\varepsilon} E_t \left[\Lambda_{t,t+1} \frac{\pi_{t+1} (\pi_t - 1) Y_{t+1}}{Y_t} \right] \tag{2.39}$$

where rmc_t is the real marginal cost and $\pi_t = \frac{P_t}{P_{t-1}}$ is the inflation rate. Note from the first term in equation (2.39) that when φ is zero, the optimal price is still above the marginal cost. It is because intermediate-good producers hold a mark-up.

The first order conditions relative to production factors yield the demand for labour and capital.

$$\frac{W_t}{P_t} = (1 - \alpha) A_t rmc_t \left(\frac{K_t}{L_t} \right)^{\alpha} \tag{2.40}$$

$$Z_t = \alpha A_t rmc_t \left(\frac{K_t}{L_t} \right)^{\alpha - 1} \tag{2.41}$$

$$R_{k,t} = \frac{[Z_t + Q_t(1 - \delta)]}{Q_{t-1}} \tag{2.42}$$

Equation (2.40) is the demand for labour that equalise the real wage. Equation (2.41) is the real gross profits per unit of capital and equation (2.42) presents the return on capital $R_{k,t}$.

At the end of each period, intermediate-good producers buy new capital and finance their new acquisitions by borrowing from banks. This side of the market is frictionless, so intermediate-good producers do not face constraints to obtain funds. They issue S_t claims equivalent to the units of their new capital K_{t+1}. S_t can be seen as perfectly state-contingent debt and Q_t is the price of each unit. In the model, the value of new capital is equal to the value of the state-contingent debt for firms, that corresponds to the value of assets for banks.

$$Q_t K_{t+1} = Q_t S_t \tag{2.43}$$

To examine an experiment of a financial crisis into the model, we incorporate a capital quality shock following Gertler and Kiyotaki (2010) and Gertler and Karadi (2011). Intuitively, S_t is seen as "capital in process" that will be transformed in capital for next period. The amount of state-contingent debt at time t becomes K_{t+1} since

$$K_{t+1} = \psi_{t+1} S_t \tag{2.44}$$

where ψ_{t+1} is the capital quality shock defined by an AR(1) process

$$\psi_{t+1} = (\psi_t)^{\gamma_\psi} e^{\epsilon_{\psi,t+1}} \tag{2.45}$$

where $0 < \gamma_\psi < 1$ is the persistence parameter and $\epsilon_{\psi,t+1}$ is distributed as $\epsilon_{\psi,t+1} \sim N(0, \sigma_\psi)$.

We can re-write equation (2.31) because the capital quality shock introduces a wedge between capital and the capital in process

$$S_t = I_t \left[1 - S_t^k(X_t)\right] + (1 - \delta) S_{t-1} \tag{2.46}$$

and the return on capital using equation (2.42).

$$R_{kt} = \psi_t \frac{[Z_t + Q_t - (1 - \delta)]}{Q_{t-1}}$$

The capital quality shock triggers an exogenous variation in the value of capital. It yields changes in asset prices and the balance sheet of banks. The mechanism of transmission is similar in Gertler and Kiyotaki (2010) and Gertler and Karadi (2011) models. The link between physical capital and banking assets will be the transmission mechanism of the financial accelerator in this framework.

2.2.4 Central Bank and Resource Constraint

In our model the central bank conducts monetary policy using a standard Taylor rule

$$R_t = R\left(\frac{\pi_t}{\pi}\right)^{\kappa_\pi}\left(\frac{y_t}{y}\right)^{\kappa_y}\vartheta_t \tag{2.47}$$

where $\{\kappa_\pi\} \in (1, \infty]$, $\{\kappa_y\} \in (0, \infty]$, R is the steady state nominal interest rate, π is the steady state inflation rate, y is the steady state output, κ_π is the inflation coefficient of the Taylor rule, and κ_y the output coefficient of the Taylor rule. ϑ_t is an AR(1) process that represents an exogenous monetary policy shock

$$\vartheta_t = (\vartheta_{t-1})^{\gamma_\vartheta} e^{\epsilon_{\vartheta,t}} \tag{2.48}$$

where $0 < \gamma_\vartheta < 1$ is the persistence of the shock and $\epsilon_{\vartheta,t}$ is distributed as $\epsilon_{\vartheta,t} \sim N(0, \sigma_\vartheta)$.

Government expenditures are equal to lump-sum taxes.

$$G_t = T_t \tag{2.49}$$

and output is equal to total consumption, investment and government expenditures.

$$Y_t = C_t + I_t + G_t \tag{2.50}$$

2.3 Calibration

We calibrate our model for Brazil for two separate reasons. First, Brazil is a fairly closed economy; its ratio of exports plus imports to GDP is 25.6% similar to the US (27% in

2017). Indeed, among the Latin American countries, Brazil has one of the lowest trade openness.[2] Secondly, Brazil is among a (small) number of countries that adopted both credit interventions and extended MaPs in the aftermath of the 2008-09 financial crisis.

In Table 2.1, we present the calibration using standard values from the literature for some parameters and matching some values using data. The discount factor β is set at 0.976 implying a riskless annual return of approximately 4 per cent in the steady-state. We set labour L equal to 0.3 matching at 2.102 the relative utility weight of labour. Capital share α is set at 0.33 and δ is equal to 0.025, implying an annual depreciation rate of 10%, we follow the standard literature and Gertler and Karadi (2011).

Table 2.1: Calibration of Parameters

Parameter		Value	Source or target
Real Sector			
Discount factor	β	0.976	Castro et al. (2011)
Relative utility weight of labour	χ	2.102	target value[a]
Capital share	α	0.330	Gertler and Karadi (2011)
Steady state depreciation rate	δ	0.025	Gertler and Karadi (2011)
Adjustment cost parameter	Φ_X	1.500	Tavman (2015)
Elast. of substitution	ε	11.00	Castro et al. (2011); Areosa et al (2013)
Inflation Taylor Rule Parameter	κ_π	2.430	Castro et al. (2011)
Output Taylor Rule Parameter	κ_y	0.160	Castro et al. (2011)
Menu Cost, Rotemberg Parameter	φ	111.0	Castro et al. (2011); Areosa et al (2013)[b]
Government Spending to GDP Ratio	$\frac{G}{Y}$	0.200	target value[c]
Banking Sector			
Survival rate	θ	0.909	target value[d]
Fraction of diverting funds	λ	0.480	target value[e]
Fraction of starting funds	ω	0.002	Gertler and Karadi (2011)
Shock Processes			
Financial Crisis: Quality Capital Shock	γ_ψ	0.950	Tavman (2015)
Monetary Policy Shock	γ_ϑ	0.790	Areosa et al (2013)
Productivity Shock	γ_A	0.950	Gertler and Karadi (2011)

[a] Targeted χ to match L equal to 0.3.
[b] Calibrated φ equivalent to the Calvo stickiness used by Castro et al. (2011) and Areosa et al (2013).
[c] Matched $\frac{G}{Y}$ with the Government Final Consumption Expenditure to Output in Brazil, FRED statistics.
[d] Targeted θ by matching the average year spread in 110 basis points as Gertler and Karadi (2011).
[e] Targeted λ by matching the leverage ratio close to Gertler and Karadi (2011).

The elasticity of substitution among varieties ε is equal to 11, implying a 10% markup in the steady state. Using the Rotemberg (1982) contracts, we set the stickiness parameter φ at 111, which would adjust the prices every four quarters in the Calvo price model

[2] In Latin America, the average trade openness is 43.9% based on the World Bank data.

such as Castro et al. (2011) and Areosa and Arrigoni (2013). These values are very close to Mimir (2013) who calibrate the Gertler and Karadi (2011) framework for Turkey.

The adjustment cost parameter of investment Φ_X is 1.5 following Tavman (2015). We set the ratio government spending at 20% at the steady state, matching the Brazilian data from 2000 to 2016. The inflation coefficient Taylor rule κ_π is set at 2.43 and the output coefficient Taylor rules κ_y is 0.16, that corresponds to a 0.64/4 for output, same than Castro et al. (2011) who estimate these parameters for Brazil.

To calibrate the survival rate of banks θ at 0.909, we target the steady state of the spread interest rate using a yearly average spread at 110 basis points borrowing the value from Cuadra and Nuguer (2016) study on Mexico. We do not used the spread for Brazil since is highly volatile. We target a diverting funds fraction λ equal to 0.480 to obtain a leverage ratio close to Gertler and Karadi (2011). New banks receive the starting funds ratio ω equivalent to 0.18 percent of the assets from the previous period, this value is equal to Gertler and Kiyotaki (2010) and Gertler and Karadi (2011).

Finally, we set the persistence of the capital quality shock γ_ψ equal to 0.95 and the persistence of the technology shock γ_A equal to 0.95 using the values of Tavman (2015) and Gertler and Karadi (2011), respectively. For the persistence of the monetary policy shock, we choose the same value than Areosa and Arrigoni (2013) and γ_ϑ is 0.79. They estimate the parameter for the Brazilian economy with a similar framework.

2.4 Model Dynamics

2.4.1 Business Cycle Facts in Brazil

To generate confidence in the ability of our model to capture the dynamics of the emerging economy, we compare some moments from the model with data from Brazil. We select output, consumption, investment, bank assets and leverage ratio to validate the model. We use quarterly data of Gross Domestic Product by Expenditure, Private Final Consumption Expenditure, Gross Fixed Capital Formation and Credit to Private non-financial sector from Banks for the period 2000(1)-2016(4). The four variables are in constant prices of 2010 and seasonally adjusted. Consumption, investment and output were taken from the Federal Reserve Bank of St. Louis while private credit from the BIS statistics. We also include leverage ratio calculated using total equity and total assets in millions of Reales reported by the Central Bank of Brazil. We use the Financial Stability Indicators available at the Press releases – Monetary Policy and Financial System Credit Operations and the Time Series Management System (SGS) from 2001(1) to 2016(4).

Our variables are in logarithms and we de-trend the series using a HP filter with a factor λ=1600. We simulate data from the model to obtain empirical moments. Our calculations result from a simulation of 100 000 periods and we examine a 1% standard deviation of a capital quality shock. In Table 2.2, we compute the standard deviation of each variable, the volatility of the series by the standard deviation relative to the output standard deviation, the contemporaneous correlation relative to output and the autocorrelation of first order of each variable in the model and data.

Table 2.2: Matching Moments between Model and Data

	St.Dev. X_t		St.Dev. X_t / GDP St.Dev.		Corr X_t to $GDPt$		Autocorr (X_t, X_{t-1})	
X_t	**Model**	**Data**	**Model**	**Data**	**Model**	**Data**	**Model**	**Data**
Output	0.010	0.016	1.000	1.000	1.000	1.000	0.915	0.777
Consumption	0.012	0.020	1.216	1.222	0.849	0.722	0.948	0.756
Investment	0.037	0.048	3.789	2.937	0.210	0.877	0.942	0.753
Bank Assets	0.029	0.044	3.035	2.684	0.848	0.500	0.924	0.816
Leverage Ratio	0.187	0.031	19.262	1.919	-0.404	0.775	0.506	0.663

We display the standard business cycles facts as King and Rebelo (2000). One can observe in the first column the standard deviation from the model and data of the selected variables. Output, consumption, investment and bank assets present an accurate fit while leverage ratio is slightly overestimated in the model. In the second column, we display the volatility of the selected variables, all of them are more volatile than output confirming an empirical regularity in emerging markets. However, we find that leverage ratio in the model does not fit well the data. One possible explanation is that there is a direct and quick effect from asset prices to banks' net worth in Gertler and Karadi (2011) model. It clearly, affects the leverage ratio. Therefore, when we observe a fall in output, bank net worth declines and the leverage ratio rises sharply and significantly.

In column three, one can appreciate that consumption, investment and bank assets are procyclical variables in the data and the model, expected for an emerging market economy. Leverage ratio is a procyclical variable in the data but countercyclical in the model. This discrepancy is a feature of Gertler and Karadi (2011) model and is in line with previous studies (Gertler et al., 2012; Mimir, 2013; Tavman, 2015).

In the last column of Table 2.2, we present the first order autocorrelation of the selected variables from the model and data. In all cases the signs are correct and the values are fairly close between the model and data. Overall, the model fits well the data with exception of the high volatility and countercyclicality in the leverage ratio discussed earlier.

2.4.2 The Financial Accelerator Mechanism

In this section, we analyse the role of financial intermediaries-banks-in the model, in amplifying the propagation of shocks. The Latin American countries are an interesting sample of economies to analyse, as they have experienced financial and banking crises during the nineties. The case of Brazil is particularly appealing because the country implemented a couple of monetary and bank regulatory policies during the 2008-09 financial crisis, which are widely believed to have allowed the economies in question to recover from the crisis faster than other emerging economies.

To explore the dynamics of the model, we examine a total factor productivity shock, a monetary policy shock and a capital quality shock. We analyse the responses in a model with banks á la Gertler and Karadi (2011) and compare with a benchmark New Keynesian model without banks.

2.4.2.1 Total Factor Productivity Shock

We set a negative one percent shock in the total factor productivity and compare the responses of our model (with banks) and the New Keynesian model without banks. In Figure 2.1, we illustrate the responses from our model in star-marked line and continuous line from the New Keynesian model without banks. The shock is interpreted as an unexpected decrease in productivity leading to the fall in investment and output. It reduces leisure in the economy since workers are willing to supply more hours of work to compensate for the lower productivity. Therefore, labour L_t tends to go up at first although it reverses, offsetting pressures on wages and marginal cost.

In our model, there is a direct link between physical capital and bank assets. Each unit of capital K_t is financed by a bank asset S_t bought at a price Q_t. Thus the value of capital is equivalent to the value of assets in the economy. As a result, the negative productivity shock that reduces investment induces the decrease in capital price, and consequently, the drop in asset prices.

The shock is spread to the banking sector since bank assets lose value and that reduces the banks' net worth N_t, which erodes increasing the leverage and weakening banks balance sheets. The lack of funds from banks shrinks the credit supply in the economy. In an attempt to improve their balance sheets, banks increase the cost of capital $R_{k,t}$ amplifying the external finance premium in the market. However, the initial output contraction and the higher cost of loans, discourage intermediate-good producers to take additional credit.

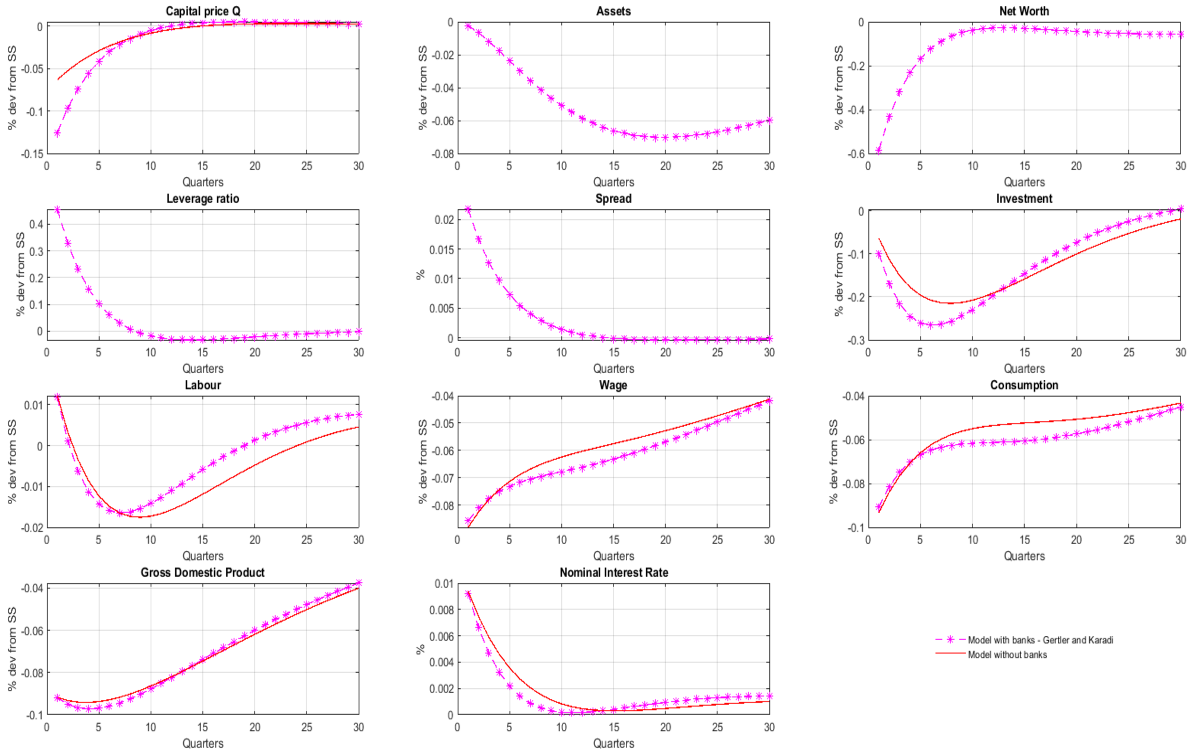

Figure 2.1: Responses to Total Factor Productivity Shock

In the standard New Keynesian model without banks, we observe that the negative productivity shock also shrinks the economic activity reducing investment. However, the impact on the price of capital is significantly lower because the financial accelerator mechanism does not have a place in the model. Therefore, the model does not account for the borrowing constraints that intermediate-good producers face after the shock. That is, there is no impact on the credit market that implies the further drop in capital price.

In the absence of the transmission channel from capital prices to asset prices, and from there to the bank credit supply, the fall in investment is less severe. The lower productivity explains output contraction, but also we observe a significant drop in consumption. In general, a model with banking sector amplifies the effect of a total productivity shock because it captures a channel of transmission usually dismissed in models without banks, which catalyses the response of the economy.

2.4.2.2 Monetary Policy Shock

In this section, we analyse the case of an increase in the interest rate in the economy. Our primary objective is to determine whether the financial accelerator mechanism through banks plays a role in the transmission of monetary policy. We set a one percent rise in the interest rate. In Figure 2.2, we present the responses using our model with the star-marked line, whereas the continuous line displays the New Keynesian model without banks.

The rise in the interest rate increases the return of deposits, which stimulates the preference for savings. Households substitute present for future consumption leading to the fall in aggregate demand. The higher interest rate increases the cost of the short-term liabilities of banks reducing their net worth. Furthermore, the rise in deposits cost narrows the external finance premium, because at first the return on capital remains constant. The decline in banks' net worth rises the leverage ratio and discourages banks from building assets since the margin of profits per loan is decreasing. Banks attempt to face up the constraint of their balance sheets by enhancing the credit market conditions for them. Thus, they increase the cost of credit R_k, pushing up the external finance premium. It dampens the demand for loans from intermediate-good producers. The credit constraint is accentuated because the fall in consumption reduces aggregate demand and therefore, production.

The fall in demand for credit reduces the demand for capital amplifying the drop in capital price Q_t. It further weakens banks' net worth and the balance sheets of banks deepening the fall in investment. Output contraction, therefore, contributes to the decrease in the demand for labour and wages. Thus, the marginal cost declines leading to a decrease in the inflation rate.

Overall, output goes down because households consume less, given the higher interest rate on deposits. Investment decreases as a result of the lower demand for goods but also for the worsening conditions in the credit market. That is, the increase in the monetary policy interest rate rule that raises the cost of capital triggering the financial accelerator mechanism deepening the effects on the external finance premium, the price of capital, investment and output.

In a standard New Keynesian model without banks, the primary transmission channel of the monetary policy operates by the Euler equation. The substitution between present consumption and savings dampens the aggregate demand. However, the effects on the credit market are usually short-lived because there are no banks intermediating assets in the economy. The external finance premium that allows banks receive profits does not take place. Excluding banks from the model leaves out an essential channel of transmission that explains the further fall of capital price, and the lower decline in investment and output observed in Figure 2.2.

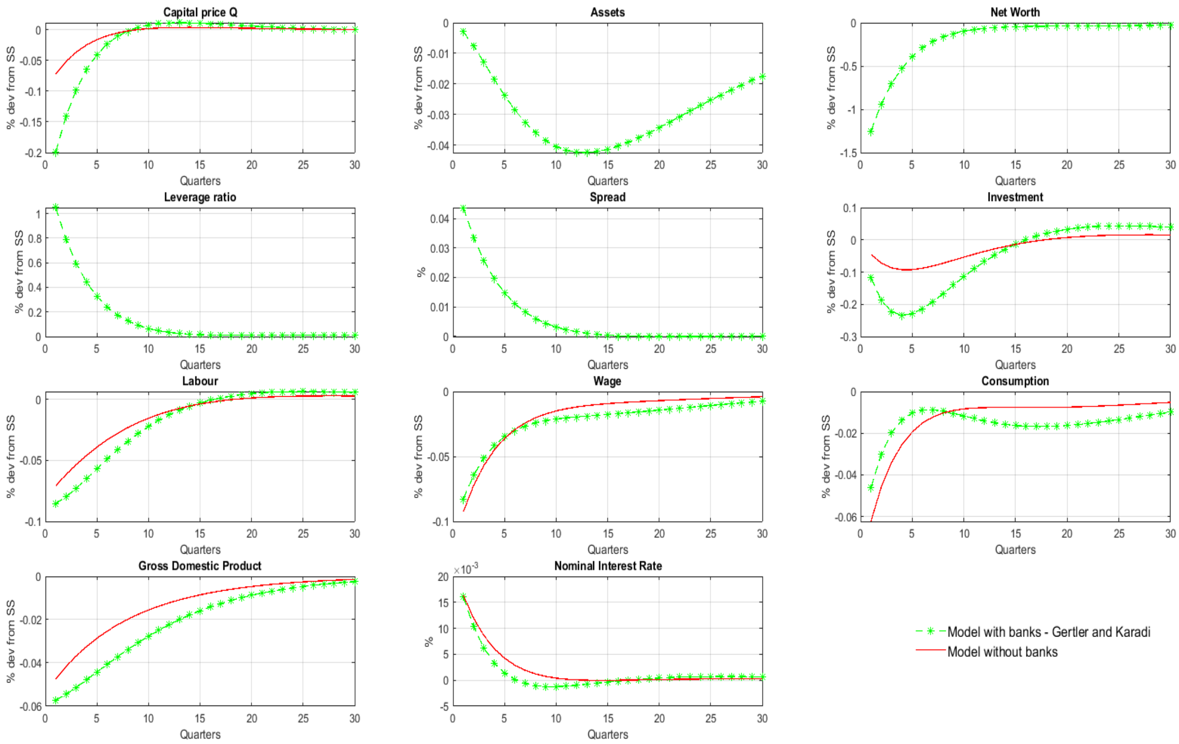

Figure 2.2: Responses to a Monetary Policy Shock

Comparing the two models, we observe that a monetary policy shock relative to the productivity shock yields broader differences in the responses in real variables. This in turn, suggests that the role of banks and their response to a change in the interest rate have a greater impact in the real economy than the effect of a real shock that indirectly deteriorates the credit market conditions.

During the 2008-09 financial crisis, the central bank of Brazil eased monetary policy by reducing the SELIC interest rate by five percentage points from December 2008 to September 2009.[3] It stimulated the domestic credit and contributed to reviving the economic growth in the Brazilian economy. In that case, the shock was in the opposite direction than in Figure 2.2. Nonetheless, the exercise provides a clear explanation of the dynamics of the model under a monetary policy shock. It is relevant because during the 2008-09 financial crisis, the central Bank of Brazil implemented a set of policies to recover the economy such as, the softening of monetary policy, the decline of reserve requirements and the credit market intervention.

2.4.3 Financial Crisis Experiment

We examine the case of a financial crisis by exploring the implications of a capital quality shock for the economy. We aim to observe how an exogenous shock such as a decrease in the quality of bank assets is transmitted to the rest of the economy and the role of the financial accelerator mechanism in this transmission. We set a negative one percent change in the capital quality that decreases the value of capital through equation (2.44). In Figure 2.3, we display with the star-marked line the transmission mechanism of the capital quality shock using our model. To observe the role of financial frictions in an economy like Brazil, we compare these responses with the New Keynesian model without banks.

In our model with banks, the initial decline in the value of capital reduces asset prices and immediately erodes the bank's equity capital. This raises the leverage of banks weakening their balance sheets and shrinking credit supply from banks to non-financial firms. The demand for assets goes down since it is more costly, it further decreases asset prices Q_t. Overall, the price of capital declines for the initial exogenous shock and also drops due to, the credit market constraint. Additionally, the external finance premium goes up because leveraged banks impose a higher price on loans, increasing the cost of

[3]SELIC is the instrument of monetary policy and it refers the acronym of Special System for Settlement and Custody in Portuguese.

capital and worsening the borrowing opportunities of non-financial firms. The higher cost of capital decreases investment and output of the economy.

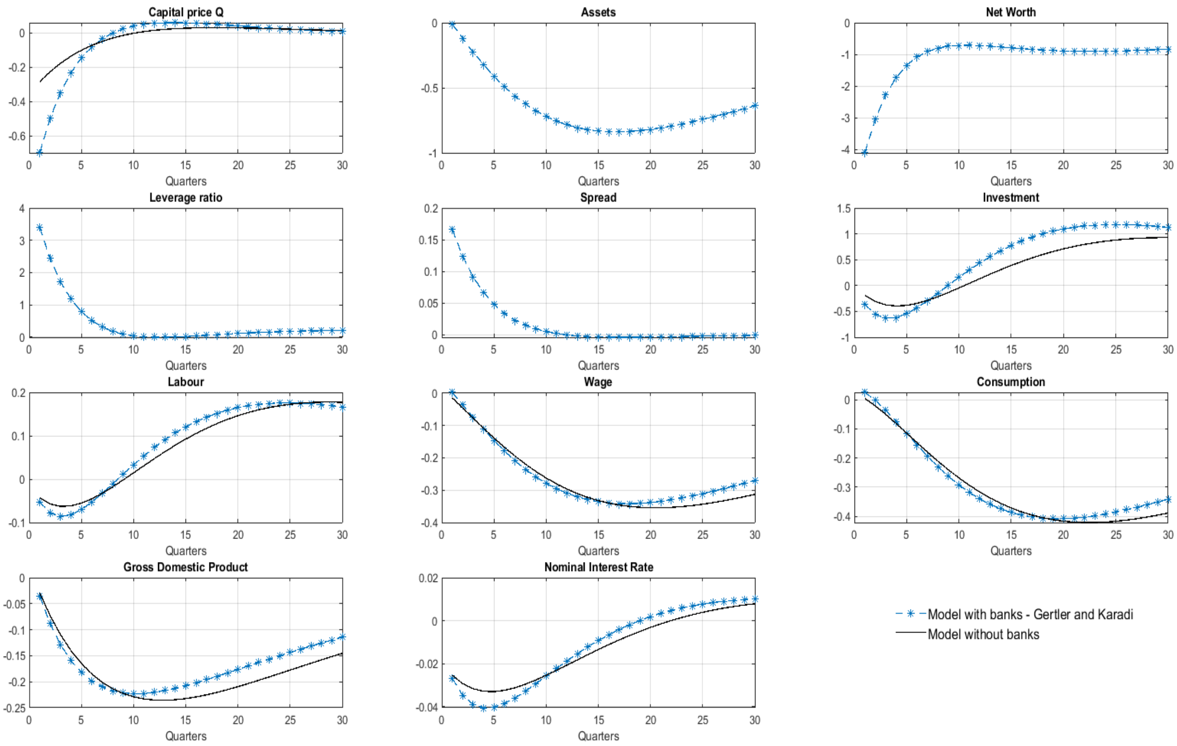

Figure 2.3: Responses to Capital Quality Shock

The tighter borrowing conditions that non-financial firms face induce a lower demand for capital and a deeper fall in the price of capital. Consequently, non-financial firms reduce their demand for labour leading to a drop in wages, marginal cost and inflation rate. Households receive less income hence consumption falls relative to its level before the shock.

Similar to Gertler and Karadi (2011), we observe that the capital quality shock triggers a sharp recession in the economy. Output and investment slowly recover from the downturn, and it only occurs around five years after the shock. The external finance premium and net worth go back to the trend after two years. However, for assets, the recovery is slower, delaying deleverage of banks.

In Figure 2.3, we compare the role of the financial sector by displaying the responses to the capital quality shock between a model with banks with a model without them. In the continuous line the New Keynesian model without banks, the fall in asset prices Q_t

is significantly lower because there is no intermediation of assets. The channel of transmission through the balance sheets of banks and credit supply to aggregate demand is neglected. The capital quality shock only affects the capital return and its accumulation. It results in a lower decline of investment and output, smaller than in the model with banks. We also find that the recovery of production is faster over time.

2.4.4 How did the financial regulation and monetary policy help the Brazilian economy during the global financial crisis?

The 2008-09 financial crisis spread around the world including Latin America and countries like Mexico, Brazil, Chile and Venezuela fell into recession in 2009. However, the Brazilian economy was one of the least affected economies and grew by 7.5% the following year. Brazil implemented economic policies that allowed it to recover faster and be resilient to the global slowdown and the international financial contagion (Ferrari Filho, 2011; Moreira et al., 2011).

At the end of 2008, the foreign capital flows shrank abruptly leading to the depreciation of the Brazilian currency and raising the interest rate spreads. Domestic credit conditions deteriorated after the sudden drought of external finance. Nevertheless, the central bank conducted a set of policies for smoothing the exchange rate behaviour and expanding domestic credit. The central bank stabilised the currency intervening in the foreign exchange market, only on November 6, it sold 5.2 billion in USD dollar in the spot market combined with derivative sales of 25.8 billion in USD dollars through currency swaps (Canuto, 2008).

The monetary authorities promptly took action in the domestic economy by loosening monetary policy (see for example, the central bank declined the SELIC interest rate from 13.75% to 8.75% between December 2008 and September 2009). The central bank increased the liquidity in the interbank market delaying the increase in reserve requirements and implementing reductions in the reserve requirements of some sectors. This MaP aimed to influence the availability of funds in the banking sector (Canuto, 2008; Ferrari Filho, 2011; Moreira et al., 2011).

In addition to this, the Brazilian government injected liquidity by expanding the credit supply through earmarked loans. Government-owned banks allocated funds to non-financial firms in specific sectors playing a countercyclical role in a context of tightening credit conditions for private banks. Thus, the earmarked credit increased from 32% in 2008 to 49% at the end of 2015. On November 2008 and August 2009 the Ministry of Finance announced a series of new initiatives with new credit lines for various sectors, small and midsize businesses. Overall, the additional funds aimed to avoid the sharp drop of the economic activity (Ferrari Filho, 2011; Bonomo et al., 2014; Pazarbasioglu et al., 2017).

In summary, the changes in the reserve requirements, the easing of monetary policy, credit expansion by the state-owned banks and the FX interventions contributed to getting out of the recession and recovering the economic growth during the global financial crisis. The results were remarkable as Brazil performed better than the rest of Latin America in the following years.

In the recent financial stability literature, changes in reserve requirements and capital requirements are categorized as MaPs. A number of Latin American countries including Brazil incorporated them in their tool-kit of instruments after their episodes of crises in the 1990s. In the aftermath of the 2008-09 financial crisis the Brazilian central bank successfully reduced the reserves requirements increasing the availability of funds to expand credit.[4] Areosa and Arrigoni (2013) study this policy using the Gertler and Karadi (2011) framework. They replicate the decrease in reserve requirements in Brazil in 2009 and present some evidence about the positive impact of the policy in the credit market and the output recovery.

Finally, the type of policy operated in Brazil to drive the credit expansion can be viewed as similar to the kind of UMP implemented by the US and the UK with the QE in the aftermath of the 2008-09 financial crisis. The circumstances and the source of the

[4] In fact, the liquidity of the smaller institutions increased in 41.8 billions of Reales in the last quarter of 2008 according to Ferrari Filho (2011).

limited liquidity in emerging and developed countries were different. While developed economies were in the centre of the crisis facing the bankruptcy of banks; emerging markets like Brazil handled sudden capital outflows and worse credit conditions. However, in both cases, there was a massive injection of public funds to expand credit. In the Brazilian case, public financed banks received funds from the government to extend new credit lines and provide loans to firms. It encouraged the economic activity and alleviated the hardship in the credit market.

Dedola et al. (2013) and Cuadra and Nuguer (2016) show that under financial integration, credit constraints in AEs are transmitted to credit markets and real variables in EMEs. These spillovers are triggered by the financial accelerator mechanism that deteriorates the EME banks' balance sheets. In the aftermath of the 2008-09 financial crisis, Brazil faced a lack of liquidity, the currency depreciation, and erosion of the credit market conditions. The gross capital formation to GDP decreased by 3% in 2009, and the economic growth went from 5% to -0.1%. Overall, it confirms that the effects of the 2008-09 financial crisis spread and reached countries like Brazil.

In the next section, we broadly mimic the Brazilian economic conditions at the beginning of the 2008-09 financial crisis using a capital quality shock. We abstract the currency depreciation given our limitation of working with a closed economy model. However, we can replicate the dynamics in the rest of variables. First, we emulate the credit market intervention pursued by the Brazilian government during this period and examine whether the economy recovers faster. Second, we turn to the analysis of capital requirements and explain the dynamics of the economy when this policy is implemented. In the last subsection, we display the results of the welfare analysis.

2.4.4.1 Credit Market Intervention

In this section, the central bank injects public funds $Q_t S_{g,t}$, into the domestic credit market when the private credit $Q_t S_t$ is shrinking such as in Brazil during the 2008-09 financial crisis. We follow the credit policy explored by Gertler and Karadi (2011), and we define total credit in the economy $Q_tS_t^T$, equal to the public and private credit

$$Q_tS_t^T = Q_tS_{g,t} + Q_tS_t \tag{2.51}$$

where public credit $Q_tS_{g,t}$, is a fraction Θ_t of credit in the economy. We will name public credit to the new credit allocated by the government in the public financed banks during the period of this policy. In this scenario, the value of capital equates total credit rather than private credit.

$$Q_tK_{t+1} = Q_tS_t^T \tag{2.52}$$

Banks face the same maximisation problem than before, but some part of the assets in the economy are publicly intermediated, in the Brazilian case through public banks.

The private leverage ratio is defined as equation (2.21), private assets to net worth.

$$Q_ts_t = \phi_tN_t \tag{2.53}$$

Arranging equation (2.51), we define the total leverage ratio ϕ_t^T, that includes the new public credit and the existing private credit

$$Q_tS_t^T = \Theta_tQ_tS_t^T + \phi_tN_t \tag{2.54}$$

and

$$\phi_t^T = \frac{\phi_t}{1-\Theta_t} \tag{2.55}$$

The total leverage is the ratio of total assets to net worth

$$Q_tS_t^T = \phi_t^TN_t \tag{2.56}$$

ϕ_t^T is procyclical and co-moves with the fraction of credit intervention Θ. ϕ_t^T is higher than ϕ_t and the multiplier depends on the value of Θ_t.[5]

[5]A further research question is about the optimal intervention level Θ_t^* of public funds in Brazil during the 2008-09 financial crisis. It avoids pervasive credit expansion such as Bonomo et al. (2014)

The publicly intermediated assets are allocated to non-financial firms at the return on capital $R_{k,t}$. Public banks pay the return for the additional deposits equal to $R_t \frac{1}{\pi_t}$; we assume this public credit is financed by the government instead of households. The model preserves the same external finance premium in all assets, and the intermediation of public funds is done through public banks. The government expenditures are financed by lum-sump taxes T_t and revenues from the public intermediated assets as below

$$G_t + \tau Q_t S_{g,t} - Q_t S_{g,t-1} \left[R_{k,t} - \frac{R_t}{\pi_t} \right] = T_t \tag{2.57}$$

Accordingly, the new resource constraint is

$$Y_t = C_t + I_t + G_t + \tau Q_t S_{g,t} \tag{2.58}$$

where $\tau Q_t S_{g,t}$ is the cost of public intermediation.

In our model, the rule to conduct the credit market intervention is similar to Gertler and Karadi (2011). The intermediation of public assets responds to the external finance premium

$$\Theta_t = \Theta \left(\frac{EFP_t}{EFP} \right)^{v} \tag{2.59}$$

where $EFP_t = \left[R_{k,t} - \frac{R_t}{\pi_t} \right]$, EFP is the external finance premium at the steady state, Θ is the credit market intervention at the steady state, and v its intensity.

We examine the one percent shock in the capital quality, same as in the previous section. In Figure 2.4, we compare the responses of the economy in the presence of credit market intervention with the marked-line and without intervention in the continuous line. We set Θ at 0.10 at the steady state, which means 10% of the total assets are publicly intermediated, and the parameter v is set at 1.1.[6]

analysed from a micro perspective.

[6] According to Barbi (2014) public credit grew from 10 to 20 percent as a share of GDP from 2008 to 2010.

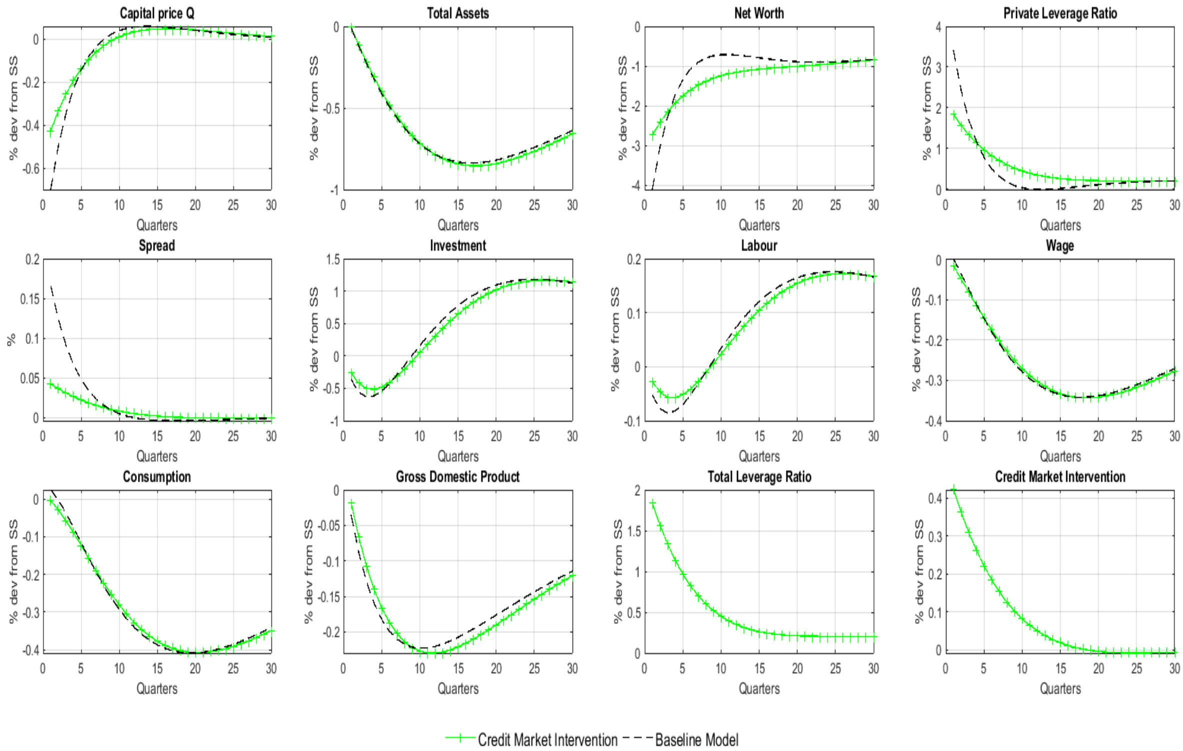

Figure 2.4: Responses to Capital Quality Shock

Previously, we found that the capital quality shock led to a fall in asset prices and the leverage of banks, which eroded their balance sheets and increased the external finance premium. Since the credit market intervention responds to equation (2.59), the additional supply of loans allocated to non-financial firms and financed with government funds. It eases the credit market conditions decreasing the fall in capital price and net worth as public credit offsets the shrink on private assets. The cost of capital and spread decreases while more public assets increase the credit supply and it enhances the banks' balance sheets indirectly. Credit market intervention finances some investment that would not be funded otherwise given the recession.

We observe that the contraction in investment and production is less severe, and the broader difference is in the first quarter after the shock. Overall, credit expansion improves the credit market conditions and de-leverage banks leading to the faster recovery of the economy.

2.4.4.2 Countercyclical Capital Requirements

Finally, we explore the case, where domestic banks are subject to the countercyclical capital requirements following the Basel III agreement. We examine the dynamics of the economy using capital requirements under the financial crisis scenario.

The countercyclical capital is used to reduce the leverage of banks by setting a minimum threshold. Banks breaching the threshold incur severe reputational costs and adverse market reactions. The capital threshold may operate even when banks are not at immediate risk of breaching the minimum. In this case, they face a cost seen as a tax that varies with the size of the cushion above the requirement (Borio and Zhu, 2012).

We examine capital requirements which set a cost to banks when they do not hold the minimum. We define the additional cost in deposits Ψ_t, parametrized by ψ

$$\Psi_t\left(\frac{1}{\phi_t}\right) = \psi\left(\zeta_t - \frac{1}{\phi_t}\right) \tag{2.60}$$

where $\frac{1}{\phi_t}$ is the capital to assets ratio N_t/Q_tS_t, and ζ_t is the countercyclical capital requirements. When banks meet the capital threshold there is no deviation respect to ζ_t and the cost Ψ_t is zero. If the capital-assets ratio is below the minimum requirement ζ_t and Ψ_t is positive, it results in a cost for banks. When the capital-asset ratio is above the minimum, Ψ_t is negative implies low exposure and a benefit for banks, which stimulates credit supply in periods of crisis. Capital requirements ζ_t adjust with the financial cycle reducing the ability of banks to building assets and mitigating systemic risk during booms.

Along the lines of Tavman (2015), we introduce Ψ_t, as an additional cost term of deposits in the banks' net worth motion equation (8).

$$n_t = R_{k,t}Q_{t-1}s_{t-1} - \left[\frac{1}{\pi_t}R_t + \Psi_t\right]d_{t-1} \tag{2.61}$$

Breaching the capital requirements would result in a positive Ψ_t, that would increase the cost of short-term liabilities for banks. Meeting the requirements above the minimum would imply a negative Ψ_t, that would reduce the cost of deposits extending the ability of banks to supply more credit. This mechanism is dynamic and especially beneficial for the banking system during downturns because it reduces the high exposure.

Banks solve their maximisation problem with the modified net worth expression.

$$V_t\left(s_{t-1}, d_{t-1}\right) = E_{t-1}\Lambda_{t-1,t}\left\{(1-\theta)\, n_t + \theta\left[\max_{s_t,d_t}\ V_t\left(s_t, d_t\right)\right]\right\} \tag{2.62}$$

$$V_t\left(s_t, d_t\right) \geq \lambda Q_t s_t$$

The leverage ratio changes to $\phi_t = \frac{Q_t s_t}{n_t}$ and the shadow value of a unit of net worth is $\Omega_t = (1-\theta) + \theta\left(\mu_{s,t}\phi + \nu_{d,t}\right)$. Additionally, the new cost of holding deposits is equal to

$$\nu_{d,t} = E_t\Lambda_{t,t+1}\Omega_{t+1}\left[\frac{1}{\pi_t}R_t + \Psi_t\right] \tag{2.63}$$

Similarly, the new external finance premium is given by

$$\mu_{s,t} = E_t\Lambda_{t,t+1}\Omega_{t+1}\left(R_{k,t+1} - \left[\frac{1}{\pi_t}R_t + \Psi_t\right]\right) \tag{2.64}$$

The aggregate net worth level of existing banks and total banks is as follows

$$N_{e,t} = \theta\left(R_{k,t}Q_{t-1}S_{t-1} - \left[\frac{1}{\pi_t}R_t + \Psi_t\right]D_{t-1}\right) \tag{2.65}$$

$$N_t = (\theta+\omega)R_{k,t}Q_{t-1}S_{t-1} - \theta\left[\frac{1}{\pi_t}R_t + \Psi_t\right]D_{t-1} \tag{2.66}$$

Similar to the credit market intervention, the capital requirements follows a dynamic rule based on credit growth

$$\zeta_t = \zeta + \gamma\left(\frac{Q_t S_t}{QS} - 1\right) \tag{2.67}$$

where ζ is the steady state level of the capital to assets ratio, QS is credit at the steady state, and $\gamma > 0$ is the parameter that denotes the intensity of the policy.

In Figure 2.5, we examine the case of one percent capital quality shock to the Brazilian economy. We set $\gamma = \psi = 1$ and we observe the impulse responses under the capital requirements policy in star-marked line and no MaP in dashed line.

