Essays on Macroprudential Policies, Non-bank Financing, and Welfare

TEVY CHAWWA

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Tevy Chawwa

Department of Economics and Finance

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Abstracts

This thesis contributes to the emerging literature of macroprudential policy by investigating the macroeconomic and welfare impacts of various regulations in banking sector.

First, I examine the long-run impact of government subsidies on the bank's information costs by evaluating the combination of different types of subsidies and taxes. By extending the basic model of De Fiore & Uhlig (2015), I find that subsidy on bank's information acquisition cost improves aggregate welfare if the government funds the subsidy with labour-income tax or lump-sum tax. In contrast, subsidy on monitoring cost generates welfare losses for both the household and the entrepreneur. Therefore, government supports in lowering the costs of bank access are preferable to government supports for default resolution costs.

Second, I evaluate the effectiveness of the macroprudential policy in a framework that accounts for the possible substitution from bank-based financial intermediation to non-bank intermediation in response to the policy. Employing the model of De Fiore & Uhlig (2015), I find that a countercyclical macroprudential regulation improves welfare in the case of banking shocks and uncertainty shocks but not in the case of technology shocks. A modified rule, which reacts not only to bank credit growth but to total credit growth, provides welfare gains in the case of technology shocks. Consequently, macroprudential authorities should consider not only the condition of the banking sector but also the non-banking financial markets.

Finally, I study the impact of the reserve requirement and Liquidity Coverage Ratio (LCR) by extending the framework of Gerali *et al.* (2010). I find that the effect of the two liquidity requirements on lending and output are relatively similar. However, changing the LCR has consequences on demand for government bonds, and thus different impacts on taxes, household deposits and bank's profit. I also find that countercyclical liquidity regulations can improve welfare and reduce the volatility of bank loans.

Declaration

I, Tevy Chawwa, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis. The work in this thesis is based on research carried out at the Department of Economics and Finance, Durham University Business School, England. No part of this thesis has been submitted elsewhere for any other degree or qualification.

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I dedicate this thesis to my parents who always give their prayers and support throughout my lifetime. Finally and foremost, I am thankful to my husband Hasan Alatas for his unlimited support, love, and care. I would not have reached this far without you.

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Chapter 1

Overview of Thesis and Related Literature Review

1.1 Overview of Thesis

> *"More academic research is needed on macroprudential regulations. This is not an easy field to delve into. It requires learning a substantial number of acronyms and technical language—none of which is taught in graduate school"* (Forbes (2019)).

The implementation of macroprudential policy aims to provide financial and macroeconomic stability and has become a more important area of research since the global financial crisis. There have been increasing efforts to develop theoretical and empirical models in this research area to provide better guidance for policymakers around the world. The modelling framework of the interaction between the financial system and the macroeconomy becomes more critical with the development of financial intermediation (Woodford (2010)).

This thesis contributes to the growing literature of macroprudential policy by investigating the macroeconomic and welfare impacts of various regulations in banking sector.[1] The thesis consists of introductions and three chapters which is

[1] As mentioned in Svensson (2018), the ultimate goal for overall economic policy is to safe-

followed by a summarising conclusion. Each of the main chapters investigates a particular regulation in an elaborated model environment.

In the second and third chapter, I employ the model of the De Fiore & Uhlig (2015) to study the effects of subsidy on the bank's agency cost and the impact of macroprudential policy in an economy where firms have access to bank finance and market finance. Most of the literature on the macroprudential policy has focused on the impact of this policy on banks without accounting for the possibility that financial risk is shifted to the non-banking sector. Thus, the main contribution of my two chapters is to bring the existence of non-bank debt financing as a substitute for bank financing into macroprudential policy analysis. The second and the third chapters assume a flexible price economy and assume monetary policy in the form of liquidity injection. Those assumptions are not commonly used in the recent central bank modelling framework. Therefore, in the fourth chapter, I employ a medium-scale New Keynesian DSGE model with a banking sector as in Gerali *et al.* (2010) and Angelini *et al.* (2014) that includes financial, price and wage frictions. I enhance the model by adding liquidity features of the banking sector to study the impact of macroprudential policy in the form of countercyclical liquidity regulations: Reserve Requirements (RR) and Liquidity Coverage Ratio (LCR). The implementation of LCR is relatively new, and only a few research has been done to analyse the impact of this policy in a general equilibrium framework. Therefore, the main contribution of my fourth chapter is to bring together RR and LCR regulation into a DSGE modelling framework and to calibrate the model for the Indonesian economy.

The second chapter studies the long-run impact of government subsidy on bank's information acquisition cost and bank's monitoring cost on firms' debt structure, various macroeconomic variables, and welfare.[2] The motivation of this

guard and improve the welfare of citizens. This ultimate goal can be represented in terms of a few more specific goals that contribute to welfare such as, efficient resource allocation (including an efficient financial system), high and stable growth, full and stable employment, price stability, etc.

[2] The draft of the second chapter was presented at the 4th Workshop in International Economics and Finance "Macro-stabilisation policies and bank risk-taking", University of Bordeaux,

research emerges from the thought that one cause of the slowdown in lending activities after the crisis is the costly information acquisition and monitoring process in the banking sector. How if the government intervene by giving support in the form of subsidy to reduce the information cost in the credit market? Using a numerical simulation of the steady-state values of the general equilibrium model, I found that government subsidy on the bank's information acquisition cost could improve aggregate welfare. However, the policy is not Pareto improving since it increases entrepreneurs' welfare at the expense of households' welfare. The government could gain economic efficiency by imposing taxes on the labour income to finance the subsidy and impose a redistribution policy on the entrepreneur and household consumption. This chapter suggests that government support in lowering the cost of access to banks has a more positive impact on welfare, compared to government support for default resolution cost.

The third chapter evaluates the effectiveness of macroprudential policy in a framework that accounts for the possible substitution from the bank-based financial intermediation to the non-bank intermediation in response to such policy.[3] Macroprudential policy is modelled in the form of a premium introduced by regulation to the bank's cost of borrowing and thus transmitted to the economy through the change in credit spread. First, I consider a policy when the regulation premium rises proportionally with bank credit growth. The simulation shows that a countercyclical macroprudential regulation has desirable benefits on financial stability and welfare in the case of banking shock. However, in the case of technology and uncertainty shocks, the unintended consequences from the risk shifting from the bank to the non-bank sector make the policy less effective. I found that a modified rule, which reacts not only to bank credit growth but total credit growth, provides welfare gains in the case of technology shock. Therefore,

France on 13 December 2016.

[3] The drafts of the third chapter were presented at: (1) 12th BiGSEM Doctoral Workshop on Economic Theory organised by the Bielefeld University, Germany on 4-5 December 2017; (2) 5th MMF PhD-students conference at University of Kent, Canterbury on 19 - 20 April 2018; and (3) International Conference on Economic Modeling organised by the Global Economic Modeling Network (ECOMOD) at Università Ca' Foscari Venezia, Italy, on July 4-6, 2018.

it is essential that macroprudential authorities take into consideration not only the condition of the banking sector but also the non-banking financial markets.

The fourth chapter investigates a medium-scale DSGE model in which the bank endogenously determines the optimal level of reserves and high-quality liquid assets under reserve requirement and liquidity coverage ratio (LCR) regulation.[4] The model is calibrated to match data for Indonesia. I employ the model to study the impact of liquidity shock, technology shock and liquidity regulations shock on the banking sector and the real economy. Since the impact of liquidity shock is non-linear, I use piecewise linear perturbation method by utilising Occbin toolkit (Guerrieri & Iacoviello (2015)). The results show that the effects of a negative liquidity shock into credit, investment and total output are relatively small. Additionally, the simulation shows that the impact of changing the two liquidity requirements on lending and output are relatively similar. However, lowering the LCR has consequences on the decline of demand for government bonds, so that it has a different impact on taxes, household deposits and bank's profit. This chapter also found that countercyclical liquidity regulations can improve welfare and reduce the volatility of bank loans.

The results from this thesis indirectly deliver some policy implications concerning the implementation of macroprudential policy. First is the importance of coordination among policy authorities. Supports on the banking sector in the form of subsidy surely need to be coordinated with the fiscal policy regarding the optimal source of funding for the subsidy. Moreover, the implementation of bank liquidity regulations also needs to be coordinated with the fiscal authorities, for example regarding the supply of government bond as risk-free assets. Second, there is a need to broaden the scope of macroprudential policy analysis not only focus on the banking sector but also to the non-banking sector considering regulatory arbitrage across sectors. The third is the need of awareness regarding the

[4] The drafts of the fourth chapter were presented at: (1) CEGAP PhD Workshop, Durham University on 12 November 2018 and (2) "International Symposium on Economics, Finance and Econometrics" on 6-7 December 2018 in Bandirma University, Turkey.

welfare implications of macroprudential policies. Since the welfare benefit of some macroprudential policies goes only to entrepreneur at the cost of household, the policy authorities should consider some redistribution policy to make everyone better off.

The research I conducted can be extended in many exciting directions. The studies in this thesis still focus only on evaluating the impacts of macroprudential policies on welfare and macroeconomic stability, i.e. smoothing credit expansion period and helping to preserve the financial system's capability to give loans to the economy during a credit contraction period, whilst the aims of macroprudential policies are much wider. Therefore, one interesting area of future research is to extend the models in this thesis and evaluate the impact of macroprudential policies on reducing negative externalities that can lead to systemic risk and controlling the build-up of the financial system vulnerabilities. Another possible area of future research is to explore the interaction of macroprudential policies with monetary policy and capital flow management which are also essential issues for the central bankers. There is plenty of scope for future studies to complete the findings in this thesis allowing a better understanding of the effect of macroprudential policy and to help policymakers designing strategy in maintaining financial and macroeconomic stability.

1.2 Related Literature

1.2.1 Macroprudential Policy and Externalities in Financial System

Before discussing the macroprudential policy, we need to examine why government intervention or government policy within the financial system is necessary in the first place. According to Stiglitz (1994), the main reason is that market failures in the financial market are more appearing than in other markets. Government intervention could make the functioning of the financial system better and also improve the performance of the economy. In contrast with the standard theory of the efficiency of competitive markets that are based on the assumption of perfect information, the financial market's information is imperfect and the market is incomplete. Therefore, the financial market is not Pareto efficient, and there are possible government interventions that can make all individuals better off (Stiglitz (1994)). One example of government policy in the financial system that became popular after the global financial crisis is macroprudential policy.

Unlike monetary policy, which has been established over time, the definitions, goals, and instruments of macroprudential policy are less well-defined (Galati & Moessner (2018)).[5] According to FSB *et al.* (2011), macroprudential policy aims to limit systemic risk, defined as the risk of widespread disruptions to the functionality of financial services that have a severe impact on the overall economy. In contrast to microprudential policies that focus on the individual component of the financial system, the focus of macroprudential policy is on the financial system as a whole, including the interactions between the financial and real sectors. The externalities of the financial system that can induce systemic risk in the economy, justify the need for macroprudential policy. De Nicolo *et al.* (2012) classified externalities that can lead to systemic risk as:

1. Externalities related to strategic complementarities. Strategic complementarities mean that the payoff from a particular strategy increases when more agents undertake the same strategy. This incentive induces banks and other financial institutions to choose to correlate their risk, and it increases the vulnerabilities during the financial cycle expansion phase.

2. Externalities related to fire-sales. In the financial downturn, the financial institutions are typically forced to sell assets at a price below their fundamental value because of limited potential buyers. The generalised sell-off of financial assets will lead to a decline in asset prices. It is not only that

[5] The term "macroprudential" has been used in the Basel Commitee documents since 1979. However, only since the Global Financial Crisis 2007-2008 macroprudential policy becomes an important development in central bank policymaking circles (Mizen *et al.* (2018)).

particular asset price that declines but also other similar assets held by other banks, which causes deterioration of the bank's balance sheet.

3. Externalities related to interconnectedness. A failure of a bank can have contagious effects on other banks or financial institutions because banks operate in an interconnected system.

Other literature classifies externalities into: (i) externalities that are more related to a time-series dimension and (ii) externalities that are more related to a cross-sectional dimension. For example, Galati & Moessner (2013) suggest that from a time-series dimension, the financial system tends to have a pro-cyclical behaviour that is characterised by excess risk-taking during booms and excess deleveraging during busts. Additionally, from a cross-sectional dimension, the simultaneous failure of financial institutions can lead to a contagion risk to the other financial institutions or the real sector.

To contain those externalities and to increase the financial system's resilience, the IMF suggested that macroprudential policy has the following tasks: the first is to provide cushions that absorb the impact of aggregate systemic shock and help preserve the financial system's capability to continue lending to the economy. The second is to decrease the pro-cyclical feedback between asset prices and credit as well as to decrease unsustainable rises in leverage and unstable funding. The third is control of the build-up of the financial system vulnerabilities that arise through the interconnectedness between financial intermediaries (Nier & Osinski (2013)).

A recent paper by Forbes (2019) defines three broad objectives for macroprudential policy. Firstly, to address excessive credit expansion and build resilience in the overall financial system. Secondly, to reduce key amplification mechanisms of systemic risk, and thirdly to mitigate structural vulnerabilities related to important institutions and markets.

A general representation of macroprudential policy's role during the expansion and contraction phase of the financial cycle is illustrated in Figure 1.1. Macroprudential policy aims to reduce excessive risk-taking behaviour during the expansion phase (lower the peak of the financial cycle) and to reduce excess deleveraging during the contraction phase (lessen the severity of the financial cycle's trough).

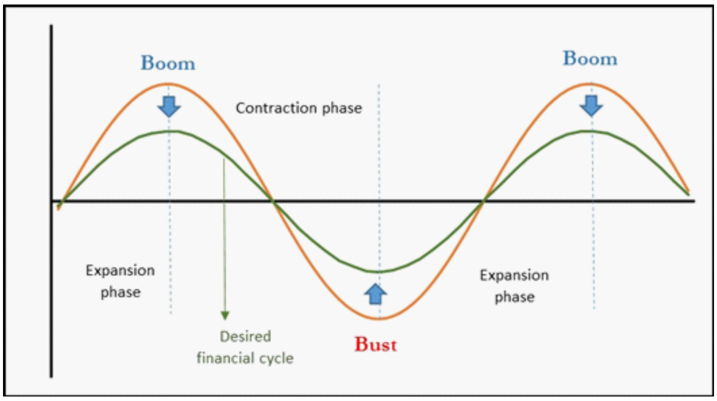


Figure 1.1: Financial Cycle and Macroprudential Policy

According to the IMF survey in 2010, an increasing number of emerging and advanced countries have used various instruments for macroprudential objectives after the global financial crisis.[6] Various tools, including credit-related, liquidity-related, and capital-related instruments, have been used to address systemic risks. According to Blanchard *et al.* (2013), macroprudential tools are divided into three classifications: (1) tools focusing on lenders' behaviour, such as cyclical capital requirements, leverage ratios, or dynamic provisioning; (2) tools focusing on borrowers' behaviour, such as ceilings on loan-to-value ratios (LTVs) or on debt-to-income ratios (DTIs); and (3) capital flow management tools. The countries' exchange rate regime, their degree of economic and financial development, and their vulnerability to specific shocks determined the choice of instruments (Lim *et al.* (2011)). According to the most recent survey of the usage of macroprudential policy, LTV limit is the most popular tool among advanced economies, while limits on foreign exchange (FX) position are the tools

[6]The most recent survey of macroprudential policy is available in the IMF integrated Macroprudential Policy Database (iMaPP) which provides (1) dummy-type indices of tightening and loosening actions for 17 macroprudential policy instruments and their subcategories; (2) detailed description of each policy action; and (3) country-level averages of the regulatory limits on loan-to-value (LTV) ratios at a monthly frequency. The scope is for 134 countries from January 1990 to December 2016 (Alam *et al.* (2019))

most widely used among emerging economies (Alam *et al.* (2019)). The choice of tools may reflect differences in key risks: advanced economies tend to be more concerned about housing sector vulnerabilities while emerging economies are more exposed to vulnerabilities from external shocks, including volatile capital flows and exchange rate. On the other hand, some instruments such as capital requirements and liquidity requirements are widely used in both advanced and emerging economies.

Most of the central banks use banking regulation as macroprudential policy instruments. However, many externalities stretch beyond the banking sector. According to Jeanne & Korinek (2014), dealing with the externalities of the financial system using only banking regulation could lead to different types of leakage. The authors added that one of the possible leakages in implementing macroprudential policies in the banking sector occurs when corporate borrowers substitute domestic bank loans with borrowing from unregulated financial institutions, borrowing from domestic capital markets, or borrowing from abroad. These leakages can reduce the effectiveness of macroprudential policy (Financial Stability Board (2015), Aiyar *et al.* (2014), Bengui & Bianchi (2018)). Therefore, the scope of macroprudential policies should be extended beyond banking regulation, for example, by targeting policies on borrowers rather than lenders (Jeanne & Korinek (2014)).

The implementation of macroprudential policies cannot be exclusively separated from other policies because they are not the only policy aimed at economic and financial stability. Macroprudential policies interact with monetary, microprudential, fiscal, capital flow and competition policies (Claessens (2015)). Macroprudential and monetary policies can be used for countercyclical management, but each has a different primary function. Monetary policies focus on price stability; macroprudential policies are more concerned with the financial stability. However, both policies interact with each other and each policy may enhance or diminish the effectiveness of the other. Therefore, much research analyses the interaction between macroprudential and monetary policy and looks for the optimal coordination between these policies. Fiscal policies such as taxes and levies can also affect financial stability. Therefore, coordination between macroprudential and fiscal agencies is essential (Claessens (2015)).

1.2.2 DSGE Models with Macroprudential Policies

Financial frictions in DSGE Model

Since the global financial crisis, DSGE models have been criticised for relying heavily on the assumption of a perfect financial market without asymmetric information or non-convex transaction cost (Bank for International Settlements (2012)). The crisis highlighted the need to incorporate the role of financial frictions in macroeconomic modelling. According to Vlcek & Roger (2012), there are three typical approaches to modeling financial frictions: (i) The financial accelerator or external premium framework (Bernanke & Gertler (1989); Bernanke *et al.* (1999); Carlstrom & Fuerst (1997)), (ii) The collateral constraints framework (Kiyotaki & Moore (1997)), and (iii) via explicit modelling of financial intermediaries.

A comparison of the moments and impulse response generated by the first and second approaches with US data found that the business cycle properties of the external finance premium framework are more closely matched with the US data compared to the collateral constraint model (Brzoza-Brzezina *et al.* (2013)). One example of a DSGE model that uses the explicit modelling of financial intermediaries approach is the credit and banking model of the Euro Area (Gerali *et al.* (2010)). In their model, the banks have some degree of market power and accumulate bank capital subject to a capital requirement. Banks enjoy some degree of market power by setting different rates for households and firms although they face the cost of adjusting the retail rate. Banks also face a capital requirement target, so that they accumulate capital from retained earnings to keep close to the target. The research showed that the existence of the banking sector to some extent reduces the effect of demand shocks, while it helps propagate supply shocks. The model also showed that unpredicted shocks of bank capital have a significant impact on the real economy, especially on investment.

The DSGE model with financial frictions has now been widely used to explain the transmission channels of various shocks to the economy and the transmission of different economic policies, including macroprudential policy. Regardless of their limitations, DSGE models bring important advantages for macroprudential analysis including: (i) they can be compared with a benchmark in which there is only monetary policy, (ii) they include many sources of shocks that can be used to check for different economic trajectories, and (iii) they rely on general equilibrium analysis and are suitable for simulations to study the impact of new policy instruments (Mizen *et al.* (2018)). The DSGE model has been enhanced to compare the effects of various macroprudential instruments, such as countercyclical capital requirements and loan-to-value ratios, with traditional monetary policy in mitigating the business-cycle fluctuations after technological shocks, monetary shocks or financial shocks. Furthermore, many DSGE models have also been enhanced to assess the interaction between monetary and macroprudential policies and the design of an optimal mix of these policies (Bank for International Settlements (2012)).

Modelling Macroprudential Policy in DSGE

Modelling macroprudential policy in the DSGE model can be done in various ways. The first way is by using an explicit type of macroprudential instrument such as capital requirements (for example: Angelini *et al.* (2014), Kollmann (2013)), reserve requirements (for example: Tavman (2015), Primus (2017)) or loan to value ratio (for example: Mendicino & Punzi (2014), Rubio & Carrasco-Gallego (2014), Garbers & Liu (2018)). The second way is by imposing a tax or subsidy that incentivises banks to adjust their liabilities' structure (for example: Aoki *et al.* (2016), Gertler *et al.* (2012), Levine & Lima (2015)). The third way is by using a generic form of macroprudential policy that affects the fraction of liabilities that banks can lend or affects the spread between lending-deposit rate (for example: Kannan *et al.* (2014), Ozkan & Unsal (2014), Quint & Rabanal (2014)). Most of the macroprudential policy rules in DSGE models are introduced in a counter-cyclical manner to obtain a smoother financial cycle.

The Impact of Macroprudential Policy and Interaction with Other Policies

The effectiveness of macroprudential policy in reducing the volatility of output depends on the type of shocks and the coordination between other policies such as monetary policy. According to Angelini *et al.* (2014), when the economy experiences only a technological shock, the impact of time-varying capital requirements on reducing output or inflation volatility is relatively small. Moreover, their study showed that the absence of cooperation between the macroprudential and monetary authorities might produce excessive volatility of the policy instrument. In contrast, when the economy experiences financial shock, capital requirements can reduce the volatility of output and the volatility of loan to output ratio, regardless of the cooperation between monetary and macroprudential policy. Therefore, the authors argue that capital requirements should not be treated as a substitute for monetary policy or as an all-purpose tool for stabilisation. Instead, capital requirements should be addressed as an additional mean to deal with the financial shock.

The interaction of macroprudential policy and monetary policy is also necessary for dealing with house price fluctuations. Kannan *et al.* (2014) found that the interaction of monetary policy with macroprudential policy will reduce house price fluctuations and increase welfare if the economy faces a financial shock. However, the study found that when the source of the housing boom arises from a productivity shock, the macroprudential policy will decrease welfare.

Macroprudential policy is also useful in altering the risk-taking behaviour that arises from other policies. For example, government credit policy has the effect of incentivising risk-taking (moral hazard) for banks, especially in a high-risk economy. Therefore, the combination of macroprudential policy and government credit policy leads to a more stable economy and brings the highest welfare (Gertler *et al.* (2012)).

Globalisation has deepened the connection between the financial and the real sector among the countries throughout the world. Thus, it is essential to add open economy aspects into the analysis of macroprudential policy. The impact of monetary or macroprudential policy in one country may affect the macroeconomic variables in other countries and vice versa. Ozkan & Unsal (2014) examine the role of the sources of borrowing (domestic versus foreign) on the relative effectiveness of the monetary and macroprudential policy. They adopt a small open economy framework to analyse the crisis scenario brought about by a sudden reversal in capital flows and its impact on the exchange rate. In their model, entrepreneurs can have two funding sources: foreign borrowing and domestic borrowing. Each of the sources of finance has a different interest rate because the interest rate depends on the nominal interest rate of each country and also its risk premium. The paper shows that both monetary policy and macroprudential policy help macroeconomic and financial stability, even though macroprudential policy implies a better result. Furthermore, the findings of this paper suggest that it is better to use macroprudential policy to handle credit/financial issues rather than monetary policy because the impact of the monetary policy that reacts to credit growth, in the presence of macroprudential policy, is negligible. However, the benefit of macroprudential policy depends on the size of foreign borrowing. The macroprudential instrument can directly influence the cost of credit when the source of borrowing is external. Thus, the more significant the size of foreign borrowing, the higher the benefit of macroprudential policies in helping macroeconomic and financial stability.

The interaction between macroprudential and monetary policy could optimally dampen the macroeconomic and financial fluctuation that rises from the inter-linkages between current account deficit and financial vulnerabilities (Mendicino & Punzi (2014)). The authors analyse several types and combination of monetary and macroprudential policy parameters and do some welfare analysis to find optimal policy. There are six shocks discussed in the paper to explain the performance of each type and combination of policies: productivity shocks, house preference shocks, domestic borrowing limits shocks, risk premium shocks, foreign discount factor shocks and monetary policy shocks. Calibrated using US and G7 countries' data, the paper concludes that the optimal policy which can dampen macroeconomic and financial fluctuation, as well as Pareto improving, is the combination of macroprudential policy featuring a countercyclical LTV ratio that responds to house price dynamics and with a monetary policy rule that reacts not only to inflation but also to household credit.

The introduction of macroprudential policy within a currency union, like in the Euro area where ECB controls the monetary policy, can help in reducing macroeconomic volatility and improving welfare (Quint & Rabanal (2014)). Quint and Rabanal developed a two-country model using financial frictions where there are two types of financial intermediaries, domestic and foreign. Domestic financial intermediaries take deposits, grant loans and issue bonds. Foreign financial intermediaries trade the bonds across countries to channel funds from one country to the others. Using the Bayesian estimation to analyse the optimal policies, they found that the introduction of macroprudential policy reduces macroeconomic volatility and improves welfare. Additionally, the macroprudential regulation also helps monetary policy so that the optimal response of the nominal interest rate to a shock is smaller. Welfare improvement to the economy is achieved when macroprudential policies respond to nominal credit growth.

In emerging market economies, macroprudential policy is better able to withstand the impact of external financial shocks (Aoki *et al.* (2016)). The source of funds of financial intermediaries in the Aoki et al. model is obtained from domestic deposits (denominated in domestic currency) and from foreign borrowing (denominated in foreign currency). By incorporating the external source of financing, their model can capture the dynamics of the "taper tantrum" in 2013. The paper found that the relative impact of the macroprudential policy depends on the extent of external financial and non-financial shocks to the economy. Moreover, there is a significant welfare gain from cyclical macroprudential policy, especially when foreign interest rates have a more substantial role and when the prices are more flexible. Additionally, when a foreign interest rate hike triggers a recession, then a conservative monetary policy which aims to stabilise inflation rate tends to worsen the economy.

Which macroprudential instrument is more effective? Since the nature and objective of each instrument is different, it might not be reasonably to compare. One of the researches that tried to compare some macroprudential tools using the DSGE model is that of Tavman (2015)). Within a closed economy framework, she compared three macroprudential policy tools (i) reserve requirement, (ii) capital requirement and (iii) regulation premium. She used the New Keynesian with financial frictions DSGE model referring to Gertler & Karadi (2011) calibrated with US data. She used welfare maximising monetary and macroprudential policy rule analysis and found that all the macroprudential tools are successful in lowering the adverse effects of exogenous shocks to the economy and decreasing welfare loss. Among those three tools, she found that capital requirement is the most effective macroprudential tool in lowering the negative effects of the shocks and generates higher welfare gains, both under technology shocks as well as capital quality shocks.

1.2.3 The Role of Bond Finance as an Alternative Corporate Source of Financing

The majority of DSGE models with the macroprudential policy described in the previous subsection assumed that firms obtain external finance only from banks.

However, in reality, firms have other sources of external funding including issuing bonds in the capital market. Adrian *et al.* (2012) supported this opinion and argued that the current macroeconomic models with financial frictions do not capture some facts during the crisis. Most models suggest that loans to corporate borrowers contracted during the crisis. However, the evidence of their research showed that although there was a contraction in bank lending, financing through bond issuance increased to fill the gap, although the cost of both types of credit rose during the crisis. The role of bond financing is essential in providing credit to non-financial corporations during an economic downturn. Model of Adrian *et al.* (2012) captures the relation between bank and bond finance. However, their model is not within a general equilibrium framework, and there is no analysis of the macroeconomic implications of debt substitution.

The importance of bond financing during the financial crisis is also pointed out by Contessi *et al.* (2013). The authors analyse the cycle of United States' corporate bond and bank loans from 1952 – 2013 and found that bank loans are pro-cyclical while the bond market is countercyclical. The correlation between real GDP and the cyclical component of real bank loans is 0.34, whereas the correlation with the cyclical component of real corporate bonds is -0.21. Based on the result, the authors argue that the impact of a financial crisis is less harmful to firms which have access to a bond market. Therefore, examining heterogeneity in access to financing through bank loans and bonds is important in the analysis of business cycle dynamics. This substitution of bank loans with market finance was also found in the United Kingdom. Loan growth increases when corporate bond spreads widen, whereas it falls during periods when corporate bond spreads decline. Bank loans appear to substitute for other forms of finance in some periods of bad market conditions such as in 1998 Q3 (Baumann *et al.* (2005)).

Some literature has tried to model how firms choose their sources of external finance. Boot & Thakor (1997) put forward a theory of financial system architecture which explained comprehensively how and why banks and the financial market emerge and why borrowers prefer either banks or financial markets. Their model showed that high-quality borrowers would access the financial market. A financial system that is in its early stages will be bank-dominated, and after that, it will develop to be a more sophisticated financial market, and bank lending will diminish. Additionally, Holmstrom & Tirole (1997) constructed a model of financial intermediation in which firms' choice of the form of financing are influenced by the financial status of the firm as well as of the intermediaries. The features of the model show that firms with substantial net worth will be able to access market financing directly, whereas firms with low net worth have to turn to financial intermediaries (banks), who intensively monitor the project so the demand for collateral can be reduced. Firms with very low net worth cannot convince investors to give loans. Thus, those firms cannot obtain external finance to fund their project. Holmstrom & Tirole (1997) emphasised two types of moral hazard problem in the financial intermediation process. The first is known as a demand-side moral hazard. An entrepreneur can choose to conceal the actual condition of the project for his benefit because the depositor or the bank cannot observe it. To mitigate this type of moral hazard, bankers need to monitor the entrepreneur, but that is costly. The second type is known as a supply-side moral hazard. Bankers can choose not to monitor the entrepreneur properly because it is costly, and because the depositors can only see the result of the project but cannot verify whether the bank is properly monitoring the entrepreneur. To mitigate this type of moral hazard bankers need to invest some of their funds (capital) to be properly incentivised to monitor the project.

Repullo & Suarez (2000) also develop a static partial equilibrium model of choice between bank and market finance which depends on the firm's net worth. The characteristics of the equilibrium credit market are similar to those of Holmstrom & Tirole (1997) in which firms with high net worth prefer market lending, those with medium net worth choose bank lending and those with small net worth are unable to obtain external funding. They expand the model to analyse the transmission of some monetary policies such as deposit interest ceilings and capital requirement.

A more recent model of firms dynamics where firms can choose the source of their debt is developed by Crouzet (2015). In his model, firms can choose between bank finance, market finance or a combination of the two. The advantage of bank finance is that it provides flexibility: the firm can ask for a loan restructuring during a time of economic distress. However, bank intermediation costs are higher compared to market finance because banks are more restrictive in giving loans. One of the conclusions of his paper is that as firms grow, or as their credit risk declines, they will reduce their reliance on bank debt because the advantage of the flexibility of bank's finance is of little value to them. He also found that when the bank's intermediation costs increase, some of the firms will switch to market debt. Theferore, the share of bank finance over the total debt decreases. However, since market debt doesn't provide flexibility in difficult times, firms reduce their borrowing and investment.

Chang *et al.* (2016) develop a theoretical framework for a small open economy in which the quantities of bank loan versus bond finance are determined endogenously. Their model, which is embedding the model of Holmstrom & Tirole (1997), provides an economic explanation of the increase of the ratio of bonds to bank loans as a response to the falling world interest rates. One of the conclusions of the study is that the leverage effects are quite different in the banks-only economy vis-à-vis the bonds-only economy. They found that an economy which can rely only on bond-financing is less volatile than the benchmark or an economy with banks only. The reason is that because the existence of banks, by alleviating moral hazard problems, allows us to accommodate more investment projects than otherwise, which leads to amplification of aggregate shocks. When both modes of finance are possible, the financial accelerator changes over time in response to the endogenous choice of bonds versus bank loans.

How does the development of nonbank financing sources such as the corporate bond market and shadow banking affect financial fragility? If overall credit demand doesn't change, an increase in the size of nonbank financing sources creates a condition of excess bank supply. Thus, bank spread will be lower, and banks will be more attracted to holding riskier assets. This behaviour makes banks become more fragile and affects the fragility of the financial system as a whole. The impact of shadow banking is more significant than corporate bonds because shadow banking allows banks to have higher leverage. On the other hand, corporate bonds could help firms to access credit during a crisis when bank lending contracts. In conclusion, although non-bank financing sources could increase the fragility of the banking sector, they also make a banking crisis less costly (Aoki & Nikolov (2015)).

Is a bank-based financial system better than a market based financial system? According to Levine (2002), there are two competing theories of financial structure: one supports a bank-based financial system and the second supports a market-based financial system. The supporters of a bank-based system give emphasis to some positive roles of banks in (i) obtaining information about firms and managers so as to design a better capital allocation and corporate governance; (ii) managing the risks such as cross-sectional, intertemporal, and liquidity risk so they can enhance investment efficiency and economic growth, and (iii) mobilising capital to exploit economies of scale. In contrast, the supporters of a market-based system emphasised the growth-enhancing role of well-functioning markets in (i) fostering bigger incentives to research firms because the information gathered can lead to a more profitable trading in big, liquid markets; (ii) improving corporate governance by easing takeovers and making it easier to link managerial reward to a firm's performance; and (iii) facilitating risk management. The supporters of the market-based view highlight that markets will decrease the inefficiencies related to banks and boost economic growth.

1.2.4 Liquidity Regulation as Macroprudential Policy and Interaction with Other Policies

The global financial crisis highlighted the importance of liquidity regulation in the banking sector.[7] Liquidity regulations have been important instruments used for microprudential, macroprudential, and also monetary policy purposes. From the microprudential perspective, Basel III regulation specifically required a bank to hold sufficient liquidity which is measured as Liquidity Coverage Ratio (LCR) and Net Stable Funding Ratio (NSFR).[8] On the other hand, macroprudential authorities also use liquidity regulation as part of their macroprudential instruments. Liquidity regulation such as countercyclical reserves requirements can be used to mitigate the systemic risk caused by the credit cycle.[9] Liquidity regulation also plays an essential role in monetary policy. Reserve requirement has been used as part of monetary policy instruments to control the money multiplier in the economy and to strengthen the transmission of policy rate on the interbank market rate. Remuneration on reserves has now also been considered as an instrument of central bank monetary policy, mainly when the central bank operates in zero lower bound interest rate (Bowman *et al.* (2010)).

The need for a liquidity-based macroprudential policy is supported by Landau (2016). He argues that unlike countercyclical capital buffer ratios that have a cyclical component, liquidity requirements in Basel III are fixed over the cycle. A constant liquidity requirement may become a source of inefficiency because financial cycles are created by the interaction between leverage on the one hand and maturity transformation on the other. Consequently, he suggests macroprudential measures that would act directly on liquidity and maturity transformation.

[7] The necessities of liquidity regulation on banking sector and related literature regarding liquidity regulation are comprehensively discussed in Allen & Gale (2017) and Bouwman (2014).

[8] Basel III regulations on liquidity are sometimes also categorised as macroprudential policy (Nier *et al.* (2018))

[9] Some examples of macroprudential policy instruments regarding liquidity are the countercyclical reserves requirements, macroprudential liquidity buffer, limits on currency mismatch, reserve requirements on foreign currency deposits or foreign liabilities, and many others (Hardy & Hochreiter (2014))

Cecchetti & Kashyap (2018) highlight the importance of examining interactions among banking regulations: this research inspired my fourth chapter. In the paper, they present a simplified framework to explore the interactions between the risk-weighted capital ratio, the leverage ratio, the liquidity coverage ratio, and the net stable funding ratio. The framework helps us understand which requirements are likely to bind and how those regulations affect banks' business models. One of their conclusions is that LCR and NSFR requirements almost inevitably will never bind at the same time.

Evaluating the interaction between monetary policy and bank liquidity regulations, particularly Reserve Requirement (RR) and LCR, is also crucial. Bech & Keister (2017) extend the standard model of interbank borrowing/lending to study how the introduction of an LCR requirement affects interbank interest rates, and how it alters the effects of central bank monetary policy operations. In the model, banks can borrow and lend in the interbank market, and they trade two types of contract: overnight and term loans. They introduce a payment shock after the interbank market closed so that the bank may need to borrow from the central bank at the end of the period to meet two liquidity regulations: reserve requirement and LCR requirement. The strength of the model is the different runoff-rate for each type of liability (deposits, overnight loan and term loans) in the calculation of LCR which is closer to the real regulation. Their paper strongly influences the critical features regarding how I model the interaction of RR and LCR of my fourth chapter. The main different is that they use a static model and focus on the impact of LCR on the open market operation, while my chapter tries to see the effect of the RR and LCR regulation in a dynamic general equilibrium setting.

There are several ways to model the bank's reserves requirement in a DSGE model. Roger & Vlcek (2011) developed a model with financial frictions in credit markets to assess the costs of increasing capital and liquidity requirements. The disadvantage of their model is that they assume an always binding reserve requirement constraint, so the bank will maintain reserves equal to the required reserve. However, as stressed by Chadha & Corrado (2012), it is essential to allow banks to endogenously choose excess reserve holding. They compare the economy responses in an environment where commercial banks have incentives to endogenously select their optimal reserves versus an economy where the bank's reserve to deposit ratio is constant. They find that the first case performs better concerning welfare. The reserves holding over the business cycle can reduce the volatility of interest spreads to shocks and can act as a stabiliser in the economy. Therefore, the paper supports the countercyclical policy in liquidity that encourages banks to increase reserve holdings in a boom to limit the expansion of loans and then to release the liquidity in recession preventing too rapid reduction in loans. Primus (2017) developed a model with endogenous excess reserves as banks voluntarily demand these assets, and there are convex costs associated with holding reserves. However, different from my model, he assumes a perfectly elastic supply of liquidity, so that the bank is not subject to stochastic withdrawal risk which has been an essential aspect in reserve management models. Therefore, increased uncertainty about the size of deposits withdrawals does not influence the quantity of the bank's excess reserves in his model. The optimal bank reserves holding are determined by the spread between the interest rate on reserves and the cost of borrowing from the central bank, and affected by the convex cost of holding reserves. Primus' paper found that the countercyclical reserve requirement rule has no effect on the real variables. However, the model suggests that the combination of an augmented Taylor rule which reacts to excess reserves, and a countercyclical reserve requirement rule, is optimal to mitigate the macroeconomic and financial volatility associated with liquidity shocks.

Another strand of literature studies the interaction of capital requirement and liquidity requirement. Covas & Driscoll (2014) develop a non-linear model to study the macroeconomic impact of introducing a minimum liquidity standard for banks on top of existing capital adequacy requirements. The strengths of the model are: bankers are heterogeneous concerning wealth holdings, loan balances, deposit balances and productivity; and both liquidity and capital constraints are occasionally binding. However, the authors did not differentiate between reserve and other liquid assets in the liquidity requirements and bundled it is as safe assets. Although the authors do not explicitly model the supply of risk-free assets, they find that increasing the availability of safe assets can mitigate the macroeconomic impact of introducing a liquidity requirement. They also highlight the importance of using general equilibrium modelling to estimate the macroeconomic impact of the new regulations. The partial equilibrium model provides an overstated effect due to the muting of the adjustment of the loan interest rate and rate of return on securities, a channel that would decrease the impact of the new regulation.

Corrado & Schuler (2015) also develop a DSGE model to study the interaction of liquidity requirement and capital requirement. The focus of their model is on the impact of those requirements on macroeconomy through the interbank market lending. The authors use liquidity measure as a proxy for the LCR and NSFR and do not explicitly discuss reserve requirements. The paper concludes that an increase in the liquidity requirements effectively reduces the impact of an interbank shock on output and employment, while an increased capital requirement propagates only through nominal variables as inflation and interest rates. De Bandt & Chahad (2016) studies the impact of solvency and liquidity regulations using a large scale DSGE model. The authors use an ad-hoc approach to model the bank's capital and liquidity holding by imposing quadratic adjustment costs when a bank is deviating from all regulations (CAR, LCR and NSFR). The strength of their model is that they use multi-period assets so they can address the maturity mismatch problem and able to model the liquidity ratio in a more relatable way with the Basel III regulation.

Only a few studies have attempted to empirically examine the impact of LCR because the regulation is relatively new and full implementation is just started in 2019. Rezende *et al.* (2016) shows that implementation of LCR increases bank demand in the Federal Reserve's monetary policy operations. Banerjee & Mio (2017) indicate that a stricter Individual Liquidity Guidance (ILG), which is similar in design with LCR, changes the composition of bank balance sheet in the United Kingdom. Banks respond to the tightening regulation by increasing the share of high-quality liquid assets and non-financial deposits while reducing intra-financial loans and short-term wholesale funding. However, the impact on lending to the non-financial sector is not significant. Bonner & Eijffinger (2016) analyses the implication of liquidity rule, that similar to LCR, on bank lending in the Netherlands. The authors found that the bank does not pass on the higher cost to their lending rate. A tighter liquidity regulation seems to lower the bank's interest margin.

Much recent monetarist literature studies the bank liquidity management with a search frictions feature to explain the behaviour of bank reserves and interbank rates in the OTC market such as Afonso & Lagos (2015), Bianchi & Bigio (2014), Bech & Monnet (2016). However, those areas of new monetarists research are beyond the scope of this thesis.

Chapter 2

Long-term Effects of Government Subsidy on Bank Information Cost

2.1 Introduction

The global financial crisis in 2008 brought a consensus among policy makers and researchers about the interdependencies between financial sector stability and macroeconomic stability. The externalities of the financial system spread the problem in some banks into a systemic issue in the financial sector and then affected the real sector. The contraction in bank loans during the crisis had an impact to the significant drop in investment and output. The government has been conducting various policy to support the banking sector to stabilize the aggregate demand, particularly investment. Most euro area government have provided substantial financial assistance to financial institutions with the objective to safeguard financial system stability and prevent a credit crunch (ECB (2015)).[1] The common measures of government support are in the form of de-

[1] Various forms of credit policies also has been considered as an alternative tools for macroeconomic stabilization since the usage of standard monetary policy is limited by the zero lower bound constraint (Correia *et al.* (2016))

posit insurance, credit guarantees, capital injections and asset support (Stolz & Wedow (2011)). Public support to increase bank credit for entrepreneur are commonly implemented. However, it is not clear whether the intervention increases welfare and relatively few theoritical literature address the topic (Arping *et al.* (2010), Williamson (1994)).

Argument of government intervention in credit markets tends to be based on asymmetric information problem leading to the adverse selection, moral hazard problem and credit rationing. When information is endogenous or market incomplete, the economy is not constrained Pareto optimal. Therefore, government interventions (e.g. taxes and subsidies or credit guarantees) that take into account the costs of information might make everyone better off (Greenwald & Stiglitz (1986)). After the global crisis, a costly information acquisition and monitoring process can cause a slowdown in lending activities so that the potential of economic growth and development is not being realised. How if the government intervene by giving subsidy to reduce the information cost in the bank credit?

This chapter tries to examine the long-run impact of government subsidies on the bank's information cost and evaluate the combination of type of subsidies and financing strategy under which government intervention might raise welfare. In the model, bank's information costs consist of bank's information acquisition cost and bank's monitoring cost. Information acquisition cost is an up-front fee paid by the firms that approach a bank, and it covers the bank's cost of information acquisition about some of the firm's productivity level. Thus, subsidy on this fee is related to the reduction of screening cost in the banking sector. Monitoring cost is the fee paid by the lenders to reveal actual realisation of the firm's output in the case of default.[2]. Therefore, subsidy on monitoring cost is somewhat can be associated with a loan guarantee, a policy that has been used in many countries, although in this case, the guarantee is only on a small part of the bank's cost. The aim of both subsidy policy is to increase the access of the firms to bank's

[2] Monitoring takes place only in the event of default as in Townsend (1979) costly state verification contract.

finance.

The main research questions of this chapter are:

1. What is the impact of government subsidy on bank's information cost on the financial structure and macroeconomic variables?

2. What is the welfare implication of government subsidy on bank's information cost given that the government is financing the subsidy using taxes?

Several studies show that the role of bond financing is essential in providing credit to non-financial corporations during an economic downturn (for example: Contessi *et al.* (2013), Adrian *et al.* (2012), Baumann *et al.* (2005)). Therefore this chapter employs a framework that takes into account the existence of both bank and bond markets. One comparative advantage of banks, compared to the bond market, is the bank's ability to give information about the firm's productivity before the firm decide to proceeds with the loan. Therefore, increasing access to the bank will not only increase the production and the economic output but also reduce the risk faced by the uninformed firms about their productivity.

This chapter found that a subsidy on bank's information acquisition cost improves aggregate welfare if the government funds the subsidy by the tax on labour income or lump-sum tax. Benefits of the subsidy mostly go to the entrepreneur's welfare because a cheaper access to bank lending leads to higher firms profits, net worth, and consumption. In contrast, the household's welfare decrease because they consume less due to the distortionary tax and because they have to work more. Some economic efficiency can be gained from the policy if the government imposes a redistribution policy on the entrepreneur and household consumption. In contrast, I found that a subsidy on monitoring costs generates welfare loss both for households and entrepreneur. Therefore, this chapter suggests that the government support for lowering the cost of accessing bank have a more positive impact on welfare, compared to government support for taking care of the cost of the loan default.

This research is related with the recent literature on government subsidy on the banking sector such as credit subsidies by Antunes *et al.* (2014); Li (2002) and Correia *et al.* (2016). In that literature, the government subsidises some of the loan interest payment to increase bank lending. My study is different from theirs regarding the type of subsidy given to the banking sector which is more specified on information cost. Furthermore, their paper and other related literature about government support for banking sector usually only focuses on bank loans as the financial intermediary in the model, such as Kollmann *et al.* (2012), Arping *et al.* (2010), and Williamson (1994).[3]. Meanwhile, I use a DSGE model that has taken into account the role of bond financing in providing credit to non-financial corporations in the analysis of government policy. To my knowledge, this is the first study that combines the analysis of subsidy on bank's information costs and the role of bond financing in providing credit to non-financial corporations using a DSGE model.

The remainder of the chapter proceeds as follows. Section 2 presents the set-up of basic model. In Section 3 I show some modification of the model to include various types of government subsidy on bank's information cost and types of taxation. Section 4 provides the results regarding the impact of subsidy on financial structure, macroeconomic variables and welfare. Section 5 concludes.

2.2 Basic Model

The basic model of my research is based heavily on De Fiore & Uhlig (2015) and De Fiore & Uhlig (2011). It is a closed economy with a flexible price. The economy is constituted by households who consume, save and supply labour, and productive entrepreneurs who can borrow either from the bank or directly from the capital market fund (CMF). The central bank injects liquidity. The model has

[3]Kollmann *et al.* (2012) model government support for the banking system as a transfer to banks that is financed by higher taxes. The government support will boosts bank capital, and it lowers the spread between the bank lending rate and the deposit rate, which stimulates investment and output. Arping *et al.* (2010) and Williamson (1994) discuss theoritically the impact of credit guarantees and direct government loans in the presence of informational frictions in the bank market.

features of informational frictions in the credit market which make it suitable for the purpose of the study. In this chapter I add government as the authority who provides subsidy on the banking sector and collects taxes. Figure 2.1 illustrates the overview of the model. The red dashed lines show the new components that I add to the basic model.

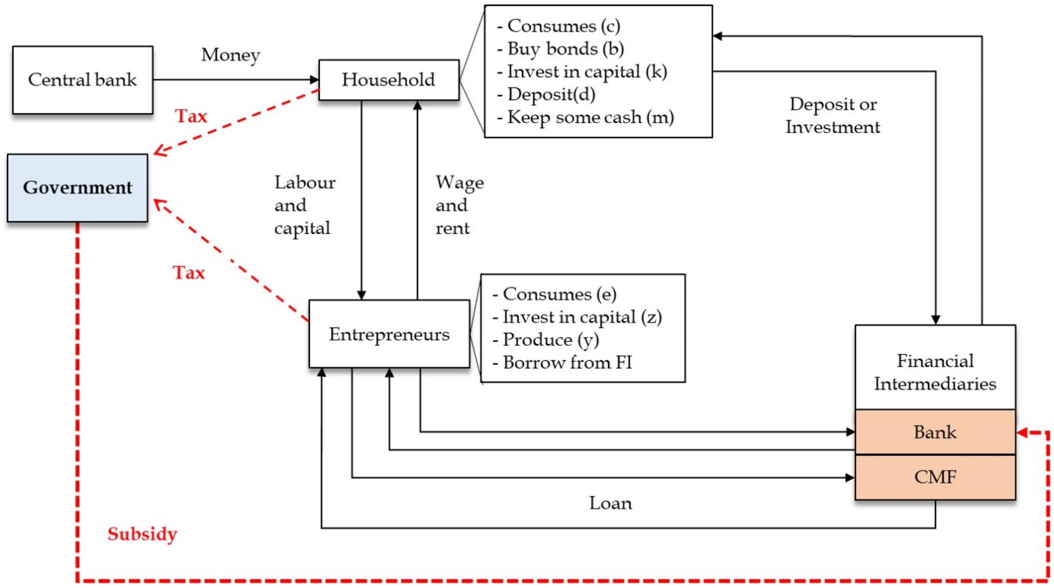


Figure 2.1: Overview of Model

2.2.1 Households

The households maximise utility, given by:

$$U = E_0 \left(\sum_{t=0}^{\infty} \beta^t \left[log\left(c_t\right) - \frac{\eta}{1+\frac{1}{\kappa}} h_t^{1+\frac{1}{\kappa}} \right] \right), \tag{2.1}$$

where c_t is the consumption, and h_t is the labour. β denotes the households' discount rate, η is a preference parameter, and κ is the Frisch elasticity of labour supply. The budget constraint of households is given by:

$$M_t + D_t + E_t\left[Q_{t,t+1} B_{t+1}\right] \leq W_t, \tag{2.2}$$

where W_t is the nominal wealth, M_t is the cash kept for transaction purposes, D_t denotes total deposits which consist of deposits with banking sector, D_t^B, and securities bought on capital market, D_t^C. It should be noted that $D_t = D_t^B + D_t^C$. The safe return, R_t, on banks deposits and capital market securities must be the same to avoid arbitrage. B_{t+1} is nominal bonds which pay a unit of currency in period $t+1$, and $Q_{t,t+1}$is the nominal stochastic discount factor for pricing assets.

The nominal wealth at the beginning of period t is:

$$W_t = B_t + R_{t-1}D_{t-1} + P_t\theta_t + \widetilde{M}_{t-1}, \tag{2.3}$$

where $P_t\theta_t$ denote the nominal transfers from the central bank and $\tilde{M}_{t-1}$ is the cash which held by the households at the beginning of period t.

Moreover, the households are subjected to the cash-in-advance constraint which is provided by:

$$\widetilde{M}_t \equiv M_t - P_t\left[c_t + k_{t+1} - (1-\delta)\,k_t\right] + P_t(w_t h_t + r_t k_t) \geq 0, \tag{2.4}$$

where k_t is capital, δ is depreciation rate, w_t is real wage and r_t is the real rent on capital. This constraint limits the household expenditures for consumption and investment not more than their total available cash. In this model, household can go to the goods market after receiving wages and rental payment in cash. Since keeping money to the next period does not giving any returns, equation 2.4 is always binding.

The first-order conditions for the household imply:

$$\eta h_t^{\frac{1}{\kappa}} c_t = w_t, \tag{2.5}$$

$$\frac{1}{c_t} = \beta R_t E_t\left[\frac{1}{c_{t+1}\pi_{t+1}}\right], \tag{2.6}$$

$$\frac{1}{c_t} = \beta E_t\left[\frac{1}{c_{t+1}}\left(1-\delta+r_{t+1}\right)\right], \tag{2.7}$$

$$R_t = \left(E_t\left[Q_{t,t+1}\right]\right)^{-1}. \tag{2.8}$$

2.2.2 Entrepreneurs

Production

There is a continuum $i \in [0,1]$ of entrepreneurs. An entrepreneur enters the period holding capital z_{it} that depreciates at rate δ, earns a rental rate r_t, and accumulates the net worth n_{it} given by:

$$n_{it} = (1 - \delta + r_t)\, z_{it}. \tag{2.9}$$

An entrepreneur produces y_{it} by employing capital K_{it} and hiring labour H_{it}. The model assumes that each entrepreneur need cash x_{it} as working capital to pay workers' wages w_t, and capital rental prices r_t before the start of production.

$$x_{it} = w_t H_{it} + r_t K_{it}. \tag{2.10}$$

The production technology of each entrepreneur is:

$$y_{it} = A_t \varepsilon_{1,it} \varepsilon_{2,it} \varepsilon_{3,it} K_{it}^{1-\alpha} H_{it}^{\alpha}, \tag{2.11}$$

where A_t is aggregate productivity common to all entrepreneur and $\varepsilon_{j,it}$ are the entrepreneur-specific levels of productivity. $\varepsilon_{1,it}, \varepsilon_{2,it}$, and $\varepsilon_{3,it}$ are random shocks that realised sequentially during the period. $\varepsilon_{1,it}$ are known before production, $\varepsilon_{2,it}$ can only be revealed by the bank, and $\varepsilon_{3,it}$ are known by the entrepreneur after the production. The shocks are strictly positive and mutually independent with probability density functions $\varphi(\varepsilon_1;\sigma_{1t})$, $\varphi(\varepsilon_2;\sigma_{2t})$, $\varphi(\varepsilon_3;\sigma_{3t})$ and cumulative distribution functions $\Phi(\varepsilon_1;\sigma_{1t})$, $\Phi(\varepsilon_2;\sigma_{2t})$, $\Phi(\varepsilon_3;\sigma_{3t})$ with expectations normalised to 1, $E\left[\varepsilon_{j,it}\right] = 1$.

The size of the project that an entrepreneur is capable of running, represented by its working capital x_{it}, is proportional to his net worth:

$$x_{it} = \xi n_{it}, \quad \xi \geq 1. \tag{2.12}$$

Furthermore, a fraction of the working capital is borrowed from a financial intermediary and the amount of loan is proportional with the entrepreneur's net worth $(\xi - 1)n_{it}$. Therefore, the amount of each entrepreneur's loan is given by:

$$loan_{it} = \frac{(\xi - 1)}{\xi} x_{it}. \tag{2.13}$$

De Fiore & Uhlig (2011) emphasise the necessity of the assumption regarding the fixed ratio of loan to net worth to ensure that all firms raise finite amounts of external finance; otherwise, only entrepreneurs with high initial productivity would receive all the funding. This situation may creates a homogenous pool of firms with a potentially high leverage ratio.

The entrepreneur can choose to borrow from a bank or the capital market fund (CMF). Following De Fiore & Uhlig (2011), I assume that banks are institutions that have close relationships with entrepreneurs. The bank acquires costly additional information about the entrepreneur's second productivity shock ($\varepsilon_{2,it}$) and adapting the terms of the debt financing arrangements accordingly. In contrasts, CMF relies on publicly available information about the first productivity shock only.[4] The cost obtain some additional information about the productivity is borne by the entrepreneur, and the amount is equal to a proportion τ of the entrepreneur's net worth. After approaching a bank, and learning the value of $\varepsilon_{2,it}$, the entrepreneur has an opportunity to choose whether to drop out or proceed with the loan and continue producing. An entrepreneur who decides to drop out will hold his remaining net worth $(1 - \tau)n_{it}$ to the end of the period.