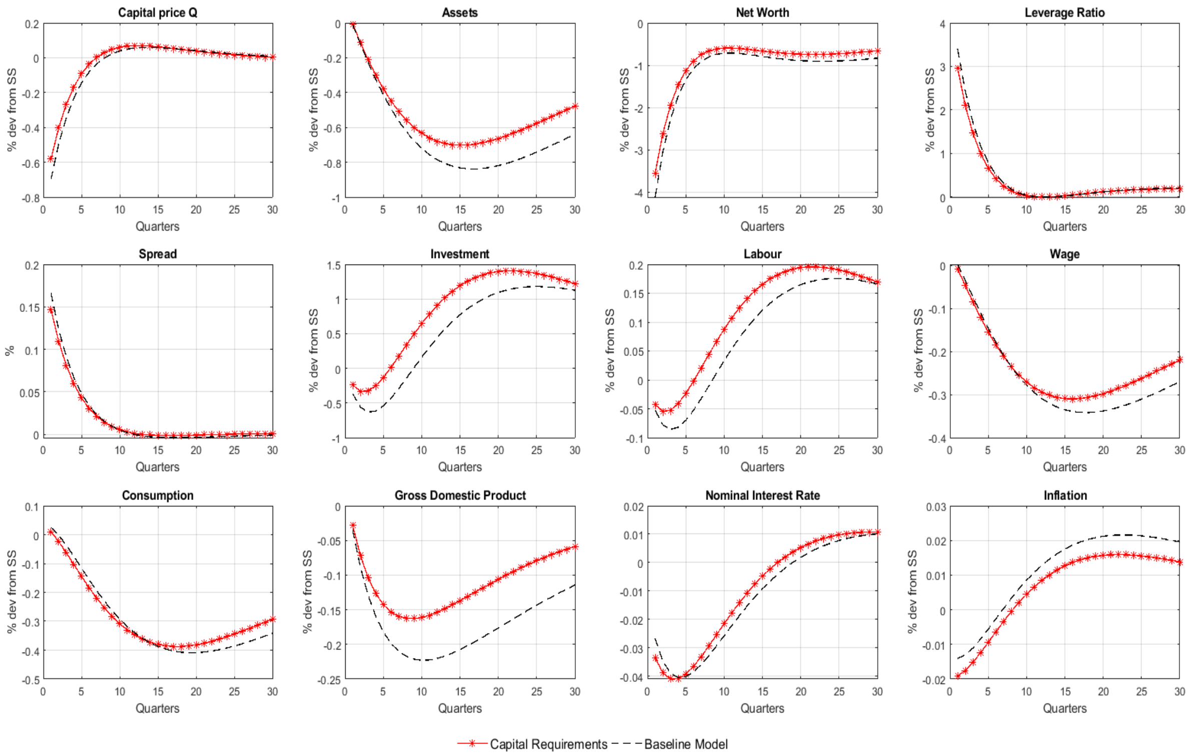

Figure 2.5: Responses to Capital Quality Shock

As we explain in previous sections, the capital quality shock reduces asset prices and banks' leverage. It weakens the banks' balance sheets worsening the credit market conditions and shrinking the credit supply. It leads to the decline in investment and output in the economy.

Using a countercyclical MaP such as capital requirements, the central bank can dampen the effects of the credit constraint in the economy by lowering the decline in assets, asset prices and net worth. The increase in the external finance premium and leverage is smaller, enhancing banks' balance sheets and the credit market conditions. Similarly, the drop in investment and output is less severe.

The capital requirements is a dynamic stabiliser that adjusts the threshold of required capital to asset ratio with the credit conditions in the market, see equation (2.67). Under MaP, the fall in asset values or credit, decreases the requirement of capital ζ_t, that co-moves with the financial cycle. That results in a lower cost Ψ_t per unit of short-term liabilities, dampening the decline in net worth after the shock and enhancing the balance sheets of banks. It pushes the external finance premium down reducing the fall in investment and output. Overall, the financial accelerator mechanism is mitigated to some extent with the implementation of MaP.

2.4.4.3 Welfare Analysis

Following Schmitt-Grohe and Uribe(2004), we can write recursively the households' utility function to define the welfare function

$$V_0^r = E_0 \sum_{t=0}^{\infty} \beta^t U\left(C_t^r, 1 - L_t^r\right) \tag{2.68}$$

where V_0^r is the welfare, C_t^r and $1 - L_t^r$ denote the contingent plans of consumption and leisure associated with the baseline model. V_0^a is the welfare when the central bank implements the credit market intervention or the capital requirements policy. Equation (2.69) shows that the welfare cost represents the equivalent consumption needed to equalise the welfare in the benchmark model and the welfare with the credit market intervention or MaP.

$$V_0^a = E_0 \sum_{t=0}^{\infty} \beta^t U\left((1-\lambda)C_t^r, L_t^r\right) \tag{2.69}$$

Let λ be the welfare cost of adopting one of the policies instead of the baseline model. It measures the fraction of consumption in the baseline model that a household is willing to give up to be as well off under the alternative policy. If $\lambda < 0$, that results in a gain of adopting the credit market intervention or MaP since V_0^a is higher than V_0^r.

The welfare cost is obtained by the following expression

$$\lambda = 1 - exp\left[(V_0^a - V_0^r)(1-\beta)\right] \tag{2.70}$$

We write recursively the utility function $V_t(C_t, L_t) = U_t + \beta V_{t+1}$, and take the second order approximation of V_t around the steady state. We use the second order solution and compute the welfare and the welfare cost for each of the two implemented policies. In Table 2.3, we present our results from a one percent capital quality shock in the economy.

We find that the welfare level when the central bank intervenes in the credit market is -7.482, which is higher than -15.411 in the baseline model. The welfare cost is equal to -0.210 meaning that households would have to raise their steady state consumption in 0.210 percent to be as well off as without credit market intervention policy. Under the capital requirements, welfare is equal to -6.752, that is clearly higher than the welfare in the baseline model. The welfare gain from implementing MaP is larger than a quarter of one percentage point. Therefore, households would have to increase their steady state consumption in 0.231 percent in the baseline model to have the same welfare than under a case where the central bank implements capital requirements as MaP.

Table 2.3: Welfare Analysis

	Welfare Cost	Welfare
Baseline model	-	-15.411
Credit Market Intervention	-0.210	-7.482
Capital Requirements	-0.231	-6.752

A negative welfare cost figure indicates that welfare under the policy is higher than under the baseline model.

Overall, both policies are welfare improving although households would be better off with MaP. The credit market intervention at 10 percent implies a massive amount of resources injected into the economy whereas, the countercyclical MaP enhances the credit market conditions by the regulation of the financial system. The credit market intervention in Brazil operated by financing only public banks while MaP would improve the balance sheets of all banks.

2.5 Concluding Remarks

In this chapter, we examined the scope of UMP versus MaP to recover the economy under a financial crisis scenario. We exposed the dynamics of the model under a credit expansion policy and a capital requirements in Brazil. We used a New Keynesian DSGE model *á la* Gertler and Kiyotaki (2010) and Gertler and Karadi (2011) to develop our analysis, and we explored the response of the economy under three shocks and two policy regimes.

A capital quality shock leads to a drop in asset prices, worsens the balance sheets of banks, increases the cost of capital and reduces credit supply. It amplifies the contraction of investment and output. As such, a shock is viewed as the representation of a financial crisis, as is widely adopted (see for example, Gertler and Kiyotaki (2010), Gertler and Karadi (2011), Gertler et al. (2012) and others). We also explored a monetary policy shock where a rise in interest rates weakens the balance sheets of banks increasing the cost of banks' liabilities and the finance external premium. The higher interest rate increases the cost of borrowing and leads to a decline in investment and output. In the case of a shock to total factor productivity, the propagation is from the real to the financial sector, reducing asset prices and deteriorating banks' balance sheets that amplify the contraction.

The credit market intervention policy finances additional investment and eases the credit market conditions through public banks. The policy successfully reduces the decline in investment and output under a financial crisis scenario. Countercyclical capital requirements dampens the effects of the credit constraint in the economy under the same circumstances. However, the mechanism is different. UMP injects liquidity into the economy to extend credit from public banks to non-financial firms. It alleviates the lack of funds in the credit markets, reducing the external finance premium and hence stimulating the economy. On the contrary, capital requirements strengthen the banks' balance sheets by reducing capital-assets ratio required. It enhances the position of banks' balance sheets expanding credit supply, alleviating the decline in investment and output.

Our results suggest that both policies mitigate the effects of the financial crisis. However, the channels of transmission of UMP and MaP are different. Capital requirements trigger a faster recovery than UMP. Although both policies are welfare improving, the welfare gain of households under capital requirements is significantly higher. Therefore, MaP is more effective in mitigating the shock whereas UMP is slower and more costly.

Overall, our findings suggest that a UMP with the target of cleaning after the financial crisis is not optimal regarding time of recovery, cost and welfare of households. In contrast, the implementation of capital requirements do not require the injection of money and provides faster recovery from the financial crisis. Moreover, the benefits for using MaP are greater relative to households' welfare. Finally, capital requirements viewed as a preventing measure strengthen the banking sector and address the potential risks of financial crisis. Therefore MaP is more effective in mitigating shocks.

Chapter 3

Global Financial Spillovers and Coordination of Macroprudential Policies

3.1 Introduction

The 2008-09 global financial crisis clearly highlighted the importance of financial stability. In the last ten years, there was a growing consensus among policy-makers and academics in favour of the financial markets regulation. Macroprudential Policies (MaPs) became one of the mechanisms for dampening the procyclicality of the financial system, particularly towards controlling systemic risk (IMF, 2011).

What has received less attention is the extent of the consequences of the global financial cycle on the peripheral economies. At present, a global liquidity squeeze can amplify cyclical movements and trigger international spillovers towards other countries. Central banks transmit their monetary policy within their jurisdictions but also across countries (Panetta, 2011; Rey, 2018). Miranda-Agrippino and Rey (2015) observe that the US monetary policy shocks are transmitted by the international credit channel to other countries.

Cetorelli and Goldberg (2012, 2009) relate changes in monetary policy shocks with constraints in cross border loans in Emerging Market Economies (EMEs). They use balance sheet data from 17 source countries and 24 destinations including Latin America, Emerging Asia and Emerging Europe. They observe that banks with global operations face monetary policy shocks by reducing the supply of cross border loans in EMEs.[1] Takats and Temesvary (2017) find similar evidence analysing currencies rather than countries. Global financial conditions also affect the international credit supply in EMEs. Cetorelli and Goldberg (2009); Herrmann and Mihaljek (2010); Takats (2010) and Lane (2014) find that global financial factors constrain cross border loans in EMEs.

In the presence of global financial spillovers, the question is whether the implementation of MaPs in a country can alleviate credit constraints in other countries. In the last few years, there has emerged an extensive literature linking global financial spillovers and MaPs. A joint study from the International Banking Research Network (IBRN), the ECB and the BIS relates changes in MaPs to changes in credit growth. The study focuses on the implications of MaPs on lending growth in a sample of countries (Buch and Goldberg, 2016; Baskaya et al., 2017; Berrospide et al., 2016; Jara et al., 2017; Baskaya et al., 2017; Levin-Konigsberg et al., 2017).

In a different approach, Avdjiev et al. (2017) link cross border loans and MaPs in the presence of a monetary policy shock, they find significant spillovers between countries. Similarly, Takáts et al. (2017) present empirical evidence that MaPs contribute to reduce the decline in cross border loans in EMEs following the taper tantrum. Aizenman et al. (2017) test empirically the degree of EMEs monetary independence under a US monetary policy shock. They find that a more extensive use of MaPs in EMEs contributes to increasing their monetary independence and are effective in controlling capital inflows.

In this chapter, we examine to what extent central banks can spur financial stability across jurisdictions by implementing MaPs. We use a New Keynesian two-country DSGE model, featuring banks a la Gertler and Kiyotaki (2010) and Gertler and Karadi (2011).

[1] A *cross border loan* is defined as the flow of loans from a bank in a country to a bank or non-bank in another.

We calibrate the model for an EME and an Advanced Economy (AE), Mexico and the US respectively. We incorporate global banks featuring the cross border bank lending between the AE and the EME as in Cuadra and Nuguer (2016). Central banks conduct monetary policy independently following a simple standard Taylor rule.

Our chapter differs from Cuadra and Nuguer (2016) in the research question and the scope of the analysis. They focus on the assessment of MaP in the EME under a global financial crisis shock. We explore how central banks can foster financial stability across jurisdictions. We assess the implementation of MaPs in the AE and the EME under a global financial crisis and a monetary policy shock. We also examine the case of coordination of policies between the AE and the EME under the same shocks.

Our aim in this chapter is twofold. First, we attempt to contribute to the international financial contagion literature by examining the transmission of global spillovers from an AE to an EME. Second, we show to what extent MaP are effective in mitigating shocks across countries and within their jurisdictions. We explore three policy scenarios, in the first case, there is a countercyclical MaP implemented in the AE by using capital requirements. The MaP aims to mitigate the shock in its jurisdiction and it may attenuate global spillovers in the EME. In the second case, the EME is the only economy fostering financial stability. The EME's central bank imposes a levy on cross border loans and we measure whether this is effective in dampening the effects of shocks in the EME. In the third case, both economies are conducting MaP.

We find that capital requirements in the AE enhance the AE banks' balance sheets dampening the effects of the credit constraint in that economy and mitigating the shock in the EME. Cross border loans are more resilient to the capital quality shock and foreign monetary policy shock with the MaP in place. A levy on cross border loans is highly effective in alleviating the decline in EME's investment and output. A coordination of MaP between the AE and the EME substantially mitigates systemic risk across countries. Capital requirements yield positive spillovers to the EME and are effective in controlling the spillovers in the AE. The levy reinforces the alleviation of the financial constraint in the EME.

Our results are in line with the empirical literature on the global financial spillovers and MaPs across countries (Avdjiev and Takáts, 2014; Miranda-Agrippino and Rey, 2015; Buch and Goldberg, 2016; Avdjiev et al., 2017; Takáts et al., 2017; Aizenman et al., 2017). Our findings are also consistent with the evidence on the international spillovers of the US monetary policy to Mexico (Cetorelli and Goldberg, 2012; Takats and Temesvary, 2017; Morais et al., 2014).

The chapter is organised into seven sections as follows. The second part describes some stylised facts. We present the model in the third section. We explain the calibration and diagnostics in the fourth section. The fifth section contains the results on the international lending transmission mechanism using a global financial crisis scenario and a monetary policy shock. The sixth and seventh sections present all the analysis of MaPs and the welfare evaluation. Finally, we state some concluding remarks.

3.2 Stylized Facts

EMEs experienced increasing inflows of cross border loans in the last twenty years. In Developing Asia and Pacific, cross border loans intensified since the 2000s, only decreasing in the 2008-09 financial crisis. Latin America and the Caribbean also attracted more cross border loans than in the past although they grew at a slower rate. In Developing Europe, cross border loans grew constantly before the 2008-09 financial crisis, however, they have been decreasing since 2009 see Figure 3.1.

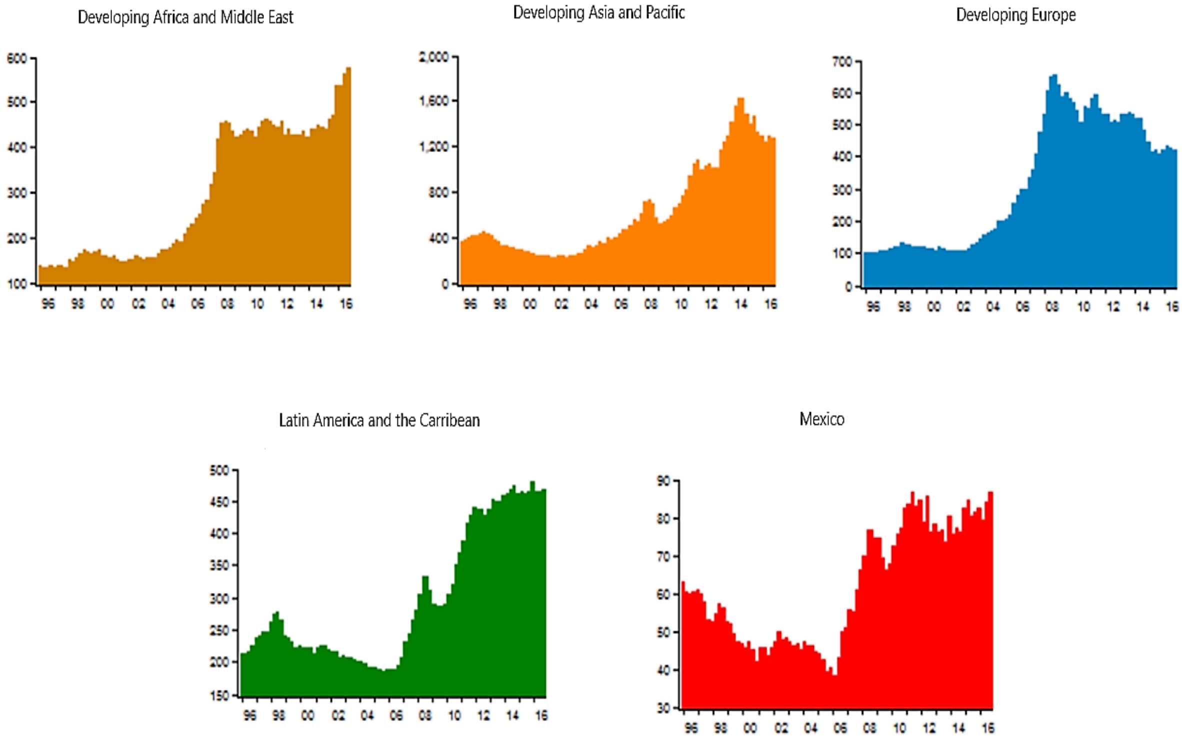

Figure 3.1: Cross Border Loans by Region of EMEs (in billions of USD dollars)

Source: BIS Locational Statistics

Figure 3.2 illustrates that a third of cross border loans in Mexico come from the US. It is explained by the close financial and commercial relations between these two countries, as formalized by The North American Free Trade Agreement (NAFTA).

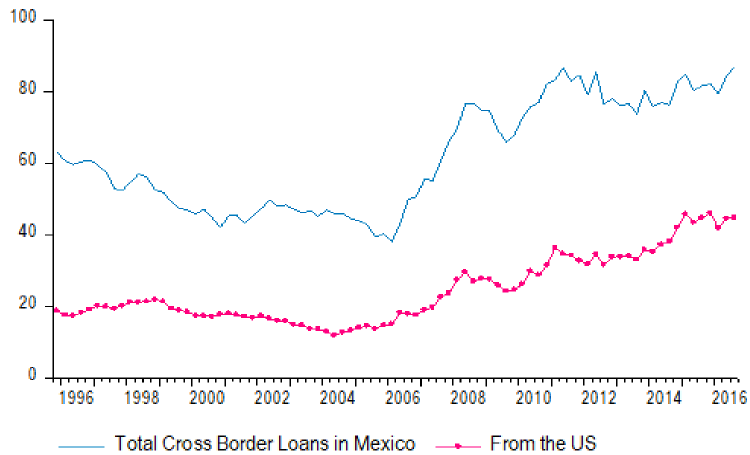

Figure 3.2: Cross Border Loans in Mexico, in Billion of USD Dollars

Source: BIS Locational Statistics, data by counterparty country

In Figure 3.3, we present the countries of origin that contribute to the rest of the cross border loans coming to Mexico. Flows from Spain and the UK have been growing recently. In the last few years, the Spanish banks increased their operations in the Mexican banking system, and banks like BBVA Bancomer or Santander Serfin gained a higher share of the market.

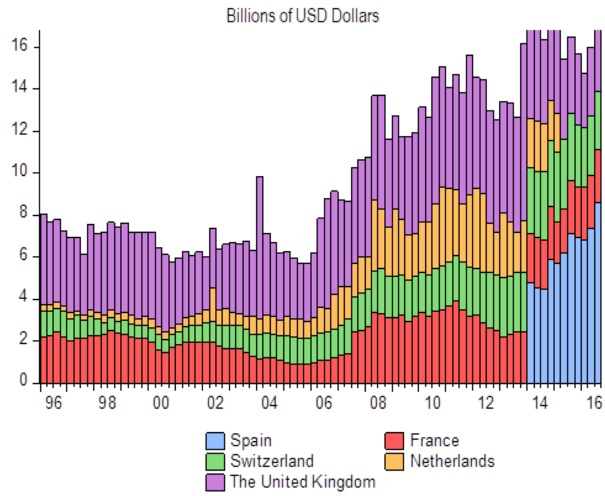

Figure 3.3: Cross Border Loans in Mexico from Other Main Origin Countries

Source: BIS Locational Statistics, data by counterparty country

Similarly, the key currencies used in Mexico for cross border loans are the USD dollars, the Euro and the Japanese Yen. Around 60% of the cross border operations (loans) are carried out in USD Dollars, 7% in Euros, and 3% in Japanese Yen, (Tables 5 and 6 in Appendix B.2 present more details).

3.3 Set-up of the Model

The analytical framework is a New Keynesian two-country model with financial frictions, global banks and cross border loans. Financial intermediaries are modelled as in Gertler and Kiyotaki (2010) and Gertler and Karadi (2011) and the cross border loans follows the approach of Dedola et al. (2013) and Cuadra and Nuguer (2016). We model the domestic country as an EME while the foreign country is an AE.

Foreign economy banks raise funds from households to operate and finance non-financial firms. Additionally, these banks provide funding to the domestic economy banks through cross border loans. In the foreign economy, banks live longer allowing them to accumulate more equity to operate. Banks in the EME acquire external funding from two sources: the first comes from the domestic households' deposits and the second from the AE bank loans.

The model does not differentiate subsidiaries of foreign banks operating in the domestic economy from domestic banks. Therefore, they are treated as domestic banks with their own capital. That is is feasible for the EME that we calibrate, since Mexico implemented some changes in the regulation after the Tequila crisis. The Central Bank of Mexico required foreign financial institutions to operate as separate legal entities with their own capital instead of as branches of foreign banks (Guzman-Calafell, 2013). In this regard, cross border loans are the operations between domestic banks and foreign banks. Henceforth, we will refer to domestic economy banks as *domestic banks* and foreign economy banks as *foreign banks* for simplicity.

The agents in the model are households, two types of good producers —intermediate and final-good firms—capital producers, banks and the central bank. Intermediate-good firms face quadratic menu costs á la Rotemberg (1982), a key source of nominal rigidities. The foreign and domestic central banks conduct monetary policy and MaP and they do independently.

In what follows we only describe the model for the domestic economy given that the framework is analogous for the foreign economy. However, we explain banks separately because some features of domestic banks are different from the foreign banks. We denote with an asterisk (*) all variables for the foreign country.

3.3.1 Households

There is a continuum of identical households that consume domestic and imported goods. They hold savings (in the domestic banks) and receive the risk-less return. Each household has two kinds of members: workers and bankers. Workers supply labour and obtain wages whereas bankers manage a bank and receive some earnings transferred to their own households at the end of the bank's life. Households deposit their savings in banks they do not own.

At each point in time, the fraction *1-f* of members in a household correspond to workers and the fraction f to bankers, and these ratios are constant. The horizon of the lifetime for bankers is finite, which guarantee banks do not reach the self-funding with their own net worth. Each period with probability θ a banker stays as a banker independently of her history while $1-\theta$ is the probability that this banker becomes a worker in the next period. The average survival time for a banker in any given period is $\frac{1}{1-\theta}$. At the beginning of time t the new bankers receive the fraction ω as "starting funds" from the household they belong to start the business. On the contrary, the exiting bankers (new workers), transfer their retained earnings to their respective households. All the above features follow closely those in Gertler and Kiyotaki (2010).

3.3.1.1 Preferences

The household preferences are represented by

$$maxE_t \sum_{t=0}^{\infty} \beta^t \left[lnC_t + \chi ln(1-L_t) \right] \tag{3.1}$$

where $\beta \in (0,1)$ is the discount factor and $\chi > 0$ is the relative weight of labour. Domestic households buy consumption goods from home $C_{H,t}$ and from the foreign country $C_{F,t}$. C_t is the composite consumption index of the two bundles of goods defined by a CES aggregator function

$$C_t = \left[(1-\gamma)^{\frac{1}{\eta}} C_{H,t}^{\frac{\eta-1}{\eta}} + \gamma^{\frac{1}{\eta}} C_{F,t}^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}} \tag{3.2}$$

where η is the elasticity of substitution between foreign and home goods. Following Faia and Monacelli (2008), we define γ as the weight of imported goods in the domestic consumption basket. It is composed for two elements, the relative size of the domestic economy n and the trade openness α_x. The total measure of the world economy is normalised to the unity, with the domestic economy having measure n and the foreign economy $1-n$. Therefore, the weight of imported goods in the domestic economy is $\gamma \equiv (1-n)\alpha_x$.[2]

The optimal allocation of domestic and foreign goods expenditure within each variety of goods are given by

$$C_{H,t}(i) = \frac{1}{n}\left(\frac{P_{H,t}(i)}{P_t}\right)^{-\varepsilon} C_{H,t} \tag{3.3}$$

$$C_{F,t}(i) = \frac{1}{1-n}\left(\frac{P_{F,t}(i)}{P_t}\right)^{-\varepsilon} C_{F,t} \tag{3.4}$$

where $C_{H,t} \equiv \int_0^n \left[C_{H,t}(i)^{\frac{\varepsilon-1}{\varepsilon}} di\right]^{\frac{\varepsilon}{\varepsilon-1}}$ and $C_{F,t} \equiv \int_0^n \left[C_{F,t}(i)^{\frac{\varepsilon-1}{\varepsilon}} di\right]^{\frac{\varepsilon}{\varepsilon-1}}$ are the aggregate levels of domestic and foreign goods, $P_{H,t}$ and $P_{F,t}$ are the price indexes for domestic and imported goods in domestic currency for the domestic economy and P_t is the CPI price index expressed by $P_t = \left[(1-\gamma)P_{H,t}^{1-\eta} + \gamma P_{F,t}^{1-\eta}\right]^{\frac{1}{1-\eta}}$. $C_{H,t}$ and $C_{F,t}$ are composed from imperfect and substitutable varieties with elasticity of substitution $\varepsilon > 1$. Thus, the optimal allocation of expenditures between domestic $C_{H,t}$ and imported goods $C_{F,t}$ yields

$$C_{H,t} = (1-\gamma)\left(\frac{P_{H,t}}{P_t}\right)^{-\eta} C_t \tag{3.5}$$

$$C_{F,t} = \gamma\left(\frac{P_{F,t}}{P_t}\right)^{-\eta} C_t \tag{3.6}$$

The budget constraint of domestic households is expressed as follows

$$C_t = \frac{W_t}{P_t}L_t + \Pi_t + \frac{R_t}{P_t}D_t - \frac{D_{t+1}}{P_t} - \frac{T_t}{P_t} \tag{3.7}$$

where D_t is the total quantity of short term debt from domestic households, R_t is the gross nominal return, W_t is the nominal wage, Π_t is the real profits from domestic firms and banks, T_t is nominal lump-sum tax and P_t the prices.

[2] In the foreign economy the CES composite function aggregator is similar to the domestic one $C_t^* = \left[(1-\gamma^*)^{\frac{1}{\eta}} C_{F,t}^{*\frac{\eta-1}{\eta}} + \gamma^{*\frac{1}{\eta}} C_{H,t}^{*\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}}$ and the weight of their imports is given by $\gamma^* \equiv n\alpha_x^*$.

Domestic households solve a maximization problem of their discounted expected utility subject to the budget constraint. Households choose $\{C_t, L_t, D_{t+1}\}$ and the first order conditions for consumption, labour and deposits are as follow

$$\varrho_t = \frac{1}{C_t} \tag{3.8}$$

$$\varrho \frac{W_t}{P_t} = \frac{\chi}{1 - L_t} \tag{3.9}$$

$$\varrho_t = \beta R_{t+1} \frac{P_t}{P_{t+1}} E_t \left[\varrho_{t+1}\right] \tag{3.10}$$

where equation (3.8) defines the Lagrange multiplier, ϱ_t as the marginal utility of consuming an additional unit of income at time t. Equation (3.9) is the labour supply and shows that the marginal rate of substitution between consumption and leisure is equal to the real wage. Equation (3.10) describes that the marginal utility from consuming one unit of income in time t is equal to the discounted marginal utility from consuming the gross income saved for future consumption. We arrange equation (3.10) to obtain the Euler equation for consumption so we take expectations in both sides and define $\Lambda_{t,t+1} = \beta \frac{\varrho_{t+1}}{\varrho_t}$ as the real stochastic discount factor over the time t and $t+1$.

$$E_t \left[\Lambda_{t,t+1} \frac{R_{t+1}}{\pi_{t+1}}\right] = 1 \tag{3.11}$$

3.3.1.2 The Exchange Rate, Terms of Trade and the Law of One Price

There is a continuum of foreign intermediate goods of i varieties which are composed in a foreign good, some part of this production goes to the foreign economy consumption $C^*_{F,t}$ and the rest is exported to the domestic economy $C_{F,t}$. Then, the law of one price holds for every variety of goods that $P_{F,t}(i) = \epsilon_t P^*_{F,t}(i)$, where ϵ_t is the nominal exchange rate of the foreign currency in terms of domestic units and $P^*_{F,t}(i)$ is the price of the (i) foreign goods in foreign currency.

The optimal allocation of foreign demands for the different varieties of goods are analogous to equations (3.5) and (3.6), therefore, the foreign demands for domestic and imported goods are as follows

$$C^*_{F,t} = (1-\gamma^*)\left(\frac{P^*_{F,t}}{P^*_t}\right)^{-\eta} C^*_t \tag{3.12}$$

$$C^*_{H,t} = \gamma^*\left(\frac{P^*_{H,t}}{P^*_t}\right)^{-\eta} C^*_t \tag{3.13}$$

where $C^*_{H,t}$ is the foreign demand for imports, that is from domestic goods. Additionally, P^*_t is the CPI index for the foreign economy, which is given by

$$P^*_t = \left[(1-\gamma^*)P^{*1-\eta}_{F,t} + \gamma^* P^{*1-\eta}_{Ht}\right]^{\frac{1}{1-\eta}}.$$

The terms of trade are defined as the relative price of imported goods $tot_t = \frac{P_{F,t}}{P_{H,t}}$ and the real exchange rate is equal to $q_{e,t} = \frac{\epsilon_t P^*_t}{P_t}$.

3.3.2 Non-financial Firms

There are three types of firms in each economy: capital producers, final-good producers and intermediate-good producers. The first two operate in a competitive market whereas the last in a market with monopolistic competition. The latter allows nominal rigidity for the wholesale firms. We assume that firms have symmetric setup in the domestic and foreign economy. In what follows, we present the structure for the domestic economy, and the equations can be easily extended to the foreign country.

3.3.2.1 Capital Producers

Domestic capital producers operate in a perfectly competitive market. They refurbish obsolete capital acquired from intermediate-good producers at the end of each period. Capital producers transform depreciated capital into new capital. The new and repaired capital is sold to the domestic intermediate good firms at the end of the time t for the next period. Q_t is the price of capital per unit that is endogenous in the model. This feature is relevant in the sense that fluctuations in the price of capital drive the financial accelerator mechanism, trigger balance sheet effects in the banking sector and have an impact on the investment decisions of firms.

Capital producers incur quadratic investment adjustment costs per unit of investment $S_t^k(X_t)$, given by $S_t^k(X_t) = \Phi_X (X_t - 1)^2$ where Φ_X is the parameter for adjustment cost, I_t is investment and $X_t = \frac{I_t}{I_{t-1}}$. Thus, capital producers choose I_t to maximise their expected discounted profits.

$$maxE_t \sum_{t=0}^{\infty} \Lambda_{t,t+1}\{Q_t[1 - S^k(X_t)I_t] - I_t\} \tag{3.14}$$

The optimality condition yields the following Q-investment relation for capital goods.

$$Q_t \left(1 - S^k(X_t) - X_t S^{k'}(X_t)\right) + E_t \left[\Lambda_{t,t+1} Q_{t+1} S^{k'}(X_{t+1}) X_{t+1}^2\right] = 1 \tag{3.15}$$

Therefore, K_{t+1} is the aggregate capital stock in time $t + 1$ and equation (3.16) is the capital accumulation

$$K_{t+1} = I_t \left[1 - S_t^k(X_t)\right] + (1 - \delta)K_t \tag{3.16}$$

where δ is the parameter that denotes the depreciation rate of capital. The optimisation problem can be seen in detail the Appendix B.1.1.

3.3.2.2 Final Goods Firms

Final-good producers operate in a competitive market, combining different varieties of goods $Y_{H,t}(i)$ from the i domestic intermediate-good firms. Final-good producers purchase each unit of $Y_{H,t}(i)$ at the price $P_{H,t}(i)$ that is determined in the intermediate good market. They repackage these varieties and obtain a homogeneous compound final good that is sold at the competitive price $P_{H,t}$ in the domestic market.[3] The domestic

[3] Imports occur once the intermediate goods have been compounded in the final ones and the prices have been determined for the intermediate-good firms. The price of imports is taken as given and the law of one price holds.

output is expressed by a Dixit-Stiglitz aggregator

$$Y_{H,t} = \frac{1}{n}\left[\int_0^n Y_{H,t}(i)^{\frac{\varepsilon-1}{\varepsilon}} di\right]^{\frac{\varepsilon}{\varepsilon-1}} \tag{3.17}$$

where $Y_{H,t}$ is the aggregate domestic output in period t of the retailers, $Y_{H,t}(i)$ is the intermediate good i and ε is the elasticity of substitution between varieties. The model assumes imperfect substitution among varieties, which means each intermediate-good firm has some market power to set prices and $\varepsilon > 1$. This parameter expresses the curvature of the aggregation, and the more it approaches to the unit $\varepsilon \to 1$, the closer to perfect substitutes these goods are. Additionally, n denotes the size of the domestic market and $\frac{1}{n}$ is the share of the domestic economy. Final-good producers maximise as follows

$$P_{H,t}Y_{H,t}(i) - \int_0^n P_{H,t}Y_{H,t}(i)di \tag{3.18}$$

subject to

$$Y_{H,t}(i) = \left(\frac{1}{n}\right)^{\frac{1}{\varepsilon}}\left[\int_0^n Y_{H,t}(i)^{\frac{\varepsilon-1}{\varepsilon}} di\right]^{\frac{\varepsilon}{\varepsilon-1}} \tag{3.19}$$

yielding the demand for good i

$$Y_{H,t}(i) = \frac{1}{n}\left(\frac{P_{H,t}(i)}{P_{H,t}}\right)^{-\varepsilon} Y_{H,t} \tag{3.20}$$

3.3.2.3 Intermediate Good Firms

There is a large number of intermediate-good producers in the domestic country, they are indexed by i and produce the variety $Y_{H,t}(i)$ combining capital and labour with constant returns to scale technology

$$Y_{H,t}(i) = A_t K_t(i)^{\alpha} L_t(i)^{1-\alpha} \tag{3.21}$$

where α is the share of capital, A_t denotes an exogenous and stochastic total factor productivity shock, that follows an AR(1) process described by

$$ln(A_t) = \gamma_A ln(A_{t-1}) + \epsilon_{A,t} \tag{3.22}$$

where the parameter persistence is $0 < \gamma_A < 1$ and $\epsilon_{A,t}$ is distributed as $\epsilon_{A,t} \sim N(0, \sigma_A)$.

The intermediate-good producer i chooses the optimal price $P_{H,t}(i)$ to meet the aggregate domestic demand for the variety i given by equation (3.20).

$$Y_{H,t}(i) = \frac{1}{n}\left(\frac{P_{H,t}(i)}{P_{H,t}}\right)^{-\varepsilon} Y_{H,t}$$

Intermediate good producers operate as monopolistic competitors. These firms incur in nominal marginal cost of production mc_t and additionally face Rotemberg(1982) quadratic menu costs of price adjustment represented by the following form

$$\frac{\varphi^H}{2}\left[\frac{P_{H,t}(i)}{P_{H,t-1}(i)} - 1\right]^2 \tag{3.23}$$

where φ^H captures the intensity of the price rigidity in nominal terms. The domestic intermediate-good producers decide the optimal price level to maximise their present discounted real profits such as follows,

$$maxE_t \sum_{t=0}^{\infty} \beta^t \left[\frac{P_t(i)}{P_t} Y_{H,t}(i) - \frac{W_t}{P_t} L_t(i) - Q_t R_{k,t} K_t(i) - \frac{\varphi^H}{2}\left[\frac{P_{H,t}(i)}{P_{H,t-1}(i)} - 1\right]^2 Y_{H,t}\right]$$

subject to

$$Y_{H,t}(i) = \left(\frac{P_{H,t}(i)}{P_{H,t}}\right)^{-\varepsilon} Y_{H,t}$$

$$Y_{H,t}(i) = A_t K_t(i)^{\alpha} L_t(i)^{1-\alpha}$$

where $R_{k,t}$ is the return on capital. Intermediate-good firms take identical decisions then the aggregate level is defined by adding over i. The first order conditions yield the optimal price and the optimal factor demands. In equation (3.24), the optimal relative price in the domestic economy is $\frac{P_{H,t}}{P_t}$, the marginal cost is $mc_t = \frac{\varepsilon-1}{\varepsilon}$ and $rmc_t = \frac{mc_t}{P_t}$ denotes the real marginal cost. Additionally, $\pi_{H,t} = \frac{P_{H,t}}{P_{H,t-1}}$ is the domestic inflation.

$$\frac{P_{H,t}}{P_t} = \frac{\varepsilon}{\varepsilon-1} rmc_t - \frac{\varphi^H}{\varepsilon-1}\pi_{H,t}\left(\pi_{H,t}-1\right) + \frac{\varphi^H}{\varepsilon-1} E_t\left\{\Lambda_{t,t+1}\frac{\pi_{H,t+1}\left(\pi_{H,t}-1\right)Y_{H,t+1}}{Y_{H,t}}\right\} \tag{3.24}$$

Note that under full flexibility of prices $\varphi^H = 0$, the optimal sales price still would be above the marginal cost because intermediate-good firms hold a mark-up, then $\frac{P_{H,t}}{P_t} = \frac{\varepsilon}{\varepsilon-1} rmc_t$. This price-setting framework is analogous in the domestic and foreign economies and φ^H is calibrated according to each economy.

We display the demand for labour in equation (3.25), the real gross profits per unit of capital Z_t, in (3.26) and the return on capital in (3.27)

$$\frac{W_t}{P_t} = (1-\alpha)A_t rmc_t \left(\frac{K_t}{L_t}\right)^{\alpha} \tag{3.25}$$

$$Z_t = (\alpha)A_t rmc_t \left(\frac{K_t}{L_t}\right)^{\alpha-1} \tag{3.26}$$

$$R_{k,t} = \frac{[Z_t + Q_t(1-\delta)]}{Q_{t-1}} \tag{3.27}$$

3.3.3 Banks

To finance operations, banks in each country borrow funds from local households in the form of deposits D_t. In addition, domestic banks receive foreign currency funds from the foreign banks in the form of *cross border loans* B_t, these flows are negotiated between the financial institutions of the two countries. Taking into account their balance sheets and net worth N_t, banks decide how much to lend to local intermediate-good firms S_t.

The lifetime of banks is finite to guarantee they do not reach the self-funding. A bank stays as a bank next period with probability θ independently of its history, and $1-\theta$ is the probability that this bank exits the sector in the next period. At the beginning of time t, new banks receive the starting funds ω, that is a fraction of total assets. Note that foreign banks have a higher survival rate $\theta^* > \theta$, then, their lifetime is longer, and they accumulate a larger net worth. It allows them to finance domestic banks, such as in Cuadra and Nuguer (2016).

The model has two financial frictions, the first one constrains the banks' ability to accumulate assets indefinitely. They face a moral hazard enforcement problem such as in Gertler and Kiyotaki (2010) and Gertler and Karadi (2011). Households save deposits in banks as long as the present value of the future profits of an individual bank is higher than its earnings from diverting funds. In the model, this constraint always binds, and the level of the restriction depends on the diverting funds' fraction λ. When $\lambda \Rightarrow 1$ it implies there is a tighter borrowing constraint for banks and when $\lambda \Rightarrow 0$ that means there is a higher accumulation of assets because they receive more funding.

The second financial friction relies on the ability of domestic banks for being financed by foreign banks. Domestic banks are borrowing-constrained to obtain foreign bank loans so they face the enforcement problem and pay a risk premium for the uncertainty. Domestic banks may run away with a fraction ω_a of the cross-border loans. If $\omega_a = 1$, domestic banks do not run away with cross border loans. In the case of the first financial constraint did not bind, domestic banks would only divert domestic funds. On the contrary, when $\omega_a \Rightarrow 0$ the degree of domestic banks' risk increases as domestic banks may divert a fraction of cross border loans and some domestic deposits. Cuadra and Nuguer (2016) explore the two cases, we have allowed a very small level of risk and the EME is calibrated with ω_a close to 1.

As a result of the financial frictions, the model presents two significant features: there exist an external finance premium and a risk premium. Firstly, the external finance premium is the difference between the return on capital $R_{k,t}$ and the interest rate of deposits R_t see equation (3.28). The external finance premium is a result of the financial friction between households and banks.

$$E_t\left\{\Lambda_{t,t+1}[R_{k,t+1} - R_{t+1}\frac{1}{\pi_{t+1}}]\right\} \geq 0 \tag{3.28}$$

Secondly, the risk premium is the excess of return between the cross border loans $R_{b,t}$ and deposits R_t see equation (3.29). It emerges from the domestic banks uncertainty of borrowing from foreign banks. Domestic banks maximise profits internalising the risk of running away with cross border loans ω_a yielding the risk premium such as Cuadra and Nuguer (2016). When domestic banks can run away with a fraction of cross border loans, the risk premium is higher than zero. We calibrate the model assuming that ω_a is very close to 1.[4]

$$E_t\left\{\Lambda_{t,t+1}\frac{1}{\pi_{t+1}}[R_{b,t+1} - R_{t+1}]\right\} \geq 0 \tag{3.29}$$

The return on capital is higher than the return on cross border loans, then, domestic banks hold a margin of profits to provide credit to domestic intermediate-good firms by borrowing cross border loans.

3.3.3.1 Domestic Banks

In the domestic economy the balance sheet of an individual bank is as follows

$$Q_t s_t = n_t + d_t + Q_{b,t} b_t \tag{3.30}$$

where s_t are assets that equates the amount of loans made to domestic wholesale firms. Q_t, is the relative price of each domestic asset, n_t is the net worth, d_t the amount of deposits, b_t the quantity of cross border loans and $Q_{b,t}$ its relative price. The accumulation of net worth for an individual bank is

$$n_t = R_{k,t} Q_{t-1} s_{t-1} - R_{b,t} Q_{b,t-1} b_{t-1} \frac{1}{\pi_t} - R_t d_{t-1} \frac{1}{\pi_t} \tag{3.31}$$

[4] Country risk premium in Mexico was equal to 1.38% in December 2017, following the available data calculated by Aswath Damodaran, Stern School Business `http://www.stern.nyu.edu/~adamodar/pc/datasets/ctryprem.xls`.

where $R_{k,t}$ is the return on loans to intermediate-good firms, $R_{b,t}$ is the interest rate of cross border loans and R_t is the return on deposits, the three of them from period $t-1$ to t, and π_t is the inflation rate. For the domestic banks, cross border loans and deposits are a liability. The second term of equation (3.31) is defined in domestic currency so it has been adjusted by ϵ_t, the nominal exchange rate and $Q_{b,t-1}b_{t-1} = \epsilon_t Q^*_{b,t-1}b^*_{t-1}$.

At the end of period t, the individual bank maximises the present value of its future dividends, where θ is the probability of surviving in the next period and $\Lambda_{t,t+i}$ the stochastic discount factor.

$$V_t = maxE_t \sum_{i=1}^{\infty} (1-\theta)(\theta)^{i-1} \Lambda_{t,t+i} n_{t+i} \tag{3.32}$$

The maximisation problem of the individual bank is subject to the incentive constraint of banks

$$V_t(s_t, b_t, d_t) \geq \lambda(Q_t s_t - \omega_a Q_{b,t} b_t) \tag{3.33}$$

where the expected value $V_t(s_t, b_t, d_t)$ must be at least as large as the gain of diverting a fraction of its funds $\lambda(Q_t s_t - \omega_a Q_{b,t} b_t)$. The constraint always binds and it implies that it is more profitable for banks to not divert funds. It ensures households are willing to deposit their money in banks.

For domestic banks, the amount of funds available for diverting is subject to the value of ω_a. If $\omega_a = 1$ domestic banks do not run away with cross border loans from foreign banks. It means in case of diverting funds, domestic banks would discount first the total amount of cross border loans. For values of $0 < \omega_a < 1$ there is a fraction of cross border loans which domestic banks can divert.

To solve the maximisation problem of the individual bank, equation (3.32) is written as a Bellman equation as it is stated below with the constraint given by equation (3.33).

$$V_t(s_{t-1}, b_{t-1}, d_{t-1}) = E_{t-1}\Lambda_{t-1,t}\left\{(1-\theta) n_t + \theta \left[\max_{s_t, b_t, d_t} V_t(s_t, b_t, d_t)\right]\right\} \tag{3.34}$$

$$V_t(s_t, b_t, d_t) \geq \lambda(Q_t s_t - \omega_a Q_{b,t} b_t)$$

Following the approach of Gertler and Kiyotaki (2010) and Cuadra and Nuguer (2016) to solve the maximisation problem, we guess and verify the value function of an individual bank. For simplicity we assume this functional form is linear in s_t, b_t and d_t such as

$$V_t\left(s_t, b_t, d_t\right) = \nu_{s,t}s_t - \nu_{b,t}b_t - \nu_{d,t}d_t \tag{3.35}$$

where $\nu_{j,t}\forall,\ j = s, b, d$ are the time-varying marginal values of assets, cross border loans and deposits, all of them at the end of time t.