An entrepreneur chooses the composition of inputs maximising the production subject to the cash-in-advance constraint (equation 2.10) which limits working

[4]As explained in De Fiore & Uhlig (2011), the distinction between banks and CMFs in the model is consistent with recent theories of financial intermediation. Banks treat firms differently in situations of financial difficulties because they are long-term players in the debt market, while bondholders are not. Therefore, banks have an incentive to acquire more information about firms. By obtaining information about firms, banks minimize the possibility of inefficient liquidation and build a reputation for financial flexibility. Based on that reason, banks are more attractive for firms that are likely to face temporary situations of distress.

capital. The expected output of an entrepreneur y_{it}^e can then be derived as:[5]

$$y_{it}^e = \varepsilon_{it}^e q_t x_{it}, \tag{2.14}$$

where ${\varepsilon_{it}}^e$ is the known productivity factor which is defined as:[6]

$$\varepsilon_{it}^e \equiv \begin{cases} \varepsilon_{1,it} & \text{if using CMF finance,} \\ \varepsilon_{1,it}\varepsilon_{2,it} & \text{if using bank finance,} \end{cases}$$

and q_t is the aggregate entrepreneurial markup over input costs, which can be derived as:

$$q_t \equiv A_t \left(\frac{\alpha}{w_t}\right)^{\alpha} \left(\frac{1-\alpha}{r_t}\right)^{1-\alpha}. \tag{2.15}$$

Financing Contract

Both bank and CMF offer a break-even costly state verification contract based on the ex-ante available information about productivity level (ε_{it}^e) as in Townsend (1979). At the end of the period, all the remaining uncertainties of productivity level (ω_{it}) are revealed and the actual output of an entrepreneur, y_{it}, is given by:

$$y_{it} \equiv \omega_{it} y_{it}^e, \tag{2.16}$$

where

$$\omega_{it} \equiv \begin{cases} \varepsilon_{2,it}\varepsilon_{3,it} & \text{if using CMF finance,} \\ \varepsilon_{3,it} & \text{if using bank finance.} \end{cases} \tag{2.17}$$

The optimal contract sets a threshold $\bar{\omega}_{it}$ corresponding to repayment of the loan. If the realisation of the level of uncertain productivity is higher than the threshold ($\omega_{it} \geq \bar{\omega}_{it}$), the entrepreneurs will pay $\bar{\omega}{\varepsilon_{it}}^e q_t x_{it}$ to the lender and keep

[5] The detailed derivation is available in Appendix 6.1.2.

[6] One of the comparative advantage of banks is that they are able to obtain information about some of the entrepreneur's productivity shocks ($\varepsilon_{2,it}$). Therefore, an entrepreneur who approaches a bank knows his $\varepsilon_{1,it}$ and $\varepsilon_{2,it}$ before the contract. While an entrepreneur who borrows from the CMF only know his $\varepsilon_{1,it}$

$(\omega_{it} - \bar{\omega}_{it})\varepsilon_{it}{}^e q_t x_{it}$ as profit. Otherwise, if the realisation of the level of uncertain productivity is lower than the threshold $(\omega_{it} < \bar{\omega}_{it})$, the entrepreneur will default and gain nothing. In the case of default, the lender pays some monitoring costs that are a fixed proportion μ of the output and takes all the remaining output, $\omega_{it}\varepsilon_{it}{}^e q_t x_{it}$.

Given the threshold $\bar{\omega} = \bar{\omega}_{it}$, the expected share of final output for the entrepreneur is given by:[7]

$$f(\bar{\omega};\sigma) = \int_{\bar{\omega}}^{\infty} (\omega - \bar{\omega})\,\varphi(\omega;\sigma)\,d\omega, \tag{2.18}$$

and the expected share of final output for the lender is given by:

$$g(\bar{\omega};\sigma,\mu) = \int_{0}^{\bar{\omega}} (1-\mu)\,\omega\varphi(\omega;\sigma)\,d\omega + \bar{\omega}\left[1 - \Phi(\bar{\omega};\sigma)\right]. \tag{2.19}$$

The first part of the right-hand side of equation 2.19 represents the expected share for the lender if the borrower defaults, and the second part of the equation represents the expected share if the entrepreneur payback the loan.

With the assumption of perfect competition between the financial intermediaries, the expected return earned by a financial intermediary from giving a loan must be equal to the funding cost. The zero profit condition for the financial intermediaries is given by:

$$\frac{(\xi - 1)}{\xi} x_{it} R_t = g(\bar{\omega}_{it};\sigma_{it},\mu)\, y_{it}^e. \tag{2.20}$$

The left hand side of equation represents the funding cost that lender has to pay to their depositors and the right hand side represents the expected total payment from a borrower. By using equation 2.14, we can rewrite the zero profit

[7] $\varphi(\omega;\sigma)$ and $\Phi(\bar{\omega};\sigma)$ are the probability distribution function and cumulative density function of ω_{it} implied by the distributional assumptions for $\varepsilon_{2,it}$ and $\varepsilon_{3,it}$ and the lending decision of the entrepreneur as described in equations 2.17 and 2.22.

condition of equation 2.20 as:

$$g\left(\bar{\omega}_{it};\sigma_{it},\mu\right)=\frac{R_t}{\varepsilon_{it}^{e}q_t}\left(1-\frac{1}{\xi}\right), \tag{2.21}$$

where

$$\sigma_{it}\equiv\begin{cases}\sqrt{\sigma_{2t}^2+\sigma_{3t}^2} & \text{if using CMF finance,}\\ \sigma_{3t} & \text{if using bank finance,}\end{cases} \tag{2.22}$$

and we define the threshold of the optimal contract for each intermediaries as follows:

$$\bar{\omega}_{it}\equiv\begin{cases}\bar{\omega}^{c}\left(\varepsilon_{1,it};q_t,R_t,\sigma_{2t},\sigma_{3t}\right) & \text{if using CMF finance,}\\ \bar{\omega}^{b}\left(\varepsilon_{1,it}\varepsilon_{2,it};q_t,R_t,\sigma_{3t}\right) & \text{if using bank finance.}\end{cases} \tag{2.23}$$

Based on this contract, we can calculate the loan rate paid by each firm (R_{it}^{l}) and the spread between the lending rate and the risk-free rate for a firm i (Λ_{it}) as follows:

$$R_{it}^{l}=\varepsilon_{it}^{e}q_t\bar{\omega}_{it}\frac{\xi}{\xi-1}, \tag{2.24}$$

$$\Lambda_{it}=\frac{R_{it}^{l}}{R_t}-1. \tag{2.25}$$

Financing Decision

The stages of entrepreneur's borrowing decision can be divided into three stages. In the first stage, $\varepsilon_{1,it}$ is realised and publicly observed. An entrepreneur chooses among these following options: (i) abstain from production and retain his net worth, (ii) approach a bank and pay τ of his net worth for information acquisition cost, or (iii) borrow from a CMF. In the second stage, an entrepreneur who approaches a bank will obtain information about his $\varepsilon_{2,it}$. Then, he can decide to proceed with the bank loan or to drop out and retain his net worth ($\widehat{n}_{it}=(1-\tau)n_{it}$). In the third stage, the entrepreneur produces and the remaining uncertainties (ω_{it}) are revealed. The entrepreneur decisions on production and source of external financing are based on the expected share of output from each financial intermediary and the expected payoff from holding the remaining net worth until the end of the period. We derive the solution of the entrepreneur's financing decision backward, starting from the second stage decision.

In the second stage, the entrepreneur will proceed with the bank loan if the expected payoff is more than that of holding the net worth to the end of the period:

$$\underbrace{f\left(\bar{\omega}^b\left(\varepsilon_{1,it}\varepsilon_{2,it};q_t,R_t,\sigma_{3t}\right);\sigma_{3t}\right)}_{\text{share of output for entrepreneur}}\underbrace{\varepsilon_{1t}\varepsilon_{2t}q_t\xi\hat{n}_{it}}_{y^e_{it}}\geq\hat{n}_{it}.$$

Let define

$$F^d\left(\varepsilon_1,\varepsilon_2;q,R,\sigma_3\right)=\varepsilon_1\varepsilon_2 qf\left(\bar{\omega}^b\left(\varepsilon_1\varepsilon_2;q,R,\sigma_3\right);\sigma_3\right)\xi, \tag{2.26}$$

as the expected profit from production when the entrepreneur borrow from bank. Then, the entrepreneur will proceed with the bank loan if the value of ε_{2it} is higher than the threshold $\varepsilon_{2,it}\geq\bar{\varepsilon}^d_{it}=\bar{\varepsilon}^d\left(\varepsilon_{1,it};q_t,R_t,\sigma_{3t}\right)$ which satisfies:

$$F^d\left(\varepsilon_{1,it},\bar{\varepsilon}^d_{it};q_t,R_t,\sigma_{3t}\right)=1. \tag{2.27}$$

In the first stage, given the information about $\varepsilon_{1,it}$, the entrepreneur's expected profit if he approaches the bank is:[8]

$$\begin{aligned}F^b\left(\varepsilon_1;q,R,\tau,\sigma_2,\sigma_3\right)\equiv(1-\tau)\Bigg(&\int_{\bar{\varepsilon}_d(\varepsilon_1;q,R,\sigma_3)}F^d\left(\varepsilon_1,\varepsilon_2;q,R,\sigma_3\right)\Phi\left(d\varepsilon_2\right)\\&+\Phi\left(\bar{\varepsilon}_d\left(\varepsilon_1;q,R,\sigma_3\right);\sigma_2\right)\Bigg).\end{aligned} \tag{2.28}$$

The first part of the right-hand side of the equations is the expected profit if $\varepsilon_{2,it}\geq\bar{\varepsilon}^d_{it}$ such that he will proceed with the bank loan and pursue production. The second part is the expected profit if $\varepsilon_{2,it}<\bar{\varepsilon}^d_{it}$ such that he will not proceed with the loan and choose to abstain from production. Adhering to the assumptions of De Fiore & Uhlig (2015) model[9], there is a threshold $\bar{\varepsilon}_{bt}=\bar{\varepsilon}_b\left(q_t,R_t,\tau_t,\sigma_{2t},\sigma_{3t}\right)$

[8] We denote $\Phi\left(d\varepsilon_i\right)=\varphi(\varepsilon_i;\sigma_i)d\varepsilon_i$ for i=1,2,3.

[9] They assume that $\frac{\partial F_b(\cdot)}{\partial\varepsilon_1}\geqslant 0$, and $\frac{\partial F_b(\cdot)}{\partial\varepsilon_1}<\frac{\partial F_c(\cdot)}{\partial\varepsilon_1}$ for all ε_1.

for $\varepsilon_{1,it}$ below which the entrepreneur will choose not to borrow from bank. The condition where $\varepsilon_{1,it} = \bar{\varepsilon}_{bt}$ will satisfy:

$$F^b\left(\bar{\varepsilon}_{bt}; q_t, R_t, \tau_t, \sigma_{2t}, \sigma_{3t}\right) = 1. \tag{2.29}$$

The entrepreneur will borrow from the CMF if the expected profit is not only higher than that of holding net worth to the end of the period, but also greater than the expected profit of borrowing from the bank. Based on De Fiore & Uhlig (2015) assumptions, there exists a unique threshold $\bar{\varepsilon}_{ct} = \bar{\varepsilon}_c\left(q_t, R_t, \tau_t, \sigma_{2t}, \sigma_{3t}\right)$ for $\varepsilon_{1,it}$ above which entrepreneurs will choose financing from the CMF. Let $F^c\left(\varepsilon_1; q, R, \sigma_2, \sigma_3\right) = f(\bar{\omega}^c\left(\varepsilon_1; q, R, \sigma_2, \sigma_3\right))\varepsilon_1 q\xi$ defines the expected profit of entrepreneur if borrowing from CMF. The condition where $\varepsilon_{1,it} = \bar{\varepsilon}_{ct}$ will satisfy:

$$F^c\left(\bar{\varepsilon}_{ct}; q_t, R_t, \sigma_{2t}, \sigma_{3t}\right) = F^b\left(\bar{\varepsilon}_{ct}; q_t, R_t, \tau_t, \sigma_{2t}, \sigma_{3t}\right). \tag{2.30}$$

The entrepreneur calculates the expected profit from all options and chooses the best option giving the highest profit:

$$F\left(\varepsilon_1; q, R, \tau, \sigma_2, \sigma_3\right) \equiv \max\Big(1; F^b\left(\varepsilon_1; q, R, \tau, \sigma_2, \sigma_3\right); F^c\left(\varepsilon_1; q, R, \sigma_2, \sigma_3\right)\Big). \tag{2.31}$$

Given the thresholds $\bar{\varepsilon}_{bt}$ and $\bar{\varepsilon}_{ct}$, entrepreneurs will spread into three groups. We can compute the shares of each groups as follows:

- Shares of the firms that abstain from producing:

$$s_t^a = \Phi\left(\bar{\varepsilon}^b\left(q_t, R_t, \tau_t, \sigma_{2t}, \sigma_{3t}\right); \sigma_{1t}\right). \tag{2.32}$$

- Shares of the firms that approach a bank:

$$s_t^b = \Phi\left(\bar{\varepsilon}^c\left(q_t, R_t, \tau_t, \sigma_{2t}, \sigma_{3t}\right); \sigma_{1t}\right) - \Phi\left(\bar{\varepsilon}^b\left(q_t, R_t, \tau_t, \sigma_{2t}, \sigma_{3t}\right); \sigma_{1t}\right). \tag{2.33}$$

Conditional on obtaining information from the bank, some of the firms will proceed with the loan:

$$s_t^{bp} = \int_{\bar{\varepsilon}^b(q_t,R_t,\tau_t,\sigma_{2t},\sigma_{3t})}^{\bar{\varepsilon}^c(q_t,R_t,\tau_t,\sigma_{2t},\sigma_{3t})} \int_{(\bar{\varepsilon}^d(\varepsilon_1;q_t,R_t,\sigma_{3t})} \Phi\left(d\varepsilon_2\right)\Phi\left(d\varepsilon_1\right). \tag{2.34}$$

- Shares of the firms that borrow from CMF:

$$s_t^c = 1 - \Phi\left(\bar{\varepsilon}^c\left(q_t, R_t, \tau_t, \sigma_{2t}, \sigma_{3t}\right); \sigma_{1t}\right). \tag{2.35}$$

Consumption and Capital

Following the literature on financial accelerator, entrepreneurs are risk-neutral and have a finite life period. I assume that entrepreneurs have linear preference over consumption and have a constant probability, γ, to "die".[10] Moreover, entrepreneurs who "die" in period t are not allowed to purchase capital, but instead simply consume their accumulated resources and exit from the economy.[11] When an entrepreneur dies or defaults, he is replaced by a new entrepreneur who receives a very small amount of transfer from the government to start the production. Thus, the aggregate firm's consumption, e_t, and capital, z_t follow:

$$e_t = \gamma\psi^f\left(\varkappa_t\right)n_t, \tag{2.36}$$

$$z_{t+1} = \left(1-\gamma\right)\psi^f\left(\varkappa_t\right)n_t, \tag{2.37}$$

[10] I assume that the lifetime utility of an entrepreneur is: $\sum_{t=0}^{\infty}\beta_E^t e_t$.

[11] The explanation of this assumption can be found in Bernanke *et al.* (1999): Entrepreneurs are assumed to be risk-neutral and have finite horizons. The assumption of finite horizons is intended to capture the phenomenon of ongoing births and deaths of firms, as well as to avoid the possibility that the entrepreneurial sector will ultimately accumulate enough wealth to be fully self-financing. Having the survival probability be constant (independent of age) facilitates aggregation.

where $\psi^f(\varkappa_t) n_t$ denotes the aggregate profits in the entrepreneurial sector and $\varkappa \equiv [q_t, R_t, \tau_t, \sigma_{1,t}, \sigma_{2,t}, \sigma_{3,t}]$. The formulation of $\psi^f(\varkappa_t)$ is given by:

$$\psi^f(\varkappa) = s^a + \int_{\bar{\varepsilon}_b(q,R,\tau,\sigma_2,\sigma_3)}^{\bar{\varepsilon}_c(q,R,\tau,\sigma_2,\sigma_3)} F^b(\varepsilon_1; q, R, \tau, \sigma_2, \sigma_3) \Psi(d\varepsilon_1) + \int_{\bar{\varepsilon}_c(q,R,\tau,\sigma_2,\sigma_3)} F^c(\varepsilon_1; q, R, \sigma_2, \sigma_3) \Psi(d\varepsilon_1). \tag{2.38}$$

2.2.3 Aggregation

Given the share of firms in each group from equation 2.32, 2.33, 2.34 and 2.35, we can compute the aggregate bank loan (l_t^b) and CMF loan (l_t^c) as follows:

$$l_t^b = (1-\tau_t) s_t^{bp} (\xi - 1) n_t, \tag{2.39}$$

$$l_t^c = s_t^c (\xi - 1) n_t. \tag{2.40}$$

The aggregate cash for production x_t is calculated as the sum of all the producing entrepreneur's loans and net worth, which is given by:

$$x_t = \left[(1-\tau_t) s_t^{bp} + s_t^c\right] \xi n_t. \tag{2.41}$$

The total economic output, y_t, follows:

$$y_t = \psi^y(\varkappa_t) q_t \xi n_t, \tag{2.42}$$

where $\psi^y(\varkappa)$ is the aggregation of the realised productivity factors across all producing firms. The formulation of $\psi^y(\varkappa)$ is given by:

$$\psi^y(\varkappa) = (1-\tau) \int_{\bar{\varepsilon}_b(q,R,\tau,\sigma_2,\sigma_3)}^{\bar{\varepsilon}_c(q,R,\tau,\sigma_2,\sigma_3)} \varepsilon_1 \int_{\bar{\varepsilon}_d(\varepsilon_1;q,R,\sigma_3)} \varepsilon_2 \Phi(d\varepsilon_2) \Phi(d\varepsilon_1) + \int_{\bar{\varepsilon}_c(q,R,\tau,\sigma_2,\sigma_3)} \varepsilon_1 \Phi(d\varepsilon_1). \tag{2.43}$$

The agency cost which consists of information cost and monitoring cost are sunk cost which turns into output losses for the economy. The aggregate of those agency costs is given by:

$$y_t^a = \left[\tau_t s_t^b + \psi^m(\varkappa_t)\,\mu\xi q_t\right] n_t, \tag{2.44}$$

where $\tau_t s_t^b$ measure the loss due to bank information acquisition costs, while $\psi^m(\varkappa_t)\,\mu\xi q_t$ measure the loss due to bank and capital market monitoring cost. The calculation of $\psi^m(\varkappa)$ is given by:

$$\psi^m(\varkappa) = (1-\tau)\,\psi^{mb}(\varkappa) + \psi^{mc}(\varkappa), \tag{2.45}$$

where

$$\psi^{mb}(\varkappa) = \int_{\bar{\varepsilon}_b(q,R,\tau,\sigma_2,\sigma_3)}^{\bar{\varepsilon}_c(q,R,\tau,\sigma_2,\sigma_3)} \int_{\bar{\varepsilon}_d(\varepsilon_1;q,R,\sigma_3)} \Phi\left(\bar{\omega}^b(\varepsilon_1\varepsilon_2;q,R,\sigma_3);\sigma_3\right)\Phi(d\varepsilon_2)\,\Phi(d\varepsilon_1), \tag{2.46}$$

and

$$\psi^{mc}(\varkappa) = \int_{\bar{\varepsilon}_c(q,R,\tau,\sigma_2,\sigma_3)} \Phi\left(\bar{\omega}^c(\varepsilon_1;q,R,\sigma_2,\sigma_3);\sigma_2\sigma_3\right)\Phi(d\varepsilon_1). \tag{2.47}$$

The aggregate capital demand, labour demand, and investment follows:

$$r_t(k_t+z_t) = (1-\alpha)\,x_t, \tag{2.48}$$

$$w_t h_t = \alpha x_t, \tag{2.49}$$

$$I_t = k_{t+1} + z_{t+1} + (1-\delta)(k_t+z_t). \tag{2.50}$$

The aggregate ratio of funds raised by bank financed-firms to the funds raised by CMF-financed firms (bank/bond ratio), ϑ, is given by:

$$\vartheta = \frac{(1-\tau_t)\,s_t^{bp}}{s_t^c}. \tag{2.51}$$

The average risk premium for bank finance (rp_t^b) and bond finance (rp_t^c) are as follows:

$$rp_t^b \equiv \frac{\psi^{rb}(\varkappa)}{s_t^{bp}}, \tag{2.52}$$
$$rp_t^c \equiv \frac{\psi^{rc}(\varkappa)}{s_t^c}. \tag{2.53}$$

The formulation of $\psi^{rb}(\varkappa)$ and $\psi^{rc}(\varkappa)$ is given by:

$$\psi^{rb}(\varkappa) = \int_{\bar{\bar{\varepsilon}}_b(q,R,\tau,\sigma_2,\sigma_3)}^{\bar{\bar{\varepsilon}}_c(q,R,\tau,\sigma_2,\sigma_3)} \int_{\bar{\bar{\varepsilon}}_d(\varepsilon_1;q,R,\sigma_3)} \left[\frac{\left(\frac{\xi}{\xi-1}\right) q\varepsilon_1\varepsilon_2\bar{\omega}^b(\varepsilon_1\varepsilon_2;q,R,\sigma_3)}{R} - 1 \right] \Phi(d\varepsilon_2)\,\Phi(d\varepsilon_1), \tag{2.54}$$

$$\psi^{rc}(\varkappa) = \int_{\bar{\bar{\varepsilon}}_c(q,R,\tau,\sigma_2,\sigma_3)} \left[\frac{\left(\frac{\xi}{\xi-1}\right) q\varepsilon_1\bar{\omega}^c(\varepsilon_1;q,R,\sigma_2,\sigma_3)}{R} - 1 \right] \Phi(d\varepsilon_1). \tag{2.55}$$

The aggregate debt to output ratio is given by:

$$\chi = \left[(1-\tau_t)\, s_t^{bp} + s_t^c\right](\xi - 1)\frac{n_t}{y_t}. \tag{2.56}$$

The default rate on banks (ϱ_t^c) and bonds (ϱ_t^c) are given by the share of firms which borrow from the intermediary but cannot repay the debt:

$$\varrho_t^b = \frac{\psi^{mb}(\varkappa_t)}{s_t^{bp}}, \tag{2.57}$$

$$\varrho_t^c = \frac{\psi^{mc}(\varkappa_t)}{s_t^c}. \tag{2.58}$$

2.2.4 Monetary Policy

The central bank undertakes monetary policy in the forms of liquidity injections by transferring nominal money to households ($P_t\theta_t$). The total amount of liquidity injections is given by:

$$P_t\theta_t = M_t^s - M_{t-1}^s, \tag{2.59}$$

and the growth rate of money supply, M_t^s, is assumed to be constant:

$$\frac{M_t^s}{M_{t-1}^s} = \nu. \tag{2.60}$$

where v is equal to the target inflation rate ($\nu = \pi$).[12]

2.2.5 Market Clearing

The market clearing conditions for labour, capital and output are given by:

$$H_t = h_t, \tag{2.61}$$

$$K_t = k_t + z_t, \tag{2.62}$$

$$y_t^a = y_t - c_t - e_t - K_{t+1} + (1-\delta) K_t. \tag{2.63}$$

The market clearing conditions for money, asset, and loans, in real terms, are given by:

$$m_t^s = m_t + d_t, \tag{2.64}$$

$$b_t = 0, \tag{2.65}$$

$$d_t = \left[(1-\tau_t) s_t^{bp} + s_t^c\right] (\xi - 1) n_t. \tag{2.66}$$

2.2.6 Competitive Equilibrium

The competitive equilibrium is defined by the set of allocations and prices such that all agents behave optimally and markets clear. Appendix 6.1.3 compiles all the equations of competitive equilibrium condition.

[12] Although I am not conducting monetary policy analysis, for this thesis I choose to follow entirely the De Fiore & Uhlig (2015) model regarding cash-in-advance constraint and liquidity injection monetary policy to make sure the results of basic model replication are consistent with theirs.

2.2.7 Calibration

I use all the parameters used by De Fiore & Uhlig (2015) as presented in Table 2.1. Parameters $\beta, \delta, \alpha, \mu$ and κ were set to follow common values in related literature. Other parameters $\xi, \tau, \gamma, \sigma_1, \sigma_2, \sigma_3$ were calibrated to match the steady state values of the model with the financial facts of some Euro-area financial structure in the period of 1999-2010. Some financial facts used as the target are: the ratio of aggregate bank loans to debt securities for non-financial corporations (5.5), the ratio of aggregate debt to equity (0.64), the annual average spread on debt securities (143 bps), the annual average spread on bank loans (119 bps), the annual default rate of debt securities (5%), and the expected return of entrepreneurial capital (9.3%). The disutility of labour parameter, η, is calibrated such that consumption in the steady state is unity. The entrepreneur-specific levels of productivity shock $\varepsilon_{j,it}$ are assumed to be lognormally distributed, i.e $\log(\varepsilon_{j,it})$ are normally distributed with variance $\sigma_{j,t}$ and mean $-\sigma_{j,t}^2/2$; so that $E\left[\varepsilon_{j,it}\right] = 1$.

Table 2.1: Parameters

Parameters	Value	Description
β	0.99	Household discount factor
δ	0.02	Depreciation rate
α	0.64	Shares of labour on production function
μ	0.15	Monitoring cost
κ	3	The inverse of Frisch elasticity of labour supply
ξ	3.195	Working capital to net worth ratio
τ	0.0099	Information acquisition cost
γ	0.022	Probability of firm dies
η	3.753	Preference parameter
σ_1	0.0165	Standard deviation of ε_1
σ_2	0.0225	Standard deviation of ε_2
σ_3	0.1711	Standard deviation of ε_3

2.3 Modification of the Basic Model

In this section, I present the modification of the model to include various types of government subsidy on bank's information cost and taxation. There are six combinations of policy, which are categorised based on the type of the subsidy and the form of the tax. The alternative types of subsidy policies are:

1. Government subsidy on the bank's information acquisition cost (s_t^I)
2. Government subsidy on the bank's monitoring cost (s_t^M)

I assume that the government has a balanced budget financed by one of the following type of taxes:

1. Lump-sum tax (t^{ls})
2. Tax on labour income (t^l)
3. Tax on consumption that applies to the household and the firm's consumption (t^c)

In the next subsection, I will derive the modification of some equations from the basic model for each combination of subsidy and tax policies.

2.3.1 Subsidy on The Bank's Information Acquisition Cost

I assume that the government subsidy s_t^I is proportional to the bank's information acquisition cost. This subsidy enters the entrepreneur's expected profit from approaching a bank (equation 2.28) in the following:

$$F^b\left(\varepsilon_1; q, R, \tau, \sigma_2, \sigma_3, s^I\right) \equiv \left(1 - \tau + s_t^I \tau\right) \left(\int_{\bar{\varepsilon}_d(\varepsilon_1; q, R, \sigma_3)} F^d\left(\varepsilon_1, \varepsilon_2; q, R, \sigma_3\right) \Phi\left(d\varepsilon_2\right) \right. \tag{2.67}$$

$$\left. + \Phi\left(\bar{\varepsilon}_d\left(\varepsilon_1; q, R, \sigma_3\right); \sigma_2\right) \right).$$

Moreover, the subsidy affects the total bank loan in the economy and the aggregation equations 2.39 and 2.41 become:

$$l_t^b = \left(1 - \tau_t + s_t^I \tau_t\right) s_t^{bp} (\xi - 1) n_t, \tag{2.68}$$

$$x_t = \left[\left(1 - \tau_t + s_t^I \tau_t\right) s_t^{bp} + s_t^c\right] \xi n_t. \tag{2.69}$$

The subsidy also affects total output in the economy through the change in the aggregation of the realised productivity factors across all producing firms (in equation 2.42):

$$\begin{aligned} \psi^y(\varkappa) = \left(1 - \tau + s_t^I \tau_t\right) \int_{\bar{\varepsilon}_b(q,R,\tau,\sigma_2,\sigma_3,s^I)}^{\bar{\varepsilon}_c\left(q,R,\tau,\sigma_2,\sigma_3,s^I\right)} \varepsilon_1 \int_{\bar{\varepsilon}_d(\varepsilon_1;q,R,\sigma_3)} \varepsilon_2 \Phi(d\varepsilon_2)\, \Phi(d\varepsilon_1) \\ + \int_{\bar{\varepsilon}_c(q,R,\tau,\sigma_2,\sigma_3,s^I)} \varepsilon_1 \Phi(d\varepsilon_1). \end{aligned} \tag{2.70}$$

In response to the changes in the total bank loan equation, the computation of some financial structure variables also need to be modified. The change in the calculation of bank/bond ratio, ϑ (from equation 2.51) and the calculation of the aggregate debt to output ratio (equation 2.56) are:

$$\vartheta = \frac{\left(1 - \tau_t + s_t^I \tau_t\right) s_t^{bp}}{s_t^c}, \tag{2.71}$$

$$\chi = \left[\left(1 - \tau_t + s_t \tau_t\right) s_t^{bp} + s_t^c\right] (\xi - 1) \frac{n_t}{y_t}. \tag{2.72}$$

The market clearing condition for loans (equation 2.66) are modified as:

$$d_t = \left[\left(1 - \tau_t + s_t^I \tau_t\right) s_t^{bp} + s_t^c\right] (\xi - 1) n_t. \tag{2.73}$$

In addition, I add the government budget constraint equation which varies with the type of tax policy as follows:

- Case 1: Subsidy is financed by a lump-sum tax

$$s_t^I \tau_t s_t^b n_t = t_t^{ls}, \tag{2.74}$$

- Case 2: Subsidy is financed by the labour income tax

$$s_t^I \tau_t s_t^b n_t = t_t^l w_t h_t, \tag{2.75}$$

- Case 3: Subsidy is financed by the consumption tax

$$s_t^I \tau_t s_t^b n_t = t_t^c (c_t + e_t), \tag{2.76}$$

The taxation affects the budget constraints and thus the first-order conditions of household and entrepreneur. The complete modification of household and entrepreneurs's competitive equilibrium conditions is available in the Appendix 6.2.1.

2.3.2 Subsidy on The Bank's Monitoring Cost

I assume that the government subsidy s_t^M is proportional to the bank's monitoring cost. This subsidy has an impact on the expected share of final output to the bank (equation 2.19):

$$g^b\left(\bar{\omega}; \sigma, \mu, s^M\right) = \int_0^{\bar{\omega}} \left(1 - \mu + s^M \mu\right) \omega \varphi\left(\omega; \sigma\right) d\omega + \bar{\omega}\left[1 - \Phi\left(\bar{\omega}; \sigma\right)\right], \tag{2.77}$$

whilst the calculation of the expected share of final output to the CMF is not affected

$$g^c\left(\bar{\omega}; \sigma, \mu\right) = \int_0^{\bar{\omega}} \left(1 - \mu\right) \omega \varphi\left(\omega; \sigma\right) d\omega + \bar{\omega}\left[1 - \Phi\left(\bar{\omega}; \sigma\right)\right]. \tag{2.78}$$

The subsidy on the bank's monitoring cost indirectly affects the threshold $\bar{\omega}^b$ in the debt contract between the bank and the entrepreneur. Consequently, it affects the loan rate paid by the firms who borrow from the bank and have effects on the value of other variables.

The total amount of subsidies depends on the value of aggregate bank loan that default. The government balanced budget equation varies with the government financing strategy as follows:

- Case 1: Subsidy is financed by a lump-sum tax

$$s_t^M(1-\tau)\mu\psi^{mb}q_t\xi n_t = t_t^{ls}, \tag{2.79}$$

- Case 2: Subsidy is financed by the labour income tax

$$s_t^M(1-\tau)\mu\psi^{mb}q_t\xi n_t = t_t^{l}w_t h_t, \tag{2.80}$$

- Case 3: Subsidy is financed by the consumption tax

$$s_t^M(1-\tau)\mu\psi^{mb}q_t\xi n_t = t_t^{c}(c_t + e_t), \tag{2.81}$$

2.3.3 Welfare

I evaluate the long-run benefit of subsidy policy using welfare analysis at the steady state. I compute social welfare as the summation of households' and entrepreneurs' utility with equal weights:

$$W(c,h,e) = U(c,h) + U(e). \tag{2.82}$$

Furthermore, I use consumption equivalents as an indicator of welfare changes. As mentioned in Rubio & Carrasco-Gallego (2014), the consumption equivalents define the constant fraction of consumption that the agents should give to acquire the benefits of the policy. A positive value means that the policy is welfare improving. Household and entrepreneur would be willing to pay in consumption units for the implementation of the policy because it increases their utility. The concept of consumption equivalent is expressed in the equation 2.83. c_o, h_0, and e_o denote the household's consumption, work hours, and entrepreneurs' consumption in the baseline model respectively, and c_1, h_1, and e_1 denote the household's consumption, work hours, and entrepreneurs' consumption in the modified model with policy.

$$W_0(c_0(1 + CE\%), h_{0,}e_0(1 + CE\%)) = W_1(c_1, h_1, e_1). \tag{2.83}$$

With the functional form of utility, we can compute the consumption equivalent by solving the following formula:[13]

$$\log(1 + CE\%) + e_0.CE\% = W_1(c_1, h_1, e_1) - W_0(c_0, h_0, e_0). \tag{2.84}$$

2.4 Simulation Results

2.4.1 Impact of Subsidies on Financial Structure

In this section, I present some simulation results regarding the effects of subsidy policies on the financial structure variables at the steady state.[14] Figure 2.2 shows the sensitivities of the steady-state values to the changes in the rate of subsidy. The horizontal axes denote the rate of subsidy as a proportion of the total cost, while the vertical axes denote the value of the corresponding variables in percentage terms.

The upper left panels show that the shares of firms abstaining from external finance and the shares of firms borrowing from CMF decrease as the rate of subsidy on the bank's information acquisition rise (Figure 2.2 A). In contrast, more firms approach the bank and obtain information on ε_2 because the subsidy raises their expected profit. For example, if government subsidies 30% of the bank's information cost, the share of firms who abstain from production decreases

[13] The derivation for this is available in the Appendix 6.2.2.

[14] The impacts of the subsidy on the steady state value of all variables are available in Appendix 6.2.3.

from 39% to 33%; the share of firms who approach a bank increases from 56% to 65%; and the share of firms who choose CMF decreases from 5% to 2%. However, not all the firms who approach the bank will proceed with the loan. After learning their ε_2, some of the low productive firms will choose to drop out. Therefore, in the case of subsidy more than 40%, the share of firms who borrow from the bank starts to decline. The upper right panels show that higher subsidy rates lead to a rise in the bank's average risk premium and a decline in the CMF's average risk premium. The reason for that is because the subsidy encourages low productive firms to approach the bank. The bank will charge a higher risk premium on these low productive firms to avoid losses. Consequently, the average bank's risk premium increases. In contrast, the risk premium of CMF decreases because only firms with higher productivity level choose to borrow directly from this market. In general, subsidy on the bank's information acquisition cost could increase the bank lending but at the same time, increase the credit risk in the banking system.

The lower left panels (Figure 2.2 B) show that as the rate of subsidy on bank's monitoring cost raises, the shares of firms abstaining from external finance and the shares of firms borrowing from CMF decrease while the shares of firms approaching a bank increase. However, unlike in Figure 2.2 A, there is no bending shape in the graph about the share of firms who borrow from banks. Higher subsidy on bank's information cost will raise the share of firms who proceeds with the loan almost linearly. The reason for that is because the risk premium of bank loan declining with the subsidy. Therefore, it is still profitable for the lower productive firms to proceed with the bank loan, although their ε_2 is not high.

Different impacts of those two types of subsidy on the bank's risk premium can be explained by the simple graph analysis in Figure 2.3. This figure shows the relationship between the quantity and the interest rate of the loan. Subsidy on bank information cost encourages more firms to approach the bank, so the policy affects the demand side of loans. Thus, the policy shifts the demand curve upward (from D^{L0} to D^{L1}). The equilibrium point thus moves from (R^0, L^0)

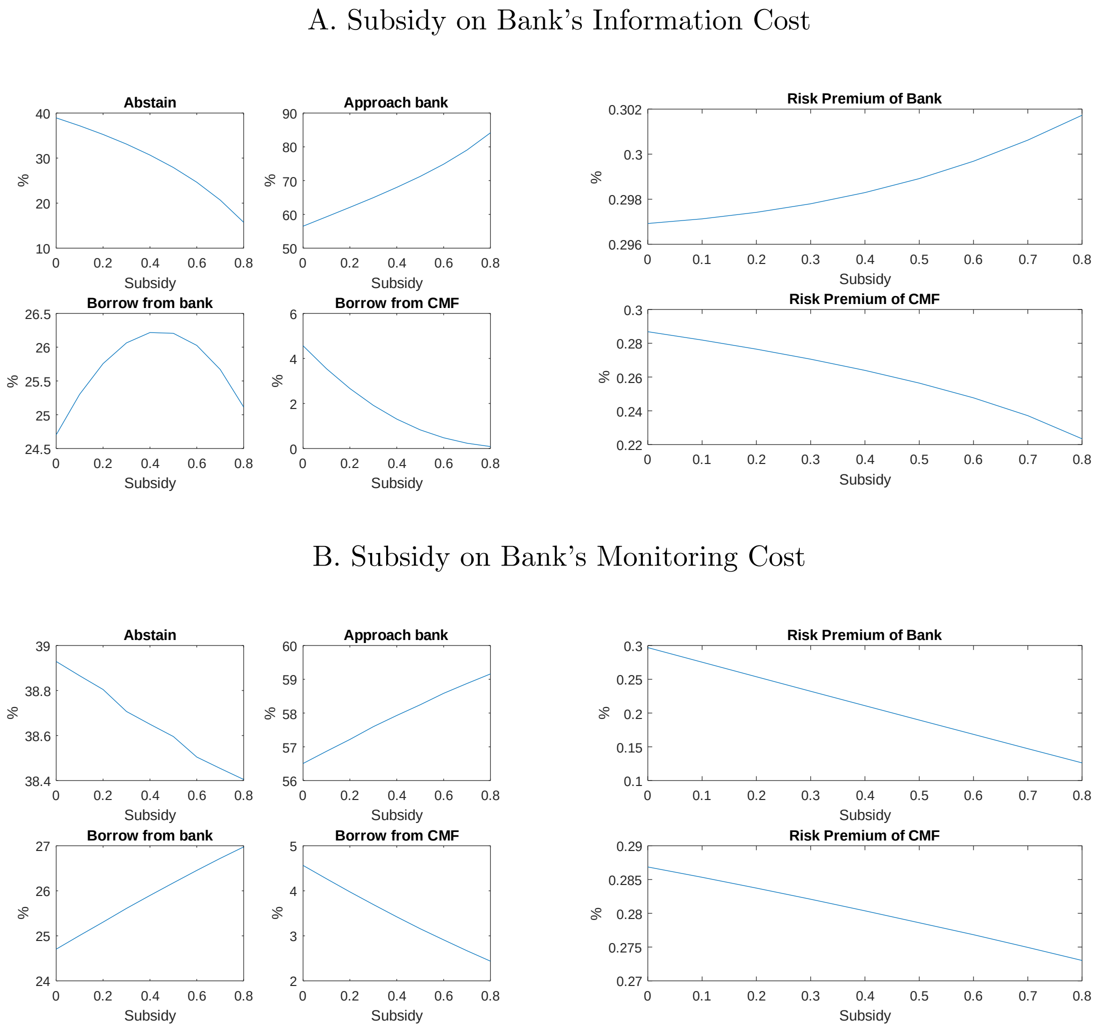


Figure 2.2: Share of Firms and Risk Premium of Financial Intermediaries versus Subsidy Rate

to (R^1, L^1) where the quantity of loans and the loan rate (risk premium) are higher than before. In contrast, the subsidy on bank's monitoring cost has more impact on the supply side of loan because the bank is exposed to a smaller credit risk cost. The policy shifts the supply curve upward (from $S^0$to S^1), and the equilibrium point (R^1, L^1) is then characterised by a higher quantity of loans but a lower loan rate (risk premium).

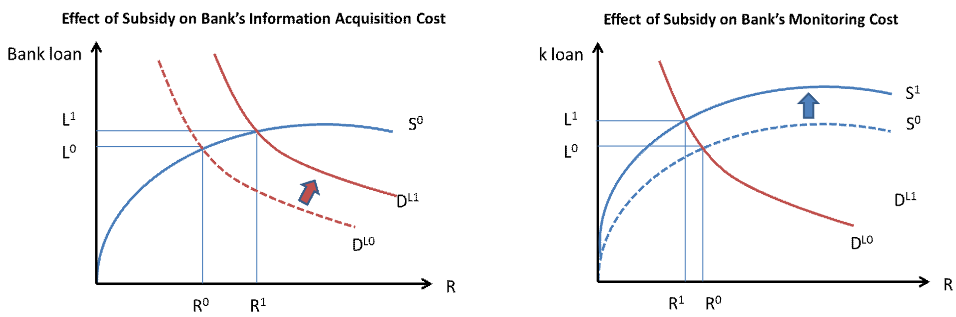


Figure 2.3: Impact of Policy on Loan Supply - Demand Curve

2.4.2 Impact of Subsidies on Macroeconomic Variables

Both types of the subsidy policies lead to higher levels of total bank lending, capital accumulation and total output in the economy. The impact of the subsidy on the consumption, net output and utility vary with the types of taxes imposed to finance the subsidy. In the case of subsidy on bank's information acquisition cost (Figure 2.4), households' consumption will increase only if the government imposes a non-distortionary lump-sum tax. Entrepreneurs' consumption and aggregate consumption increase with all types of taxation. Entrepreneurs' utility increase but the households' utility decrease for all three types of tax policy, because households consume less and work more in the steady state (Figure 2.5). The aggregate utility in the economy increases only in the case where the government finances the subsidy by imposing a labour income tax or a lump-sum tax. The aggregate utility is higher with a lump-sum tax. However, this type of taxation is almost impossible to implement in practice.

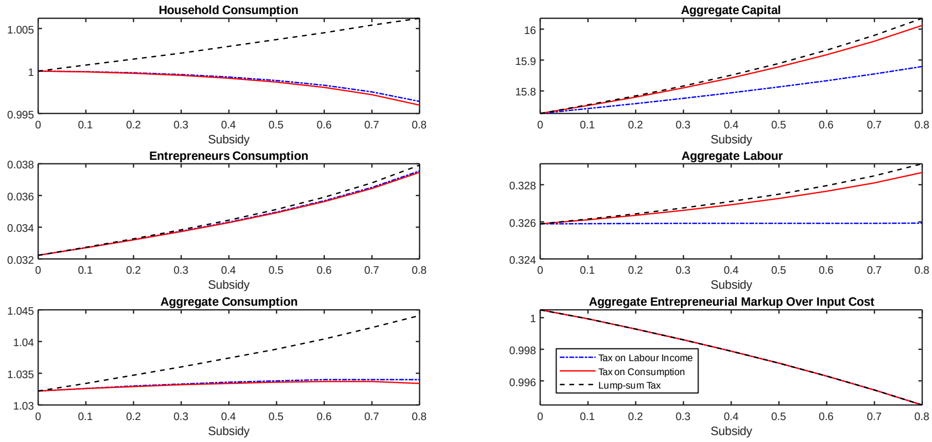


Figure 2.4: Impact of the Subsidy on Bank's Information Cost on Macroeconomic Variables

The impact of subsidy on bank's monitoring cost on macroeconomic variables are quite small (Figure 2.6). Households' consumption will increase only if the government imposes a non-distortionary lump-sum tax. Furthermore, the benefit of monitoring cost subsidy is still not large enough to raise the entrepreneurs' consumption. Although the subsidy increases the total output of the economy, it brings even higher loss in resources due to the increases in information acquisition and monitoring cost (sunk cost). Thus, the net output decreases when the government imposes a distortionary tax (Figure 2.7). With all three types of tax policies, subsidy on bank's monitoring cost reduces both households' and entrepreneurs' utility. Therefore, this type of the subsidy is not preferable in the long run.

2.4.3 Impact of Subsidies on Welfare

In this subsection, I evaluate the benefit of each combination of the type of subsidy and tax in terms of social welfare. As shown by Figure 2.8, the subsidy on bank information cost would improve the aggregate welfare if it is funded by the labour income tax or a lump-sum tax. Benefits of the subsidy mostly go to the entrepreneurs because a cheaper access to the bank lending leads to a

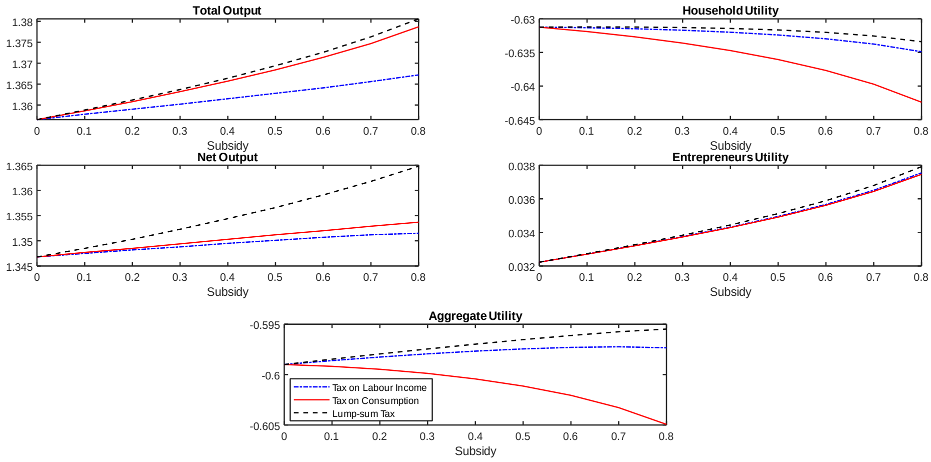


Figure 2.5: Impact of the Subsidy on Bank's Information Cost on Macroeconomic Variables (Continued)

higher profits, net worth, and consumption. In contrast, the welfare of households decrease not only because households consume less due to the distortionary tax but also because they have to work more. In general, the government support for bank lending has a good impact on the financial sector and entrepreneurs, but it decreases the households' welfare. The second graph of Figure 2.8 shows that a subsidy on monitoring cost generates a welfare losses for both households and entrepreneurs.

The results from previous the section shows that the subsidy on banks information acquisition cost could improve social welfare but the benefit only goes to entrepreneurs. Therefore, the policy is not Pareto improving. The government can conduct another intervention by redistributing the benefit of the policy to households. Redistribution of some entrepreneurs' consumption for households can improve economic efficiency. By using an optimisation solver, I find the possible economic efficiency in the scenario with tax on labour income and subsidy on the bank's information acquisition cost (Figure 2.9). For example, the subsidy policy will generate a 0.03% welfare gain for households and a 2.31% welfare gain for entrepreneurs if the government offers 30% of the subsidy on bank's information acquisition cost and redistribute 2.3% of entrepreneurs' consumption to

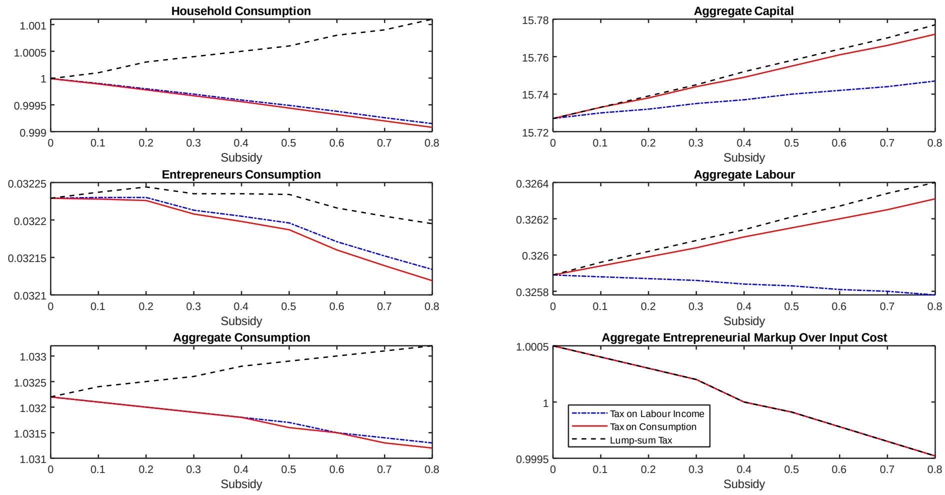


Figure 2.6: Impact of the Subsidy on Bank's Monitoring Cost on Macroeconomic Variables

households. With this combination, all agents in the economy are better off.

2.5 Conclusion

This chapter investigates the effects of two types of government subsidies to support bank credit in an environment where non-bank credit also exist. I found that both subsidies on the bank's information acquisition cost and subsidy on the bank's monitoring cost can increase bank lending and may prevent the bank credit crunch. Both subsidy policies generate a higher total lending, a higher capital accumulation and higher total output in the economy. However, the subsidy potentially increases the bank's credit risk and each policy has different impacts on welfare. The main finding of this chapter is that a subsidy on the bank's information cost has a better impact on the aggregate economic welfare rather than a subsidy on the bank's monitoring cost. However, the policy is not Pareto improving since it increases entrepreneurs' welfare at the expense of households' welfare. The government could gain economic efficiency by imposing taxes on the labour income to finance the subsidy and impose a redistribution policy on

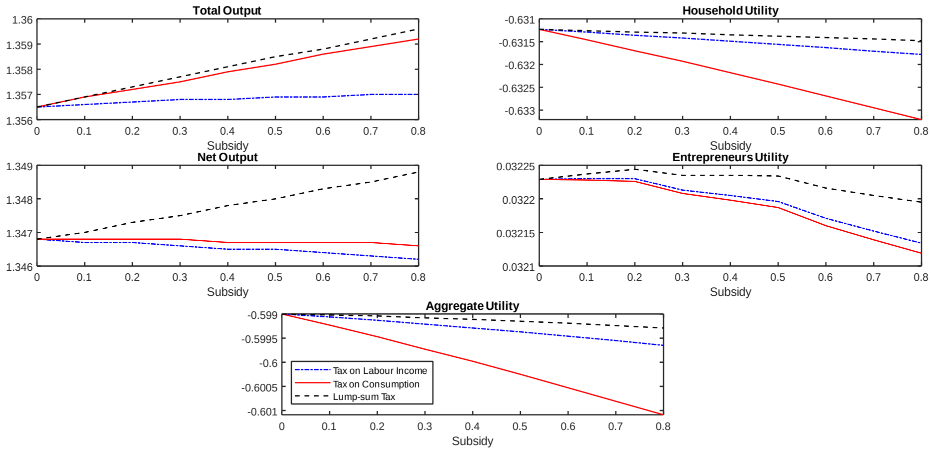


Figure 2.7: Impact of the Subsidy on Bank's Monitoring Cost on Macroeconomic Variables (Continued)

the entrepreneurs and the households' consumption. This chapter suggests that the government support for lowering the cost of access to banking have a more positive impact on welfare, compared to government support for taking care of the cost of the lender's default.

Possible future research would be to analyse the dynamic impact of the policies. As mentioned by Auerbach & Kotlikoff (1987), the steady state analysis of fiscal policy can reflect the long-run position of an economy. But, it can be misleading if used to compare alternative fiscal policies. Studying fiscal policy in a dynamic model provides a more comprehensive analysis because it considers both current and future generations and permits one to differentiate policies that truly improve economic efficiency from policies that simply redistribute resources across generations.

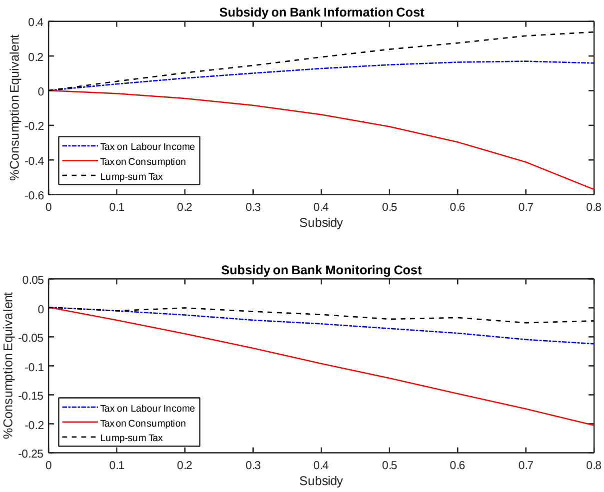


Figure 2.8: Impact of Policies on Welfare

Figure 2.9: Illustration of the Redistribution Policy for Pareto Efficiency

Chapter 3

The Impact of Macroprudential Policy in The Presence of Non-bank Financing

3.1 Introduction

The implementation of macroprudential policy aims to provide financial and macroeconomic stability and has become a more important area of research since the global financial crisis. There have been increasing efforts to develop theoretical and empirical models in this research area to provide better guidance for policymakers around the world. The modelling framework of the interaction between the financial system and the macroeconomy becomes more critical with the development of financial intermediation (Woodford (2010)).

In practice, macroprudential policy has mainly been designed to regulate the banking sector.[1] However, as pointed out by Galati & Moessner (2018), one

[1] Cerutti *et al.* (2015) presented some examples of macroprudential policies that have been implemented such as Debt to Income Ratio (DTI), Loan to Value Ratio (LTV), countercyclical capital buffer, dynamic provisioning, tax/levy on banks, leverage ratio, etc. In July 2016 ECB

of the major issues that influence the effectiveness of macroprudential policy is regulatory arbitrage because the introduction of macroprudential policy can cause the risk to move outside the regulated banking sector (Jeanne & Korinek (2014), ECB (2016)).[2]

Most of the literature on macroprudential policy has focused on the impact of this policy on banks without accounting for the possibility of the shifting of financial risk to the non-banking sector.[3] Therefore, Galati & Moessner (2018) suggest further research on the substitution from bank-based financial intermediation to non-bank intermediation in response to the macroprudential policy to obtain a better understanding of the effectiveness of the policy. As non-bank financial intermediation has taken on an increasing role in the global financial system, the shifting from bank lending to bond issuance becomes a more important concern for the policymakers (Chapter 3 IMF (2016)).

This chapter contributes to the literature of macroprudential policy by providing new insights regarding the transmission and the impact of the policy by taking into account the existence of non-bank debt financing as a substitute for bank financing. Moreover, unlike most related literature that focuses only on the effects of macroprudential policy on smoothing credit growth and welfare, this chapter also investigates the transmission of the policy on the average default of loan in the economy. Specifically, the main research questions of this chapter are:

1. How does the introduction of macroprudential policy affect the firms' choices of bank financing or non-bank debt financing?

published a strategy paper regarding the need for macroprudential policies beyond banking (ECB (2016))

[2] Another important issue is the interaction of macroprudential policy and monetary policy. There has been a great deal of research on this issue, such as Angelini *et al.* (2014), Kannan *et al.* (2014), Suh (2014), Quint & Rabanal (2014), Rubio & Carrasco-Gallego (2014), Levine & Lima (2015), Svensson (2018), Silvo (2019) which showed that the two policies are closely interrelated and need to be coordinated.