In Appendix B.1.4.1, we explain the optimisation problem in detail, here we present the first order conditions for s_t, b_t and d_t as follows

$$\left(\frac{\nu_{s,t}}{Q_t} - \frac{\nu_{b,t}}{Q_{b,t}}\right)(1 + \lambda_{lag,t}) = \lambda_{lag,t}\lambda(1 - \omega_a) \tag{3.36}$$

$$\left(\frac{\nu_{b,t}}{Q_{b,t}} - \nu_{d,t}\right)(1 + \lambda_{lag,t}) = \lambda_{lag,t}\lambda\omega_a \tag{3.37}$$

$$Q_t s_t\left[\lambda - \left(\frac{\nu_{s,t}}{Q_t} - \nu_{d,t}\right)\right] - Q_{b,t}b_t\left[\lambda\omega_a - \left(\frac{\nu_{b,t}}{Q_{b,t}} - \nu_{d,t}\right)\right] = \nu_{d,t}n_t \tag{3.38}$$

From equations (3.36) and (3.37), we obtain the shadow value of an additional unit of holding assets and it is higher than the shadow cost of holding cross border loans. $\frac{\nu_{b,t}}{Q_{b,t}}$ is equal to $\frac{\nu_{s,t}}{Q_t}$ only when banks do not run away with cross border loans ($\omega_a = 1$) and the risk premium is equal to zero see equation (3.39).

$$\frac{\nu_{b,t}}{Q_{b,t}} = \omega_a\frac{\nu_{s,t}}{Q_t} + (1 - \omega_a)\,\nu_t \tag{3.39}$$

Let $\mu_{s,t} = \left(\frac{\nu_{s,t}}{Q_t} - \nu_{d,t}\right)$ and $\mu_{b,t} = \left(\frac{\nu_{b,t}}{Q_{b,t}} - \nu_{d,t}\right)$ be the excess marginal value of assets over deposits and the excess marginal value of cross border loans over deposits. Then, $\mu_{s,t}$ is higher than $\mu_{b,t}$ because domestic banks are constrained in their ability to be financed by foreign banks. Domestic banks pay a risk premium for the cross border loans as $0 < \omega_a < 1$. The cost of borrowing with foreign banks is higher than the cost of deposits reducing $\mu_{b,t}$ relative to $\mu_{s,t}$. On the contrary, they are equal when $\omega_a = 1$.

$$(\mu_{s,t} - \mu_{b,t})\,\omega_a = \mu_{b,t}(1 - \omega_a)$$

$$\mu_{s,t}\omega_a = \mu_{b,t} \tag{3.40}$$

Besides, the balance sheet of the individual bank can be re-written by using the first order condition (3.38) and the definitions of $\mu_{s,t}$ and $\mu_{b,t}$.

$$Q_t s_t \left[\lambda - \left(\frac{\nu_{s,t}}{Q_t} - \nu_{d,t}\right)\right] - Q_{b,t} b_t \left[\lambda\omega_a - \left(\frac{\nu_{b,t}}{Q_{b,t}} - \nu_{d,t}\right)\right] = \nu_{d,t} n_t \tag{3.41}$$

$$Q_t s_t \left(\lambda - \mu_{s,t}\right) - Q_{b,t} b_t \left(\lambda\omega_a - \mu_{b,t}\right) = \nu_{d,t} n_t \tag{3.42}$$

We define ϕ_t as the leverage ratio of banks that is the ratio of assets to equity.

$$\phi_t = \frac{\nu_{d,t}}{\lambda - \mu_{s,t}} \tag{3.43}$$

When λ is higher, the leverage ratio goes down because the accumulation of assets is lower, therefore, they move in opposite direction. On the other hand, the excess value of assets over deposits $\mu_{s,t}$ co-moves with the leverage. That is, λ is a countercyclical variable whereas $\mu_{s,t}$ is pro-cyclical.

The balance sheet of an individual domestic bank is as below

$$Q_t s_t - \omega_a Q_{b,t} b_t = \phi_t n_t \tag{3.44}$$

In Appendix B.1.4.1, we guess and verify the functional form of the value function from an individual bank. The final equation for each variable, assets s_t, cross border loans b_t and deposits d_t respectively are as follow,

$$\nu_{s,t} = E_t \Lambda_{t,t+1} \Omega_{t+1} R_{k,t+1} Q_t \tag{3.45}$$

$$\nu_{b,t} = E_t \Lambda_{t,t+1} \Omega_{t+1} R_{b,t+1} Q_{b,t+1} \frac{1}{\pi_{t+1}} \tag{3.46}$$

$$\nu_{d,t} = E_t \Lambda_{t,t+1} \Omega_{t+1} R_{t+1} \frac{1}{\pi_{t+1}} \tag{3.47}$$

where Ω_t is the shadow value of a unit of net worth.

$$\Omega_t = (1-\theta) + \theta \left(\mu_{s,t}\phi_t + \nu_{d,t}\right) \tag{3.48}$$

We obtain equations for excess marginal value of assets over deposits $\mu_{s,t}$ and the excess marginal value of cross border loans over deposits $\mu_{b,t}$, we re-write them as below.

$$\mu_{s,t} = E_t \Lambda_{t,t+1} \Omega_{t+1} \left(R_{k,t+1} - R_{t+1} \frac{1}{\pi_{t+1}} \right) \tag{3.49}$$

$$\mu_{b,t} = E_t \Lambda_{t,t+1} \Omega_{t+1} \frac{1}{\pi_{t+1}} \left(R_{b,t+1} - R_{t+1}\right) \tag{3.50}$$

The financial friction in the domestic economy ensures that the spread between returns on capital and deposits is greater than zero $(R_{k,t+1} - R_{t+1}) > 0$, at the same time the borrowing constraint of domestic banks makes the interest rate on the cross border loans greater than the return on deposits $(R_{b,t+1} - R_{t+1}) > 0$. From equation (3.40), in the model $\mu_{s,t} > \mu_{b,t}$, the return o capital is higher than the interest rate on cross border loans and it is higher than the cost of holding deposits $R_{k,t+1} > R_{bt+1} > R_{t+1}$. Under the assumption that banks are not risky, $R_{b,t+1}$ is equal to R_{t+1}.

3.3.3.2 Foreign Banks

In the foreign economy the balance sheet of an individual bank is as follows; its assets are equal to loans made to local wholesale firms s_t^* at the relative price Q_t^* plus cross border loans made to the domestic banks b_t^* at the relative price $Q_{b,t}^*$. In the right side, we have the amount of net worth n_t^* and deposits d_t^* at time t.

$$Q_t^* s_t^* + Q_{b,t}^* b_t^* = n_t^* + d_t^* \tag{3.51}$$

The net worth accumulation from an individual bank is equal to the payoff from assets net of the payments for liabilities

$$n_t^* = R_{k,t}^* Q_{t-1}^* s_{t-1}^* + R_{b,t}^* Q_{b,t-1}^* b_{t-1}^* \frac{1}{\pi_t^*} - R_t^* d_{t-1}^* \frac{1}{\pi_t^*} \tag{3.52}$$

where $R_{k,t}^*$ is the return on loans to intermediate good firms, $R_{b,t}^*$ is the return on cross border loans, R_t^* is the return on deposits all from period $t-1$ to t and π_t^* is the inflation rate.

At the end of each period an individual bank maximises the present value of its future dividends

$$V_t^* = maxE_t \sum_{i=1}^{\infty} (1-\theta)^* (\theta^*)^{i-1} \Lambda_{t,t+i}^* n_{t+i}^* \tag{3.53}$$

The maximisation problem of a foreign individual bank is subject to the incentive constraint of banks to diverting funds. In this case the value of the individual bank $V_t^* (s_t^*, b_t^*, d_t^*)$ must be at least as large as the gain of diverting funds $\lambda^*(Q_t^* s_t^* + Q_{b,t}^* b_t^*)$. This inequality always binds such as in the domestic economy.

$$V_t^* (s_t^*, b_t^*, d_t^*) \geq \lambda^*(Q_t^* s_t^* + Q_{b,t}^* b_t^*) \tag{3.54}$$

Analogously, the individual foreign bank maximises the expected value subject to the incentive constraint, so we write the Bellman equation as below

$$V_t^* \left(s_{t-1}^*, b_{t-1}^*, d_{t-1}^*\right) = E_{t-1} \Lambda_{t-1,t}^* \left\{ (1-\theta)^* n_t^* + \theta^* \left[\max_{s_t^*, b_t^*, d_t^*} V_t^* (s_t^*, b_t^*, d_t^*) \right] \right\} \tag{3.55}$$

$$V_t^* (s_t^*, b_t^*, d_t^*) \geq \lambda^*(Q_t^* s_t^* + Q_{b,t}^* b_t^*)$$

The guess for the value function is linear in s_t^*, b_t^* and d_t^* for simplicity and $\nu_{j,t}^* \forall$, $j = s^*, b^*, d^*$ are the time-varying marginal values of assets, cross border loans and the marginal cost of deposits at the end of time t

$$V_t^*\left(s_t^*, b_t^*, d_t^*\right) = \nu_{s,t}^* s_t^* + \nu_{b,t}^* b_t^* - \nu_{d,t}^* d_t^* \tag{3.56}$$

In Appendix B.1.4.2, we present the optimisation problem with more detail the results are similar to the domestic banks, with the difference that $\left(\frac{\nu_{s,t}^*}{Q_t^*} - \nu_{d,t}^*\right)$ is equal to $\left(\frac{\nu_{b,t}^*}{Q_{b,t}^*} - \nu_{d,t}^*\right)$. Therefore, $\mu_{s,t}$ is the excess value of the banks' total assets, s_t^* and b_t^*.

$$\mu_{s,t}^* = \frac{\nu_{s,t}^*}{Q_t^*} - \nu_{d,t}^* \tag{3.57}$$

and the leverage ratio is

$$\phi_t^* = \frac{\nu_{d,t}^*}{\lambda^* - \mu_{s,t}^*} \tag{3.58}$$

The final equations for s_t^*, b_t^*, d_t^*, μ_t^* and Ω_t^* are as follows

$$\nu_{s,t}^* = E_t \Lambda_{t,t+1}^* \Omega_{t+1}^* R_{k,t+1}^* Q_t^* \tag{3.59}$$

$$\nu_{b,t}^* = E_t \Lambda_{t,t+1}^* \Omega_{t+1}^* R_{b,t+1}^* Q_{b,t+1}^* \frac{1}{\pi_{t+1}^*} \tag{3.60}$$

$$\nu_{d,t}^* = E_t \Lambda_{t,t+1}^* \Omega_{t+1}^* R_{t+1}^* \frac{1}{\pi_{t+1}^*} \tag{3.61}$$

$$\mu_t^* = E_t \Lambda_{t,t+1}^* \Omega_{t+1}^* \left(R_{k,t+1}^* - R_{t+1}^* \frac{1}{\pi_{t+1}^*}\right) \tag{3.62}$$

Since $\frac{\nu_{s,t}^*}{Q_t^*} = \frac{\nu_{b,t}^*}{Q_{b,t}^*}$ the returns on loans to intermediate good firms and returns on cross border loans sent to domestic banks are equal and foreign banks are indifferent to lending either to foreign intermediate-good firms or domestic banks.

$$E_t \Lambda_{t,t+1}^* \Omega_{t+1}^* R_{k,t+1}^* = E_t \Lambda_{t,t+1}^* \Omega_{t+1}^* R_{b,t+1}^* \frac{1}{\pi_{t+1}^*} \tag{3.63}$$

3.3.3.3 Aggregate Net Worth in Domestic and Foreign Banks

We have assumed banks are homogeneous in the economy, therefore the aggregate balance sheet of banks does not include specific features of an individual bank and it is expressed as in equations (3.64) and (3.65) for the domestic and foreign economy.

$$Q_t S_t - \omega_a Q_{b,t} B_t = \phi_t N_t \tag{3.64}$$

$$Q_t^* S_t^* + Q_{b,t}^* B_t^* = \phi_t^* N_t^* \tag{3.65}$$

The motion equations for the net worth in each economy are

$$N_t = (\theta + \omega) R_{k,t} Q_{t-1} S_{t-1} - \theta \frac{1}{\pi_t} R_t D_{t-1} - \theta \frac{1}{\pi_t} R_{b,t} Q_{b,t-1}^* B_{t-1} \tag{3.66}$$

$$N_t^* = (\theta^* + \omega^*) \left[R_{k,t}^* Q_{t-1}^* S_{t-1}^* + \frac{1}{\pi_t^*} R_{b,t}^* Q_{b,t-1}^* B_{t-1}^* \right] - \theta^* \frac{1}{\pi_t^*} R_t^* D_{t-1}^* \tag{3.67}$$

where ω and ω^* denote the fraction of assets that are provided as "starting funds" every period. θ and θ^* are the survival rate of banks each period, then we have aggregated the net worth of the existing and new banks in the domestic and foreign economy, in equations (3.66) and (3.67) respectively.

Finally, such as in Cuadra and Nuguer (2016) we include an additional term in equation (3.63) to close the model and induce stationarity since the domestic country is a small open economy. We follow Schmitt-Grohé and Uribe (2003) and add a foreign debt-elastic interest rate premium see equation (3.68). In this framework foreign debt is given by the cross border loans

$$E_t \Lambda_{t,t+1}^* \Omega_{t+1}^* R_{k,t+1}^* = E_t \Lambda_{t,t+1}^* \Omega_{t+1}^* R_{b,t+1}^* \frac{1}{\pi_{t+1}^*} + \Psi_b \left[exp(B_t^* - B^*) - 1 \right] \tag{3.68}$$

where Ψ is the elasticity of foreign debt, B_t^* is the aggregate level of cross border loans emitted by foreign banks to the domestic country and B^* is its steady state level. This term is linked to the risk premium for the domestic economy.

Intermediate good firms in both countries determine future plans of investment and finance them with bank loans. At the end of t, intermediate good producers buy new capital issuing a claim for each unit. Assets in the banking sector of each economy are backed up for the amount of capital in each economy. The link between assets and capital features the financial accelerator mechanism (Bernanke et al., 1999; Gertler and Kiyotaki, 2010).

3.3.4 Monetary Policy and Resource Constraints

We assume that monetary policy is conducted by the central bank through the nominal interest rate function constrained to be linear in logarithms of the relevant arguments

$$ln\left(\frac{R_t}{R}\right) = \kappa_\pi ln\left(\frac{\pi_t}{\pi}\right) + \kappa_y ln\left(\frac{y_t}{y}\right) \tag{3.69}$$

where R is the nominal interest rate at the steady state level, π is the steady state inflation rate and y is the steady state output with $\{\kappa_\pi\} \in (1, \infty]$ and $\{\kappa_y\} \in (0, \infty]$. Similar to Schmitt-Grohé and Uribe (2007) and Faia and Monacelli (2007), we model the monetary policy using an implementable Taylor rule. The central bank sets the short run nominal interest rate in response to observable variables and we use the steady state output instead of the natural level.

The resource constraints in the domestic and foreign economy are as follows

$$C_t = P_{H,t}Y_{H,t} - I_t - G_t - R_{b,t-1}\frac{B_{t-1}}{\pi_t} + B_t \tag{3.70}$$

$$C_t^* = P_{F,t}^*Y_{F,t} - I_t^* - G_t^* - R_{b,t-1}^*\frac{B_{t-1}^*}{\pi_t^*} - B_t^* \tag{3.71}$$

and the capital account is defined by

$$CA_t = Q_{b,t}B_t - R_{b,t-1}Q_{b,t-1}\frac{B_t}{\pi_t} \tag{3.72}$$

The government budget is balanced.

$$G_t = T_t \tag{3.73}$$

$$G_t^* = T_t^* \tag{3.74}$$

3.3.5 Exogenous Processes

We consider two types of shocks in our analysis. The first is a negative capital quality shock to mimic a global financial crisis along the lines Gertler and Kiyotaki (2010). The second is a negative shock to foreign monetary policy that raises the foreign policy interest rate. In both cases, we observe the activation of the international transmission mechanism between flows of foreign and domestic banks. The capital quality shock in the foreign economy triggers the deterioration of banks balance sheets in the foreign economy, and reduces the cross border banking loans. The shock over the foreign interest rate reduces the incentives of the foreign banks for lending to domestic banks as the empirical evidence from Cetorelli and Goldberg (2012, 2009), Herrmann and Mihaljek (2010) and Takats and Temesvary (2017) have shown.

3.3.5.1 Foreign Capital Quality Shock

S_t^*, is defined as *the capital in process*, S_t^* is transformed into final capital K_{t+1}^* once it is adjusted by the foreign capital quality shock ψ_t^*.

$$K_{t+1}^* = \psi_t^* S_t^* \tag{3.75}$$

where ψ_t^* follows an AR(1) process and that introduces an exogenous variation in the value of foreign capital

$$ln(\psi_t^*) = \gamma_{\psi_t^*} ln(\psi_{t-1}^*) + \epsilon_{\psi,t}^* \tag{3.76}$$

where $0 < \gamma_\psi^* < 1$ and $\epsilon_{\psi,t+1}^*$ is distributed as $\epsilon_{\psi,t+1}^* \sim N(0, \sigma_\psi^*)$. ψ_t^* is a random variable that may be seen as a proxy for certain economic obsolescence, more than a physical depreciation phenomenon. We include the quality capital shock following Gertler and Kiyotaki (2010), Gertler and Karadi (2011), Gertler et al. (2012) and others. The shock to capital quality is a simple way to introduce an exogenous source of variation in the value of capital.

$$R_{kt}^* = \psi_t^* \frac{[Z_t^* + Q_t^* - (1 - \delta^*)]}{Q_{t-1}^*}$$

As in previous literature, a negative shock in ψ_t^* reduces the value of foreign capital and foreign asset prices. It worsens the foreign banks' balance sheets and constrains credit supply in the foreign economy. We will explain in the next section posterior channels of transmission of the shock on the domestic economy.

3.3.5.2 Foreign Monetary Policy Shock

In the foreign economy, the central bank follow a similar simple and implementable Taylor rule

$$ln\left(\frac{R_t^*}{R^*}\right) = \kappa_\pi^* ln\left(\frac{\pi_t^*}{\pi^*}\right) + \kappa_y^* ln\left(\frac{y_t^*}{y^*}\right) + \vartheta_t^* \tag{3.77}$$

where ϑ_t^* is an AR(1) process that represents an exogenous foreign monetary policy shock, $0 < \gamma_{\vartheta^*} < 1$ is the shock persistence and $\epsilon_{\vartheta,t}^*$ is distributed as $\epsilon_{\vartheta,t}^* \sim N(0, \sigma_\vartheta^*)$.

$$ln(\vartheta_t^*) = \gamma_\vartheta ln(\vartheta_{t-1}^*) + \epsilon_{\vartheta,t}^* \tag{3.78}$$

3.4 Calibration

In this section, we present the calibration in Table 3.1, we match the parameters whenever is possible with data from Mexico and the US. The rest of the parameter values are according to the standard literature. We solve the model numerically up to the first order approximation around the non-stochastic steady state.

The discount factor β is set at 0.99 in both countries to obtain a riskless annualized quarterly steady state interest rate around four percent as Cuadra and Nuguer (2018). We set labour L, equal to 0.3 in both countries and determine the relative utility weight of labour χ at 1.913 in Mexico and 2.100 in the US.

Table 3.1: Calibration of Parameters

Parameter		EME Mexico	AE US	Source or target
Real Sector				
Discount factor	β	0.990	0.990	Cuadra and Nuguer (2018)
Relative utility weight of labour	χ	1.913	2.100	target value[a]
Capital share	α	0.330	0.330	Gertler and Karadi (2011)
Depreciation rate	δ	0.025	0.025	Gertler and Karadi (2011)
Adjustment cost parameter	Φ_X	1.500	1.500	Tavman (2015)
Elast. of substitution f and d	η_i	1.556	1.556	Cuadra and Nuguer (2018)
Home bias	γ	0.360	0.220	target value[b]
Country size	n	0.100	0.900	Cuadra and Nuguer (2018)
Inflation Taylor Rule Parameter	κ_π	1.800	1.500	Gertler and Karadi (2011); Garcia Cicco et al. (2017)
Output Taylor Rule Parameter	κ_y	0.125	0.125	Gertler and Karadi (2011); Garcia Cicco et al. (2017)
Elast. of substitution	ε	6.000	6.000	target value[c]
Rotemberg Parameter	φ	85.00	77.00	target value[d]
Government Spending/GDP	$\frac{G}{Y}$	0.110	0.210	target value[e]
Banking Sector				
Survival rate	θ	0.972	0.972	Gertler and Karadi (2011); Gertler and Kiyotaki (2010)
Fraction of diverting funds	λ	0.210	0.248	target value[f]
Fraction of starting funds	ω	0.002	0.002	Gertler and Karadi (2011)
Risky banks parameter	ω_a	0.956		target value[g]
Elasticity of cross border loans	Ψ_b	0.000		target value[h]
Cross Border Loans/assets	$\frac{B}{S}$	0.067		close to Cuadra and Nuguer (2018)
Shock Processes				
Quality Capital Shock	γ_ψ^*		0.660	Gertler and Karadi (2011)
US Monetary Policy Shock	γ_ϑ^*		0.7000	Galí (2015)

[a] Targeted χ to match L to 0.3.

[b] Targeted γ to match Imports/GDP according to data from World Development Indicators, 1993-2016.

[c] Targeted to set a 20% mark-up.

[d] Targeted φ to match an equivalent stickiness in Calvo prices such as.

[e] Targeted to match Government Spending/GDP to data from World Development Indicators, 1993-2016.

[f] Targeted to match the annual average interest rate spread equal to 110 and 115 basis point for the US and Mexico, respectively.

[g] Targeted to match the spread ratio between the two economies.

[h] To close the small open economy. [i] Targeted to match cross border loans to credit ratio at 0.06 to match data for Mexico from the Bank of Mexico and BIS statistics.

The capital share α is 0.33 and the quarterly depreciation rate of capital δ is set at 0.025 in both countries. It implies a 10 percent annual capital depreciation. These values are standard in the literature and equal to Gertler and Karadi (2011). We use an adjustment cost parameter Φ_X at 1.5 same in both economies, the value is as in Tavman (2015).

The home bias γ was chosen to match the imports to GDP ratio, 25 percent on average in Mexico and 13 percent in the US. We use data from the World Development Indicators between 1993 and 2016. We set γ at 0.36 and 0.22 for Mexico and the US, respectively. The relative size of the domestic economy is n equal to 0.1 and $(1-n)$ equivalent to 0.9 for the foreign economy.

The elasticity of substitution between foreign and domestic goods η is set at 1.556 and 1.556 in both countries as in Cuadra and Nuguer (2018). The elasticity of substitution between differentiated varieties ε is set equal to 6, implying a 20% markup at the steady state as in the standard literature such as Galí (2015). Using the Rotemberg (1982) contracts, we set the price stickiness φ at 85 and 77 for Mexico and the US, respectively. It implies that firms would adjust prices every 12 to 15 months under the Calvo price model based on Keen and Wang (2007).[5]

For the monetary policy reaction function, we set κ_π at 1.5 for the US and 1.8 for Mexico while the parameter for output κ_y is set to 0.5/4 in both countries. We take the values from Gertler and Karadi (2011) in the case of the US and Garcia Cicco et al. (2017) in the case of Mexico. Government spending to GDP is set at 11 and 20 percent in Mexico and the US, respectively. We match the government spending to GDP ratio using data from the World Development Indicators from 1993 to 2016.

Regarding the banking sector parameters, we set the survival rate of banks θ at 0.972 for both countries as in Gertler and Kiyotaki (2010) and Gertler and Karadi (2011). It implies banks survive 9 years in average[6]. To calibrate the fraction of diverting funds λ, we target the steady state of the interest rate spread. We use the average yearly

[5] See Keen and Wang (2007) for more discussion.

[6] $\frac{1}{1-\theta}$ is the survival rate.

credit spread at 112 and 115 basis points for the US and Mexico, respectively, rough approximations of the 2007-08 pre-crisis period according to Cuadra and Nuguer (2016). Thus, we set λ equal to 0.210 and 0.248 for the US and Mexico, respectively.

The parameter of starting funds ω is set at 0.18 percent of the assets from the previous period such as Gertler and Kiyotaki (2010), Gertler and Karadi (2011) and Cuadra and Nuguer (2016). We set the degree of riskiness of EME banks ω_a targeting the AE spread to the EME ratio, ω_a matches our target at 0.96. Additionally, we match the cross border loans to asset ratio $\frac{B}{S}$ at 0.067 accordingly to the data. We use the Locational banking statistics from the BIS to obtain cross border loans and the Bank of Mexico data for credit. To close the model,we set the elasticity of cross border loans Ψ_b at one thousandth, lower than Cuadra and Nuguer (2018).

Finally, we set the capital quality shock persistence γ_ψ^* equal to 0.66 to replicate output decline in the US during the 2008-09 financial crisis as Gertler and Karadi (2011). In the case of the the monetary policy shock, we choose a moderate persistence γ_ϑ^* of 0.7 slightly higher than Galí (2015).

3.4.1 Business Cycle Dynamics

We now present some business cycle facts for Mexico similar to what Angeloni and Faia (2013), King and Rebelo (2000) and Mimir (2013) present for the US and Turkey respectively. We use data on real and financial variables and compare their moments with the moments of the same variables from the model. This exercise presents the capability of the model to replicate fluctuations in the EME regarding GDP, consumption, investment, government spending, imports, bank assets and leverage ratio. We use data from the National Accounts Statistics at the National Institute of Statistics and Geography (INEGI) for the real variables from 1994(1) to 2016(4). For bank assets we use banking loans, code series CF445 taken from the Commercial Banks Statistics at the Bank of Mexico from 2000(1) to 2016(4). Finally, leverage ratio was calculated by using the same database from the Commercial Banks Statistics at the Bank of Mexico from 2000(1) to

2016(4).

The variables are in logarithms and they were de-trended using a HP filter with a λ=1600. We compute moment from the model by running a simulation of 100,000 periods and a five percent capital quality shock. We calculate the standard deviation of the variables from the data and model, we present them in the first two columns of Table 3.2. In the third and four columns, we display the standard deviation relative to the standard deviation of output, which is a measure of volatility or fluctuations respect to GDP. The last two columns show the contemporaneous correlation between the variables and output.

Table 3.2: Matching Moments between Model and Data

	St.Dev. X_t		St.Dev. X_t / GDP St.Dev.		Corr X_t to $GDPt$	
X_t	**Model**	**Data**	**Model**	**Data**	**Model**	**Data**
Output	0.010	0.024	1.000	1.000	1.000	1.000
Consumption	0.012	0.034	1.191	1.451	0.863	0.910
Investment	0.044	0.055	4.394	2.313	0.312	0.839
Government Spending	0.009	0.019	0.888	0.798	0.766	0.647
Imports	0.031	0.074	3.092	3.110	0.680	0.845
Bank Assets	0.025	0.055	2.468	2.270	-0.334	0.493
Leverage Ratio	0.013	0.037	1.325	1.488	-0.747	-0.553

Standard deviations of the model and data fit notably well, the greater difference is in imports. The standard deviation relative to the standard deviation of output is greater than one for consumption, investment, imports, bank assets and leverage ratio in the data and the model. That means these variables are more volatile than output while government spending is more stable relative to output. These results are in line with the empirical facts for EMEs. In the last two columns, the contemporaneous correlation denote the cyclicality of the variables relative to output. The components of the aggregate demand are procyclical in the model and data. However, bank assets in the model is countercyclical, which is a regularity in Gertler and Karadi (2011) model. Finally, the leverage ratio is countercyclical an fit well in the three measures between the data and model. Our calculations shows that assets and leverage ratio are more volatile than output.

3.5 Global Financial Crisis and Monetary Policy Shocks

3.5.1 Global Financial Crisis Experiment: A Negative Capital Quality Shock

We start by exploring the case of a capital quality shock in the foreign country to mimic the global financial crisis. In Figure 3.4, we display the responses of a five percent shock, and we present two scenarios, the first when prices are sticky and the second when they are flexible.

In our model, the shock reduces initially the foreign value of capital that leads to the decline of foreign asset prices and shrinks foreign banks' equity capital. It increases the leverage of foreign banks sharply eroding their balance sheets. Credit spread goes up since foreign leveraged banks impose a higher interest rate on loans. It increases the cost of capital and constrains the borrowing opportunities of non-financial firms in the foreign country. The financial accelerator mechanism amplifies the effect, and it results in the sharp decline of foreign investment and output.

So far, the transmission mechanism is the same as in Gertler and Karadi (2011) in their model for the US economy. Our results are also consistent with Gertler and Kiyotaki (2010), Villa and Yang (2011), Villa (2011), Gertler et al. (2012), Vasco and Guilardi (2012) and Tavman(2015) that explore closed economy models for developed economies.

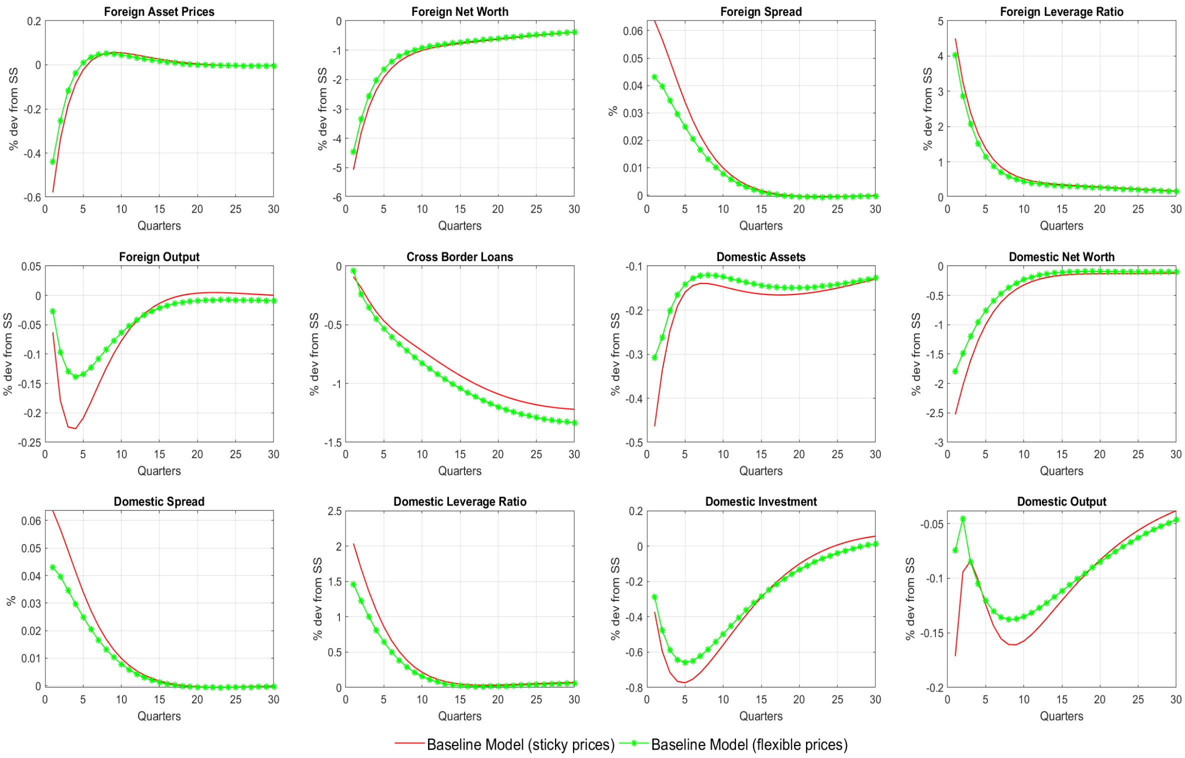

Figure 3.4: Responses to a 5% Capital Quality Shock.

In our New Keynesian two-country model with global banks, we observe additional channels of transmission that trigger spillovers from the foreign to the domestic economy. These transmission channels are related to the presence of cross border loans and are similar to Cuadra and Nuguer (2016). The capital quality shock in the foreign economy leads to a fall in foreign asset prices eroding foreign banks' balance sheets which, in turn, shrinks foreign banks' liquidity. It reduces the local and international lending see for example, Cetorelli and Goldberg (2012, 2009) and Aizenman et al. (2017). In the model, the decline in cross border loans depreciates the domestic currency sending away financial flows from the EME.

The lower cross border loans reduce domestic banks' net worth, weakening domestic banks' balance sheets and dropping domestic asset prices. It deteriorates the domestic credit market conditions and pushes up credit spread raising the price of loans to domestic non-financial firms. Overall, it causes the decline in domestic investment and output. Thus, the shock is spread across economies through the cross border bank lending.

The decline in foreign output yields the relative scarcity of foreign goods and increases foreign prices. It enhances the terms of trade of the domestic economy since foreign goods become more expensive than domestic goods. The domestic currency depreciation improves the domestic trade balance in the short run. However, the overall effect is negative for the domestic country since the sharp foreign output contraction reduces the scope to expand domestic exports.

In the domestic economy, output declines because the external sector is highly concentrated in the US market even though the Mexican trade openness is around 66%.[7] Overall, the net effect in EME's output also depends on the importance of the exports versus the financial contagion channel, as is emphasised by Ozkan and Unsal (2017).

Although our analysis is developed using a New Keynesian model with Rotemberg sticky prices, we also display in Figure 3.4 the impulse responses in the case that prices are completely flexible. Looking at both cases aims at comparing our results with the responses from Cuadra and Nuguer (2016), who work with an RBC model with cross border loans. We observe that domestic financial variables in the sticky price model are more sensitive to the capital quality shock, as expected. Domestic investment and output are more responsive and persistent in both countries in the same model. Overall, our impulse responses under flexible prices are in line with the results from Cuadra and Nuguer (2016).

3.5.2 Foreign Monetary Policy Shocks and Cross Border Loans

We now turn to the transmission of foreign monetary policy shocks onto other jurisdictions given the global financial cycle (Rey, 2018; Miranda-Agrippino and Rey, 2015; Aizenman et al., 2017). There is an extensive literature linking cross border loans in EMEs and the US monetary policy (Cetorelli and Goldberg, 2012, 2009; Herrmann and Mihaljek, 2010; Takats and Temesvary, 2017). In 2013, the US Federal Reserve announced that it might slow down the rate of bonds purchases, part of its Quantitative Easing (QE). The announcement triggered a substantial exchange rate volatility in

[7] Trade openness is measured as exports plus imports relative to output.

EMEs, a sharp drop in asset prices and the abrupt outflows of cross border loans from EMEs to AEs (Avdjiev and Takáts, 2014, 2016; Takáts et al., 2017).

Regarding the countries of our calibration, it is well known that Mexico keeps a close relationship with the US economy because of geographical and economic reasons, mainly due to the active financial and trade interactions. Therefore, it is likely that a foreign monetary policy shock will have a significant effect on the EME.

In this section, we examine the consequences of one percent shock in the foreign interest rate as can be seen in Figure 3.5. The rise in foreign interest rate reduces the liquidity of foreign banks because short-term liabilities become more expensive. This results in the decline in foreign banks' net worth and the deterioration of their balance sheets. Foreign banks tend to react by increasing the interest rate on loans to mitigate the shock, pushing up credit spread and dampening the demand for credit in the foreign economy.

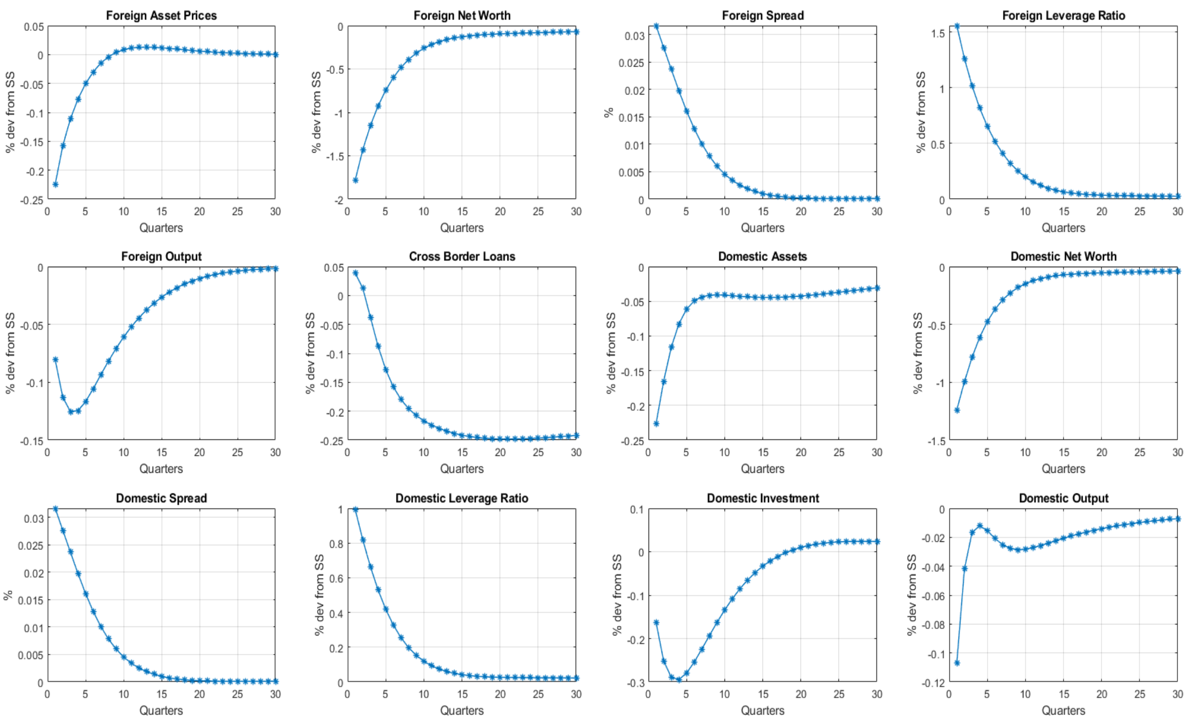

Figure 3.5: Responses to a 1% Foreign Monetary Policy Shock.

In Figure 3.5, we observe -once again- that cross border loans go down sharply, which triggers credit constraints in the domestic economy since cross border loans partially finance domestic banks. According to Cetorelli and Goldberg (2012, 2009) under monetary policy shocks, global banks tend to face their constraints by shrinking the international credit supply to EMEs. In addition to this, the rise in the foreign interest rate makes more attractive investing in the AE. Therefore, cross border loans fly back to the foreign country. For instance, during the taper tantrum in 2013, a significant outflow of cross border loans and capital flows in the EMEs (Avdjiev and Takáts, 2014, 2016).

In our exercise, the foreign monetary policy shock exacerbates the balance sheets of domestic banks as cross border loans become more expensive and scarce. The decline in cross border loans leads to a lower domestic banks' net worth that reflects their higher leverage. It also increases domestic credit spread and raises the cost of loans to domestic non-financial firms, reducing investment and output in the domestic economy. Overall, we find that the foreign monetary policy shock transmits over onto the EME, increasing the financial constraint and dampening domestic output. The financial contagion is transmitted through the banks, and the cross border loans are a crucial channel to spill volatility and financial stability over the EMEs. Our findings coincide with the empirical work of Morais et al. (2014) for Mexico.

3.5.3 Sensitivity Analysis of riskiness ω_a in EME's banks

In this section, we explore the case that the riskiness of the EME's banks is different than the baseline model. In the calibration (section 3.4), we set the value of ω_a equal to 0.96, which implies a small level of risk that banks from the domestic economy divert cross border loans. We allow for other two cases, in the first $\omega_a = 1.0$, EME's banks do not divert cross border loans. In the second, $\omega_a = 0.5$ the level of risk is significantly high. In the baseline model, $\omega_a = 0.96$ results from the ratio between the spread in the foreign and domestic economy, 110 and 115 basis points, respectively. A higher level of risk ω_a corresponds to a higher spread in the EME, 220 basis points for ω_a equal to 0.5 and 110 for ω_a equalt to 1.

In Figure 3.6, we present the impulse responses of the model under the three values of ω_a. We observe that the dynamics of the foreign variables, in the first row, are similar in all cases since the degree of risk of the EME's banks causes no significant effects in the domestic economy. In the second and third rows of Figure 3.6, we display the dynamics of the EME under the three levels of risk. The decline of cross border loans is sharper when $\omega_a = 0.5$ while close to each other for ω_a equal to 0.96 and 1.0. At the highest level of risk, EME banks are in a more fragile position since they have less funding from the foreign economy. Thus, we observe an amplified decline of domestic assets and investment. However, the response on domestic output is not significantly different. Overall the dynamics of the model preserve the mechanism of transmission, the direction and signs of the responses in the main variables.

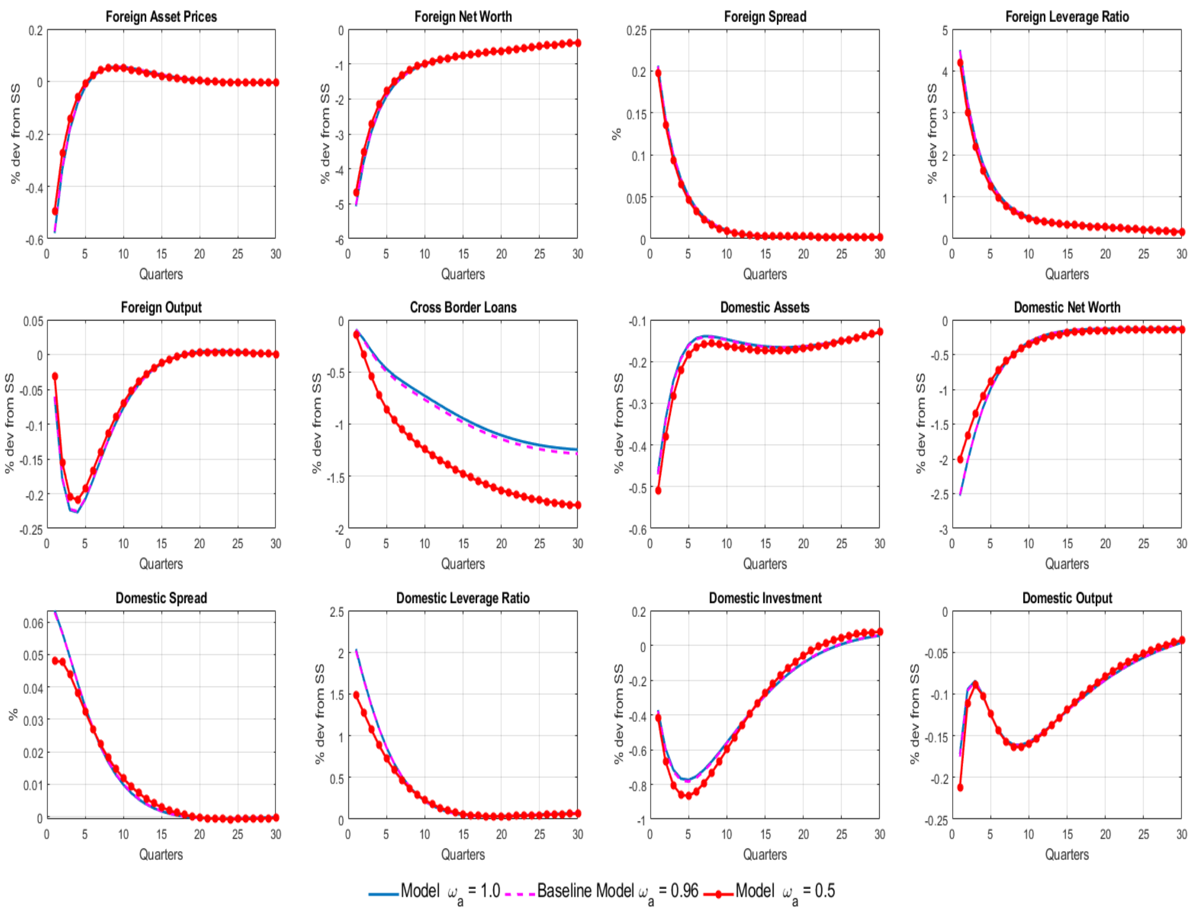

Figure 3.6: Responses to a 5% Capital Quality Shock.

3.6 Analysis of Macroprudential Policies

In the previous section, we find that a capital quality shock and a foreign monetary policy shock trigger spillovers across countries. The transmission tends to occur from AEs to peripheral countries through capital flows and cross border loans (Rey, 2018; Cetorelli and Goldberg, 2012, 2009). EMEs have experienced the international contagion on several occasions for example, the 2008-09 financial crisis and the taper tantrum in 2013.

The question that arises is whether MaPs also trigger spillovers across jurisdictions. There is an extensive literature linking MaPs and cross border loans. We examine to what extent central banks can extend financial stability across countries. In the presence of global financial spillovers, can international financial linkages turn beneficial for EMEs? We analyse the implementation of MaPs in the presence of a financial crisis shock or a foreign monetary policy shock.

In what follows, we explore three policy scenarios, in the first case only the foreign economy foster financial stability. There is a countercyclical capital requirements policy implemented in the foreign country plus the standard monetary policy in both economies. In that case, a foreign MaP may mitigate the shock in its jurisdiction and attenuate global spillovers in the EME. We aim to determine the scope of financial stability policies across countries.

We analyse a second scenario in which the EME is the only country fostering financial stability. First, we explore a simple case where the domestic central bank includes credit deviations on the monetary policy rule. Second, we evaluate a levy on cross border loans and we measure whether such a MaP mitigates capital quality and monetary policy shocks. This second exercise is more standard and follows the Tinbergen principle, in which policymakers need a second instrument to mitigate systemic risk.

Finally, we explore the scenario in which the foreign and domestic economy are conducting MaPs simultaneously. We examine whether a coordination triggers a better environment for the two economies. We do the analysis in the presence of financial or monetary policy shocks.

3.6.1 Macroprudential Policies in the Foreign Economy

In this section, the foreign central bank implements countercyclical capital requirements following the Basel III agreement. The countercyclical MaP is aimed at reducing the leverage of banks by setting a minimum threshold. Banks breaching the threshold incur severe reputational costs and adverse market reactions reflected in deposit costs (Borio and Zhu, 2012). We examine capital requirements by setting a cost to banks when they do not hold the minimum. We define the additional cost in deposits Ψ_t^* parametrized by ψ^*

$$\Psi_t^* \left(\frac{1}{\phi_t^*} \right) = \psi^* \left(\zeta_t^* - \frac{1}{\phi_t^*} \right) \tag{3.79}$$

where ζ_t^* is the countercyclical capital requirements in the foreign economy and ϕ_t^* is the leverage ratio, that we define as total foreign assets to the foreign capital ratio.

$$\frac{1}{\phi_t^*} = \frac{N_t^*}{Q_t^* S_t^* + B_t^* Q_{b,t}^*} \tag{3.80}$$

Therefore, the additional cost on deposits $\Psi_t^* \left(\frac{1}{\phi_t^*} \right)$ is zero when banks meet the capital threshold. However, if banks breach the minimum requirement ζ_t^*, then $\Psi_t^* \left(\frac{1}{\phi_t} \right) > 0$ and deposits are more costly for these banks. In the case that foreign capital to asset ratio is above the minimum requirement then $\Psi_t^* \left(\frac{1}{\phi_t} \right) < 0$ and it results in an incentive for foreign banks to build assets and supply additional credit. The minimum requirement of capital in the foreign economy ζ_t^* is adjusted with the financial cycle. It moves countercyclically dampening the potential systemic risk which could result from an excessive credit growth.

In the spirit of Borio and Zhu (2012), Gerali et al. (2010) and Brzoza-Brzezina et al. (2013), we re-write equation (3.52) similar to Tavman (2015) in the Gertler and Karadi

(2011) model by adding the potential cost term on deposits to foreign banks $\Psi_t^{*\prime}$.

$$n_t^* = R_{k,t}^* Q_{t-1}^* s_{t-1}^* + R_{b,t}^* \frac{1}{\pi_t^*} Q_{b,t-1}^* b_{t-1}^* - \left[\frac{1}{\pi_t} R_t^* + \Psi_t^* \right] d_{t-1}^* \tag{3.81}$$

Foreign banks maximise profits with countercyclical capital requirements in place. They solve their optimisation problem based on equation (3.81) rather than (3.52) as we see below

$$V_t^* = maxE_t \sum_{i=1}^{\infty} (1-\theta)^* (\theta^*)^{i-1} \Lambda_{t,t+i}^* n_{t+i}^*$$

$$V_t^* (s_t^*, b_t^*, d_t^*) \geq \lambda^* (Q_t^* s_t^* + Q_{b,t}^* b_t^*)$$

Overall, the output of the optimisation problem changes the cost of holding deposits, the excess marginal value of assets over deposits and the evolution of net worth at aggregated level. In all cases, it adds a cost on deposits, see the following equations.

$$\nu_{d,t}^* = E_t \Lambda_{t,t+1}^* \Omega_{t+1}^* \left[\frac{1}{\pi_t^*} R_t^* + \Psi_t^* \right] \tag{3.82}$$

$$\mu_{s,t}^* = E_t \Lambda_{t,t+1}^* \Omega_{t+1}^* \left(R_{k,t+1}^* - \left[\frac{1}{\pi_t^*} R_t^* + \Psi_t^* \right] \right) \tag{3.83}$$

$$N_t^* = (\theta^* + \omega^*) \left[R_{k,t}^* Q_{t-1}^* S_{t-1}^* + \frac{1}{\pi_t^*} R_{b,t}^* Q_{b,t-1}^* B_{t-1}^* \right] - \theta^* \left[\frac{1}{\pi_t^*} R_t^* + \Psi_t^* \right] D_{t-1}^* \tag{3.84}$$

To implement capital requirements, the central bank in the foreign economy follows one of the two rules. In each case, the capital requirements $\zeta_{i,t}^*$ is the instrument, and it responds to either of the two macroeconomic variables. The central bank in the foreign economy adjusts capital requirement taking into account nominal credit and output relative to their steady state levels.

In Rule 1, the central bank increases capital requirements $\zeta_{1,t}^*$, whenever they observe credit is growing above its steady state level to avoid the excess credit in the foreign economy as in Tavman (2015) and Rubio and Carrasco-Gallego (2016). In Rule 2, we include a second indicator of credit excess, since a broad set of information could potentially improve the guidance for policymakers. Therefore, in this case, capital requirements $\zeta_{2,t}^*$

adjust whenever either credit or output is growing relative to their steady state levels. This specification follows Brzoza-Brzezina et al. (2013) and the work from Rubio and Carrasco-Gallego (2017).

Rule 1: credit growth relative to its steady state

$$\zeta^*_{1,t} = \zeta^* + \gamma^*_{cr}\left(\frac{Q^*_t S^*_t}{Q^* S^*} - 1\right) \tag{3.85}$$

Rule 2: credit and output growth relative to their steady state levels

$$\zeta^*_{2,t} = \zeta^* + \gamma^*_{cr}\left(\frac{Q^*_t S^*_t}{Q^* S^*} - 1\right) + \gamma^*_y\left(\frac{Y^*_t}{Y^*} - 1\right) \tag{3.86}$$

where $\zeta^*_{i,t}$ is the time-varying capital requirement in the foreign economy in each case, ζ^* is the foreign capital to assets ratio, QS is foreign credit and Y^* is foreign output, all of them at the steady state level. γ^*_{cr} and γ^*_y are the parameters that determine the size of the reaction of each rule relative to credit and output, respectively.

Using each of the rules, we examine how the foreign economy performs and whether its dynamics triggers any effect on the EME. In our exercises $\gamma^*_{cr} = \gamma^*_y$ and they are set at 1.5 to make the rules comparable and ψ^* is equal to 1. We set a five percent capital quality shock to the foreign economy as in our previous analysis. In Figure 3.7, we display the impulse responses under the two rules, and we compare with the dynamics in the baseline model.

We explained earlier that the capital quality shock lowers foreign asset prices and rises leverage of foreign banks weakening their balance sheets. It pushes up foreign credit spread, worsens the credit market conditions leading to the decline in foreign investment and output as the continuous line denotes in Figure 3.7. Under the countercyclical MaP, the foreign central bank dampens the effects of the credit constraint in the foreign economy by lowering the decline in foreign assets prices and foreign banks' net worth. Capital requirements reduce leverage enhancing banks' balance sheets and increasing credit supply in the foreign economy. With the MaP in place, the decline in foreign investment and output is lower.

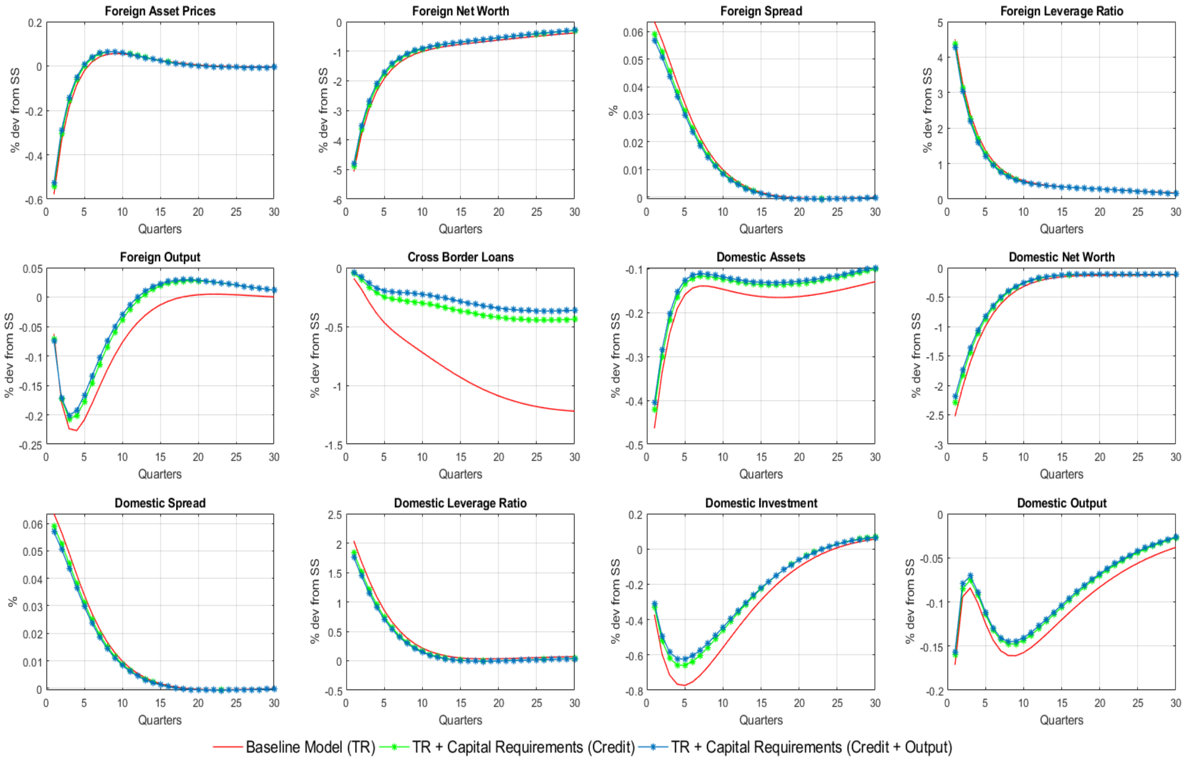

Figure 3.7: Responses to a 5% Capital Quality Shock.

Rule 1: TR+CR(Credit) and Rule 2: TR+CR(Credit + Output).

We also find that cross border loans are more resilient to the shock, in the presence of capital requirements in the foreign economy. Capital requirements as a MaP reduces the effect of the financial shock in the EME. The smaller decline in cross border loans is a buffer for domestic banks, allowing them to enhance their balance sheets. We also find that domestic output and investment decline by significantly less.

The capital requirements policy is a dynamic instrument that responds to deviations of credit and output relative to their steady state values, according to each rule. Ideally, these macroeconomic variables must provide meaningful information to indicate whenever there is excess credit in the foreign economy. In downturns, ζ_t^*, becomes more flexible but more rigorous in booms since it moves according to the financial cycle. Under our scenario, foreign banks have more leeway to build assets because the minimum requirement of capital in the foreign economy is decreasing. The lower financial constraint dampens the decline in foreign investment and output.

The slow-down in the foreign economy is significantly lower under the capital requirements policy regardless of the type of the rule. However, it seems that following Rule 2 (with credit and output growth) is more effective in mitigating the effects of the global financial shock. When the central bank implements the MaP taking into account output and credit growth as indicators of excess credit, the response is more extensive in both economies. Our results are consistent with Rubio and Carrasco-Gallego (2017) relative to the use of output as an indicator of potential systemic risk.

In the second exercise, we explore a one percent foreign monetary policy shock and analyse the transmission mechanism of cross border loans under the MaP. In Figure 3.8, we display the responses when the foreign central bank implements the capital requirements (Rule 1 or 2) and there is a foreign monetary policy shock.

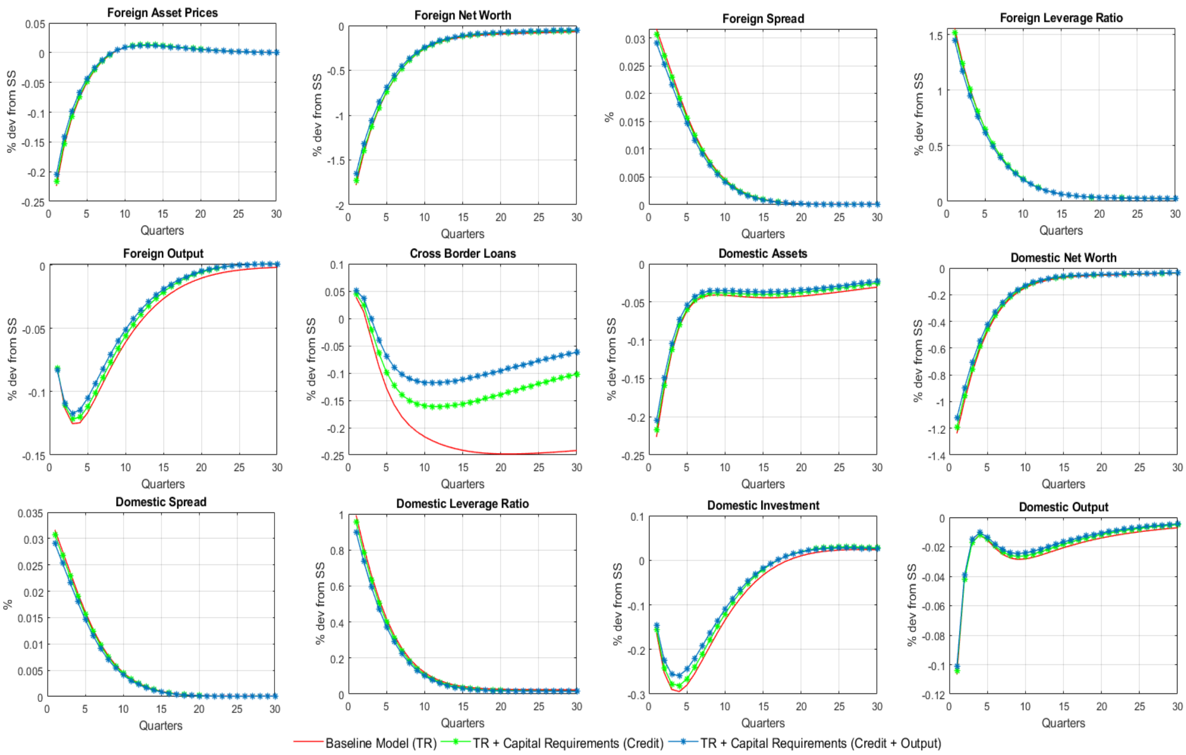

Figure 3.8: Responses to a 1% Foreign Monetary Policy Shock.

Rule 1: TR+CR(Credit) and Rule 2: TC+CR(Credit + Output).

Previously, we present that a foreign monetary policy shock increases the cost of foreign banks' liabilities eroding foreign banks' balance sheets hence reducing credit supply to foreign non-financial firms. However, with the MaP in place, there is some leeway for foreign banks to expand credit. Foreign credit spread increases slightly less, mitigating the cost of loans to non-financial firms and domestic banks. Overall, the unfavourable effect on foreign investment and output is lower under capital requirements. Moreover, the smaller decline in cross border loans reduces the transmission of the foreign monetary policy shock toward the domestic economy. The impulse responses in Figure 3.8 show that the domestic economy is better off under capital requirements. The fall in financial and real variables is less severe when the central banks conducts MaP by following Rule 2 (credit and output deviations relative their steady state levels).

In general, our findings are in line with the empirical evidence developed by IBRN regarding Mexico. For example, Levin-Konigsberg et al. (2017) find that changes in capital requirements in the US trigger the greatest spillovers on Mexican credit growth. On the contrary, there is no evidence that changes of any other MaP in the US or elsewhere have a significant impact on the Mexican credit growth.

3.6.2 Monetary and Macroprudential Policies in the Domestic Economy

3.6.2.1 Leaning Against the Wind (LAW)

In this section, the foreign economy does not conduct any MaP and the domestic economy looks after excess credit. The domestic central bank conducts monetary policy with a simple Taylor rule that responds to credit deviations. In the literature, credit growth seems to be an accurate indicator of high leverage, exposure and systemic risk. Moreover, it is widely documented that credit grows faster than deposits in the years prior to a financial crisis (Hamn et al., 2012; Shin, 2013; Miranda-Agrippino and Rey, 2015).

The 2008-09 financial crisis has led economists and policymakers to ask whether central banks should actively respond to credit growth increasing the interest rates. There is evidence in favour and against of LAW. For instance, Filardo and Phurichai

(2016) examine policy rules in models with different states and probability of crises, they conclude that LAW can be desirable since the benefits outweigh the costs. Similarly, Gambacorta and Signoretti (2013) find that LAW is desirable in the case of supply-side shocks whenever the central bank is concerned with output stabilization while strict inflation targeting is less effective.

On the contrary, Svensson (2017b) and Svensson (2017a) argument that LAW may be effective at lowering real debt growth and declining the probability of a financial crisis. However, it induces higher costs in terms of higher unemployment and lower inflation. LAW implies a higher cost of a crisis when the economy is weaker given the active policy to control credit growth. Svensson (2017a) questions the channel of transmission from LAW to reduce the probability of a financial crisis, which is through lower real debt growth. He argues that increasing the interest rate can actually move real debt to any direction. That is, LAW weakens the economy dropping price level and GDP, therefore, the real debt may be even higher after some periods. If we take real debt as a share of GDP as an indicator of a probability of crisis, the result is similar, the slow down of the economy indeed may increase the real debt to GDP ratio.

Gerdrup et al. (2017) contribute to the debate of LAW by doing endogenous the probability of a financial crisis and the severity of the crisis in a model for a small open economy. They find that the benefits of LAW to lower frequency of severe financial recessions exceed costs in terms of higher volatility in normal times, under the assumption that the severity of crisis is endogenous. However, the costs are higher inflation volatility and interest rate volatility. More importantly, they find that LAW is only optimal when the severity of the crisis is exogenous but not when it is endogenised as in their model.

In our exercise, the simple and implementable Taylor rule includes deviations of domestic credit Q_tS_t relative to its steady state level QS

$$ln\left(\frac{R_t}{R}\right) = \kappa_\pi ln\left(\frac{\pi_t}{\pi}\right) + \kappa_y ln\left(\frac{y_t}{y}\right) + \kappa_d ln\left(\frac{Q_tS_t}{QS}\right) \tag{3.87}$$

where $\{\kappa_\pi\} \in (1,\infty]$, $\{\kappa_y\} \in (0,\infty]$ and $\{\kappa_d\} \in (0,\infty]$.

In Figures 3.9 and 3.10, we present the responses of a five percent foreign capital quality shock and one percent foreign monetary policy shock. We use the same shocks than before to make comparable the results among policy scenarios. In the case of the capital quality shock, we find that the credit-augmented Taylor rule slightly dampens the effects of the credit constraint in the domestic economy. The domestic central bank softens monetary policy encouraging the accumulation of domestic assets and reducing the fall in domestic banks' net worth and leverage. It pushes down credit spread and enhances the credit market conditions for domestic non-financial firms. Monetary policy cushions the slow down of investment and output. However, expansionary monetary policy induces higher inflation and the depreciation of the exchange rate, which may offset the benefits for domestic households.

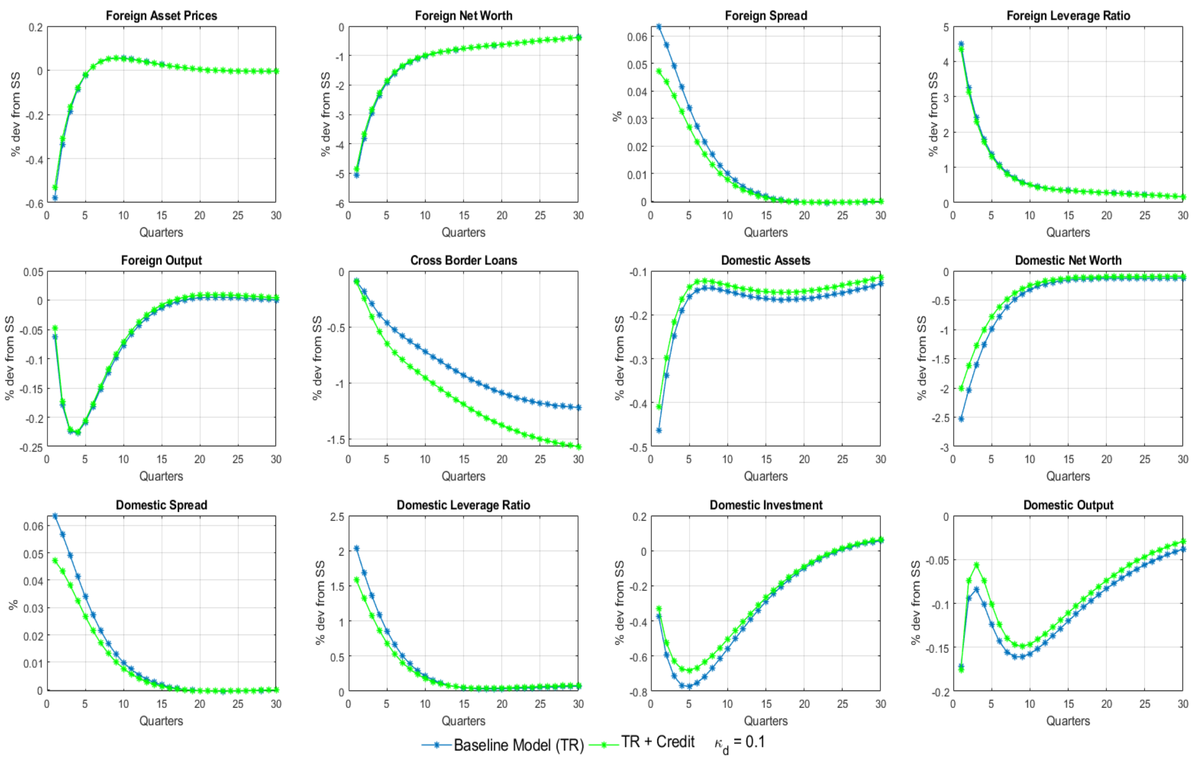

Figure 3.9: Responses to a 5% Capital Quality Shock

In Figure 3.10, we present the impulse response functions under the foreign monetary policy shock. In this case, the dynamics are relatively similar to the capital quality shock. The central bank improves the balance sheets of domestic banks by softening the interest rate, which expands consumption and investment. Domestic monetary policy lessens pressures on credit spread and pushes down the leverage ratio of domestic banks.

It results in a lower decline in domestic investment and output. However, the scope of domestic monetary policy expansion is small, since the decline in domestic interest rate counteracts the domestic capital account. In general, EMEs respond quickly whenever there are changes in AEs interest rates to avoid massive capital outflows. In the model, we find a similar result, the rise in foreign interest rate display a significant decline in cross border loans.

The softening in domestic monetary policy as a response to the increase in foreign interest rate reduces pressure in the banking system. However, it causes a significant decline in cross border loans since the exchange rate depreciates. It further, extends the credit constraint in the banking sector triggering a marginal improvement in investment and output. Monetary policy aims to stimulate the economy by changing the composition of the domestic banks' balance sheets rather than dampening the fall in cross border loans. Nonetheless, the (negative) effect of this policy on cross border loans offsets the improvement in the domestic economy.

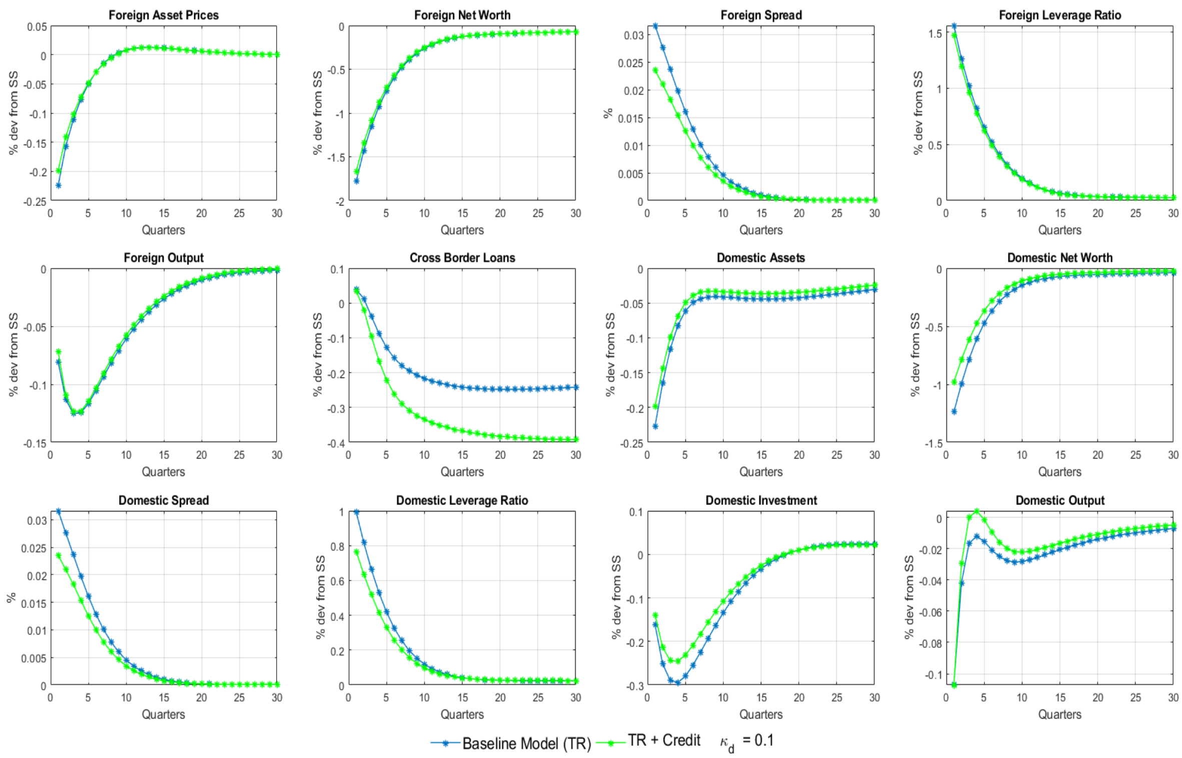

Figure 3.10: Responses to a 1% Foreign Monetary Policy Shock

3.6.2.2 Macroprudential Policies in the Domestic Economy: a Levy on Cross Border Loans

In this section, the domestic economy implements MaP by imposing a levy on cross border loans. As a reference, we have the Korean experience where the authorities imposed a tax on non-core liabilities in the Spring of 2010. In Korea, the levy consisted of an annualised 20 basis points charge on the wholesale foreign exchange liabilities of banks. This charge was collected in a special account of the financial stability authority, and treated separately from the usual tax revenues (Bruno and Shin, 2014; Galati and Moessner, 2013).

In comparison with the standard literature on MaP, a levy on non-core liabilities is seen as a different approach pursuing financial stability. While most MaPs like capital requirements target the assets side of the banks' balance sheets, the adoption of the levy targets the liability side (IMF, 2012). Cuadra and Nuguer (2016) examine a similar MaP for Mexico given its significant cross border loans. Our formulation follows theirs in assessing a similar MaP in our model. Using the same principle than in capital requirements, the central bank responds to Rule 1 or Rule 2 to implement the levy as we detail later in this section.

The levy modifies the balance sheet of banks and the net worth equation since it imposes an additional cost Υ_t to cross border loans.

$$n_t = R_{k,t} Q_{t-1} s_{t-1} - R_t d_{t-1} \frac{1}{\pi_t} - \Upsilon_t R_{b,t} Q_{b,t} \frac{1}{\pi_t} b_{t-1} \tag{3.88}$$

Domestic banks solve their optimisation problem as specified in equation (3.89) and (3.90) as the new representation of net worth

$$V_t = max E_t \sum_{i=1}^{\infty} (1-\theta)(\theta)^{i-1} \Lambda_{t,t+i} n_{t+i} \tag{3.89}$$

$$V_t(s_t, b_t, d_t) \geq \lambda (Q_t s_t - \omega_a Q_{b,t} b_t) \tag{3.90}$$

The time-varying marginal value of cross border loans, the excess marginal value of cross border loans to deposits and the aggregate net worth are as it is stated in the next equations.

$$\nu_{b,t} = E_t \Lambda_{t,t+1} \Omega_{t+1} R_{b,t+1} \Upsilon_t Q_{b,t+1} \frac{1}{\pi_{t+1}} \tag{3.91}$$

$$\mu_{b,t} = E_t \Lambda_{t,t+1} \Omega_{t+1} \frac{1}{\pi_{t+1}} \left(R_{b,t+1} \Upsilon_t - R_{t+1} \right) \tag{3.92}$$

$$N_t = (\theta + \omega) R_{k,t} Q_{t-1} S_{t-1} - \theta \frac{1}{\pi_t} R_t D_{t-1} - \theta \frac{1}{\pi_t} R_{b,t} \Upsilon_t B_{t-1} \tag{3.93}$$

Under the levy, Υ_t denotes the additional cost that domestic banks face for financing their intermediation of assets with cross border loans. In this framework, $\Upsilon_t \in [0, \infty)$, and becomes an extra cost to domestic banks when $\Upsilon_t > 1$, $\Upsilon_t = 1$ is neutral to domestic banks' balance sheets and it is an incentive when $\Upsilon_t < 1$. It implies that the value of Υ_t is procyclical, it goes above one in booms and below that value during downturns.

To implement the levy, we can follow a similar mechanism to capital requirements for the foreign economy explored earlier. In this exercise, the central bank charges a levy to domestic banks when credit is above its steady state level according to the first rule in (3.94). If the domestic central bank incorporates credit and output deviations relative to their steady state levels then, it follows the rule in (3.95)

$$\Upsilon_{1,t} = \left(\frac{Q_t S_t}{QS} \right)^{\vartheta_{cr}} \tag{3.94}$$

$$\Upsilon_{2,t} = \left(\frac{Q_t S_t}{QS} \right)^{\vartheta_{cr}} \left(\frac{Y_t}{Y} \right)^{\vartheta_y} \tag{3.95}$$

where ϑ_{cr} is the parameter that measures the size of the levy which is set at 0.01 in our benchmark. To make the policies comparable we set $\vartheta_{cr} = \vartheta_y$.

We present the responses of the domestic economy to a five percent capital quality shock in Figure 3.11 and one percent foreign monetary policy shock in Figure 3.12. We find that the levy smooths the decline in cross border loans in each of the two scenarios. It relieves the pressure on banks liabilities, the decline in domestic assets and banks' net worth is smaller. The dynamics of the model shows a clear enhancement for domestic banks since their balance sheets are not as eroded as in the baseline model. Domestic banks are less credit constrained and face lower leverage leading to a smaller drop in investment and output drop.

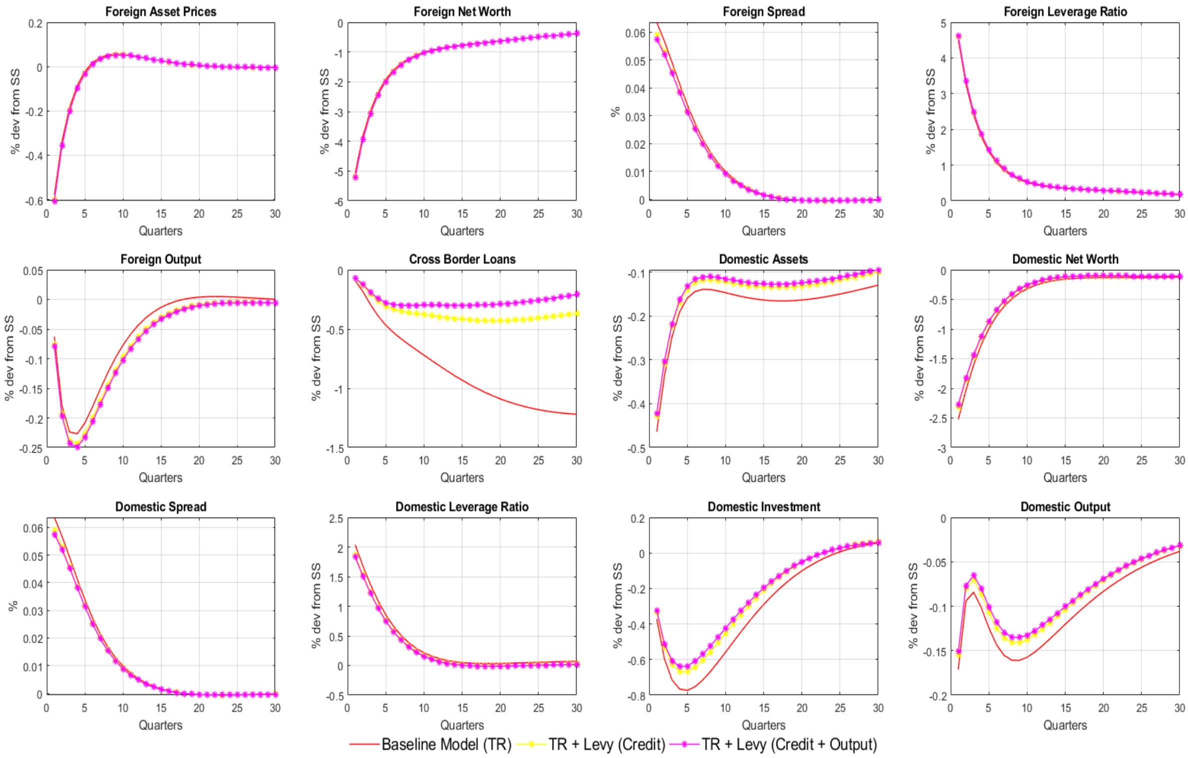

Figure 3.11: Responses to a 5% Capital Quality Shock.

Rule 1: TR + Levy(Credit) and Rule 2: TR + Levy(Credit + Output).

In Figure 3.11, we observe that the levy is more effective in controlling the decline in cross border loans when it is implemented using Rule 2 than Rule 1. The enhancement in investment and output is greater using Rule 2. That reflects the higher scope for MaPs to mitigate financial shocks when output is also used as an indicator of excess credit. The results are consistent regardless of the shock and are in line with Rubio and Carrasco-Gallego (2017).

We also find that levy on cross border loans causes small negative spillovers to the foreign economy since foreign output slightly decreases. On the contrary, we do not find significant spillovers from the EME to the AE in the case of the foreign monetary policy shock. Therefore, the results depend on the source of the shock. Hills et al. (2017) find that changes in MaPs in host countries where UK global banks operate do not have significant spillovers in the UK economy.

In Figure 3.12 is clear that the enhancement in investment and output is greater in the case of a capital quality shock, keeping the proportions of the size's shocks. A global financial crisis is clearly a significant episode, that declines cross border loans and depreciates the exchange rate substantially more than a rise in the foreign interest rate. Finally, Rule 2 is also more effective in controlling the decline in cross border loans than Rule 1. Levy on cross border loans using Rule 2 displays a better performance of domestic investment and output.

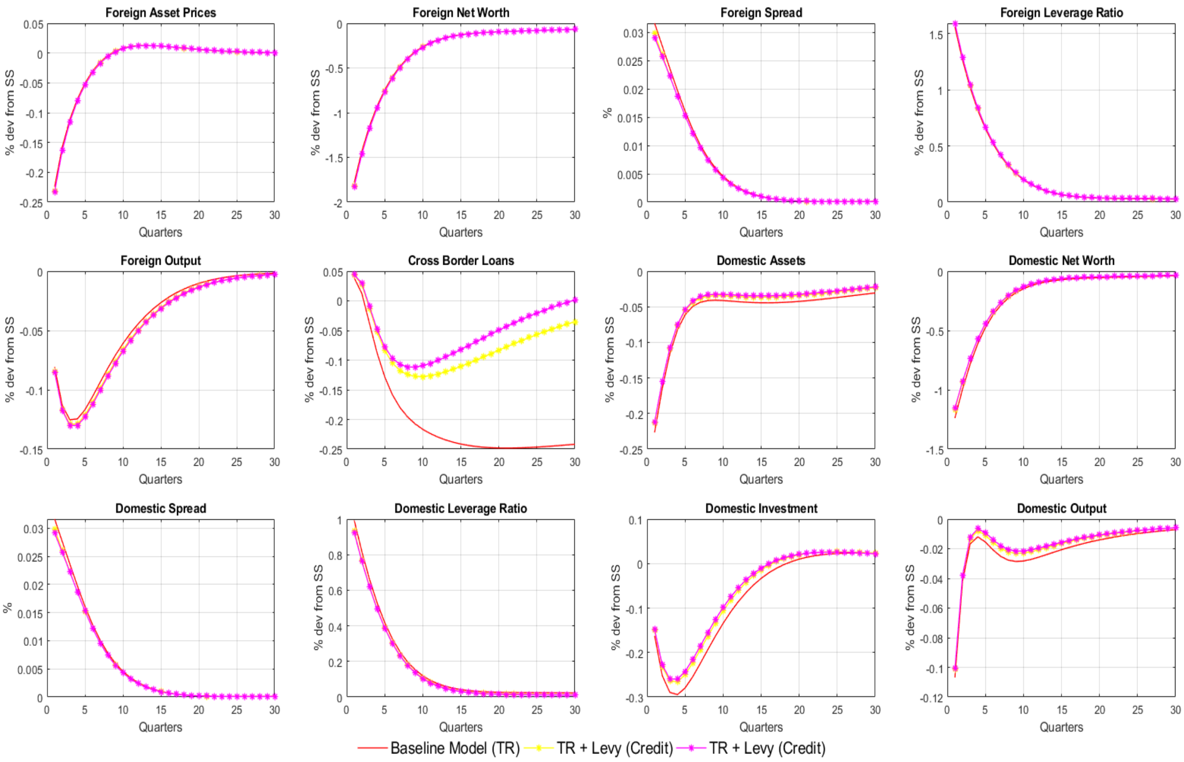

Figure 3.12: Responses to a 1% Foreign Monetary Policy Shock.

Rule 1: TR + Levy(Credit) and Rule 2: TR + Levy(Credit + Output)

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Aizenman et al. (2017) present empirical evidence that MaPs in EMEs are more effective in mitigating AE shocks when EMEs have more financial controls and hold higher international reserves. At present, MaPs in EMEs are a shield to an excessive volatility from cross border loans (or capital flows). Our results in this section are consistent with the literature, we find that the levy is effective in mitigating the implications of the global financial shock and foreign monetary policy shock in the EME.

3.6.3 Macroprudential Policies Across Countries

We examine the *de facto* coordination between the EME and the AE in fostering financial stability and working towards mitigating potential systemic risk. Both economies implement MaPs independently, AE instruments capital requirement and the EME imposes a levy on cross border loans. We have chosen this set of MaPs to compare the results from this section with our earlier findings. The US currently implements capital requirements, Mexico has not imposed a levy but looks after the volatility of cross border loans.

In Figure 3.13, we display the responses of a five percent capital quality shock. The foreign and domestic economy independently implement MaPs following Rule 1 described in equations (3.85) for capital requirements and (3.94) for the levy. In Figure 3.14, we present the responses following Rule 2 described in equation (3.86) for capital requirements and (3.95) for the levy. We exhibit in both figures the responses of *the de facto* coordination of MaPs with the responses from the scenarios analysed in the previous sections.

Under the capital quality shock, *de facto* coordination of MaPs triggers in the foreign economy similar dynamics to those when only capital requirements are in place. The enhancement of foreign banks' balance sheets dampens the decline in cross border loans mitigating the propagation of the financial crisis to the EME. In this case, capital requirements improves credit conditions in the foreign economy, reducing the fall in foreign output. In addition, the levy alleviates the credit constraint in the EME, we find that cross border loans fall significantly less under *de facto* coordination of MaPs, domestic banks are less constrained since their banks' balance sheets are enhanced leading to a smaller drop in domestic investment and output.

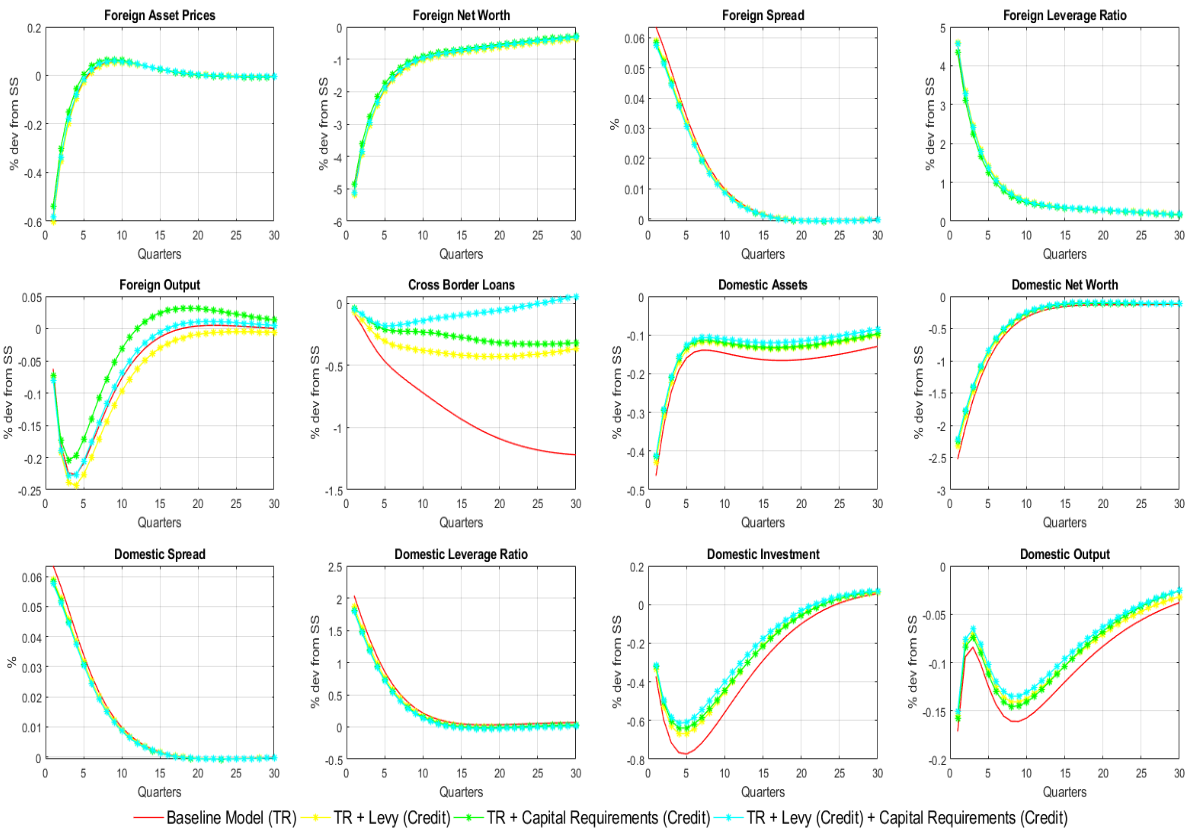

Figure 3.13: Responses to a 5% Capital Quality Shock using Rule 1.

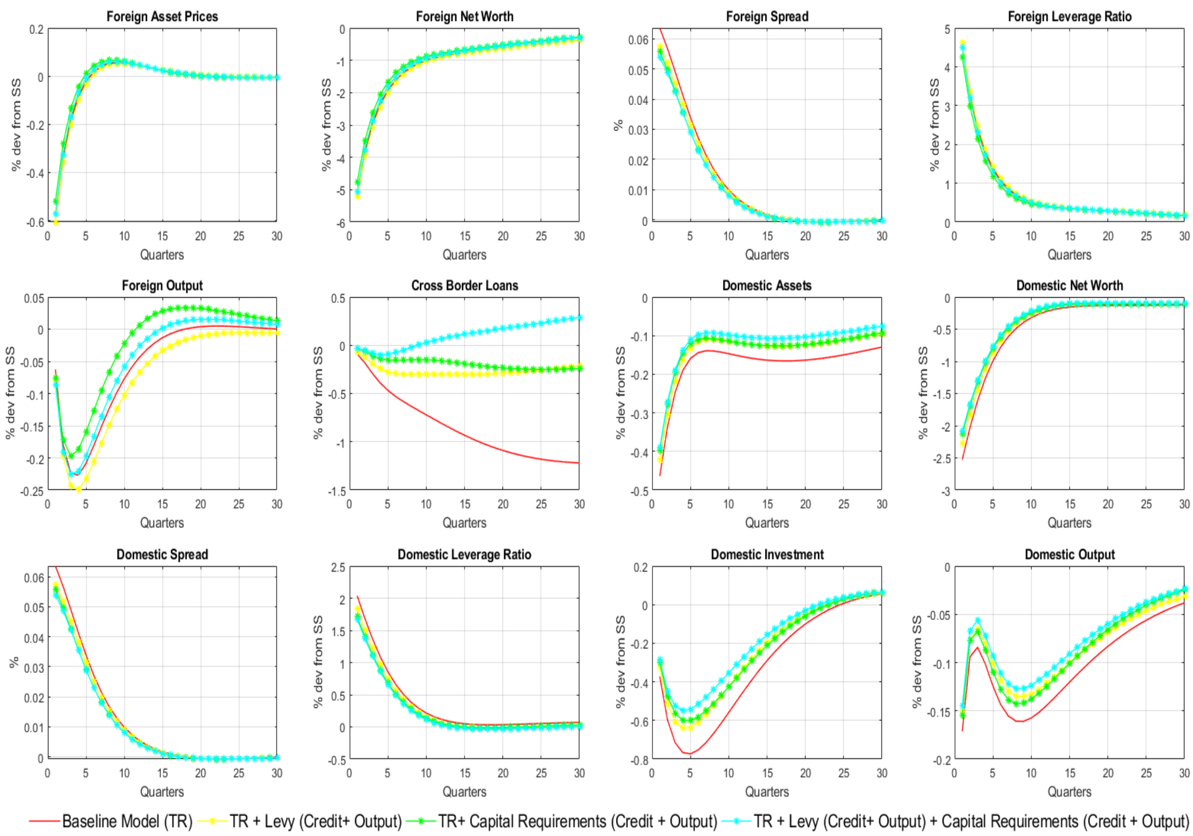

Figure 3.14: Responses to a 5% Capital Quality Shock using Rule 2.