[3] Recently few studies discuss the regulatory arbitrage effect of macroprudential policy, for example: Cizel *et al.* (2019), Aiyar *et al.* (2014), Reinhardt & Sowerbutts (2015), Danisewicz *et al.* (2015), Bengui & Bianchi (2018), and Fève *et al.* (2019). The first paper discusses empirical findings of the substitution from bank financing to bond financing; the next three papers focus more on the regulatory arbitrage involving foreign banks, and the last two papers discuss the presence of shadow banking.

2. How effective is the macroprudential regulation in increasing macroeconomic stability, financial stability and social welfare under various shocks to the economy?

To answer those questions, I utilise a closed economy with a flexible price model of De Fiore & Uhlig (2015), featuring the financial frictions as in Carlstrom & Fuerst (1997) and Bernanke *et al.* (1999). A key feature of the model is entrepreneurs are heterogeneous in terms of productivity risk, and they can choose to borrow from a bank or issue bonds in the capital market to finance their working capital cost. The bank has some advantages compared to the capital market fund. Firstly, the bank acts as an informed lender who can obtain information about some of the entrepreneur's productivity risk. Secondly, the bank offers a more flexible contract, in which an entrepreneur can choose not to continue borrowing after learning about their risk.

I employ the model to study a macroprudential policy, represented in the form of a "regulation premium", to the bank's cost of intermediation. The additional premium reflects the increase in banks' funding cost that, for instance, arises from an increase in capital requirements or liquidity requirements. I choose to use regulation premium as a general representation of macroprudential policy because the model featuring neither bank capital nor liquidity, so I can not explicitly study specific macroprudential instruments. A similar approach has been used in Filiz Unsal (2013), Kannan *et al.* (2014), Ozkan & Unsal (2014), and Quint & Rabanal (2014). The regulation premium affects lending spread through the changes in the optimal lending contract between a bank and borrower.[4] This chapter adopts a positive approach and takes the presence of macroprudential regulation for granted. Moreover, this study concentrates only on corporate loans; therefore a change in bank lending spread affects the entrepreneur's decision on the source of financing.

[4]In reality, banks are likely to use some combination of strategies to meet new capital or liquidity regulations such as increasing retained earnings, reduce risk-weighted assets, or issue new equity. However, some studies shows that the changes in those regulations affect bank interest rate spread (Roger & Vlcek (2011), Angelini *et al.* (2011))

I consider a policy where the regulation premium rises proportionally with bank credit growth, and implemented only in the banking sector. This chapter found that increasing the regulation premium in the banking sector is not only raising the bank lending rate but also the non-bank rate because of the risk shifting. Tighter regulation in the banking sector leads to a reduction in the bank lending but at the same time increasing the non-bank financing; therefore the impact on total credit is limited. Since the bank has superiority in terms of its ability to reduce firms' uncertainty of production output and has more flexible contract arrangement, the shifting to the non-bank lending can lead to a higher risk across the overall financial system.

The results of this chapter show that the countercyclical macroprudential regulation has a desirable benefit on improving financial stability and increasing welfare particularly in the case of banking shock. In the case of an uncertainty shock, the implementation of the macroprudential policy increases macroeconomic stability and improving social welfare but can have unintended consequences in terms of increasing average default. In contrast, the policy is less effective in the case of technology shock because it generates a welfare loss. I found that a modified rule, which reacts not only to bank credit growth but total credit growth, provides welfare gains in the case of technology shock. Therefore, it is essential for the policymaker to take into account the regulatory arbitrage effects of macroprudential policy and take into consideration not only the condition of the banking sector but also the credit in the financial markets.

This chapter relates to a recent work by Fève *et al.* (2019). Their paper shows that shifting from traditional bank loan toward less regulated financial intermediation (shadow bank) reduces the ability of macroprudential policies to stabilise the economy. The macroprudential policy in their paper affects the bank's assets portfolio: traditional loans and asset-backed securities issued by shadow bank. When a higher capital requirement is applied only on the traditional loan, the bank will hold more asset-backed securities, and consequently, shadow banking activity expands. Thus, the shifting of the bank toward the non-bank loans is coming from the financial intermediaries decision (lender's perspective). Different from this approach, in my study the shifting is decided by the entrepreneur (borrower's perspective). This chapter also relates to Rubio (2017b). She shows that banking regulation in terms of Loan to Value (LTV) and capital regulation will cause a shifting of the source of household loan from a formal bank toward private lenders, and cause an unexpected risk to financial stability. Concern about whether macroprudential policy remains desirable in the presence of leakages due to regulatory arbitrage are also raised in the paper of Bengui & Bianchi (2018). Their paper provides a rationale for macroprudential policy to limit pecuniary externalities and shows that the regulation improves aggregate welfare, even in the presence of leakages. However, those papers are absent from endogenous credit risk, an aspect that is important in discussing financial stability.

This study is consistent with the empirical research of Cizel *et al.* (2019) who found evidence of substitution effects from bank loan towards non-bank credit, especially in advanced economies. As a consequence, the macroprudential policies' effect on total credit can be less effective. Therefore, they also suggest that macroprudential policy should account for the expansion of non-bank finance.

The organisation of the remaining chapter is as follows. Section 2 describes the basic model and the modelling of macroprudential policy in the form of a regulation premium. Section 3 analyses the transmission and effectiveness of the macroprudential policy under various case of economic shock. This section also discusses a modification of the macroprudential policy rule. Section 4 concludes the chapter.

3.2 Model

3.2.1 Basic Model

This chapter employs model of De Fiore & Uhlig (2015) and De Fiore & Uhlig (2011). It is a closed economy with a flexible price. There are households who consume, save and supply labour, and productive entrepreneurs who can borrow either from the bank or directly from the capital market fund (CMF). The central bank injects liquidity. The details of the model had been explained in section 2.2. Table 3.1 and 3.2 summarise the equations of the model. I employ the model to study macroprudential policy.

Table 3.1: Summary of the Basic Model

Households	
Consumption-labour trade off	$\eta h_t^{\frac{1}{\kappa}} c_t = w_t$
Euler equations	$\frac{1}{c_t} = \beta R_t E_t \left[\frac{1}{c_{t+1}\pi_{t+1}}\right];$
	$\frac{1}{c_t} = \beta E_t \left[\frac{1}{c_{t+1}}\left(1-\delta+r_{t+1}\right)\right]$
Budget constraint	$m_t + d_t = \frac{R_{t-1}}{\pi_t} d_t + \theta_t$
CIA constraint	$0 = m_t + w_t h_t + r_t k_t - c_t - k_{t+1} + (1-\delta) k_t$
Entrepreneurs	
Markup over input costs	$q_t = A_t \left(\frac{\alpha}{w_t}\right)^{\alpha} \left(\frac{1-\alpha}{r_t}\right)^{1-\alpha}$
Cost of capital	$r_t (k_t + z_t) = (1-\alpha) x_t$
Cost of labour	$w_t h_t = \alpha x_t$
Ent. consumption	$e_t = \gamma \psi^f (\varkappa_t) n_t$
Ent. capital	$z_{t+1} = (1-\gamma) \psi^f (\varkappa_t) n_t$
Ent. net worth	$n_t = (1-\delta+r_t) z_t$
Financing decisions	
Threshold of productivity levels to proceed with bank loan ($\bar{\varepsilon}_i^d$)	$F^d \left(\varepsilon_{1,it}, \bar{\varepsilon}_{it}^d; q_t, R_t, \sigma_{3t}\right) = 1$
Threshold of productivity levels to approach a bank ($\bar{\varepsilon}_b$)	$F^b \left(\bar{\varepsilon}_{bt}; q_t, R_t, \tau_t, \sigma_{2t}, \sigma_{3t}\right) = 1$
Threshold of productivity levels to borrow from CMF ($\bar{\varepsilon}_c$)	$F^b \left(\bar{\varepsilon}_{ct}; q_t, R_t, \tau_t, \sigma_{2t}, \sigma_{3t}\right) = F^c \left(\bar{\varepsilon}_{ct}; q_t, R_t, \sigma_{2t}, \sigma_{3t}\right)$
Threshold in the loan contract ($\bar{\omega}$)	$g (\bar{\omega}; \sigma_{it}, \mu) = \frac{R_t}{\varepsilon_{it}^e q_t} \left(1 - \frac{1}{\xi}\right)$
Lending Rate	$R_{it}^l = \varepsilon_{it}^e q_t \bar{\omega}_{it} \frac{\xi}{\xi - 1}$
Lending Spread	$\Lambda_{it} = \frac{R_{it}^l}{R_t} - 1$

Table 3.2: Summary of Model (Continued)

Central Bank	
Money supply	$m_t^s = \nu \frac{m_{t-1}^s}{\pi_t}$
Transfer to household	$\theta_t = (\nu - 1)\frac{m_{t-1}^s}{\pi_t}$
Aggregation & Market Clearing	
Output (expenditures)	$y_t = c_t + e_t + I_t + y_t^a$
Investment	$I_t = k_{t+1} + z_{t+1} - (1-\delta)(k_t + z_t)$
Money market	$m_t^s = m_t + d_t$
Loan market	$d_t = \left[(1-\tau_t) s_t^{bp} + s_t^c\right](\xi - 1) n_t$
Bank loan	$l_t^b = (1-\tau_t) s_t^{bp}(\xi - 1) n_t$
CMF loan	$l_t^c = s_t^c(\xi - 1) n_t$
Total working capital	$x_t = \left[(1-\tau_t) s_t^{bp} + s_t^c\right]\xi n_t$
Output (production)	$y_t = \psi^y(\varkappa_t) q_t \xi n_t$
Agency cost	$y_t^a = \left[\tau_t s_t^b + \psi^m(\varkappa_t)\mu\xi q_t\right) n_t$
Financial Structure	
Risk premium bank	$rp_t^b \equiv \frac{\psi^{rb}(\varkappa_t)}{s_t^{bp}}$
Risk premium CMF	$rp_t^c \equiv \frac{\psi^{rc}(\varkappa_t)}{s_t^c}$
Average default of bank loan	$\varrho_t^b = \frac{\psi^{mb}(\varkappa_t)}{s_t^{bp}}$
Average default of CMF loan	$\varrho_t^c = \frac{\psi^{mc}(\varkappa_t)}{s_t^c}$
Average default	$\varrho_t = \frac{\psi^{mb}(\varkappa_t) + \psi^{mc}(\varkappa_t)}{s_t^{bp} + s_t^c}$
Shares of the firms that abstain from producing	$s_t^a = \Phi\left(\bar{\varepsilon}^b(\cdot); \sigma_{1t}\right)$
Shares of the firms that approach a bank	$s_t^b = \Phi\left(\bar{\varepsilon}^c(\cdot); \sigma_{1t}\right) - \Phi\left(\bar{\varepsilon}^b(\cdot); \sigma_{1t}\right)$
Shares of the firms that proceed with the bank loan	$s_t^{bp} = \int_{\bar{\varepsilon}^b(\cdot)}^{(\bar{\varepsilon}^c(\cdot)} \int_{(\bar{\varepsilon}^d(\varepsilon_1; q_t, R_t, \sigma_{3t})} \Phi(d\varepsilon_2)\Phi(d\varepsilon_1)$
Shares of the firms that borrow from CMF	$s_t^c = 1 - \Phi\left(\bar{\varepsilon}^c(\cdot); \sigma_{1t}\right)$

Note: c = HH consumption, h = labour, w = real wages, R = return on deposits, π = inflation, m = real cash holding, d = real deposits, θ = transfer, r = real rent on capital, k = HH capital, q = ent. markup, A = TFP, z = ent. capital, x = working capital, e = ent. consumption, n = ent. networth, $\varepsilon_{j,i}$ = ent. idiosyncratic productivity levels, ε^e = known productivity level before the contract, σ_j = std.dev of ε_j, τ = information acquisition cost, m^s = money supply, ν = growth rate of nominal money supply, y = output, I = investment, y^a = agency cost, $\psi^f(\varkappa_t)$ = aggregation of ent. profit (as in eq. 2.38), $\psi^y(\varkappa_t)$ = aggregation of realised productivity factors (as in eq. 2.43), $\psi^{mb}(\varkappa_t)$ = aggregation of defaulted bank loan (as in eq. 2.46), $\psi^{mc}(\varkappa_t)$ = aggregation of defaulted CMF loan (as in eq. 2.47), $\varkappa \equiv [q_t, R_t, \tau_t, \sigma_{1,t}, \sigma_{2,t}, \sigma_{3,t}]$, and $(\cdot) \equiv (q_t, R_t, \tau_t, \sigma_{2t}, \sigma_{3t})$. Definition of F^d, F^b, and F^c are as in eq. 2.26, 2.28, and 2.30 respectively.

3.2.2 Modeling Macroprudential Policy

The macroprudential policy is modelled in the form of "regulation premium" that adds or reduces the bank's cost of borrowing. The additional premium reflects the increase in banks' funding cost that, for instance, arises from an increase in capital requirements or liquidity requirements.[5] The regulation premium affects lending spread indirectly through the changes in the optimal lending contract between a bank and an entrepreneur. An increase in the regulation premium raises the bank's cost of borrowing and affects the bank's participation constraint. Specifically, the regulation premium (RP_t) affects the bank's break-even condition in equation 2.20 to be:[6]

$$\frac{(\xi-1)}{\xi} x_{it} R_t \times RP_t = g\left(\bar{\omega}^b; \sigma_{it}, \mu\right) \varepsilon_{it}{}^e q_t x_{it}, \tag{3.1}$$

which is equivalent with

$$g\left(\bar{\omega}^b; \sigma_{it}, \mu\right) = \frac{R_t \times RP_t}{\varepsilon_{it}^e q_t} \left(1 - \frac{1}{\xi}\right). \tag{3.2}$$

An increase in the regulation premium ($RP_t > 1$) raises the threshold $\bar{\omega}^b$ in the lending contract and raise both of the bank's lending rate and bank's lending spread.[7] Consequently, adding this RP_t into the model affects the entrepreneur's optimal decision through all other equations related to $\bar{\omega}^b$.[8]

In line with the practices in many countries, the macroprudential policy is adjusted countercyclically to bank credit so that it act as stabilisers on the finan-

[5] For example, an increase in capital requirements could increase banks' funding costs by requiring them to finance more of their loan with equity, which is typically perceived to be more expensive than the cost of deposit (R_t). In related literature, one alternative explanation for the higher cost of equity is that interest payments on deposit are tax-deductible.

[6] The formulation of break-even condition for CMF loan is not affected and still same as in the equation 2.20.

[7] In the case of credit downturn, this regulation premium is similar to the credit subsidies which are financed by lump-sum taxes as in Correia *et al.* (2016). In their model, the subsidy reduces the amount of borrower's payment but does not affect the lending rate set by the bank. In my model, the regulation premium affects the bank's lending rate through the changes in the bank zero profit condition.

[8] Such as the equations that characterise $F^d(\cdot), F^b(\cdot), s^a(\cdot), s^b(\cdot), s^{bp}(\cdot),\ s^c(\cdot), \psi^f(\cdot),\ \psi^y(\cdot)$, $\psi^{mb}(\cdot)$, $\psi^{mc}(\cdot)$, $\psi^{rb}(\cdot)$, and $\psi^{rc}(\cdot)$.

cial imbalances. First, in accordance with the practice of many studies regarding macroprudential policy (e.g Ozkan & Unsal (2014), Rubio & Carrasco-Gallego (2014) and Rubio (2017a)), I consider bank credit growth as the indicator of financial imbalances. Specifically, I consider that the regulation premium (RP_t) rises proportionally with the bank credit (l_t^b) growth with feedback parameter Ψ. Specification of the regulation premium rule is as follows:

$$RP_t = \left(\frac{l_t^b}{l_{t-1}^b} \right)^{\Psi} \xi_{RP_t}, \tag{3.3}$$

where ξ_{RP} is the regulation premium policy shock. I assume that the policy shock follows an AR(1) process as follows:

$$\log \xi_{RP_t} = \rho \log \xi_{RP_{t-1}} + \varepsilon_{RP,t}, \;\; \varepsilon_{RP,t} \sim N(0, \sigma_{RP}^2). \tag{3.4}$$

3.2.3 Calibration

The parameters of the model are summarised in Table 3.3. Most of the parameters are taken from the model of De Fiore & Uhlig (2015), which is calibrated to match the data of the Euro-area over the period 1999-2010. The household's discount factor is set at $\beta = 0.99$. Depreciation rate δ and the Frisch elasticity κ are set at 0.02 and 3 respectively. The share of labour on the production function α is 0.64, monitoring cost μ is 0.15, and the persistence parameter is set at $\rho = 0.95$ to follow common values in the related literature. The disutility of labour parameter, η, is calibrated such that consumption in the steady state is unity.

Other parameters $\xi, \tau, \gamma, \sigma_1, \sigma_2$, and σ_3 are calibrated to minimise the squared log-deviation of the steady state values from some facts of the Euro-area financial structure. Table 3.4 presents the comparison between the facts and the steady state values of the model. I set the entrepreneur's discount factor at $\beta_E = 0.999$ to be consistent with the assumption that the entrepreneur has a high rate of time preference.[9] A high discount factor implies that it is optimal for the entrepreneur

[9] As explained in De Fiore & Uhlig (2015), we assume β_E is sufficiently high so that the

to postpone consumption until the time of death and invest their profits for the next period capital during their lives. The entrepreneur-specific levels of productivity shock $\varepsilon_{j,it}$ are assumed to be lognormally distributed, i.e $\log(\varepsilon_{j,it})$ are normally distributed with variance $\sigma_{j,t}$ and mean $-\sigma_{j,t}^2/2$; so that $E\left[\varepsilon_{j,it}\right] = 1$.

Table 3.3: Parameters

Parameters	Value	Description
Set Exogenously		
β	0.99	Household discount factor
δ	0.02	Depreciation rate
α	0.64	Shares of labour on production function
ρ	0.95	Persistence coefficient of autoregressive process
μ	0.15	Monitoring cost
κ	3	The inverse of Frisch elasticity of labour supply
β^E	0.999	Entrepreneur's discount factor
Calibrated		
η	3.753	Preference parameter
ξ	3.195	Working capital to net worth ratio
τ	0.0099	Information acquisition cost
γ	0.022	Probability of firm dies
σ_1	0.0165	Standard deviation of ε_1
σ_2	0.0225	Standard deviation of ε_2
σ_3	0.1711	Standard deviation of ε_3

Table 3.4: Facts versus Model

Variables	Facts	Model
Ratio of aggregate bank loans to debt securities	5.3591	5.5000
Ratio of aggregate debt to equity	0.6371	0.6400
Average risk premium of debt securities	0.0029	0.0036
Average risk premium of bank loans	0.0030	0.0030
Average default rate of debt securities	0.0144	0.0125
Expected return of entrepreneurial capital	0.0230	0.0233

return on internal funds is always higher than the preference discount. It is thus optimal for entrepreneurs to postpone consumption until the time of death.

3.3 Simulation and Model Dynamics

This section presents the results of simulations and covers the discussion of the performance of macroprudential regulation in terms of macroeconomic stability, financial stability, and social welfare. First, I conduct an exercise to analyse the response of financial structure and macroeconomic variables under a one per cent macroprudential policy shock (ξ_{RP_t}). Second, I present impulse responses of the economy under various individual shocks for three cases: the case where no macroprudential policy is implemented, the case where the macroprudential policy is implemented with medium feedback parameter, and the case where the macroprudential policy is implemented with high feedback parameter. I utilise Dynare to compute the policy functions and generate the impulse responses following various individual shock scenario using the first-order approximation around the steady state.[10] Third, I analyse the benefit of the introduction of the macroprudential policy by comparing some indicators of macroeconomic stability, financial stability and social welfare before and after the implementation of policy using the results of second-order approximation around the steady state.

I consider three types of shocks in the simulation: banking shocks ($\varepsilon_{\tau,t}$), technology shocks ($\varepsilon_{A,t}$), and the uncertainty in entrepreneur's productivity shocks ($\varepsilon_{\sigma_{2,t}}$). These shocks are assumed to be normally distributed with mean 0 and affect the stochastic process of the bank information acquisition costs (τ_t), aggregate productivity (A_t), and the standard deviation of the productivity shocks ($\sigma_{2,t}$) as follow:

$$\log \tau_t - \log \tau = \rho \left(\log \tau_{t-1} - \log \tau \right) + \varepsilon_{\tau,t}, \varepsilon_{\tau,t} \sim N(0, \sigma_\tau^2) \tag{3.5}$$

[10] Since this model features heterogenous agents, I use several external MATLAB functions to compute the changes of each entrepeneur decision and compute the aggregation. Then, I call the external functions into the Dynare routine to compute policy functions, generate impulse responses and compute moments of the aggregate economy. My approach is different with De Fiore & Uhlig (2015) who log-linearise all the equations and employ the Uhlig (1995) toolkit to find the policy function and impulse response functions.

$$\log A_t - \log A = \rho (\log A_{t-1} - \log A) + \varepsilon_{A,t}, \varepsilon_{A,t} \sim N(0, \sigma_A^2) \tag{3.6}$$

$$\log \sigma_{2,t} - \log \sigma_2 = \rho (\log \sigma_{2,t-1} - \log \sigma_2) + \varepsilon_{\sigma_{2,,t}}, \varepsilon_{\sigma_{2,t}} \sim N(0, \sigma^2_{\sigma_{2,t}}) \tag{3.7}$$

3.3.1 Responses to an Increase of Regulation Premium Policy

Figure 3.1 displays the dynamic response of some variables in the financial sector to a positive regulation premium shock (ξ_{RPt} in equation 3.3). In this exercise, a tighter macroprudential policy is represented as an increase in the regulation premium which causes a higher bank funding cost. Consequently, the demand for bank loan decreases. Some entrepreneurs who have medium levels of productivity then shift from bank to the capital market fund, resulting the increases in the amount of the CMF loan. Figure 3.2 illustrates the movement of the entrepreneurs distribution in response to the increase in the regulation premium. In aggregate, the total loan as well as total agency cost decreases. The result of this simulation is in accordance with the empirical event study carried by Cizel *et al.* (2019). Using data from 30 countries within period 1997-2014, they found that macroprudential policy measures tend to reduce the growth rate of bank credit but increase the growth of nonbank credit. However, the total credit still decline because the substitution effect does not fully compensate for the impact on bank credit.

Figure 3.1 also shows that the regulation premium increases average default of both bank and CMF loan. This result is emerges as a consequence of the assumption of the model where entrepreneur's idiosyncratic productivity shock $\varepsilon_{3,it}$ is random and not affected by the policy, so an increase in the bank's lending rate leads to a higher average default of bank loan.

Figure 3.3 illustrates the transmission of increasing the regulation premium on the average loan default. Effect of regulation premium on banking sector can be transmitted through two channels. The first is the "cost effect" channel, where the higher regulation premium affects the funding cost (left-hand side of equation 3.1) and induces the bank to raise the threshold of debt repayment ($\bar{\omega}^b_{it}$).

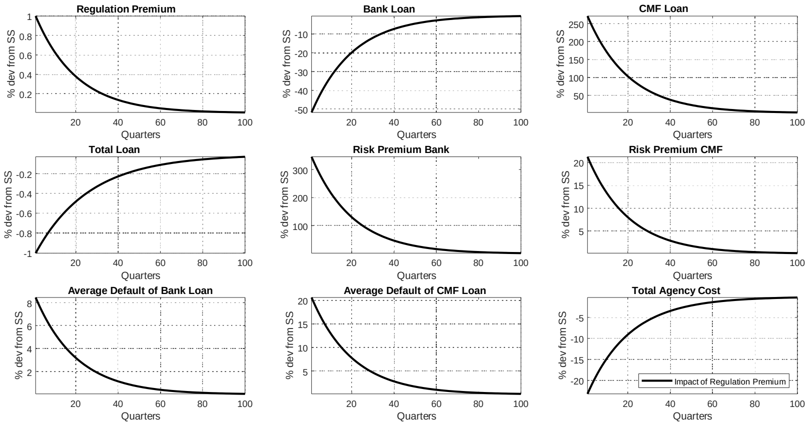


Figure 3.1: Impact of Regulation Premium on Financial Structure

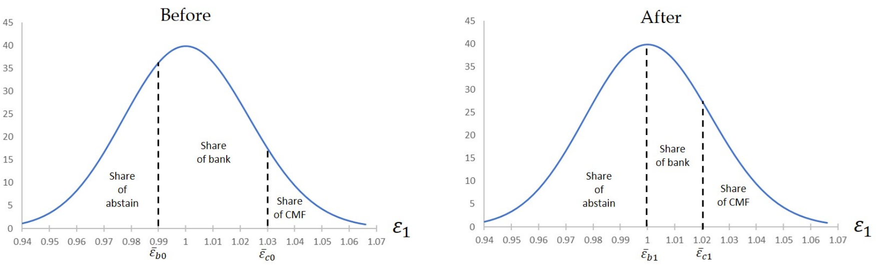


Figure 3.2: Impact of Regulation Premium on the Distribution of Entrepreneurs

The second is the "selection effect" channel, where a higher regulation premium discourages entrepreneur from borrowing from the bank. The minimum threshold of $\bar{\varepsilon}_{bt}$ increases and $\bar{\varepsilon}_{ct}$ decreases. Thus, the average ex-ante productivity level of entrepreneurs who approach the bank ($\varepsilon_{1,it}\varepsilon_{2,it}$) can be higher or lower. Following the right-hand side of equation 3.2, a higher (lower) level of known productivity reduces (increases) the threshold of debt repayment ($\bar{\omega}^b_{it}$). With the opposing impacts provided by the two channels, the overall effect of the regulation premium on bank lending rate depends on the value of parameters used in the model. The simulation shows that regulation premium increases the average bank risk premium (lending rate). A tighter regulation in the banking sector also raises the lending rate in the non-banking sector through the "substitution effect" channel. A higher cost of bank borrowing causes the minimum threshold of $\bar{\varepsilon}_{ct}$ decreases.

Therefore, the average ex-ante productivity level of entrepreneurs who approach CMF ($\varepsilon_{1,it}$) is lower. Referring to equation 3.2, a lower level of known productivity raises the threshold of CMF debt repayment ($\bar{\omega}^c_{it}$). Since unknown productivity is random and i.i.d, a higher threshold increases the average default of the CMF loan.

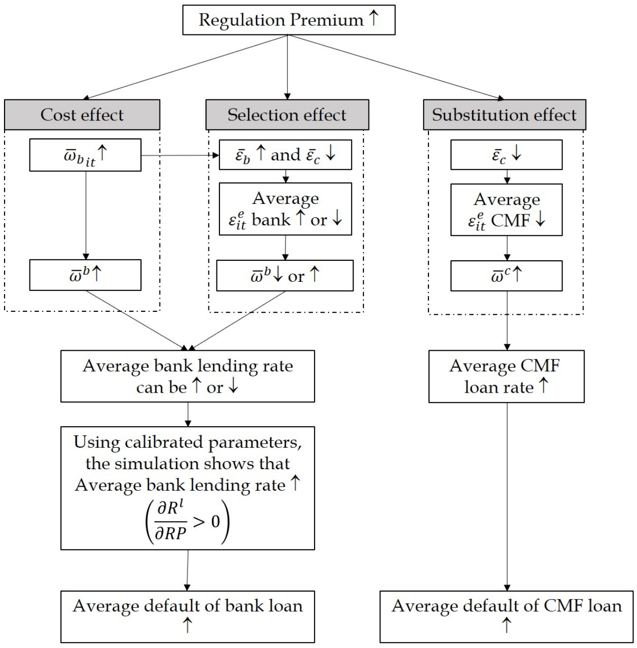


Figure 3.3: Effect of Regulation Premium on Average Default

Figure 3.4 shows the response of some real macroeconomic variables. A deterioration in the total loan affects the decline in almost all macro-variables. A lower level of production leads to lower levels of working hours, investment, GDP, and entrepreneurs' net worth. The simulation shows that a 1% increase in the regulation premium leads to a 0.5% deterioration of GDP. Although the figures are not displayed here, the real interest rate and real wage also decrease which lead to a lower households' income from working and renting his capital.

The above exercise is useful to explain the possible unintended consequences of imposing tighter banking regulation. Increasing regulation premium in the banking sector raises not only the bank lending rate but also the non-bank lending rate because of risk shifting. Stricter regulation in banking sector leads to a

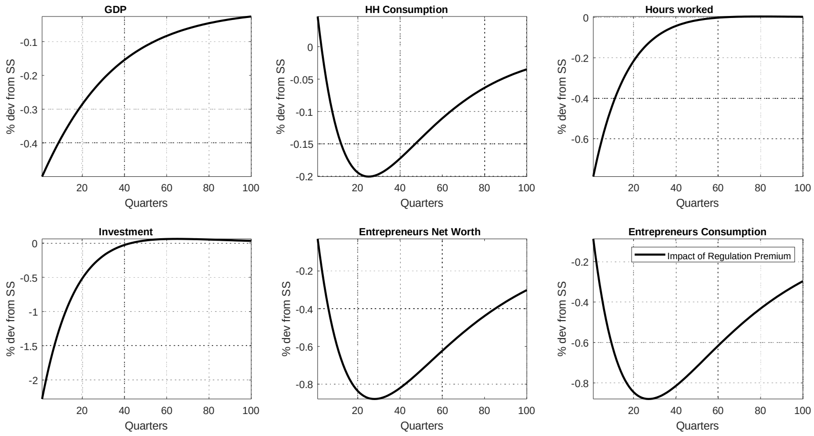


Figure 3.4: Impact of Regulation Premium on Macroeconomic Variables

reduction in the bank lending but simultaneously raises the non-bank credit. A shift to the non-bank lending implies a higher risk to the overall financial system because the bank has a more flexible arrangement in contract and the ability to reduce firms' uncertainty of output. The benefit of macroprudential policy is not obvious in the previous exercise because it seems that an increase in the regulation premium may provide a worse economic condition by lowering output and raising default of both bank and non-bank credit. Benefits of macroprudential policy will be discussed in the next subsection using welfare and stability analysis.

3.3.2 Welfare and Stability Measures

Social welfare evaluation is a common approach to examine the benefits of policies. Following Rubio & Carrasco-Gallego (2014), I define social welfare (W_t) as a weighted sum of the households' and entrepreneurs' welfare (W_t^H and W_t^E). The welfare of each agent is weighted by their discount factor so that each agent receives the same level of utility from a constant consumption stream:

$$W_t = (1-\beta)\, W_t^H + (1-\beta_E)\, W_t^E, \tag{3.8}$$

where

$$W_t^H = E_0 \left(\sum_{t=0}^{\infty} \beta^t \left[log\left(c_t\right) - \frac{\eta}{1+\frac{1}{\kappa}} h_t^{1+\frac{1}{\kappa}} \right] \right), \tag{3.9}$$

and

$$W_t^E = E_0 \sum_{t=0}^{\infty} \beta_E^t e_t. \tag{3.10}$$

I then employ the standard approach documented in the literature by expressing each agent utility function recursively:

$$W_t^H = U\left(c_t, h_t\right) + \beta W_{t+1}^H, \tag{3.11}$$

and

$$W_t^E = U\left(e_t\right) + \beta_E W_{t+1}^E, \tag{3.12}$$

where

$$U\left(c_t, h_t\right) = \left[log\left(c_t\right) - \frac{\eta}{1+\frac{1}{\kappa}} h_t^{1+\frac{1}{\kappa}} \right], \tag{3.13}$$

and

$$U\left(e_t\right) = e_t. \tag{3.14}$$

To compare the welfare benefits across policies, I follow suggestions of Kim *et al.* (2008) to use the conditional welfare criterion and choose the steady state as the initial condition.[11] Furthermore, following the standard literature, I present welfare changes in terms of consumption equivalents and take the case without macroprudential policies as the baseline.[12] A positive value means a welfare gain which indicates that the introduction of macroprudential policy is preferable for the agent.

Macroprudential policy is mainly used to improve financial stability, so it is essential to perform a stability benefit analysis in addition to the welfare analysis. To evaluate the stability benefit of the macroprudential policy, I use two types of

[11] I evaluate policies with both conditional and unconditional welfare criterion, and the results are consistent.

[12] Derivation of the consumption equivalents are available in Appendix 6.3.2.

measures. The first measures are the standard deviations of the main macro and financial variables which consists of GDP, bank loan and non-bank loan. The second measures are the average default rates of bank loan and non-bank loan. I evaluate the average default rates for a given policy with the unconditional mean of ϱ_t^b and ϱ_t^c which I obtain from the second-order approximation.

3.3.3 Case 1: Banking shock

In this subsection, I consider a shock in the banking sector which causes a positive bank's loan growth. I define the banking shock as a negative shock on the bank's information acquisition cost (ε_τ as in equation 3.5) that makes the cost to approach a bank loan is cheaper. The intuition is as follows: During an economic boom, it is easier for the bank to select a profitable borrower. Therefore, banks tend to decrease their lending requirements which implicitly reduces the cost paid by the entrepreneur to approach a bank. A lower bank information acquisition cost may induce a credit boom.[13]

Figure 3.5 presents the response of the economy to a temporary one per cent negative shock on the bank's information acquisition cost. The solid black line shows the response of the economy in an environment where there is no macro-prudential policy. A negative shock on the bank's information acquisition cost generates a higher bank's loan. Some of the entrepreneurs with low productivity are attracted to approach the bank, and some of them will proceed with the loan. Some other entrepreneurs with high productivity shift from market finance to bank finance because bank finance becomes less costly. With the current calibration, a 1% decrease in the bank information acquisition cost leads to a 0.5% increase in bank loan and -2.5% decrease in CMF from its steady state. [14] In aggregate, total loan increases. The simulation shows that the resulting increased

[13] This argument is supported by Dell'Ariccia & Marquez (2006) who show that when the efforts needed by the bank to obtain information about borrowers decline, banks may loosen their lending standards. These lower lending standards are associated with greater credit expansion and a greater risk of financial instability.

[14] Steady state values of the bank loan and the non-bank loan are 0.76 and 0.14.

share of firms who choose bank leads to a higher average default of bank loan. On the contrary, average non-bank default decreases. Figure 3.6 illustrates the transmission of the effect of banking shock on average default. When the cost to approach a bank decreases, the minimum threshold of $\bar{\varepsilon}_{bt}$ also decreases. More firms with low ε_1 decide to go to the bank. Given information about their ε_2, some of the firms then proceed with the loan. On average, the ex-ante productivity level of firms who approach the bank ($\varepsilon^e_{it} = \varepsilon_{1,it}\varepsilon_{2,it}$) is smaller, resulting in a higher average threshold in the debt contract $\overline{\omega}^b$ (equation 3.2). Since $\varepsilon_{3,it}$ is i.i.d, an increase $\overline{\omega}^b$ leads to a higher probability of bank loan default. On the other hand, a lower cost to approach the bank generates a higher minimum threshold of $\bar{\varepsilon}_{ct}$. As a result, the average ex-ante productivity level of entrepreneurs who go to the non-bank financing increases and the threshold in the debt contract, $\overline{\omega}^c$, decreases. Consequently, the average non-bank risk premium and the average default decline. From the macro perspective, the situation that more entrepreneurs decide to produce leads to an increase in total output. Consumption and investment of households increase because they earn more income from work and renting capital.

The dashed line and the dotted line represent the responses of the economy in an environment where the central bank implements the macroprudential policy with medium and high feedback rule ($\Psi = 0.5$ and $\Psi = 2$).[15] As shown in Figure 3.5, the implementation of the countercyclical regulation premium helps to stabilise the fluctuations in both total lending and GDP in the case of a banking shock. A negative shock on the bank's information cost still increase the bank loan but in a much smaller magnitude. The reason is that the bank's lending rate becomes more expensive. In the first period after the shock, the regulation premium increases sharply in response to the high bank credit growth, but then it decreases slowly. The introduction of a countercyclical regulation premium with

[15] For illustration, here I consider reaction parameters 0.5 and 2. I have experimented with several values of the feedback parameter for the policy rule Ψ, from 0.5 until 2 and the results in terms of the direction of responses are consistent. A higher value of feedback parameters leads to smoother responses of bank loan.

medium feedback increases the bank loan by a maximum only 0.16%, and CMF loan decreases by only 0.8% after a one per cent banking shock. As discussed in the previous subsection about the impact of regulation premium, an increase in the bank's lending rate due to a tighten macroprudential policy leads to a higher average default of both bank loan and CMF loan. In the economy with macroprudential policy, the impact of the banking shock on the total output and consumption is also smaller. In this exercise, the presence of macroprudential policy leads to a decline in the total cash available for working capital. Therefore, entrepreneurs need to re-optimise their composition of labour and capital in the production function, and also to compute the optimal wage and rent of capital. The simulation shows that the optimal real rent of capital declines after the introduction of macroprudential policy while real wage still increases, although in a smaller magnitude. Consequently, firms use more capital to produce and reduce the labour working hours.[16]

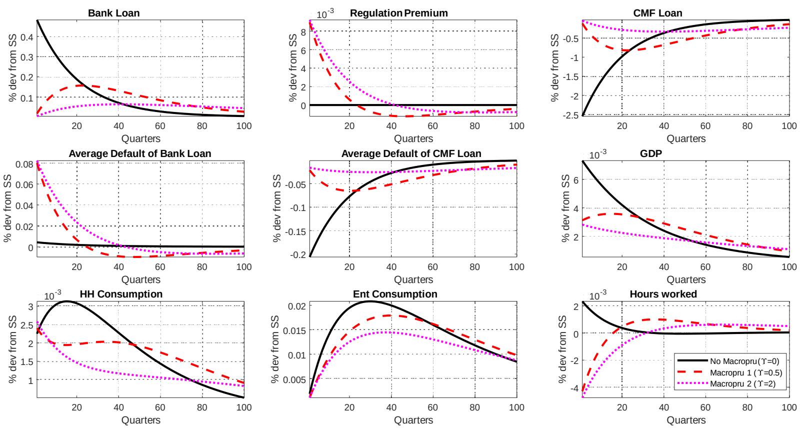


Figure 3.5: Responses to a Positive Banking Shock with and without Regulation Premium

The objective of introducing counter-cyclical macroprudential policy is to improve financial stability and thus improve macroeconomic stability and social welfare. Figure 3.7 presents the comparison of some measures that might become

[16]The graph of responses of some other variables are available in Appendix 6.3.1.

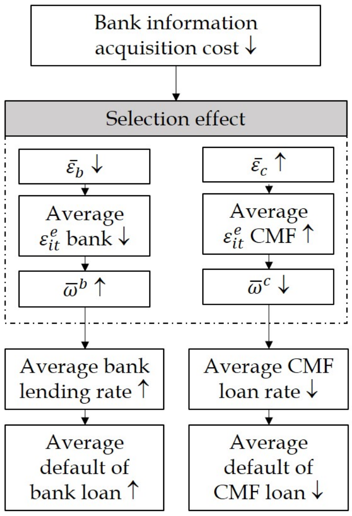


Figure 3.6: Effect of Banking Shock on Average Default

the central bank's concern regarding financial stability, macroeconomic stability and welfare. I obtain the values of those measures from theoretical moments computed at second-order approximation around the steady state. The horisontal axis is the value of feedback parameter in the policy rule (Ψ). The graphs in the figure show that, in the presence of a banking shock, the introduction of macroprudential policy reduces the average volatility of GDP and both loan. In addition, the countercyclical policy also improves social welfare and reduces average default of both the bank and the non-bank loan. The figure indicates that a higher feedback rule provides a higher benefit. However, the marginal benefit decreases with the feedback parameter. Table 3.5 shows more details about the incremental benefit of a macroprudential policy when the feedback rule is set as 0.5. The welfare benefit of the macroprudential policy goes to the entrepreneurs at the expense of households welfare. This finding is consistent with Rubio & Unsal (2017) who found that entrepreneurs are benefited from the active macroprudential policy because it delivers a more stable financial system, but make savers worse because their consumption is not directly affected by financial stability. They also find that the economy is better off with the policy in the aggregate.

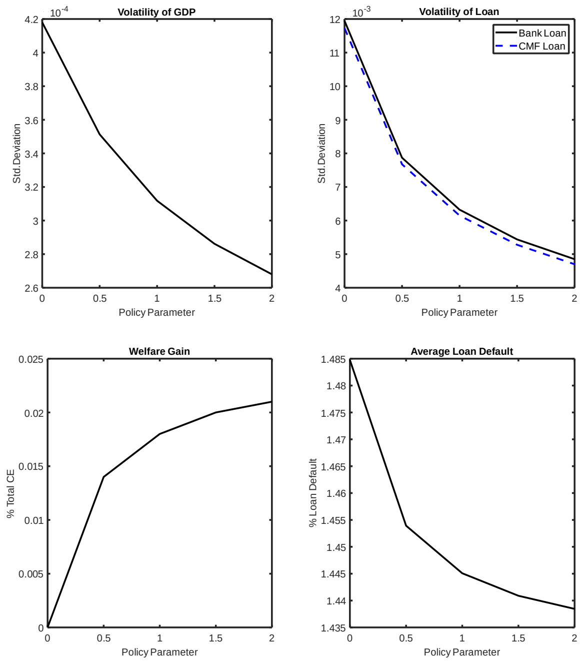


Figure 3.7: Financial Stability and Welfare - Case 1: Banking shock

3.3.4 Case 2: Technology shock

In this subsection, I simulate a one per cent positive shock in technology (ε_A as in equation 3.6) to the economy. As in the literature, I define technology shock as the aggregate productivity shock which affects the production function of all firms. Figure 3.8 shows that a positive aggregate technology shock incur increases in both bank loans (1.2%) and CMF loans (2.6%). A higher level of aggregate productivity generates a higher marginal productivity from the production and increases entrepreneur's markup over input costs (q_t). Therefore, the expected payoff from production increases and entrepreneurs are then encouraged to borrow more from financial intermediaries. As a result, the demand for both bank and non-bank financing increase. It then leads to a higher levels of credit growth, GDP, consumption, and labour working hours. The simulation shows that a positive shock in technology causes a higher average default of both the bank and the CMF loans. At first glance, the direction of the impact seems counterintuitive. However, the transmission of the aggregate productivity shock on average

Table 3.5: Macroprudential Policy Impact - Case 1: Banking Shock

	Without Policy	With Policy (Ψ = 0.5)
Volatility		
GDP	0.0004	0.0004
Bank Loan	0.0119	0.0079
CMF Loan	0.0117	0.0077
Welfare Gain (%CE)		
Household		-0.1472
Entrepreneur		18.9350
Total		0.4459
Average Default (%)		
Bank Loan	1.4943	1.4610
CMF Loan	1.4281	1.4188
Total	1.4848	1.4539

Note : Total welfare gain in terms of consumption equivalent is computed numerically using the formulation derived in Appendix 6.3.1.

default can be explained by the two channels as in Figure 3.9. The first channel is the "production effect" channel. As shown in equation 3.2, a higher average markup over the input cost induces a lower threshold of debt repayment as well as the average lending rate of both the bank and the non-bank loan. The second channel is the "selection effect" channel. A lower debt repayment threshold generates a lower levels of both $\bar{\varepsilon}_{bt}$ and $\bar{\varepsilon}_{ct}$; hence, the expected productivity level during the optimal debt contract decision is low. In this case, both financial intermediaries increase their debt repayment threshold. Those two channels provide opposite direction regarding the effect of technology shock on the lending rate. My simulation with calibrated parameters shows that the selection effect dominates. The risk premium of both intermediaries increases and consequently the average default of loans also increases.

As shown in Figure 3.8, the implementation of a regulation premium does not have a substantial effect on reducing the impact of a temporary technology shock on the real sector. The substitutability between bank borrowing and CMF borrowing makes the regulation premium less potent in decreasing the total loan. Accordingly, the policy does not impact GDP, consumption and working hours. Therefore, the regulation premium has a sizeable impact on the financial structure of the economy (in terms of decreasing the loan to bond ratio), but only have small effects on real macro variables. The impact of increasing regulation premium on default is similar to the discussion in the previous subsection.

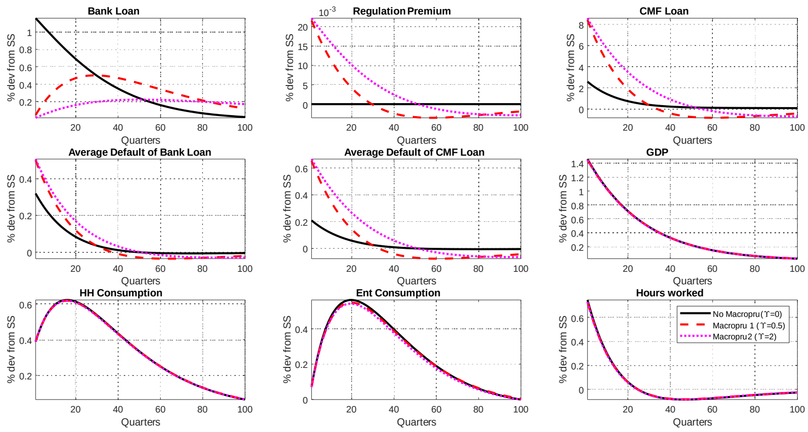


Figure 3.8: Responses to a Positive Technology Shock with and without Regulation Premium

Figure 3.10 presents the impact of policy on the average financial stability and welfare in the presence of a random technology shock. The first panel shows that the impact of the policy on improving output stability is relatively small. Moreover, the second panel shows that although the policy reduces the bank lending volatility, it has an unintended impact which increases the volatility of the non-bank loan. The aggregate financial stability is thus not improving. As a result, the economy faces a social welfare loss. Table 3.6 presents a more detail dissagregation of the impact of policy on the welfare and financial stability measures. The simulation shows that the aggregate default in the case of with policy is relatively higher than that in the case of without policy. This exercise shows that the unintended consequences of policy leakage may exceed the benefit of imposing a regulation premium on the banking sector. Macroprudential policy is not effective to curb the effects of technology shocks. This result is consistent with the studies which find that a countercyclical regulation maybe not effective and that it provides small welfare loss during the presences of technology shock

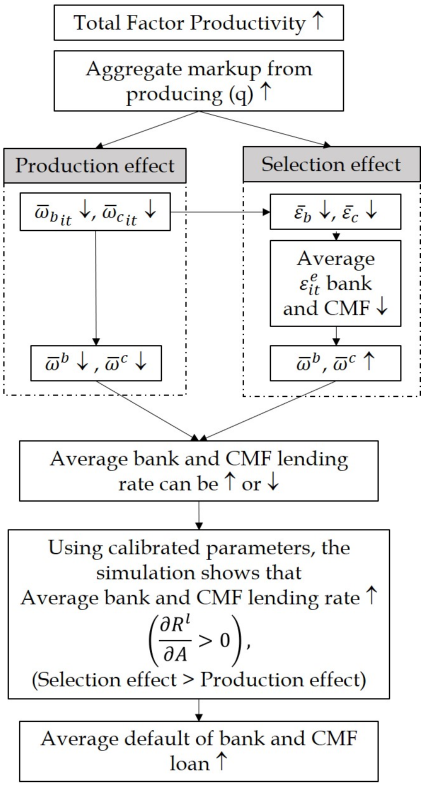


Figure 3.9: Effect of Technology Shock on Average Default

(for example: Angelini *et al.* (2014), Benes & Kumhof (2011)).

3.3.5 Case 3: Uncertainty shock

In this subsection, I simulate the impact of an increase in the uncertainty of the entrepreneur's productivity that realisation is observable once they approach a bank ($\sigma_{2,t}$ as in equation 3.7). An increase in the standard deviation $\sigma_{2,t}$ of ε_2 makes the disclosure of additional information provided by banks more valuable. Thus, it raises the attractiveness of banks as intermediaries and the share of firms who approach banks increases. Moreover, since the distribution of ε_2 has fatter tails, a higher $\sigma_{2,t}$ means that a larger share of firms would experience sufficiently high realisations of ε_2. Therefore, the proportion of firms who proceed with the bank loan increases.[17]

[17] The result is different from Christiano *et al.* (2014). In their paper, an increase in the level of uncertainty (risk shock) leads to a higher probability of low productivity. Then, to cover

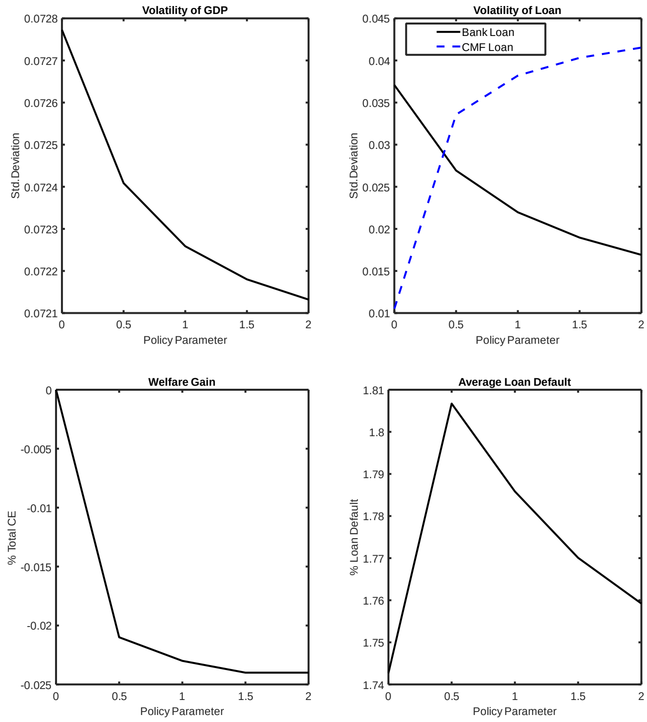


Figure 3.10: Financial Stability and Welfare - Case 2: Technology shock

As shown in Figure 3.11, a 1% increase in the $\sigma_{2,t}$ generates a rise in the bank loan by around 1.2% and a decline in the CMF loan by around 6%. In aggregate, the total loan increases. The increase in the total credit is followed by the rises in GDP, investment, and consumption. The simulation shows that an increase in $\sigma_{2,t}$ leads to a lower average default of both bank and CMF loan. Figure 3.12 offers the explanation of the impact of increasing uncertainty on the loan default with two possible channels. The first channel is the "selection effect". As mentioned before, an increase in $\sigma_{2,t}$ raises the attractiveness of banks as intermediaries so that the threshold $\bar{\varepsilon}_{bt}$ decreases while $\bar{\varepsilon}_{ct}$ increases. Therefore, the average level of ε_{1t} of entrepreneurs who approach the bank can either be lower or higher; on the other hand, the average level of ε_{1t} of entrepreneurs who approach CMF become higher and induce a lower CMF loan rates. The second

the uncertainty, the bank raises the loan rate. Consequently, credit, investment, and output all drop. The difference stems from the different information availability about the uncertainty. In this model, the bank can give information about the ε_2, and the threshold above which the entrepreneur decides to proceed with the loan depends more on the tail of the distribution. Thus, more firms proceed with loans when the tail of the distribution increases.

Table 3.6: Macroprudential Policy Impact - Case 2: TFP Shock

	Without Policy	With Policy (Ψ = 0.5)
Volatility		
GDP	0.0728	0.0724
Bank Loan	0.0371	0.0269
CMF Loan	0.0105	0.0336
Welfare (%CE)		
Household		2.4747
Entrepreneur		-26.8448
Total		-5.6191
Average Default (%)		
Bank Loan	0.4040	0.7275
CMF Loan	14.5458	12.0897
Total	1.7427	1.8067

Note : Total welfare gain in terms of consumption equivalent is computed numerically using the formulation derived in Appendix 6.3.1.

channel is the "distribution effect" that generates higher realisation of ε_2 and thus a lower level of the contract threshold $\overline{\omega}^b$. The simulation shows that the average lending rate and average default of bank loan decreases. Increasing uncertainty also reduce the average default of CMF loan.

The dashed and dotted line in Figure 3.11 shows that the response of the central bank by increasing regulation premium dampen the fluctuation in the bank loans and smoothen the impacts of the uncertainty shock on GDP and consumption. In the case with a medium feedback rule ($\Psi = 0.5$), the maximum increase in the bank loan is reduced by around one third (from 1.2% to 0.4%) and the maximum decline in the CMF loan also reduced by around one third (from -6% to -2%). The implementation of the countercyclical regulation premium also generates a smaller decline in average default of both the bank and the non-bank loans. Furthermore, the presence of macroprudential policy generates a decline in the total cash available for working capital. Therefore, entrepreneurs need to re-optimise wage, real rent of capital, and their composition of labour and capital in the production function. The simulation shows that optimal wage slightly increases while real rent of capital declines after the introduction of macroprudential policy. Consequently, the usage of capital increases, whereas labor working hours decline.[18]

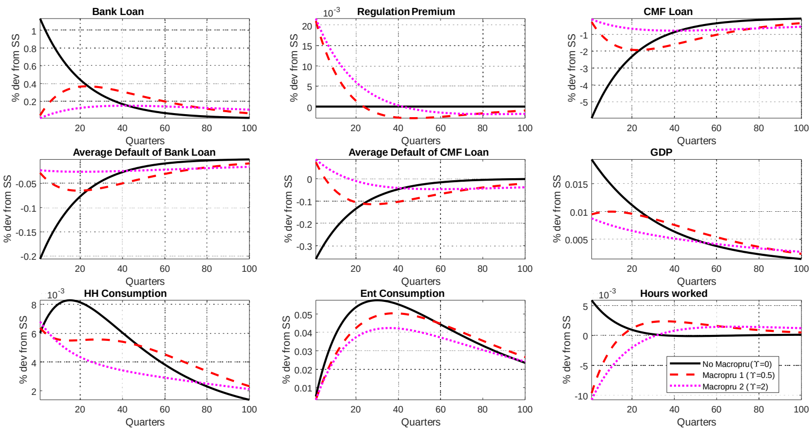


Figure 3.11: Responses to Uncertainty Shock with and without Regulation Premium

Next, I compute the moments of financial stability and welfare measures by using the second-order approximation around the steady states. The first two graphs in Figure 3.13 show that the countercyclical regulation premium reduces the volatility of GDP and the volatility of the bank and the non-bank loans. The introduction of the policy also generates a higher level of social welfare, even though the benefit of financial stability goes to entrepreneurs at the expense of the welfare of households as in the previous case. The last graph shows that the average default increases as the regulation premium is implemented. Table 3.7 presents the values in detail and shows that the rise in total average default is due to an increase in the average default of the CMF loans.

The results from the above subsections show the importance for the central bank to recognise the type of shock that causes the fluctuations in the bank credit before imposing the regulation premium policy because the impact could be contradictory with their objective. Macroprudential policy performs the best in the case of banking shock but generates undesirable impact in the case of technology shock. Figure 3.8 presents the summary of the effect of macroprudential policy

[18]The graph of responses of some other variables are available in Appendix 6.3.1.