Importantly, *de facto* coordination of MaPs across countries triggers a better performance for the EME. MaPs in both countries dampen the propagation of the shock in the EME. Cross border bank lending is the main transmission mechanism across countries in the model. This channel propagates the financial shock from the AE to the EME but serves as a mitigation channel when AE implements MaP. Capital requirements relax the conditions for foreign banks, reducing the decline in cross border loans in the EME. The levy on cross border loans further reduces the decrease in the international credit supply. Additionally, capital requirements counteract the (small and negative) spillovers caused by the levy to the AE. Comparing Figures 3.13 and 3.14, MaPs are more effective when central banks follow Rule 2 (credit and output deviations) than Rule 1 (credit deviations). Nevertheless, using both rules, the domestic economy performs better than in the previous scenarios.

In Figures 3.15 and 3.16, we analyse the same set of MaPs in the presence of one percent foreign monetary policy shock. Similar to the capital quality shock, we compare the responses of a coordination of MaPs with the responses from the previous scenarios.

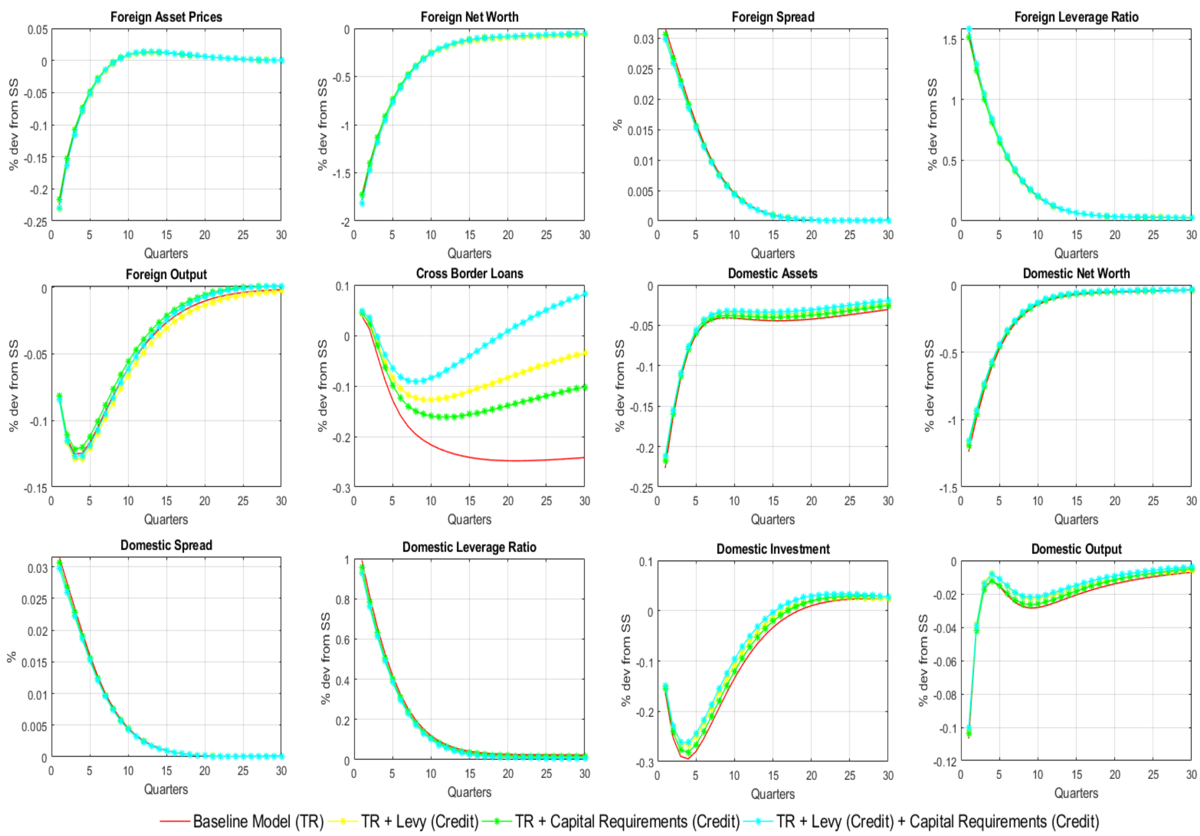

Figure 3.15: Responses to a 1% Foreign Monetary Policy Shock using Rule 1.

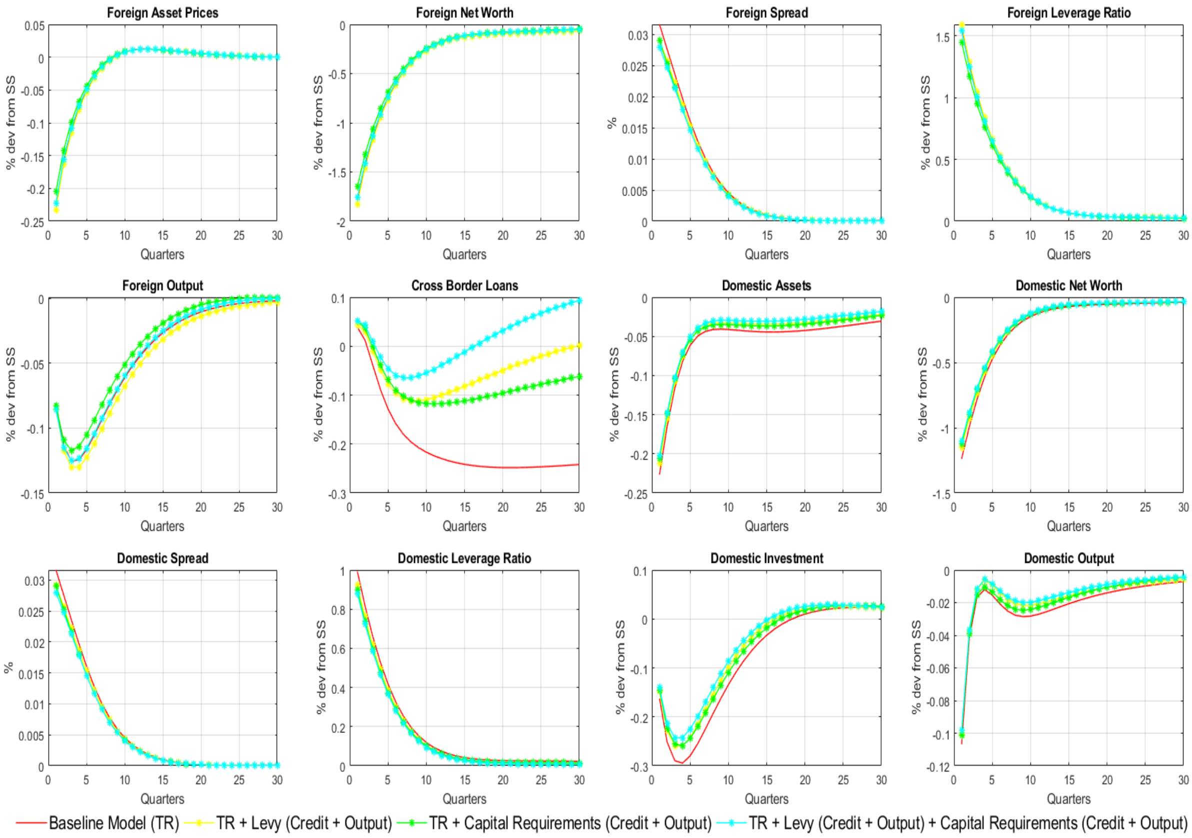

Figure 3.16: Responses to a 1% Foreign Monetary Policy Shock using Rule 2.

In previous sections, we find that the responsiveness of the domestic economy to a foreign monetary policy shock is smaller than to a capital quality shock. However, under *de facto* coordination of MaPs, the mitigation of the shock for the EME is greater than in earlier exercises. In Figures 3.15 and 3.16 cross border loans decline significantly less, enhancing the domestic banks' balance sheets and leading to a less severe decline in domestic investment and output. We do not find any significant spillover from the domestic to the foreign economy using the levy.

Regardless of the shock, our results suggest that coordination of MaPs between the AE and the EME is broadly effective in mitigating systemic risk across countries. The MaP conducted in the AE triggers positive spillovers to the EME. Capital requirements counteract the small and negative spillovers for the foreign economy caused by the levy. In addition, the levy on cross border loans reinforces the mitigation of the shock in the EME. According to our findings, the scope of implementing financial stability measures in AEs is significant. It strengthens the foreign banking sector enhancing the foreign economic conditions and hence, in turn, mitigating pressures on the international credit lending.

In our exercises, both MaPs measures mitigate the foreign monetary policy shock and the global financial crisis shock. They act in similar directions however there are cases when there may exist interaction between the two MaPs. In the literature this phenomenon is named *the regulatory war*.[8] In our exercise, capital requirements are capable of counteracting the negative spillover from the levy on the foreign output. The foreign MaP additionally triggers positive spillovers on the EME. In sum, the *de facto* coordination of MaPs across countries is highly effective in mitigating the shocks on the impact of the domestic economy.

Nevertheless, there may be cases when the macroprudential authorities are pursuing opposite objectives, or the size of the reaction is quite strong. Therefore, it is important to examine potential interactions between MaPs in different jurisdictions. Currently, the coordination of MaPs across countries is an area of growing research. In future research, we plan to explore MaPs with other channels of transmission and under other scenarios.

3.7 Welfare Analysis

To further exploration of the effectiveness of MaPs, we now present a welfare analysis in two sections. In the first, we calculate the welfare gains in the domestic economy from each of the MaPs implemented in the foreign economy and the domestic economy. In the second section, we aim to obtain the global welfare of a coordination of macroprudential policies in both economies. The global welfare gains are a measure how much consumers in both economies are better off after the coordination of MaP policies.

[8] Pereira da Silva and Chui (2017).

3.7.1 Domestic Welfare

We examine under what policy the domestic consumers are better off. Following Faia and Monacelli (2007), Schmitt-Grohé and Uribe (2007) and Gertler and Karadi (2011), we write recursively the utility function of domestic households and define welfare.

$$W_t = U\left(C_t, 1 - L_t\right) + \beta E_t W_{t+1} \tag{3.96}$$

We take the second order approximation around the steady state of W_t under each policy. Using the second order solution of the model, we take as given the parameters of the monetary and MaPs. Then, we search numerically for the parameter values to optimise and we obtain welfare W_t in each case. We report our results in Tables 3.3 and 3.4 under capital quality and monetary policy shocks, respectively. To obtain our calculations, we set a small size of shocks, equal to one percent in each case.

To compute the domestic welfare loss in each of the policies and shocks we follow closely Schmitt-Grohé and Uribe (2007) and define

$$V_0^r = E_0 \sum_{t=0}^{\infty} \beta^t U\left(C_t^r, 1 - L_t^r\right) \tag{3.97}$$

where C_t^r and $1 - L_t^r$ denote the contingent plans of domestic consumption and leisure under the optimised Taylor rule parameters in the domestic economy that maximise domestic welfare V_0^r. We define V_0^a as the maximum domestic welfare when there is in place a levy on cross border loans or capital requirements in the foreign economy.

$$V_0^a = E_0 \sum_{t=0}^{\infty} \beta^t U\left(C_t^a, L_t^a\right) \tag{3.98}$$

In this framework, the domestic welfare loss λ is the percentage of domestic steady state consumption that domestic households are willing to give up in the optimised monetary policy regime to be as well off as under any alternative policy. If $\lambda < 0$, there is a welfare gain of adopting the alternative policy and implies that V_0^a is higher than V_0^r.

In equation (3.99), the domestic welfare loss represents the equivalent domestic consumption needed to equalise the domestic welfare under the optimal monetary policy in the domestic economy, the benchmark to compare with any other policy.

$$V_0^a = E_0 \sum_{t=0}^{\infty} \beta^t U\left((1-\lambda)C_t^r, L_t^r\right) \tag{3.99}$$

We follow Faia and Monacelli (2007), who work with the same households preferences and we replace the utility function in (3.99). We solve for λ and obtain the domestic welfare loss

$$\lambda = 1 - exp\left[(V_0^a - V_0^r)(1-\beta)\right] \tag{3.100}$$

Under the capital quality shock and the foreign monetary policy shock, we find that the optimal response to output gap in the foreign and domestic economy is zero. That result is in line with Schmitt-Grohé and Uribe (2007), Faia and Monacelli (2007), Gertler and Karadi (2011) and Ozkan and Unsal (2014). Therefore, we set κ_y equal to zero and proceed to find the optimal parameters for inflation, credit growth when it corresponds, and MaPs parameters. In our model, each central bank conducts monetary and MaP independently. Thus, we search for the optimal values of the domestic Taylor rule and when it applies also for the MaP in the domestic economy whereas the values for the capital requirements are taken as given.

We present the results of the domestic welfare analysis in Tables 3.3 and 3.4. The domestic welfare and optimal parameters of the Taylor rule that maximise domestic welfare is equal to -387.483 under a capital quality shock and -364.801 in the case of a foreign monetary policy shock, our benchmarks values.

When the domestic monetary policy rule responds to credit, we observe a higher domestic welfare and the outcome is the marginal welfare gains equal to -0.034 percent of steady state domestic consumption. However, the welfare loss in the case of a monetary policy shock is higher and equal to 0.081 percent of steady state domestic consumption. In both cases, the parameter κ_d is different from zero and higher in the case of the capital quality shock.

In the case that the domestic economy operates a levy and the foreign economy does not implement any MaP the welfare gains are more significant. Under a capital quality shock, we find that using Rule 1 (credit deviations) there is a welfare improvement of -3.903 percent of steady state consumption. Using Rule 2 (credit and output deviations) the welfare gain increases up to -6.153 percent of steady state domestic consumption. Under the foreign monetary policy shock the welfare improvement is equal to -4.654 and -6.115 percent of steady state domestic consumption, respectively (Table 3.4). MaPs yield a higher welfare improvement for domestic households when the domestic central bank uses Rule 2, the domestic economy perform better in mitigating global financial shocks than under foreign monetary policy shocks at the welfare evaluation.

When the foreign economy implements capital requirements, the welfare gains are significant but lower compared to the levy in the domestic economy. Under the capital quality shock, domestic welfare improves in -2.632 percent of steady state domestic consumption using Rule 1 (foreign credit deviations) while it does in -1.512 percent using Rule 2 (foreign credit and output deviations). The welfare gain is higher if the central bank only target credit deviations.

Under the monetary policy shock, capital requirements are welfare improving for domestic households by -2.632 and -2.712 percent of steady state consumption using Rule 1 and 2, respectively. In this case, the use of Rule 2 reports a better outcome for domestic households. From the perspective of the EME, the domestic welfare gains are significant when the foreign economy implements MaPs regardless of the shock. The welfare gains are larger using the levy on cross border loans in the domestic economy, overall MaPs are welfare improving for domestic households.

Table 3.3: EME Welfare Analysis: Macroprudential Policies under Capital Quality Shock

Capital Quality Shock	**Taylor Rule**		**Levy on CBL**		**CR**		**Welfare**	
Rule	κ_π	κ_d	ϑ_{cr}	ϑ_y	γ^*_{cr}	γ^*_y	W_t	λ_t
Optimized Taylor Rule (OTR)	2.095	-	-	-	-	-	-387.483	-
OTR + Credit	1.766	0.397	-	-	-	-	-384.131	-0.034
R1. OTR + LevyMacrop EME (Credit)	1.290	-	0.010	-	-	-	-228.505	-3.903
R2. OTR + LevyMacrop EME (Credit + Output)	1.882	-	0.153	0.029	-	-	-190.723	-6.153
R1. OTR + CR (Credit) in AE	1.924	-	-	-	1.500	-	-258.492	-2.632
R2. OTR + CR (Credit + Output) in AE	1.938	-	-	-	1.500	1.500	-295.357	-1.512

Table 3.4: EME Welfare Analysis: Macroprudential Policies under Foreign Monetary Policy Shock

Foreign Monetary Policy Shock	**Taylor Rule**		**Levy on CBL**		**CR**		**Welfare**	
Rule	κ_π	κ_d	ϑ_{cr}	ϑ_y	γ^*_{cr}	γ^*_y	W_t	λ_t
Optimized Taylor Rule (OTR)	2.005	-	-	-	-	-	-364.801	-
OTR + Credit	1.784	0.146	-	-	-	-	-373.245	0.081
R1. OTR + LevyMacrop EME (Credit)	1.786	-	0.611	-	-	-	-191.569	-4.654
R2. OTR + LevyMacrop EME (Credit + Output)	1.452	-	0.277	0.511	-	-	-168.580	-6.115
R1. OTR + CR (Credit) in AE	2.845	-	-	-	1.500	-	-214.199	-2.632
R2. OTR + CR (Credit + Output) in AE	1.754	-	-	-	1.500	1.500	-233.631	-2.712

3.7.2 Global Welfare

We examine the global welfare gains under *de facto* coordination of MaPs and we compare it with a case where both countries choose the optimal values of monetary and MaP in both countries that maximise the global welfare.

Under *de facto* coordination of MaPs, each central bank independently chooses its monetary policy and the strength of its MaP that maximises households' welfare. We calculate the maximum domestic (foreign) welfare $W_{i,t}$ that optimise Γ, the vector of parameters related to monetary policy and MaPs in each country.

$$W_{i,t} = \max_{\Gamma} W_{i,0}, i = d, f \tag{3.101}$$

Therefore, we calculate the global welfare $W_{G,t}^{DF}$ under *de facto* coordination of MaPs

$$W_{G,t}^{DF} = nW_{d,t} + (1-n)W_{f,t} \tag{3.102}$$

where n is the weight of each country in the global welfare, it could be seen as the relative country size as well.[9]

Additionally, we calculate the global welfare $W_{G,t}^{J}$ when both countries jointly optimise the parameter values of monetary policy and MaPs that gives the maximum global welfare.

$$W_{G,t}^{J} = \max_{\Gamma} \left[nW_{d,t}^{J} + (1-n)W_{f,t}^{J} \right] \tag{3.103}$$

Therefore, welfare gains $WGains$ are define as the difference between the global welfare under a joint optimisation and the global welfare reported under *de facto* coor-

[9] To estimate the global welfare, we take the definition of Agénor et al. (2017). However, we did not work with Nash and cooperative equilibria. We concentrate in calculate global welfare as if both central banks jointly decide their optimal values for policy, we compared it with the scenario where both central banks decide their parameter values of policy independently, then we calculate global welfare as a weighted average.

dination of MaPs.

$$WGains = W_{G,t}^{J} - W_{G,t}^{DF} \tag{3.104}$$

In Table 3.5 and 3.6, we present the results of the analysis for a capital quality shock and foreign monetary policy shock of 1 percent in each case. In the first bloc of both tables, we display the global welfare values when both countries implement levy on cross border loans and capital requirements using Rule 1 (credit deviations). In the second block of 3.5 and 3.6, we display the levy on cross border loans and capital requirements using Rule 2(credit and output deviations).

Table 3.5: Global Welfare Gains

Capital Quality shock	n: weight of the EME			
OMP + CBL(Credit) + CR(Credit)	**0.05**	**0.15**	**0.25**	**0.50**
$W_{G,t}^{J}$	-73.787	-89.382	-104.731	-143.104
$W_{G,t}^{DF}$	-74.256	-89.659	-105.062	-143.569
$WGains$	0.469	0.277	0.330	0.464
OMP + CBL(Credit+Output) + CR(Credit+Output)				
$W_{G,t}^{J}$	-97.899	-107.330	-116.761	-140.157
$W_{G,t}^{DF}$	-98.418	-107.830	-117.242	-140.772
$WGains$	0.519	0.500	0.481	0.615

Table 3.6: Global Welfare Gains

Foreign Monetary Policy shock	n: weight of the EME			
OMP + CBL(Credit) + CR(Credit)	**0.05**	**0.15**	**0.25**	**0.50**
$W_{G,t}^{J}$	-94.073	-104.655	-115.226	-141.268
$W_{G,t}^{DF}$	-94.460	-104.713	-114.967	-140.600
$WGains$	0.387	0.058	-0.259	-0.668
OMP + CBL(Credit+Output) + CR(Credit+Output)				
$W_{G,t}^{J}$	-111.489	-117.720	-123.885	-139.215
$W_{G,t}^{DF}$	-111.820	-117.862	-123.904	-139.010
$WGains$	0.331	0.142	0.019	-0.204

Under a capital quality shock, the welfare gains of a coordination of MaPs using Rule 1 is 0.469 percent of steady state consumption.[10] It goes up to 0.519 percent when both economies implement Rule 2. In both cases the weight of the domestic economy is equal to 0.05 while the foreign economy weights the rest. In the next columns of Table 3.5, we

[10]We measure the global welfare gains as steady state weighted average consumption from domestic and foreign households.

display the welfare gains when the weight of the domestic economy is more substantial. In all cases, we find that households are better off under the explicit coordination of MaPs. In addition to this, the welfare gains are larger when central banks implement MaPs using Rule 2.

Under a monetary policy shock, the results are mix. In the firs column of Table 3.6, we find that coordination of MaPs yields global welfare gains of 0.387 and 0.331 percent of steady state consumption using Rule 1 and 2, respectively. However, the outcome turn to losses when the weight of the domestic economy increases. It could suggest that the benefits of a coordination of MaPs is more significant when the EME is smaller.[11] Finally, the implementation of MaPs using Rule 2 exhibits slightly higher welfare gains than Rule 1.

Overall, the analysis of global welfare suggests that the explicit coordination of MaPs produces a better outcome compared to *de facto* coordination of MaPs, where each central bank optimises their objectives independently. The result hold for all the weights tested under the capital quality shock. The welfare losses take place when the weight of the EME is a quarter or higher, in the case of a monetary policy shock.

3.8 Concluding Remarks

Using a New Keynesian two-country model with financial frictions, global banks and cross border loans, we study the extent to which MaPs foster financial stability across countries. We explore if cross border loans are more resilient when MaPs are in place, and in the presence of shocks. We calibrate the model for an EME, and an AE (i.e. Mexico and the US). We explore a capital quality shock and a foreign monetary policy shock.

Clearly, a capital quality shock and a foreign monetary policy shock worsen the balance sheets of foreign banks drying up their liquidity and cutting down the credit

[11] The results of Agénor et al. (2017) report lower global welfare gains when the domestic weight is higher.

supply. Global banks tend to face shocks by reducing the cross border loans sent to EMEs. Our results are in line with the empirical findings of Cetorelli and Goldberg (2012, 2009); Herrmann and Mihaljek (2010); Takats and Temesvary (2017) and Morais et al. (2014) for Mexico.

We examine the potential financial spillovers across countries with MaPs and shocks in place, we explore three scenarios. First, the foreign economy conducts MaP and the EME only the standard monetary policy. Second, only the domestic economy implements MaP. Our last scenario, the foreign and domestic economy implement MaP, we name this case as a *de facto* coordination of MaPs.

We find that MaP in the foreign economy enhances foreign banks' balance sheets and dampens the effects of the credit constraint in the foreign economy. It also mitigates the impact of the shock in the domestic country. Cross border loans are more resilient to the shocks when the economies implement MaPs. Capital requirements using Rule 2, output and credit as indicators of credit excess, the response is more extensive in the two economies. However, the welfare improvement for domestic households is greater when the MaP is implemented with a rule that only includes credit.

In the second scenario, the domestic central bank conducts macroprudential policy imposing a levy on cross border loans. We find that this MaP is highly effective in alleviating the decline in domestic investment and output. The welfare gain as a percent of steady state consumption is greater for domestic households than with capital requirements. Moreover, the mitigation of the shock and the welfare gain are more significant under the Rule 2 (output and credit deviations). These results are in line with the findings of Rubio and Carrasco-Gallego (2017).

In addition to this, we explore the case where the domestic central bank leans against the wind using a Taylor rule with credit deviations and there is no MaP in any of the two countries. We find that domestic households are worse off in the presence of a capital quality shock and marginally better off with a foreign monetary policy shock.

Finally, we explore a *de facto* coordination of MaPs across countries. The foreign economy follows capital requirements and the domestic economy imposes a levy on cross border loans. From the analysis, we find that *de facto* coordination of policies improves the foreign and domestic economic conditions. In the presence of a capital quality shock, cross border loans decline significantly less than with any other MaP implemented individually. *De facto* coordination of MaPs is beneficial for both economies. Capital requirements relax the conditions for foreign banks, reducing the international credit supply. The levy on cross border loans improves the domestic banks' balance sheets. Capital requirements also mitigate the shock in the foreign economy and counteract the small negative spillovers caused by the levy on foreign output. We find that households are better off in the case of *de facto* coordination of MaPs since each central bank implements MaPs even though they act independently of each other. However, the global welfare gains are superior if that scenario is compared with an explicit coordination of policies where both countries jointly maximise objectives.

In the analysis, *de facto* coordination of MaPs between the AE and the EME is broadly effective in mitigating the effects of the shocks across countries. Capital requirements trigger positive spillovers to the EME and the levy imposed in the EME reinforces the mitigation of the shock in that economy. The scope of implementing financial stability is substantial. It strengthens the foreign banking sector enhancing the foreign economic conditions and mitigating pressures on the international credit lending. It further contributes to alleviate the conditions of the domestic economy. We aim to further research the coordination of policies across countries, to outline scenarios experienced by countries that receive and send cross border loans.

Chapter 4

Immigration Flows and Capital-Skill Complementarity

4.1 Introduction

Immigration is a feature of social and economic life across countries. The economic impact of immigration has long been a subject of investigation, particularly in OECD countries. (Borjas, 2003; Boubtane et al., 2015; Card, 2012; Card and Peri, 2016; Dustmann et al., 2012, 2017; Nickell and Saleheen, 2008; Kiguchi and Mountford, 2017; Smith and Thoenissen, 2018; Wadsworth, 2012; Wadsworth et al., 2016). Most existing studies on immigration focus on its effects on the labour market, output and fiscal budget.

In 2017, there were approximately 258 million of people living outside of their country of birth (worldwide immigration), half of them in OECD countries. The influential study of Boubtane et al. (2015) links immigration and economic growth for 22 OECD countries between 1986 and 2006. They find that a permanent increase in immigration raises productivity growth. The study also reports that a positive impact of immigrants' human capital on GDP per capita.

OECD countries hosts two-thirds of high-skilled immigrants although they only represent 20% of the global population. High-skilled immigrants are significantly concentrated in four countries: the US, the UK, Canada and Australia receiving nearly 70%.

High-skilled immigrants hold tertiary education, in 17 of the 29 OECD countries the proportion of highly educated immigrants is greater than among the natives. The difference in education is notable in countries with selected economic immigration schemes such as Australia, Canada and the UK (OECD, 2018). However, it is observed a large proportion of overqualified workers (with tertiary education) take low-skilled and medium-skilled jobs a phenomenon Dustmann et al. (2016) call downgrading.

In this chapter, we propose a model with capital-skill complementarity and three skill types of workers to examine the effects of immigration on a host economy. We are interested in the dynamics of macroeconomic variables like domestic GDP per capita, consumption, investment and wages. In particular, we examine the implications of immigration on wages, income and consumption of the population by skill level.

Our approach is developed from a macroeconomic perspective, we are using a Dynamic Stochastic General Equilibrium model with capital accumulation and skill types. We extend in two directions the model of Canova and Ravn (2000b) and Fusshoeller and Balleer (2017) used for the German economy. First, we include an additional skill level of workers to differentiate more effectively the skill composition of occupations. The labour market is composed by three types of workers: high-skilled, medium-skilled and low-skilled workers. We provide some simulations about a transitory and a more persistent immigration shock calibrating the model for the UK and EU immigration flows.

Second, we incorporate capital-skill complementarity between physical capital and high-skilled workers proposed by Griliches (1969) and formalized in Krusell et al. (2000). We argue that this is a better specification for countries with substantial high-skilled immigration. Finally, we briefly analyse the effect of downgrading, where immigrants tend to take jobs with lower salaries and qualifications that the educational attainment they acquired in their countries of origin (Dustmann et al., 2016). We explore the effects of downgrading on the skill-composition of the labour market, wages and the overall economy.

We find that using our baseline model, high-skilled and medium-skilled workers perceive welfare gains with the transitory immigration shock. Medium-skilled workers experience a decline in their wages and income, but in the long run, their welfare improves. Low-skilled workers have a welfare loss after the shock. Using the capital-skill complementarity model, we find that the effects are more favourable for the host economy. High-skilled workers experience welfare gains in a similar size to the baseline model. However the welfare loss for low-skilled workers is significantly lower. Medium-skilled workers perceive smaller welfare gains. The economy expands at a higher pace, and output per capita falls notably less.

In the case of the gradual immigration shock, the welfare gains and losses are more pronounced. In the baseline model, high-skilled and medium-skilled workers have significant welfare gains after the shock while low-skilled workers face substantial losses. In the capital-skill complementarity model, we find that high-skilled and medium-skilled workers have lower welfare gains. However, the welfare loss for low-skilled workers is less severe. It implies that under the capital-skill complementarity model, the society is less unequal after the immigration shock.

We also present the dynamics of the economy in each of the two models when there is a transitory immigration shock, and the downgrading of immigrants is zero. In the case of the baseline model, high-skilled and medium-skilled workers are worse off, and low-skilled workers have welfare gains. In the case of the capital-skill complementarity model, the loss for high-skilled workers is substantially smaller whereas medium-skilled and low-skilled workers have welfare gains. The results show that when immigrants take the position for which they have the educational qualification, the competition for jobs is stronger in the high-skilled jobs. Therefore, it reduces welfare of high-skilled workers, but it increases their capital income. Output and investment per capita grow faster than in any other scenario.

Overall, the capital-skill complementarity model captures the complementarity between high-skilled hours worked and physical capital. It allows us to see that immigration does not necessarily imply the substitution of capital for labour. It depends on the skills of the new workers. In our model, high-skilled labour is complementary to the capital and it expands the economy, increasing the demand for more labour even the medium-skilled and low-skilled. Therefore, the effect of immigration flows on wages is less significant and it only has a negative impact on the low-skilled workers. The benefits from the immigration are higher if the downgrading of immigrant are zero.

The chapter is divided into eight sections. The second sets out our benchmark. In the third, we describe the calibration. The fourth section presents the simulations of the baseline model. The fifth explains the extension of the model with the capital-skill complementarity and the simulations. The sixth addresses the downgrading, and we present some simulations. In the seventh section, we explain the welfare analysis. The last section contains the final remarks.

4.2 Model

Our benchmark model features capital accumulation and three types of skills in the economy. We extend the model of Canova and Ravn (2000b) and Fusshoeller and Balleer (2017) which is used to explain the German Unification in earlier work and more recently to study the arrival of refugees in Germany. We incorporate three levels of skills rather than two to differentiate high and medium skill levels.

Our baseline model is an economy with high-skilled, medium-skilled and low-skilled workers supplying labour to firms and receiving wages. High-skilled workers consume goods, pay income taxes and invest in capital. Medium-skilled workers receive wages and pay income taxes. Low-skilled workers consume their wage income and are exempted from income taxes given their low earnings. Within each type of skills, there are natives and immigrants.

We extend the model to include capital-skill complementarity between physical capital and high-skilled labour. A change in the production technology gives more flexibility to the labour market and accounts for the synergies between skilled inputs. Medium-skilled and low-skilled labour keep some degree of substitutability with the high-skilled inputs.

4.2.1 Demographics

There are three types of labour in the economy, high-skilled workers N_t^s, medium-skilled workers N_t^u and low-skilled workers N_t^l. They compose the total labour force N_t, which will be equal to the population. Each period, workers face a probability of death $\pi \geq 0$ that represents their entry into the retirement age. They are replaced by newborn individuals entering the labour market, and ensuring a constant labour force every period. The probability that every newborn is a high-skilled worker is p_s, the probability of being a medium-skilled worker is p_u and $1 - p_s - p_u$ is the probability that a newborn is low-skilled.

Before any immigration shock in $t = 0$, we assume that the demographic composition of the population is in the stationary state. For simplicity, the measure of the labour force is normalised $N = 1$. In $t = 1$ and onwards the host economy experiences immigration inflows, the aggregate population is characterised by

$$N_t = N_{t-1} + N_{m,t} \tag{4.1}$$

where $N_{m,t}$ is the size of the newcomers or immigrants at $t \geq 1$. Hence the aggregate measures of high-skilled, medium-skilled and low-skilled workers are a follows

$$N_t^s = (1 - \pi) N_{t-1}^s + \pi p_s N_{t-1} + \lambda_s N_{m,t} \tag{4.2}$$

$$N_t^u = (1 - \pi) N_{t-1}^u + \pi p_u N_{t-1} + \lambda_u N_{m,t} \tag{4.3}$$

$$N_t^l = (1 - \pi) N_{t-1}^l + \pi (1 - p_s - p_u) N_{t-1} + (1 - \lambda_s - \lambda_u) N_{m,t} \tag{4.4}$$

where λ_s is the fraction of high-skilled newcomers and λ_u the fraction of medium-skilled newcomers. In equation (4.2), the first term $(1-\pi)\,N_{t-1}^{s}$ is the surviving high-skilled workers in the labour market at time t. The second term $\pi p_s N_{t-1}$ is the fraction of high-skilled newborn workers that replace the labour force that went into the retirement in the last period. The last term represents the new high-skilled immigrants $\forall\ t \geq 1$. The composition for the medium and low skilled population is similar in equations (4.3) and (4.4). The model is written in per capita units and we define γ_t^i for $i = s, u, l$ as the share of each type of workers in the total labour force.

$$\gamma_t^s = \frac{N_t^s}{N_t} \tag{4.5}$$

$$\gamma_t^u = \frac{N_t^u}{N_t} \tag{4.6}$$

$$\gamma_t^l = \frac{N_t^l}{N_t} \tag{4.7}$$

We represent the immigration shock m_t by an AR(1) process that determines the path of the net flows of immigrants $N_{m,t}$. The model does not include the movements across border of natives. Thus, the immigration shock follows

$$log(m_t) = \theta_m log(m_{t-1}) + \varepsilon_{m,t} \tag{4.8}$$

and

$$N_{m,t} = N_t log(m_t) \tag{4.9}$$

where $0 < \theta_m < 1$ and $\varepsilon_{m,t}$ is distributed as $\varepsilon_{m,t} \sim N(0, \sigma_{\theta_m})$.

4.2.2 Households Preferences

In our baseline framework, we start with three types of households differentiated by skill levels. Natives and immigrants belong to the same household type if they work in the same skill level of occupation. High-skilled workers supply labour and receive wages. They consume goods from the economy and save a fraction of their income in investments. Therefore, they also receive some capital income. Medium-skilled and low-skilled workers supply labour, receive wages and consume goods. They do not smooth consumption, and low-skilled workers are exempted from paying income taxes.

4.2.2.1 High-Skilled Households

They maximise their expected utility function by

$$maxE_t \sum_{t=0}^{\infty} [\beta(1-\pi)]^t \, [\, ln \, C_t^s + A^s \, ln \, (1 - H_t^s)] \tag{4.10}$$

subject to the high-skilled budget constraint

$$C_t^s + X_t^s = (1 - \tau^s) \, H_t^s w_t^s + (1 - \tau^s) \, r_t K_t^s \tag{4.11}$$

where $\beta \in (0, 1)$ is the discount factor and $A^s > 0$ is the preference parameter, C_t^s is the high-skilled consumption, $(1 - H_t^s)$ the high-skilled leisure, H_t^s the high-skilled hours worked and w_t^s the high-skilled wage rate. X_t^s is the investment of high-skilled workers, $r_t K_t^s$ the capital income and τ^s high-skilled income tax rate.

The capital accumulation equation is given by

$$K_{t+1}^s = X_t^s + (1 - \delta) K_t^s \tag{4.12}$$

where $\delta > 0$ is the depreciation rate of capital.

Converting into per capita terms, we rewrite the maximisation problem in the lower case letters.

$$maxE_t \sum_{t=0}^{\infty} [\beta(1-\pi)]^t \, [\, ln \, c_t^s + A^s \, ln \, (1 - h_t^s)] \tag{4.13}$$

subject to the high-skilled household constraints.

$$c_t^s + x_t^s = (1 - \tau^s)\, h_t^s w_t^s + (1 - \tau^s)\, r_t k_t^s \tag{4.14}$$

$$k_{t+1}^s = \frac{N_t^s}{{N_{t+1}}^s}\left[x_t^s + (1 - \delta)\, k_t^s\right] \tag{4.15}$$

The fist order conditions of the high-skilled households are as follow

$$\frac{1}{\lambda_t} = c_t^s \tag{4.16}$$

$$h_t^s = 1 - \frac{A^s c_t^s}{w_t^s\,(1 - \tau^s)} \tag{4.17}$$

$$1 = \beta \frac{\lambda_{t+1}}{\lambda_t} \frac{N_t^s}{N_{t+1}^s}\left[1 - \delta + (1 - \tau^s) r_{t+1}\right] \tag{4.18}$$

where λ_t is the Lagrange multiplier, that denotes the marginal utility of consuming an additional unit of income at time t. In equation (4.17), we display the optimal level of hours worked by high-skilled workers. The Euler equation of capital is written in (4.18), and the high-skilled per capita income is as follows

$$y_t^s = (1 - \tau^s)\, h_t^s w_t^s + (1 - \tau^s)\, r_t k_t^s \tag{4.19}$$

4.2.2.2 Medium-Skilled Households

Medium-skilled households maximise their expected utility making decisions of consumption C_t^u and hours worked H_t^u.

$$max E_t \sum_{t=0}^{\infty} [\beta(1 - \pi)]^t \left[\, ln\; C_t^u + A^u \; ln\; (1 - H_t^u)\right] \tag{4.20}$$

where $\beta \in (0, 1)$ is the discount factor and A^u the preference parameter that will be the same for the three skill types. Medium-skilled workers supply labour and receive wages w_t^u which is their only source of income. They pay the income tax rate τ^u, lower than the income tax rate of high-skilled workers. The budget constraint of medium-skilled households is as follows

$$C_t^u = (1 - \tau^u)\, H_t^u w_t^u \tag{4.21}$$

In per capita terms, the optimisation problem is written as follows.

$$maxE_t \sum_{t=0}^{\infty} [\beta(1-\pi)]^t \left[\, ln\; c_t^u + A^u\; ln\; (1 - h_t^u)\right] \tag{4.22}$$

subject to their budget constraint

$$c_t^u = (1 - \tau^u)\, h_t^u w_t^u \tag{4.23}$$

We write the first order conditions as below

$$h_t^u = \frac{1}{1 + A^u} \tag{4.24}$$

$$c_t^u = \frac{(1 - \tau^u)\, w_t^u}{1 + A^u} \tag{4.25}$$

Equation (4.24) defines the optimal level of medium-skilled hours worked in the host economy. Equation (4.25) is the optimal consumption of medium-skilled workers and equation (4.26) their total income.

$$y_t^u = h_t^u w_t^u \tag{4.26}$$

4.2.2.3 Low-Skilled Households

Low-skilled households maximise their expected utility as below

$$maxE_t \sum_{t=0}^{\infty} [\beta(1-\pi)]^t \left[\, ln\; C_t^l + A^l\; ln\; (1 - H_t^l)\right] \tag{4.27}$$

subject to their budget constraint.

$$C_t^l = H_t^l w_t^l \tag{4.28}$$

Households in this skill level receive the lowest wages for their work. They are exempted from paying taxes and spend all their income on consumption. In per capita terms, the maximisation problem is as below

$$maxE_t \sum_{t=0}^{\infty} [\beta(1-\pi)]^t \left[ln\, c_t^l + A^l\, ln\, (1-h_t^l) \right] \tag{4.29}$$

$$c_t^l = h_t^l w_t^l \tag{4.30}$$

The first order conditions are the following

$$h_t^l = \frac{1}{1+A^l} \tag{4.31}$$

$$c_t^l = h_t^l w_t^l \tag{4.32}$$

$$y_t^l = c_t^l \tag{4.33}$$

Equation (4.31) is the optimal supply of low-skilled hours worked, equation (4.32) is the optimal low-skilled households consumption, which in this case is equal to their income.

4.2.3 Firms

In this framework firms work in a competitive market and there is a large number of identical firms who produce output Y_t. Firms use capital K_t owned by the high-skilled households, and three types of labour aggregated in H_t^e, the efficient unit of labour.

$$Y_t = Z_t (H_t^e)^{\alpha} K_t^{1-\alpha} \tag{4.34}$$

The efficient units of labour share is α while Z_t is the total factor productivity that follows an AR(1) process

$$ln(Z_t) = \theta_Z ln(Z_{t-1}) + \varepsilon_{Z,t} \tag{4.35}$$

where $0 < \theta_Z < 1$ and $\varepsilon_{Z,t}$ is distributed as $\varepsilon_{Z,t} \sim N(0, \sigma_Z)$.

Firms hire a fraction of high-skilled hours H_t^s, medium-skilled hours H_t^u and low-skilled hours H_t^l which are aggregate by a CES function into efficiency units.

$$H_t^e = \left[(H_t^s)^{1-\rho} + \omega^u (H_t^u)^{1-\rho} + \omega^l (H_t^l)^{1-\rho}\right]^{\frac{1}{1-\rho}} \tag{4.36}$$

We measure the productivity difference of hours worked by the medium-skilled hours to high-skilled hours ratio $0 \leq \omega^u \leq 1$ and low-skilled hours to high-skilled hours ratio $0 \leq \omega^l \leq 1$, respectively. The inverse elasticity of substitution of skill hours is measured by $\rho > 0$. Perfect substitution among skills is denoted by $\rho = 0$.

Every period firms maximise their profits subject to production costs.

$$\max_{H_t^s, H_t^u, H_t^l, K_t} = Z_t \left[(H_t^s)^{1-\rho} + \omega^u (H_t^u)^{1-\rho} + \omega^l (H_t^l)^{1-\rho}\right]^{\frac{\alpha}{1-\rho}} K_t^{1-\alpha} - H_t^s w_t^s - H_t^u w_t^u - H_t^l w_t^l - r_t K_t \tag{4.37}$$

We convert equation (4.37) to per capita units using equations (4.5)-(4.7). The maximisation problem of firms per head is as follows

$$\max_{h_t^s, h_t^u, h_t^l, k_t} = z_t \left[(\gamma_t^s h_t^s)^{1-\rho} + \omega^u (\gamma_t^u h_t^u)^{1-\rho} + \omega^l (\gamma_t^l h_t^l)^{1-\rho}\right]^{\frac{\alpha}{1-\rho}} k_t^{1-\alpha} - \gamma_t^s h_t^s w_t^s - \gamma_t^u h_t^u w_t^u - \gamma_t^l h_t^l w_t^l - r_t k_t \tag{4.38}$$

The first order conditions yield the demand for capital and hours worked in each skill level of occupation as follows

$$r_t = \frac{(1-\alpha)\, z_t y_t}{k_t} \tag{4.39}$$

$$w_t^s = \frac{\alpha z_t y_t}{(h_t^e)^{1-\rho}\, (\gamma_t^s h_t^s)^{\rho}} \tag{4.40}$$

$$w_t^u = \frac{\alpha \omega^u z_t y_t}{(h_t^e)^{1-\rho} \left(\gamma_t^u h_t^u\right)^\rho} \tag{4.41}$$

$$w_t^l = \frac{\alpha \omega^l z_t y_t}{(h_t^e)^{1-\rho} \left(\gamma_t^l h_t^l\right)^\rho} \tag{4.42}$$

where y_t is per capita output and h_t^e hours worked in efficiency units. In equation (4.39), we display the return on capital. In equations (4.40) to (4.42), we present the demand for high-skilled, medium-skilled and low-skilled hours worked, respectively. The share of each skill type in the total labour force is determined by γ_t^i for $i = s, u, l$.

4.2.4 Market Clearing Conditions and the Government

In the model, the government is included in a very stylized way, and it operates in equilibrium every period. Therefore, government spending is equal to the income taxes collected from high-skilled and medium-skilled households. We assume that the owners of capital pay the same income tax rate for their capital and labour earnings.

$$\tau^s y_t^s + \tau^u y_t^u - g_t = 0 \tag{4.43}$$

To close the model, we need to write some additional equations. The high-skilled workers are the owners of the capital, then we equate the capital and investment per high skill worker in (national) per capita terms.

$$k_t = \gamma_t^s k_t^s \tag{4.44}$$

$$x_t = \gamma_t^s x_t^s \tag{4.45}$$

The per capita consumption is composed of high-skilled households consumption, medium-skilled households consumption and low-skilled households consumption.

$$c_t = \gamma_t^s c_t^s + \gamma_t^u c_t^u + \gamma_t^l c_t^l \tag{4.46}$$

Similarly, per capita income is composed by per capita income of high-skilled, medium-skilled and low-skilled households.

$$y_t = \gamma_t^s y_t^s + \gamma_t^u y_t^u + \gamma_t^l y_t^l \tag{4.47}$$

4.3 Calibration

We present the calibration of the model for the UK for two reasons. First, the UK is among the four countries receiving 70% of the high-skilled worldwide immigration. Second, the 2016 referendum opened the debate on immigration as a primary reason to leave the EU. We take as an example the EU immigration to the UK, we have excluded non EU-born immigrants to present results related to the current discussion on Brexit. However, the model could be easily extended to include non EU immigrants as a separate group.

In Table 4.1, we display the calibration, most of the parameters aim to match the UK data and in other cases we followed the standard values for the UK. The stochastic discount factor β is set at 0.99 such as DiCecio and Nelson (2007) and Harrison and Oomen (2010). The capital share $1-\alpha$ is set at 0.31 and the quarterly depreciation rate of capital δ is at 0.025 implying a 10 percent annual capital depreciation, both parameter values are in line with DiCecio and Nelson (2007), Harrison and Oomen (2010) and Faccini et al. (2011). The government spending to output ratio is set at 19.8 percent matching the UK average annual data from the World Bank statistics between 2004 and 2017.

We target the preference parameter value for low-skilled households A^l by setting the low-skilled hours worked at one third. The medium-skilled hours worked h_u is targeted to match medium-skilled to low-skilled steady-state wages ratio, accordingly high-skilled hours h_s is targeted to match high-skilled to low-skilled steady-state wages ratio. The preferences parameter for the medium-skilled and high skilled households A^u and A^s are targeted to match the hours worked for each skill type at the steady state values.

Table 4.1: Calibration of Parameters

Parameter		Value	Target or Source
General			
Discount factor	β	0.990	DiN; HO;
Labour share	α	0.690	DiN; HO; Fa
Steady state depreciation rate	δ	0.100	DiN; HO; Fa
Government Spending to GDP Ratio	$\frac{G}{Y}$	0.198	target value[a]
Labour Market			
Hours worked of medium-skilled workers	h_u	0.270	target value[b]
Hours worked of high-skilled workers	h_s	0.250	target value[c]
Low-skilled preference parameter	A^l	2.333	target value[d]
Medium-skilled preference parameter	A^u	2.704	target value[e]
High-skilled preference parameter	A^s	2.738	target value[f]
Probability of death	π	0.021	target value[g]
Probability of a high-skilled newborn	p_s	0.280	target value[h]
Probability of a medium-skilled newborn	p_u	0.280	target value[h]
Probability of a low-skilled newborn	p_l	0.430	target value[h]
Share of high-skilled newcomers	λ_s	0.200	target value[i]
Share of medium-skilled newcomers	λ_u	0.240	target value[i]
Share of low-skilled newcomers	λ_l	0.560	target value[i]
Productivity diff. medium to high-skilled hours	ω^u	0.410	target[j]
Productivity diff. between low to high-skilled hours	ω^l	0.700	target[k]
Inverse elasticity of substitution between skills	ρ	0, 0.60	DFP
High-skilled income tax rate	τ^s	0.120	target value[l]
Low-skilled income tax rate	τ^u	0.036	target value[m]
Shock Processes			
Persistence of transitory immigration shock	θ_m^T	0.7637	target value[n]
Std. error of transitory immigration shock	ρ_m^T	0.0020	target value[o]
Persistence of gradual immigration shock	θ_m^G	0.9000	target value[p]
Std. error of gradual immigration shock	ρ_m^G	0.0022	target value[q]

DiN: DiCecio and Nelson (2007); HO:Harrison and Oomen (2010); Fa:Faccini et al. (2011); DFP:Dustmann et al. (2012).

[a] Targeted $\frac{G}{Y}$ to match government spending to GDP with data from the World Bank Statistics from 2004 - 2017.

[b] Targeted h_u to match the steady-state values of medium to low-skilled wages.

[c] Targeted h_s to match the steady-state values of high to low-skilled wages.

[d] Targeted A^l to match low-skilled hours to a third.

[e] Targeted A^u to match the steady-state value of medium-skilled hours.

[f] Target A^s to match the steady-state value of high-skilled hours

[g] Targeted π to match the average working age of EU workers according to the Labour Force Survey, 2017.

[h] Targeted p_s, p_u and p_l to match the share of UK workers in high, medium and low skill occupations according to the Annual Population Survey, ONS statistics 2017.

[i] Targeted λ_s, λ_u and λ_l to match the share of EU workers in high, medium and low skill occupations according to the Annual Population Survey, ONS statistics 2017.

[j] Targeted ω^u to match gross nominal hourly earnings of medium-skilled full-time workers to high-skilled full-time workers, according to Annual Survey of Hours and Earnings, 2016.

[k] Targeted ω^l to match gross nominal hourly earnings of low-skilled full-time workers to high-skilled full-time workers, according to Annual Survey of Hours and Earnings, 2016.

[l] Targeted τ^s to match the average income tax rate for high-skilled workers net of personal allowance, the rate was estimated using data of gross nominal earnings taken from the Annual Population Survey, ONS statistics 2017.

[m] Targeted τ^u to match the average income tax rate for medium-skilled workers net of personal allowance, the rate was estimated using data of gross nominal earnings taken from the Annual Population Survey, ONS statistics 2017.

[n] Targeted θ_m^T to match the average growth rate of EU migration net flows to the UK in 2017 using data of the Long-Term International Migration (LTIM) statistics

[o] Targeted ρ_m^T to match the EU migration net flows to the UK as a share of the UK labour force in 2017 using data of LTIM.

[p] Targeted θ_m^T to match the average growth rate of EU migration net flows to the UK from 2004-2017 using data of LTIM.

[q] Targeted ρ_m^T to match the EU migration net flows to the UK as a share of the UK labour force from 2004-2017 using data of LTIM.

In the labour market, the probability of death π regulates the timing of replacement of existing workers for the newborns. We set $\pi = 0.021$ that results from the probability of being alive in year zero $1 = (1-\pi)^0$ plus the probability of being alive in year one $(1-\pi)$ and so on until 48 years, which is the lifetime of a worker in the UK in average (64-16 years). EU-born immigrants are younger than UK-population, 55 percent of them are between 20 and 40 years according to the 2017 Labour Force Survey. Therefore, we assume that the newcomers are newly born and they are expected to be replaced when they finish their working life.

The skill composition of the labour force can vary according to the indicator we use to classify workers. Many of the studies on immigration of the UK determine the skill composition using educational attainment (Kim et al., 2010; Dustmann et al., 2012; Ottaviano and Peri, 2012; Lisenkova et al., 2013; Wadsworth et al., 2016). However, in many cases, a level of education does not guarantee a job in the same level of skills. Immigrants tend to downgrade their qualifications. Thus, they may end up working in jobs with lower qualification requirements and salary (Manacorda et al., 2012; Dustmann et al., 2012). We discuss this phenomenon in more detail later in this chapter.

To calibrate the share of workers in each skill level, we use the classification reported by the Office for National Statistics (ONS). They define skill composition in four segments and by the level of occupation: high, upper-middle, lower-middle and low.[1] We map these onto our three levels by adding up the low and lower-middle as low-skilled occupations because they are similar to each other in hourly earnings. Upper-middle is the medium-skilled occupations and high is the high-skilled occupations. Our numbers are in line with the methodology followed by the Migration Advisory Committee (2014, 2017, 2018) and Vargas-Silva and Rienzo (2014).

We set the probability that a newborn is a high-skilled worker p_s by matching the share of UK-born workers at high-skilled occupations, 0.28 according to the 2016 Annual Population Survey. Similarly, the probability that a newborn is a medium-skilled worker p_u or low-skilled workers p_l is set at 0.28 and 0.43, respectively. The values match the share of UK-born workers at medium-skilled and low-skilled occupations, respectively. At the steady state γ_t^i, $i = s, u, l$ are equal to the probabilities in each skill type.

We set the share of newcomers λ_s, λ_u and λ_l at 0.20, 0.24 and 0.56, respectively. We match the parameters with the share of EU-born workers in high-skilled, medium-skilled and low-skilled occupations according to the 2016 Annual Population Survey. We present an alternative calibration of skill composition using years of full-time education as part of our robustness checks.

The productivity difference between low-skilled and high-skilled workers ω^u is set at 0.41 to match the gross nominal hourly earnings of low-skilled to high-skilled workers using data from the Annual Survey of Hours and Earnings for 2016. Following the same strategy and database, we set ω^l at 0.70 matching the gross nominal hourly earnings of medium-skilled to high-skilled workers.

To set the inverse elasticity of substitution among skills, we follow the literature. Ottaviano and Peri (2005) estimate the elasticity of substitution for the US in the interval [0.5, 0.67], Canova and Ravn (2000a) take two alternative values $\rho = 0$ and $\rho = 0.5$ for Germany where the former implies perfect substitutability. Chortareas et al.

[1]In Appendix C, we present a table with the occupations included in each level.

(2008) use the upper bound of Ottaviano and Peri (2005) for the UK and Dustmann et al. (2012) estimate 0.6 for the UK. We set ρ at 0.6 and compare the results with perfect substitutability.

The income tax rate for earnings below £34,000 a year is 20% in England. We estimate the annual average income for high-skilled and medium-skilled workers using data from the Annual Survey of Hours and Earnings for 2016. We discount the personal allowance up to £11,800 a year and calculate the average income tax rate τ^u at 3.6% and τ^s at 12%, low-skilled workers do not pay income tax.

We set the parameter values of the shocks, we use the Long-Term International Migration (LTIM) statistics as a reference and we define two immigration shocks. First, we explore a transitory migration shock using data of 2017. In this year, 107 thousand EU-born people (net flows) entered in the UK. According to the 2017 ONS statistics, 62% entered with a job or the intention of working in the UK, that is around 81.1 thousands new workers. They represent 0.2% of the total UK labour force (32 million). To capture this scenario, we set a standard error migration shock ρ_m at 0.002 with a persistence parameter θ_m equal to 0.764. It reflects the average 23.6% decrease of the EU net flows in the last two years.

To the second immigration shock, we replicate the gradual EU immigration from 2004 to 2017. The EU net flows have come gradually after the enlargement in an average of 100 thousand people per year during this period. We assume that 62% of new EU-born people enter to the UK labour market and the percentage did not change over the period. The 62.4 thousand new EU-born workers on average represent 0.22% of the UK labour force (29.9 million) between 2004-2017. Hence, we set the standard error of the migration shock ρ_m at 0.0022 and a persistence parameter θ_m at 0.9, sufficiently high to reflect the constant EU flows along the period.

Finally, in Table 4.2 we present the steady state values of relative wages under perfect and imperfect substitutability. In the first column, we exhibit medium-skilled to high-skilled wages ratio at 0.7 and low-skilled to high-skilled ratio at 0.41 under perfect substitution of labour. In this case, relative steady state wages are equal to their relative productivities, that is ω^u for medium-skilled workers and ω^l for low-skilled. That is consistent with the calibration since ω^u and ω^l are targeted to match the relative earnings per skill level according to data from the Annual Survey of Hours and Earnings, 2016. Under imperfect substitution, we obtain a very close fit in the case of medium-skilled to high-skilled wages. We observe a wider difference between low-skilled and high-skilled workers, which is partially explained for the relative size of each skill level.

Table 4.2: Steady State ratio

Wage ratio	$\rho = 0$	$\rho = 0.6$
$\frac{w_t^u}{w_t^s} = \omega^u \left(\frac{\gamma_t^s h_t^s}{\gamma_t^u h_t^u}\right)^{1-\rho}$	0.700	0.668
$\frac{w_t^l}{w_t^s} = \omega \left(\frac{\gamma_t^s h_t^s}{\gamma_t^l h_t^l}\right)^{1-\rho}$	0.410	0.280

4.4 Analysis of the Immigration Flows

In this section, we analyse two cases of immigration one is more persistent and gradual than the other. The first scenario is a transitory immigration shock with data of 2017. According to the LTIM statistics the EU net flows have been decreasing in the last two years and around 41.9% relative to 2015. The second scenario reflects the long-term immigration of EU-born people to the UK economy. We aim to emulate the average EU immigration process from 2004 to 2017. That has been characterised by a persistent and steady entrance of EU citizens in Britain. The dynamic of the immigration rise substantially after the European financial crisis. However, the EU net flows have decreased significantly, and they are currently converging to the 2012 level. We set a highly persistent shock, the size of which is an average of the data from the period.

4.4.1 Transitory Immigration Shock

In Figures 4.1 and 4.2, we display the responses of a 0.2% standard error immigration shock modelled on the data from 2017. It simulates the entry of 81.1 thousand EU workers to the UK labour market during that year. We present in the plus-marker line the responses when workers of different skills are imperfect substitutes. In star-marked line, we display the responses when there is perfect substitution among skills. It means workers could move to occupations with different skills based on the market conditions. Note that our model assumes immigrants and natives of the same skill level are perfect substitutes.

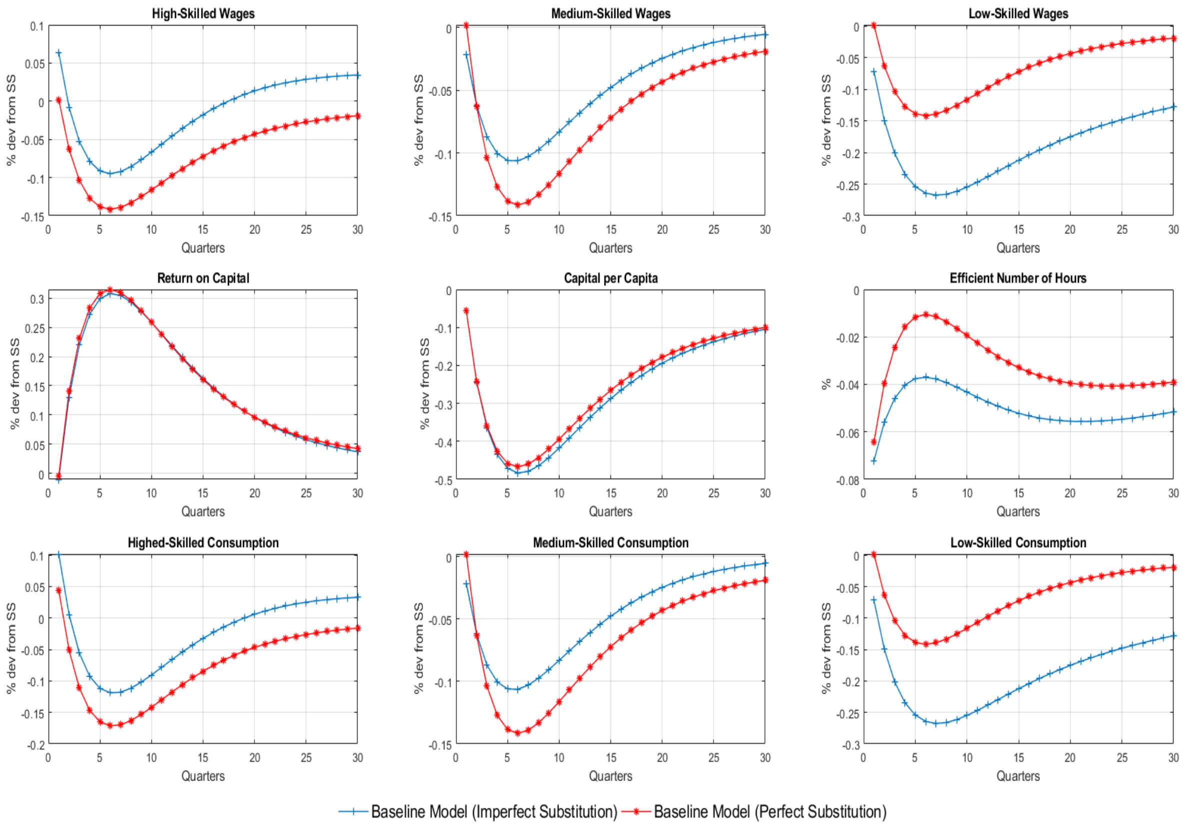

Figure 4.1: Transitory Immigration Shock by Elasticity of Substitution

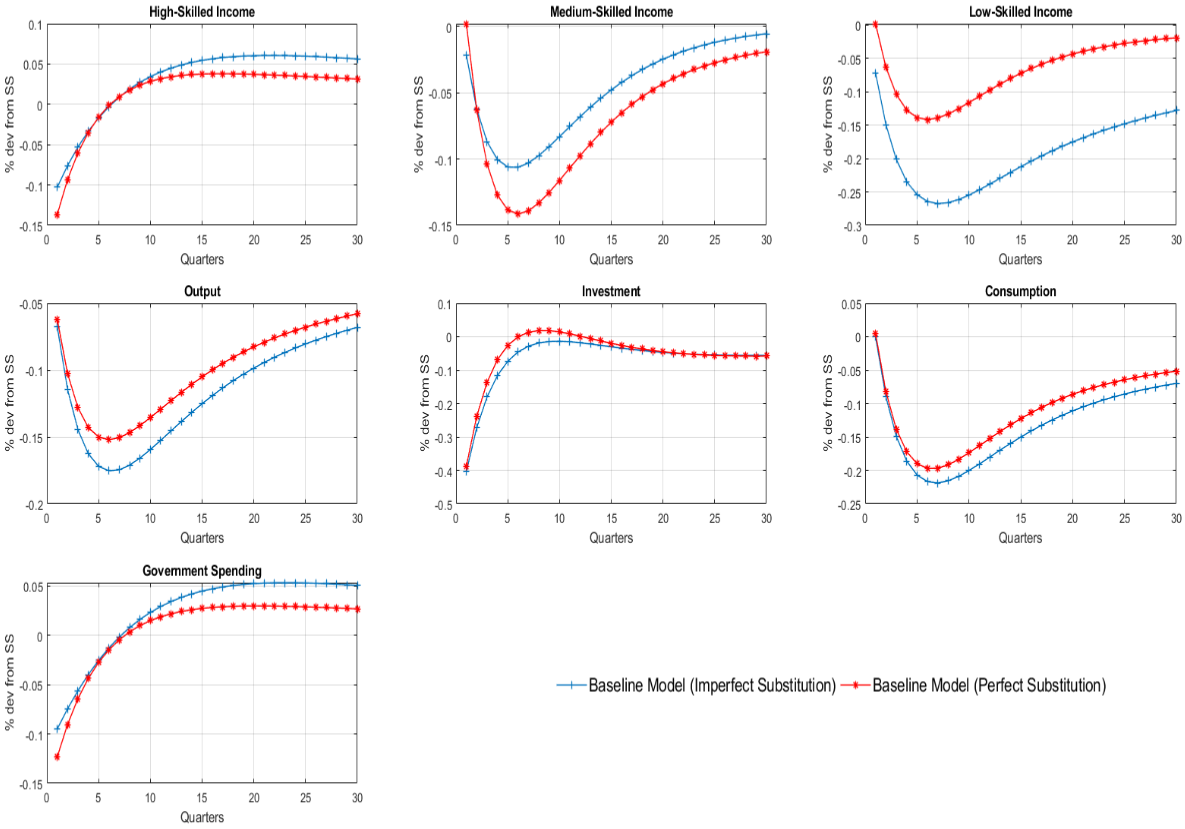

Figure 4.2: Transitory Immigration Shock by Elasticity of Substitution

The transitory immigration shock increases the labour supply in the market unevenly across skill levels. Following the distribution of immigrants from the calibration, more than 50% are hired in low-skilled occupations. Other 24% in medium-skilled jobs and 20% in the high-skilled jobs. We assume that the new immigrants follow the same distribution. Additionally, natives place fewer people in low-skilled jobs and more in medium and high skilled occupations according to the UK data. Therefore, the transitory migration shock will increase the number of workers in low-skilled occupations more than proportionally. In the high-skilled and medium-skilled levels, we observe a rise in numbers but not in the ratio.

The transitory immigration shock increases the labour supply that yields a fall in capital to labour ratio and output per capita in 0.05% and 0.15% in the first period (plus-marked line). It results in the increase in the marginal productivity of capital, that explains the rise of capital returns in 0.3% in the medium term. It triggers the recovery of investment after six periods under imperfect substitution among skills. The rise of hours worked leads to a reduction in the marginal productivity of labour in the medium and low skill levels. However, we observe the higher effect in the low-skilled occupations. Low-skilled wages go down by 0.06% in the first period and reach the highest decline after six periods with a quarter of percentage point. Medium-skilled wages fall at most 0.10% in the medium term, and then, they slightly recover above the pre-shock levels. High-skilled wages exhibit an increase of 0.06% in the first year, a temporary drop in the medium run and a significant recovery above the steady-state level in the long run. Although the number of hours worked increases, the efficient number of hours is lower since the half of the new workers are hired in low-skilled occupations.

High-skilled consumption increases by 0.1% in the first period due to the higher wages. It diminishes over time because high-skilled workers spend more on investment and wages decrease temporarily. High-skilled income declines after the shock by 0.10% since capital per head falls in the first periods. It constrains the capital income of high-skilled agents. However, as soon as investment recovers, high-skilled income goes up again. One of the primary results of the shock is the enhancement of high-skilled workers relative to wages, return on capital and therefore income. In the long run, these variables stay above their initial levels, and it may suggest that high-skilled workers are better off with the transitory immigration shock.

In the case of medium-skilled and low-skilled workers, the decreasing wages decline their per capita consumption and income by around 0.10% and 0.25% in the short and medium run. In the long run, medium-skill workers enhance their conditions since their wages, income and consumption recover to the initial levels. It does not occur for the low-skilled workers, who keep wages, per capita consumption and income below their levels before the shock.

In aggregate variables, output per capita declines in the first period, it reaches 0.17% decrease after six periods and then recovers over time. Per capita consumption has a very small increase in the first period, drops along the horizon reaching 0.15% decline six periods after the shock, and then it goes up slowly. Although government spending decreases after the shock, it goes up in the medium term. It reflects the taxes paid for the new workers allocated in high-skilled and medium-skilled occupations. Overall, the transitory migration shock triggers a distributive effect, that benefits more to high-skilled workers and worsen the position of low-skilled households.

When workers are perfect substitutes ($\rho = 0$), we observe a re-allocation of labour in the skill levels (star-marked line). We find that the supply of labour for high-skilled and medium-skilled occupations is higher than with imperfect substitution. It triggers the decline in high-skilled wages from period one. In the case of medium-skilled wages, the decline is the same at first but more profound in the following years compared to the imperfect substitution. Low-skilled wages go down less because there is a smaller group of workers who stay in low-skilled occupations. More importantly, the perfect substitution will yield that natives emigrate to the high-skilled and medium-skilled occupations. It reduces the losses for low-skilled workers relative to wages, consumption and income of around 0.15% at the worst levels.

High-skilled workers offset their loss for lower wages with more capital income given the decline in capital to labour ratio is lower. Therefore, high-skilled income does not decrease significantly. Medium-skilled income and consumption decrease more than with imperfect substitution and medium-skilled workers face the higher losses under perfect substitution. The transitory migration shock will increase the number of workers in low-skilled occupations more than proportionally. In the high-skilled and medium-skilled levels, we observe a rise in numbers of immigrants but not in the ratio. It is because of the skill composition used for the calibration, which is based on the immigration data.

4.4.2 Gradual Immigration Shock

In this section, we present the results of an average and gradual immigration shock. We use information from 2014 to 2017 to set an average 62.1 thousand immigrants every year. In Figures 4.3 and 4.4, we display the responses of an immigration shock with a standard error set at 0.022% and a highly persistent parameter to capture a similar average flows each year. The plus-marked line is the response when there is imperfect substitution between skills and the star-marked line when the substitution is perfect.

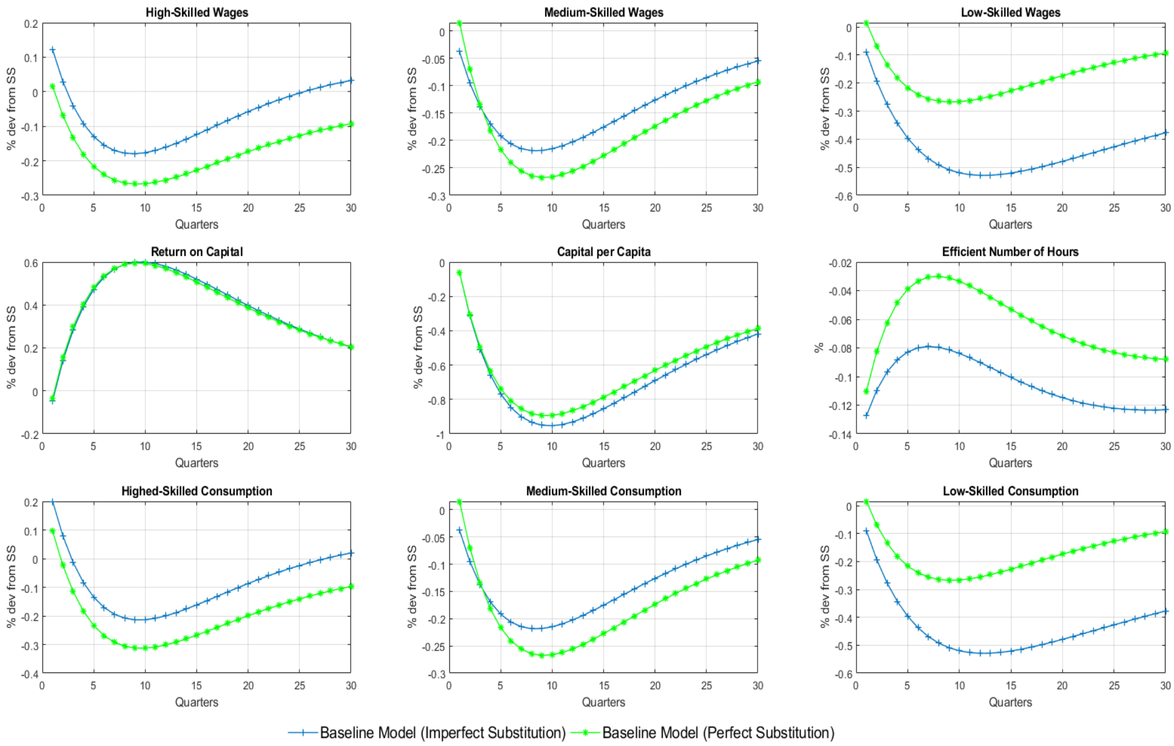

Figure 4.3: Gradual Immigration Shock by Elasticity of Substitution

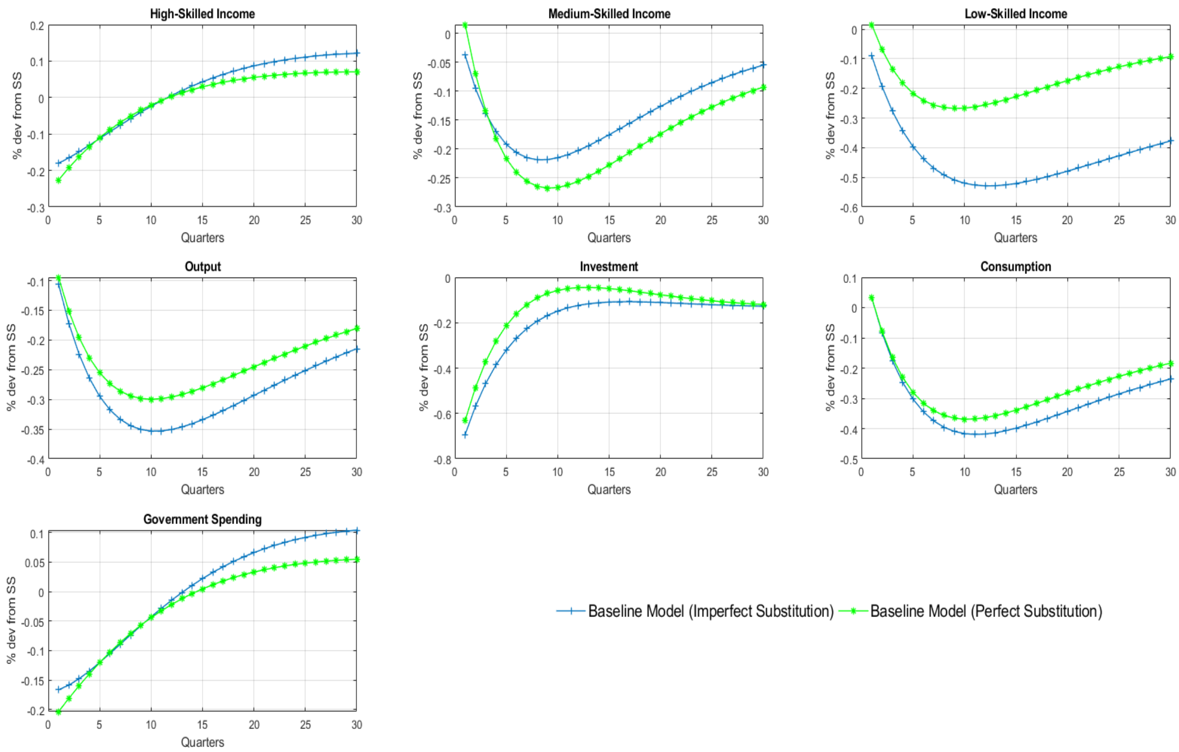

Figure 4.4: Gradual Immigration Shock by Elasticity of Substitution

We find that capital to labour ratio declines in 0.05% in the first period as a response to the additional labour supply. It reaches the highest decline at 0.9% after ten periods due to the persistent entry of immigrants into the labour market. It results in the increase of the marginal productivity of capital leading to the higher capital return, which increases up to 0.6% in the medium term. It stimulates per capita investment to recover its initial level and brings back output per capita in the long run.

New immigrants enter into the three skill occupation levels following the skill composition. As in the previous exercise, a higher share of immigrants are hired in low skill occupations. It pushes down low-skilled wages in around 0.09% in the first period and 0.5% after ten periods of the shock. Medium-skilled wages decline by about 0.02% in the first period, 0.18% in the medium term and they recover to the steady-state level in the long run. High-skilled workers benefit from the immigration shock, and their wages go up in 0.12% after the shock. The impact dies out after some periods, but high-skilled wages recover in the medium term exceeding their initial level.

Low-skilled and medium-skilled consumption decreases after the shock, the higher effect is observed for low-skilled workers, who seen declined their consumption by 0.08% after the first period and in 0.5% in the medium term. Medium-skilled consumption falls after the shock and reaches a decline in 0.21% after seven periods. While high-skilled workers experience an increase in consumption by 0.2% explained by their higher income. In the long term, high-skilled consumption outpaces their initial level, medium skilled-consumption go back to the steady state and low-skilled consumption does not reach the level before the shock.

High-skilled income declines after the shock in around 0.2%, however, it recovers in the medium term and exceeds the pre-shock levels in 0.10%. The higher return in capital explains the increase in investment and the high-skilled wages. Medium-skilled income falls in the first period and recovers in the long run to the initial level. Low-skilled income goes down significantly and does not come back to the pre-shock level. In fact, it drops in 0.40% in the long run.

Different from the transitory immigration shock, the gradual shock doubles the decline in wages and consumption in the medium and long term. It also widens the distributive effects and the benefits for the high-skilled workers relative to income and wages. According to our results, high-skilled workers are better off after the shock, medium skill workers are as well as before and low-skilled workers are worse off. It may suggest some inequality effects in the long run that we are not exploring with great detail here. Overall, the high persistence of the gradual migration shock aims to capture a permanent entry of immigrants to the host economy, implying a fraction of new workers to the domestic labour market every year.

Under perfect substitution, we find that some low-skilled workers emigrate to medium and high skill occupations. It reduces the decline in low-skilled wages and improves the conditions of low-skilled workers relative to wages, consumption and income. High-skilled wages drop in the first period more than in the case of imperfect substitution. Moreover, the decline is deeper in the medium and long run because the number of workers in high-skilled occupations is larger. In the short run, medium-skilled workers experience the same fall than under imperfect substitution. However, the decline is higher in the medium and long run. It may be explained by the gradual entry of workers to this skill occupations. Low-skilled workers are better than in the case of imperfect substitution, their wages and consumption only decrease in 0.25% in their lowest point.

Overall the gap between high-skilled workers and low skilled workers narrows. Nevertheless, high-skilled workers seems to keep positive benefits, low-skilled workers decline their losses and medium skilled-workers rise them compared to the case of imperfect substitution.

The scenario of perfect substitution is unlikely in our case but it is useful to understand the dynamics of the model. The probability that low-skilled workers end up in jobs for which they are under-qualified is low as we will see later. According to the ONS statistics, only 14% of workers are under-qualified for the jobs they work for, which is close to the average of the OECD countries (ILO, 2014). What is more common is that high-skilled and medium skill workers, particularly among immigrants, have jobs with lower qualification requirements than their educational attainment. Therefore, we continue our analysis in the following sections only with the case of imperfect substitution.

4.5 Capital-Skill Complementarity

Increases in the labour supply do not always lead to falling wages. The effect depends on the supply of capital, on the structure of the technology, the skill composition and the characteristics of the new workers. In the literature on immigration, these elements are crucial in determining the impact that the immigration flows have on national and native wages (Card, 2012; Dustmann et al., 2016). For instance, Borjas (2003) studies immigration flows in the US from 1960 to 1990. He assumes that the labour demand is downward sloping and capital is fixed in a partial equilibrium framework. Therefore, an additional labour supply inevitably depresses wages.

On the contrary, Ottaviano and Peri (2012) study the US immigration on wages for the period 1990-2006. They find small positive effects to native wages and substantial adverse effect on wages of previous immigrants. However, they allow for the capital to labour ratio adjustment to the balanced growth path using a Cobb-Douglas technology as a framework for their empirical estimations. Manacorda et al. (2012) explore the effect of immigration flows in the UK from the mid-1970s to the mid-2000s. They find that immigration has primarily affected immigrant wages, but the impact on native wages is not clear.

Our theoretical framework is a general stochastic equilibrium model that assumes that capital to labour ratio adjusts in the long run. It results in the scarcity of capital when there are immigration flows that stimulate investment and brings back the economy to their balanced growth path. In the previous section, we find that high-skilled workers benefit from immigration flows, there is a slightly positive effect for medium-skilled wages and some losses for low-skilled workers in the long run.

In the present section, we introduce a change in the technology of production to make the capital more elastic. We aim to capture the complementarity between physical capital and high-skilled labour and the substitution between capital and lower skilled labour. Griliches (1969) and Krusell et al. (2000) presented empirical and theoretical evidence on the capital-skill complementarity for the US economy. More recently, Duffy et al. (2004) confirmed the findings on capital-skill complementarity by using international data.

In migration studies, capital-skill complementarity is a feature that enhances the understanding of the capital accumulation and its interaction with the different types of labour. Ben-Gad (2008) incorporated the capital-skill complementarity using a model with overlapping dynasties calibrated for the US economy. He found that the entrance of high-skilled immigrants lowers their wages but raises the wages of unskilled workers. More importantly, the new high-skilled workers raise substantially the return on capital due to the complementarity between high-skilled labour and capital. However, in the case of an influx of unskilled workers, capital return only increases marginally.

An additional implication of the capital-skill complementarity is on the size of the immigration surplus that represents the benefit that accrues to the native population from an inflow of new immigrants. Ben-Gad (2008) found that the entrance of skilled workers actually yielded a larger immigration surplus than in the case of an unskilled workers' inflow of the same size. Capital-skill complementarity improves the differentiation between types of labour that is not even capture by differences in productivities. High-skilled immigration yields a larger immigration surplus compared to the unskilled migration. It results from the complementarity between skilled labour and capital that trigger a more significant increase in the demand for capital, causing a more substantial increase in unskilled wage and exhibiting more notable benefits for natives Ben-Gad et al. (2017).

In this section we extend the baseline model to incorporate the capital-skill complementarity between capital and high-skilled labour. We modify the production function and the framework of labour demand. We solve the new profit maximisation problem facing firms. We follow Krusell et al. (2000) and Dolado et al. (2018) to incorporate capital-skill complementarity to our model. We define H_t as the aggregate CES function of medium-skilled and low-skilled hours worked

$$H_t = \left[(H_t^u)^{\rho_h} + \omega^l (H_t^l)^{\rho_h}\right]^{\frac{1}{\rho_h}} \tag{4.48}$$

where $0 \leq \omega^l \leq 1$ is the productivity difference between medium-skilled and low-skilled hours worked. We define the elasticity of substitution between medium-skilled and low-skilled hours worked as $\sigma_h = \frac{1}{1-\rho_h}$ and $0 < \rho_h \leq 1$. We assume medium-skilled and low-skilled workers can be considered as substitutes.

S_t is the aggregation of physical capital K_t and high-skilled hours worked H_t^s in a CES function

$$S_t = \left[\lambda_k K_t^{\rho_k} + (1-\lambda_k)(H_t^s)^{\rho_k}\right]^{\frac{1}{\rho_k}} \tag{4.49}$$

where λ_k is the capital intensity of the skill input bundle. We define $\sigma_k = \frac{1}{1-\rho_k}$ as the elasticity of substitution between physical capital and high-skilled hours worked and $\rho_k < 0$. Capital-skill complementarity is captured by $0 < \sigma_k \leq 1$ and the larger in absolute terms is ρ_k, the higher the degree of the complementarity.

We propose a nested CES production function that aggregates the two type of factors, the skilled inputs S_t and the aggregation of medium-skilled and low-skilled hours worked H_t.

$$Y_t = Z_t \left[\alpha S_t^{\rho} + (1-\alpha) H_t^{\rho}\right]^{\frac{1}{\rho}} \tag{4.50}$$

where α is the skill intensity of total production and $0 < \rho \leq 1$ determine the elasticity of substitution between S_t and H_t. The elasticity of substitution is defined as $\sigma = \frac{1}{1-\rho}$ and is governed by the value of ρ. Larger values of ρ correspond to higher substitutability and $\rho = 1$ denotes perfect substitution between S_t and H_t.

Every period firms maximise their profits subject to their costs.

$$\max_{H_t^s, H_t^u, H_t^l, K_t} = Z_t \left[\alpha \left[\lambda_k K_t^{\rho_k} + (1-\lambda_k)(H_t^s)^{\rho_k}\right]^{\frac{\rho}{\rho_k}} + (1-\alpha)\left[(H_t^u)^{\rho_h} + \omega^l (H_t^l)^{\rho_h}\right]^{\frac{\rho}{\rho_h}}\right]^{\frac{1}{\rho}} - H_t^s w_t^s - H_t^u w_t^u - H_t^l w_t^l - r_t K_t \tag{4.51}$$

In per capita units the maximisation problem is as follows

$$\max_{h_t^s, h_t^u, h_t^l, k_t} = z_t \left[\alpha \left[\lambda_k k_t^{\rho_k} + (1-\lambda_k) \left(\gamma_t^s h_t^s\right)^{\rho_k} \right]^{\frac{\rho}{\rho_k}} + (1-\alpha) \left[(\gamma_t^u h_t^u)^{\rho_h} + \omega^l (\gamma_t^l h_t^l)^{\rho_h} \right]^{\frac{\rho}{\rho_h}} \right]^{\frac{1}{\rho}} - \gamma_t^s h_t^s w_t^s - \gamma_t^u h_t^u w_t^u - \gamma_t^l h_t^l w_t^l - r_t k_t \tag{4.52}$$

The first order conditions yield the demand for capital in equation (4.53), the demand for high-skilled hours, medium-skilled hours and low-skilled hours in equations (4.54)-(4.56).

$$r_t = \frac{\alpha y_t^{1-\rho} s_t^{\rho-\rho_k} \lambda_k}{z_t^{\rho} k_t^{1-\rho_k}} \tag{4.53}$$

$$w_t^s = \frac{\alpha y_t^{1-\rho} s_t^{\rho-\rho_k} (1-\lambda_k)}{z_t^{\rho} \left(\gamma_t^s h_t^s\right)^{1-\rho_k}} \tag{4.54}$$

$$w_t^u = \frac{(1-\alpha) y_t^{1-\rho} h_t^{\rho-\rho_h}}{z_t^{\rho} \left(\gamma_t^u h_t^u\right)^{1-\rho_h}} \tag{4.55}$$

$$w_t^l = \frac{(1-\alpha) \omega^l y_t^{1-\rho} h_t^{\rho-\rho_h}}{z_t^{\rho} \left(\gamma_t^l h_t^l\right)^{1-\rho_h}} \tag{4.56}$$

With these changes in the supply side of the model, the rest of the equations adjust to the new factor demands. In the next section, we set the calibration for the new parameters.

4.5.1 Calibration

Before proceeding with some simulation results, we present the calibration of the model with capital-skill complementarity in Table 4.3.

We focus in the new parameters, skill intensity α is set at 0.43 following Krusell et al. (2000) and Dolado et al. (2018). We assign α to skilled inputs rather than to efficient units of hours as in the baseline model. We set the elasticity of substitution between capital and high-skilled hours ρ_k at -0.490 and the elasticity of substitution between skilled inputs and the lower skilled labour (medium-skilled and low-skilled) ρ at 0.400. In both cases, we take the parameter values from Krusell et al. (2000) and Dolado et al. (2018).

Table 4.3: Calibration of Parameters

Parameter		Value	Target or Source
New Parameters			
Skill intensity	α	0.430	KruORV; DoMP;
Elast. of subs. capital vs high-skilled hours	ρ_k	-0.490	KruORV; DoMP;
E.o.s. medium-skilled to low-skilled hours	ρ_h	0.600	DFP
E.o.s. skilled inputs to lower skilled hours	ρ	0.400	KruORV; DoMP;
Product. diff. low-skilled to medium-skilled	ω^l	0.582	target value[a]
General			
Discount factor	β	0.990	DiN; HO;
Steady state depreciation rate	δ	0.100	DiN; HO; Fa
Government Spending to GDP Ratio	$\frac{G}{Y}$	0.198	target value[b]
Labour Market			
Low-skilled preference parameter	A^l	2.333	target value[c]
Medium-skilled preference parameter	A^u	2.704	target value[d]
Hours worked of high-skilled workers	h_s	0.260	target value[e]
Probability of death	π	0.021	target value[f]
Probability of a high-skilled newborn	p_s	0.280	target value[g]
Probability of a medium-skilled newborn	p_u	0.280	target value[g]
Probability of a low-skilled newborn	p_l	0.430	target value[g]
Share of high-skilled newcomers	λ_s	0.200	target value[h]
Share of medium-skilled newcomers	λ_u	0.240	target value[h]
Share of low-skilled newcomers	λ_l	0.560	target value[h]
High-skilled income tax rate	τ^s	0.120	target value[i]
Low-skilled income tax rate	τ^u	0.036	target value[j]
Steady state low-skilled to medium-skilled ratio $\frac{w_t^l}{w_t^u} = \omega^l \left(\frac{\gamma_t^u h_t^u}{\gamma_t^l h_t^l}\right)^{1-\rho_h}$		0.466	target value[k]
Shock Processes			
Persistence of transitory immigration shock	θ_m^T	0.7637	target value[l]
Std. error of transitory immigration shock	ρ_m^T	0.0020	target value[m]
Persistence of gradual immigration shock	θ_m^G	0.9000	target value[n]
Std. error of gradual immigration shock	ρ_m^G	0.0022	target value[o]

KruORV: Krusell et al. (2000); DoMP: Dolado et al. (2018); DiN: DiCecio and Nelson (2007); HO: Harrison and Oomen (2010); Fa: Faccini et al. (2011); DFP: Dustmann et al. (2012).

[a] Targeted ω^l to match gross nominal hourly earnings of low-skilled full-time workers to medium-skilled full-time workers, according to Annual Survey of Hours and Earnings, 2016.

[b] Targeted $\frac{G}{Y}$ to match government spending to GDP with data from the World Bank Statistics from 2004 - 2017.

[c] Targeted A^l to match low-skilled hours to a third.

[d] Targeted A^u to match the steady-state value of medium-skilled hours at 0.27.

[e] Targeted h^s to match the preference parameter value equal to the baseline model.

[f] Targeted π to match the average working age of EU workers according to the Labour Force Survey, 2017.

[g] Targeted p_s, p_u and p_l to match the share of UK workers in high, medium and low skill occupations according to the Annual Population Survey, ONS statistics 2017.

[h] Targeted λ_s, λ_u and λ_l to match the share of EU workers in high, medium and low skill occupations according to the Annual Population Survey, ONS statistics 2017.

[i] Targeted τ^s to match the average income tax rate for high-skilled workers net of personal allowance, the rate was estimated using data of gross nominal earnings taken from the Annual Population Survey, ONS statistics 2017.

[j] Targeted τ^u to match the average income tax rate for medium-skilled workers net of personal allowance, the rate was estimated using data of gross nominal earnings taken from the Annual Population Survey, ONS statistics 2017.

[k] Targeted $\frac{w_t^l}{w_t^u}$ to match ω^l times the ratio of skill's size and hours worked of medium-skilled and low-skilled workers.

[l] Targeted θ_m^T to match the average growth rate of EU migration net flows to the UK in 2017 using data of the Long-Term International Migration (LTIM) statistics

[m] Targeted ρ_m^T to match the EU migration net flows to the UK as a share of the UK labour force in 2017 using data of LTIM.

[n] Targeted θ_m^T to match the average growth rate of EU migration net flows to the UK from 2004-2017 using data of LTIM.

[o] Targeted ρ_m^T to match the EU migration net flows to the UK as a share of the UK labour force from 2004-2017 using data of LTIM.

In the case of the elasticity of substitution between medium-skilled and low-skilled hours ρ_h, it is equal to 0.600 such as Dustmann et al. (2012) same as the baseline model. The productivity difference between low-skilled and medium-skilled hours ω^l is set at 0.582, which is determined by the medium-skilled to low-skilled wages ratio. To calculate this parameter, we use the gross nominal hourly earnings from the Annual Survey of Hours and Earnings of 2016. The rest of the parameters are similarly calibrated than in the baseline model.

4.5.2 Transitory Immigration Shock

In Figures 4.5 and 4.6, we display the responses of the same transitory immigration shock (standard error of 0.20%), in star-marked line the model with capital-skill complementarity. We compare these results with the responses of the baseline model under the same shock (plus-marked line). We find that capital to labour ratio falls at the same rate in both models, in the first year. However, it decreases less and recovers faster in the medium and long run in the model with capital-skill complementarity. The highest decline occurs after five periods at 0.45%. This effect leads to a higher rise in the return on capital to 0.5% in the medium term. It triggers a significantly higher increase in per capita investment that stimulates the economy in the medium and long run. The path of per capita output is substantially better along the horizon, and per capita investment does better in the medium term.