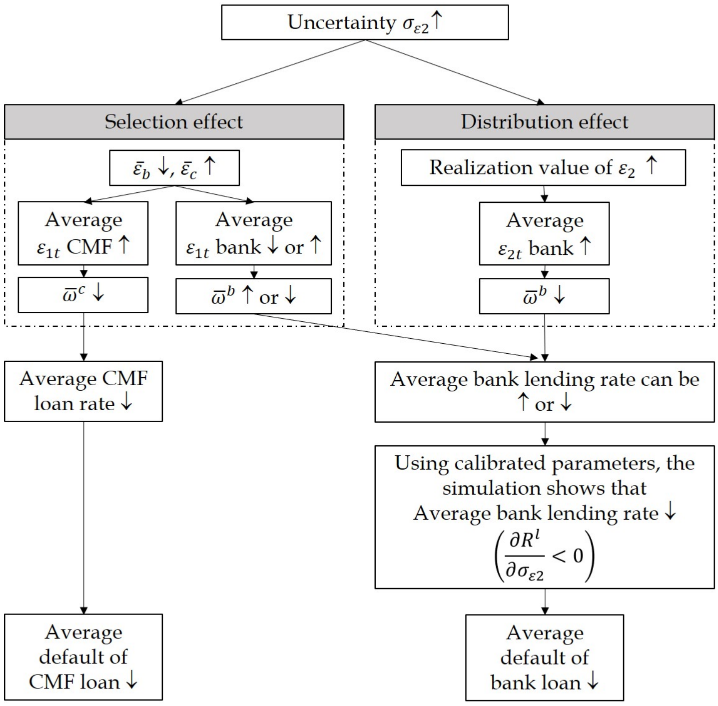


Figure 3.12: Effect of Uncertainty Shock on Average Default

on macroeconomic stability, financial stability and welfare.

3.3.6 Alternative Policy Rule

The previous simulations show that macroprudential policy could reduce social welfare in the case of a technology shock. In this subsection, I consider an alternative macroprudential policy rule by including the non-bank (CMF) credit and evaluate whether this new policy could provide better results regarding welfare under a technology shock. This alternative regulation premium rule is specified as:

$$RP_t = \left[\frac{(l_t^b + l_t^c)}{(l_{t-1}^b + l_{t-1}^c)}\right]^{\Psi} \xi_{RP_t}. \tag{3.15}$$

Under this policy rule, the regulatory premium reacts to the total loan growth.[19]

[19] I have considered to modify the rule into $RP_t = \left[\frac{l_t^b}{l_{t-1}^b}\right]^{\Psi}\left[\frac{l_t^c}{l_{t-1}^c}\right]^{\Psi_2}\xi_{RP_t}$ to differentiate the feedback parameters of bank loan growth and CMF loan growth. However, the results are not stable. Some combination of parameters generates a violation of the Blanchard Kahn condition.

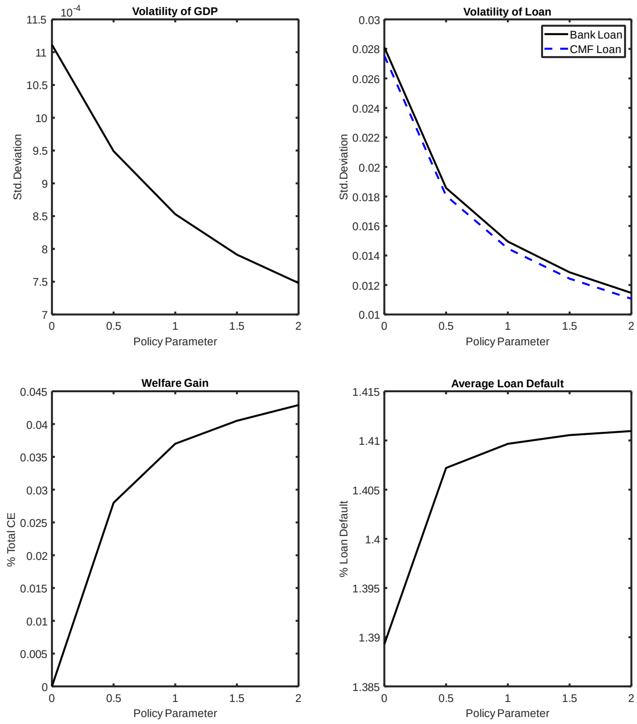


Figure 3.13: Financial Stability and Welfare - Case 3: Uncertainty shock

Figure 3.14 shows that this alternative rule generates a positive gain in welfare. The welfare gain increases with the policy rule parameter. Under this alternative rule, we only need small values of the feedback parameter because the total loan increases significantly under technology shock. Even a feedback parameter with a small value can generate a significant increase in the regulation premium.

The main idea of this new regulation rule is that under the aggregate productivity shock, the regulation premium needs to react more aggresively such that the total loan decreases, even after some of entrepreneurs move from the bank to the non-bank financing (Figure 3.15). This finding is inline with Bengui & Bianchi (2018) who suggest that, in the presence of leakages, the regulator should induce an even tighter regulation on the regulated sector to offset the increase in the borrowing by the unregulated sector.

Table 3.7: Macroprudential Policy Impact - Case 3: Uncertainty Shock

	Without Policy	With Policy (Ψ = 0.5)
Volatility		
GDP	0.0011	0.0009
Bank Loan	0.0281	0.0186
CMF Loan	0.0275	0.0180
Welfare (%CE)		
Household		-0.3226
Entrepreneur		37.5331
Total		1.0260
Average Default (%)		
Bank Loan	1.3918	1.3683
CMF Loan	1.3506	1.7788
Total	1.3893	1.4072

Note : Total welfare gain in terms of consumption equivalent is computed numerically using the formulation derived in Appendix 6.3.1.

Table 3.8: Summary of Macroprudential Policy Benefit

Performance Indicators	Type of Shock		
	Banking Shock	Technology Shock	Uncertainty Shock
Improving Macroeconomic Stability			
GDP Volatility	✓	✓	✓
Bank Loan Volatility	✓	✓	✓
CMF Loan Volatility	✓	×	✓
Improving Financial Stability			
Average Default	✓	×	×
Improving Social Welfare	✓	×	✓

Note : $\surd$ denotes yes whilst $\times$ denotes no.

3.4 Conclusion

Macroprudential policies implementation has been predominantly bank-focused. The possibility of the regulatory arbitrage in the form of substitutability between direct banking finance and market-based credit underscores the need for a broader analysis of the impact of macroprudential policies. As non-bank financial intermediation has taken on an increasing role in the global financial system, the shifting from bank lending to bond issuance become more significant concern for the policymakers.

This chapter examined the effect of macroprudential policy in a framework that accounts for the possible substitution from bank-based financial intermedia-

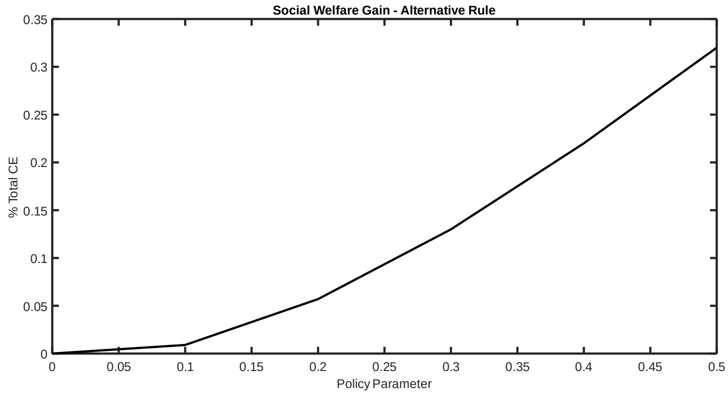


Figure 3.14: Social Welfare Implication - Alternative Policy

tion to non-bank intermediation in response to such policy. Our main results can be summarised in the following way. First, I show that an imperfect substitution between bank finance and market finance emerges when the macroprudential policy is applied only to the banking sector. Second, I show that macroprudential policy has possible unintended consequences of increasing the average default through the cost effect channel and the substitution effect channel. Tightening banking regulation could be transmitted into higher risk premiums of both bank and non-bank loans and increase the average default. Third, I find that the macroprudential policy is more effective in the case of banking shocks in terms of the improvements in long-term financial stability and social welfare. In the case of uncertainty shocks, the macroprudential policy is effective in improving social welfare and reducing the volatility of both the bank and non-bank loans. However, this policy bring about the unintended consequences of increasing the average default of the non-bank loans in this case. Imposing a countercyclical macroprudential policy is not desirable in the case of technology shocks because it increases the bank loan default and reduces social welfare, although the policy generates a lower volatility of the bank loan and GDP. Fourth, I find that a modified rule, which reacts not only to bank credit growth but total credit growth, provides welfare gains in the case of technology shock. Therefore, it is essential that macroprudential authorities take into consideration not only the condition

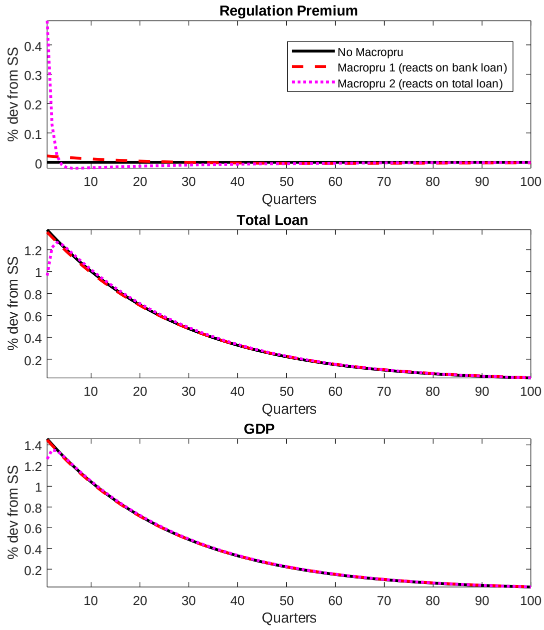


Figure 3.15: Benchmark versus Alternative Policy Rule

of the banking sector but also the credit in the financial markets.

The study I conducted in this chapter could be extended in many directions. For example, we can extend the model to capture the effect of the policy on risk-taking incentives of financial intermediaries. One possible way is by introducing a choice of the amount of credit which depends on the firm's leverage and presents a macroprudential policy in the form of taxes on credits. Banks should then react to that tax by lowering the amount of credit extended for given firm leverage. In such a model, we may see the benefits of macroprudential policy on lowering the occurrence of default.

Chapter 4

Interaction of Reserve Requirement and Liquidity Coverage Ratio

4.1 Introduction

The global financial crisis highlighted the importance of liquidity regulation in the banking sector. Liquidity regulation has been an important instrument used for microprudential, macroprudential, and also monetary policy purposes. From a microprudential perspective, Basel III regulation specifically required a bank to hold sufficient liquidity which measured as Liquidity Coverage Ratio (LCR) and Net Stable Funding Ratio (NSFR).[1] The LCR regulation was implemented progressively from 2015, and the bank has to meet the full LCR requirement in 2019 (BCBS (2013)). The implementation of LCR aims to ensure that the bank has an adequate stock of unencumbered high-quality liquid assets (HQLA) that can be converted into cash easily and immediately in private markets to meet its liquidity needs for a 30-day liquidity stress scenario. The LCR regulation will improve the banking sector's ability to absorb shocks arising from financial and

[1] Basel III regulations on liquidity are sometimes also categorised as macroprudential policy (Nier *et al.* (2018))

economic stress, whatever the source, thus reducing the risk of spillover from the financial sector to the real economy.

On the other hand, macroprudential authorities also use liquidity regulation as part of their macroprudential instruments. Liquidity regulation such as countercyclical reserves requirements can be used to mitigate the systemic risk caused by the credit cycle.[2] Liquidity regulation also plays an essential role in monetary policy. Reserve requirement has been used as part of monetary policy instruments to control the money multiplier in the economy and to strengthen the transmission of policy rate on the interbank market rate. Remuneration on reserves has now also considered as instruments of central bank monetary policy, mainly when the central bank operates in zero lower bound interest rates (Bowman *et al.* (2010)).

Despite the awareness regarding the interaction among liquidity regulations, there have been few studies that examine the interaction of LCR and reserves requirement in a general equilibrium framework.[3] This chapter contributes to the literature of macroprudential liquidity regulation by developing an explicit model of Reserve Requirement and LCR regulation in a medium scale DSGE model with financial frictions. Then, I employ the model to investigate these following research questions:

1. What is the impact of a change in the liquidity regulations and liquidity shocks on bank balance sheets and macroeconomic variables?

2. What is the welfare implication of introducing countercyclical liquidity regulations?

The model extends and modifies the framework of Gerali *et al.* (2010) that includes financial frictions in terms of borrowing constraints, price and wage

[2] Some examples of macroprudential policy instruments regarding liquidity are the countercyclical reserves requirements, macroprudential liquidity buffer, limits on currency mismatch, reserve requirements on foreign currency deposits or foreign liabilities, and many others (Hardy & Hochreiter (2014))

[3] Related literature on liquidity regulation had been discussed in the literature review in section 1.2.4.

frictions. In their model, the bank faces only one regulation: capital requirement. In my model, the bank has to comply with other two liquidity regulations: reserve requirement and liquidity coverage ratio. Parameters of the model are calibrated to match Indonesia data.[4]

The main reason for choosing Indonesia as the basis of the calibration is because their central bank, Bank Indonesia, recently issued a new liquidity-based macroprudential policy regulation called Macroprudential Liquidity Buffer (MPLB). MPLB is a refinement of the secondary reserve requirements that expected to overcome liquidity risk in the banking industry. The central bank recognised the need for a countercyclical liquidity-based macroprudential policy instrument after finding evidence of a procyclical nature of liquidity in banking that could amplify other risks to become systemic risk. The ratio of liquidity requirement in this new regulation is time-varying and act countercyclically to the liquidity risk-taking behaviour in the banking industry (Bank Indonesia (2018)). Therefore, the MPLB is expected to complement the Liquidity Coverage Ratio (LCR) and Net Stable Funding Ratio (NSFR) which are constant and regulated by the financial service authority (Otoritas Jasa Keuangan, OJK).[5]

Considering the introduction of this new regulation on the top of existing reserve requirements, studying the interaction among liquidity regulations and the welfare analysis of countercyclical liquidity regulation in Indonesia become timely and relevant.[6] Furthermore, Indonesia imposes more liquidity requirements in the banking sector compared to other ASEAN emerging countries. Only Indonesia, Cambodia, and Brunei Darussalam utilise reserve requirement policy for macroprudential purposes.[7]

[4] The DSGE model of Bank Indonesia also follows Gerali *et al.* (2010) framework in modelling the banking sector. Therefore this paper also aims to enrich their DSGE model.

[5] The Liquidity Coverage Ratio (LCR) is regulated by OJK Regulation (POJK) No. 42/POJK.03/2015 concerning the Liquidity Coverage Ratio (LCR) for Commercial Banks. The Net Stable Funding Ratio (NSFR) is regulated by OJK Regulation (POJK) No. 50/POJK.03/2017 concerning the Net Stable Funding Ratio (NSFR) for Commercial Banks.

[6] Bank Indonesia (2018) page 209 explicitly mentioned the need to study the interactions between meeting the new policy requirements and the impact on other policies.

[7] The list of liquidity regulations adopted by emerging ASEAN countries based on the IMF Macroprudential Policy Survey Database is available in Appendix 6.4.1.

Indonesia is one of the big emerging market economies (the 7th largest economy in the world in terms of GDP (PPP)) and member of the G20. Banking sector plays a dominant role in the Indonesian financial sector, with asset share around 70% of the financial institutions' total asset so that the issue about banking regulation is crucial for the Indonesian economy as a whole. However, in the context of ASEAN emerging market, the ratio of total assets of the banking sector over nominal GDP in Indonesia is relatively low (54%).[8]

I model the liquidity coverage ratio as in the Cecchetti & Kashyap (2018). Specifically, I assume that high-quality liquid assets consists of risk-free assets (government bonds) and reserves; and I model the 30-day liquidity needs as a fraction of total deposits.[9] The bank chooses endogenously the optimal level of risk-free assets and reserves taking into consideration the expected liquidity risk and the cost of borrowing from central bank in the case of liquidity shortage. I introduce a liquidity shock as a random withdrawal variable to the bank's reserves holdings.[10] Since the impact of liquidity shock is non-linear, I use piecewise linear perturbation method by utilising Occbin toolkit (Guerrieri & Iacoviello (2015)) to capture the possibility of 4 conditions of the bank liquidity position: (i) bank complies with both liquidity regulations, (ii) bank has a liquidity problem to meet reserve requirements (iii) bank has a liquidity problem to meet LCR requirements, and (iv) bank has a liquidity problem to meet both regulations.

The results of this study shows that the effects of a negative liquidity shock on credit, investment and total output are relatively small compared to the impact of a technology shock. The simulation also shows that the impact of changing the two types of liquidity requirements on lending and output are relatively similar. However, lowering the LCR regulation have consequences on the decline of de-

[8]Banking assets as percentage of nominal GDP in 2016: Indonesia: 54%, Philippine 82%, Thailand 127%, Vietnam 146%, Malaysia 199% (Kotanko *et al.* (2017))

[9]The way I model the LCR is similar to the Macroprudential Policy Liquidity Buffer (MPLB) in Indonesia. The difference is that under the MLB regulation, liquid assets that bank has to maintain only include risk-free assets. In my model, I also include reserves to follow the component of the High-Quality Liquid Asset (HQLA) in the LCR regulation.

[10]I follow classical literature on reserve management models as in Freixas & Rochet (2008) Chapter 8 and Baltensperger (1980).

mand for government bonds, so that it has a different impact on taxes, household deposits and bank profit. In the last part, this chapter also found that countercyclical liquidity regulations can improve welfare and slightly reduce the volatility of bank loan.

This chapter is related to Bech & Keister (2017) who study the impact of the introduction of an LCR requirement. They extend the standard model of interbank borrowing/lending to study how the introduction of an LCR requirement affects interbank interest rates, and how it alters the effects of central bank monetary policy operations. However, they use a partial static equilibrium model and focus more on the impact of LCR on the central bank open market operation.

This chapter also relates to several recent works of literature on DSGE model with liquidity regulations. Roger & Vlcek (2011) developed a model to assess the costs of increasing capital and liquidity requirements. The disadvantage of their model is that they assume an always binding reserve requirement constraint so that the bank will maintain reserves equal to the required reserve. However, as stressed by Chadha & Corrado (2012), it is essential to allow banks to choose excess reserve holding endogenously. Chadha & Corrado (2012) find that the reserves holding over the business cycle can reduce the volatility of interest spreads to shocks and can act as a stabiliser in the economy. Therefore, their paper supports the countercyclical policy in liquidity that encourages banks to increase reserve holdings in a boom to limit the expansion of loans and then to release the liquidity in recession preventing a too rapid reduction in loans. Primus (2017) developed a model with endogenous excess reserves as banks voluntarily demand these assets, and there are convex costs associated with holding reserves. However, different from the approach in this chapter, he assumes a perfectly elastic supply of liquidity, so that the bank is not subject to stochastic withdrawal risk which has been an essential aspect in reserve management models. Primus' paper found that the countercyclical reserve requirement rule has no effect on the real variables. However, the model suggests that the combination of an augmented Taylor rule which reacts to excess reserves, and a countercyclical reserve requirement rule, is optimal to mitigate the macroeconomic and financial volatility associated with liquidity shocks.

Furthermore, this chapter relates to a strand of literature on the interaction of capital requirement and liquidity requirement. Covas & Driscoll (2014) study the macroeconomic impact of introducing a minimum liquidity standard for banks on top of existing capital adequacy requirements. In their model, both liquidity and capital constraints are occasionally binding. However, the authors did not differentiate between reserves and other liquid assets in the liquidity requirements and bundled it is as safe assets. Covas & Driscoll (2014) also highlight the importance of using general equilibrium modelling to estimate the macroeconomic impact of the new regulations. The partial equilibrium model provides an overstated effect due to the muting of the adjustment of the loan interest rate and rate of return on securities, a channel that would decrease the impact of the new regulation. Corrado & Schuler (2015) also develop a DSGE model to study the interaction of liquidity requirement and capital requirement. The focus of their model is on the impact of those requirements on macroeconomy through the interbank market lending. The authors use liquidity measure as a proxy for the LCR and NSFR and do not explicitly discuss reserve requirements. De Bandt & Chahad (2016) studies the impact of solvency and liquidity regulations using a large scale DSGE model. Unlike this chapter, the authors use an ad-hoc approach to model the bank's liquidity holding by imposing quadratic adjustment costs when a bank is deviating from the regulations. In general, none of those existing literature that explicitly model both reserve requirement and LCR as in this chapter.

The organisation of the remaining chapter is as follows. Section 2 provides an overview of the economy set-up of this model where I mainly present each agent objective function, the corresponding constraints and the competitive equilibrium conditions. The additional liquidity features that become my main contribution are explained in the subsection regarding banks. Section 3 deals with the calibration of the model. Section 4 presents simulation results. The last section concludes and describes some possible extensions of the research for future research.

4.2 The Model

This chapter employs a simplified medium scale DSGE model with banking sector developed by Gerali *et al.* (2010) and Angelini *et al.* (2014).[11] The population of the economy comprises households, entrepreneurs, monopolistic competitive banks and firms. The representative household is modelled as a patient agent with a high discount factor such that he would save in bank deposits. On the other hand, the representative entrepreneur is modelled as a less patient agent with a lower discount factor so that he would borrow from bank. This model includes price and wage frictions as in Smets & Wouters (2003), and financial frictions in the form of borrowing constraints as in Iacoviello (2005). This section presents the overview of the model and detailedly describes my contribution regarding the introduction of liquidity-related features such as liquidity assets, liquidity shocks and liquidity regulation. Figure 4.1 illustrates the general relationship among agents in the economy. The red dashed lines show the new main components that I add to the basic model.

4.2.1 Households

The representative household (i) maximises the expected utility which depends on current individual consumption $c_t^P(i)$, lagged aggregate consumption c_{t-1}^P, and hours worked $l_t^P(i)$:

$$\max E_0 \sum_{t=0}^{\infty} \beta_P^t \left[(1-a^P) \log \left(c_t^P(i) - a^P c_{t-1}^P \right) - \frac{l_t^P(i)^{1+\phi}}{1+\phi} \right], \tag{4.1}$$

[11] Their model has two types of households that differ in the degrees of impatience. Moreover, they also include the housing good in the household's utility function and budget constraint. In this paper, I model only one type of household (patient household who acts as the lender for the bank), and I do not consider the housing good because it is not the focus of analysis. However, I enhance the model by adding government as the issuer of risk-free assets.

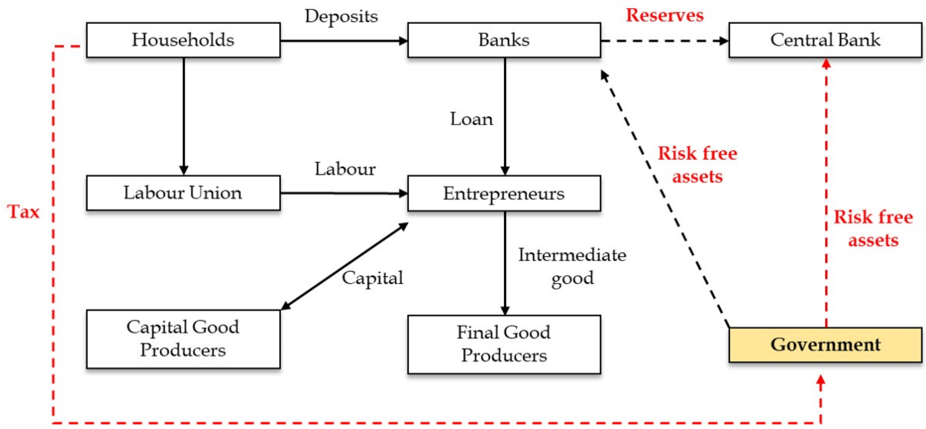


Figure 4.1: Overview of the Model

where β_P denotes the household discount factor, a^P is the external habit coefficient, and ϕ is the inverse of Frisch elasticity[12].

The household choose their consumption and deposits (d_t^P) subject to the following budget constraint (in real terms):

$$c_t^P(i) + d_t^P(i) = w_t^P l_t^P(i) + (1 + R_{t-1}^d) d_{t-1}^P(i)/\pi_t + t_t^P(i). \tag{4.2}$$

The household revenue consists of income from wages (w_t), gross interest income on last period deposits $(1 + R_{t-1}^d) d_{t-1}^P(i)/\pi_t$, and transfers ($t_t^P$) which include a labour union membership net fee, dividends from banks, dividends from firms and a lump-sum tax (τ_t^P) to government. R_t^d denotes the nominal deposit rate, d_t^P is the amount of deposits, and π_t is the inflation rate.

The first-order conditions of the household with respect to consumption and deposits are:[13]

$$\frac{(1 - a^P)}{c_t^P - a^P c_{t-1}^P} = \lambda_t^P, \tag{4.3}$$

[12] Frisch elasticity is the elasticity of labour supply to the wage, given a constant marginal utility of wealth. It measures the substitution effect. The higher the Frisch elasticity, the higher the willingness of the households to work if wages increase.

[13] Because of the presence of labour union and wage frictions, the equation regarding labour supply for a household will be explained in the subsection 4.2.5.

$$\lambda_t^P = \beta_P E_t \left(\lambda_{t+1}^P \frac{(1 + R_t^d)}{\pi_t} \right), \tag{4.4}$$

where λ^P is the Lagrange multiplier for the budget constraint.

4.2.2 Entrepreneurs

Entrepreneurs buy capital and hire labour to produce homogenous intermediate goods (y_t^E). Entrepreneurs buy the capital from capital-good producers at price q_t^k and sell the intermediate goods to the final good producers (retailer) at the wholesale price (P_t^w).

A representative entrepreneur maximises his utility which is a function of the deviation of his own consumption $c_t^E(i)$ from the aggregate lagged group consumption c_{t-1}^E with a^E as the degree of habits formation. β_E^t denotes the discount factor of the entrepreneur.

$$\max E_0 \sum_{t=0}^{\infty} \beta_E^t \log(c_t^E(i) - a^E c_{t-1}^E) \tag{4.5}$$

The entrepreneur chooses consumption c_t^E, physical capital k_t^E, loans from banks b_t^E, and labour inputs $l_t^{E,P}$ taking into account the budget constraint:

$$\begin{aligned} & c_t^E(i) + w_t^P l_t^{E,P}(i) + (1 + R_{t-1}^{bE}) b_{t-1}^E(i)/\pi_t + q_t^k k_t^E(i) \\ = \; & \frac{y_t^E(i)}{x_t} + b_t^E(i) + q_t^k (1 - \delta) k_{t-1}^E(i), \end{aligned} \tag{4.6}$$

and borrowing constraint:

$$(1 + R_t^{bE}) b_t^E(i) \leq m^E E_t \left[q_{t+1}^k k_t^E(i) \pi_{t+1} (1 - \delta) \right]. \tag{4.7}$$

Equation 4.7 limits the maximum value of gross debt repayment below the LTV ratio multiplied by the market value of physical capital (collateral). w_t^P denotes the real wage, R_t^{bE} is the nominal loan rate, and b_t^E is the amount of entrepreneur's loan. $1/x_t = P_t^w / P_t$ is the relative competitive price of the wholesale good produced by the entrepreneur, δ is the depreciation rate of capital, and m^E is the LTV ratio of the entrepreneur loan.

The entrepreneurs follows a Cobb-Douglas production technology function:

$$y_t^E = a_t^E \left[k_{t-1}^E\right]^\alpha \left[l_t^{E,P}\right]^{1-\alpha}, \tag{4.8}$$

where a_t^E is the stochastic total factor productivity, and α is the capital share parameter.

The first-order conditions of the entrepreneur's problem with respect to consumption, borrowing, capital, and labour decisions are:[14]

$$\frac{1}{(c_t^E(i) - a^E c_{t-1}^E)} = \lambda_t^E, \tag{4.9}$$

$$\lambda_t^E = \beta_E E_t \left[\lambda_{t+1}^E \left(\frac{1 + R_t^{bE}}{\pi_{t+1}}\right)\right] + s_t^E \left(1 + R_t^{bE}\right), \tag{4.10}$$

$$\lambda_t^E q_t^k = \beta_E E_t \lambda_{t+1}^E \left[r_{t+1}^k + q_{t+1}^k (1-\delta)\right] + s_t^E m^E E_t \left(q_{t+1}^k \pi_{t+1} (1-\delta)\right), \tag{4.11}$$

$$w_t^P = (1-\alpha) \frac{y_t^E}{l_t^{E,P}} \frac{1}{x_t}, \tag{4.12}$$

where λ^E is the Lagrange multiplier associated with the entrepreneur's budget constraint, s^E is the Langrange multiplier associated with the borrowing constraint, and r_t^k is the marginal productivity of capital given by:

$$r_t^k = \alpha a_t^E \left[k_{t-1}^E\right]^{\alpha-1} \left[\left(l_t^{E,P}\right)\right]^{1-\alpha} \frac{1}{x_t}. \tag{4.13}$$

[14] The detailed derivation of the model is available in Appendix 6.4.3.

4.2.3 Capital Goods Producers

Capital goods producers operate in a perfectly competitive market. They buy capital used in the last-period, $(1-\delta)k_{t-1}$, from the entrepreneurs at price Q_t^k. They produce new capital stock k_t by investing I_t of final goods bought from final good producers at price P_t. The transformation of the final goods into new capital goods is subject to an adjustment cost. The capital good producers then sell the new capital to entrepreneurs at price Q_t^k.

Capital good producers maximise their profits given by (in real terms)[15]:

$$\max E_0 \sum_{t=0}^{\infty} \Lambda_{0,t} \left(q_t^k \left(k_t - (1-\delta)k_{t-1} \right) - i_t \right), \tag{4.14}$$

subject to capital formation technology:

$$k_t - (1-\delta)k_{t-1} = \left[1 - \frac{\kappa_i}{2} \left(\frac{i_t}{i_{t-1}} - 1 \right)^2 \right] i_t, \tag{4.15}$$

where κ_i denotes the cost of adjusting investment. The first-order condition of capital good producers with respect of i_t is given by:

$$\begin{aligned} 1 \quad = \quad & q_t^k \left[\left(1 - \frac{\kappa_i}{2} \left(\frac{i_t}{i_{t-1}} - 1 \right)^2 \right) - \kappa_i \left(\frac{i_t}{i_{t-1}} - 1 \right) \frac{i_t}{i_{t-1}} \right] \\ & + \beta_E E_t \left[\frac{\lambda_{t+1}^E}{\lambda_t^E} q_{t+1}^k \kappa_i \left(\frac{i_{t+1}}{i_t} - 1 \right) \left(\frac{i_{t+1}}{i_t} \right)^2 \right]. \end{aligned} \tag{4.16}$$

4.2.4 Final Goods Producers (Retailers)

Each final good retailer is assumed to be monopolistically competitive. The retailers buy the intermediate good from the entrepreneur at a price P_t^w, convert the intermediate good to a differentiated final good $y_t(j)$ and sell it at retailer price $P_t(j)$. Retailers price their final product with a mark-up taking into account the demand function of the final good which is characterised by the price elasticity

[15] The capital producers value future profits by using the entrepreneur discount factor $\Lambda_{0,t}^E$, which can be defined as $E_0 \Lambda_{t+s} = \beta_E E_t \left(\frac{u_{c,t+s}^E}{u_{c,t}^E} \right) = \beta_E E_t \left(\frac{\lambda_{t+s}^E}{\lambda_t^E} \right)$.

(ε^Y).

Retailers face a quadratic price adjustment cost that make the retail price sticky (with parameter κ_p). This adjustment cost is indexed to a combination of the past and steady-state inflations, with relative weights parameterised by ι_P. Thus, each retailer chooses retail price $P_t(j)$, to maximise:[16]

$$\max_{P_t(j)} E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^P \left[P_t(j) y_t(j) - P_t^w y_t(j) - \frac{\kappa_p}{2} \left(\frac{P_t(j)}{P_{t-1}(j)} - \pi_{t-1}^{\iota_P} \pi^{1-\iota_P} \right)^2 P_t y_t \right], \tag{4.17}$$

subject to the demand function:

$$y_t(j) = \left(\frac{P_t(j)}{P_t} \right)^{-\varepsilon^y} y_t. \tag{4.18}$$

The first-order condition of retailers after imposing symmetric equilibrium is given by:

$$\begin{aligned} & -1 + \varepsilon^y - \frac{\varepsilon^y}{x_t} + \kappa_p \left(\pi_t - \pi_{t-1}^{\iota_P} \pi^{1-\iota_{wP}} \right) \pi_t \\ = \quad & \beta_P E_t \left[\frac{\lambda_{t+1}^P}{\lambda_t^{EP}} \kappa_p \left(\pi_{t+1} - \pi_t^{\iota_P} \pi^{1-\iota_P} \right) \frac{\pi_{t+1}^2 y_{t+1}}{y_t} \right]. \end{aligned} \tag{4.19}$$

4.2.5 Labour Union

Households supply differentiated labour input to a "labour union" (or a labour packer). The labour union bundles the differentiated labour input into a homogeneous labour input, and then sell it to entrepreneurs for production. The labour union sets nominal wages for each type of labour $W_t^P(m)$ by maximising their utility, with the constraints of a labour demand function and a quadratic wage adjustment cost (with parameter κ_w). The adjustment cost is indexed to a weighted average of lagged wage and steady-state inflation. ι_w denotes the relative weights parameter. The labour union charges each member of the household

[16] The retailers value future profits by using the patient discount factor $\Lambda_{0,t}^P$, which can be defined as $E_0 \Lambda_{t+s} = \beta_P E_t \left(\frac{u_{c,t+s}^P}{u_{c,t}^P} \right) = \beta_P E_t \left(\frac{\lambda_{t+s}^P}{\lambda_t^P} \right)$.

a net membership fee to cover adjustment costs.

The labour union's objective function is:

$$\max E_0 \sum_{t=0}^{\infty} \beta_P^t \left\{ \begin{array}{c} U_{c_t^P(i,m)} \left[\frac{W_t^P(m)}{P_t} l_t^P(i,m) - \frac{\kappa_w}{2} \left(\frac{W_t^P(m)}{W_{t-1}^P(m)} - \pi_{t-1}^{\iota_w} \pi^{1-\iota_w} \right)^2 \frac{W_t^P}{P_t} \right] \\ - \frac{l_t^P(i,m)^{1+\phi}}{1+\phi} \end{array} \right\}, \tag{4.20}$$

subject to a downward-sloping demand for each variety of labour that depend on the aggregate labour demand and the relative wage of variety labour as follows:

$$l_t^P(i,m) = l_t^P(m) = \left(\frac{W_t^P(m)}{W_t^P} \right)^{-\varepsilon^l} l_t^P. \tag{4.21}$$

The parameter ε^l measures the elasticity of substitution among different types of labour and it is assumed to be greater than one so that different types of labour are substitutes.

The first-order condition of the labour union in a symmetric equilibrium provides the labour supply function for a household is as follows:

$$\begin{aligned} \kappa_w \left(\pi_t^{wP} - \pi_{t-1}^{\iota_w} \pi^{1-\iota_w} \right) \pi_t^{wP} &= \beta_P E_t \left(\frac{\lambda_{t+1}^P}{\lambda_t^P} \kappa_w \left(\pi_{t+1}^{wP} - \pi_t^{\iota_w} \pi^{1-\iota_w} \right) \frac{\pi_{t+1}^{wP^2}}{\pi_{t+1}} \right) \\ &\quad + \left(l_t^P (1-\varepsilon^l) \right) + \frac{\varepsilon^l l_t^{P^{1+\phi}}}{\lambda_t^P w_t^P}. \end{aligned} \tag{4.22}$$

where the nominal wage inflation is denoted by $\pi_t^{wP} = \frac{w_t^P}{w_{t-1}^P} \pi_t$.

4.2.6 Banks

The banks have three different units in conducting their intermediation activities: the deposit unit, the loan unit and the wholesale unit. The deposit unit is responsible for raising differentiated deposits from patient households. The loan unit is responsible for giving out differentiated loans to entrepreneurs. Banks are assumed to operate in a monopolistic competitive deposit and loan markets. Thus, the loan and deposit units have a power to adjust rates on loans and deposits subject to both the demand from entrepreneurs and adjustment costs. The wholesale unit receives funds from the deposit unit and issues wholesale credits to the loan unit. The wholesale unit is responsible for managing the bank's balance sheet composition to maximise profit, subject to the capital and liquidity regulation.

I expand the models of Gerali *et al.* (2010) and Angelini *et al.* (2014) by including the liquid assets in the bank balance sheet. The asset side of balance sheets consists of two types of liquid assets: (i) reserves in the central bank and (ii) government bonds as risk-free assets, and one type of non-liquid assets: loan to entrepreneurs. On the liability side, the wholesale unit manages deposits and bank capital.

The bank has to obey capital regulation and liquidity regulations imposed by the central bank. I follow Angelini *et al.* (2014) to model the cost that banks incur when they deviate from the capital adequacy ratio requirement. I add two types of liquidity regulations in the model: reserve requirements and Liquidity Coverage Ratio (LCR)[17]. In the case of violation of those requirements, the bank has to borrow from the central bank and pay back in the next period at a penalty rate. Since the model only includes one-period type of assets, I model the liquidity coverage ratio in a simple way. High liquidity assets only include risk-free assets (government bonds) and reserves, whilst the 30-day liquidity needs are assumed to be proportional to the value of deposits.

Deposit unit

The retail deposit branch of bank j collects deposits $d_t^P(j)$ from households and passes the funds on to the wholesale unit, which remunerates them at rate R_t in the next period. The retail deposit branch maximises profit by setting deposit rate $R_t^d(j)$, considering interest rate adjustment costs (with adjustment parameter

[17] The way I model the LCR is similar to the Macroprudential Liquidity Buffer (MLB) that has been implemented in Indonesia since March 2018. The difference is that under the MLB regulation, liquid assets that bank has to maintain only include risk-free assets. In my model, I also include reserves to follow the component of the High-Quality Liquid Asset (HQLA) in the LCR regulation.

$= \kappa_d$). The deposit unit solves the following problem (in real terms):

$$\Pi^d = \max_{R_t^d(j)} E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^P \begin{bmatrix} R_{t-1} \frac{D_{t-1}(j)}{\pi_t} - R_{t-1}^d(j) \frac{d_{t-1}^P(j)}{\pi_t} \\ -\frac{\kappa_d}{2} \left(\frac{R_t^d(j)}{R_{t-1}^d(j)} - 1 \right)^2 R_t^d d_t \end{bmatrix}, \tag{4.23}$$

subject to an upward-sloping demand of deposits for each bank, that depend on the aggregate deposit demand and the relative deposit rate of bank j :

$$d_t^P(j) = \left(\frac{R_t^d(j)}{R_t^d} \right)^{-\varepsilon^d} d_t, \tag{4.24}$$

where d_t is the aggregate deposit collected by the deposit units of all banks and ε^d denotes the elasticity of substitution of deposits demand among banks.[18] The total fund received by the wholesale unit of bank j ($D_t(j)$) is equal to the deposits collected by the deposit unit of bank j :

$$D_t(j) = d_t^P(j). \tag{4.25}$$

With a symmetry equilibrium, the first-order condition for the deposit interest rate setting is given by:[19]

$$\begin{aligned} \varepsilon^d \frac{R_t}{R_t^d} &= -1 + \varepsilon^d - \left(1 + R_t^d\right) \kappa_d \left(\frac{R_t^d}{R_{t-1}^d} - 1 \right) \frac{R_t^d}{R_{t-1}^d} \\ &\quad + E_t \left[\pi_{t+1} \kappa_d \left(\frac{R_{t+1}^d}{R_t^d} - 1 \right) \frac{d_{t+1}}{d_t} \left(\frac{R_{t+1}^d}{R_t^d} \right)^2 \right]. \end{aligned} \tag{4.26}$$

Loan unit

The retail loan branch of bank j obtains wholesale loans $B_t(j)$ from the wholesale units at rate R_t^b that will be paid in the next period. The loan unit differentiates

[18] We can also interpret $\frac{\varepsilon^d}{\varepsilon^d - 1}$ as the markdown on the deposit rate in steady-state.

[19] Detailed derivation is available in Appendix 6.4.3. In the derivation, I use the Euler equation of households to substitute $E_t \frac{\Lambda_{0,t+1}^P}{\pi_{t+1}} = \frac{1}{1+R_t^d}$. The result is slightly different with the Angelini *et al.* (2014). The reason is that I consider that the interest payment is paid/received in the next period. Some of the terms are therefore should be discounted at deposit rate.

the loans and lend them to entrepreneurs $b_t^E(j)$ at rate $R_t^{bE}(j)$.The loan branch maximises profit by setting the lending rate, taking into consideration the loan rate adjustment costs (with adjustment parameter κ_{bE}), and the loan demand. The loan branch problem at time t is given by (in real terms):

$$\Pi^l = \max_{R_t^{bE}(j)} \sum_{t=0}^{\infty} \Lambda_{0,t}^P \left[\begin{array}{c} R_{t-1}^{bE}(j) \frac{b_{t-1}^E(j)}{\pi_t} - R_{t-1}^b \frac{B_{t-1}(j)}{\pi_t} \\ -\frac{\kappa_{bE}}{2} \left(\frac{R_t^{bE}(j)}{R_{t-1}^{bE}(j)} - 1 \right)^2 R_t^{bE} b_t^E \end{array} \right], \tag{4.27}$$

subject to following the demand function and identity equation:

$$b_t^E(j) = \left(\frac{R_t^{bE}(j)}{R_t^{bE}} \right)^{-\varepsilon^{bE}} b_t^E, \tag{4.28}$$

$$B_t(j) = b_t^E(j), \tag{4.29}$$

where ε^{bE}denotes the elasticity of substitution of each type of demand for loan among banks.

The first-order condition for entrepreneurs' loan interest rate (after imposing the symmetry equilibrium setting) is:

$$\begin{aligned} \varepsilon^{bE} \frac{R_t^b}{R_t^{bE}} &= \varepsilon^{bE} - 1 \\ &+ \left(1 + R_t^d\right) \kappa_{bE} \left(\frac{R_t^{bE}}{R_{t-1}^{bE}} - 1 \right) \frac{R_t^{bE}}{R_{t-1}^{bE}} \\ &- E_t \left[\pi_{t+1} \kappa_{bE} \left(\frac{R_{t+1}^{bE}}{R_t^{bE}} - 1 \right) \frac{b_{t+1}^E}{b_t^E} \frac{R_{t+1}^{bE^2}}{R_t^{bE2}} \right]. \end{aligned} \tag{4.30}$$

Wholesale unit

I expand the components of the wholesale bank's balance sheet to include the liquid assets as presented in Table 4.1. The bank holds some assets in the forms of reserves in the central bank (RV) and risk-free government bonds (RF^b). Both assets are liquid since they can be easily converted to cash in the case of deposit withdrawal. In contrast, loans are illiquid so they cannot be liquidated easily. Each wholesale branch manages the composition of the balance sheet to maximise profit subject to capital and liquidity regulations.

Table 4.1: Bank Balance Sheet

Assets	**Liabilities**
Liquid Assets	Deposits (D)
- Reserves (RV)	
- Risk Free Assets (RF^b)	
Non-liquid Assets	Equity (K^b)
- Loans (B)	

Capital Management As in Angelini *et al.* (2014), the bank aims to keep the capital to weighted-risk asset ratio (CAR) close to an exogenous target v_t, which can be thought as a capital requirement imposed by the regulator. The bank pays a quadratic cost whenever their CAR deviate from the target value:[20]

$$\frac{\kappa_{Kb}}{2}\left(\frac{K_t^b}{w^L B_t^E} - v_t\right)^2 K_t^b, \tag{4.31}$$

where κ_{Kb} is the cost parameter, and w^L is the average of risk weight of loans.

The bank capital is adjusted through bank investment. I assume that the investment cannot be higher than profit j_t^b:

$$K_t^b = (1-\delta_b)\frac{K_{t-1}^b}{\pi_t} + j_t^b. \tag{4.32}$$

Liquidity Management To capture liquidity management in the wholesale banking, I introduce a stochastic liquidity shock in the model. The liquidity shock is modelled as a random withdrawal ε_t^{liq} to the bank's reserve holdings. The shock is symmetrically distributed according to a cumulative distribution function F with mean $\mu^{\varepsilon_{liq}}$ and standard deviation $s^{\varepsilon_{liq}}$. When ε_t^{liq} is positive

[20]Angelini *et al.* (2014) use a more detailed formula: $\frac{\kappa_{Kb}}{2}\left(\frac{K_t^b}{w_t^E B_t^E + w_t^H B_t^H} - v_t\right)^2 K_t^b$, where w_t^E is the risk weight for entrepeneurs loans and w_t^H is the risk weight for household loans. Both w_t^E and w_t^H vary with the business cycle. In this paper, I simplify the denominator since I do not have household loan and assume a constant risk weight w^L.

(negative), the bank receives unexpected outflows (inflows) of funds.

The bank faces two types of liquidity regulations:

1. Reserve Requirement (RR)

   The bank's reserves holdings at the end of the period, taking into account the liquidity withdrawal, have to be higher or equal to the reserve requirement. As in practice, the central bank sets the reserve requirement, and the value is proportional (η_t) to the bank's deposit:

$$RV_t - \varepsilon_t^{liq} D_t \geq \eta_t D_t. \tag{4.33}$$

   The central bank pays the remuneration R_t^{RR} only to the required reserves $\eta_t D_t$. The bank does not get any remuneration for excess reserve $ER_t = (RV_t - \eta D_t)$. If the liquidity withdrawal ($\varepsilon_t^{liq} D_t$) exceeds the amount of bank excess reserves, the bank faces a reserves shortage and has to borrow X_t^{RR} from the central bank.[21] The bank repay the loan at a penalty rate $R_t^{x1} > R_t$ in the next period. The amount of reserves shortage is given by:

$$X_t^{RR} = \max\left\{\varepsilon_t^{liq} D_t - (RV_t - \eta_t D_t), 0\right\}. \tag{4.34}$$

   I assume that the liquidity withdrawal cannot exceed the available deposits ($\varepsilon_t^{liq} \leq 1$) and the parameters in the liquidity shock distribution function are constant.[22] Therefore, the expectation of reserves shortage can be written as follows:

$$E(X_t^{RR}) = \int_{\frac{RV_t - \eta_t D_t}{D_t}}^{1} (\varepsilon^{liq} D_t - RV_t + \eta_t D_t) f(\varepsilon^{liq}) d\varepsilon^{liq}. \tag{4.35}$$

2. Liquidity Coverage Ratio (LCR)

[21] There is no interbank market in this model, so banks only borrow from the central bank in the case of liquidity shortage.

[22] I will relax the assumption regarding constant parameters of the liquidity shock distribution in section 4.5.5. There, I will assume that the mean of liquidity shock distribution is time varying.

The objective of LCR requirement as mentioned in BCBS (2013) is to ensure that banks have adequate stocks of unencumbered high-quality liquid assets (HQLA) that can be converted easily and immediately into cash in private markets to meet their liquidity needs for a 30 calendar day liquidity stress scenario. Following Cecchetti & Kashyap (2018), I model the LCR denominator as a fraction of deposits .[23] Furthermore, as in Bech & Keister (2017), my definition of high liquidity assets only includes reserves and risk free-assets (government bonds).[24]. The bank receives R^{RF} as the interest for holding the government bond.

The bank liquidity position has to meet the LCR requirement as follows:

$$\frac{HQLA_t}{\vartheta_t D_t} \geq 100\%, \tag{4.36}$$

which is equivalent to the following expression:

$$RF_t + RV_t - \varepsilon_t^{liq} D_t \geq \vartheta_t D_t. \tag{4.37}$$

ϑ_t is the average run-off rate of deposits that is also part of the LCR regulation.

As in the case of reserves requirement, if the withdrawal ($\varepsilon_t^{liq} D_t$) on reserves make the LCR position of the bank declines to below 100%, the bank faces an LCR shortage and has to borrow X_t^{LCR} from the central bank. The bank has to pay the loan at a penalty rate $R_t^{x2} > R_t$ in the next period.

[23] The formulation for LCR in Cecchetti & Kashyap (2018) is $R \geq \alpha D + \omega OBSA$, where R denotes high-quality liquid assets which includes reserves, D denotes deposits, and $OBSA$ denotes the total of the off-balance sheet assets. α denotes the average run-off rate on deposits, and ω is the average run-off rate on off-balance sheets item. Without the off-balance sheet items, my formulation of the LCR is equivalent to $R \geq \alpha D$.

[24] In the Basel III documents, HQLA that can be categorised as Level 1 assets are limited to: (i) coins and banknotes; (ii) central bank reserves (including required reserves), (iii) marketable securities representing claims on or guaranteed by sovereigns, central banks, PSEs, the Bank for International Settlements, the International Monetary Fund, the European Central Bank and European Community, or multilateral development banks.

The definition of LCR in this paper is rather simple since the model only has one-period government bonds and abstracts from other forms of the central-bank money (cash and notes).

This approach is similar to Bech & Keister (2017). The amount of LCR shortage is given by:

$$X_t^{LCR} = \max\left\{\varepsilon_t^{liq} D_t - (RF_t + RV_t - \vartheta_t D_t), 0\right\}. \tag{4.38}$$

The expectation of the LCR shortage can be written as follows:

$$E(X_t^{LCR}) = \int_{\frac{RF_t + RV_t - \vartheta_t D_t}{D_t}}^{1} \left(\varepsilon^{liq} D_t - (RF_t + RV_t - \vartheta_t D_t)\right) f(\varepsilon^{liq}) d\varepsilon^{liq}. \tag{4.39}$$

Penalty rates (R_t^{x1} and R_t^{x2}) are identical and assumed to be proportional to the policy rate:[25]

$$R_t^{x1} = R_t^{x2} = \Omega^{RX}.R_t. \tag{4.40}$$

Profit Maximisation The wholesale unit maximises the sum of discounted real cash flow by choosing loans, deposits, reserves and risk-free assets, taking into account the cost of deviating from the capital requirement and the cost of liquidity shortage:

$$\Pi^W = \max_{\{B_t, D_t, RV_t, RF_t\}} E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^P \begin{bmatrix} (1 + R_{t-1}^{RF}) \frac{RF_{t-1}}{\pi_t} - RF_t + \frac{RV_{t-1}}{\pi_t} \\ + R_{t-1}^{RR} \eta_{t-1} \frac{D_{t-1}}{\pi_t} - RV_t \\ + \left(1 + R_{t-1}^B\right) \frac{B_{t-1}}{\pi_t} - B_t \\ + D_t - (1 + R_{t-1}^d) \frac{D_{t-1}}{\pi_t} \\ + K_t^b - \frac{K_{t-1}^b}{\pi_t} \\ - \frac{\kappa_{Kb}}{2} \left(\frac{K_t^b}{w^L B_t} - v_t\right)^2 K_t^b - \frac{penalty_{t-1}}{\pi_t} \end{bmatrix}, \tag{4.41}$$

subject to the bank balance sheet constraint:

$$B_t + RV_t + RF_t = D_t + K_t^b. \tag{4.42}$$

The cost of liquidity shortage is defined as the total of both reserves shortage

[25] This assumption is in line with the practice in Indonesia where the central bank's discount window rate varies with the policy rate.

and LCR shortage:

$$penalty_t = R_t^{x1} X_t^{RR} + R_t^{x2} X_t^{LCR}.$$

By using the constraints, we can rewrite the problem as:

$$\Pi^W = \max_{\{B_t, D_t, RV_t RF_t\}} E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^P \begin{bmatrix} R_{t-1}^{RF} \frac{RF_{t-1}}{\pi_t} + R_{t-1}^b \frac{B_{t-1}}{\pi_t} - R_{t-1} \frac{D_{t-1}}{\pi_t} \\ -\frac{\kappa_{Kb}}{2} \left(\frac{K_t^b}{w^L B_t} - v_t \right)^2 K_t^b \\ +R_{t-1}^{RR} \eta_{t-1} \frac{D_{t-1}}{\pi_t} \\ -R_{t-1}^{x1} \frac{X_{t-1}^{RR}}{\pi_t} - R_{t-1}^{x2} \frac{X_{t-1}^{LCR}}{\pi_t} \end{bmatrix} \quad (4.43)$$

The first-order conditions of banks present the optimal choices between giving loan and holding liquid assets as follows:

$$R_t^{RF} = R_t^{x1} \int_{\frac{RV_t - \eta_t D_t}{D_t}}^{1} .f(\varepsilon^{liq}) d\varepsilon^{liq}, \quad (4.44)$$

$$\begin{aligned} R_t^b \quad = \quad & R_t - R_t^{RR} \eta_t - (1 + R_t^d) \kappa_{Kb} \left(\frac{K_t^b}{w^L B_t} - v_t \right) K_t^b \frac{K_t^b}{w^L B_t^2} \\ & + R_t^{x1} \eta_t \int_{\frac{RV_t - \eta_t D_t}{D_t}}^{1} f(\varepsilon^{liq}) d\varepsilon^{liq} + R_t^{x1} \int_{\frac{RV_t - \eta_t D_t}{D_t}}^{1} \varepsilon^{liq} f(\varepsilon^{liq}) d\varepsilon^{liq} \\ & + R_t^{x2} \int_{\frac{RF_t + RV_t - \vartheta_t D_t}{D_t}}^{1} \varepsilon^{liq} f(\varepsilon^{liq}) d\varepsilon^{liq} \\ & + R_t^{x2} \vartheta_t \int_{\frac{RF_t + RV_t - \vartheta_t D_t}{D_t}}^{1} f(\varepsilon^{liq}) d\varepsilon^{liq}, \end{aligned} \quad (4.45)$$

$$R_t^{RF} + R_t^{x2} \int_{\frac{RF_t + RV_t - \vartheta_t D_t}{D_t}}^{1} .f(\varepsilon^{liq}) d\varepsilon^{liq} = R_t^b + (1 + R_t^d) \kappa_{Kb} \left(\frac{K_t^b}{w^L B_t} - v_t \right) K_t^b \frac{K_t^b}{w^L B_t^2}. \quad (4.46)$$

Total Bank Profit

The total bank profits are the sum of net earnings from the wholesale unit, the deposit unit and the loan unit as follows:

$$\begin{aligned} j_t^b \;=\; & R_{t-1}^{RF} RF_{t-1}^b \frac{1}{\pi_t} + R_{t-1}^{RR} \eta D_{t-1} \frac{1}{\pi_t} + R_{t-1}^{bE} B_{t-1}^E \frac{1}{\pi_t} - R_{t-1}^d D_{t-1} \frac{1}{\pi_t} \\ & - \frac{\kappa_d}{2} \left(\frac{R_t^d}{R_{t-1}^d} - 1 \right)^2 R_t^d D_t - \frac{\kappa_{bE}}{2} \left(\frac{R_t^{bE}}{R_{t-1}^{bE}} - 1 \right)^2 R_t^{bE} B_t^E \\ & - \frac{\kappa_{Kb}}{2} \left(\frac{K_t^b}{w^L B_t} - v_t \right)^2 K_t^b \\ & - penalty_{t-1} \frac{1}{\pi_t} \end{aligned} \tag{4.47}$$

Since the realised penalty cost involves a nonlinear maximum function, I use the Occbin toolkit developed by Guerrieri & Iacoviello (2015) which applies a piecewise linear perturbation approach to solve the dynamic models.[26] There are four regimes of the bank's liquidity position that affects the bank's need to borrow from the central bank. The first one is the reference regime, and the other three are the alternate regimes with conditions listed in Table 4.2:[27]

Table 4.2: Liquidity Condition Regimes

Regimes	$\mathbf{X}^{RR}$	$\mathbf{X}^{LCR}$	Condition
1: Reference	0	0	Bank can meet both RR and LCR, penalty = 0
2: Alternate 1	> 0	0	Bank can't meet RR, pay penalty cost $R_t^{x1} X_t^{RR}$
3: Alternate 2	0	> 0	Bank can't meet LCR, pay penalty cost $R_t^{x2} X_t^{LCR}$
4: Alternate 3	> 0	> 0	Bank can't meet both RR and LCR, pay penalty cost $R_t^{x1} X_t^{RR} + R_t^{x2} X_t^{LCR}$

[26] One of the limitations of this method is that it cannot capture precautionary behaviour linked to the possibility that a constraint may become binding in the future, as a result of shocks yet unrealised. Thus, in the model, I can not capture the precautionary behaviour of banks regarding the potential liquidity risk in the future.

[27] One limitation of this approach is that the total amount that the bank borrows from central bank in the regime 4 exceed their actual needs. The actual needs is $X = \max\{X^{RR}, X^{LCR}\}$.To remove this limitation, we will need a more complicated model because more regime needed in the Occbin code.

4.2.7 Central Bank

Budget Constraint As in Hall & Reis (2015), the central bank issues additional reserves to fund the sum of: (1) real interest on the previous level of required reserves, (2) net government bond purchases (RF_t^{cb}), and (3) transfer/seignorage to the government (τ_t^{cb}). The funding needs are reduced by: (4) interest on last period's bond holdings, and (5) interest payment from the commercial bank loan in the case of liquidity problem (penalty):

$$\begin{aligned} RV_t - RV_{t-1}/\pi_t &= R_{t-1}^{RR}\eta_{t-1}D_{t-1}\frac{1}{\pi_t} + RF_t^{cb} + \tau_t^{cb} - (1 + R_{t-1}^{RF})RF_{t-1}^{cb}/\pi_t \\ &\quad -penalty_{t-1}\frac{1}{\pi_t}. \end{aligned} \tag{4.48}$$

As in Chadha & Corrado (2012) the central bank balance sheet position is given by[28]:

$$RV_t = RF_t^{cb}. \tag{4.49}$$

Interest Rate Policy The central bank sets the policy rate according to a Taylor-rule with the following specification:

$$(1 + R_t) = \left(1 + \overline{R}\right)^{(1-\rho_R)} (1 + R_{t-1})^{\rho_R} \left(\frac{\pi_t}{\overline{\pi}}\right)^{\chi_\pi(1-\rho_R)} \left(\frac{Y_t^P}{Y_{t-1}^P}\right)^{\chi_Y(1-\rho_R)} \varepsilon_t^{MP}, \tag{4.50}$$

where ρ_R denotes the inertia in the adjustment of policy rate, χ_π denotes the response to deviations of inflation from target, and χ_Y denotes the the response to output growth. ε_t^{MP} denotes monetary policy shock.

The central bank also sets the remuneration rate for required reserves and the penalty rate for the bank borrowing in the case of RR or LCR liquidity shortage. I assume that both the remuneration rate for required reserves and penalty rates are proportional to the policy rate, with parameter $\Omega^{RRR}, \Omega^{RX1}, \Omega^{RX2}$ as in equation 4.40.

[28] This equation is needed to avoid multiple solutions of RF_t^{cb} and τ^{cb} in the steady state.

Financial Sector Policy The central bank sets regulations regarding LCR, RR η_t and Capital Requirements Ratio υ_t. By equation 4.37, we can use ϑ_t to denote the LCR regulation. We can interpret the changes in ϑ_t as the changes in the LCR regulation either in the form of new supervisory run-off rates or in the form of new level of minimum LCR ratio. In the basic model, I use simple policy rules for all financial regulations:

$$\eta_t = \overline{\eta}^{(1-\rho_\eta)} \eta_{t-1}^{\rho_\eta} \varepsilon_t^{\eta}, \tag{4.51}$$

$$\vartheta_t = \overline{\vartheta}^{(1-\rho_\vartheta)} \vartheta_{t-1}^{\rho_\vartheta} \varepsilon_t^{\vartheta}, \tag{4.52}$$

$$\upsilon_t = \overline{\upsilon}^{(1-\rho_\upsilon)} \upsilon_{t-1}^{\rho_\upsilon} \varepsilon_t^{\upsilon}, \tag{4.53}$$

where ρ_η, ρ_ϑ and ρ_υ denote the inertia in the adjustment of the RR, the LCR and the capital requirement respectively. ε_t^{η}, $\varepsilon_t^{\vartheta}$ and ε_t^{υ} denote the RR, the LCR and the capital requirement shock. In the further analysis (subsection 4.4.5), I modify the RR and the LCR policy rule to include the countercyclical aspect of financial regulation.

4.2.8 Government.

The government purchases final goods (G_t) and obtains funds from the lump-sum taxes, the issuance of government bond (RF^T), and the transfers from central bank (τ_t^{cb}). The government budget constraint in real terms is:[29]

$$RF_t^T = G_t + (1 + R_{t-1}^{RF}) RF_{t-1}^T / \pi_t - \tau_t^{cb} - \tau_t. \tag{4.54}$$

To simplify the model, I assume a constant ratio of the government spending

[29] I do not have government bond price in the equation because the government bond in this model is only a one-period bond that give return R^{RF} in the next period. This is constrast with Hall & Reis (2015) who use a long-term government bond.

to the total output as follows:

$$G_t = \Gamma Y_t. \tag{4.55}$$

Furthermore, I assume that the risk-free interest rate varies proportionally with the policy rate:

$$R_t^{RF} = \Omega^{RF} R_t. \tag{4.56}$$

4.2.9 Market Clearing

Market clearing conditions in the good market is:

$$\begin{aligned} Y_t &= C_t + q_t^k i_t + \delta_b \frac{K_{t-1}^b}{\pi_t} + G_t \\ &\quad + \kappa_t^{firms} + \kappa_t^{bank}, \end{aligned} \tag{4.57}$$

where

$$C_t = c_t^P + c_t^E, \tag{4.58}$$

κ_t^{firms} denotes the total adjustment costs in the production sector defined by:

$$\begin{aligned} \kappa_t^{firms} &= \frac{\kappa_P}{2}(\pi_t - \pi_{t-1}^{\iota_P}\overline{\pi}^{1-\iota_P})^2 y_t + \frac{\kappa_w}{2}\left(\frac{W_t^P}{W_{t-1}^P} - \pi_{t-1}^{\iota_w}\pi^{1-\iota_w}\right)^2 \frac{W_t^P}{P_t} \\ &\quad + q_t^k \frac{\kappa_i}{2}\left(\frac{i_t}{i_{t-1}} - 1\right)^2 i_t, \end{aligned} \tag{4.59}$$

and κ_t^{bank} denotes total adjustment costs in the banking sector defined by:

$$\begin{aligned} \kappa_t^{bank} &= \frac{\kappa_d}{2}\left(\frac{R_t^d}{R_{t-1}^d} - 1\right)^2 R_t^d D_t + \frac{\kappa_{bE}}{2}\left(\frac{R_t^{bE}}{R_{t-1}^{bE}} - 1\right)^2 R_t^{bE} B_t^E \\ &\quad + \frac{\kappa_{Kb}}{2}\left(\frac{K_t^b}{w^L B_t} - v_t\right)^2 K_t^b. \end{aligned} \tag{4.60}$$

The market clearing conditions also characterised by the identities as follows:

$$B_t = b_t^E \tag{4.61}$$

$$D_t = d_t^P \tag{4.62}$$

$$l_t^{E,P} = l_t^P \tag{4.63}$$

$$RF_t^T = RF_t^{cb} + RF_t^b \tag{4.64}$$

4.2.10 Shocks

In this subsection, I simulate the impact of four types of shocks. The first shock is the liquidity shock ε_t^{liq}, which is the unexpected withdrawal from bank's reserve in terms of fraction of deposits. The second shock is the aggregate productivity shock, a_t^E, which illustrates the problem that emerges from the real sector. The third and fourth shocks are liquidity policy shocks to:(1) the reserve requirement policy, ε_t^{η}, and (2) the LCR policy, $\varepsilon_t^{\vartheta}$, respectively. All shocks follow AR(1) processes as follows:

- *Liquidity shock*

$$\varepsilon_t^{liq} = \rho^{liq}\varepsilon_{t-1}^{liq} + \xi_t^{liq} \tag{4.65}$$

- *Total factor productivity shock*

$$\log a_t^E = \rho^a \log a_{t-1}^E + \xi_t^a \tag{4.66}$$

- *Reserve requirement policy shock*

$$\log \varepsilon_t^{\eta} = \phi^{\eta} \log \varepsilon_{t-1}^{\eta} + \xi_t^{\eta} \tag{4.67}$$

- *LCR policy shock*

$$\log \varepsilon_t^{\vartheta} = \phi^{\vartheta} \log \varepsilon_{t-1}^{\vartheta} + \xi_t^{\vartheta} \tag{4.68}$$

4.3 Calibration

I calibrate the model to match the first moments of some Indonesia data throughout 2005Q3 - 2017Q4.[30] One period is a quarter.[31] The targets of the calibration process are the model's steady-state values, which computed using various macroeconomic and aggregate banking data that have been filtered using HP-filter ($\lambda =$ 1600). The detailed description regarding sources of data for calibration is available in Appendix 6.4.5. I set inflation in the steady state to 1.016, which is equivalent to the average annual inflation rate of 6.4%. The discount factor for patient household, β^P and the elasticity of deposit demand, ε^d, are calibrated to match the steady-state value of interest rate on deposits and policy rate. I use the rate of deposits with one-month maturity as a benchmark and use BI rate data for the policy rate.[32]

The target of capital to loan ratio is 7.6%, which is in line with the average capital adequacy ratio requirement in Indonesia. The weighted average of the bank's risk profile, w^L, is set to 1.079. Reserve requirement ratio in the steady-state is 6.5%, and the remuneration on required reserves is 0 because recently the Indonesian central bank gives no more remuneration on the required reserves. I use government bond yield rate as a proxy for risk-free asset return, and it implies that the ratio of risk-free assets rate to the policy rate, Ω^{RF}, is 1.01. Parameter Γ is set to be 9%, following the average of the ratio of government consumption to GDP.

Some literature uses the central bank's discount window rate or the interbank market rate as a proxy for penalty rate. However, penalty rate does not only capture the actual rate of lending facilities but also nonpecuniary costs such as

[30] I use data from 2005Q3 because Indonesia starts to adopt Inflation Targeting Framework (ITF) since July 2005, and since then uses the interest rate as the main monetary policy instrument.

[31] I realise that there is a potential problem with a quarterly period when we discuss bank liquidity management. Usually, bank liquidity management is a daily decision. However, to make it consistent with other quarterly macro variables, I assume that liquidity management is the sum of daily activities in a quarter.

[32] Since 2016Q3, Bank Indonesia changes its policy rate from BI Rate to 7 Days Repo Rate.

a reputational cost, e.g the stigma associated with borrowing from the central bank's emergency facilities (Acharya & Naqvi (2012)). Therefore, it is difficult to observe the exact value of the penalty rate. Thus, I calibrate the ratio of penalty rate to policy rate (Ω^{RX1}, Ω^{RX2}) jointly with other unobservable parameters including δ, m^E, ϑ, δ^b, and parameters regarding the distribution of liquidity shock $\mu^{\varepsilon_{liq}}$ and $s^{\varepsilon_{liq}}$ to match several target variables.

First, I need to assume the type of liquidity shock distribution. I did that by fitting the data of the percentage of aggregate deposit withdrawal within the sample period with various type of distributions using Matlab.[33] I found that the closest type of distribution with the data is logistic distribution and normal distribution. I choose normal distribution because it is commonly used in the literature and also consistent with the assumption of the exogenous shocks used in Dynare program[34]

Then I do calibration to get the steady-state values of the model as close as possible with these following target variables: reserves to deposit ratio (8.1%), liquid assets to deposit ratio (27.8%), capital to risk-weighted loan ratio (19%), capital to deposit ratio (17%), total risk-free assets to output ratio (40%), investment to output ratio (24%), and total loan to output ratio (81%). The calibration process gives a relatively high depreciation rate parameter (δ =0.1) and high run-off rate parameter in the LCR computation (ϑ =27%). The high value of the run-off rate parameter can be accepted because from the model specification, the parameter can also be interpreted as a high LCR position. The evaluation by The Basel Committee on Banking Supervision (BCBS) on Indonesian banking sector liquidity shows that as of June 2016 the aggregate bank LCR position is 227%, which is much higher than the required ratio 100% (Committee on Banking Supervision (2016)). The calibration shows that the value of m^E is

[33] The histogram and distribution fitting result is available in Appendix 6.4.6. I realise that the liquidity shock in the model is an idiosyncratic shock, and it might be better if I use the data of individual bank deposit flow. However, I assume that all bank are homogenous regarding the expectation of liquidity shock. Therefore I can use aggregate deposit outflow as a proxy for the distribution type.

[34] Logistic distribution looks like the normal distribution in shape but has heavier tails.

0.55. In Indonesia, there is no specific regulation regarding LTV ratio on the entrepreneur loan, but I think this value makes sense. Depreciation on bank capital (δ^b) is 2%, which is acceptable because the value is similar to the non-performing loan ratio. The ratio of penalty rate to policy rate is 1.8. As expected, the value of the penalty rate is higher than the lending facilities rate, which on average is 1.15 times of policy rate. The mean of the liquidity shock distribution is 0.019, and the standard deviation is 0.04. Table 4.3 presents the summary of calibrated parameters.

Remaining parameters follows related literature. Some of parameters follow the Bank Indonesia's DSGE model as in Harmanta *et al.* (2014) or Purwanto (2016) (presented in the Table 4.4), and some other parameters follow standard literature as in Angelini *et al.* (2014), Chadha & Corrado (2012) and Primus (2017) (presented in the Table 4.5).[35]

The calibration of steady-state parameters implies ratios and interest rate as listed in Table 4.6.

Table 4.3: Calibrated Parameters

Parameter	**Value**	**Description**
β^P	0.999	Patient household's discount factor
ε^d	-19.44	$\varepsilon^d / \left(\varepsilon^d - 1\right)$ is the mark down on deposit rate
v	0.076	Minimum capital requirement ratio regulated
w^L	1.079	Risk weight of loan for the CAR calculation
μ	0.065	Reserve requirement ratio
ϑ	0.27	Run-off rate of deposit for LCR calculation
Ω^{RRR}	0	Ratio of reserve remuneration rate to policy rate
Ω^{RF}	1.01	Ratio of risk free rate to policy rate
Γ	0.09	Ratio of government spending/GDP
δ	0.1	Depreciation rate of physical capital
m^E	0.55	Entrepreneur's LTV Ratio
δ^b	0.02	Depreciation of bank capital
$\Omega^{RX1}, \Omega^{RX2}$	1.8	Ratio of RR penalty rate to policy rate
$\mu^{\varepsilon_{liq}}$	0.019	Mean of liquidity shock distribution
$s^{\varepsilon_{liq}}$	0.04	Standard deviation of liquidity shock distribution

[35] I realise that it would be better to estimate some of the parameters affecting dynamics of the model for example by using Bayesian estimation. However, the method to combine Bayesian estimation with Occbin toolkit is relatively new and complicated as in Guerrieri & Iacoviello (2017).

Table 4.4: Parameters following Indonesia's DSGE literature

Parameter	Value	Description
a^P, a^E	0.6	Degree of habit formation in consumption
κ_i	0.98	Cost for adjusting investment
κ_{bE}	3.7	Cost for adjusting rate on loans to entrepreneur
κ_D	3.23	Cost for adjusting rate on deposits
κ_{kb}	1.78	Cost for adjusting capital-loan ratio
ρ_R	0.74	Persistence of the monetary policy rule
ρ_v	0.5	Persistence of the capital requirement rule
χ_π	1.89	Response of monetary policy to inflation
χ_Y	0.25	Response of monetary policy to output

Note : All the parameters on this table are following Harmanta *et al.* (2014), except parameter ρ_v is following Purwanto (2016)

4.4 Simulation Results

This section presents the numerical simulation to explore the responses of the bank and macroeconomic variables to the liquidity shock and the technology shock. In this section I also study the impact of imposing countercyclical liquidity regulations on welfare and volatilities of various variables.

4.4.1 Long run Impact of Higher Expectation of Liquidity Shock

In the first exercise, I increase the value of the mean of the liquidity shock distribution ($\mu^{\varepsilon_{liq}}$) to learn how it affects bank's optimal decision and macroeconomic variables in the long-run.[36] We can relate this shifting in the liquidity distribution mean with the situation after the global financial crisis. In the first quarter of 2008, there was a quite high deposit outflow in the Indonesian banking sector (3 % nominal deposit outflow, equivalent with 7.3% real deposit outflow) which is the biggest outflow since 2005. Since the effect of the global financial crisis lasts quite long, that event could increase banks' long-term expectation about liquidity shock.

Figure 4.2 and 4.3 show the simulation results. The horizontal lines denote the value of the mean of the liquidity shock distribution. Higher values imply

[36] I change the value of parameter $\mu^{\varepsilon_{liq}}$ from 0.01 to 0.05 and compute the steady-state values of all other variables.

Table 4.5: Parameters following standard literature

Parameter	Value	Description
β^E	0.975	Entrepreneur's discount factor
ϕ	1	Inverse of the Frisch Elasticity
α	0.3	Capital share in the production function
ε^y	6	$\varepsilon^y / (\varepsilon^y - 1)$ is the mark up in the goods market
ε^l	5	$\varepsilon^l / \left(\varepsilon^l - 1\right)$ is the mark up in the labour market
ε^{bE}	2.7	$\varepsilon^{bE} / \left(\varepsilon^{bE} - 1\right)$ is the mark up on rate on loans to entrepreneur
κ^P	28.65	Cost for adjusting good prices
κ^W	99.9	Cost for adjusting nominal wages
ι_P	0.16	Indexation of prices to past inflation
ι_W	0.276	Indexation of nominal wages to past inflation
ρ^{liq}	0.33	Persistence of the liquidity shock
ρ^a	0.97	Persistence of the technology shock
ρ_η	0.15	Persistence of the reserve requirement policy rule
ρ_ϑ	0.15	Persistence of the LCR policy rule
ϕ^η	0.3	Persistence of reserve requirement shock
ϕ^ϑ	0.33	Persistence of run-off rate shock
χ^η	1.2	Feedback parameter of countercyclical reserve requirement policy
χ^ϑ	1.2	Feedback parameter of countercyclical LCR policy

Note : Most of the parameters on this table are from Angelini *et al.* (2014). Parameters related with liquidity $(\rho^{liq}, \phi^\eta, \phi^\vartheta)$ follow Chadha & Corrado (2012), while parameters ρ_η, χ^η follow Primus (2017). I assume that $\rho_\vartheta = \rho_\eta$ and $\chi^\vartheta = \chi^\eta$.

higher liquidity risk perceived by the bank. The vertical lines denote the steady state values of the corresponding variables. The first graph of Figure 4.2 shows that bank's optimal reserves depend significantly on the probability of liquidity shortage. The bank holds more reserves because they serve both liquidity regulations. The second graph (top row, middle) shows that it is optimal for the bank to reduce risk-free assets as long as the reserves ratio and the LCR ratio are higher than the minimum required level of the regulation. Higher liquidity risk also raises the marginal cost of giving a loan so the bank will charge a higher loan rate to the entrepreneurs (middle graph). As a consequence, there will be a lower level of bank lending in the economy. However, the simulation shows that the bank still can obtain higher profits because the bank raises the lending rate such that the total income from lending increases, even though the total loan decreases. The combination of higher capital from additional profits and lower lending leads to a rise in the bank capital to loan ratio (bottom row, middle

Table 4.6: Steady State Values

Variables	Data	Model
Policy Rate	0.018	0.018
Deposits Rate	0.018	0.017
Loan rate to entrepreneur	0.032	0.023
Risk-Free Asset Rate	0.018	0.018
Total Consumption/Output	0.56	0.58
Government Expenditures/Output	0.08	0.08
Investment/Output	0.24	0.18
Entrepreneurs Loan/Output	0.81	0.89
Risk-free assets/Output	0.40	0.37
Bank Capital/Risk-weighted Loan	0.19	0.18
Bank Capital/Deposit	0.17	0.16
Reserves/Deposit	0.08	0.08
Liquid Assets/Deposit	0.28	0.34

graph).

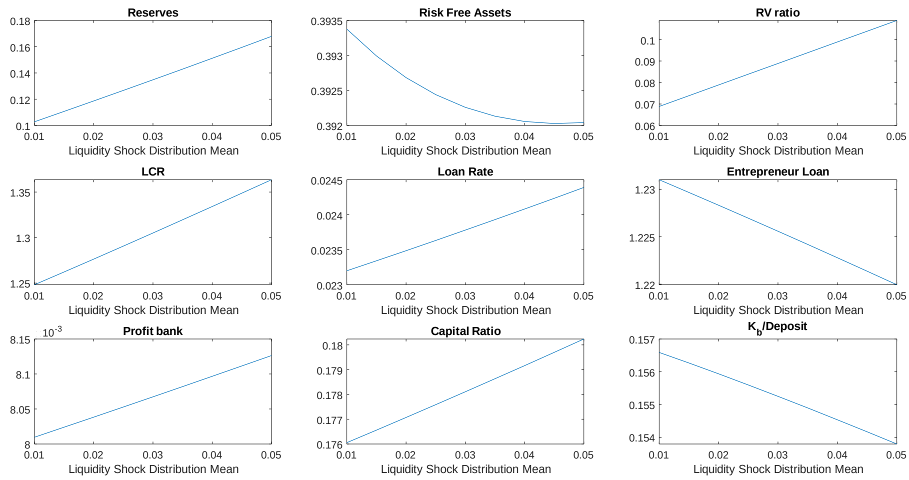


Figure 4.2: Impact of Higher Expectation of Liquidity Shock on Steady-state Values of Bank Variables

As shown in first row graphs in Figure 4.3, investment and GDP decline as banks choose to hold more reserves and reduce lending. Furthermore, from the perspective of the central bank balance sheet, higher demand for reserves must be backed-up by government bond holding. A higher demand for high-quality liquid assets can affect government's financing strategy. The government can finance its spending by issuing more bonds and reducing taxes. The reduction of taxes leads to an increment in the household deposits. Therefore, the exercise shows that, although the bank capital increases, the proportion of capital to deposit declines (bottom row, right graph of Figure 4.2).[37] The level of total consumption declines because entrepreneurs borrow less.

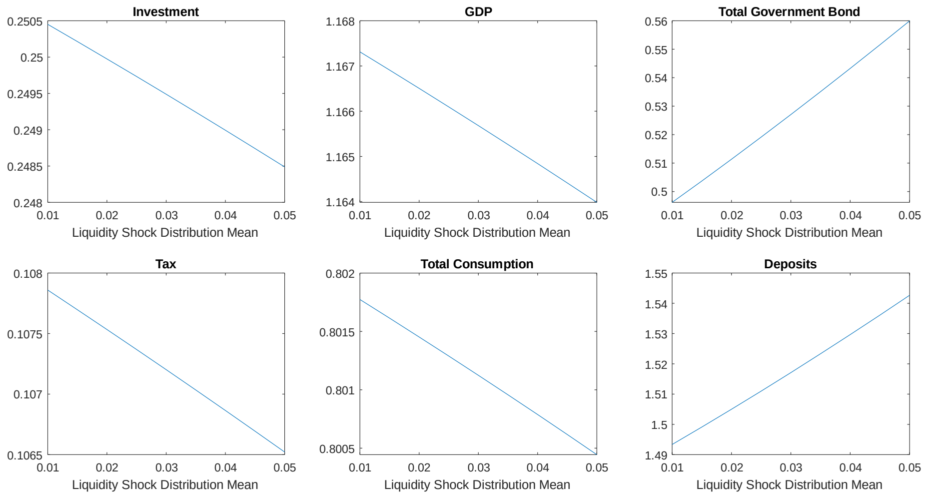


Figure 4.3: Impact of Higher Expectation of Liquidity Shock on Steady-State Values of Macroeconomic Variables

Some of the responses of the bank toward higher liquidity risk generated by this model inline with some empirical literature such as de Haan & van den End (2013). Using Dutch banks data over the period January 2004 - April 2010, they found that banks respond to a negative funding liquidity shock in a number of ways including reduce lending and hoard liquidity in the form of liquid bonds and central bank reserves. Furthermore, the study of Ivashina & Scharfstein (2010) found that banks with higher liquidity risk, in terms of greater volatility of deposits and draws on committed credit lines, tend to reduce more lending during the financial crisis.

[37] It should be noted that this result strongly depends on the assumption that the supply of the government bond is perfectly elastic. In reality, the government faces constraints in issuing bonds. I tried to modify the government rule such that the government debt per GDP ratio is constant ($RF_t^T = \Gamma Y_t$). However, I can not obtain the steady-state solution.

4.4.2 Dynamic Analysis of Unexpected Liquidity Shock

Explanation of the liquidity shock

In the second exercise, I simulate the impact of an unexpected liquidity shock to the banking sector. Since my model is a closed economy with no cash, this shock can be viewed as an unanticipated late-day bank's customer payment activity[38]. To illustrate the mechanism, I divide each period into three stages. At the first stage, the wholesale unit of banks make portfolio decisions of loans, reserves, risk-free assets and deposits, and solve liquidity and capital management problem. In this stage, all banks have the same expectation of liquidity shock. At the second stage, banks are subject to a random idiosyncratic withdrawal of deposits ($\varepsilon_t^{liq} D_t$). If ε_t^{liq} is positive, the bank would experience an unexpected withdrawal of funds. I assume that household does not hold cash, so a deposit withdrawn from one bank will be transferred to other banks and deposits are only reshuffled across banks. Moreover, since there is no interbank market in my model, banks that receive deposit inflow (positive ε_t^{liq}) are assumed to keep the additional deposits as excess reserves in the central bank. In the third stage, banks who experience deposit outflow may need to borrow from the central bank to fulfil the liquidity regulations. These banks pay back the loan with a penalty rate in the next period. The unexpected liquidity shock affects the bank's profit, capital and its optimal decisions on the lending rate and other components of the balance sheet.

Figure 4.4 shows the changes in the balance sheet during the process. Suppose Bank A illustrates the bank that experiences positive liquidity shocks and bank B illustrates the opposites. As we can see, even though the two banks experience different liquidity shocks, the balance-sheet constraints of the aggregate bank and the central bank are still the same as those illustrated by equation 4.42 and 4.49.

[38]As mentioned in Bech & Keister (2017), introducing this kind of shock is a standard way of capturing the inability of banks to exactly target their end-of-day reserve balance.

Bank A — Bank B

Stage 1: Before Shock

Bank A

Asset	Liabilities
Reserves (RV_A)	Deposits (D_A)
Risk-Free Assets ($RF^b{}_A$)	
Loan (B_A)	Capital (K_{bA})

Bank B

Asset	Liabilities
Reserves (RV_B)	Deposits (D_B)
Risk-Free Assets ($RF^b{}_B$)	
Loan (B_B)	Capital (K_{bB})

Stage 2: Bank A experiences deposit outflow, Bank B experience deposit inflow ($\varepsilon^{liq}D$)

Bank A

Asset	Liabilities
Reserves (RV_A) - $\varepsilon^{liq}D$	Deposits (D_A) - $\varepsilon^{liq}D$
Risk-Free Assets ($RF^b{}_A$)	
Loan (B_A)	Capital (K_{bA})

Bank B

Asset	Liabilities
Reserves (RV_B) +$\varepsilon^{liq}D$	Deposits (D_B) +$\varepsilon^{liq}D$
Risk-Free Assets ($RF^b{}_B$)	
Loan (B_B)	Capital (K_{bB})

Stage 3: Bank A borrow from CB (X)

Bank A

Asset	Liabilities
Reserves (RV_A) - $\varepsilon^{liq}D$+X	Deposits (D_A) - $\varepsilon^{liq}D$
Risk-Free Assets ($RF^b{}_A$)	X
Loan (B_A)	Capital (K_{bA})

Bank B

Asset	Liabilities
Reserves (RV_B) +$\varepsilon^{liq}D$	Deposits (D_B) +$\varepsilon^{liq}D$
Risk-Free Assets ($RF^b{}_B$)	
Loan (B_B)	Capital (K_{bB})

Aggregate Bank — Central Bank

Stage 1: Before Shock

Aggregate Bank

Asset	Liabilities
Reserves (RV)	Deposits (D)
Risk-Free Assets (RF^b)	
Loan (B)	Capital (K_b)

Central Bank

Asset	Liabilities
Risk-Free Assets (RF^{cb})	Reserves (RV)

Stage 2: Bank A experiences deposit outflow, Bank B experience deposit inflow ($\varepsilon^{liq}D$)

Aggregate Bank

Asset	Liabilities
Reserves (RV)	Deposits (D)
Risk-Free Assets (RF^b)	
Loan (B)	Capital (K_b)

Central Bank

Asset	Liabilities
Risk-Free Assets (RF^{cb})	Reserves (RV)

Stage 3: Bank A borrow from CB (X)

Aggregate Bank

Asset	Liabilities
Reserves (RV)+X	Deposits (D)
Risk-Free Assets (RF^b)	X
Loan (B)	Capital (K_b)

Central Bank

Asset	Liabilities
Risk-Free Assets (RF^{cb}) Lending Facilities (X)	Reserves (RV)+X

Figure 4.4: Changes in the Bank and the Central Bank Balance Sheet due to Liquidity Shocks

Size of the shock

Following the calibration process, I assume that the liquidity shock follows a normal distribution $f(\varepsilon^{liq};0.019,0.04)$. To determine the size of the shock in the simulation exercise, I use the quantile function of a normal distribution as follows:

$$Q(p;\mu,s) = \mu + s.z_p \tag{4.69}$$

I simulate two sizes of shock: first is in the 90th quantile and second is in the 99th quantile.[39] That is to say, the probability for the first shock to happen is 10% and that for the second shock is 1%. According to the formula above, in Q_{90}, $\varepsilon^{liq} = 8.5\%$ and $Q_{99} = 12.2\%$ which I round it to 12.5%. Therefore, in the next subsection, I will simulate the impacts of 8.5% and 12.5% withdrawal to the bank reserves holding.

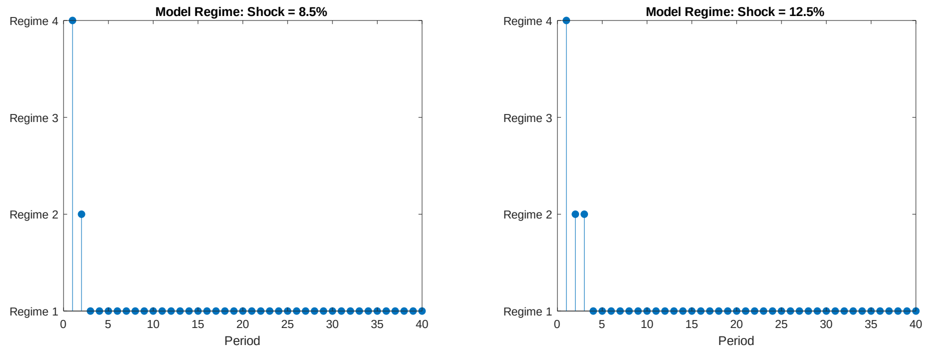
Impacts on Aggregate Bank and Macroeconomic Variables

Unexpected withdrawal to some bank reserves holding makes the bank's liquidity position moves across regimes as described in Table 4.2. The first graph of Figure 4.5 shows that after an 8.5% liquidity shock, the bank's liquidity position is in regime 4, meaning that the bank simultaneously cannot meet the RR and LCR for one period. The bank's liquidity position then moves to regime 2 where the only problem of the bank is the reserves requirement. The bank's liquidity position ultimately moves back to regime 1. A liquidity shock with larger magnitude 12.5% induces a similar effect, except that the bank will be in regime 2 for two periods.

Unexpected liquidity shock in some bank can affect the aggregate output through the transmission mechanism as shown in Figure 4.6 and Figure 4.7. First, a liquidity shock induces some banks to borrow from the central bank at a higher rate, and both the profits and the capital of the bank therefore decrease (Graph No.3). With a lower capital position, the bank increases the lending

[39] According to the standard normal distribution table: $z_{90} = 1.66$ and $z_{99} = 2.58$

Figure 4.5: Liquidity Position after the Shock



rate, causing a decline in the lending to the entrepreneur (Graph No.4 - 6). The problem in the banking sector transmits into the real sector. Investment decreases because the entrepreneur borrows less from the bank. As a result, total output in the economy deteriorates, and the demand for labour also decline. The reduction in the entrepreneur investment leads to a fall in both the real rate and the price of capital (Graph 2 -3 in Figure 4.7). As consequences, the marginal cost of production and price of goods decrease which leads to deflation. Following the Taylor rule, the central bank reacts to the drops in inflation and output by lowering interest rate. Total consumption increases temporarily because of the lower interest rate, but then it decreases because household and entrepreneur income declines.

Under the current calibrated parameters, the result shows a relatively small impact of liquidity shock on the aggregate loan and output. For example, 8.5% of liquidity shock only causes an immediate impact of 0.08% decline in the bank lending. The lending continues to decline until around 0.13% in the sixth period. The impact of the liquidity shock on the deterioration of GDP is around 0.13%. This relatively small impact is understandable due to the constant distribution parameters of liquidity shock set in my modelling framework. Therefore, there is no feedback effect of the ex-post liquidity shock on the expectation of the liquidity shortage in the next period. As can be seen in Figure 4.8, the bank reserves ratio and the LCR ratio are constant and unaffected by the liquidity shock. The bank

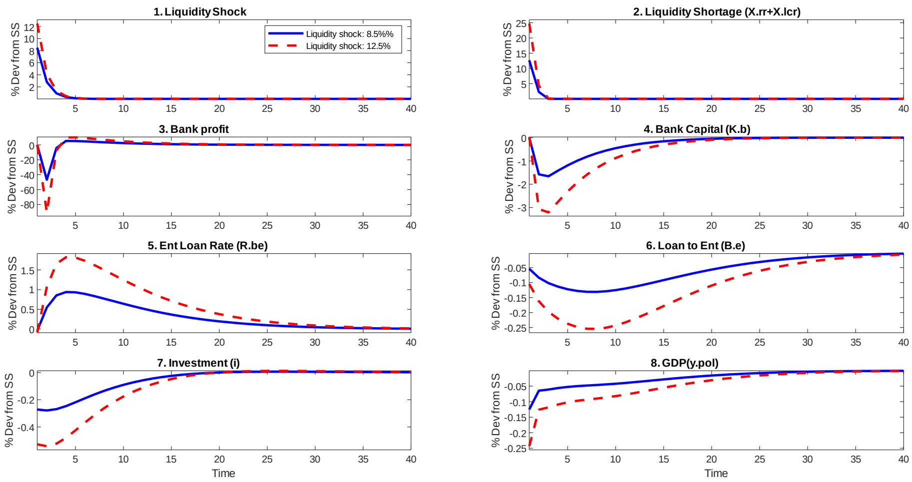


Figure 4.6: Impact of Liquidity Shock on Bank Lending and Output

maintains its reserves ratio and LCR ratio at the optimal level as in the steady-state and there are no precautionary hoarding after the shock. The impact of the liquidity shock on the bank's optimal decision is only transmitted through the deterioration in bank capital position due to a decline in the bank's profit, which is relatively small.

4.4.3 Technology Shock

Figure 4.9 presents the effects of a one per cent standard deviation negative technology shock on the economy. A negative technology shock leads to a decline in the output, consumption and investment. The household chooses to increase its working hours to avoid further decline in the consumption. The marginal cost of production increases and leads to a higher inflation. The central bank reacts by raising the policy rate because the Taylor rule's reaction to inflation is higher than that to output. The bank lending to the entrepreneur declines not only because of a higher loan rate but also because of the financial friction mechanism where the decline in entrepreneur's capital causes a lower borrowing capacity. The impact of the technology shock on the bank lending persists relatively longer because of the feedback loop relationship among lending, investment and capital

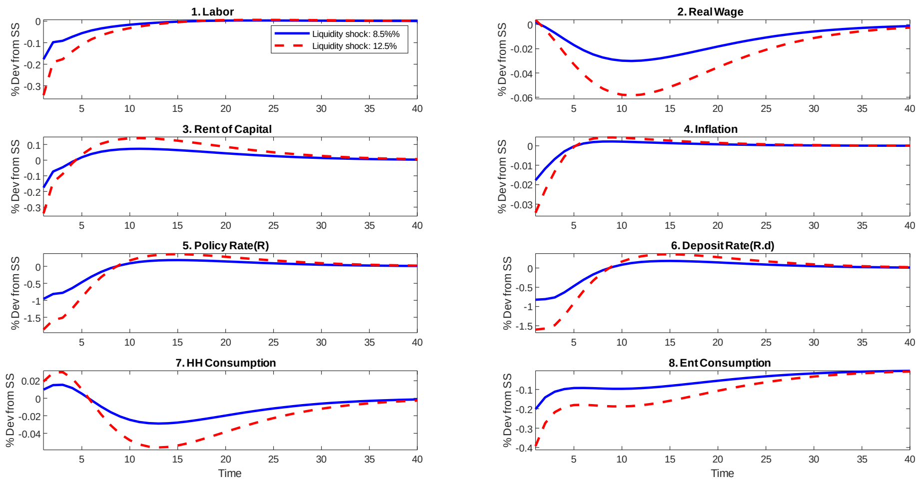


Figure 4.7: Impact of Liquidity Shock on Macroeconomic Variables

induced by the borrowing constraint features of the model.

Figure 4.10 shows how the technology shock transmitted to other components of bank's balance sheet. The decline in household's income leads to a decline in total deposits. Total bank's reserves and risk-free assets also decline because bank optimal reserves and LCR ratio are relatively constant while total deposits decline. Furthermore, bank capital declines as a consequence of the lower profit from the lending contraction. Moreover, since I assume that the government spending is proportional to the total output, a negative technology shock leads to a lower government spending. Therefore, government issues less bonds and reduce taxes.

4.4.4 Liquidity Regulations

In this subsection, I compare the impacts of the reserve requirement and the LCR regulations by doing simulation with the scenario of loosening each liquidity regulation by 10%. For example, the central bank changes the reserve requirement ratio from 6.5% to 5.85%. The blue solid lines of Figure 4.11 denote the response of the variables to a reserve requirement shock, and the red dashed lines indicate the response to an LCR shock.

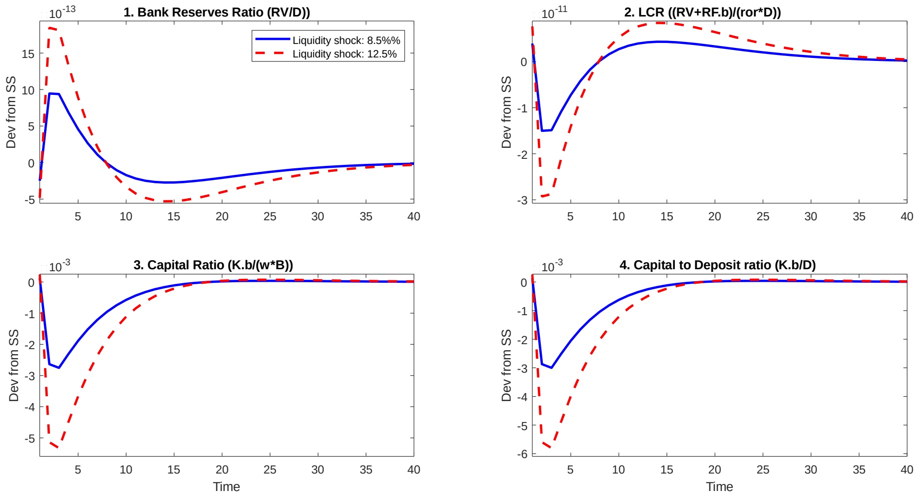


Figure 4.8: Impact of Liquidity Shock on Aggregate Bank's Ratio

The lower liquidity regulation makes it optimal for the bank to decrease the lending rate and give more loan. More lending to the entrepreneur leads to higher investment and output and causes an increase in inflation. These results inline with some empirical studies about the impact of liquidity regulation. For example, Cordella *et al.* (2014) studied the usage of reserve requirements as the credit stabilisation tools in emerging countries. They found empirically that reserve requirements have a negative relationship with real GDP and a positive relationship with the interest rate spread. The result also inline with Gómez *et al.* (2019) that showed a significant negative effect of reserve requirement and credit growth in Columbia and the effect is moderated for more levered and liquid banks. In a similar vein but opposite direction of shock, Glocker & Towbin (2015) empirical study also showed that a positive shock to the required reserve ratio in Brazil leads to an increase in credit spreads and a contraction in economic activity. Furthermore, using a DSGE model calibrated with Brazil data, Carvalho *et al.* (2013) found that a positive shock to the required reserve ratio raises banks' funding costs and lending rates which results in a contraction in output.

As we can see in Figure 4.11, the impacts of both RR or LCR on the real sector

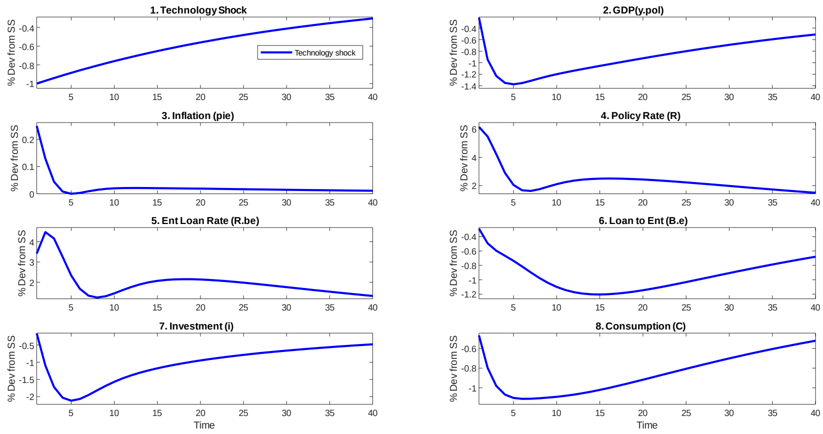


Figure 4.9: Impact of Negative Technology Shock on Macroeconomic Variables

are similar regarding direction, and the magnitude of the effects are relatively small. My finding of relatively small impact of liquidity regulation is consistent with those of Hoerova *et al.* (2018) in that the impacts of liquidity regulations on bank credit supply and cost of credit are not quantitatively large. However, some empirical paper found different responses of banks to the changes in LCR. Banerjee & Mio (2017) indicate that the bank in UK responding to a stricter Individual Liquidity Guidance (ILG), which is similar in design with LCR, by reducing intra-financial loans and short-term wholesale funding. Therefore the impact on lending to the non-financial sector is not significant. Furthermore, Bonner & Eijffinger (2016) found that the banks in Netherland do not pass on the higher cost caused by a higher LCR-like regulation to their lending rate. A tighter liquidity regulation seems to lower the bank's interest margin. Duijm & Wierts (2016) also found that banks adjust more the composition of their liabilities (from wholesale funding to more stable deposits) rather than changing the composition of the asset side as a reaction to the LCR policy. Since my model only has one type of liabilities, the results presented in this chapter can not explore more about the bank's optimal decision regarding liabilities composition.

The impact of RR and LCR on the bank's balance sheet and profit are quite different, as shown in Figure 4.12. When the central bank decreases the reserve

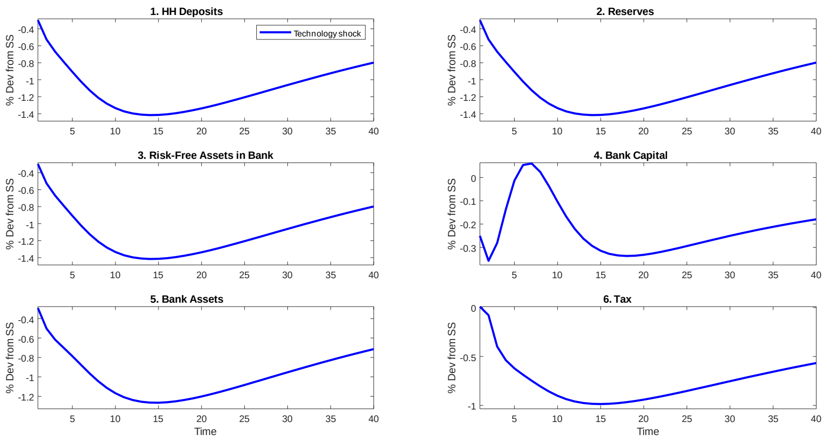


Figure 4.10: Impact of Negative Technology Shock on Bank Balance Sheet

requirement regulation, the bank reduces its reserves. However, the bank needs to have more risk-free assets to meet LCR. Therefore, the government bond holding in the central bank declines whilst government bond holding in the banking sector increases. In total, the demand for government bond is relatively constant, implying that taxes would be unaffected in the economy. Aggregate household deposits and bank assets are quite stable. The bank obtains more returns from the conversion from reserves to risk-free assets. The profit of the bank thus increases.

In contrast, when the central bank loosen the LCR regulation, bank reduce both reserves and risk-free assets. So the total demand for government bond decline and the government has to raise more tax to finance government spending. Higher tax makes household put less deposit in the bank. Bank total asset and profit decline.

4.4.5 Welfare Implications of Countercyclical Liquidity Regulation

Some countries use countercyclical liquidity regulations as macroprudential policy tools to mitigate macroeconomic fluctuations. In the next simulation, I consider

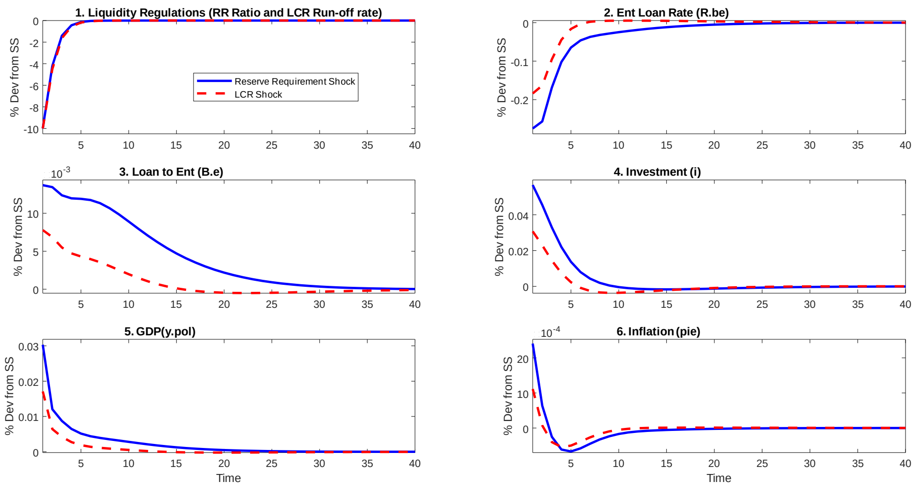


Figure 4.11: Impact of Liquidity Regulations on Bank Lending and Output

the case where the central bank sets the reserve requirement rule and the LCR run-off rate countercyclically to the loan growth. I modify equations 4.51 and 4.52 into:

$$\eta_t = \overline{\eta}^{(1-\rho_\eta)} \eta_{t-1}^{\rho_\eta} \left(B_t / B_{t-1}\right)^{\chi_\eta (1-\rho_\eta)}, \tag{4.70}$$

$$\vartheta_t = \overline{\vartheta}^{(1-\rho_\vartheta)} \vartheta_{t-1}^{\rho_\vartheta} \left(B_t / B_{t-1}\right)^{\chi_\vartheta (1-\rho_\vartheta)}, \tag{4.71}$$

where ρ_η and ρ_ϑ denote the degrees of persistence in the policy rule, while χ_η and χ_ϑ measure the reaction of the policy to counter credit growth. The positive values of χ_η and χ_ϑ indicate that the central bank raises the liquidity requirement ratio to avoid a credit boom in the case of an increase in credit growth, and vice versa.

To assess whether the countercyclical rule is more beneficial than constant rule, I compare the total welfare in the case of a 1% technology shock and a 10% expectation of liquidity shock under the two alternatives rules[40]. In this subsection, the mean of the liquidity shock distribution ($\mu^{\varepsilon_{liq}}$) is no longer constant but

[40] I can not perform the welfare analysis for the case of unexpected liquidity shock because that case has to be solved using piece-wise linear pertubation method, while welfare computation need a second order approximation method.

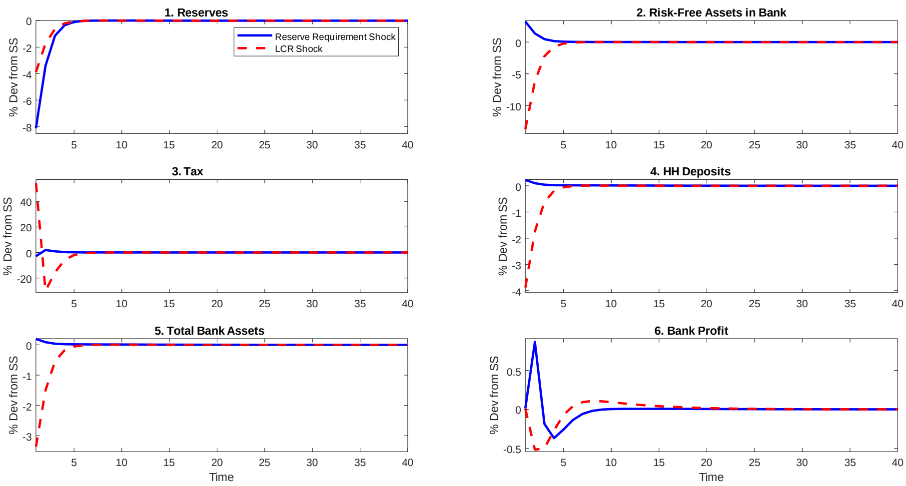


Figure 4.12: Impact of Liquidity Regulations on Bank Balance Sheet and Profit

time varying. $\mu^{\varepsilon_{liq}}$ follows an AR(1) process:

$$\log \mu_t^{\varepsilon_{liq}} = \rho^{\mu} \log \mu_{t-1}^{\varepsilon_{liq}} + \xi_t^{\mu}. \tag{4.72}$$

I search the optimal parameters of the liquidity regulations rule that can improve welfare. I simulate the model by using the second-order approximation and compute the conditional welfare starting at the steady-state condition. Following Rubio & Carrasco-Gallego (2014), I define total welfare as the weighted sum of the household's and entrepreneurs' welfare (W_t^P and W_t^E). Each agent's welfare is weighted by their discount factor so that they receive the same level of utility from a constant consumption stream:

$$W_t = \left(1 - \beta^P\right) W_t^P + \left(1 - \beta^E\right) W_t^E,$$

where

$$W_t^P = E_0 \sum_{t=0}^{\infty} \beta^t \left[\left(1 - a^P\right) \log\left(c_t^P(i) - a^P c_{t-1}^P\right) - \frac{l_t^P(i)^{1+\phi}}{1+\phi} \right], \tag{4.73}$$

and

$$W_t^E = E_0 \sum_{t=0}^{\infty} \beta_E^t \log(c_t^E(i) - a^E c_{t-1}^E). \tag{4.74}$$

I then follow the approach of Ozkan & Unsal (2014) by expressing each agent's utility function recursively:

$$W_t^P = U\left(c_t^P, l_t^P\right) + \beta W_{t+1}^P, \tag{4.75}$$

and

$$W_t^E = U\left(c_t^{eE}\right) + \beta W_{t+1}^E, \tag{4.76}$$

where

$$U\left(c_t^P, l_t^P\right) = \left[(1 - a^P)\log\left(c_t^P(i) - a^P c_{t-1}^P\right) - \frac{l_t^P(i)^{1+\phi}}{1+\phi}\right], \tag{4.77}$$

and

$$U\left(c_t^E\right) = \log(c_t^E(i) - a^E c_{t-1}^E). \tag{4.78}$$

I search the optimal reserve requirement policy rules numerically in a grid of parameters $(\rho_\eta, \chi_\eta, \rho_\vartheta, \chi_\vartheta)$ that optimise Wt in response to the shocks.[41] I present the welfare in terms of consumption equivalents (ζ), not only to make results more intuitive but also to follow the existing studies in the literature. Consumption equivalent is a fraction of consumption required to equate the welfare under the constant policy rule, W^0 to the one under the optimal countercyclical rule, W^{opt}. A positive value means a welfare gain. According to the specification of the utility function, I derive the consumption equivalent of household and entrepreneur as follows:[42]

$$\zeta^P = \exp\left[\frac{1-\beta_P}{(1-a^P)}\left(W^{opt} - W^0\right)\right] - 1, \tag{4.79}$$

[41] The grid for ρ_η and ρ_ϑ is [0:0.05:0.95] while grid for χ_η and χ_ϑ is [0:0.5:20].
[42] Derivation is available in Appendix 6.4.7.

$$\zeta^E = \exp\left[(1-\beta_E)\left(W^{opt} - W^0\right)\right] - 1. \tag{4.80}$$

Table 4.7 shows that under a technology shock, the optimal welfare is gained when the reserves requirement rule has a relatively high persistence and a high feedback parameter ($\rho_\eta = 0.95$ and $\chi_\eta = 20$). Furthermore, I find that the combination of both countercyclical RR and LCR does not provide a better welfare implication compared to only a countercyclical RR. In contrast, Table 4.8 shows that in the case of a higher expectation of liquidity shock, the combination of countercyclical RR and LCR improves both household's and entrepreneur's welfare. However, in both cases, I find that the impacts of countercyclical liquidity regulations on increasing welfare is negligible.