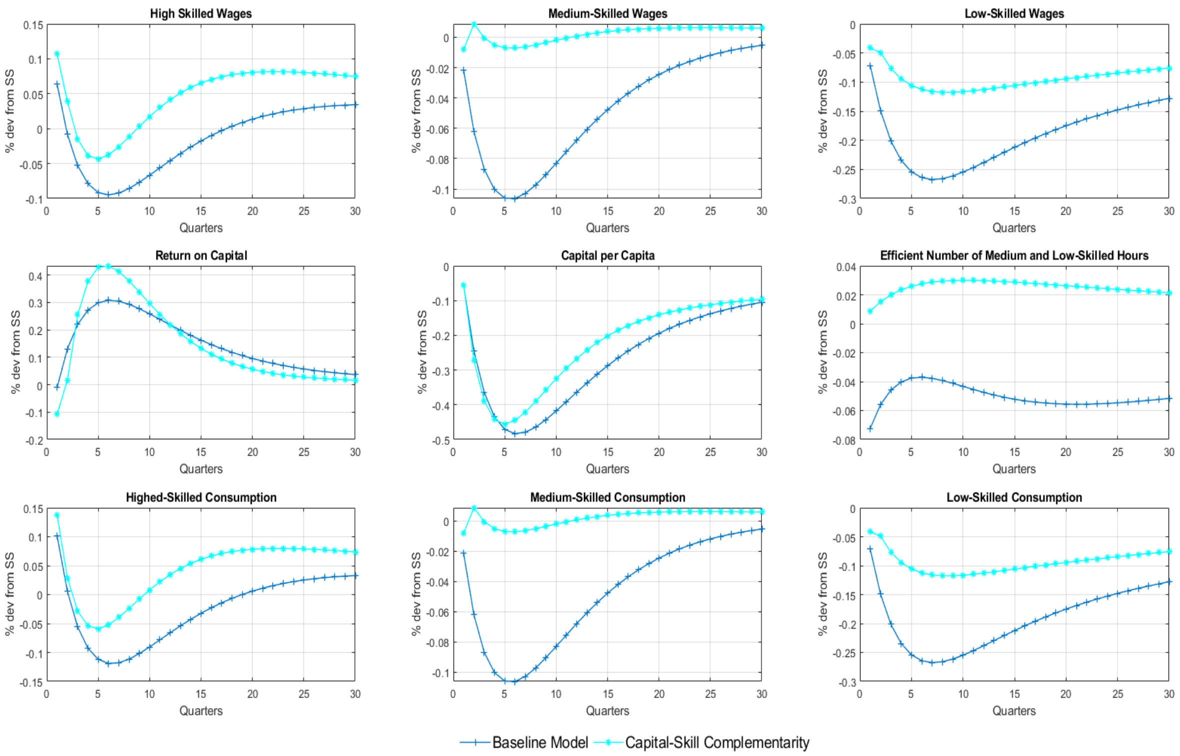

Figure 4.5: Transitory Immigration Shock of Capital-Skill Complementarity

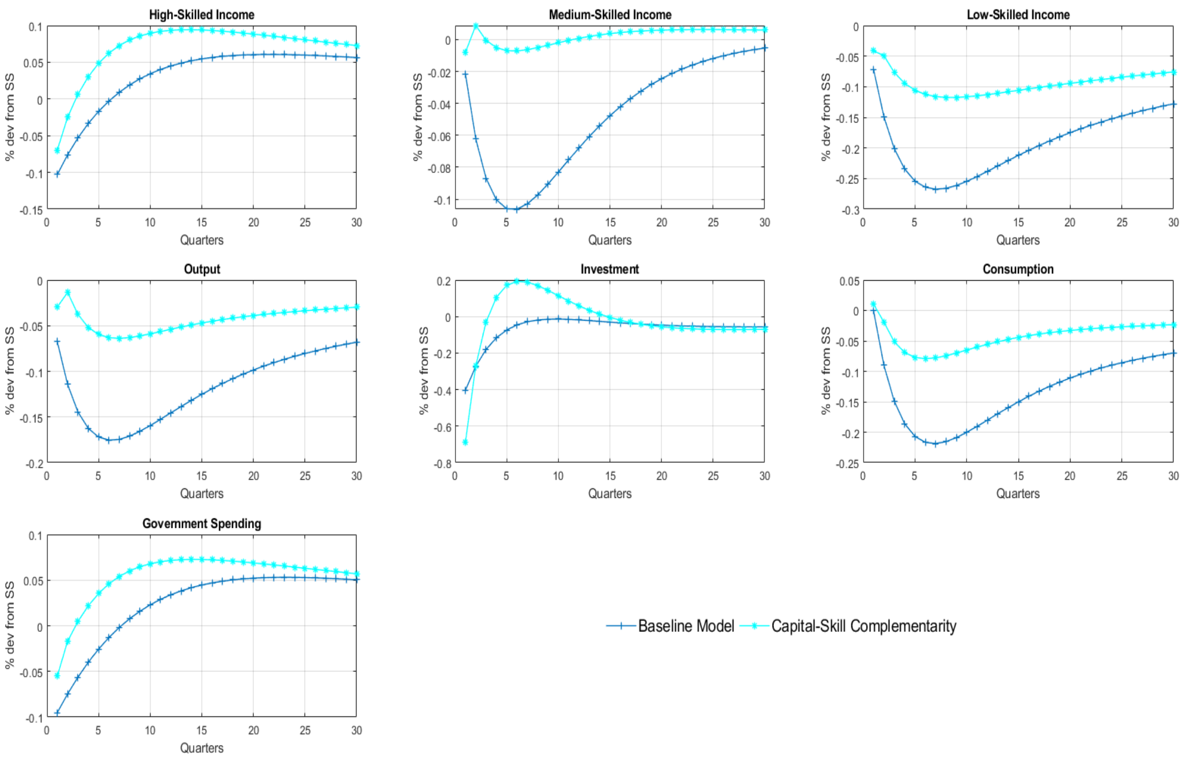

Figure 4.6: Transitory Immigration Shock of Capital-Skill Complementarity

With the same skill composition of occupations than before, the additional supply of labour is similar in the two models. The entry of new high-skilled workers to the economy yields some synergies with physical capital, which are not captured in the baseline model (plus-marked line). In the capital-skill complementarity model (star-marked line), physical capital and high-skilled workers behave as complements. It expands the economy at a higher pace, increasing investment and output more than in the baseline model. Therefore, per capita output falls significantly less along the horizon.

The increase of capital tends to raise the marginal productivity of high-skilled labour because they are not seen as substitutes. It stimulates production leading to the rise in high-skilled wages, which go up to 0.12% in the first period. They decrease for a short period but recover significantly above their initial level in the medium and long run. Hence, the average 20% of the new immigrants allocated in high-skilled occupations potentially complement equipment and machines in the country. It represents a direct and positive impact to the economy. In the model with capital-skill complementarity, H_t increases and stays above the initial levels, although they have a degree of substitution with the skilled inputs. However, the expansion of the economy demands more medium-skilled and low-skilled hours worked.

Medium-skilled wages are also benefited from the capital-skill complementarity that causes higher investment and production because it also raises the demand for medium-skilled hours worked. Medium-skilled wages only go down in the first period but increase steadily to around 0.01% along the horizon. Low-skilled wages fall significantly less, they decline in around 0.03% in the first period and have the highest decline after six periods at 0.1%. These values contrast with the decline in the baseline model (plus-marker line). Under capital-skill complementarity, immigration flows seem to affect less all wages.

High-skilled consumption rises to 0.15% in the first period after the shock, which is higher than in the baseline model. High-skilled income falls less in the short run and recovers in the medium-run. It reaches a rise in 0.1% after ten periods. Medium-skilled consumption and income also present positive dynamic maintaining levels above the steady state. That contrasts with the decline in these variables in the baseline model.

Low-skilled consumption and income decline significantly less and that improves the conditions of low-skilled workers. Finally, the synergies between capital and high-skilled hours worked that improve the conditions of the economy and expand production trigger an increase in taxes in a shorter period than in the baseline model.

4.5.3 Gradual Immigration Shock

In Figures 4.7 and 4.8, we display the responses of the capital-skill complementarity model (star-marked line) and the baseline model (plus-marked line). The gradual and persistent shock has a standard error at 0.22%, and the shock is highly persistent. Capital to labour ratio declines at the same rate in the first period in both models. However, it decreases less and recovers faster in the medium run, in the case of the capital-skill complementarity model. It leads to a higher increase in the return on capital, which goes up to 0.8% in the medium term, compared with the 0.6% in the baseline model.

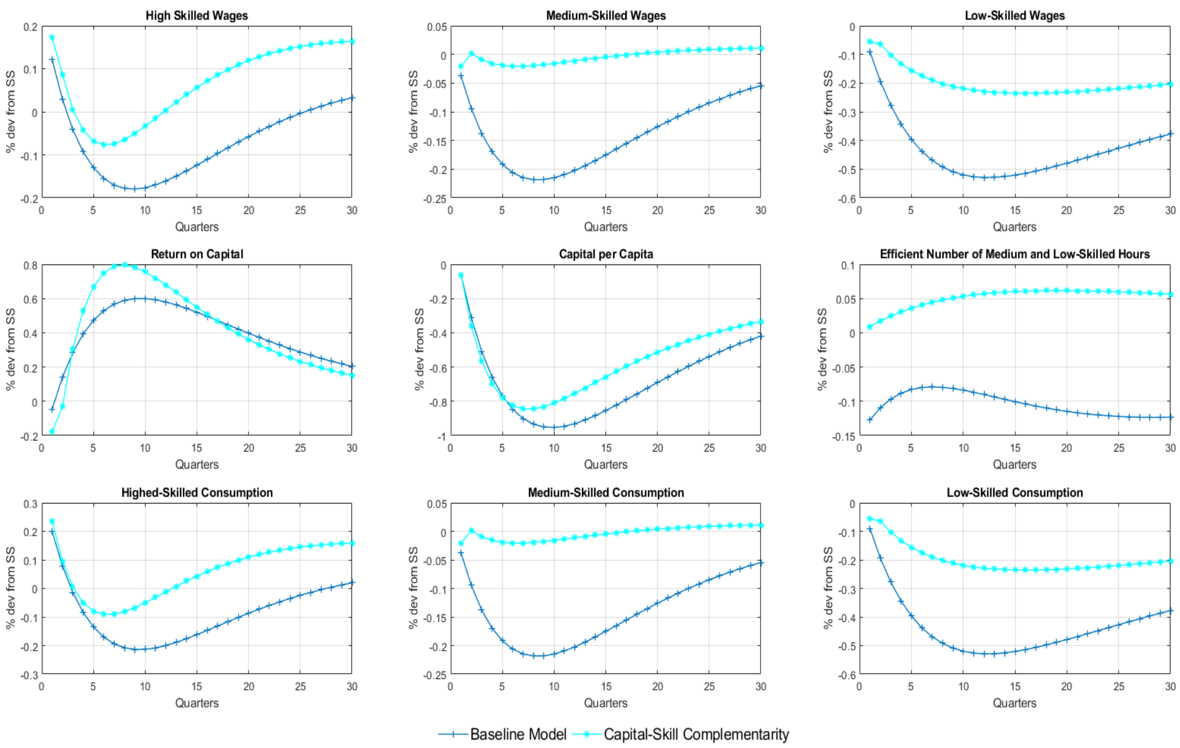

Figure 4.7: Gradual Immigration Shock of Capital-Skill Complementarity

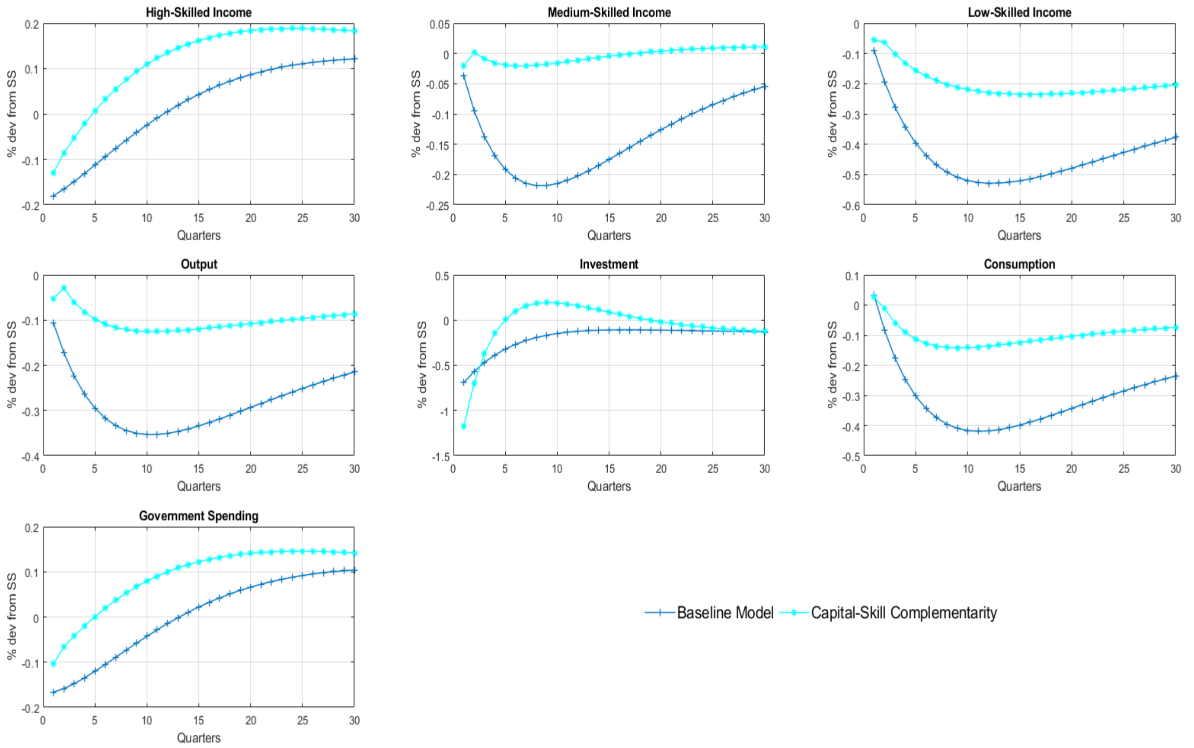

Figure 4.8: Gradual Immigration Shock of Capital-Skill Complementarity

The number of medium-skilled and low-skilled hours worked increases in the short run and reaches 0.05% rise in the medium and long run. The complementarity between the high-skilled hours worked, and the physical capital explains this result. It contrasts with the decline that we observe in the baseline model. It also pushes up per capita investment in the medium run.

High-skilled wages increase 0.18% after the shock, they decline marginally in the medium run and rise again reaching larger numbers to the steady state. Medium-skilled wages fall in the first period, but the next increase offsets the negative impact. In the long run, they rise in around 0.020% relative to the steady state. Low-skilled wages decline, however, the fall is significantly lower. The conditions of low-skilled workers enhance in a model with capital-skilled complementarity either in a transitory or a gradual immigration shock.

In the capital-skill complementarity, the conditions for high-skilled and medium-skilled workers are much better. High-skilled wages decline less, and investment increases more. Therefore, high-skilled income goes up to higher levels relative to the steady state.

Medium-skilled wages, income and consumption, increase slightly along the path instead of declining as in the baseline model. In addition to this, the negative impact for low-skilled workers is smaller, and the decline in wages, consumption and income is around 0.2% at most in the medium run compared to the decline in 0.5% in the baseline model.

Finally, the decline in output and consumption per head is substantially smaller in the medium and long run. In the same horizon, government spending increases persistently. Overall, the capital-skill complementarity reports a substantially enhanced outcome, with a smaller negative impact on low-skilled households and benefits for high-skilled and medium-skilled households. The results are highly relevant because our calibration is conservative in the skill composition of natives and immigrants. We calibrate the skill composition of the model based on the workers' occupation rather than their qualification by education. As we analyse in the next section it triggers significantly different results.

4.6 Downgrading, Skill Composition and Capital-Skill Complementarity

In the literature on immigration, it is usual to classify the skills of a worker according to the educational attainment and experience (Borjas, 2003; Ottaviano and Peri, 2005; Wadsworth et al., 2016; Manacorda et al., 2012; Dustmann et al., 2012; Lisenkova et al., 2013; Dustmann et al., 2016; Card and Peri, 2016; Dustmann et al., 2017). However, Manacorda et al. (2012); Dustmann et al. (2012, 2016) have presented empirical evidence about the recurrent phenomenon of downgrading in studies for the US and the UK. It occurs when the position of immigrants in the labour market, measured by wage or occupation, is systematically lower than the position of natives with the same observed education and experience levels. Immigrants tend to receive lower returns than natives for the same education and experience acquired in their countries of origin (Dustmann et al., 2016).

Downgrading is a well-known phenomenon in the literature on immigration to the UK because there is a high share of immigrants from the EU and the Rest o the World (RoW) who posse high levels of qualification (Wadsworth, 2012). Nonetheless, it is not always reflected in the allocation of occupation. The Migration Advisory Committee (2014) in its report about low-skilled workers cites examples of immigrants with the university and postgraduate degrees working in low-skilled occupations. In the best scenario, they may be overseas students with part-time jobs, in the worst case, a significant mismatch of full-time workers.

In Figure 4.9, we present the skill mismatch reported in the 2016 Annual Population Survey of the ONS. This calculation is the difference between educational attainment and average education level required in the occupation that a worker is hired. Matched are employed people whose highest level of educational attainment is within one standard deviation of the mean for their given occupation. Over-educated are workers who have the highest educational attainment greater that one standard deviation below the mean. Under-educated have the lowest educational attainment higher than one standard deviation above the mean.

We observe that 38% of immigrants (from the EU and the RoW) are over-educated relative to the occupation they are employed. EU-born workers from the EU8 countries (Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia, Slovenia and Czechoslovakia) present the highest mismatch, 40% of them are in lower occupations than their educational attainment. Workers from EU14 and EU2 countries face a similar level of over-education.[2] On the contrary, workers from the EU14 countries have the lowest percentage in under-education. UK-born workers are matched in 70% of cases, the highest among the distinct groups and above the national average. In addition to this, its under-education offsets its percentage of over-education.

[2]EU2 are Bulgaria and Romania while the group of EU14 includes Austria, Belgium, Denmark, Finland, France, Germany, Greece, Italy, Luxembourg, Netherlands, Portugal, Spain (except Canary Islands), Sweden, Canary Islands, Monaco Vatican City and Republic of Ireland.

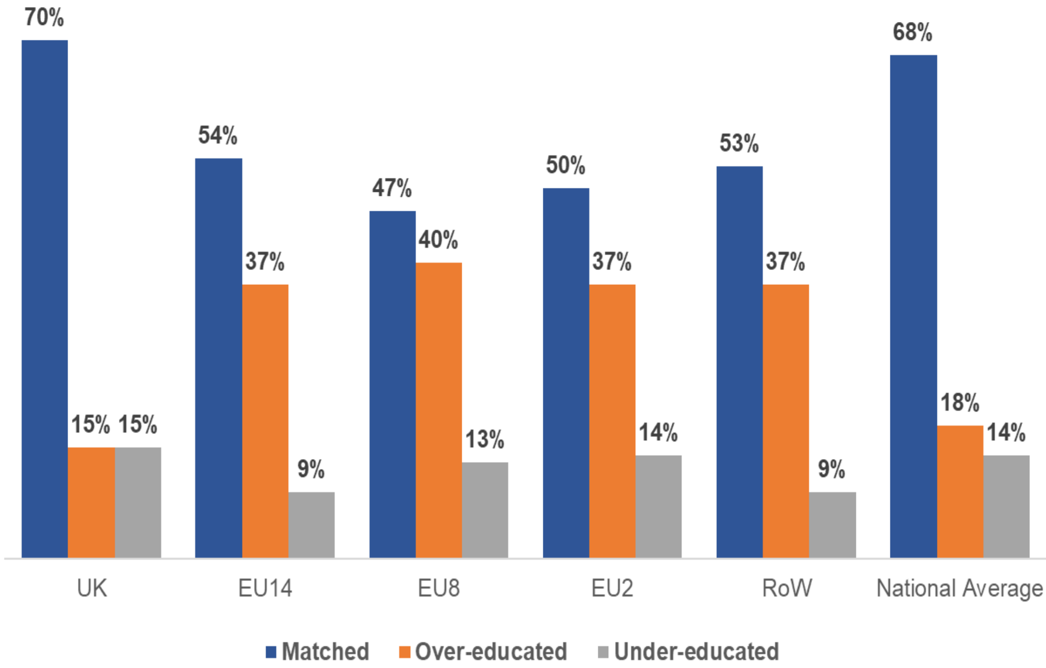

Figure 4.9: Share of Matched, Over-educated and Under-educated Workers by Country of Birth.

Source: Annual Population Survey, ONS Statistics, 2016.

In Figure 4.10, we display over-education from 2004 to 2015. We find that EU14-born workers displayed a lower mismatch in the previous decade, over-education accelerated during the European financial crisis. It is in line with the period of the highest increase in the EU immigration flows to the UK. Over-education in the EU10 countries has decreased over time and remained stable at more than 35% after 2011. The numbers for UK-born are very stable and close to the national average since they represent more than 80% of the total labour force.

Downgrading measured by occupation seems to be significant relative to educational attainment. Dustmann et al. (2016) argue that this is one of the reasons of the discrepancy in the results among immigration studies. Previously, we calibrate the model using the skill composition based on the ONS statistics and the Migration Advisory Committee (2017, 2018). It classifies workers by occupation regardless of their educational attainment.

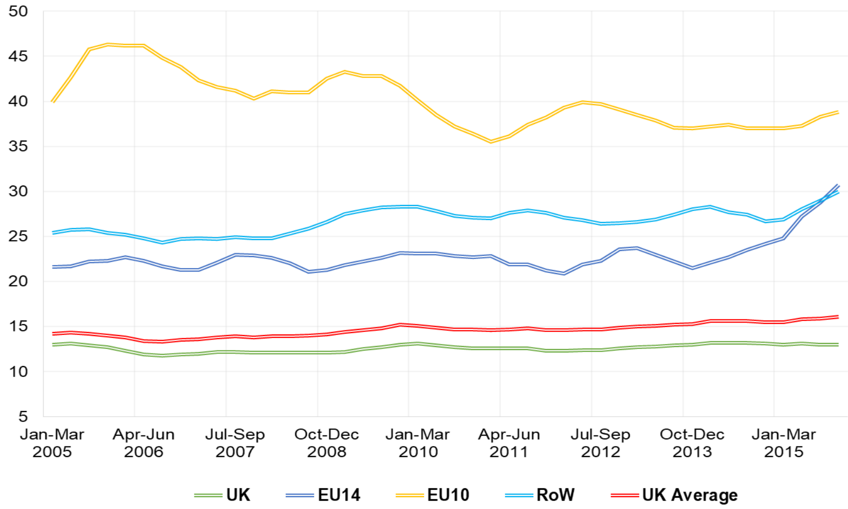

Figure 4.10: Share of Over-educated Workers by Country of Birth, 2004 - 2015

Source: Annual Population Survey, ONS Statistics, 2016.

In Figure 4.11, we find that using this classification, there are 28% UK-born workers in high-skilled occupations, 28% in the medium-skilled occupations and 43% in the low-skilled. There are 56% of the EU-born workers in the low-skilled occupations, 24% in the medium-skilled occupations and only 20% in the high-skilled occupations. EU2 and EU8 immigrants tend to work more in the low-skilled jobs whereas the share of EU14 immigrants in the high-skilled occupations is ten percentage points larger than the share of natives.

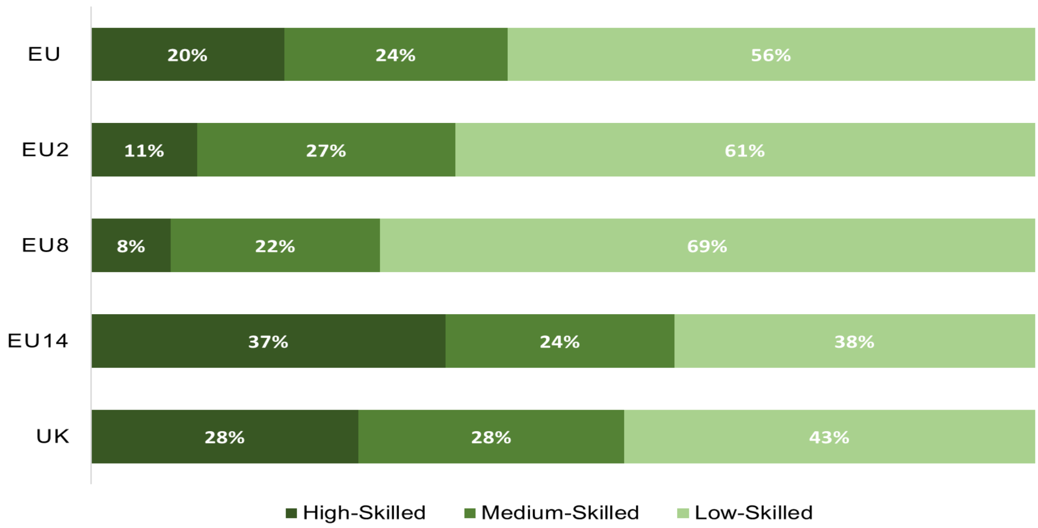

Figure 4.11: Skill Composition by Occupation

Source: ONS Statistics and Annual Population Survey, 2016

Using skill composition by occupation reduces the bias in results for the downgrading and mismatch. However, it hides the potential impact that immigrants would bring to the host economy given their formal qualifications. Although the Annual Population Survey and the Labour Force Survey provide information about the qualification level, there are more than 30% of EU immigrants that place themselves in 'other qualifications' category. To overcome this problem, the studies in immigration for the UK that use educational attainment (Kim et al., 2010; Dustmann et al., 2012; Ottaviano and Peri, 2012; Lisenkova et al., 2013; Wadsworth et al., 2016) define the skill level of a worker using the years at which the worker left to study full-time education. That is, a worker is high-skilled if in full-time education at age 21 or later, a medium-skilled worker between 17 and 20 years and a low-skilled worker at 16 years or less.

In Figure 4.12, we observe that 43% of EU-born are high-skilled whereas only 23% of UK-born are in that category. There are 42% of medium-skilled workers compared to the 33% in the UK-born population. Using educational attainment, 44% of the UK-born population studied until 16 years old while only 15% of the EU-born working population is in the same category. The skill composition of UK born population is similar if we use educational attainment or occupation. We find that the more significant differences are among EU immigrants. EU-born workers are more qualified than UK-born workers, but they work primarily in low-skilled and medium-skilled jobs.

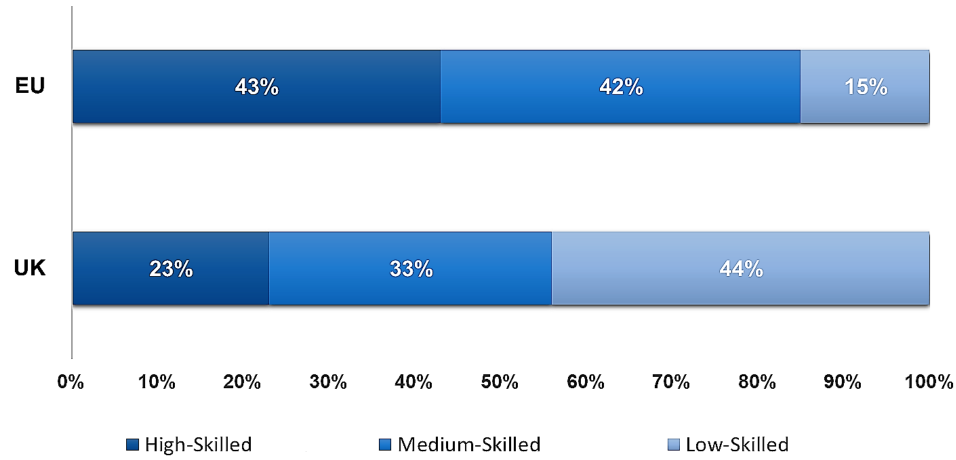

Figure 4.12: Skill Composition by Education

Source: Elaborated with data from Wadsworth et al. (2016)

To reflect these features on our results, we re-calibrate the skill composition of natives and immigrants according to the educational attainment, and we compare the results with the skill composition by occupation. In Figures 4.13 and 4.14, we present the responses of a transitory immigration shock. In the light plus-marked line (blue), we display the baseline model and in the light star-marked line (cyan) the capital-skill complementarity model responses. In both cases, the calibration of the skill composition is based on the occupation. In the plus-marked line (green), the baseline model and star-marked line (magenta) the capital-skill complementarity both are calibrated with the skill composition based on the educational attainment.

The baseline model with the educational attainment calibration changes the composition of immigrants significantly. In this scenario, 85% of the new immigrants would be looking for a job in the high-skilled or medium-skilled occupations. The new skill composition increases the pressure on the high-skilled and medium-skilled wages leading to their higher decline compared to the baseline model (skill composition by occupation). Low-skilled wages increase over time because the size of new EU-born workers looking for low-skilled jobs is only 15%.

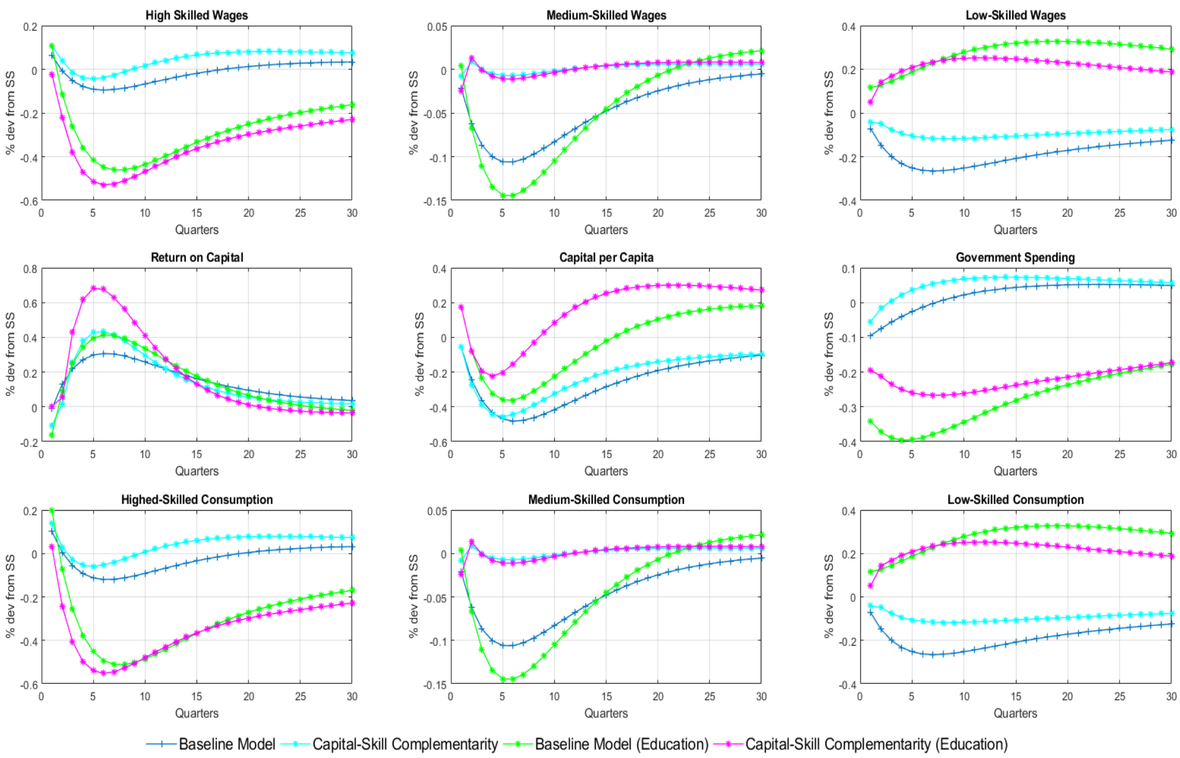

Figure 4.13: Transitory Immigration Shock, Downgrading

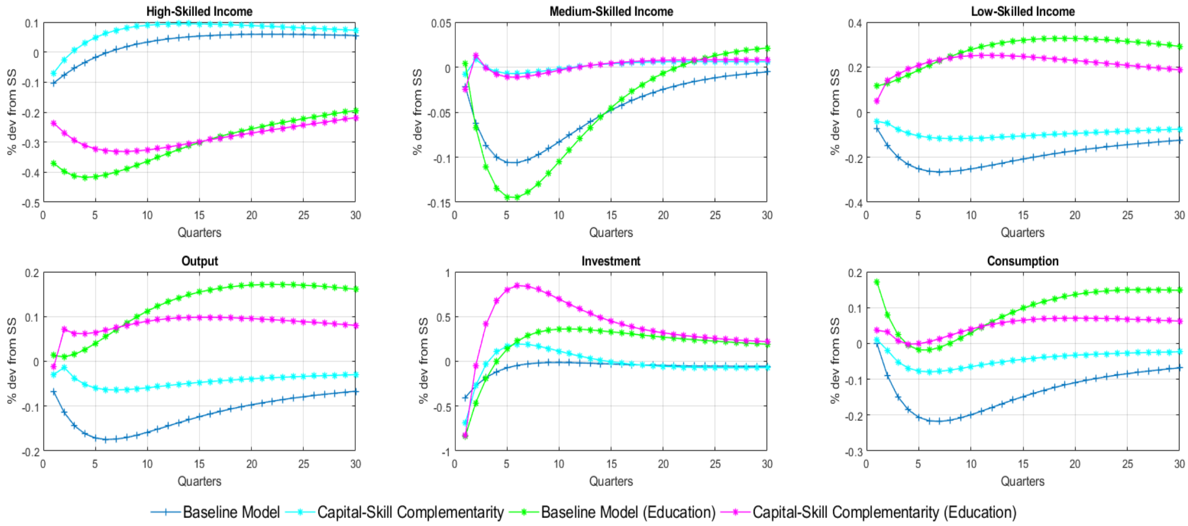

Figure 4.14: Transitory Immigration Shock, Downgrading

Capital to labour ratio falls less in the baseline model (skill composition by education). It leads to higher investment in the medium run and results in the lower decline of per capita consumption. Output per capita drops in the first periods, but it recovers above the pre-shock level in the medium and long run. In general, the results from the baseline model (skill composition by education) seem to yield a distributive effect in favour of the low-skilled workers and against the high-skilled. Overall, the economy expands more since output and investment per capita perform better along the horizon.

In the fifth section, we observe that the capital-skill complementarity model captures the synergies between high-skilled hours worked and physical capital. Here we present a hypothetical case with zero downgrading. In this scenario, immigrants work in the jobs for which they are qualified. We present the responses of this model when the calibration of the skill composition is based on educational attainment. Therefore, there will be a 43% of the new immigrants entering in the high-skilled occupations. It would trigger a significant impact in the production given physical capital and high-skilled hours worked are complements.

In this model, the capital to labour ratio falls significantly less and the returns on capital increase up to 0.7% in the medium run. It increases investment close to 1% relative to the steady-state level. It rises per capita output and consumption along the horizon, which is a relevant outcome. This is the only case where there is not a decline in per capita output below the steady-state level after an immigration shock. On the contrary, it increases in around 0.08% relative to the initial level along the horizon.

We find that using the skill composition by education, the effect on wages benefit low-skilled workers and trigger the decline in high-skilled wages. Medium-skilled wages are also higher in the capital-skill complementarity because the economy expands and it increases the demand for medium-skilled hours worked. Although high-skilled wages decline, high-skilled workers offset the drop in their income by the increase of return on capital. Overall, an immigration shock with this model, yields the expansion of the economy, the increase in output and consumption per capita as well as the high stimulus for investment. High-skilled wages decline, however, high-skilled workers perceive welfare gains and receive higher returns since capital becomes a scarce input. Medium-skilled workers face a moderate decline in wages, and low-skilled wages are benefited from the shock.

4.7 Welfare Analysis

Our findings above suggest that immigration flows have distributive effects across types of households. In this section, we measure losses or gains regarding consumption. We follow Schmitt-Grohé and Uribe (2007) and Faia and Monacelli (2008), we write recursively each utility function to define the welfare function for high-skilled, medium-skilled and low-skilled households $i = s, u, l$

$$V_0^i\left(c_0^i, h_0^i\right) = U_0^i + \beta V_1^i \tag{4.57}$$

where V_0^i is the welfare, c_0^i and h_0^i denote the contingency plans of consumption and hours worked of each of the household types at the steady state level, that is before the immigration shock. We define equation (4.58) as the present value generated by consuming $(1+\Omega)c_0^i$ and working h_0^i hours in each household type. It will be equal to the present value of consuming c_t^i and working h_t^i, which reflect consumption and hours worked along the transition path.

$$E_0 \sum_{t=0}^{\infty} [\beta(1-\pi)]^t V_0^i \left((1+\Omega)c_0^i, h_0^i\right) = V_t^i \left(c_t^i, h_t^i\right) \quad (4.58)$$

Let Ω be the welfare cost of the immigration shock. It measures the fraction of consumption process at the pre-shock level that each type of household is willing to give up to be as well off after the immigration shock. When $\Omega > 0$ it means that i type of households are better off than before the shock. The welfare cost represents the equivalent consumption needed to equalise the welfare before and after the immigration shock. Using the utility function that we set in the model, the expression for the welfare cost is as follows

$$\Omega = exp\left[(V_t^i - V_0^i)(1-\beta)\right] - 1 \quad (4.59)$$

In Table 4.4, we present the results from a transitory immigration shock with a standard error at 0.2%. In the baseline model (skill composition by occupation), we find that high-skilled and medium-skilled households obtain welfare gains and low-skilled households present some losses. The welfare gain for high-skilled workers is 0.011% of their steady-state consumption and 0.002% for the medium-skilled households. Low-skilled households lose 0.031% of their steady state consumption along the transition path.

In the second row of the Table 4.4, we display the welfare calculations of the capital-skill complementarity model. We observe that high-skilled workers gain 0.016% of their steady state consumption, substantially higher than in the baseline model. Medium-skilled households gain 0.002% of their steady state consumption and low-skilled households exhibit a decline in their loses in 0.011% of their steady state consumption.

We also estimate the welfare when there is gradual immigration shock with a standard error at 0.22%. Because of the high persistence parameter of this shock, the supply of new workers is higher, triggering more significant gains and losses. The welfare gains for high-skilled workers are 0.091% of their steady-state consumption, while medium-skilled workers have gains equivalent to 0.014% of their steady-state consumption. How-

Table 4.4: Welfare Analysis

Model	Welfare gain Ω		
	High-Skilled	Medium-Skilled	Low-Skilled
Transitory Immigration Shock			
Baseline model	0.0108	0.0023	-0.0311
Capital-Skill Complementarity	0.0161	0.0018	-0.0205
Gradual Immigration Shock			
Baseline model	0.0913	0.0138	-0.2805
Capital-Skill Complementarity	0.1353	0.0154	-0.1809

ever, the losses for low-skilled workers increase significantly, they are at -0.281% of their steady-state consumption. Certainly, a gradual immigration shock ends up affecting more to low-skilled workers and benefiting more to high-skilled and medium-skilled people. In the baseline model, around 56% of the immigrants are hired in low-skilled occupations.

Under the gradual immigration shock and the capital-skill complementarity model high-killed workers observe additional welfare gains in steady state consumption, which reach the 0.135%. Additionally, they also perceived higher capital income, since return on capital increases substantially. For the medium-skilled workers, the gain is 0.015% of steady-state consumption, and the loss for low-skilled workers decline to 0.181%. Overall the welfare gap among type of households persists. However, it shift upwards, low-skilled workers are better off than in the baseline model.

In Table 4.5, we present the welfare calculations for the baseline model and the capital-skill complementarity when we calibrate the model using a skill composition based on educational attainment. We set a transitory migration shock with a standard error at 0.20%. We find that in the two cases high-skilled workers face some losses whereas low-skilled workers benefit from the immigration shock. In the baseline model, the gains and losses are slightly higher than in the capital-skill complementarity model. High-skilled workers lose 0.102% of their steady-state consumption and medium-skilled workers 0.009%. However, low-skilled workers gain 0.050% of their consumption at the steady-state level. This gain increases to 0.066% if we refer to the capital-skill complementarity model while the loss of high-skilled and medium-skilled workers is 0.084% and 0.003% of their steady-state consumption, respectively.

Table 4.5: Welfare Analysis -Education

Model	Welfare Gain Ω		
Education and Transitory shock	High-Skilled	Medium-Skilled	Low-Skilled
Capital-Skill Complementarity	-0.1016	0.0085	0.0503
Baseline model	-0.0841	0.0033	0.0660

4.8 Concluding Remarks

We explore the impact of immigration flows in a host economy, we take as an example the UK and the EU immigration. We developed a DSGE model that includes three types of workers: high-skilled, medium-skilled and low-skilled. We extend the model to include capital-skill complementarity between capital and high-skilled labour. We analyse wages, income per capita and welfare allowing us to examine the dynamics of aggregate variables like output, consumption and investment per capita. We obtain some simulation results with this (baseline) model, and we explore the effects of two immigration shocks in the economy.

The model with capital-skill complementarity allows us to set physical capital and high-skill hours as complements rather than substitutes. It brings a significant change in the production of the economy because the additional supply of labour does not necessarily reduce all wages even in the short run. The complementarity between physical capital and high-skilled labour expands the economy, raises investment, increases the demand for medium-skilled and low-skilled hours worked and it triggers higher output per capita. We simulate some results by using a transitory immigration shock in the host economy and we compare how the baseline versus the capital-skill complementarity model perform.

Using the baseline model, we find that in the long run, high-skilled households are better off with the transitory immigration shock. Their wages, capital income and consumption increases. Based on the welfare analysis, we find that high-skilled workers experience an increase of 0.011% in their steady state consumption after the shock. Medium-skilled workers experience a decline in their wages, consumption and income in the short run. However, these variables recover in the long run. Using our welfare analysis, we find that medium-skilled workers increase their consumption relative to the steady-state level in 0.002%. Low-skilled wages, consumption and income, decreased even in the long run. Regarding welfare, they have losses of 0.031% consumption at the steady-state level. When we explore the case of a gradual immigration shock, the dynamics are quite close to the transitory immigration shock. However, the welfare gains and losses are more pronounced.

The transitory immigration shock using the model with capital-skill complementarity brings more positive effects to the host economy. We find that the synergies between the skilled inputs trigger a higher return on capital and increases significantly investment leading the higher expansion of the economy. High-skilled workers achieve higher wages and capital income, and they also invest more. Medium-skilled wages and income go up steadily, and low-skilled wages fall significantly less.

More specifically, we find that high-skilled workers are better off by 0.016% of their state consumption, higher than in the baseline model. The welfare gain for medium-skilled workers is 0.002%, four times smaller than in the baseline model. However, the welfare loss for low-skilled workers is only 0.021% of their steady-state consumption, which is a half of the loss in the baseline model. Using the gradual immigration shock, we find that the gain of high-skilled workers is 0.135% and 0.015% for medium-skilled workers. On the contrary, low-skilled workers lose -0.181% of their steady-state consumption.

Additionally, we present the dynamics of the economy when there is a transitory immigration shock, and the downgrading of immigrants is zero. That is when immigrants end up working in the jobs for which they qualify and not in lower paid jobs or with lower qualifications required. To carry out this exercise, we calibrate the model using the skill composition of natives and immigrants based on educational attainment rather than by occupation.

In the case of the baseline model, high-skilled and medium-skilled workers are worse off after the shock. They see a reduction in their welfare by 0.11% and 0.005% of their steady state consumption levels, respectively. On the contrary, low-skilled workers are better off after the shock. They present some welfare gains equal to 0.07% of the steady-state consumption. In the case of the capital-skill complementarity model, the lose for high-skilled workers is diminished by 0.067% of their steady-state consumption, while medium-skilled and low-skilled workers have welfare gains. For medium-skilled workers, the welfare is equal to 0.006% of their steady-state consumption and for low-skilled workers 0.011%

Overall, the capital-skill complementarity model captures the complementarity between high-skilled hours worked and physical capital. It allows us to see that an additional supply of labour do not always conducts to the substitution of capital for labour. On the contrary, in this model high-skilled labour is complementary to capital. It expands the economy and increases the demand for more labour even the medium-skilled and low-skilled. Therefore, the effect of immigration flows on wages is less significant and it only has a negative impact on the low-skilled workers.

We further modify the benchmark model by considering a greater substitution between capital and labour. Our model adjusts the capital to labour ratio in the long run to preserve the balance growth path, as suggested by Card (2012); Ottaviano and Peri (2012); Dustmann et al. (2012, 2016) suggest. We additionally account for the synergies between factors of production, by relaxing the assumption that capital is fixed different from Nickell and Saleheen (2008).

The skill composition of the labour force is crucial in determining the impact of immigration flows in the economy. The ratio of natives to immigrants in each skill level is a key determinant of the pressures on wages by skill type. Immigrants have more years of education than the natives. However, the degree of downgrading is notable. Therefore, competition in low-skilled occupations is higher triggering greater welfare losses.

We plan to extend the research by opening the economy to explore the interactions of the economy with international trade and foreign capital. Similarly, we plan to differentiate household types in immigrants and natives to examine the effects on wages by nationality of birth.

Chapter 5

Concluding Remarks and Further Research

Central banks face new challenges in the era of global financial integration. In the last ten years, there has been a significant rise in the use of MaPs towards ensuring financial stability worldwide although they have been implemented in EMEs since the 1990s. With greater global financial integration, monetary and MaPs in AEs (centre economies) exert significant externalities on EMEs (peripheral economies).