Table 4.7: Countercyclical Parameters and Welfare Under Technology Shock

Parameters	**Constant Rule**	**Countercyclical Rule**		
		RR Only	LCR Only	RR and LCR
ρ_η	0.15	0.95		0.95
χ_η	0	20		20
ρ_ϑ	0.15		0.95	0.7
χ_ϑ	0		1.5	0
Welfare (in % CE)				
- Household (ζ^P)		0.0002	0.00002	0.0002
- Entrepreneur (ζ^E)		0.0025	-0.000002	0.0025
- Total		**0.0005**	0.000003	**0.0005**

I also assess whether the countercyclical rule can help to reduce volatility. I compare the standard deviations of the main variables under the constant rule and those under the countercyclical rule in the case of a technology shock and and expectation of liquidity shock. I use the optimal parameters obtained from the previous simulations. The results in Table 4.9 and 4.10 show that the countercyclical reserve requirement and LCR rule have a small impact on the volatility of bank loan but have no impact on the real variables. These findings are consistent with those of Primus (2017) who show that although the countercyclical

Table 4.8: Countercyclical Parameters and Welfare Under Higher Expectation of Liquidity Shock

Parameters	Constant Rule	Countercyclical Rule		
		RR Only	LCR Only	RR and LCR
ρ_η	0.15	0.95		0.95
χ_η	0	20		20
ρ_ϑ	0.15		0.85	0.85
χ_ϑ	0		20	20
Welfare (in % CE)				
- Household (ζ^P)		0.00002	0.00004	0.00006
- Entrepreneur (ζ^E)		0.00256	0.00259	0.00511
- Total		0.00051	0.00053	**0.00103**

reserve requirement rule is successful in reducing fluctuations in excess reserves and total reserves, this policy rule has no effect on the real variables. One possible explanation is that, in Indonesia, both liquidity requirements are not binding and the bank lending is more affected by demand rather than supply. Therefore, the effects of the changes of RR and the LCR on lending and on the real sector are relatively small.

Table 4.9: Volatility under Technology Shock : Constant vs Countercyclical Liquidity Regulations

Variables	Constant RR	Countercyclical RR		
		RR Only	LCR Only	RR and LCR
	Std.dev	Std.dev	Std.dev	Std.dev
Loan	0.0817	0.0814	0.0817	0.0814
Labour	0.0128	0.0128	0.0128	0.0128
HH Consumption	0.0454	0.0454	0.0454	0.0454
Ent Consumption	0.0020	0.0020	0.0020	0.0020
Output	0.0726	0.0725	0.0726	0.0725
Inflation	0.0031	0.0031	0.0031	0.0031
Loan Rate	0.0034	0.0033	0.0034	0.0033

4.5 Conclusion

The chapter has presented a model in which the bank endogenously determines the optimal level of reserves and high-quality liquid asset under Reserve Requirement (RR) and Liquidity Coverage Ratio (LCR) regulation. The model has been

Table 4.10: Volatility under Higher Expectation of Liquidity Shock : Constant vs Countercyclical Liquidity Regulations

Variables	**Constant RR**	**Countercyclical RR**		
		RR Only	LCR Only	RR and LCR
	Std.dev	Std.dev	Std.dev	Std.dev
Loan	0.0078	0.0077	0.0078	0.0077
Labour	0.0009	0.0009	0.0009	0.0009
HH Consumption	0.0010	0.0010	0.0010	0.0010
Ent Consumption	0.0002	0.0002	0.0002	0.0002
Output	0.0027	0.0027	0.0027	0.0027
Inflation	0.0001	0.0001	0.0001	0.0001
Loan Rate	0.0008	0.0008	0.0008	0.0008

calibrated to match data for Indonesia over the period 2005Q3 - 2017Q4, to study the transmission of liquidity shocks and liquidity regulations to the real economy.

First, I study the long-run effect of higher expectation of liquidity shock. Banks increase their RR and LCR to anticipate higher liquidity shock. To maintain profit, the bank raises loan rates and total lending declines. Consequently, aggregate investment, output and consumption decline. Since reserves can serve both liquidity regulations, the bank increase reserves but reduce their government bond holding. Therefore, the government bonds held by the central bank increases while the government bonds held by commercial bank declines. In total, higher expectation of liquidity shock increases total demand of government bonds and can affect the fiscal financing strategy.

Second, I analyse the impact of unanticipated withdrawal on some bank's reserves holdings. The bank responses to the unexpected shock by borrowing liquidity from the central bank at a penalty rate to fulfil RR and LCR requirements. This causes a deterioration in the bank's profit and capital, which is then transmitted into a decline in credit, investment and total output. However, the impact on aggregate lending and output are relatively small in terms of magnitude. For example, an 8.5% of reserves withdrawal in some banks only causes approximately 0.13% decline in total lending and output.

Third, I analyse the impact of a technology shock, defined as a sudden decline in total factor productivity. The shock will cause a deterioration in almost all component of bank balance sheets, and it leads to a decline of around 1.2% in total bank's assets. Moreover, I found that the impact on lending and output are also significant. A 1% decline in TFP can cause an approximately 1.5% decline in aggregate lending and output.

Fourth, I analyse the impact of loosening the liquidity regulations. The effect of changes in RR or LCR on the real sector in term of direction are similar. Lower liquidity requirements lead to a decrease in lending rate, which causes a slight rise in lending, investment, output and inflation. However, the impact of those regulations on bank's profit and government budget is quite different. As a reaction to a lower reserve requirement ratio, the bank reduces its reserves but buys more government bonds to meet the LCR so the total demand of government bonds is relatively not affected. The bank gets more return from the conversion of reserves into risk-free assets, and their profits slightly rises. In contrast, the bank reacts to a decline in LCR regulation by reducing both reserves and risk-free assets. Therefore, the total demand for government bonds decline and the government has to raise more tax to finance government spending. Higher tax makes household deposit less in the bank. Consequently, bank total assets and profit decline.

Finally, I investigate the welfare implication of countercyclical liquidity regulations. First, I found that in the case of a technology shock, the optimal policy combination is a countercyclical reserve requirement and constant LCR. Second, in the case of random expectation of liquidity shock, the combination of countercyclical liquidity reserves requirement and LCR improves welfare. Third, I found that countercyclical liquidity regulations reduce the volatility of bank loan, but the impact on the volatility of the real sector variables are negligible.

There are many mechanisms regarding the effects of bank liquidity problem that have not captured in this chapter's model such as the decline in asset prices, precautionary hoarding by banks, depositors expectations and bank-runs, etc. Those limitations make the impact of liquidity problems and the benefit of liquidity regulation in this chapter are relatively small. Therefore, future research can extends the model of this study. For example, it would be interesting to add an interbank market and introduce heterogeneity among bank regarding liquidity risk. Issues about the supply and the price of government bond are also important aspects to explore. Furthermore, another point to address is the incorporation of credit risk in the model because it potentially motivates the bank to hold more reserves in post-crisis (Damjanovic *et al.* (2017)). Finally, it will be interesting to improve the model such that the liquidity shock is endogenous, considering that the liquidity regulations can mitigate bank runs.

Chapter 5

General Conclusion

This thesis contributes to extend our understanding regarding the transmission mechanism and welfare implications of macroprudential policies. The main focus of the thesis is to explore the regulatory arbitrage effect (the shifts of credit from the regulated banking sector into the non-regulated capital market fund) and the interaction among liquidity policies. The regulatory arbitrage effect of macroprudential policies discussed in the second and third chapter has been a crucial issue addressed by the authorities, especially in advanced economies. The liquidity-related macroprudential policies explored in the fourth chapter are relatively used more in emerging economies due to their concerns with large and volatile capital flows and related systemic risks.[1]

Several main messages of this thesis are: (i) In general, the implementation of macroprudential policies generates social welfare gains; (ii) The welfare benefit mostly goes to the entrepreneurs. Thus, a redistribution policy is needed to make everyone better-off; (iii) Considering the regulatory arbitrage, macroprudential policy authorities should consider not only the condition of the banking sector but also the non-bank credit in their policy rule; (iv) There are possible unintended consequences of macroprudential policies in terms of increasing cost of credit

[1] This argument is supported by the study of Federico *et al.* (2014) who find that around two -thirds of developing countries have used RR policy as a macroeconomic stabilization tool compared to just one-third of industrial countries.

and loan default; and (v) There is strong interaction between the impact of macroprudential policies and fiscal policies. Therefore, the coordination across policies is crucial.

The results of the second chapter support the first, second and fifth messages. In the second chapter, I examined the long-run impact of government subsidy on bank's information acquisition cost and bank's monitoring cost. I found that government subsidy on the bank's information acquisition cost could improve aggregate welfare. However, the policy is not Pareto improving since it increases entrepreneurs' welfare at the expense of households' welfare. The government could gain economic efficiency by imposing taxes on the labour income to finance the subsidy and impose a redistribution policy on the entrepreneur and household's consumption. I also found that a subsidy on monitoring cost, which is similar to loan guarantee scheme, generates welfare losses both for household and entrepreneur. Thus, the policy implication of this chapter is that government support for lowering the cost of access to the bank is more preferable than government support for default resolution costs.

The third chapter's results support the first, third, and fourth point of the thesis's main messages. In this chapter, I studied the effect of the macroprudential policy in a framework that accounts for the possible substitution from bank-based financial intermediation to non-bank intermediation in response to such policy. I model the macroprudential policy in the form of a premium introduced by regulation to the bank's cost of borrowing. I found that a countercyclical macroprudential policy that reacts proportionally with bank credit growth is effective in improving social welfare in the case of banking shocks and uncertainty shocks. However, in the case of a technology shocks, the policy is less effective. I found that a modified rule, which reacts not only to bank credit growth but total credit growth, provides social welfare gains in the case of technology shocks. Therefore, the main policy implication of this chapter is that macroprudential authorities should consider the source of the shocks, and take into consideration not only the condition of the banking sector but also the credit in the financial markets. The result of this chapter also indirectly suggests coordination between the banking sector regulator and the non-banking sector regulator. Moreover, although not explicitly discussed in this thesis, coordination of macroprudential policies across countries is crucial because these policies often have unintended spillover effects in the form of credit shifting to other countries.

The results of the fourth chapter support the first and fifth main messages of the thesis. The chapter has presented a model in which the bank endogenously determines the optimal level of reserves and high-quality liquid asset under Reserve Requirement (RR) and Liquidity Coverage Ratio (LCR) regulation. I found that countercyclical liquidity regulations improve welfare and reduce the volatility of bank loan, but the size of the impacts are relatively small. I also found that changing RR and LCR regulation have different consequences on demand for government bonds, and generate dissimilar impacts on taxes and the bank's profit. Thus, coordination between macroprudential and fiscal authorities is crucial.

This thesis shows that there are many aspects to be considered by the central bank in conducting macroprudential policies. The central bank should be aware of the spillover effects and unintended consequences of the policies. There are conditions in which the implementation of macroprudential policies generate desirable benefit on macroeconomic stability, financial stability and welfare, but there are also conditions that provide undesirable effects. Understanding the intended and unintended impact of a policy in facing a particular shock is necessary for designing a policy that can improve both macroeconomic and financial stability.

The studies conducted in this thesis can be extended in many exciting directions. The evaluation of macroprudential policies in this thesis is still focused only on welfare and macroeconomic stability, i.e. smoothing credit expansion period and helping to preserve the financial system's capability to give loans to the economy during a credit contraction period, whilst the aims of macroprudential policies are much wider. Therefore, one interesting area of future research is to extend the models in this thesis and evaluate the impact of macroprudential policies on reducing negative externalities that can lead to systemic risk and controlling the build-up of the financial system vulnerabilities. Another possible area of future research is to explore the interaction of macroprudential policies with monetary policy and capital flow management which are also essential issues for the central bankers. There is plenty of scope for future studies to complete the findings in this thesis allowing a better understanding of the effect of macroprudential policy and to help policymakers designing strategy in maintaining financial and macroeconomic stability.

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Chapter 6

Appendixes

6.1 Appendix for Basic Model of Chapter 2 and 3

6.1.1 List of Variables

Households

c	=	consumption
h	=	labour
w	=	real wage
R	=	return on deposits
m	=	real cash holding
d	=	real deposits
θ	=	transfer from the central bank
r	=	real rent on capital
k	=	HH capital

Entrepreneur

A	=	TFP
z	=	ent. capital
e	=	ent. consumption
x	=	working capital
n	=	ent. networth
$\varepsilon_{j,i}$	=	ent. idiosyncratic productivity levels
q	=	ent. markup
σ_j	=	std.dev of ε_j
ε^e	=	known productivity level before the contract
τ	=	information acquisition cost

Financing Decision

$\bar{\omega}^b$ = threshold corresponding to repayment of bank loan
$\bar{\omega}^c$ = threshold corresponding to repayment of CMF loan
$\bar{\varepsilon}_d$ = threshold of productivity levels to proceed with bank loan
$\bar{\varepsilon}_b$ = threshold of productivity levels to approach a bank
$\bar{\varepsilon}_c$ = threshold of productivity levels to borrow from CMF

Monetary authority

m^s = money supply
ν = growth rate of nominal money supply

Aggregate variables

y = output
I = investment
y^a = agency costs
l^b = total bank loan
l^c = total CMF loan
ψ^f = aggregation of ent. profit
ψ^y = aggregation of realised productivity factors
ψ^{mb} = aggregation of defaulted bank loan
ψ^{mc} = aggregation of defaulted CMF loan
ψ^{rb} = aggregation of bank risk premium
ψ^{rc} = aggregation of CMF risk premium

Financial structure

ϑ = loan to bond ratio
rp^b = risk premium bank
rp^c = risk premium CMF
χ = loan to output ratio
ϱ^b = average default of bank loan
ϱ^c = average default of CMF loan
ϱ = average default
s^a = shares of the firms that abstain from producing
s^b = shares of the firms that approach a bank
s^{bp} = shares of the firms that proceed with the bank loan
s^c = shares of the firms that borrow from CMF

6.1.2 Derivation of Household and Entrepreneur Optimal Condition

Household

Objective function:

$$\max U = E_0 \left(\sum_{t=0}^{\infty} \beta^t \left[log\,(c_t) - \frac{\eta}{1+\frac{1}{\kappa}} h_t^{1+\frac{1}{\kappa}} \right] \right) \tag{6.1}$$

Budget constraint:

$$M_t + D_t + E_t\left[Q_{t,t+1}B_{t+1}\right] \leq W_t \tag{6.2}$$

$$W_t = B_t + R^d_{t-1}D_{t-1} + P_t\theta_t + \widetilde{M}_{t-1} \tag{6.3}$$

Cash in advance constraint:

$$\widetilde{M}_t \equiv M_t - P_t\left[c_t + k_{t+1} - (1-\delta)\,k_t\right] + P_t(w_t h_t + r_t k_t) \geq 0 \tag{6.4}$$

The Lagrangian equation for households is as follows:

$$\mathcal{L} = E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \begin{array}{c} \left[log\,(c_t) - \frac{\eta}{1+\frac{1}{\kappa}} h_t^{1+\frac{1}{\kappa}}\right] + \lambda_{1t} \left[\begin{array}{c} B_t + R^d_{t-1}D_{t-1} \\ +P_t\theta_t + \widetilde{M}_{t-1} - M_t \\ -D_t - E_t\left[Q_{t,t+1}B_{t+1}\right] \end{array} \right] \\ +\lambda_{2t}\left[M_t - P_t\left(c_t + k_{t+1} - (1-\delta)\,k_t\right) + P_t(w_t h_t + r_t k_t)\right] \end{array} \right\} \tag{6.5}$$

Then, deriving the first-order conditions with respects to consumption, working hours, capital, money holding, bond holding and deposits yields the following equations:

$$\frac{\partial \mathcal{L}}{\partial c_t} = \frac{1}{c_t} - \lambda_{2t}P_t = 0 \Leftrightarrow \lambda_{2t} = \frac{1}{P_t c_t} \tag{6.6}$$

$$\frac{\partial \mathcal{L}}{\partial h_t} = -\eta h_t^{\frac{1}{\kappa}} + \lambda_{2t}P_t w_t = 0 \Leftrightarrow \eta h_t^{\frac{1}{\kappa}} c_t = w_t \tag{6.7}$$

$$\begin{aligned} \frac{\partial \mathcal{L}}{\partial k_{t+1}} &= -\lambda_{2t}P_t + \beta E_t\left[\lambda_{2t+1}P_{t+1}\left(1-\delta+r_{t+1}\right)\right] = 0 \\ &\Leftrightarrow \frac{1}{c_t} = \beta E_t\left[\frac{1}{c_{t+1}}\left(1-\delta+r_{t+1}\right)\right] \end{aligned} \tag{6.8}$$

$$\frac{\partial \mathcal{L}}{\partial M_t} = -\lambda_{1t} + \lambda_{2t} = 0 \Leftrightarrow \lambda_{1t} = \frac{1}{P_t c_t} \tag{6.9}$$

$$\begin{aligned} \frac{\partial \mathcal{L}}{\partial B_{t+1}} &= -\lambda_{1t} E_t Q_{t,t+1} + \beta E_t \lambda_{1t+1} = 0 \\ &\Leftrightarrow \frac{1}{P_t c_t} E_t Q_{t,t+1} = \beta E_t \left[\frac{1}{P_{t+1} c_{t+1}} \right] \\ &\Leftrightarrow \frac{1}{c_t} = \beta E_t \left[\frac{1}{\pi_{t+1} c_{t+1} Q_{t,t+1}} \right] \end{aligned} \tag{6.10}$$

$$\begin{aligned} \frac{\partial \mathcal{L}}{\partial D_t} &= -\lambda_{1t} + \beta E_t \lambda_{1t+1} R_t^d = 0 \\ &\Leftrightarrow \frac{1}{P_t c_t} = \beta E_t \left[\frac{1}{P_{t+1} c_{t+1}} \right] R_t^d \\ &\Leftrightarrow \frac{1}{c_t} = \beta E_t \left[\frac{1}{\pi_{t+1} c_{t+1}} \right] R_t^d \end{aligned} \tag{6.11}$$

$$\begin{aligned} \frac{\partial \mathcal{L}}{\partial \lambda_{2t}} &= M_t - P_t \left(c_t + k_{t+1} - (1-\delta) k_t \right) + P_t (w_t h_t + r_t k_t) = 0 \\ &\Leftrightarrow m_t - \left(c_t + k_{t+1} - (1-\delta) k_t \right) + (w_t h_t + r_t k_t) = 0 \end{aligned} \tag{6.12}$$

$$\begin{aligned} \frac{\partial \mathcal{L}}{\partial \lambda_{1t}} &= B_t + R_{t-1}^d D_{t-1} + P_t \theta_t + \widetilde{M}_{t-1} - M_t - D_t - E_t \left[Q_{t,t+1} B_{t+1} \right] = 0 \\ &\Leftrightarrow R_{t-1} \frac{d_{t-1}}{\pi_t} + \theta_t - m_t - d_t = 0 \end{aligned} \tag{6.13}$$

In a competitive equilibrium, $\widetilde{M}_{t-1} = 0$, $B_t = 0$ and $R_t^d = R_t$. Variable in small letter represents the variable in real terms, which defined as the nominal variable divided by the price at the same period. Inflation at time t, π_t is calculated as $\frac{P_t}{P_{t-1}}$. From equation 6.10 and 6.11 we can derive the deposit rate as an inverse of the expectation of asset price in the next period,$R_t^d = E_t \left[Q_{t,t+1} \right]^{-1}$.

Entrepreneur

Production function:

$$y_{it} = A_t \varepsilon_{1,it} \varepsilon_{2,it} \varepsilon_{3,it} k_{it}^{1-\alpha} h_{it}^{\alpha} \tag{6.14}$$

Expected output before the debt contract:

$$y_{it}^{e} = A_t {\varepsilon_{it}}^{e} k_{it}^{1-\alpha} h_{it}^{\alpha} \tag{6.15}$$

$$\varepsilon_{it}^{e} \equiv \begin{cases} \varepsilon_{1,it} = E\left[\varepsilon_{1,it}\varepsilon_{2,it}\varepsilon_{3,it} \mid \varepsilon_{1,it}\right] & \text{if CMF finance} \\ \varepsilon_{1,it}\varepsilon_{2,it} = E\left[\varepsilon_{1,it}\varepsilon_{2,it}\varepsilon_{3,it} \mid \varepsilon_{1,it}\varepsilon_{2,it}\right] & \text{if bank finance} \end{cases}$$

Entrepreneur's objective function:

$$\max \Pi_{it} = A_t {\varepsilon_{it}}^{e} k_{it}^{1-\alpha} h_{it}^{\alpha} - w_t h_{it} - r_t k_{it} \tag{6.16}$$

Financing constraint :

$$P_t x_{it} = P_t \left(w_t h_{it} + r_t h_{it}\right) \tag{6.17}$$

The Lagrangian is:

$$\mathcal{L} = A_t {\varepsilon_{it}}^{e} k_{it}^{1-\alpha} h_{it}^{\alpha} - w_t h_{it} - r_t k_{it} + \lambda_t (w_t h_{it} + r_t k_{it} - x_{it}) \tag{6.18}$$

The first-order conditions of the entrepreneur's problem are:

$$\begin{aligned} \frac{\partial \mathcal{L}}{\partial H_{it}} &= \alpha A_t {\varepsilon_{it}}^{e} k_{it}^{1-\alpha} h_{it}^{\alpha-1} - w_t + \lambda_t w_t = 0 \\ &\Leftrightarrow \alpha A_t {\varepsilon_{it}}^{e} k_{it}^{1-\alpha} h_{it}^{\alpha} - w_t h_{it} + \lambda_t w_t h_{it} = 0 \end{aligned} \tag{6.19}$$

$$\begin{aligned} \frac{\partial \mathcal{L}}{\partial K_{it}} &= (1-\alpha) A_t {\varepsilon_{it}}^{e} k_{it}^{-\alpha} h_{it}^{\alpha} - r_t + \lambda_t r_t = 0 \\ &\Leftrightarrow (1-\alpha) A_t {\varepsilon_{it}}^{e} k_{it}^{1-\alpha} h_{it}^{\alpha} - r_t k_{it} + \lambda_t r_t k_{it} = 0 \end{aligned} \tag{6.20}$$

By adding equation 6.19 and 6.20, we obtain:

$$A_t {\varepsilon_{it}}^e k_{it}^{1-\alpha} H_{it}^{\alpha} - (w_t h_{it} + r_t k_{it}) + \lambda_t (w_t h_{it} + r_t k_{it}) = 0$$

$$\Leftrightarrow \quad y_{it}^e - x_{it} + \lambda_t x_{it} = 0$$

$$\Leftrightarrow \quad \lambda_t = -\frac{y_{it}^e - x_{it}}{x_{it}} \tag{6.21}$$

Using equation 6.21, we can rewrite equation 6.19 as:

$$\alpha y_{it}^e - w_t h_{it} - \frac{y_{it}^e - x_{it}}{x_{it}} w_t h_{it} = 0$$

$$\Leftrightarrow \alpha y_{it}^e x_{it} - w_t h_{it} x_{it} - (y_{it}^e - x_{it}) w_t h_{it} = 0$$

$$\Leftrightarrow \alpha y_{it}^e x_{it} - y_{it}^e w_t h_{it} = 0$$

$$\Leftrightarrow \alpha x_{it} = w_t h_{it} \tag{6.22}$$

Using equation 6.21, we can also rewrite equation 6.20 as:

$$(1-\alpha) y_{it}^e - r_t k_{it} - \frac{y_{it}^e - x_{it}}{x_{it}} r_t k_{it} = 0$$

$$\Leftrightarrow (1-\alpha) y_{it}^e x_{it} - r_t k_{it} x_{it} - (y_{it}^e - x_{it}) r_t k_{it} = 0$$

$$\Leftrightarrow (1-\alpha) y_{it}^e x_{it} - y_{it}^e r_t k_{it} = 0$$

$$\Leftrightarrow (1-\alpha) x_{it} = r_t k_{it} \tag{6.23}$$

Expected output of production (equation 6.15) can also written in terms of total production cost so that we can derive the equation of q_t:

$$y_{it}^e = A_t {\varepsilon_{it}}^e k_{it}^{1-\alpha} h_{it}^{\alpha} = {\varepsilon_{it}}^e q_t x_{it} \tag{6.24}$$

$$\begin{aligned} q_t &= \frac{A_t k_{it}^{1-\alpha} h_{it}^{\alpha}}{x_{it}} \\ &= \frac{A_t \left(\frac{(1-\alpha)x_{it}}{r_t}\right)^{(1-\alpha)} \left(\frac{\alpha x_{it}}{w_t}\right)^{\alpha}}{x_{it}} \\ &= A_t \left(\frac{1-\alpha}{r_t}\right)^{(1-\alpha)} \left(\frac{\alpha}{w_t}\right)^{\alpha} \end{aligned} \tag{6.25}$$

Equation 6.22 and 6.23 is aggregated as follows:

$$\alpha x_t = w_t h_t \tag{6.26}$$

$$(1-\alpha)x_t = r_t k_t \tag{6.27}$$

Aggregation

- Total loan from bank

$$l_t^b = (1-\tau_t) s_t^{bp} (\xi - 1) n_t \tag{6.28}$$

- Total bond (loan from CMF)

$$l_t^c = s_t^c (\xi - 1) n_t \tag{6.29}$$

- Loan to bond ratio

$$\begin{aligned} \vartheta &= \frac{l_t^b}{l_t^c} = \frac{(1-\tau_t) s_t^{bp} (\xi - 1) n_t}{s_t^c (\xi - 1) n_t} \\ &\Leftrightarrow \ \vartheta = \frac{(1-\tau_t)\, s_t^{bp}}{s_t^c} \end{aligned} \tag{6.30}$$

- Total entrepreneur net worth used for production

$$ownfund = (1-\tau_t) s_t^{bp} n_t + s_t^c n_t$$

- Total cash for production

$$x_t = l_t^b + l_t^c + ownfund$$

$$\Leftrightarrow x_t = \left[(1-\tau_t)\, s_t^{bp} + s_t^c \right] \xi n_t \quad (6.31)$$

- Total output

Total output in the economy is the aggregation of total production of entrepreneurs who borrow from bank and entrepreneurs who borrow from CMF

$$y_t = y_t^b + y_t^c$$

First, output of an entrepreneur using bank financing is computed as follows:

$y_{it}^b = \varepsilon_{1i}\varepsilon_{2i}\varepsilon_{3i} q_t x_{it}^b = \varepsilon_{1i}\varepsilon_{2i}\varepsilon_{3i} q_t (1-\tau)\, \xi n_{it}$

where $\bar{\varepsilon}_b < \varepsilon_{1i} \leqslant \bar{\varepsilon}_c$ and $\varepsilon_{2i} > \bar{\varepsilon}_{di}$.

Thus, in aggregate, the total output of entrepreneurs using bank financing is:

$$y_t^b = \left[\int_{\bar{\varepsilon}_b}^{\bar{\varepsilon}_c} \varepsilon_1 \int_{\bar{\varepsilon}_d} \varepsilon_2 \Phi(d\varepsilon_2)\, \Phi(d\varepsilon_1) \int \varepsilon_3 \Phi(d\varepsilon_3) \right] q_t (1-\tau)\, \xi n_t.$$

Second, output of an entrepreneur using CMF financing is computed as:

$y_{it}^c = \varepsilon_{1i}\varepsilon_{2i}\varepsilon_{3i} q_t x_{it}^c = \varepsilon_{1i}\varepsilon_{2i}\varepsilon_{3i} q_t \xi n_{it}$

where $\varepsilon_{1i} > \bar{\varepsilon}_c$

Thus, in aggregate, the total output of entrepreneurs using CMF financing is:

$$y_t^c = \left[\int_{\bar{\varepsilon}_c} \varepsilon_1 \Phi(d\varepsilon_1) \int \varepsilon_2 \Phi(d\varepsilon_2) \int \varepsilon_3 \Phi(d\varepsilon_3) \right] q_t \xi n_t.$$

Since $\int \varepsilon_2 \Phi(d\varepsilon_2)$ and $\int \varepsilon_3 \Phi(d\varepsilon_3) = 1$, we can write the total output as:

$$y_t = \psi^y(\varkappa_t)\, q_t \xi n_t \quad (6.32)$$

where

$$\psi^{y}(\varkappa) = (1-\tau)\int_{\bar{\varepsilon}_b}^{\bar{\varepsilon}_c} \varepsilon_1 \int_{\bar{\varepsilon}_d} \varepsilon_2 \Phi(d\varepsilon_2)\,\Phi(d\varepsilon_1) + \int_{\bar{\varepsilon}_c} \varepsilon_1 \Phi(d\varepsilon_1) \tag{6.33}$$

and $\varkappa \equiv [q_t, R_t, \tau_t, \sigma_{1,t}, \sigma_{2,t}, \sigma_{3,t}, RP_t]$.

- Total institution cost

  Total institution cost is the aggregation of information acquisition cost, y_t^{ai}, and monitoring cost, y_t^{am} :

$$y_t^a = y_t^{ai} + y_t^{am} \tag{6.34}$$

  - Total information acquisition cost is computed as $y_t^{ai} = \tau_t s_t^b n_t$
  - Total monitoring cost is computed as the multiplication of the value of defaulted entrepreneur's output by monitoring cost rate
  - First, we compute the total output of entrepreneur who borrow from bank and default as follows:

    $\Phi\left(\bar{\omega}^b;\sigma_3\right)\varepsilon_1\varepsilon_2 q_t(1-\tau)\xi n_t$ for $\bar{\varepsilon}_b < \varepsilon_1 \leqslant \bar{\varepsilon}_c$ and $\varepsilon_2 > \bar{\varepsilon}_d$,

    which equal to: $\left[\int_{\bar{\varepsilon}_b}^{\bar{\varepsilon}_c}\int_{\bar{\varepsilon}_d}\Phi\left(\bar{\omega}^b;\sigma_3\right)\Phi(d\varepsilon_2)\,\Phi(d\varepsilon_1)\right] q_t(1-\tau)\xi n_t$
  - Then, we can rewrite the total monitoring cost of bank as $\psi^{mb}(\varkappa)\, q_t(1-\tau)\xi n_t\mu$, where $\psi^{mb}(\varkappa) = \int_{\bar{\varepsilon}_b}^{\bar{\varepsilon}_c}\int_{\bar{\varepsilon}_d}\Phi\left(\bar{\omega}^b;\sigma_3\right)\Phi(d\varepsilon_2)\,\Phi(d\varepsilon_1)$
  - Second, we compute the total output of entrepreneur who borrow from CMF and default as follows:

    $\Phi(\bar{\omega}^c;\sigma_2\sigma_3)\,\varepsilon_1 q_t\xi n_t$ for $\varepsilon_1 > \bar{\varepsilon}_c$

    which equal to

    $\int_{\bar{\varepsilon}_c}\Phi(\bar{\omega}^c;\sigma_2\sigma_3)\,\Phi(d\varepsilon_1)\, q_t\xi n_t$
  - Then, we can rewrite the total monitoring cost of CMF as $\psi^{mc}(\varkappa)\, q_t\xi n_t\mu$, where $\psi^{mc}(\varkappa) = \int_{\bar{\varepsilon}_c}\Phi(\bar{\omega}^c;\sigma_2\sigma_3)\,\Phi(d\varepsilon_1)$

– Third, we can compute the total monitoring cost by adding total monitoring cost of bank and CMF as follows:

$$y_t^{am} = \psi^{mb}(\varkappa)\, q_t (1-\tau)\, \xi n_t \mu + \psi^{mc}(\varkappa)\, q_t \xi n_t \mu$$

$$\Leftrightarrow y_t^{am} = \left[(1-\tau)\, \psi^{mb}(\varkappa) + \psi^{mc}(\varkappa)\right] q_t \xi n_t \mu$$

– Finally, total institution cost (equation 2.44) can be written as

$$y_t^a = \tau_t s_t^b n_t + \left[(1-\tau)\, \psi^{mb}(\varkappa) + \psi^{mc}(\varkappa)\right] q_t \xi n_t \mu$$

$$\Leftrightarrow y_t^a = \left[\tau_t s_t^b + \left[(1-\tau)\, \psi^{mb}(\varkappa) + \psi^{mc}(\varkappa)\right] q_t \xi \mu\right] n_t$$

$$\Leftrightarrow y_t^a = \left[\tau_t s_t^b + \psi^m(\varkappa_t)\, q_t \xi \mu\right] n_t, \tag{6.35}$$

where $\psi^m(\varkappa) = (1-\tau)\, \psi^{mb}(\varkappa) + \psi^{mc}(\varkappa)$

- Aggregate profits of the entrepreneurial sector

  Aggregate profits of the entrepreneurial sector is computed as the sum of: (1) profits of entrepreneurs who abstain from production, (2) profits of entrepreneurs who produce using bank financing, and (3) profits of entrepreneur who produce using CMF financing.

  1. Profit rate of entrepreneurs who abstain from production $= \frac{n}{n} = 1$
  2. Profit rate of entrepreneurs who produce using bank financing $= \frac{F^b(\cdot)n}{n} = F^b(\cdot)$ for $\bar{\varepsilon}_b < \varepsilon_1 \leqslant \bar{\varepsilon}_c$ and $\varepsilon_2 > \bar{\varepsilon}_d$, which equal to $\int_{\bar{\varepsilon}_b}^{\bar{\varepsilon}_c} F^b(\cdot)\, \Phi(d\varepsilon_1)$
  3. Profit rate of entrepreneur who produce using CMF financing $= \frac{F^c(\cdot)n}{n} = F^c(\cdot)$ for $\varepsilon_1 > \bar{\varepsilon}_c$, which equal to $\int_{\bar{\varepsilon}_c} F^c(\cdot)\, \Phi(d\varepsilon_1)$

  – Then, the aggregate profit rate of entrepreneurial sector is

$$\psi^f(\varkappa) = s^a + \int_{\bar{\varepsilon}_b}^{\bar{\varepsilon}_c} F^b(\cdot)\, \Phi(d\varepsilon_1) + \int_{\bar{\varepsilon}_c} F^c(\cdot)\, \Phi(d\varepsilon_1) \tag{6.36}$$

where $\varkappa \equiv [q_t, R_t, \tau_t, \sigma_{1,t}, \sigma_{2,t}, \sigma_{3,t}]$

- Aggregate risk premium
  - As in 2.25, risk premium for a bank loan is $\Lambda_{it} = \frac{\bar{\omega}\varepsilon_{it}{}^e q_t}{R_t} \frac{\xi}{(\xi-1)} - 1$. Therefore, the aggregation of bank's risk premium for all entrepreneurs who use bank financing ($\bar{\varepsilon}_b < \varepsilon_1 \leqslant \bar{\varepsilon}_c$ and $\varepsilon_2 > \bar{\varepsilon}_d$) is as follows:

$$\psi^{rb}(\varkappa) = \int_{\bar{\varepsilon}_b}^{\bar{\varepsilon}^c} \int_{\bar{\varepsilon}_d} \left[\frac{\left(\frac{\xi}{\xi-1}\right) q\varepsilon_1\varepsilon_2\bar{\omega}^b(\cdot)}{R} - 1 \right] \Phi(d\varepsilon_2)\Phi(d\varepsilon_1) \quad (6.37)$$

  - Using the similar approach, we can get the aggregation of CMF's risk premium for all entrepreneurs who use CMF financing ($\varepsilon_1 > \bar{\varepsilon}_c$) as follows:

$$\psi^{rc}(\varkappa) = \int_{\bar{\varepsilon}^c} \left[\frac{\left(\frac{\xi}{\xi-1}\right) q\varepsilon_1\bar{\omega}^c(\cdot)}{R} - 1 \right] \Phi(d\varepsilon_1) \quad (6.38)$$

  - Then, the average risk premium of bank and risk premium of CMF can be computed as the total risk premium divided by the share of entrepreneurs in each category of financing type:

$$rp_t^b \equiv \frac{\psi^{rb}(\varkappa_t)}{s_t^{bp}} \quad (6.39)$$

$$rp_t^c \equiv \frac{\psi^{rc}(\varkappa_t)}{s_t^c} \quad (6.40)$$

- The debt to output ratio in the economy is computed as:

$$\chi_t = \frac{l_t^b + l_t^c}{y_t}$$

$$\Leftrightarrow \chi_t = \frac{\left[(1-\tau_t)\, s_t^{bp} + s_t^c\right](\xi - 1)\, n_t}{y_t} \quad (6.41)$$

- Average default rate of bank is computed as the total defaulted loan from bank divided by the total value of loan from bank

$$\varrho_t^b = \frac{\psi^{mb}(\varkappa)(1-\tau_t)(\xi-1)\,n_t}{(1-\tau_t)s_t^{bp}(\xi-1)\,n_t} = \frac{\psi^{mb}(\varkappa)}{s_t^{bp}} \tag{6.42}$$

- Average default rate of bond is computed as the total defaulted loan from CMF divided by the total value of loan from CMF

$$\varrho_t^c = \frac{\psi^{mc}(\varkappa)(\xi-1)n_t}{s_t^c(\xi-1)\,n_t} = \frac{\psi^{mc}(\varkappa)}{s_t^c} \tag{6.43}$$

Central Bank

- Total amount of liquidity injections :

$$P_t\theta_t = M_t^s - M_{t-1}^s \tag{6.44}$$

$$\begin{aligned}
\Leftrightarrow \quad \theta_t &= \frac{M_t^s - M_{t-1}^s}{P_t} \\
\Leftrightarrow \quad \theta_t &= \frac{M_t^s}{P_t} - \frac{M_{t-1}^s}{P_t}\frac{P_{t-1}}{P_{t-1}} \\
\Leftrightarrow \quad \theta_t &= m_t^s - \frac{m_{t-1}^s}{\pi_t}
\end{aligned} \tag{6.45}$$

- Money supply:

$$\frac{M_t^s}{M_{t-1}^s} = \nu$$

$$\Leftrightarrow \frac{\frac{M_t^s}{P_t}}{\frac{M_{t-1}^s}{P_t}\frac{P_{t-1}}{P_{t-1}}} = \nu$$

$$\Leftrightarrow \frac{m_t^s\pi_t}{m_{t-1}^s} = \nu$$

$$\Leftrightarrow m_t^s = \frac{m_{t-1}^s}{\pi_t}\nu \tag{6.46}$$

Using equation 6.46, we can write equation 6.45 as:

$$\theta_t = \frac{m_{t-1}^s \nu}{\pi_t} - \frac{m_{t-1}^s}{\pi_t}$$

$$\Leftrightarrow \theta_t = \frac{m_{t-1}^s}{\pi_t} (\nu - 1) \tag{6.47}$$

6.1.3 Competitive Equilibrium Condition

This appendix compiles all the relevant competitive equilibrium condition of the basic model

Households

$$\eta h_t^{\frac{1}{\kappa}} c_t = w_t \tag{6.48}$$

$$\frac{1}{c_t} = \beta R_t E_t \left[\frac{1}{c_{t+1}\pi_{t+1}} \right] \tag{6.49}$$

$$\frac{1}{c_t} = \beta E_t \left[\frac{1}{c_{t+1}} (1 - \delta + r_{t+1}) \right] \tag{6.50}$$

$$m_t + d_t = \frac{R_{t-1}}{\pi_t} d_t + \theta_t \tag{6.51}$$

$$0 = m_t + w_t h_t + r_t k_t - c_t - k_{t+1} + (1 - \delta) k_t \tag{6.52}$$

Entrepreneurs

$$q_t = A_t \left(\frac{\alpha}{w_t}\right)^{\alpha} \left(\frac{1-\alpha}{r_t}\right)^{1-\alpha} \tag{6.53}$$

$$r_t (k_t + z_t) = (1-\alpha) x_t \tag{6.54}$$

$$w_t h_t = \alpha x_t \tag{6.55}$$

$$e_t = \gamma \psi^f (\varkappa_t) n_t \tag{6.56}$$

$$z_{t+1} = (1-\gamma) \psi^f (\varkappa_t) n_t \tag{6.57}$$

$$n_t = (1 - \delta + r_t) z_t \tag{6.58}$$

$$F^d \left(\varepsilon_{1,it}, \bar{\varepsilon}_{it}^d; q_t, R_t, \sigma_{3t}\right) = 1 \tag{6.59}$$

$$F^b (\bar{\varepsilon}_{bt}; q_t, R_t, \tau_t, \sigma_{2t}, \sigma_{3t}) = 1 \tag{6.60}$$

$$F^b (\bar{\varepsilon}_{ct}; q_t, R_t, \tau_t, \sigma_{2t}, \sigma_{3t}) = F^c (\bar{\varepsilon}_{ct}; q_t, R_t, \sigma_{2t}, \sigma_{3t}) \tag{6.61}$$

Central Bank

$$m_t^s = \nu \frac{m_{t-1}^s}{\pi_t} \tag{6.62}$$

$$\theta_t = (\nu - 1) \frac{m_{t-1}^s}{\pi_t} \tag{6.63}$$

Market clearing:

$$y_t^a = y_t - c_t - e_t - I_t \tag{6.64}$$

$$I_t = k_{t+1} + z_{t+1} - (1-\delta)(k_t + z_t) \tag{6.65}$$

$$m_t^s = m_t + d_t \tag{6.66}$$

$$d_t = \left[(1-\tau_t)\, s_t^{bp} + s_t^c\right](\xi - 1)\, n_t \tag{6.67}$$

$$l_t^b = (1-\tau_t)\, s_t^{bp}(\xi - 1) n_t \tag{6.68}$$

$$l_t^c = s_t^c(\xi - 1) n_t \tag{6.69}$$

$$x_t = \left[(1-\tau_t)\, s_t^{bp} + s_t^c\right] \xi n_t \tag{6.70}$$

$$y_t = \psi^y(\varkappa_t)\, q_t \xi n_t \tag{6.71}$$

$$y_t^a = \left[\tau_t s_t^b + \psi^m(\varkappa_t)\, \mu \xi q_t\right) n_t \tag{6.72}$$

Financial structure

$$\vartheta = \frac{(1-\tau_t)\, s_t^{bp}}{s_t^c} \tag{6.73}$$

$$rp_t^b \equiv \frac{\psi^{rb}(\varkappa_t)}{s_t^{bp}} \tag{6.74}$$

$$rp_t^c \equiv \frac{\psi^{rc}(\varkappa_t)}{s_t^c} \tag{6.75}$$

$$\chi_t = \frac{d_t}{y_t} \tag{6.76}$$

$$\varrho_t^b = \frac{\psi^{mb}(\varkappa_t)}{s_t^{bp}} \tag{6.77}$$

$$\varrho_t^c = \frac{\psi^{mc}(\varkappa_t)}{s_t^c} \tag{6.78}$$

$$\varrho_t = \frac{\psi^{mb}(\varkappa_t) + \psi^{mc}(\varkappa_t)}{s_t^{bp} + s_t^c} \tag{6.79}$$

$$s_t^a = \Phi\left(\bar{\varepsilon}^b\left(q_t, R_t, \tau_t, \sigma_{2t}, \sigma_{3t}\right); \sigma_{1t}\right) \tag{6.80}$$

$$s_t^b = \Phi\left(\bar{\varepsilon}^c\left(q_t, R_t, \tau_t, \sigma_{2t}, \sigma_{3t}\right); \sigma_{1t}\right) - \Phi\left(\bar{\varepsilon}^b\left(q_t, R_t, \tau_t, \sigma_{2t}, \sigma_{3t}\right); \sigma_{1t}\right) \tag{6.81}$$

$$s_t^{bp} = \int_{\bar{\varepsilon}^b(q_t,R_t,\tau_t,\sigma_{2t},\sigma_{3t})}^{(\bar{\varepsilon}^c(q_t,R_t,\tau_t,\sigma_{2t},\sigma_{3t})} \int_{(\bar{\varepsilon}^d(\varepsilon_1;q_t,R_t,\sigma_{3t})} \Phi\left(d\varepsilon_2\right)\Phi\left(d\varepsilon_1\right) \tag{6.82}$$

$$s_t^c = 1 - \Phi\left(\bar{\varepsilon}^c\left(q_t, R_t, \tau_t, \sigma_{2t}, \sigma_{3t}\right); \sigma_{1t}\right) \tag{6.83}$$

6.2 Appendix for Chapter 2

This appendix compiles all the relevant competitive equilibrium condition of the modified model for chapter 2. Types of taxation rate are denoted by: t_t^c for consumption tax, t_t^l for labour income tax, and t_t^{ls} for lump-sum tax

6.2.1 Competitive Equilibrium Equations

Households

$$\eta h_t^{\frac{1}{\kappa}}(1+t_t^c)c_t = \left(1 - t_t^l\right) w_t \tag{6.84}$$

$$\frac{1}{(1+t_t^c)c_t} = \beta R_t E_t\left[\frac{1}{(1+t_{t+1}^c)c_{t+1}\pi_{t+1}}\right] \tag{6.85}$$

$$\frac{1}{(1+t_t^c)c_t} = \beta E_t\left[\frac{1}{(1+t_{t+1}^c)c_{t+1}}\left(1-\delta+r_{t+1}\right)\right] \tag{6.86}$$

$$m_t + d_t = \frac{R_{t-1}}{\pi_t} d_{t-1} + \theta_t \tag{6.87}$$

$$0 = m_t + (1 - t_t^l) w_t h_t + r_t k_t - (1 + t_t^c) c_t - k_{t+1} + (1 - \delta) k_t - t_t^{ls} \tag{6.88}$$

Entrepreneurs

$$n_t = (1 - \delta + r_t) z_t \tag{6.89}$$

$$q_t = A_t \left(\frac{\alpha}{w_t} \right)^{\alpha} \left(\frac{1 - \alpha}{r_t} \right)^{1-\alpha} \tag{6.90}$$

$$r_t (k_t + z_t) = (1 - \alpha) x_t \tag{6.91}$$

$$w_t h_t = \alpha x_t \tag{6.92}$$

$$(1 + t_t^c) e_t = \gamma \psi^f (\varkappa_t) n_t \tag{6.93}$$

$$z_{t+1} = (1 - \gamma) \psi^f (\varkappa_t) n_t \tag{6.94}$$

$$1 = F^d \left(\varepsilon_{1,it}, \bar{\varepsilon}_{it}^d; q_t, R_t, \sigma_{3t}, s_t^M \right) \tag{6.95}$$

$$1 = F^b \left(\bar{\varepsilon}_{bt}; q_t, R_t, \tau_t, \sigma_{2t}, \sigma_{3t}, s_t^I, s_t^M \right) \tag{6.96}$$

$$F^b \left(\bar{\varepsilon}_{ct}; q_t, R_t, \tau_t, \sigma_{2t}, \sigma_{3t}, s_t^I, s_t^M \right) = F^c \left(\bar{\varepsilon}_{ct}; q_t, R_t, \sigma_{2t}, \sigma_{3t}, s_t^I, s_t^M \right) \tag{6.97}$$

Monetary authority

$$\theta_t = (\nu - 1) \frac{m_{t-1}^s}{\pi_t} \tag{6.98}$$

$$m_t^s = \frac{m_{t-1}^s}{\pi_t} \nu \tag{6.99}$$

Government Budget

$$\sum Subsidy = \sum TaxRevenue \tag{6.100}$$

Market clearing

$$y_t^a = y_t - c_t - e_t - I_t \tag{6.101}$$

$$I_t = k_{t+1} + z_{t+1} - (1-\delta)(k_t + z_t) \tag{6.102}$$

$$m_t^s = m_t + d_t \tag{6.103}$$

$$d_t = \left[\left(1 - \tau_t + s_t^I \tau_t\right) s_t^{bp} + s_t^c\right] (\xi - 1) n_t \tag{6.104}$$

$$x_t = \left[\left(1 - \tau_t + s_t^I \tau_t\right) s_t^{bp} + s_t^c\right] \xi n_t \tag{6.105}$$

$$y_t = \psi^y (\varkappa_t) q_t \xi n_t \tag{6.106}$$

$$y_t^a = \left[\tau_t s_t^b + \psi^m (\varkappa_t) \mu \xi q_t\right] n_t \tag{6.107}$$

Financial structure

$$\vartheta_t = \frac{\left(1 - \tau_t + s_t^I \tau_t\right) s_t^{bp}}{s_t^c} \tag{6.108}$$

$$rp_t^b \equiv \frac{\psi^{rb} (\varkappa_t)}{s_t^{bp}} \tag{6.109}$$

$$rp_t^c \equiv \frac{\psi^{rc} (\varkappa_t)}{s_t^c} \tag{6.110}$$

$$\chi_t = \frac{d_t}{y_t} \tag{6.111}$$

$$\varrho_t^c = \frac{\psi^{mc} (\varkappa_t)}{s_t^c} \tag{6.112}$$

$$\varrho_t = \frac{\psi^{mb} (\varkappa_t) + \psi^{mc} (\varkappa_t)}{s_t^{bp} + s_t^c} \tag{6.113}$$

$$s_t^a = \Phi\left(\bar{\varepsilon}^b \left(q_t, R_t, \tau_t, \sigma_{2t}, \sigma_{3t}, s_t^I, s_t^M\right); \sigma_{1t}\right) \tag{6.114}$$

$$s_t^b = \Phi\left(\bar{\varepsilon}^c \left(q_t, R_t, \tau_t, \sigma_{2t}, \sigma_{3t}, s_t^I, s_t^M\right); \sigma_{1t}\right) - \Phi\left(\bar{\varepsilon}^b \left(q_t, R_t, \tau_t, \sigma_{2t}, \sigma_{3t}, s_t^I, s_t^M\right); \sigma_{1t}\right) \tag{6.115}$$

$$s_t^c = 1 - \Phi\left(\bar{\varepsilon}^c \left(q_t, R_t, \tau_t, \sigma_{2t}, \sigma_{3t}, s_t^I, s_t^M\right); \sigma_{1t}\right) \tag{6.116}$$

$$s_t^{bp} = \int_{\bar{\varepsilon}^b\left(q_t,R_t,\tau_t,\sigma_{2t},\sigma_{3t},s_t^I,s_t^M\right)}^{(\bar{\varepsilon}^c\left(q_t,R_t,\tau_t,\sigma_{2t},\sigma_{3t},s_t^I,s_t^M\right)} \int_{(\bar{\varepsilon}^d\left(\varepsilon_1;q_t,R_t,\sigma_{3t},s_t^M\right)} \Phi\left(d\varepsilon_2\right)\Phi\left(d\varepsilon_1\right) \tag{6.117}$$

6.2.2 Derivation of Consumption Equivalent

First, I define the aggregate welfare as the total of household and entrepreneur's utility in the steady state:

$$W(c,h,e) = U(c,h) + U(e)$$

Second, I define the level of welfare of the baseline model without policy as $W_0(c_0, h_0, e_0)$, and the welfare in the alternative model with additional policy as $W_1(c_1, h_1, e_1)$. Then I compute consumption equivalent (CE) such that:

$$W_0(c_0(1+CE\%), h_0, e_0(1+CE\%)) = W_1(c_1, h_1, e_1)$$

Using the functional form of household utility as in equation 2.1 and the linear utility function of entrepreneur, I can derive the consumption equivalent as follows:

$$\log\left(c_0(1+CE\%)\right) - \frac{\eta}{1+\frac{1}{\kappa}} h_0^{1+\frac{1}{\kappa}} + (1+CE\%)e_0 = W_1(c_1, h_1, e_1)$$

$$\log(c_0) + \log(1+CE\%) - \frac{\eta}{1+\frac{1}{\kappa}} h_0^{1+\frac{1}{\kappa}} + e_0 + e_0.CE\% = W_1(c_1, h_1, e_1)$$

$$\log(1+CE\%) + e_0.CE\% = W_1(c_1, h_1, e_1) - W_0(c_0, h_0, e_0) \tag{6.118}$$

Finally, we can obtain the value of CE using a mathematical solver.

6.2.3 Detailed Results: Impact of Subsidy on Steady State Values

Table 6.1: Policy 1 - Subsidy on Bank Information Acquisition Cost, Tax on Labour Income

Variables	subs=0	subs=0.1	subs=0.3	subs=0.8	Trend
Financial sector variables					
Threshold of e_1 for approaching bank (eps bar b)	0.9952	0.9945	0.9927	0.9834	
Threshold of e_1 for borrowing from CMF (eps bar c)	1.0282	1.0302	1.0348	1.0530	
Share of firms that abstain from external finance (sa)	0.3893	0.3717	0.3311	0.1575	
Share of firms that approacing bank (sb)	0.5651	0.5929	0.6497	0.8416	
Share of firms that borrow from CMF (sc)	0.0456	0.0354	0.0192	0.0009	
Share of firms that approach bank and borrow (sbp)	0.2470	0.2530	0.2606	0.2511	
Share of firms that approach bank but not borrow (sb - sbp)	0.3180	0.3399	0.3890	0.5904	
Aggregate bankloans/bond	5.3591	7.0746	13.4945	282.5203	
Aggregate debt/equity	0.6371	0.6284	0.6103	0.5522	
Risk premium CMF	0.0029	0.0028	0.0027	0.0022	
Risk premium of bank	0.0030	0.0030	0.0030	0.0030	
Average default of bank	0.0149	0.0150	0.0150	0.0152	
Average default of CMF	0.0144	0.0141	0.0136	0.0113	
Average overall default	0.0149	0.0149	0.0149	0.0152	
Aggregate debt to GDP	0.6660	0.6661	0.6663	0.6672	
Macroeconomic variables					
Household consumption (c)	1.0000	0.9999	0.9996	0.9964	
Household deposit (d)	0.9035	0.9044	0.9063	0.9122	
Household money cash (m)	0.0137	0.0137	0.0137	0.0138	
Money supply (ms)	0.9172	0.9181	0.9200	0.9260	
Work hours (h)	0.3259	0.3259	0.3259	0.3259	
Household's capital (k)	14.3236	14.3179	14.3058	14.2435	
Entrepeneur's capital (z)	1.4038	1.4248	1.4701	1.6355	
Total capital (K)	15.7274	15.7427	15.7759	15.8790	
Entrepreneur consumption (e)	0.0322	0.0327	0.0337	0.0375	
Firm's net worth (n)	1.4180	1.4392	1.4849	1.6520	
Tax rate (t)	0.0000	0.0010	0.0034	0.0130	
Real wage (w)	2.5825	2.5849	2.5903	2.6071	
Real rent (r)	0.0301	0.0301	0.0301	0.0301	
Entrepreneur's funds (x)	1.3150	1.3163	1.3191	1.3277	
Total output (y)	1.3565	1.3578	1.3602	1.3672	
Total junk cost (information + monitoring cost, ya)	0.0098	0.0103	0.0114	0.0156	
Information cost(ytau)	0.0079	0.0084	0.0095	0.0138	
Monitoring cost (ym)	0.0018	0.0018	0.0018	0.0019	
GDP (ynet)	1.3468	1.3475	1.3488	1.3515	
Entrepreneurial markup over input cost (q)	1.0005	0.9999	0.9986	0.9945	
HH Income from rent and work (1-t)*wh+rk	1.2728	1.2726	1.2720	1.2675	
Tax revenue : t*w*h = total subsidy	0.0000	0.0008	0.0029	0.0110	
Total consumption (C)	1.0322	1.0326	1.0333	1.0340	
Entrepreneur Investment	0.0281	0.0285	0.0294	0.0327	
Household Investment	0.2865	0.2864	0.2861	0.2849	
Total Investment (I)	0.3145	0.3149	0.3155	0.3176	
Subsidy/GDP (%)	0.00%	0.06%	0.21%	0.81%	

Table 6.2: Policy 2 - Subsidy on Bank Information Acquisition Cost, Tax on Consumption

Variables	subs=0	subs 0.1	subs=0.3	subs=0.8	Trend
Financial sector variables					
Threshold of e_1 for approaching bank (eps bar b)	0.9952	0.9945	0.9927	0.9834	
Threshold of e_1 for borrowing from CMF (eps bar c)	1.0282	1.0302	1.0348	1.0530	
Share of firms that abstain from external finance (sa)	0.3893	0.3717	0.3311	0.1575	
Share of firms that approacing bank (sb)	0.5651	0.5929	0.6497	0.8416	
Share of firms that borrow from CMF (sc)	0.0456	0.0354	0.0192	0.0009	
Share of firms that approach bank and borrow (sbp)	0.2470	0.2530	0.2606	0.2511	
Share of firms that approach bank but not borrow (sb - sbp)	0.3180	0.3399	0.3890	0.5904	
Aggregate bankloans/bond	5.3591	7.0746	13.4946	282.5232	
Aggregate debt/equity	0.6371	0.6284	0.6103	0.5522	
Risk premium CMF	0.0029	0.0028	0.0027	0.0022	
Risk premium of bank	0.0030	0.0030	0.0030	0.0030	
Average default of bank	0.0149	0.0150	0.0150	0.0152	
Average default of CMF	0.0144	0.0141	0.0136	0.0113	
Average overall default	0.0149	0.0149	0.0149	0.0152	
Aggregate debt to GDP	0.6660	0.6661	0.6663	0.6672	
Macroeconomic variables					
Household consumption (c)	1.0000	0.9999	0.9995	0.9960	
Household deposit (d)	0.9035	0.9049	0.9082	0.9198	
Household money (cash)	0.0137	0.0137	0.0138	0.0139	
Money supply (ms)	0.9172	0.9186	0.9220	0.9338	
Work hours (h)	0.3259	0.3261	0.3266	0.3287	
Household's capital (k)	14.3236	14.3270	14.3367	14.3632	
Entrepeneur's capital (z)	1.4038	1.4257	1.4732	1.6492	
Total capital (K)	15.7274	15.7527	15.8100	16.0123	
Entrepreneur consumption (e)	0.0322	0.0327	0.0337	0.0375	
Firm's net worth (n)	1.4180	1.4402	1.4881	1.6658	
Tax rate (t)	0.0000	0.0008	0.0028	0.0107	
Real wage (w)	2.5825	2.5849	2.5903	2.6071	
Real rent (r)	0.0301	0.0301	0.0301	0.0301	
Entrepreneur's funds (x)	1.3150	1.3171	1.3219	1.3389	
Total output (y)	1.3565	1.3586	1.3632	1.3787	
Total junk cost (information + monitoring cost, ya)	0.0098	0.0110	0.0138	0.0250	
Information cost(ytau)	0.0079	0.0084	0.0096	0.0139	
Monitoring cost (ym)	0.0018	0.0025	0.0042	0.0111	
GDP (ynet)	1.3468	1.3477	1.3494	1.3537	
Entrepreneurial markup over input cost (q)	1.0005	0.9999	0.9986	0.9945	
HH Income from rent and work (wh+rk)	1.2728	1.2742	1.2776	1.2892	
Tax revenue : t*(c+e) = total subsidy	0.0000	0.0008	0.0029	0.0111	
Total consumption (C)	1.0322	1.0326	1.0332	1.0334	
Entrepreneur Investment	0.0281	0.0285	0.0295	0.0330	
Household Investment	0.2865	0.2865	0.2867	0.2873	
Total Investment I)	0.3145	0.3151	0.3162	0.3202	
Subsidy/GDP (%)	0.00%	0.06%	0.21%	0.82%	

Table 6.3: Policy 3 - Subsidy on Bank Information Acquisition Cost, Lumpsum Tax

Variables	subs=0	subs 0.1	subs=0.3	subs=0.8	Trend
Financial sector variables					
Threshold of e_1 for approaching bank (eps bar b)	0.9952	0.9945	0.9927	0.9834	
Threshold of e_1 for borrowing from CMF (eps bar c)	1.0282	1.0302	1.0348	1.0530	
Share of firms that abstain from external finance (sa)	0.3893	0.3717	0.3311	0.1575	
Share of firms that approacing bank (sb)	0.5651	0.5929	0.6497	0.8416	
Share of firms that borrow from CMF (sc)	0.0456	0.0354	0.0192	0.0009	
Share of firms that approach bank and borrow (sbp)	0.2470	0.2530	0.2606	0.2511	
Share of firms that approach bank but not borrow (sb - sbp)	0.3180	0.3399	0.3890	0.5904	
Aggregate bankloans/bond	5.3591	7.0746	13.4945	282.5203	
Aggregate debt/equity	0.6371	0.6284	0.6103	0.5522	
Risk premium CMF	0.0029	0.0028	0.0027	0.0022	
Risk premium of bank	0.0030	0.0030	0.0030	0.0030	
Average default of bank	0.0149	0.0150	0.0150	0.0152	
Average default of CMF	0.0144	0.0141	0.0136	0.0113	
Average overall default	0.0149	0.0149	0.0149	0.0152	
Aggregate debt to GDP	0.6660	0.6661	0.6663	0.6672	
Macroeconomic variables					
Household consumption (c)	1.0000	1.0007	1.0021	1.0062	
Household deposit (d)	0.9035	0.9050	0.9086	0.9211	
Household money (cash)	0.0137	0.0137	0.0138	0.0140	
Money supply (ms)	0.9172	0.9187	0.9223	0.9351	
Work hours (h)	0.3259	0.3261	0.3267	0.3291	
Household's capital (k)	14.3236	14.3287	14.3423	14.3835	
Entrepeneur's capital (z)	1.4038	1.4259	1.4738	1.6515	
Total capital (K)	15.7274	15.7546	15.8161	16.0350	
Entrepreneur consumption (e)	0.0322	0.0327	0.0338	0.0379	
Firm's net worth (n)	1.4180	1.4403	1.4887	1.6682	
Tax rate (t)	0.0000	0.0008	0.0029	0.0111	
Real wage (w)	2.5825	2.5849	2.5903	2.6071	
Real rent (r)	0.0301	0.0301	0.0301	0.0301	
Entrepreneur's funds (x)	1.3150	1.3173	1.3224	1.3407	
Total output (y)	1.3565	1.3588	1.3637	1.3806	
Total junk cost (information + monitoring cost, ya)	0.0098	0.0103	0.0114	0.0158	
Information cost(ytau)	0.0079	0.0085	0.0096	0.0139	
Monitoring cost (ym)	0.0018	0.0018	0.0018	0.0019	
GDP (ynet)	1.3468	1.3485	1.3523	1.3648	
Entrepreneurial markup over input cost (q)	1.0005	0.9999	0.9986	0.9945	
HH Income from rent and work (wh+rk)	1.2728	1.2744	1.2781	1.2910	
Tax revenue = total subsidy	0.0000	0.0008	0.0029	0.0111	
Total consumption (C)	1.0322	1.0334	1.0360	1.0441	
Entrepreneur Investment	0.0281	0.0285	0.0295	0.0330	
Household Investment	0.2865	0.2866	0.2868	0.2877	
Total Investment I)	0.3145	0.3151	0.3163	0.3207	
Subsidy/GDP (%)	0.00%	0.06%	0.21%	0.81%	

Table 6.4: Policy 4 - Subsidy on Bank Monitoring Cost, Tax on Labour Income

Variables	subs=0	subs=0.1	subs=0.3	subs=0.8	Trend
Financial sector variables					
Threshold of e_1 for approaching bank (eps bar b)	0.9952	0.9952	0.9951	0.9950	
Threshold of e_1 for borrowing from CMF (eps bar c)	1.0282	1.0288	1.0299	1.0331	
Share of firms that abstain from external finance (sa)	0.3893	0.3887	0.3871	0.3840	
Share of firms that approacing bank (sb)	0.5651	0.5687	0.5760	0.5916	
Share of firms that borrow from CMF (sc)	0.0456	0.0427	0.0369	0.0244	
Share of firms that approach bank and borrow (sbp)	0.2470	0.2501	0.2561	0.2698	
Share of firms that approach bank but not borrow (sb - sbp)	0.3180	0.3186	0.3199	0.3218	
Aggregate bankloans/bond	5.3591	5.8026	6.8623	10.9607	
Aggregate debt/equity	0.6371	0.6372	0.6377	0.6398	
Risk premium CMF	0.0029	0.0029	0.0028	0.0027	
Risk premium of bank	0.0030	0.0028	0.0023	0.0013	
Average default of bank	0.0149	0.0149	0.0149	0.0148	
Average default of CMF	0.0144	0.0143	0.0141	0.0137	
Average overall default	0.0149	0.0148	0.0148	0.0147	
Aggregate debt to GDP	0.6660	0.6661	0.6662	0.6666	
Macroeconomic variables					
Household consumption (c)	1.0000	0.9999	0.9997	0.9991	
Household deposit (d)	0.9035	0.9036	0.9039	0.9046	
Household money cash (m)	0.0137	0.0137	0.0137	0.0137	
Money supply (ms)	0.9172	0.9173	0.9176	0.9183	
Work hours (h)	0.3259	0.3259	0.3259	0.3258	
Household's capital (k)	14.3236	14.3260	14.3315	14.3471	
Entrepeneur's capital (z)	1.4038	1.4039	1.4032	1.3997	
Total capital (K)	15.7274	15.7299	15.7347	15.7468	
Entrepreneur consumption (e)	0.0322	0.0322	0.0322	0.0321	
Firm's net worth (n)	1.4180	1.4181	1.4173	1.4138	
Tax rate (t)	0.0000	0.0003	0.0009	0.0026	
Real wage (w)	2.5825	2.5830	2.5840	2.5866	
Real rent (r)	0.0301	0.0301	0.0301	0.0301	
Entrepreneur's funds (x)	1.3150	1.3152	1.3156	1.3166	
Total output (y)	1.3565	1.3566	1.3568	1.3570	
Total junk cost (information + monitoring cost, ya)	0.0098	0.0099	0.0102	0.0108	
Information cost(ytau)	0.0079	0.0080	0.0081	0.0083	
Monitoring cost (ym)	0.0018	0.0019	0.0021	0.0026	
GDP (ynet)	1.3468	1.3467	1.3466	1.3462	
Entrepreneurial markup over input cost (q)	1.0005	1.0004	1.0002	0.9995	
HH Income from rent and work (1-t)*wh+rk	1.2728	1.2727	1.2726	1.2724	
tax revenue : t*w*h = total subsidy	0.0000	0.0003	0.0008	0.0022	
Total consumption (C)	1.0322	1.0321	1.0319	1.0313	
Entrepreneur Investment	0.0281	0.0281	0.0281	0.0280	
Household Investment	0.2865	0.2865	0.2866	0.2869	
Total Investment (I)	0.3145	0.3146	0.3147	0.3149	
Subsidy/GDP (%)	0.00%	0.02%	0.06%	0.16%	

Table 6.5: Policy 5 - Subsidy on Bank Monitoring Cost, Tax on Consumption

Variables	subs=0	subs 0.1	subs=0.3	subs = 0.8	Trend
Financial sector variables					
Threshold of e_1 for approaching bank (eps bar b)	0.9952	0.9952	0.9951	0.9950	
Threshold of e_1 for borrowing from CMF (eps bar c)	1.0282	1.0288	1.0299	1.0331	
Share of firms that abstain from external finance (sa)	0.3893	0.3887	0.3871	0.3840	
Share of firms that approacing bank (sb)	0.5651	0.5687	0.5760	0.5916	
Share of firms that borrow from CMF (sc)	0.0456	0.0427	0.0369	0.0244	
Share of firms that approach bank and borrow (sbp)	0.2470	0.2501	0.2561	0.2698	
Share of firms that approach bank but not borrow (sb - sbp)					
Aggregate bankloans/bond	5.3591	5.8026	6.8623	10.9607	
Aggregate debt/equity	0.6371	0.6372	0.6377	0.6398	
Risk premium CMF	0.0029	0.0029	0.0028	0.0027	
Risk premium of bank	0.0030	0.0028	0.0023	0.0013	
Average default of bank	0.0149	0.0149	0.0149	0.0148	
Average default of CMF	0.0144	0.0143	0.0141	0.0137	
Average overall default	0.0149	0.0148	0.0148	0.0147	
Aggregate debt to GDP	0.6660	0.6661	0.6662	0.6666	
Macroeconomic variables					
Household consumption (c)	1.0000	0.9999	0.9997	0.9991	
Household deposit (d)	0.9035	0.9038	0.9044	0.9060	
Household money cash (m)	0.0137	0.0137	0.0137	0.0137	
Money supply (ms)	0.9172	0.9175	0.9181	0.9198	
Work hours (h)	0.3259	0.3259	0.3260	0.3263	
Household's capital (k)	14.3236	14.3287	14.3398	14.3703	
Entrepeneur's capital (z)	1.4038	1.4041	1.4040	1.4019	
Total capital (K)	15.7274	15.7328	15.7438	15.7722	
Entrepreneur consumption (e)	0.0322	0.0322	0.0322	0.0321	
Firm's net worth (n)	1.4180	1.4183	1.4181	1.4161	
Tax rate (t)	0.0000	0.0002	0.0007	0.0021	
Real wage (w)	2.5825	2.5830	2.5840	2.5866	
Real rent (r)	0.0301	0.0301	0.0301	0.0301	
Entrepreneur's funds (x)	1.3150	1.3155	1.3164	1.3188	
Total output (y)	1.3565	1.3569	1.3575	1.3592	
Total junk cost (information + monitoring cost, ya)	0.0098	0.0101	0.0108	0.0126	
Information cost(ytau)	0.0079	0.0080	0.0081	0.0083	
Monitoring cost (ym)	0.0018	0.0021	0.0027	0.0043	
GDP (ynet)	1.3468	1.3468	1.3468	1.3466	
Entrepreneurial markup over input cost (q)	1.0005	1.0004	1.0002	0.9995	
HH Income from rent and work (wh+rk)	1.2728	1.2732	1.2741	1.2766	
Tax revenue : t*(c+e) = total subsidy	0.0000	0.0003	0.0008	0.0021	
Total consumption (C)	1.0322	1.0321	1.0319	1.0312	
Entrepreneur Investment	0.0281	0.0281	0.0281	0.0280	
Household Investment	0.2865	0.2866	0.2868	0.2874	
Total Investment (I)	0.3145	0.3147	0.3149	0.3154	
Subsidy/GDP (%)	0.00%	0.02%	0.06%	0.16%	

Table 6.6: Policy 6 - Subsidy on Bank Monitoring Cost, LumpsumTax

Variables	subs=0	subs 0.1	subs=0.3	subs = 0.8	Trend
Financial sector variables					
Threshold of e_1 for approaching bank (eps bar b)	0.9952	0.9952	0.9951	0.9950	
Threshold of e_1 for borrowing from CMF (eps bar c)	1.0282	1.0288	1.0299	1.0331	
Share of firms that abstain from external finance (sa)	0.3893	0.3887	0.3871	0.3840	
Share of firms that approacing bank (sb)	0.5651	0.5687	0.5760	0.5916	
Share of firms that borrow from CMF (sc)	0.0456	0.0427	0.0369	0.0244	
Share of firms that approach bank and borrow (sbp)	0.2470	0.2501	0.2561	0.2698	
Share of firms that approach bank but not borrow (sb - sbp)	0.3180	0.3186	0.3199	0.3218	
Aggregate bankloans/bond	5.3591	5.8026	6.8623	10.9607	
Aggregate debt/equity	0.6371	0.6372	0.6377	0.6398	
Risk premium CMF	0.0029	0.0029	0.0028	0.0027	
Risk premium of bank	0.0030	0.0028	0.0023	0.0013	
Average default of bank	0.0149	0.0149	0.0149	0.0148	
Average default of CMF	0.0144	0.0143	0.0141	0.0137	
Average overall default	0.0149	0.0148	0.0148	0.0147	
Aggregate debt to GDP	0.6660	0.6661	0.6662	0.6666	
Macroeconomic variables					
Household consumption (c)	1.0000	1.0001	1.0004	1.0011	
Household deposit (d)	0.9035	0.9038	0.9045	0.9063	
Household money cash (m)	0.0137	0.0137	0.0137	0.0137	
Money supply (ms)	0.9172	0.9175	0.9182	0.9200	
Work hours (h)	0.3259	0.3260	0.3261	0.3264	
Household's capital (k)	14.3236	14.3292	14.3414	14.3745	
Entrepeneur's capital (z)	1.4038	1.4042	1.4041	1.4023	
Total capital (K)	15.7274	15.7334	15.7455	15.7768	
Entrepreneur consumption (e)	0.0322	0.0322	0.0322	0.0322	
Firm's net worth (n)	1.4180	1.4184	1.4183	1.4165	
Tax rate (t)	0.0000	0.0003	0.0008	0.0021	
Real wage (w)	2.5825	2.5830	2.5840	2.5866	
Real rent (r)	0.0301	0.0301	0.0301	0.0301	
Entrepreneur's funds (x)	1.3150	1.3155	1.3165	1.3192	
Total output (y)	1.3565	1.3569	1.3577	1.3596	
Total junk cost (information + monitoring cost, ya)	0.0098	0.0099	0.0102	0.0108	
Information cost(ytau)	0.0079	0.0080	0.0081	0.0083	
Monitoring cost (ym)	0.0018	0.0019	0.0021	0.0025	
GDP (ynet)	1.3468	1.3470	1.3475	1.3488	
Entrepreneurial markup over input cost (q)	1.0005	1.0004	1.0002	0.9995	
HH Income from rent and work (wh+rk)	1.2728	1.2733	1.2743	1.2769	
Tax revenue : t = total subsidy	0.0000	0.0003	0.0008	0.0021	
Total consumption (C)	1.0322	1.0324	1.0326	1.0332	
Entrepreneur Investment	0.0281	0.0281	0.0281	0.0280	
Household Investment	0.2865	0.2866	0.2868	0.2875	
Total Investment (I)	0.3145	0.3147	0.3149	0.3155	
Subsidy/GDP (%)	0.00%	0.02%	0.06%	0.16%	

6.3 Appendix for Chapter 3

6.3.1 Additional Impulse Response Functions

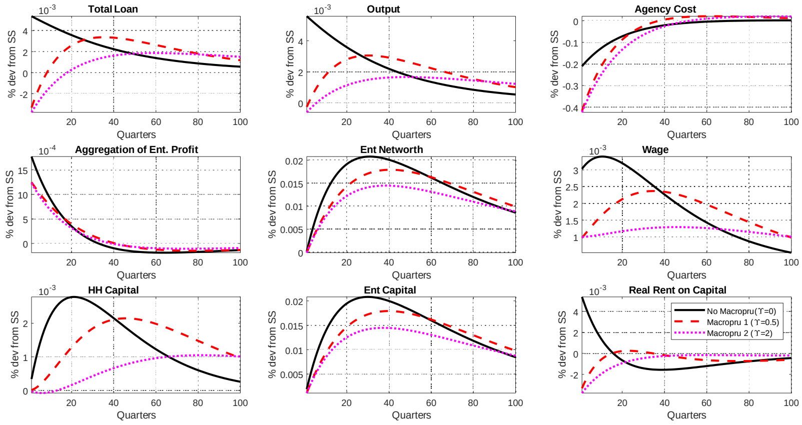


Figure 6.1: Responses to a Positive Banking Shock with and without Regulation Premium (additional)

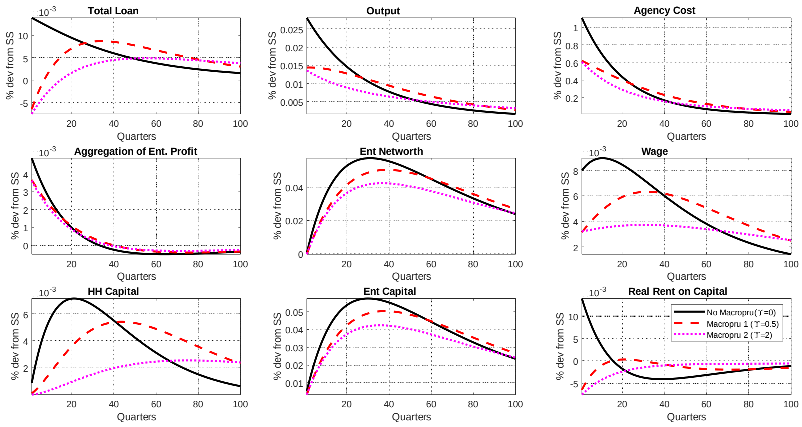


Figure 6.2: Responses to a Uncertainty Shock with and without Regulation Premium (additional)

6.3.2 Derivation of Consumption Equivalent

In subsection 6.2.2 I had derived the consumption equivalent at the steady state. In this subsection, I derive the computation of consumption equivalent considering the dynamics of the model in every period.

Household

First, I define the households' welfare in the baseline case (no macroprudential policy) as:

$$W^0 = \sum_{t=0}^{\infty} \beta^t \left[log\left(c_t^0\right) - \frac{\eta}{1+\frac{1}{\kappa}} h_t^{0(1+\frac{1}{\kappa})} \right]$$

and the households' welfare in the alternative case (with macroprudential policy) as:

$$W^1 = \sum_{t=0}^{\infty} \beta^t \left[log\left(c_t^1\right) - \frac{\eta}{1+\frac{1}{\kappa}} h_t^{1(1+\frac{1}{\kappa})} \right]$$

Consumption equivalent CE^H is fraction of c_t^0that households willing to give away in order to obtain the benefits of the optimal policy and can be written in the following form:

$$W^0(\left(1+CE^H\right) c_t^0, h_t^0) = W^1(c_t^1, h_t^1)$$

Therefore, I can derive CE^H as follows:

$$\sum_{t=0}^{\infty} \beta^t \left[\log\left[(1+CE^H)c_t^0\right] - \frac{\eta}{1+\frac{1}{\kappa}} h_t^{0(1+\frac{1}{\kappa})} \right] = W^1$$

$$\Leftrightarrow \sum_{t=0}^{\infty} \beta^t \left[\log(1+CE^H) + \log c_t^0 - \frac{\eta}{1+\frac{1}{\kappa}} h_t^{0(1+\frac{1}{\kappa})} \right] = W^1$$

$$\Leftrightarrow \sum_{t=0}^{\infty} \beta^t \log(1+CE^H) + \sum_{t=0}^{\infty} \beta^t \left(\log c_t^0 - \frac{\eta}{1+\frac{1}{\kappa}} h_t^{0(1+\frac{1}{\kappa})} \right) = W^1$$

$$\Leftrightarrow \sum_{t=0}^{\infty} \beta^t \log(1 + CE^H) + W^0 = W^1$$

$$\Leftrightarrow \frac{1}{1-\beta} \log(1 + CE^H) = W^1 - W^0$$

$$\Leftrightarrow \log(1 + CE^H) = (1-\beta)\left(W^1 - W^0\right)$$

Finally we get the expression of household's consumption equivalent:

$$CE^H = \exp\left[(1-\beta)\left(W^1 - W^0\right)\right] - 1 \tag{6.119}$$

Entrepreneur

Similar to the previous derivation, I define the entrepreneurs' welfare in the baseline case (no macroprudential policy) as:

$$W^0 = \sum_{t=0}^{\infty} \beta_E^t e_t^0$$

and entrepreneurs' welfare in the alternative case (with macroprudential policy) as:

$$W^1 = \sum_{t=0}^{\infty} \beta_E^t e_t^1$$

Using the similar approach as before, we can compute consumption equivalent of entrepreneur CE^E as follows:

$$\sum_{t=0}^{\infty} \beta_E^t \left[(1 + CE^E) e_t^0\right] = W^1$$

$$\Leftrightarrow (1 + CE^E) \sum_{t=0}^{\infty} \beta_E^t e_t^0 = W^1$$

$$\Leftrightarrow (1 + CE^E) = W^1 / W^o$$

And we obtain the entrepreneurs' consumption equivalent as:

$$CE^{E} = W^{1}/W^{o} - 1 \tag{6.120}$$

Social welfare

Total social welfare is defined as:

$$W_t = (1-\beta)\, W_t^{H} + (1-\beta_E)\, W_t^{E}.$$

Using the definition of W_t^H and W_t^E in equation 3.9 and equation 3.10, we can define social welfare in the baseline case as:

$$W^{0} = (1-\beta) \sum_{t=0}^{\infty} \beta^{t} \left[log\left(c_t^{0}\right) - \frac{\eta}{1+\frac{1}{\kappa}} h_t^{0(1+\frac{1}{\kappa})} \right] + \left(1-\beta^{E}\right) \sum_{t=0}^{\infty} \beta_E^{t} e_t^{0},$$

and the social welfare in the alternative case (with macroprudential policy) as:

$$W^{1} = (1-\beta) \sum_{t=0}^{\infty} \beta^{t} \left[log\left(c_t^{1}\right) - \frac{\eta}{1+\frac{1}{\kappa}} h_t^{1(1+\frac{1}{\kappa})} \right] + \left(1-\beta^{E}\right) \sum_{t=0}^{\infty} \beta_E^{t} e_t^{1}.$$

Total Consumption equivalent, CE, is fraction of c and e that households and entrepreneur are willing to give away in order to obtain the benefits of the optimal policy which can be written in the following form:

$$W^{0}((1+CE)\, c_t^{0}, h_t^{0}, (1+CE)e_t^{0}) = W^{1}(c_t^{1}, h_t^{1}, e_t^{1}).$$

The formulation to compute CE is derived by substituting the components of W^0 and W^1 and do some algebra steps as follows:

$$\left[\begin{array}{c} (1-\beta) \sum_{t=0}^{\infty} \beta^{t} \left[log\left((1+CE)\, c_t^{0}\right) - \frac{\eta}{1+\frac{1}{\kappa}} h_t^{0(1+\frac{1}{\kappa})} \right] \\ + \left(1-\beta^{E}\right) \sum_{t=0}^{\infty} \beta_E^{t} \,(1+CE)\, e_t^{0} \end{array} \right] = W^{1}(c_t^{1}, h_t^{1}, e_t^{1})$$

$$\Leftrightarrow \begin{bmatrix} (1-\beta)\sum_{t=0}^{\infty}\beta^t\left[log\left(1+CE\right)+log\left(c_t^0\right)-\frac{\eta}{1+\frac{1}{\kappa}}h_t^{0(1+\frac{1}{\kappa})}\right] \\ +\left(1+CE\right)\left(1-\beta^E\right)\sum_{t=0}^{\infty}\beta_E^t e_t^0 \end{bmatrix} = W^1(c_t^1,h_t^1,e_t^1)$$

$$\Leftrightarrow \begin{bmatrix} (1-\beta)\sum_{t=0}^{\infty}\beta^t\left[log\left(1+CE\right)\right]+(1-\beta)\sum_{t=0}^{\infty}\beta^t\left[log\left(c_t^0\right)-\frac{\eta}{1+\frac{1}{\kappa}}h_t^{0(1+\frac{1}{\kappa})}\right] \\ +\left(1-\beta^E\right)\sum_{t=0}^{\infty}\beta_E^t e_t^0+CE\left(1-\beta^E\right)\sum_{t=0}^{\infty}\beta_E^t e_t^0 \end{bmatrix} = W^1(c_t^1,h_t^1,e_t^1)$$

$$\Leftrightarrow \begin{bmatrix} (1-\beta)\sum_{t=0}^{\infty}\beta^t\left[log\left(1+CE\right)\right]+W^0(c_t^0,h_t^0,e_t^0) \\ +CE\left(1-\beta^E\right)\sum_{t=0}^{\infty}\beta_E^t e_t^0 \end{bmatrix} = W^1(c_t^1,h_t^1,e_t^1)$$

$$\Leftrightarrow \left[(1-\beta)\sum_{t=0}^{\infty}\beta^t\left[log\left(1+CE\right)\right]+CE\left(1-\beta^E\right)\sum_{t=0}^{\infty}\beta_E^t e_t^0\right] = W^1(c_t^1,h_t^1,e_t^1)-W^0(c_t^0,h_t^0,e_t^0)$$

$$\Leftrightarrow \left[\left[log\left(1+CE\right)\right](1-\beta)\frac{1}{1-\beta}+CE\left(1-\beta^E\right)W^{0E}(e_t^0)\right] = W^1(c_t^1,h_t^1,e_t^1)-W^0(c_t^0,h_t^0,e_t^0)$$

$$\Leftrightarrow \left[log\left(1+CE\right)\right]+CE\left(1-\beta^E\right)W^{0E}(e_t^0) = W^1(c_t^1,h_t^1,e_t^1)-W^0(c_t^0,h_t^0,e_t^0)$$

$$\Leftrightarrow \left[log\left(1+CE\right)\right]+CE\left(1-\beta^E\right)W^{0E}(e_t^0)-W^1(c_t^1,h_t^1,e_t^1)+W^0(c_t^0,h_t^0,e_t^0)=0.$$

Then we can use solver to find the value of CE.

6.4 Appendix for Chapter 4

6.4.1 Liquidity Regulations in Emerging ASEAN Countries

Table 6.7: Liquidity Regulations in Emerging ASEAN Countries

Country	Liquidity buffer requirements	Stable funding requirements	Levies or charges on noncore funding	Reserve requirements for macroprudential purposes	Limits on foreign exchange positions	Constraints on foreign exchange funding	Other measures to mitigate systemic liquidity risks	Total number of Liquidity buffer requirements
Indonesia	✓	✓		✓	✓			4
Cambodia	✓			✓	✓			3
Lao P.D.R.	✓	✓			✓			3
Myanmar	✓				✓		✓	3
Philippines	✓				✓		✓	3
Thailand	✓	✓			✓			3
Vietnam	✓	✓			✓			3
Brunei Darussalam				✓				1
Malaysia	✓							1

Source: 2017 IMF's Macroprudential Policy Survey database:
https://www.elibrary-areaer.imf.org/Macroprudential/Pages/Home.aspx.

6.4.2 List of Variables

Patient households

c^P = consumption
λ_t^P = Lagrange multiplier of budget constraint
l^P = labor supply
w^P = real wage
t^P = transfers to patient household
π^{wP} = nominal wage inflation
R^d = interest rate on deposits
τ^P = lumpsum tax to patient household

Entrepreneurs

c^E = consumption
λ^E = Lagrange multiplier of budget constraint
s^E = Lagrange multiplier of borrowing constraint
r_t^k = return on capital

Capital Goods Producers

K = capital goods bought by capital goods producers
i = investment
q^k = price of investment goods in terms of consumption goods

Final Goods Producers

π = consumption goods inflation
J^R = real profits for firms
x = markup

Banks

R^b = wholesale interest rate
$R^{b,E}$ = retail interest rate on loans to entrepreneurs
K^b = bank capital in real terms
B^E = loans to entrepreneurs in real terms
B = total loans
D = deposits in real terms
$penalty$ = penalty because of liquidity shortage
j^b = real profits for banks
RV = reserves
RF^B = risk free liquid assets hold by bank
X^{RR} = reserves shortage
X^{LCR} = LCR shortage

Aggregate variables

Y = total output in the economy
Y^P = GDP (output used in the policy rule)
κ^{firm} = total firm adjustment cost
κ^{bank} = total bank adjustment cost

Central bank

R = monetary policy rate
v = capital requirements
ϑ = run-off rate in LCR requirement
η = reserve requirement ratio
R^{x1} = penalty rate for reserves shortage
R^{x2} = penalty rate for LCR shortage
R^{RR} = remuneration on required reserve
τ^{CB} = central bank dividend
RF^{cb} = risk free asset owned by central bank

Government

τ = total lumpsum tax
G = government expenditures
RF^T = total risk free asset issued by government
R^{RF} = return on risk free asset

Shocks

a^E = TFP
ε^{liq} = liquidity shock
ε^{η} = reserve requirement policy shock
ε^{ϑ} = LCR shock

6.4.3 Model Derivation

Household

Objective function:

$$\max E_0 \sum_{t=0}^{\infty} \beta_P^t \left[(1-a^P) \log \left(c_t^P(i) - a^P c_{t-1}^P \right) - \frac{l_t^P(i)^{1+\phi}}{1+\phi} \right] \tag{6.121}$$

Budget constraint:

$$c_t^P(i) + d_t^P(i) = w_t^P l_t^P(i) + (1+R_{t-1}^d) d_{t-1}^P(i)/\pi_t + t_t^P(i) \tag{6.122}$$

The Lagrangian for household problem is:

$$\mathcal{L} = E_0 \sum_{t=0}^{\infty} \beta_P^t \left\{ \begin{array}{c} \left[(1-a^P) \log \left(c_t^P(i) - a^P c_{t-1}^P \right) - \frac{l_t^P(i)^{1+\phi}}{1+\phi} \right] \\ +\lambda_t^P \left[\begin{array}{c} w_t^P l_t^P(i) + (1+R_{t-1}^d) d_{t-1}^P(i)/\pi_t + t_t^P(i) \\ -c_t^P(i) - d_t^P(i) \end{array} \right] \end{array} \right\}. \tag{6.123}$$

Then, deriving the first-order conditions for the households problems with respect to consumption, deposits, and budget constraint yields the following:

$$\frac{\partial \mathcal{L}}{\partial c_t^P(i)} = \frac{(1-a^P)}{c_t^P - a^P c_{t-1}^P} - \lambda_t^P = 0$$

$$\Leftrightarrow \frac{(1-a^P)}{c_t^P - a^P c_{t-1}^P} = \lambda_t^P \tag{6.124}$$

$$\frac{\partial \mathcal{L}}{\partial d_t^P(i)} = \beta_P E_t \left(\lambda_{t+1}^P \frac{(1+R_t^d)}{\pi_{t+1}} \right) - \lambda_t^P = 0$$

$$\Leftrightarrow \lambda_t^P = \beta_P E_t \left(\lambda_{t+1}^P \frac{(1+R_t^d)}{\pi_{t+1}} \right) \tag{6.125}$$

$$\frac{\partial \mathcal{L}}{\partial \lambda_t^P} = w_t^P l_t^P + (1+R_{t-1}^d) d_{t-1}^P/\pi_t + t_t^P - c_t^P - d_t^P = 0$$

$$\Leftrightarrow w_t^P l_t^P + (1+R_{t-1}^d)d_{t-1}^P/\pi_t + t_t^P = c_t^P + d_t^P \tag{6.126}$$

Entrepreneurs

Objective function:

$$\max E_0 \sum_{t=0}^{\infty} \beta_E^t \log(c_t^E(i) - a^E c_{t-1}^E) \tag{6.127}$$

Subject to budget constraint:

$$\begin{aligned} & c_t^E(i) + w_t^P l_t^{E,P}(i) + (1+R_{t-1}^{bE})b_{t-1}^E(i)/\pi_t + q_t^k k_t^E(i) \\ = \; & \frac{y_t^E(i)}{x_t} + b_t^E(i) + q_t^k(1-\delta)k_{t-1}^E(i), \end{aligned} \tag{6.128}$$

and borrowing constraint:

$$(1+R_t^{bE})b_t^E(i) \le m^E E_t \left[q_{t+1}^k k_t^E(i) \pi_{t+1}(1-\delta) \right]. \tag{6.129}$$

The Lagrangian for entrepreneur's problem is:

$$\mathcal{L} = E_0 \sum_{t=0}^{\infty} \beta_E^t \left\{ \begin{array}{c} \left[\log(c_t^E(i) - a^E c_{t-1}^E)\right] \\ +\lambda_t^E \left[\begin{array}{c} \frac{y_t^E(i)}{x_t} + b_t^E(i) + q_t^k(1-\delta)k_{t-1}^E(i) \\ -c_t^E(i) - w_t^P l_t^{E,P}(i) - (1+R_{t-1}^{bE})b_{t-1}^E(i)/\pi_t - q_t^k k_t^E(i) \end{array} \right] \\ +s_t^E \left[m^E E_t \left(q_{t+1}^k k_t^E(i) \pi_{t+1}(1-\delta) \right) - (1+R_t^{bE}) b_t^E(i) \right] \end{array} \right\}. \tag{6.130}$$

The first-order conditions of entrepreneurs problem are derived as follows:

$$\frac{\partial \mathcal{L}}{\partial \lambda_t^E} = \frac{y_t^E}{x_t} + b_t^E + q_t^k(1-\delta)k_{t-1}^E - c_t^E - w_t^P l_t^{E,P} - (1+R_{t-1}^{bE})b_{t-1}^E/\pi_t - q_t^k k_t^E = 0$$

$$\Leftrightarrow \frac{y_t^E}{x_t} + b_t^E + q_t^k(1-\delta)k_{t-1}^E = c_t^E + w_t^P l_t^{E,P} + (1+R_{t-1}^{bE})b_{t-1}^E/\pi_t + q_t^k k_t^E \quad (6.131)$$

$$\frac{\partial \mathcal{L}}{\partial s_t^E} = m^E E_t\left(q_{t+1}^k k_t^E \pi_{t+1}(1-\delta)\right) - (1+R_t^{bE})b_t^E = 0$$

$$\Leftrightarrow m^E E_t\left(q_{t+1}^k k_t^E \pi_{t+1}(1-\delta)\right) = (1+R_t^{bE})b_t^E \quad (6.132)$$

$$\frac{\partial \mathcal{L}}{\partial c_t^E} = \frac{1}{(c_t^E(i) - a^E c_{t-1}^E)} - \lambda_t^E = 0$$

$$\Leftrightarrow \frac{1}{(c_t^E(i) - a^E c_{t-1}^E)} = \lambda_t^E \quad (6.133)$$

$$\frac{\partial \mathcal{L}}{\partial b_t^E} = \lambda_t^E - \beta_E E_t\left(\lambda_{t+1}^E(1+R_t^{bE})/\pi_{t+1}\right) - s_t^E(1+R_t^{bE}) = 0$$

$$\Leftrightarrow \lambda_t^E = \beta_E E_t\left[\lambda_{t+1}^E\left(\frac{1+R_t^{bE}}{\pi_{t+1}}\right)\right] + s_t^E\left(1+R_t^{bE}\right) \quad (6.134)$$

$$\frac{\partial \mathcal{L}}{\partial k_t^E} = \beta_E E_t\left[\lambda_{t+1}^E\frac{y_{kt+1}^E}{x_{t+1}}\right] + \beta_E E_t\left[\lambda_{t+1}^E q_{t+1}^k(1-\delta)\right] - \lambda_t^E q_t^k + s_t^E m^E E_t\left(q_{t+1}^k \pi_{t+1}(1-\delta)\right)$$

The expression of $\frac{y_{kt+1}^E}{x_{t+1}}$ is derived from the profit maximisation problem of entrepreneur as the followings.

First, entrepreneurs' production function is defined as:

$$y_t^E = a_t^E\left[k_{t-1}^E\right]^\alpha\left(l_t^{E,P}\right)^{1-\alpha}. \quad (6.135)$$

So, the marginal productivity of capital is derived as:

$$y^E_{kt-1} = \alpha a^E_t \left[k^E_{t-1}\right]^{\alpha-1} \left(l^{E,P}_t\right)^{1-\alpha}. \tag{6.136}$$

Another entrepreneur problem is to maximise profit from their production:

$$\max \Pi^E = \frac{y^E_t}{x_t} - w^P_t l^{E,P}_t - r^k_t k_{t-1}, \tag{6.137}$$

which can be rewritten as:

$$\max \Pi^E = \frac{a^E_t \left[k^E_{t-1}\right]^{\alpha} \left(l^{E,P}_t\right)^{1-\alpha}}{x_t} - w^P_t l^{E,P}_t - r^k_t k_{t-1}. \tag{6.138}$$

The first-order conditions of entrepreneur's profit maximisation problems are:

$$\frac{\partial \Pi^E}{\partial k_{t-1}} = \frac{\alpha a^E_t \left[k^E_{t-1}\right]^{\alpha-1} \left(l^{E,P}_t\right)^{1-\alpha}}{x_t} - r^k_t = 0$$

$$\Leftrightarrow r^k_t = \alpha a^E_t \left[k^E_{t-1}\right]^{\alpha-1} \left(l^{E,P}_t\right)^{1-\alpha} \frac{1}{x_t} \tag{6.139}$$

Combining equations 6.136 and 6.139 we can obtain the expression of $\frac{y^E_{kt+1}}{x_{t+1}}$:

$$\frac{y^E_{kt+1}}{x_{t+1}} = \frac{\alpha a^E_{t+1} \left[k^E_t\right]^{\alpha-1} \left(l^{E,P}_{t+1}\right)^{1-\alpha}}{x_{t+1}} = r^k_{t+1}.$$

Then, we can plug this to continue deriving the first-order condition of entrepreneur's problem with respect to capital:

$$\frac{\partial \mathcal{L}}{\partial k^E_t} = \beta_E E_t \left[\lambda^E_{t+1} r^k_{t+1}\right] + \beta_E E_t \left[\lambda^E_{t+1} q^k_{t+1}(1-\delta)\right] - \lambda^E_t q^k_t + s^E_t m^E E_t \left(q^k_{t+1}\pi_{t+1}(1-\delta)\right) = 0$$

$$\Leftrightarrow \beta_E E_t \lambda^E_{t+1} \left[r^k_{t+1} + q^k_{t+1}(1-\delta)\right] - \lambda^E_t q^k_t + s^E_t m^E E_t \left(q^k_{t+1}\pi_{t+1}(1-\delta)\right) = 0$$

$$\Leftrightarrow \lambda_t^E q_t^k = \beta_E E_t \lambda_{t+1}^E \left[r_{t+1}^k + q_{t+1}^k (1-\delta) \right] + s_t^E m^E E_t \left(q_{t+1}^k \pi_{t+1} (1-\delta) \right). \quad (6.140)$$

Next, we continue to derive the first-order conditions with respect to labour demand as follows:

$$\frac{\partial \mathcal{L}}{\partial l_t^{E,P}} = \lambda_t^E \left(\frac{y_{l^P,t}^E}{x_t} - w_t^P \right) = 0.$$

The expression of $y_{l^P,t}^E$ is derived from the profit maximisation problem in equation 6.138:

$$y_{l^P,t}^E = (1-\alpha) a_t^E \left[k_{t-1}^E \right]^\alpha \left(l_t^{E,P} \right)^{1-\alpha} \left(l_t^{E,P} \right)^{-1}$$

$$\Leftrightarrow y_{l^P,t}^E = (1-\alpha) y_t^E \left(l_t^{E,P} \right)^{-1}.$$

Then, we plug this result into the first-order conditions to get the relationship between real wage and labour demand:

$$\frac{\partial \mathcal{L}}{\partial l_t^{E,P}} = \lambda_t^E \left(\frac{(1-\alpha) y_t^E \left(l_t^{E,P} \right)^{-1}}{x_t} - w_t^P \right) = 0$$

$$\Leftrightarrow \frac{(1-\alpha) y_t^E \left(l_t^{E,P} \right)^{-1}}{x_t} - w_t^P = 0$$

$$\Leftrightarrow w_t^P = (1-\alpha) \frac{y_t^E}{l_t^{E,P}} \frac{1}{x_t}. \quad (6.141)$$

Capital good producers

Objective function:

$$\max E_0 \sum_{t=0}^{\infty} \Lambda_{0,t} \left(q_t^k \left(k_t - (1-\delta) k_{t-1} \right) - i_t \right), \quad (6.142)$$

subject to capital formation process:

$$k_t - (1-\delta)k_{t-1} = \left[1 - \frac{\kappa_i}{2}\left(\frac{i_t}{i_{t-1}} - 1\right)^2\right] i_t. \tag{6.143}$$

To solve this, first lets define:

$$S(x_t) = \frac{\kappa_i}{2}\left(\frac{i_t}{i_{t-1}} - 1\right)^2,$$

where $x_t = \frac{i_t}{i_{t-1}}$, so that

$S(x_t) = \frac{\kappa_i}{2}\left(x_t - 1\right)^2$

Then, the problem can be written as:

$$\max \Pi^{CP} = E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}\left(q_t^k\left(1 - S(x_t)\right) i_t - i_t\right)$$

The first-order conditions with respect to investment decision is:

$$\frac{\partial \Pi^{CP}}{\partial i} = q_t^k\left(1 - S(x_t)\right) - q_t^k \frac{\partial S_t}{\partial x_t}\frac{\partial x_t}{\partial i_t} i_t - 1 - E_t \Lambda_{t+1} q_{t+1}^k \frac{\partial S_{t+1}}{\partial x_{t+1}}\frac{\partial x_{t+1}}{\partial i_t} i_{t+1} = 0,$$

where

$$S_i(x_t) = \frac{\partial S(x_t)}{\partial i} = \kappa_i\left(\frac{i_t}{i_{t-1}} - 1\right)\frac{1}{i_{t-1}}.$$

We can derive:

$$\frac{\partial S_t}{\partial x_t}\frac{\partial x_t}{\partial i_t} = \kappa_i\left(\frac{i_t}{i_{t-1}} - 1\right)\frac{1}{i_{t-1}},$$

and iterate one period ahead to get:

$$\frac{\partial S_{t+1}}{\partial x_{t+1}}\frac{\partial x_{t+1}}{\partial i_t} = \kappa_i\left(\frac{i_{t+1}}{i_t} - 1\right). - \frac{i_{t+1}}{i_t^2},$$

Plug $\frac{\partial S_{t+1}}{\partial x_{t+1}}\frac{\partial x_{t+1}}{\partial i_t}$into the the first-order condition:

$$\frac{\partial \Pi^{CP}}{\partial i} = \begin{bmatrix} q_t^k\left(1 - S(x_t)\right) - q_t^k \kappa_i\left(\frac{i_t}{i_{t-1}} - 1\right)\frac{1}{i_{t-1}} i_t \\ -1 - E_t\left[\Lambda_{t+1} q_{t+1}^k \kappa_i\left(\frac{i_{t+1}}{i_t} - 1\right). - \frac{i_{t+1}}{i_t^2} i_{t+1}\right] \end{bmatrix} = 0$$

$$\Leftrightarrow \begin{bmatrix} q_t^k \left(1 - \frac{\kappa_i}{2}\left(\frac{i_t}{i_{t-1}} - 1\right)^2\right) - q_t^k \kappa_i \left(\frac{i_t}{i_{t-1}} - 1\right)\frac{i_t}{i_{t-1}} \\ -1 - E_t \left[\Lambda_{t+1} q_{t+1}^k \kappa_i \left(\frac{i_{t+1}}{i_t} - 1\right). - \left(\frac{i_{t+1}}{i_t}\right)^2\right] \end{bmatrix} = 0$$

$$\Leftrightarrow \begin{bmatrix} q_t^k \left[\left(1 - \frac{\kappa_i}{2}\left(\frac{i_t}{i_{t-1}} - 1\right)^2\right) - \kappa_i \left(\frac{i_t}{i_{t-1}} - 1\right)\frac{i_t}{i_{t-1}}\right] \\ -1 + E_t \left[\Lambda_{t+1} q_{t+1}^k \kappa_i \left(\frac{i_{t+1}}{i_t} - 1\right). \left(\frac{i_{t+1}}{i_t}\right)^2\right] \end{bmatrix} = 0$$

$$\Leftrightarrow 1 = \begin{bmatrix} q_t^k \left[\left(1 - \frac{\kappa_i}{2}\left(\frac{i_t}{i_{t-1}} - 1\right)^2\right) - \kappa_i \left(\frac{i_t}{i_{t-1}} - 1\right)\frac{i_t}{i_{t-1}}\right] \\ +E_t \left[\Lambda_{t+1} q_{t+1}^k \kappa_i \left(\frac{i_{t+1}}{i_t} - 1\right). \left(\frac{i_{t+1}}{i_t}\right)^2\right] \end{bmatrix}.$$

From this result and the definition of $E_t\Lambda_{t+1} = \beta_E E_t\left(\frac{\lambda_{t+1}^E}{\lambda_t^E}\right)$, we can get:

$$\begin{aligned} 1 \quad = \quad & q_t^k \left[\left(1 - \frac{\kappa_i}{2}\left(\frac{i_t}{i_{t-1}} - 1\right)^2\right) - \kappa_i \left(\frac{i_t}{i_{t-1}} - 1\right)\frac{i_t}{i_{t-1}}\right] \\ & +\beta_E E_t \left[\frac{\lambda_{t+1}^E}{\lambda_t^E} q_{t+1}^k \kappa_i \left(\frac{i_{t+1}}{i_t} - 1\right). \left(\frac{i_{t+1}}{i_t}\right)^2\right]. \end{aligned} \tag{6.144}$$

Final goods Producers (Retailers)

Nominal profit of retailers is given by:

$$P_t y_t - P_t^w y_t - \frac{\kappa_p}{2}\left(\frac{P_t}{P_{t-1}} - \pi_{t-1}^{\iota_P}\pi^{1-\iota_P}\right)^2 P_t y_t.$$

We can get the real profit by dividing the nominal profit by relative price of final goods:

$$J_t^R = y_t - \frac{P_t^w}{P_t} y_t - \frac{\kappa_p}{2}\left(\frac{P_t}{P_{t-1}} - \pi_{t-1}^{\iota_P}\pi^{1-\iota_P}\right)^2 y_t.$$

Then, we define $x_t = \frac{P_t}{P_t^w}$ as relative price of final goods to wholesale price, and rewrite the real profit as:

$$J_t^R = y_t(1 - \frac{1}{x_t}) - \frac{\kappa_p}{2}\left(\frac{P_t}{P_{t-1}} - \pi_{t-1}^{\iota_P}\pi^{1-\iota_P}\right)^2 y_t. \tag{6.145}$$

The retailers' objective function is:

$$\max_{P_t(j)} E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^P \left[P_t(j) y_t(j) - P_t^w y_t(j) - \frac{\kappa_p}{2} \left(\frac{P_t(j)}{P_{t-1}(j)} - \pi_{t-1}^{\iota_P} \pi^{1-\iota_P} \right)^2 P_t y_t \right], \tag{6.146}$$

subject to consumer demand:

$$y_t(j) = \left(\frac{P_t(j)}{P_t} \right)^{-\varepsilon^y} y_t.$$

We can rewrite the problem by subtituting the constraint to the objective function:

$$\Pi^P = \max E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^P \begin{bmatrix} P_t(j) \left(\frac{P_t(j)}{P_t} \right)^{-\varepsilon^y} y_t - P_t^w \left(\frac{P_t(j)}{P_t} \right)^{-\varepsilon^y} y_t \\ -\frac{\kappa_p}{2} \left(\frac{P_t(j)}{P_{t-1}(j)} - \pi_{t-1}^{\iota_P} \pi^{1-\iota_P} \right)^2 P_t y_t \end{bmatrix}.$$

The first-order conditions of retailer problem with respect to price decision is:

$$\frac{\partial \Pi^P}{\partial P_t(j)} = \begin{bmatrix} \left(\frac{P_t(j)}{P_t} \right)^{-\varepsilon^y} y_t - \varepsilon^y P_t(j) \left(\frac{P_t(j)}{P_t} \right)^{-\varepsilon^y - 1} \frac{1}{P_t} y_t \\ +\varepsilon^y P_t^w \left(\frac{P_t(j)}{P_t} \right)^{-\varepsilon^y - 1} y_t \frac{1}{P_t} - \kappa_p \left(\frac{P_t(j)}{P_{t-1}(j)} - \pi_{t-1}^{\iota_P} \pi^{1-\iota_P} \right) P_t y_t \frac{1}{P_{t-1}(j)} \\ +E_t \Lambda_{0,t+1}^P \left[\kappa_p \left(\frac{P_{t+1}(j)}{P_t(j)} - \pi_t^{\iota_P} \pi^{1-\iota_P} \right) \frac{P_{t+1} P_{t+1} y_{t+1}}{P_t^2} \right] \end{bmatrix} = 0.$$

In equilibrium, $P_t(j) = P_t$, therefore:

$$\begin{bmatrix} y_t - \varepsilon^y y_t + \varepsilon^y P_t^w y_t \frac{1}{P_t} - \kappa_p \left(\pi_t - \pi_{t-1}^{\iota_P} \pi^{1-\iota_{wP}} \right) \pi_t y_t \\ +E_t \Lambda_{0,t+1}^P \left[\kappa_p \left(\pi_{t+1} - \pi_t^{\iota_P} \pi^{1-\iota_P} \right) \pi_{t+1}^2 y_{t+1} \right] \end{bmatrix} = 0.$$

Then, we divide the previous equation by y_t and get:

$$\begin{bmatrix} 1 - \varepsilon^y + \varepsilon^y P_t^w \frac{1}{P_t} - \kappa_p \left(\pi_t - \pi_{t-1}^{\iota_P} \pi^{1-\iota_{wP}} \right) \pi_t \\ +E_t \Lambda_{0,t+1}^P \left[\kappa_p \left(\pi_{t+1} - \pi_t^{\iota_P} \pi^{1-\iota_P} \right) \frac{\pi_{t+1}^2 y_{t+1}}{y_t} \right] \end{bmatrix} = 0.$$

Using the definition of $x_t = \frac{P_t}{P_t^w}$ and $E_t\Lambda_{0,t+1}^P = \beta_P E_t\left[\frac{\lambda_{t+1}^P}{\lambda_t^{EP}}\right]$, we obtain:

$$\left[\begin{array}{c} 1-\varepsilon^y+\frac{\varepsilon^y}{x_t}-\kappa_p\left(\pi_t-\pi_{t-1}^{\iota_P}\pi^{1-\iota_{wP}}\right)\pi_t \\ +\beta_P E_t\left[\frac{\lambda_{t+1}^P}{\lambda_t^{EP}}\kappa_p\left(\pi_{t+1}-\pi_t^{\iota_P}\pi^{1-\iota_P}\right)\frac{\pi_{t+1}^2 y_{t+1}}{y_t}\right]\end{array}\right]=0. \tag{6.147}$$

Labour Market

Objective function:

$$\max E_0\sum_{t=0}^{\infty}\beta_P^t\left\{\begin{array}{c} U_{c_t^P(i,m)}\left[\frac{W_t^P(m)}{P_t}l_t^P(i,m)-\frac{\kappa_w}{2}\left(\frac{W_t^P(m)}{W_{t-1}^P(m)}-\pi_{t-1}^{\iota_w}\pi^{1-\iota_w}\right)^2\frac{W_t^P}{P_t}\right] \\ -\frac{l_t^P(i,m)^{1+\phi}}{1+\phi}\end{array}\right\},$$

subject to demand from labour packers:

$$l_t^P(i,m)=l_t^P(m)=\left(\frac{W_t^P(m)}{W_t^P}\right)^{-\varepsilon^l}l_t^P.$$

Substituting the $l_t^p(i,m)$ into the objective function give us:

$$\Pi^L=\max_{W_t^P(m)}E_0\sum_{t=0}^{\infty}\beta_P^t\left\{\begin{array}{c} U_{c_t^P(i,m)}\left[\begin{array}{c}\frac{W_t^P(m)}{P_t}\left(\frac{W_t^P(m)}{W_t^P}\right)^{-\varepsilon^l}l_t^P \\ -\frac{\kappa_w}{2}\left(\frac{W_t^P(m)}{W_{t-1}^P(m)}-\pi_{t-1}^{\iota_w}\pi^{1-\iota_w}\right)^2\frac{W_t^P}{P_t}\end{array}\right] \\ -\frac{\left(\left(\frac{W_t^P(m)}{W_t^P}\right)^{-\varepsilon^l}l_t^P\right)^{1+\phi}}{1+\phi}\end{array}\right\}$$