Chapter 2 evaluated the effectiveness of and welfare losses from implementing UMP versus MaP in an emerging economy. The analysis is framed taking as reference the 'clean versus lean' debate. We examined the scope of the policies considering the outcomes such as consumption, credit conditions, investment and output. Under a financial crisis shock, central bank conducted one of the two policies: (i) UMP by intervening in the credit market through public banks offering new credit lines to non-financial firms, and (ii) countercyclical capital requirements, which worked as an automatic stabiliser to enhance banks' balance sheets and boost credit supply.

We found that both policies mitigated the effects of the financial crisis, by alleviating the decline in asset prices and the worsening of banks' balance sheets. UMP and MaP dampened the decline in investment and output. However, in the case of capital requirements, the recovery was faster and greater. In addition to this, the welfare gain of households was significantly higher under capital requirements than under UMP. Our results suggested that policies conducted to prevent financial risks were more effective in alleviating the financial crisis. MaP responded promptly and its cost was significantly lower. Moreover, capital requirements yielded higher welfare gains to households. We concluded that it was more effective to lean against the wind than clean up after the financial crisis.

Chapter 3 examined the extent of MaPs in an AE and an EME in the presence of global financial spillovers. We used a two-country New Keynesian DSGE model, featuring international lending through cross border loans. We assessed the impact of MaPs in the country of implementation and across borders. Under a global financial crisis, we evaluated three policy scenarios: (i) AE implemented capital requirements, (ii) EME imposed a levy on cross border loans, and (iii) AE and EME conducted MaP.

(i) Capital requirements improved credit market conditions, reduced the fall in bank's net worth and bank's balance sheets in the AE. Through the cross border bank lending, the mitigation of the shock was propagated to the EME. Capital requirements contained the decline in cross border loans, enhancing credit conditions of the EME's banks. Moreover, the welfare of EME's households improved with the MaP in place. Interestingly, the international lending channel that aggravated financial contagion during the financial crisis, performed as a mitigation mechanism when AE conducted MaP.

(ii) Under the commitment of EME to regulate the financial system, a global financial crisis yielded substantially lower effects on the EME. A levy on cross border loans operated as an automatic and countercyclical stabiliser of the credit market conditions in EME, operating as a shield against the propagation of the shock through cross border loans. The MaP, however, did not have a significant impact on AE. Regarding welfare evaluation, the levy on cross border loans enhanced substantially consumption in the EME.

(iii) In the case of coordination in MaPs, the mitigation of the financial crisis was effective in both countries but particularly in the EME. Capital requirements alleviated the conditions of the AE' banks stimulating AE's credit supply, investment and output. Earlier we explained that capital requirements also contributed to mitigate the shock in the EME. Therefore, coordination of MaPs (capital requirements in AE and levy on cross-border loans in EME), further eased the EME banks' balance sheets. In this scenario, both MaPs operated through countercyclical automatic stabilisers dampening the effects of the credit constraint domestically (within the economies). In the case of capital requirements, the effects also extended across countries. Coordination of MaPs triggered the highest welfare gain for EME's households.

These findings shed light on the challenges that policymakers face in a financially connected world. Our results suggest that although financial policy in AE is a domestic commitment, there are substantial spillovers to peripheral economies. inevitably with considerable benefits for EME. However, it does not suggest that financial stability is not a primary commitment for EMEs. On the contrary, coordination of policies between AE and EME is substantially beneficial for both economies but particularly for EME. More importantly, the cross border bank lending -that serves as the mechanism to propagate the shocks- operates as the channel of the mitigation under the presence of MaPs in the AE.

Global financial integration requires the engagement of AE and EME for global financial stability. There may be cases where the MaPs in two jurisdictions target opposite objectives. In this regard, the debate on the interaction between monetary and MaPs in a single country may need to be extended to the interaction of MaPs across countries. We plan to expand the investigation in this direction and include potential spillovers from monetary policy in future research. As Galati and Moessner (2018) pointed out, "...the literature on the effectiveness and the transmission mechanism of MaP is still in its infancy and has so far provided only limited guidance for policy decisions."

Chapter 4 proposed a capital-skill complementarity model to explain the effects of immigration on a country with high-skilled migration. We explained the impact on the labour market and per capita macroeconomic variables using a DSGE model. We extended Canova and Ravn (2000b) and Fusshoeller and Balleer (2017) in two directions incorporating (i) the skill composition of occupations in three levels: high-skilled, medium-skilled, and low-skilled, and (ii) capital-skill complementarity between physical capital and high-skilled workers in the model.

Using a transitory and a gradual immigration shock, we compared the dynamics of a capital-skill complementarity model versus a capital accumulation model with skill types (baseline model). In the baseline model, high-skilled and medium-skilled workers were better off relative to their steady-state consumption. Low-skilled workers experienced a small welfare loss. The economy expanded but GDP per capita declined (in the short run). In the capital-skill complementarity model, high-skilled workers observed a welfare gain, with low-skilled workers experiencing significantly lower welfare loss. In this case, the economy expanded significantly more than in the baseline model, the decline in output per capita was substantially smaller (in the short run).

In the final part of Chapter 4, we considered a case where there was a better matching between the qualifications and occupations. We found that using the skill composition by education, the effect on wages benefits low-skilled workers and triggered the decline in high-skilled wages. Medium-skilled wages increased in the capital-skill complementarity model because the economy expanded substantially and it increased the demand for medium-skilled workers.

High-skilled wages declined, high-skilled workers offset the drop in their income by the increase of return on capital. Overall, an immigration shock with this model, yielded the expansion of the economy; the high stimulus for investment, the increase in output as well as in consumption per capita. High-skilled workers faced losses, a decline in wages, but they obtained significant gains from the new investment. Medium-skilled workers faced a moderate decline in wages while low-skilled wages increased. Low-skilled workers benefited from the substantial expansion of the economy and the smaller share of immigrants looking for low-skilled jobs.

Our findings allowed us to infer that immigration flows conveyed benefits for the most qualified workers and losses for the less qualified. High-skilled and medium-skilled workers faced welfare losses and low-skilled workers welfare gains. The economy expanded more featuring the capital-skill complementarity. It reduced the welfare loss of low-skilled workers and maintained the welfare gains of high-skilled workers. The results were consistent regardless of the persistence of the shock. In addition to this, the zero downgrading provided significant results for the implementation of public policies. The evaluation of immigration showed that low-skilled workers performed better and received higher welfare gains than with downgrading.

We plan to extend the research on migration by including foreign capital in the model, exploring the dynamics of an open economy and its effects on income distribution. Further research should also relax the assumption on the substitutability between natives and immigrants of the same skill type. Despite the limitations of our framework, the model is effective in explaining the outcomes of an immigration shock by skill type. Our findings from using the capital-skill complementarity model suggest that the effects of immigration on low-skilled workers are significantly less severe that those from a model without that feature.

Appendix A

Appendices to Chapter 2

A.1 Optimization Problems

A.1.1 Banks

Banks maximise their expected discounted value. The value of an individual is defined with small case letters as below

$$V_t = maxE_t \sum_{i=0}^{\infty} (1-\theta)(\theta)^{i-1} \Lambda_{t,t+i} n_{t+i} \tag{A.1}$$

the Bellman equation

$$V_t(s_{t-1}, d_{t-1}) = E_{t-1} \Lambda_{t-1,t} \left\{ (1-\theta) n_t + \theta \left[\max_{s_t, d_t} V_t(s_t, d_t) \right] \right\} \tag{A.2}$$

Bank i maximises profits subject to the incentive constraint

$$V_t(s_t, d_t) \geq \lambda(Q_t s_t) \tag{A.3}$$

We guess and verify the value function of an individual bank, and we assume that s_t and d_t are on linear relation with the value of bank.

$$V_t\left(s_t, d_t\right) = \nu_{s,t} s_t - \nu_{d,t} d_t \tag{A.4}$$

where ν_s and ν_d are the time-varying marginal values of assets and deposits.

Working with the maximisation problem, the first order conditions for assets, deposits and the Lagrange multiplier $\lambda_{lm,t}$

$$\mathcal{L} = \nu_{s,t} s_t - \nu_{d,t} d_t - \lambda_{lm,t}\left(\lambda Q_t s_t - \nu_{s,t} s_t + \nu_{d,t} d_t\right) \tag{A.5}$$

$$\nu_{s,t} - \lambda_{lm,t}(\lambda Q_t - \nu_{s,t}) = 0 \tag{A.6}$$

$$-\nu_{d,t} - \lambda_{lm,t}\nu_{d,t} = 0 \tag{A.7}$$

$$\lambda Q_t s_t - \nu_{s,t} s_t + \nu_{d,t} d_t = 0 \tag{A.8}$$

From equation (A.6)

$$\lambda_{lm,t} = \frac{\nu_{s,t}}{\lambda Q_t - \nu_{s,t}} \tag{A.9}$$

We use equation (A.8) and the balance sheet of a bank $d_t = Q_t s_t - n_t$ to obtain

$$\lambda Q_t s_t - \nu_{s,t} s_t + \nu_{d,t}(Q_t s_t - n_t) = 0 \tag{A.10}$$

It yields

$$Q_t s_t \left[\lambda - \left(\frac{\nu_{s,t}}{Q_t} - \nu_{d,t}\right)\right] = \nu_{d,t} n_t \tag{A.11}$$

where $\mu_{s,t}$ is the excess value of the banks' assets over deposits or the excess return on capital,

$$\mu_t = \frac{\nu_{s,t}}{Q_t} - \nu_{d,t} \tag{A.12}$$

$$Q_t s_t \left[\lambda - \mu_t\right] = \nu_{d,t} n_t \tag{A.13}$$

For definition, the value of asset over the equity is the leverage ratio.

$$\phi_t = \frac{\nu_{d,t}}{\lambda - \mu_t} \tag{A.14}$$

That is

$$Q_t s_t = \phi_t n_t \tag{A.15}$$

Then, we verify the functional form of the value function, we plug it in the Bellman equation and replace d_t

$$V_t\left(s_{t-1}, d_{t-1}\right) = E_{t-1}\Lambda_{t-1,t}\left\{\left(1-\theta\right)n_t + \theta\left[\max_{s_t,d_t}\ V_t\left(s_t, d_t\right)\right]\right\}$$

$$V_t\left(s_t, d_t\right) = \nu_{s,t}s_t - \nu_{d,t}d_t$$

$$V_t\left(s_{t-1}, d_{t-1}\right) = E_{t-1}\Lambda_{t-1,t}\left\{\left(1-\theta\right)n_t + \theta\left[\nu_{s,t}s_t - \nu_{d,t}(Q_t s_t - n_t)\right]\right\} \tag{A.16}$$

$$V_t\left(s_{t-1}, d_{t-1}\right) = E_{t-1}\Lambda_{t-1,t}\left\{\left(1-\theta\right)n_t + \theta\left[\left(\frac{\nu_{s,t}}{Q_t} - \nu_{d,t}\right)Q_t s_t + \nu_{d,t}n_t\right]\right\} \tag{A.17}$$

Taking the definition of $\mu^*_{s,t}$, the expression above is written as follows,

$$V_t\left(s_{t-1}, d_{t-1}\right) = E_{t-1}\Lambda_{t-1,t}\left\{\left(1-\theta\right)n_t + \theta\left[\mu_{s,t}Q_t s_t + \nu_{d,t}n_t\right]\right\} \tag{A.18}$$

$$V_t\left(s_{t-1}, d_{t-1}\right) = E_{t-1}\Lambda_{t-1,t}n_t\left\{\left(1-\theta\right) + \theta\left(\mu_{s,t}\phi_t + \nu_{d,t}\right)\right\} \tag{A.19}$$

We replace in equation (A.19) the net worth earnings $n_t = R_{k,t}Q_{t-1}s_{t-1}\frac{1}{\pi_t} - R_t d_{t-1}\frac{1}{\pi_t}$.

Following Gertler and Kiyotaki (2010) and Gertler and Karadi (2011), we define $\Omega_t = (1-\theta) + \theta\left(\mu_{s,t}\phi_t + \nu_{d,t}\right)$ as the shadow value of net worth. Finally, V_t is rolled one period ahead and there we obtain expressions for all the variables.

$$V_t\left(s_t,d_t\right)=\nu_{s,t}s_t-\nu_{d,t}d_t=E_t\Lambda_{t,t+1}\Omega_{t+1}\left(R_{k,t+1}Q_ts_t\frac{1}{\pi_{t+1}}-R_{t+1}d_t\frac{1}{\pi_{t+1}}\right) \tag{A.20}$$

We obtain expressions for assest, deposits and the excess value of assets over deposits

For s_t

$$\nu_{s,t}=E_t\Lambda_{t,t+1}\Omega_{t+1}R_{k,t+1}Q_t \tag{A.21}$$

For d_t

$$\nu_{d,t}=E_t\Lambda_{t,t+1}\Omega_{t+1}R_{t+1}\frac{1}{\pi_{t+1}} \tag{A.22}$$

For μ_t

$$\mu_t=E_t\Lambda_{t,t+1}\Omega_{t+1}\left(R_{k,t+1}-R_{t+1}\frac{1}{\pi_{t+1}}\right) \tag{A.23}$$

A.1.2 Capital Producers

$$maxE_t\sum_{t=0}^{\infty}\Lambda_{t,t+1}\{Q_t[1-S^k(X_t)I_t]-I_t\} \tag{A.24}$$

given $X_t=\frac{I_t}{I_{t-1}}$

$$Q_tI_t-Q_tI_tS^k(X_t)+E_t\Lambda_{t,t+1}\{Q_{t+1}I_{t+1}-Q_tI_{t+1}S^k(X_{t+1})\}-I_t=0 \tag{A.25}$$

$$Q_tI_t-Q_tI_t\Phi_X\left(X_t-1\right)^2+E_t\Lambda_{t,t+1}\{Q_{t+1}I_{t+1}-Q_tI_{t+1}\Phi_X\left(X_{t+1}-1\right)^2\}-I_t=0 \tag{A.26}$$

$$Q_tI_t-Q_tI_t\Phi_X\left(\frac{I_t}{I_{t-1}}-1\right)^2+E_t\Lambda_{t,t+1}\{Q_{t+1}I_{t+1}-Q_tI_{t+1}\Phi_X\left(\frac{I_{t+1}}{I_t}-1\right)^2\}-I_t=0 \tag{A.27}$$

$$Q_t-Q_t\Phi_X\left(\frac{I_t}{I_{t-1}}-1\right)^2+Q_t2\Phi_X\left(\frac{I_t}{I_{t-1}}-1\right)\frac{I_t}{I_{t-1}}-E_t\Lambda_{t,t+1}\{Q_t2\Phi_X\left(\frac{I_{t+1}}{I_t}-1\right)\frac{I_{t+1}^2}{I_t}\}=1 \tag{A.28}$$

The optimality condition yields

$$Q_t\left(1 - X_t S^k(X_t) - X_t S^{k'}(X_t)\right) + E_t\left[\Lambda_{t,t+1} Q_{t+1} S^{k'}(X_{t+1}) X_{t+1}^2\right] = 1 \tag{A.29}$$

A.1.3 Intermediate Good Producers

$$Max E_t \sum_{t=0}^{\infty} \beta^t \Lambda_t \left[\frac{P_t(i)}{P_t} Y_t(i) - \frac{W_t}{P_t} L_t(i) - Q_t R_t^k K_t(i) - \frac{\varphi}{2}\left[\frac{P_t(i)}{P_{t-1}(i)} - 1\right]^2 Y_t\right] \tag{A.30}$$

s.t.

$$Y_t(i) = \left(\frac{P_t(i)}{P_t}\right)^{-\varepsilon} Y_t \tag{A.31}$$

$$Y_t(i) = A_t K_t(i)^{\alpha} L_t(i)^{1-\alpha} \tag{A.32}$$

Intermediate good producers choose $\{\frac{W_t}{P_t}, z_t, P_t\}$

$$Max E_t \sum_{t=0}^{\infty} \beta^t \Lambda_t \left[\frac{P_t(i)}{P_t}\left(\frac{P_t(i)}{P_t}\right)^{-\varepsilon} Y_t - \frac{W_t}{P_t} L_t(i) - Q_t R_t^k K_t(i) - \frac{\varphi}{2}\left[\frac{P_t(i)}{P_{t-1}(i)} - 1\right]^2 Y_t\right] \tag{A.33}$$

s.t.

$$Y_t(i) = A_t K_t(i)^{\alpha} L_t(i)^{1-\alpha} \tag{A.34}$$

Optimalities

$$\frac{W_t}{P_t} = (1-\alpha) A_t rmc_t \left(\frac{K_t}{L_t}\right)^{\alpha} \tag{A.35}$$

$$z_t = (\alpha) A_t rmc_t \left(\frac{K_t}{L_t}\right)^{\alpha-1} \tag{A.36}$$

$$rmc_t = \frac{\varepsilon-1}{\varepsilon} + \frac{\varphi}{\varepsilon}\pi_t(\pi_t - 1) - \frac{\varphi}{\varepsilon} E_t\left[\Lambda_{t,t+1}\frac{\pi_{t+1}(\pi_t - 1) Y_{t+1}}{Y_t}\right] \tag{A.37}$$

A.1.4 Final Good Producers

$$P_t Y_t(i) - \int_0^1 P_t Y_t(i) di \tag{A.38}$$

s.t.

$$Y_t(i) = \left[\int_0^1 Y_t(i)^{\frac{\varepsilon-1}{\varepsilon}} di\right]^{\frac{\varepsilon}{\varepsilon-1}} \tag{A.39}$$

$$P_t \left[\int_0^1 Y_t(i)^{\frac{\varepsilon-1}{\varepsilon}} di\right]^{\frac{\varepsilon}{\varepsilon-1}} - \int_0^1 P_t Y_t(i) di \tag{A.40}$$

Equation (A.18) is the first order condition respect to prices.

$$\frac{\varepsilon}{\varepsilon-1} P_t \left[\int_0^1 Y_t(i)^{\frac{\varepsilon-1}{\varepsilon}} di\right]^{\frac{1}{\varepsilon-1}} Y_t(i)^{\frac{1}{\varepsilon}} \frac{\varepsilon-1}{\varepsilon} - P_t(i) = 0 \tag{A.41}$$

$$P_t Y_t^{\frac{1}{\varepsilon}} Y_t(i)^{-\frac{1}{\varepsilon}} - P_t(i) = 0 \tag{A.42}$$

The demand for the variety (i) is expressed in the following equation.

$$Y_t(i) = \left(\frac{P_t(i)}{P_t}\right)^{-\varepsilon} Y_t \tag{A.43}$$

Appendix B

Appendices to Chapter 3

B.1 Optimisation Problems

B.1.1 Capital Producers' Maximisation Problem

$$maxE_t \sum_{t=0}^{\infty} \Lambda_{t,t+1}\{Q_t[1 - S^k(X_t)I_t] - I_t\} \tag{B.1}$$

given $X_t = \frac{I_t}{I_{t-1}}$

$$Q_tI_t - Q_tI_tS^k(X_t) + E_t\Lambda_{t,t+1}\{Q_{t+1}I_{t+1} - Q_tI_{t+1}S^k(X_{t+1})\} - I_t = 0 \tag{B.2}$$

$$Q_tI_t - Q_tI_t\phi\,(X_t - 1)^2 + E_t\Lambda_{t,t+1}\{Q_{t+1}I_{t+1} - Q_tI_{t+1}\phi\,(X_{t+1} - 1)^2\} - I_t = 0 \tag{B.3}$$

$$Q_tI_t - Q_tI_t\phi\left(\frac{I_t}{I_{t-1}} - 1\right)^2 + E_t\Lambda_{t,t+1}\{Q_{t+1}I_{t+1} - Q_tI_{t+1}\phi\left(\frac{I_{t+1}}{I_t} - 1\right)^2\} - I_t = 0 \tag{B.4}$$

$$Q_t - Q_t\phi\left(\frac{I_t}{I_{t-1}} - 1\right)^2 + Q_t2\phi\left(\frac{I_t}{I_{t-1}} - 1\right)\frac{I_t}{I_{t-1}} - E_t\Lambda_{t,t+1}\{Q_t2\phi\left(\frac{I_{t+1}}{I_t} - 1\right)\frac{I_{t+1}^2}{I_t}\} = 1 \tag{B.5}$$

The optimality condition yields

$$Q_t\left(1 - X_tS^k(X_t) - X_tS^{k'}(X_t)\right) + E_t\left[\Lambda_{t,t+1}Q_{t+1}S^{k'}(X_{t+1})X_{t+1}^2\right] = 1 \tag{B.6}$$

B.1.2 Intermediate Good Producers' Maximisation Problem

$$MaxE_t \sum_{t=0}^{\infty} \beta^t \Lambda_t \left[\frac{P_{H,t}(i)}{P_t} Y_{H,t}(i) - \frac{W_t}{P_t} L_t(i) - Q_t R_t^k K_t(i) - \frac{\varphi^H}{2} \left[\frac{P_{H,t}(i)}{P_{H,t-1}(i)} - 1 \right]^2 Y_{H,t} \right] \tag{B.7}$$

s.t.

$$Y_{H,t}(i) = \left(\frac{P_{H,t}(i)}{P_{H,t}} \right)^{-\varepsilon} Y_{H,t} \tag{B.8}$$

$$Y_{H,t}(i) = A_t K_t(i)^{\alpha} L_t(i)^{1-\alpha} \tag{B.9}$$

Firms choose the variables $\{\frac{W_t}{P_t}, z_t, \frac{P_{H,t}}{P_t}\}$

$$MaxE_t \sum_{t=0}^{\infty} \beta^t \Lambda_t \left[\frac{P_{H,t}(i)}{P_t} \left(\frac{P_{H,t}(i)}{P_{H,t}} \right)^{-\varepsilon} Y_{H,t} - \frac{W_t}{P_t} L_t(i) - Q_t R_t^k K_t(i) - \frac{\varphi^H}{2} \left[\frac{P_{H,t}(i)}{P_{H,t-1}(i)} - 1 \right]^2 Y_{H,t} \right] \tag{B.10}$$

s.t.

$$Y_{H,t}(i) = A_t K_t(i)^{\alpha} L_t(i)^{1-\alpha} \tag{B.11}$$

Optimalities

$$\frac{W_t}{P_t} = (1-\alpha) A_t rmc_t \left(\frac{K_t}{L_t} \right)^{\alpha} \tag{B.12}$$

$$z_t = (\alpha) A_t rmc_t \left(\frac{K_t}{L_t} \right)^{\alpha-1} \tag{B.13}$$

where mc_t is the marginal cost, $rmc_t = \frac{mc_t}{P_t}$ is the real marginal cost and $\pi_{H,t} = \frac{P_{H,t}}{P_{H,t-1}}$ is the domestic inflation.

$$\frac{P_{H,t}}{P_t} = \frac{\varepsilon}{\varepsilon - 1} rmc_t - \frac{\varphi^H}{\varepsilon - 1} \pi_{H,t} \left(\pi_{H,t} - 1 \right) + \frac{\varphi^H}{\varepsilon - 1} E_t \left\{ \Lambda_{t,t+1} \frac{\pi_{H,t+1} \left(\pi_{H,t} - 1 \right) Y_{H,t+1}}{Y_{H,t}} \right\} \tag{B.14}$$

B.1.3 Final Good Producers' Maximisation Problem

$$P_{H,t} Y_{H,t}(i) - \int_0^n P_{H,t} Y_{H,t}(i) di \tag{B.15}$$

s.t.

$$Y_{H,t}(i) = \left(\frac{1}{n}\right)^{\frac{1}{\varepsilon}} \left[\int_0^n Y_{H,t}(i)^{\frac{\varepsilon-1}{\varepsilon}} di\right]^{\frac{\varepsilon}{\varepsilon-1}} \tag{B.16}$$

It gives a maximization problem that can be easily solved by substituting equations and taking the FOC as it is shown below

$$P_{H,t}\left(\frac{1}{n}\right)^{\frac{1}{\varepsilon}} \left[\int_0^n Y_{H,t}(i)^{\frac{\varepsilon-1}{\varepsilon}} di\right]^{\frac{\varepsilon}{\varepsilon-1}} - \int_0^n P_{H,t}Y_{H,t}(i)di \tag{B.17}$$

$$\frac{\varepsilon}{\varepsilon-1}\left(\frac{1}{n}\right)^{\frac{1}{\varepsilon}} P_{H,t}\left[\int_0^n Y_{H,t}(i)^{\frac{\varepsilon-1}{\varepsilon}} di\right]^{\frac{1}{\varepsilon-1}} Y_{H,t}(i)^{\frac{1}{\varepsilon}}\frac{\varepsilon-1}{\varepsilon} - P_{H,t}(i) = 0 \tag{B.18}$$

$$\left(\frac{1}{n}\right)^{\frac{1}{\varepsilon}} P_{H,t}Y_{H,t}^{\frac{1}{\varepsilon}}Y_{H,t}(i)^{-\frac{1}{\varepsilon}} - P_{H,t}(i) = 0 \tag{B.19}$$

After some algebra the demand for the variety (i) is expressed in the following equation.

$$Y_{H,t}(i) = \frac{1}{n}\left(\frac{P_{H,t}(i)}{P_{H,t}}\right)^{-\varepsilon} Y_{H,t} \tag{B.20}$$

B.1.4 Banks' Optimisation Problem

B.1.4.1 Domestic Economy Banks

The expected profits of bank i in the domestic economy is defined as

$$V_t = maxE_t\sum_{i=0}^{\infty}(1-\theta)\,(\theta)^{i-1}\Lambda_{t,t+i}n_{t+i} \tag{B.21}$$

The bank i maximises subject to the incentive constraint. Here cross border loans are a liability.

$$V_t\left(s_{t-1}, b_{t-1}, d_{t-1}\right) = E_{t-1}\Lambda_{t-1,t}\left\{(1-\theta)\,n_t + \theta\left[\max_{s_t,b_t,d_t} V_t\left(s_t, b_t, d_t\right)\right]\right\} \tag{B.22}$$

$$V_t\left(s_t, b_t, d_t\right) \geq \lambda(Q_t s_t - \omega_a Q_{b,t} b_t) \tag{B.23}$$

Maximising by the Bellman equation, we guess the functional form of the value function.

$$V_t\left(s_t, b_t, d_t\right) = \nu_{s,t} s_t - \nu_{b,t} b_t - \nu_{d,t} d_t \tag{B.24}$$

where $\nu_{j,t}\forall,\ j = s, b, d$ are the time-varying marginal values. We present the first order conditions below and λ_{lag} is the Lagrange multiplier,

$$\mathcal{L} = \nu_{s,t}s_t - \nu_{b,t}b_t - \nu_{d,t}d_t + \lambda_{lag}\left(\lambda Q_t s_t - \lambda\omega_a Q_{b,t} b_t - \nu_{s,t}s_t + \nu_{b,t}b_t + \nu_{d,t}d_t\right) \tag{B.25}$$

$$\nu_{s,t} - \lambda_{lag}(\nu_{s,t} - \lambda Q_t) = 0 \tag{B.26}$$

$$\nu_{b,t} - \lambda_{lag}(\nu_{b,t} - \lambda\omega_a Q_{b,t}) = 0 \tag{B.27}$$

$$\nu_{d,t}(1 + \lambda_{lag}) = 0 \tag{B.28}$$

$$\lambda Q_t s_t - \lambda\omega_a Q_{b,t} b_t - \nu_{s,t}s_t + \nu_{b,t}b_t + \nu_{d,t}d_t = 0 \tag{B.29}$$

Arranging we obtain the equations

$$\left(\frac{\nu_{s,t}}{Q_t} - \frac{\nu_{b,t}}{Q_{b,t}}\right)(1 + \lambda_{lag,t}) = \lambda_{lag,t}\lambda(1 - \omega_a) \tag{B.30}$$

$$\left(\frac{\nu_{b,t}}{Q_{b,t}} - \nu_t\right)(1 + \lambda_{lag,t}) = \lambda_{lag,t}\lambda\omega_a \tag{B.31}$$

$$Q_t s_t\left[\lambda - \left(\frac{\nu_{s,t}}{Q_t} - \nu_{s,t}\right)\right] - Q_{b,t}b_t\left[\lambda\omega_a - \left(\frac{\nu_{b,t}}{Q_{b,t}} - \nu_{s,t}\right)\right] = \nu_{d,t}n_t \tag{B.32}$$

From (A.32), we obtain $\mu_t = \left(\frac{\nu_{s,t}}{Q_t} - \nu_{s,t}\right)$ and $\mu_{b,t} = \left(\frac{\nu_{b,t}}{Q_{b,t}} - \nu_{s,t}\right)$

$$Q_t s_t\left(\lambda - \mu_t\right) - Q_{b,t}b_t\left(\lambda\omega_a - \mu_{b,t}\right) = \nu_{d,t}n_t \tag{B.33}$$

From (A.30) and (A.31)

$$\frac{1}{1-\omega_a}\left(\frac{\nu_{s,t}}{Q_t} - \frac{\nu_{b,t}}{Q_{b,t}}\right) = \frac{1}{\omega_a}\left(\frac{\nu_{b,t}}{Q_{b,t}} - \nu_t\right) \tag{B.34}$$

Using μ_t and $\mu_{b,t}$ it yields (A.37) as the difference between of excess value of assets over deposits and excess value of cross border lending over deposits.

$$\frac{1}{1-\omega_a}\left(\frac{\nu_{s,t}}{Q_t}-\nu_t+\nu_t-\frac{\nu_{b,t}}{Q_{b,t}}\right)=\frac{1}{\omega_a}\left(\frac{\nu_{b,t}}{Q_{b,t}}-\nu_t\right)$$

$$\left(\mu_t-\mu_{b,t}\right)\frac{\omega_a}{1-\omega_a}=\mu_{b,t}$$

$$\mu_t\omega_a=\mu_{b,t} \tag{B.35}$$

The next equations result by verifying the the functional form of the value function

$$\nu_{s,t}=E_t\Lambda_{t,t+1}\Omega_{t+1}R_{k,t+1}Q_t \tag{B.36}$$

$$\nu_{b,t}=E_t\Lambda_{t,t+1}\Omega_{t+1}R_{b,t+1}Q_{b,t+1}\frac{1}{\pi_{t+1}} \tag{B.37}$$

$$\nu_{d,t}=E_t\Lambda_{t,t+1}\Omega_{t+1}R_{t+1}\frac{1}{\pi^*_{t+1}} \tag{B.38}$$

$$\mu_t=E_t\Lambda_{t,t+1}\Omega_{t+1}\left(R_{k,t+1}-R_{t+1}\frac{1}{\pi_{t+1}}\right) \tag{B.39}$$

$$\mu_{b,t}=E_t\Lambda_{t,t+1}\Omega_{t+1}\left(R_{b,t+1}-R_{t+1}\frac{1}{\pi_{t+1}}\right) \tag{B.40}$$

B.1.4.2 Foreign Economy Banks

The value of bank i is defined by

$$V^*_t=maxE_t\sum_{i=0}^{\infty}\left(1-\theta\right)^*\left(\theta^*\right)^{i-1}\Lambda^*_{t,t+i}n^*_{t+i} \tag{B.41}$$

the Bellman equation

$$V^*_t\left(s^*_{t-1},b^*_{t-1},d^*_{t-1}\right)=E_{t-1}\Lambda^*_{t-1,t}\left\{\left(1-\theta\right)^*n^*_t+\theta^*\left[\max_{s^*_t,b^*_t,d^*_t}\ V^*_t\left(s^*_t,b^*_t,d^*_t\right)\right]\right\} \tag{B.42}$$

Bank i maximises profits subject to the incentive constraint

$$V^*_t\left(s^*_t,b^*_t,d^*_t\right)\geq\lambda^*(Q^*_ts^*_t+Q^*_{b,t}b^*_t) \tag{B.43}$$

Guessing and verifying the value function of bank i, it is assumed that s_t^*, b_t^* and d_t^* keep a linear relation such as

$$V_t^*\left(s_t^*, b_t^*, d_t^*\right) = \nu_{s,t}^* s_t^* + \nu_{b,t}^* b_t^* - \nu_{d,t}^* d_t^* \tag{B.44}$$

where $\nu_{j,t}^* \forall$, $j = s, b, d$ are the time-varying marginal values of assets

The first order conditions are as below and λ_{lag} is the lagrange multiplier,

$$\mathcal{L} = \nu_{s,t}^* s_t^* + \nu_{b,t}^* b_t^* - \nu_{d,t}^* d_t^* - \lambda_{lag}\left(\lambda Q_t^* s_t^* + \lambda Q_{b,t}^* b_t^* - \nu_{s,t}^* s_t^* - \nu_{b,t}^* b_t^* + \nu_{d,t}^* d_t^*\right) \tag{B.45}$$

$$\nu_{s,t}^* - \lambda_{lag}(\lambda^* Q_t^* - \nu_{s,t}^*) = 0 \tag{B.46}$$

$$\nu_{b,t}^* - \lambda_{lag}(\lambda^* Q_{b,t}^* - \nu_{b,t}^*) = 0 \tag{B.47}$$

$$-\nu_{d,t}^* - \lambda_{lag}\nu_{d,t}^* = 0 \tag{B.48}$$

$$\lambda^* Q_t^* s_t^* + \lambda^* Q_{b,t}^* b_t^* - \nu_{s,t}^* s_t^* - \nu_{b,t}^* b_t^* + \nu_{d,t}^* d_t^* = 0 \tag{B.49}$$

Taking (A.46) and (A.47), it is shown the marginal value of cross border loans is equal to the marginal value of loans to intermediate good firms.

$$\frac{\nu_{s,t}^*}{\lambda^* Q_t^* - \nu_{s,t}^*} = \frac{\nu_{b,t}^*}{\lambda^* Q_{b,t}^* - \nu_{b,t}^*} \tag{B.50}$$

$$\frac{\nu_{s,t}^*}{Q_t^*} = \frac{\nu_{b,t}^*}{Q_{b,t}^*} \tag{B.51}$$

Using (A.49) and the definition of balance sheet of bank i, deposits are eliminated from the expression,

$$d_t^* = Q_t^* s_t^* + Q_{b,t}^* b_t^* - n_t^* \tag{B.52}$$

$$\lambda^* Q_t^* s_t^* + \lambda^* Q_{b,t}^* b_t^* - \nu_{s,t}^* s_t^* - \nu_{b,t}^* b_t^* + \nu_{d,t}^*(Q_t^* s_t^* + Q_{b,t}^* b_t^* - n_t^*) = 0 \tag{B.53}$$

Once the expression is arranged, it yields (A.35)

$$Q_t^* s_t^* \left[\lambda^* - \left(\frac{\nu_{s,t}^*}{Q_t^*} - \nu_{s,t}^*\right)\right] + Q_{b,t}^* b_t^* \left[\lambda^* - \left(\frac{\nu_{b,t}^*}{Q_{b,t}^*} - \nu_{s,t}^*\right)\right] = \nu_{d,t}^* n_t^* \tag{B.54}$$

where $\mu_{s,t}$ is the excess value of the banks' assets over deposits or the excess return of capital,

$$\mu_{s,t}^* = \frac{\nu_{s,t}^*}{Q_t^*} - \nu_{s,t}^* \tag{B.55}$$

$$Q_t^* s_t^* \left[\lambda^* - \mu_{s,t}^*\right] + Q_{b,t}^* b_t^* \left[\lambda^* - \mu_{b,t}^*\right] = \nu_{d,t}^* n_t^* \tag{B.56}$$

and the leverage ratio net of cross border lending is

$$\phi_t^* = \frac{\nu_{d,t}^*}{\lambda^* - \mu_{s,t}^*} \tag{B.57}$$

That is

$$Q_t^* s_t^* = \phi_t^* n_t^* \tag{B.58}$$

Next step is verify the functional form of the value function, which is plugged in the Bellman equation and d_t^* is replaced by (A.33).

$$V_t^*\left(s_{t-1}^*, b_{t-1}^*, d_{t-1}^*\right) = E_{t-1}\Lambda_{t-1,t}^* \left\{(1-\theta)^* n_t^* + \theta^* \left[\max_{s_t^*, b_t^*, d_t^*} V_t^*\left(s_t^*, b_t^*, d_t^*\right)\right]\right\}$$

$$V_t^*\left(s_t^*, b_t^*, d_t^*\right) = \nu_{s,t}^* s_t^* + \nu_{b,t}^* b_t^* - \nu_{d,t}^* d_t^*$$

$$V_t^*\left(s_{t-1}^*, b_{t-1}^*, d_{t-1}^*\right) = E_{t-1}\Lambda_{t-1,t}^* \left\{(1-\theta)^* n_t^* + \theta^* \left[\nu_{s,t}^* s_t^* + \nu_{b,t}^* b_t^* - \nu_{d,t}^* (Q_t^* s_t^* + Q_{b,t}^* b_t^* - n_t^*)\right]\right\} \tag{B.59}$$

$$V_t^*\left(s_{t-1}^*, b_{t-1}^*, d_{t-1}^*\right) = E_{t-1}\Lambda_{t-1,t}^* \left\{(1-\theta)^* n_t^* + \theta^* \left[\left(\frac{\nu_{s,t}^*}{Q_t^*} - \nu_{s,t}^*\right) Q_t^* s_t^* + \left(\frac{\nu_{b,t}^*}{Q_{b,t}^*} - \nu_{b,t}^*\right) Q_{b,t}^* b_t^* + \nu_{d,t}^* n_t^*\right]\right\} \tag{B.60}$$

Taking the definition of $\mu^*_{s,t}$, the expression above is written as follows,

$$V^*_t\left(s^*_{t-1}, b^*_{t-1}, d^*_{t-1}\right) = E_{t-1}\Lambda^*_{t-1,t}\left\{(1-\theta)^* n^*_t + \theta^*\left[\mu^*_{s,t}Q^*_t s^*_t + \mu^*_{b,t}Q^*_{b,t}b^*_t + \nu^*_{d,t}n^*_t\right]\right\} \tag{B.61}$$

$$V^*_t\left(s^*_{t-1}, b^*_{t-1}, d^*_{t-1}\right) = E_{t-1}\Lambda^*_{t-1,t}n^*_t\left\{(1-\theta)^* + \theta^*\left(\mu^*_{s,t}\phi^*_t + \nu^*_{d,t}\right)\right\} \tag{B.62}$$

Following Gertler and Kiyotaki (2010) and Gertler and Kiyotaki (2010); Cuadra and Nuguer (2016) I replace the net worth earnings $n^*_t = R^*_{k,t}Q^*_{t-1}s^*_{t-1} + R^*_{b,t}Q^*_{b,t}b^*_{t-1}\frac{1}{\pi^*_t} - R^*_t d^*_{t-1}\frac{1}{\pi^*_t}$, then it is defined $\Omega^*_t = (1-\theta)^* + \theta^*\left(\mu^*_{s,t}\phi^*_t + \nu^*_{d,t}\right)$ as the shadow value of net worth. Thus V^*_t is rolled one period ahead and there we obtain expressions for all the variables.

$$V^*_t\left(s^*_t, b^*_t, d^*_t\right) = \nu^*_{s,t}s^*_t + \nu^*_{b,t}b^*_t - \nu^*_{d,t}d^*_t = E_t\Lambda^*_{t,t+1}\Omega^*_{t+1}\left(R^*_{k,t+1}Q^*_t s^*_t + R^*_{b,t+1}Q^*_{b,t+1}b^*_t\frac{1}{\pi^*_{t+1}} - R^*_{t+1}d^*_t\frac{1}{\pi^*_{t+1}}\right) \tag{B.63}$$

For s^*_t

$$\nu^*_{s,t} = E_t\Lambda^*_{t,t+1}\Omega^*_{t+1}R^*_{k,t+1}Q^*_t \tag{B.64}$$

For b^*_t

$$\nu^*_{b,t} = E_t\Lambda^*_{t,t+1}\Omega^*_{t+1}R^*_{b,t+1}Q^*_{b,t+1}\frac{1}{\pi^*_{t+1}} \tag{B.65}$$

For d^*_t

$$\nu^*_{d,t} = E_t\Lambda^*_{t,t+1}\Omega^*_{t+1}R^*_{t+1}\frac{1}{\pi^*_{t+1}} \tag{B.66}$$

μ^*_t the excess value of assets over deposits is expressed by

$$\mu^*_t = E_t\Lambda^*_{t,t+1}\Omega^*_{t+1}\left(R^*_{k,t+1} - R^*_{t+1}\frac{1}{\pi^*_{t+1}}\right) \tag{B.67}$$

and from the fact that $\frac{\nu^*_{s,t}}{Q^*_t} = \frac{\nu^*_{b,t}}{Q^*_{b,t}}$, It can be equalized (A.47) and (A.48) to obtain the returns of loans to intermediate good firms and domestic banks.

$$E_t \Lambda^*_{t,t+1} \Omega^*_{t+1} R^*_{k,t+1} = E_t \Lambda^*_{t,t+1} \Omega^*_{t+1} R^*_{b,t+1} \frac{1}{\pi^*_{t+1}} \tag{B.68}$$

B.2 Data

Table B.1: Claims: Cross Border Banking Flows to Mexico by Currency

Amounts outstanding in Millions of USD Dollars							
Claims	**Total**	**Loans and Depts.**	**US Dollars**	**Euro**	**JP Y**	**GBP Pounds**	**Swiss Franc**
1995-Q4	73,310	63,019	65,814	4,580	1,314	45	335
1996-Q4	72,930	60,808	65,521	4,356	1,112	152	215
1997-Q4	65,057	52,394	56,920	3,915	1,215	174	215
1998-Q4	65,613	52,433	58,248	4,628	1,166	253	182
1999-Q4	61,374	46,757	53,144	4,416	1,179	230	171
2000-Q4	58,101	41,986	49,345	3,141	1,116	336	113
2001-Q4	60,937	45,290	51,110	2,693	833	237	159
2002-Q4	64,411	48,221	54,731	3,167	831	81	200
2003-Q4	65,481	45,110	50,351	3,746	1,021	80	245
2004-Q4	65,284	44,404	50,159	2,949	744	190	324
2005-Q4	60,302	40,180	45,827	3,447	483	140	288
2006-Q4	76,103	50,538	53,886	5,113	315	387	332
2007-Q4	94,787	65,842	67,734	6,063	842	498	507
2008-Q4	102,678	74,515	74,621	4,629	2,109	304	380
2009-Q4	95,922	67,885	62,946	4,342	2,861	325	304
2010-Q4	114,933	82,207	71,178	4,626	4,328	349	265
2011-Q4	123,847	84,587	74,729	5,716	4,691	625	229
2012-Q4	123,717	78,127	70,742	6,766	4,743	1,146	245
2013-Q4	122,999	80,148	67,709	5,273	3,429	530	724
2014-Q4	126,156	82,562	76,636	5,482	3,428	422	697
2015-Q4	119,744	82,154	79,551	6,524	3,146	275	708
2016-Q3	130,919	86,725	81,001	9,474	4,529	214	752

Source: BIS, Locational Banking Statistics

Table B.2: Liabilities: Cross Border Banking Flows to Mexico by Currency

Amounts outstanding in Millions of USD Dollars							
Liabilities	**Total**	**Loans and Depts.**	**US Dollars**	**Euro**	**JPY**	**GBP Pounds**	**Swiss Franc**
1995-Q4	33,514	33,509	32,027	1,006	66	127	158
1996-Q4	37,754	37,754	32,919	2,440	239	756	110
1997-Q4	43,263	43,263	38,230	1,810	557	841	117
1998-Q4	43,874	43,872	38,688	2,815	653	1,038	209
1999-Q4	47,689	47,688	41,040	2,512	1,557	1,523	322
2000-Q4	53,969	52,665	49,745	1,567	444	1,063	401
2001-Q4	62,637	62,221	57,366	1,929	511	1,105	137
2002-Q4	52,019	49,352	46,060	3,201	368	322	146
2003-Q4	62,212	54,443	48,651	3,934	450	918	164
2004-Q4	58,067	53,961	48,786	4,411	414	867	193
2005-Q4	60,124	56,367	50,564	3,415	377	1,118	169
2006-Q4	66,441	62,356	56,401	3,394	213	1,549	108
2007-Q4	77,607	74,528	68,359	4,232	443	1,489	137
2008-Q4	91,294	87,214	76,709	5,375	3,367	595	190
2009-Q4	81,394	78,321	68,988	4,487	1,873	821	370
2010-Q4	96,029	92,875	72,994	10,015	3,348	2,976	343
2011-Q4	108,745	103,728	77,955	14,037	4,751	1,288	318
2012-Q4	88,316	83,907	65,617	8,314	2,392	3,119	303
2013-Q4	108,648	104,128	83,264	7,573	5,537	4,288	321
2014-Q4	121,528	116,149	88,277	15,622	8,975	1,310	316
2015-Q4	116,984	111,559	87,933	5,106	2,288	10,269	416
2016-Q3	135,250	127,726	102,366	14,662	2,278	3,222	459

Source: BIS, Locational Banking Statistics

Appendix C

Appendices to Chapter 4

Table C.1: ONS Skill Occupations

Skill level	**Standard Occupational Classifications 2010 included**
High (High-Skilled)	Corporate managers and directors Science, research, engineering and technology professionals Health professionals Teaching and educational professionals Business, media and public service professionals
Upper middle (Medium-Skilled)	Other managers and proprietors Science, research, engineering and technology associate professionals Health and social care associate professionals Protective service occupations Culture, media and sports occupations Business and public service associate professionals Skilled agricultural and related trades Skilled metal, electrical and electronic trades Skilled construction and building trades Textiles, printing and other skilled trades
Lower middle (Low-Skilled)	Administrative occupations Secretarial and related occupations Caring personal service occupations Leisure, travel and related personal service occupations Sales occupations Customer service occupations Process, plant and machine operatives Transport and mobile machine drivers and operatives
Low (Low-Skilled)	Elementary trades and related occupations Elementary administration and service occupations

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