The first-order condition of labour union with respect to nominal wage is:

$$\frac{\partial\Pi}{\partial W_t^P(m)}=\left[\begin{array}{c} U_{c_t^P(i,m)}\left[\begin{array}{c}\frac{1}{P_t}\left(\frac{W_t^P(m)}{W_t^P}\right)^{-\varepsilon^l}l_t^P-\frac{W_t^P(m)}{P_t}\varepsilon^l\left(\frac{W_t^P(m)}{W_t^P}\right)^{-\varepsilon^l-1}l_t^P\frac{1}{W_t^P} \\ -\kappa_w\left(\frac{W_t^P(m)}{W_{t-1}^P(m)}-\pi_{t-1}^{\iota_w}\pi^{1-\iota_w}\right)\frac{W_t^P}{P_t}\frac{1}{W_{t-1}^P(m)}\end{array}\right] \\ +\beta E_t\left(U_{c_{t+1}^P(i,m)}\kappa_w\left(\frac{W_{t+1}^P(m)}{W_t^P(m)}-\pi_t^{\iota_w}\pi^{1-\iota_w}\right)\frac{W_{t+1}^P}{P_{t+1}}\frac{W_{t+1}^P}{W_t^{P2}}\right) \\ +\left(\left(\frac{W_t^P(m)}{W_t^P}\right)^{-\varepsilon^l}l_t^P\right)^{\phi}\varepsilon^l\left(\frac{W_t^P(m)}{W_t^P}\right)^{-\varepsilon^l-1}l_t^P\frac{1}{W_t^P}\end{array}\right]=0$$

Using the symmetric condition in equilibrium $W_t^P(m)=W_t^P$, and the definition of nominal wage inflation as $\pi_t^{w^P} = \frac{W_t^P}{W_{t-1}^P}$, we can rewrite the first-order condition as:

$$\frac{\partial \Pi}{\partial W_t^P(m)} = \begin{bmatrix} U_{c_t^P(i,m)} \left[\frac{1}{P_t} l_t^P - \frac{1}{P_t} \varepsilon^l l_t^P - \kappa_w \left(\pi_t^{w^P} - \pi_{t-1}^{\iota_w} \pi^{1-\iota_w}\right) \frac{\pi_t^{w^P}}{P_t}\right] \\ +\beta E_t \left(U_{c_{t+1}^P(i,m)} \kappa_w \left(\pi_{t+1}^{w^P} - \pi_t^{\iota_w} \pi^{1-\iota_w}\right) \frac{\pi_{t+1}^{w^P 2}}{P_{t+1}}\right) + \varepsilon^l l_t^{P^{1+\phi}} \frac{1}{W_t^P} \end{bmatrix} = 0$$

$$\Leftrightarrow \begin{bmatrix} U_{c_t^P} \left(\frac{1}{P_t} l_t^P (1 - \varepsilon^l)\right) - U_{c_t^P} \kappa_w \left(\pi_t^{w^P} - \pi_{t-1}^{\iota_w} \pi^{1-\iota_w}\right) \frac{\pi_t^{w^P}}{P_t} \\ +\beta E_t \left(U_{c_{t+1}^P(i,m)} \kappa_w \left(\pi_{t+1}^{w^P} - \pi_t^{\iota_w} \pi^{1-\iota_w}\right) \frac{\pi_{t+1}^{w^P 2}}{P_{t+1}}\right) + \varepsilon^l l_t^{P^{1+\phi}} \frac{1}{W_t^P} \end{bmatrix} = 0.$$

Then, multiply the above equation by P_t :

$$\begin{bmatrix} U_{c_t^P} \left(l_t^P (1 - \varepsilon^l)\right) - U_{c_t^P} \kappa_w \left(\pi_t^{w^P} - \pi_{t-1}^{\iota_w} \pi^{1-\iota_w}\right) \pi_t^{w^P} \\ +\beta E_t \left(U_{c_{t+1}^P} \kappa_w \left(\pi_{t+1}^{w^P} - \pi_t^{\iota_w} \pi^{1-\iota_w}\right) \frac{\pi_{t+1}^{w^P 2}}{\pi_{t+1}}\right) + \varepsilon^l l_t^{P^{1+\phi}} \frac{P_t}{W_t^P} \end{bmatrix} = 0$$

$$\Leftrightarrow U_{c_t^P} \kappa_w \left(\pi_t^{w^P} - \pi_{t-1}^{\iota_w} \pi^{1-\iota_w}\right) \pi_t^{w^P} = \begin{bmatrix} \beta E_t \left(U_{c_{t+1}^P} \kappa_w \left(\pi_{t+1}^{w^P} - \pi_t^{\iota_w} \pi^{1-\iota_w}\right) \frac{\pi_{t+1}^{w^P 2}}{\pi_{t+1}}\right) \\ +U_{c_t^P} \left(l_t^P (1 - \varepsilon^l)\right) + \varepsilon^l l_t^{P^{1+\phi}} \frac{P_t}{W_t^P} \end{bmatrix}$$

Next, divide both side of the above equations by $U_{c_t^P}$:

$$\kappa_w \left(\pi_t^{w^P} - \pi_{t-1}^{\iota_w} \pi^{1-\iota_w}\right) \pi_t^{w^P} = \begin{bmatrix} \beta E_t \left(\frac{U_{c_{t+1}^P}}{U_{c_t^P}} \kappa_w \left(\pi_{t+1}^{w^P} - \pi_t^{\iota_w} \pi^{1-\iota_w}\right) \frac{\pi_{t+1}^{w^P 2}}{\pi_{t+1}}\right) \\ + \left(l_t^P (1 - \varepsilon^l)\right) + \varepsilon^l l_t^{P^{1+\phi}} \frac{1}{U_{c_t^P} w_t^P} \end{bmatrix}$$

and substitute $U_{c_t^P} = \lambda_t^P$ to obtain:

$$\kappa_w \left(\pi_t^{w^P} - \pi_{t-1}^{\iota_w} \pi^{1-\iota_w}\right) \pi_t^{w^P} = \begin{bmatrix} \beta E_t \left(\frac{\lambda_{t+1}^P}{\lambda_t^P} \kappa_w \left(\pi_{t+1}^{w^P} - \pi_t^{\iota_w} \pi^{1-\iota_w}\right) \frac{\pi_{t+1}^{w^P 2}}{\pi_{t+1}}\right) \\ + \left(l_t^P (1 - \varepsilon^l)\right) + \frac{\varepsilon^l l_t^{P^{1+\phi}}}{\lambda_t^P w_t^P} \end{bmatrix}, \tag{6.148}$$

where:

$$\pi_t^{wP} = \frac{W_t^P}{W_{t-1}^P} = \frac{w_t^P P_t}{w_{t-1}^P P_{t-1}} = \frac{w_t^P}{w_{t-1}^P}\pi_t \tag{6.149}$$

Banks

Loan branch The objective function of loan brach is:

$$\Pi^l = \max_{R_t^{bE}(j)} E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^P \begin{bmatrix} R_{t-1}^{bE}(j)\frac{b_{t-1}^E(j)}{\pi_t} - R_{t-1}^b \frac{B_{t-1}(j)}{\pi_t} \\ -\frac{\kappa_{bE}}{2}\left(\frac{R_t^{bE}(j)}{R_{t-1}^{bE}(j)} - 1\right)^2 R_t^{bE} b_t^E \end{bmatrix}, \tag{6.150}$$

subject to loan demand function:

$$b_t^E(j) = \left(\frac{R_t^{bE}(j)}{R_t^{bE}}\right)^{-\varepsilon^{bE}} b_t^E.$$

In equilibrium $B_t(j) = b_t(j) = b_t^E(j)$, so we can rewrite the loan branch problem as:

$$\max E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^P \begin{bmatrix} R_{t-1}^{bE}(j)\left(\frac{R_{t-1}^{bE}(j)}{R_{t-1}^{bE}}\right)^{-\varepsilon^{bE}} \frac{b_{t-1}^E}{\pi_t} \\ -R_{t-1}^b \left(\frac{R_{t-1}^{bE}(j)}{R_{t-1}^{bE}}\right)^{-\varepsilon^{bE}} \frac{b_{t-1}^E}{\pi_t} \\ -\frac{\kappa_{bE}}{2}\left(\frac{R_t^{bE}(j)}{R_{t-1}^{bE}(j)} - 1\right)^2 R_t^{bE} b_t^E \end{bmatrix}$$

The first-order conditions of loan branch with respect to lending rate is:

$$\frac{\partial \Pi}{\partial R_t^{bE}(j)} = \begin{bmatrix} E_t \frac{\Lambda_{0,t+1}^P}{\pi_{t+1}} \begin{bmatrix} \left(\frac{R_t^{bE}(j)}{R_t^{bE}}\right)^{-\varepsilon^{bE}} b_t^E - R_t^{bE}(j)\varepsilon^{bE}\left(\frac{R_t^{bE}(j)}{R_t^{bE}}\right)^{-\varepsilon^{bE}-1} \frac{1}{R_t^{bE}} b_t^E \\ +R_t^b \varepsilon^{bE}\left(\frac{R_t^{bE}(j)}{R_t^{bE}}\right)^{-\varepsilon_t^{bE}-1} b_t^E \frac{1}{R_t^{bE}} \end{bmatrix} \\ -\kappa_{bE}\left(\frac{R_t^{bE}(j)}{R_{t-1}^{bE}(j)} - 1\right) R_t^{bE} b_t^E \frac{1}{R_{t-1}^{bE}(j)} \\ +E_t \Lambda_{0,t+1}^P \left[\kappa_{bH}\left(\frac{R_{t+1}^{bE}(j)}{R_t^{bE}(j)} - 1\right) R_{t+1}^{bE} b_{t+1}^H \frac{R_{t+1}^{bE}(j)}{R_t^{bE}(j)^2}\right] \end{bmatrix} = 0.$$

Imposing the condition that in equilibrium $R_t^{bE}(j) = R_t^{bE}$ give us:

$$\left[\begin{array}{c} E_t \frac{\Lambda^P_{0,t+1}}{\pi_{t+1}} \left[b^E_t - \varepsilon^{bE} b^E_t + \varepsilon^{bE} b^E_t \frac{R^b_t}{R^{bE}_t}\right] - \kappa_{bE}\left(\frac{R^{bE}_t}{R^{bE}_{t-1}} - 1\right) b^E_t \frac{R^{bE}_t}{R^{bE}_{t-1}} \\ +E_t \Lambda^P_{0,t+1}\left[\kappa_{bE}\left(\frac{R^{bE}_{t+1}}{R^{bE}_t} - 1\right) b^E_{t+1} \frac{R^{bE^2}_{t+1}}{R^{bE2}_t}\right] \end{array}\right] = 0.$$

Divide both side of equations by b^E_t to get:

$$\left[\begin{array}{c} E_t \frac{\Lambda^P_{0,t+1}}{\pi_{t+1}} \left[1 - \varepsilon^{bE} + \varepsilon^{bE} \frac{R^b_t}{R^{bE}_t}\right] - \kappa_{bE}\left(\frac{R^{bE}_t}{R^{bE}_{t-1}} - 1\right) \frac{R^{bE}_t}{R^{bE}_{t-1}} \\ +E_t \Lambda^P_{0,t+1}\left[\kappa_{bE}\left(\frac{R^{bE}_{t+1}}{R^{bE}_t} - 1\right) \frac{b^E_{t+1}}{b^E_t} \frac{R^{bE^2}_{t+1}}{R^{bE2}_t}\right] \end{array}\right] = 0$$

Then, using the definition of the stochastic discount factor of patient household $E_t \Lambda^P_{t+1} = \beta_P E_t \left(\frac{U^P_{c,t+1}}{U^P_{c,t}}\right) = \beta_P E_t \left(\frac{\lambda^P_{t+1}}{\lambda^P_t}\right)$,

we can rewrite the previous equation into:

$$\begin{aligned} \beta_P E_t \left(\frac{\lambda^P_{t+1}}{\lambda^P_t \pi_{t+1}}\right)\left[\varepsilon^{bE}_t \frac{R^b_t}{R^{bE}_t}\right] &= \beta_P E_t \left(\frac{\lambda^P_{t+1}}{\lambda^P_t \pi_{t+1}}\right)\left[\varepsilon^{bE}_t - 1\right] \\ &\quad + \kappa_{bE}\left(\frac{R^{bE}_t}{R^{bE}_{t-1}} - 1\right)\frac{R^{bE}_t}{R^{bE}_{t-1}} \\ &\quad - \beta_P E_t \left[\frac{\lambda^P_{t+1}}{\lambda^P_t} \kappa_{bE}\left(\frac{R^{bE}_{t+1}}{R^{bE}_t} - 1\right)\frac{B^E_{t+1}}{B^E_t}\frac{R^{bE^2}_{t+1}}{R^{bE2}_t}\right] \end{aligned}$$

Then, using the Euleur equation 6.125 we can substitute: $\beta_P E_t \left[\frac{\lambda^P_{t+1}}{\pi_{t+1}\lambda^P_t}\right] = \frac{1}{(1+R^d_t)}$ into the equation and get:

$$\begin{aligned} \frac{1}{(1+R^d_t)}\left[\varepsilon^{bE}_t \frac{R^b_t}{R^{bE}_t}\right] &= \frac{1}{(1+R^d_t)}\left[\varepsilon^{bE}_t - 1\right] \\ &\quad + \kappa_{bE}\left(\frac{R^{bE}_t}{R^{bE}_{t-1}} - 1\right)\frac{R^{bE}_t}{R^{bE}_{t-1}} \\ &\quad - \beta_P E_t \left[\frac{\lambda^P_{t+1}}{\lambda^P_t} \kappa_{bE}\left(\frac{R^{bE}_{t+1}}{R^{bE}_t} - 1\right)\frac{B^E_{t+1}}{B^E_t}\frac{R^{bE^2}_{t+1}}{R^{bE2}_t}\right] \end{aligned}$$

Multiplying both sides with $\left(1+R_t^d\right)$ gives us:

$$\begin{aligned}
\varepsilon_t^{bE}\frac{R_t^b}{R_t^{bE}} &= \varepsilon_t^{bE}-1 \\
&+\left(1+R_t^d\right)\kappa_{bE}\left(\frac{R_t^{bE}}{R_{t-1}^{bE}}-1\right)\frac{R_t^{bE}}{R_{t-1}^{bE}} \\
&-\left(1+R_t^d\right)\beta_P E_t\left[\frac{\lambda_{t+1}^P}{\lambda_t^P}\kappa_{bH}\left(\frac{R_{t+1}^{bE}}{R_t^{bE}}-1\right)\frac{B_{t+1}^E}{B_t^E}\frac{R_{t+1}^{bE^2}}{R_t^{bE2}}\right]
\end{aligned}$$

$$\begin{aligned}
\Leftrightarrow\quad & \varepsilon_t^{bE}\frac{R_t^b}{R_t^{bE}}=\varepsilon_t^{bE}-1 \\
& +\left(1+R_t^d\right)\kappa_{bE}\left(\frac{R_t^{bE}}{R_{t-1}^{bE}}-1\right)\frac{R_t^{bE}}{R_{t-1}^{bE}} \\
& -E_t\left[\pi_{t+1}\kappa_{bE}\left(\frac{R_{t+1}^{bE}}{R_t^{bE}}-1\right)\frac{B_{t+1}^E}{B_t^E}\frac{R_{t+1}^{bE^2}}{R_t^{bE2}}\right].
\end{aligned} \tag{6.151}$$

Deposit branch Objective function:

$$\Pi^d=\max_{R_t^d(j)}E_0\sum_{t=0}^{\infty}\Lambda_{0,t}^P\left[R_{t-1}\frac{D_{t-1}(j)}{\pi_t}-R_{t-1}^d(j)\frac{d_{t-1}^P(j)}{\pi_t}-\frac{\kappa_d}{2}\left(\frac{R_t^d(j)}{R_{t-1}^d(j)}-1\right)^2R_t^d d_t\right], \tag{6.152}$$

subject to the deposit demand function:

$$d_t^P(j)=\left(\frac{R_t^d(j)}{R_t^d}\right)^{-\varepsilon^d}d_t.$$

In equilibrium $D_t(j)=d_t^P(j)$, so that we can rewrite the deposit unit's objective function as:

$$\Pi^d=\max_{R_t^d(j)}E_0\sum_{t=0}^{\infty}\Lambda_{0,t}^P\left[R_{t-1}\frac{D_{t-1}(j)}{\pi_t}-R_{t-1}^d(j)\frac{d_{t-1}^P(j)}{\pi_t}-\frac{\kappa_d}{2}\left(\frac{R_t^d(j)}{R_{t-1}^d(j)}-1\right)^2R_t^d d_t\right]$$

$$\Leftrightarrow \Pi^d = \max E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^P \begin{bmatrix} R_{t-1}\left(\frac{R_{t-1}^d(j)}{R_{t-1}^d}\right)^{-\varepsilon^d}\frac{d_{t-1}}{\pi_t} - R_{t-1}^d(j)\left(\frac{R_t^d(j)}{R_t^d}\right)^{-\varepsilon^d}\frac{d_{t-1}}{\pi_t} \\ -\frac{\kappa_d}{2}\left(\frac{R_t^d(j)}{R_{t-1}^d(j)}-1\right)^2 R_t^d d_t \end{bmatrix}.$$

The first-order condition for deposit branch is:

$$\frac{\partial \Pi}{\partial R_t^d(j)} = \begin{bmatrix} E_0 \frac{\Lambda_{0,t+1}^P}{\pi_{t+1}} \begin{bmatrix} -\varepsilon^d R_t \left(\frac{R_t^d(j)}{R_t^d}\right)^{-\varepsilon^d-1} d_t \frac{1}{R_t^d} - \left(\frac{R_t^d(j)}{R_t^d}\right)^{-\varepsilon^d} d_t \\ +\varepsilon^d R_t^d(j)\left(\frac{R_t^d(j)}{R_t^d}\right)^{-\varepsilon^d-1} d_t \frac{1}{R_t^d} \end{bmatrix} \\ -\kappa_d \left(\frac{R_t^d(j)}{R_{t-1}^d(j)}-1\right)\frac{R_t^d}{R_{t-1}^d(j)} d_t \\ +E_t \Lambda_{0,t+1}^P \left[\kappa_d \left(\frac{R_{t+1}^d(j)}{R_t^d(j)}-1\right) R_{t+1}^d d_{t+1} \frac{R_{t+1}^d(j)}{R_t^d(j)^2}\right] \end{bmatrix} = 0.$$

By applying symmetric equilibrium $R_t^d(j) = R_t^d$, we can obtain:

$$\frac{\partial \Pi}{\partial R_t^d(j)} = \begin{bmatrix} E_t\left(\frac{\Lambda_{0,t+1}^P}{\pi_{t+1}}\right)\left[-\varepsilon^d R_t d_t \frac{1}{R_t^d} - d_t + \varepsilon^d d_t\right] \\ -\kappa_d\left(\frac{R_t^d}{R_{t-1}^d}-1\right)\frac{R_t^d}{R_{t-1}^d} d_t + E_t \Lambda_{0,t+1}^P \left[\kappa_d \left(\frac{R_{t+1}^d}{R_t^d}-1\right) d_{t+1} \frac{R_{t+1}^{d2}}{R_t^{d2}}\right] \end{bmatrix} = 0.$$

Then, simplifying the above equation by dividing it by d_t, and using the Euler equation of household: $E_t \frac{\Lambda_{0,t+1}^P}{\pi_{t+1}} = \frac{1}{1+R_t^d}$ give us:

$$\begin{bmatrix} \frac{1}{1+R_t^d}\left[-\varepsilon^d \frac{R_t}{R_t^d} - 1 + \varepsilon^d\right] - \kappa_d \left(\frac{R_t^d}{R_{t-1}^d}-1\right)\frac{R_t^d}{R_{t-1}^d} \\ +\beta E_t \left[\frac{\lambda_{t+1}^P}{\lambda_t^P}\kappa_d\left(\frac{R_{t+1}^d}{R_t^d}-1\right)\frac{d_{t+1}}{d_t}\left(\frac{R_{t+1}^d}{R_t^d}\right)^2\right] \end{bmatrix} = 0.$$

$$\Leftrightarrow \varepsilon_t^d \frac{R_t}{R_t^d} = \begin{bmatrix} -1+\varepsilon^d - \left(1+R_t^d\right)\kappa_d\left(\frac{R_t^d}{R_{t-1}^d}-1\right)\frac{R_t^d}{R_{t-1}^d} \\ +\left(1+R_t^d\right)\beta E_t \left[\frac{\lambda_{t+1}^P}{\lambda_t^P}\kappa_d\left(\frac{R_{t+1}^d}{R_t^d}-1\right)\frac{d_{t+1}}{d_t}\left(\frac{R_{t+1}^d}{R_t^d}\right)^2\right] \end{bmatrix}$$

$$\Leftrightarrow \varepsilon_t^d \frac{R_t}{R_t^d} = \begin{bmatrix} -1 + \varepsilon^d - \left(1 + R_t^d\right) \kappa_d \left(\frac{R_t^d}{R_{t-1}^d} - 1 \right) \frac{R_t^d}{R_{t-1}^d} \\ +E_t \left[\pi_{t+1} \kappa_d \left(\frac{R_{t+1}^d}{R_t^d} - 1 \right) \frac{d_{t+1}}{d_t} \left(\frac{R_{t+1}^d}{R_t^d} \right)^2 \right] \end{bmatrix} \tag{6.153}$$

Wholesale unit

Objective function:

$$\Pi^W = \max_{\{B_t, D_t, RV_t, RF_t\}} E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^P \begin{bmatrix} (1 + R_{t-1}^{RF}) \frac{RF_{t-1}}{\pi_t} - RF_t + \frac{RV_{t-1}}{\pi_t} \\ +R_{t-1}^{RR} \eta \frac{D_{t-1}}{\pi_t} - RV_t \\ + \left(1 + R_{t-1}^B\right) \frac{B_{t-1}}{\pi_t} - B_t \\ +D_t - (1 + R_{t-1}^d) \frac{D_{t-1}}{\pi_t} \\ +K_t^b - \frac{K_{t-1}^b}{\pi_t} \\ -\frac{\kappa_{Kb}}{2} \left(\frac{K_t^b}{w^L B_t} - v_t \right)^2 K_t^b - \frac{penalty_{t-1}}{\pi_t} \end{bmatrix}, \tag{6.154}$$

subject to bank balance sheet constraint:

$$B_t + RV_t + RF_t = D_t + K_t^b, \tag{6.155}$$

and the cost of liquidity shortage which can be defined as:

$$penalty_t = R_t^{x1} X_t^{RR} + R_t^{x2} X_t^{LCR}.$$

Using the constraints, we can rewrite the problem as:

$$\Pi^W = \max_{\{B_t, D_t, RV_t RF_t\}} E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^P \begin{bmatrix} R_{t-1}^{RF} \frac{RF_{t-1}}{\pi_t} + R_{t-1}^b \frac{B_{t-1}}{\pi_t} - R_{t-1} \frac{D_{t-1}}{\pi_t} \\ -\frac{\kappa_{Kb}}{2} \left(\frac{K_t^b}{w^L B_t} - v_t \right)^2 K_t^b \\ +R_{t-1}^{RR} \eta \frac{D_{t-1}}{\pi_t} \\ -R_{t-1}^{x1} \frac{X_{t-1}^{RR}}{\pi_t} - R_t^{x2} \frac{X_{t-1}^{LCR}}{\pi_t} \end{bmatrix} \tag{6.156}$$

The Lagrangian for wholesale unit problem is:

$$\mathcal{L} = E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^P \left[\begin{array}{c} R_{t-1}^{RF} \frac{RF_{t-1}}{\pi_t} + R_{t-1}^b \frac{B_{t-1}}{\pi_t} - R_{t-1} \frac{D_{t-1}}{\pi_t} \\ -\frac{\kappa_{Kb}}{2} \left(\frac{K_t^b}{w^L B_t} - \upsilon_t \right)^2 K_t^b + R_{t-1}^{RR} \eta \frac{D_{t-1}}{\pi_t} \\ -R_{t-1}^{x1} \frac{1}{\pi_t} \int_{\frac{RV - \eta_{t-1} D_{t-1}}{D_{t-1}}}^{1} (\varepsilon_{t-1}^{liq} D_{t-1} - RV_{t-1} + \eta_{t-1} D_{t-1}) f(\varepsilon_t^{liq}) d\varepsilon_t^{liq} \\ -R_{t-1}^{x2} \frac{1}{\pi_t} \left(\begin{array}{c} \int_{\frac{RF_{t-1} + RV_{t-1} - \vartheta_{t-1} D_{t-1}}{D_{t-1}}}^{1} \\ \left(\varepsilon_{t-1}^{liq} D_{t-1} - (RF_{t-1} + RV_{t-1} - \vartheta_{t-1} D_{t-1}) \right) f(\varepsilon_t^{liq}) d\varepsilon_t^{liq} \end{array} \right) \end{array} \right]$$
$$+\lambda_{1t} \left(D_t + K_t^b - B_t - RV_t - RF_t \right)$$

First-order conditions with respect to amount of lending is derived as follows:

$$\frac{\partial \mathcal{L}}{\partial B_t} = E_t \frac{\Lambda_{0,t+1}^P}{\pi_{t+1}} R_t^b + \kappa_{Kb} \left(\frac{K_t^b}{w^L B_t} - \upsilon_t \right) K_t^b \frac{K_t^b}{w^L B_t^2} - \lambda_{1t} = 0$$

From previous steps, we know that $E_t \frac{\Lambda_{0,t+1}^P}{\pi_{t+1}} = \frac{1}{1+R_t^d}$, thus the FOC can be written as:

$$\frac{1}{1+R_t^d} R_t^b + \kappa_{Kb} \left(\frac{K_t^b}{w^L B_t} - \upsilon_t \right) K_t^b \frac{K_t^b}{w^L B_t^2} - \lambda_{1t} = 0$$

$$\Leftrightarrow R_t^b + (1+R_t^d) \kappa_{Kb} \left(\frac{K_t^b}{w^L B_t} - \upsilon_t \right) K_t^b \frac{K_t^b}{w^L B_t^2} - (1+R_t^d) \lambda_{1t} = 0 \qquad (6.157)$$

First-order conditions with respect to amount of deposits is:

$$\frac{\partial \mathcal{L}}{\partial D_t} = \left(\begin{array}{c} -R_t E_t \frac{\Lambda_{0,t+1}^P}{\pi_{t+1}} + R_t^{RR} \eta E_t \frac{\Lambda_{0,t+1}^P}{\pi_{t+1}} + \lambda_{1t} \\ -E_t \frac{\Lambda_{0,t+1}^P}{\pi_{t+1}} R_t^{x1} \eta_t \int_{\frac{RV - \eta_t D_t}{D_t}}^{1} f(\varepsilon^{liq}) d\varepsilon^{liq} \\ -E_t \frac{\Lambda_{0,t+1}^P}{\pi_{t+1}} R_t^{x1} \int_{\frac{RV - \eta_t D_t}{D_t}}^{1} \varepsilon^{liq} f(\varepsilon^{liq}) d\varepsilon^{liq} \\ -E_t \frac{\Lambda_{0,t+1}^P}{\pi_{t+1}} R_t^{x2} \int_{\frac{RF_t + RV_t - \vartheta_t D_t}{D_t}}^{1} \varepsilon^{liq} f(\varepsilon^{liq}) d\varepsilon^{liq} \\ -E_t \frac{\Lambda_{0,t+1}^P}{\pi_{t+1}} R_t^{x2} \vartheta_t \int_{\frac{RF_t + RV_t - \vartheta_t D_t}{D_t}}^{1} f(\varepsilon^{liq}) d\varepsilon^{liq} \end{array} \right) = 0$$

$$\Leftrightarrow \frac{1}{1+R_t^d}\begin{pmatrix} -R_t + R_t^{RR}\eta - R_t^{x1}\eta_t \int_{\frac{RV-\eta_t D_t}{D_t}}^{1} f(\varepsilon^{liq})d\varepsilon^{liq} \\ -R_t^{x1} \int_{\frac{RV-\eta_t D_t}{D_t}}^{1} \varepsilon^{liq} f(\varepsilon^{liq})d\varepsilon^{liq} \\ -R_t^{x2} \int_{\frac{RF_t+RV_t-\vartheta_t D_t}{D_t}}^{1} \varepsilon^{liq} f(\varepsilon^{liq})d\varepsilon^{liq} \\ -R_t^{x2}\vartheta_t \int_{\frac{RF_t+RV_t-\vartheta_t D_t}{D_t}}^{1} f(\varepsilon^{liq})d\varepsilon^{liq} \end{pmatrix} + \lambda_{1t} = 0$$

$$\Leftrightarrow \begin{pmatrix} -R_t + R_t^{RR}\eta - R_t^{x1}\eta_t \int_{\frac{RV-\eta_t D_t}{D_t}}^{1} f(\varepsilon^{liq})d\varepsilon^{liq} \\ -R_t^{x1} \int_{\frac{RV-\eta_t D_t}{D_t}}^{1} \varepsilon^{liq} f(\varepsilon^{liq})d\varepsilon^{liq} \\ -R_t^{x2} \int_{\frac{RF_t+RV_t-\vartheta_t D_t}{D_t}}^{1} \varepsilon^{liq} f(\varepsilon^{liq})d\varepsilon^{liq} \\ -R_t^{x2}\vartheta_t \int_{\frac{RF_t+RV_t-\vartheta_t D_t}{D_t}}^{1} f(\varepsilon^{liq})d\varepsilon^{liq} \end{pmatrix} + \left(1+R_t^d\right)\lambda_{1t} = 0 \quad (6.158)$$

The first-order condition with respect to the amount of reserves holding is derived as follows:

$$\frac{\partial \mathcal{L}}{\partial RV_t} = \begin{bmatrix} E_t \frac{\Lambda_{0,t+1}^P}{\pi_{t+1}} R_t^{x1} \int_{\frac{RV-\eta_t D_t}{D_t}}^{1} .f(\varepsilon^{liq})d\varepsilon^{liq} \\ +E_t \frac{\Lambda_{0,t+1}^P}{\pi_{t+1}} R_t^{x2} \int_{\frac{RF_t+RV_t-\vartheta_t D_t}{D_t}}^{1} .f(\varepsilon^{liq})d\varepsilon^{liq} - \lambda_{1t} \end{bmatrix} = 0$$

$$\Leftrightarrow \begin{bmatrix} \left(R_t^{x1} \int_{\frac{RV-\eta_t D_t}{D_t}}^{1} .f(\varepsilon^{liq})d\varepsilon^{liq} + R_t^{x2} \int_{\frac{RF_t+RV_t-\vartheta_t D_t}{D_t}}^{1} .f(\varepsilon^{liq})d\varepsilon^{liq}\right) \\ -(1+R_t^d)\lambda_{1t} \end{bmatrix} = 0 \quad (6.159)$$

The first-order condition with respect to government bond holding is:

$$\frac{\partial \mathcal{L}}{\partial RF_t} = E_t \frac{\Lambda_{0,t+1}^P}{\pi_{t+1}} R_t^{RF} + E_t \frac{\Lambda_{0,t+1}^P}{\pi_{t+1}} R_t^{x2} \int_{\frac{RF_t+RV_t-\vartheta_t D_t}{D_t}}^{1} .f(\varepsilon^{liq})d\varepsilon^{liq} - \lambda_{1t} = 0$$

$$\Leftrightarrow \left(R_t^{RF} + R_t^{x2} \int_{\frac{RF_t + RV_t - \vartheta_t D_t}{D_t}}^{1} .f(\varepsilon^{liq}) d\varepsilon^{liq} \right) - (1 + R_t^d)\lambda_{1t} = 0 \tag{6.160}$$

Combining equation 6.159 and 6.160 gives us the optimal choices between holding RF and RV. It shows that the income from risk free asset should be equal to the possible cost of not holding enough reserves.

$$\begin{aligned} R_t^{RF} + R_t^{x2} \int_{\frac{RF_t + RV_t - \vartheta_t D_t}{D_t}}^{1} .f(\varepsilon^{liq}) d\varepsilon^{liq} &= R_t^{x1} \int_{\frac{RV - \eta_t D_t}{D_t}}^{1} .f(\varepsilon^{liq}) d\varepsilon^{liq} \\ &+ R_t^{x2} \int_{\frac{RF_t + RV_t - \vartheta_t D_t}{D_t}}^{1} .f(\varepsilon^{liq}) d\varepsilon_t^{liq} \end{aligned}$$

$$\Leftrightarrow R_t^{RF} = R_t^{x1} \int_{\frac{RV - \eta_t D_t}{D_t}}^{1} .f(\varepsilon^{liq}) d\varepsilon^{liq}. \tag{6.161}$$

Next, by combining equation 6.157 and 6.158 we can obtain optimal choices between giving loan and holding liquid assets:

$$\left(\begin{array}{c} -R_t + R_t^{RR}\eta + R_t^b + (1 + R_t^d)\kappa_{Kb} \left(\frac{K_t^b}{w^L B_t} - v_t \right) K_t^b \frac{K_t^b}{w^L B_t^2} \\ -R_t^{x1}\eta_t \int_{\frac{RV - \eta_t D_t}{D_t}}^{1} f(\varepsilon^{liq}) d\varepsilon^{liq} - R_t^{x1} \int_{\frac{RV - \eta_t D_t}{D_t}}^{1} \varepsilon^{liq} f(\varepsilon^{liq}) d\varepsilon^{liq} \\ -R_t^{x2} \int_{\frac{RF_t + RV_t - \vartheta_t D_t}{D_t}}^{1} \varepsilon^{liq} f(\varepsilon^{liq}) d\varepsilon^{liq} - R_t^{x2}\vartheta_t \int_{\frac{RF_t + RV_t - \vartheta_t D_t}{D_t}}^{1} f(\varepsilon^{liq}) d\varepsilon^{liq} \end{array} \right) = 0$$

$$\begin{aligned} \Leftrightarrow \quad R_t^b = {} & R_t - R_t^{RR}\eta - (1 + R_t^d)\kappa_{Kb} \left(\frac{K_t^b}{w^L B_t} - v_t \right) K_t^b \frac{K_t^b}{w^L B_t^2} \\ & + R_t^{x1}\eta_t \int_{\frac{RV - \eta_t D_t}{D_t}}^{1} f(\varepsilon^{liq}) d\varepsilon^{liq} + R_t^{x1} \int_{\frac{RV - \eta_t D_t}{D_t}}^{1} \varepsilon^{liq} f(\varepsilon^{liq}) d\varepsilon^{liq} \\ & + R_t^{x2} \int_{\frac{RF_t + RV_t - \vartheta_t D_t}{D_t}}^{1} \varepsilon^{liq} f(\varepsilon^{liq}) d\varepsilon^{liq} \\ & + R_t^{x2}\vartheta_t \int_{\frac{RF_t + RV_t - \vartheta_t D_t}{D_t}}^{1} f(\varepsilon^{liq}) d\varepsilon^{liq} \end{aligned} \tag{6.162}$$

Then, combining equation 6.157 and 6.160 gives the optimal choices between holding risk free asset and give loan:

$$R_t^{RF} + R_t^{x2} \int_{\frac{RF_t + RV_t - \vartheta_t D_t}{D_t}}^{1} .f(\varepsilon^{liq}) d\varepsilon^{liq} = R_t^b + (1 + R_t^d)\kappa_{Kb} \left(\frac{K_t^b}{w^L B_t} - v_t \right) K_t^b \frac{K_t^b}{w^L B_t^2} \tag{6.163}$$

Liquidity Condition Regime (for Occbin toolkit)

Reserves shortage and LCR shortage are formulated as follows:

$$X^{RR} = \max \left\{ \varepsilon_t^{liq} D_t - (RV_t - \eta_t D_t), 0 \right\}$$

$$X_t^{LCR} = \max \left\{ \varepsilon_t^{liq} D_t - (RF_t + RV_t - \vartheta_t D_t), 0 \right\}$$

Since the model involve non linear equation (max function), we need to define four regimes in the coding: one is reference regime, and the other three are alternate regimes. Before that we need to define a temporary variabel X^{RR}_temp and X^{LCR}_temp as:

$$X^{RR}\_temp = \varepsilon_t^{liq} D_t - (RV_t - \eta_t D_t),$$

$$X^{LCR}\_temp = \varepsilon_t^{liq} D_t - (RF_t + RV_t - \vartheta_t D_t).$$

- The reference model is used for the case where bank has enough liquidity to meet both regulations.

  Condition: $X^{RR}\_temp <= 0$ and $X^{LCR}\_temp <= 0 \Rightarrow X^{RR} = 0$ and $X^{LCR} = 0$

- The first alternate model is used for the case where bank experience a liquidity shortage to meet reserve requirement.

Condition: $X^{RR}\_temp > 0$ and $X^{LCR}\_temp <= 0 \Rightarrow X^{RR} = \varepsilon_t^{liq} D_t - (RV_t - \eta_t D_t)$ and $X^{LCR} = 0$

- The second alternate model is used for the case where bank experience a liquidity shortage to meet LCR requirement.

  Condition: $X^{RR}\_temp <= 0$ and $X^{LCR}\_temp > 0 \Rightarrow X^{RR} = 0$ and $X^{LCR} = \varepsilon_t^{liq} D_t - (RF_t + RV_t - \vartheta_t D_t)$

- The third alternate model is used for the case where bank experience liquidity shortage to meet both regulations.

  Condition: $X^{RR}\_temp > 0$ and $X^{LCR}\_temp > 0 \Rightarrow X^{RR} = \varepsilon_t^{liq} D_t - (RV_t - \eta_t D_t)$ and $X^{LCR} = \varepsilon_t^{liq} D_t - (RF_t + RV_t - \vartheta_t D_t)$

6.4.4 Competitive Equilibrium Equations

Patient Households

$$c_t^P + D_t = w_t^P l_t^P + (1 + R_{t-1}^d) D_{t-1}/\pi_t + t_t^P \tag{6.164}$$

$$\frac{1 - a^P}{c_t^P - a^P c_{t-1}^P} = \lambda_t^P \tag{6.165}$$

$$\lambda_t^P = \beta_P E_t \left[\lambda_{t+1}^P \frac{(1 + R_t^d)}{\pi_{t+1}} \right] \tag{6.166}$$

$$t_t^P = J_t^R - \frac{\kappa_w}{2} \left(\frac{W_t^P}{W_{t-1}^P} - \pi_{t-1}^{\iota_w} \pi^{1-\iota_w} \right)^2 \frac{W_t^P}{P_t} - \tau_t^P \tag{6.167}$$

Entrepreneurs

$$\begin{aligned} & c_t^E + w_t^P l_t^P + (1 + R_{t-1}^{bE}) B_{t-1}^E/\pi_t + q_t^k K_t \\ = \; & \frac{Y_t}{x_t} + B_t^E + q_t^k (1 - \delta) K_{t-1} \end{aligned} \tag{6.168}$$

$$(1+R_t^{bE})B_t^E = m^E E_t\left[q_{t+1}^k K_t \pi_{t+1}(1-\delta)\right] \tag{6.169}$$

$$\frac{1}{c_t^E - a^E c_{t-1}^E} = \lambda_t^E \tag{6.170}$$

$$\lambda_t^E = \beta_E E_t\left[\lambda_{t+1}^E \frac{(1+R_t^{bE})}{\pi_{t+1}}\right] + s_t^E(1+R_t^{bE}) \tag{6.171}$$

$$\begin{aligned}\lambda_t^E q_t^k &= \beta_E E_t \lambda_{t+1}^E\left[r_{t+1}^k + q_{t+1}^k(1-\delta)\right] \\ &\quad + E_t\left[s_t^E m^E q_{t+1}^k \pi_{t+1}(1-\delta)\right]\end{aligned} \tag{6.172}$$

$$Y_t = a_t^E\left[K_{t-1}\right]^\alpha \left(l_t^P\right)^{1-\alpha} \tag{6.173}$$

$$w_t^P = (1-\alpha)\frac{Y_t}{l_t^P}\frac{1}{x_t} \tag{6.174}$$

$$r_t^k = \alpha a_t^E\left[K_{t-1}\right]^{\alpha-1}\left(l_t^P\right)^{1-\alpha}\frac{1}{x_t} \tag{6.175}$$

Capital Goods Producers

$$K_t = (1-\delta)K_{t-1} + \left[1 - \frac{\kappa_i}{2}\left(\frac{i_t}{i_{t-1}} - 1\right)^2\right] i_t \tag{6.176}$$

$$\begin{aligned}1 &= q_t^k\left[1 - \frac{\kappa_i}{2}\left(\frac{i_t}{i_{t-1}} - 1\right)^2 - \kappa_i\left(\frac{i_t}{i_{t-1}} - 1\right)\frac{i_t}{i_{t-1}}\right] \\ &\quad + \beta_E E_t\left[\frac{\lambda_{t+1}^E}{\lambda_t^E} q_{t+1}^k \kappa_i\left(\frac{i_{t+1}}{i_t} - 1\right)\left(\frac{i_{t+1}}{i_t}\right)^2\right]\end{aligned} \tag{6.177}$$

Final Goods Producers

$$J_t^R = Y_t(1 - \frac{1}{x_t}) - \frac{\kappa_P}{2}(\pi_t - \pi_{t-1}^{\iota_P}\overline{\pi}^{1-\iota_P})^2 y_t \qquad (6.178)$$

$$\begin{aligned} & 1 - \varepsilon^y + \frac{\varepsilon^y}{x_t} - \kappa_P(\pi_t - \pi_{t-1}^{\iota_P}\overline{\pi}^{1-\iota_P})\pi_t \\ & +\beta_P E_t \left[\frac{\lambda_{t+1}^P}{\lambda_t^P}\kappa_P(\pi_{t+1} - \pi_t^{\iota_P}\overline{\pi}^{1-\iota_P})\pi_{t+1}^2 \frac{Y_{t+1}}{Y_t} \right] \\ = \; & 0 \end{aligned} \qquad (6.179)$$

Labour Unions

$$\begin{aligned} \kappa_W(\pi_t^{wP} - \pi_{t-1}^{\iota_w}\overline{\pi}^{1-\iota_w})\pi_t^{wP} \; = \; & \beta_P E_t \left[\frac{\lambda_{t+1}^P}{\lambda_t^P}\kappa_W(\pi_{t+1}^{wP} - \pi_t^{\iota_w}\overline{\pi}^{1-\iota_w})\frac{\left(\pi_{t+1}^{wP}\right)^2}{\pi_{t+1}} \right] \\ & + \left(1 - \varepsilon^l\right) l_t^P + \frac{\varepsilon^l (l_t^P)^{1+\phi}}{w_t^{wP}\lambda_t^P} \end{aligned} \qquad (6.180)$$

$$\pi_t^{wP} = \frac{w_t^{wP}}{w_{t-1}^{wP}}\pi_t \qquad (6.181)$$

Banks

Retail units

$$\begin{aligned} \varepsilon^{bE}\frac{R_t^b}{R_t^{bE}} \; = \; & \varepsilon^{bE} - 1 \\ & + \left(1 + R_t^d\right)\kappa_{bE}\left(\frac{R_t^{bE}}{R_{t-1}^{bE}} - 1\right)\frac{R_t^{bE}}{R_{t-1}^{bE}} \\ & - E_t\left[\pi_{t+1}\kappa_{bE}\left(\frac{R_{t+1}^{bE}}{R_t^{bE}} - 1\right)\frac{b_{t+1}^E}{b_t^E}\frac{R_{t+1}^{bE^2}}{R_t^{bE2}}\right] \end{aligned} \qquad (6.182)$$

$$\varepsilon^d \frac{R_t}{R_t^d} = -1 + \varepsilon^d - \left(1 + R_t^d\right) \kappa_d \left(\frac{R_t^d}{R_{t-1}^d} - 1\right) \frac{R_t^d}{R_{t-1}^d} + E_t \left[\pi_{t+1} \kappa_d \left(\frac{R_{t+1}^d}{R_t^d} - 1\right) \frac{D_{t+1}}{D_t} \left(\frac{R_{t+1}^d}{R_t^d}\right)^2\right] \tag{6.183}$$

Wholesale unit

$$R_t^b = R_t - R_t^{RR} \eta - (1 + R_t^d) \kappa_{Kb} \left(\frac{K_t^b}{w^L B_t} - v_t\right) K_t^b \frac{K_t^b}{w^L B_t^2} + R_t^{x1} \eta_t \int_{\frac{RV - \eta_t D_t}{D_t}}^{1} f(\varepsilon^{liq}) d\varepsilon^{liq} + R_t^{x1} \int_{\frac{RV - \eta_t D_t}{D_t}}^{1} \varepsilon^{liq} f(\varepsilon^{liq}) d\varepsilon^{liq} + R_t^{x2} \int_{\frac{RF_t + RV_t - \vartheta_t D_t}{D_t}}^{1} \varepsilon^{liq} f(\varepsilon^{liq}) d\varepsilon^{liq} + R_t^{x2} \vartheta_t \int_{\frac{RF_t + RV_t - \vartheta_t D_t}{D_t}}^{1} f(\varepsilon^{liq}) d\varepsilon^{liq} \tag{6.184}$$

$$K_t^b = (1 - \delta_b) \frac{K_{t-1}^b}{\pi_t} + j_t^b \tag{6.185}$$

$$B_t^E + RV_t + RF_t^b = D_t + K_t^b \tag{6.186}$$

$$X_t^{RR} = \max \left[(\varepsilon_t^{liq} D_t - RV_t + \eta_t D_t), 0\right] \tag{6.187}$$

$$X_t^{LCR} = \max \left[\varepsilon_t^{liq} D_t - (RF_t^b + RV_t - \vartheta_t D_t)\right] \tag{6.188}$$

$$\begin{aligned} j_t^b &= R_{t-1}^{RF} RF_{t-1}^b \frac{1}{\pi_t} + R_{t-1}^{RR} \eta_{t-1} D_{t-1} \frac{1}{\pi_t} + R_{t-1}^{bE} B_{t-1}^E \frac{1}{\pi_t} \\ & -R_{t-1}^d D_{t-1} \frac{1}{\pi_t} \\ & -\frac{\kappa_d}{2} \left(\frac{R_t^d}{R_{t-1}^d} - 1 \right)^2 R_t^d D_t - \frac{\kappa_{bE}}{2} \left(\frac{R_t^{bE}}{R_{t-1}^{bE}} - 1 \right)^2 R_t^{bE} B_t^E \\ & -\frac{\kappa_{Kb}}{2} \left(\frac{K_t^b}{w^L B_t} - \upsilon_t \right)^2 K_t^b \\ & -penalty_{t-1} \frac{1}{\pi_t} \end{aligned} \tag{6.189}$$

$$\begin{aligned} & R_t^{RF} + R_t^{x2} \int_{\frac{RF_t + RV_t - \vartheta_t D_t}{D_t}}^{1} .f(\varepsilon^{liq}) d\varepsilon^{liq} \\ = \; & R_t^b + (1 + R_t^d) \kappa_{Kb} \left(\frac{K_t^b}{w^L B_t} - \upsilon_t \right) K_t^b \frac{K_t^b}{w^L B_t^2} \end{aligned} \tag{6.190}$$

$$R_t^{RF} = R_t^{x1} \int_{\frac{RV - \eta_t D_t}{D_t}}^{1} .f(\varepsilon^{liq}) d\varepsilon^{liq} \tag{6.191}$$

$$penalty_t = R_t^{x1} X_t^{RR} + R_t^{x2} X_t^{LCR} \tag{6.192}$$

Central Bank

$$\begin{aligned} RV_t - RV_{t-1}/\pi_t &= R_{t-1}^{RR} \eta_{t-1} D_{t-1} \frac{1}{\pi_t} + RF_t^{cb} + \tau_t^{cb} - (1 + R_{t-1}^{RF}) RF_{t-1}^{cb}/\pi_t \\ & -penalty_{t-1} \frac{1}{\pi_t} \end{aligned} \tag{6.193}$$

$$RF_t^{cb} = RV_t \tag{6.194}$$

Government

$$RF_t^T = G_t + (1 + R_{t-1}^{RF})RF_{t-1}^T/\pi_t - \tau_t^{cb} - \tau_t \tag{6.195}$$

$$G_t = \Gamma Y_t \tag{6.196}$$

Market Clearing Conditions and Definitions

$$\begin{aligned} Y_t &= c_t^P + c_t^E + G_t + q_t^k i_t + \delta_b \frac{K_{t-1}^b}{\pi_t} \\ &+ \kappa_t^{firms} + \kappa_t^{bank} \end{aligned} \tag{6.197}$$

$$\begin{aligned} \kappa_t^{firms} &= \frac{\kappa_P}{2}(\pi_t - \pi_{t-1}^{\iota_P}\overline{\pi}^{1-\iota_P})^2 y_t + \frac{\kappa_w}{2}\left(\frac{W_t^P}{W_{t-1}^P} - \pi_{t-1}^{\iota_w}\pi^{1-\iota_w}\right)^2 \frac{W_t^P}{P_t} \\ &+ q_t^k \frac{\kappa_i}{2}\left(\frac{i_t}{i_{t-1}} - 1\right)^2 i_t \end{aligned} \tag{6.198}$$

$$\begin{aligned} \kappa_t^{bank} &= \frac{\kappa_d}{2}\left(\frac{R_t^d}{R_{t-1}^d} - 1\right)^2 R_t^d D_t + \frac{\kappa_{bE}}{2}\left(\frac{R_t^{bE}}{R_{t-1}^{bE}} - 1\right)^2 R_t^{bE} B_t^E \\ &+ \frac{\kappa_{Kb}}{2}\left(\frac{K_t^b}{w^L B_t} - v_t\right)^2 K_t^b \end{aligned} \tag{6.199}$$

$$Y_t^P = c_t^P + c_t^E + G_t + q_t^k i_t \tag{6.200}$$

$$B_t = B_t^E \tag{6.201}$$

$$RF_t^T = RF_t^{cb} + RF_t^b \tag{6.202}$$

$$\tau_t^P = \tau_t \tag{6.203}$$

Central Bank

Policy Rate

$$(1+R_t) = \left(1+\overline{R}\right)^{(1-\rho_R)} (1+R_{t-1})^{\rho_R} \left(\frac{\pi_t}{\overline{\pi}}\right)^{\chi_\pi (1-\rho_R)} \left(\frac{Y_t^P}{Y_{t-1}^P}\right)^{\chi_Y (1-\rho_R)} \varepsilon_t^{MP} \tag{6.204}$$

Capital Requirements Policy

$$\upsilon_t = \overline{\upsilon}^{(1-\rho_\upsilon)} \upsilon_{t-1}^{\rho_\upsilon} \varepsilon_t^{\upsilon} \tag{6.205}$$

Reserve Requirement Policy

a. Constant

$$\eta_t = \overline{\eta}^{(1-\rho_\eta)} \eta_{t-1}^{\rho_\eta} \varepsilon_t^{\eta} \tag{6.206}$$

b. Countercyclical:

$$\eta_t = \overline{\eta}^{(1-\rho_\eta)} \eta_{t-1}^{\rho_\eta} \left(B_t/B_{t-1}\right)^{\chi_\eta (1-\rho_\eta)} \tag{6.207}$$

Liquidity Coverage Ratio Run-off Rate

a. Constant

$$\vartheta_t = \overline{\vartheta}^{(1-\rho_\vartheta)} \vartheta_{t-1}^{\rho_\vartheta} \varepsilon_t^{\vartheta} \tag{6.208}$$

b. Countercyclical

$$\vartheta_t = \overline{\vartheta}^{(1-\rho_\vartheta)} \vartheta_{t-1}^{\rho_\vartheta} \left(B_t/B_{t-1}\right)^{\chi_\vartheta (1-\rho_\vartheta)} \tag{6.209}$$

Interest Rate

$$R_t^{RR} = \Omega^{RRR}.R_t \tag{6.210}$$

$$R_t^{x1} = \Omega^{RX1}.R_t \tag{6.211}$$

$$R_t^{x2} = \Omega^{RX2}.R_t \tag{6.212}$$

$$R_t^{RF} = \Omega^{RF}.R_t \tag{6.213}$$

Shocks

Total factor productivity

$$\log a_t^E = \rho^a \log a_{t-1}^E + \xi_t^a \tag{6.214}$$

Liquidity shock

$$\varepsilon_t^{liq} = \rho^{liq} \varepsilon_{t-1}^{liq} + \xi_t^{liq} \tag{6.215}$$

Reserve requirement policy shock

$$\log \varepsilon_t^{\eta} = \phi^{\eta} \log \varepsilon_{t-1}^{\eta} + \xi_t^{\eta} \tag{6.216}$$

LCR shock

$$\log \varepsilon_t^{\vartheta} = \phi^{\vartheta} \log \varepsilon_{t-1}^{\vartheta} + \xi_t^{\vartheta} \tag{6.217}$$

Expectation of liquidity shock

$$\log \mu_t^{\varepsilon_{liq}} = \rho^{\mu} \log \mu_{t-1}^{\varepsilon_{liq}} + \xi_t^{\mu}. \tag{6.218}$$

6.4.5 Sources of Data for Calibration

The data used are at a quarterly frequency and cover the period 2005 Q1 - 2017 Q4. All the GDP-related data is taken from The Indonesian Financial Statistics, while the banking sector data is taken from the Bank Indonesia Banking Statistics. The variables are defined and measured as follows.

- Household Consumption, Government Expenditures, and Investment are part of GDP by Expenditure data. I re-base the data to 2000 Constant Prices (2000=100).
- Output is Gross Domestic Bruto at constant price (2000=100)
- Entrepreneurs Loan is the total of the working-capital loan and investment loan, divided by GDP deflator.
- Risk-Free assets in Bank is the total of central bank certificate (SBI) and government bond (SPN & SUN) held by the commercial bank divided by GDP deflator.
- Reserves is total reserves of commercial banks held by the central bank divided by GDP deflator.
- Deposits is total third party fund in the liabilities of commercial bank divided by GDP deflator. It includes Demand Deposit, Saving and Time Deposits.
- Policy Rate is the BI rate (from 2005Q3 – 2016Q2) and 7-day repo-rate (2016Q3 - 2017Q4). I convert it to quarterly rate by dividing it with 4.
- Deposit Rate is the 1-month deposit rate. I choose 1-month deposit because the majority of the household deposits is short-term deposit with 1-month maturity. It also converted to quarterly rate by dividing it with 4.
- Loan rate to entrepreneur is the weighted average of working capital loan rate and investment loan rate.

- Inflation is an annual growth of Consumer Price Index (CPI) divided by 4 to make it quarterly.
- Risk-free rate is the yield of government bond with maturity 1 year. I obtain it from Bloomberg with ticker GIDN1Y. At first I want to use government bond with maturity 3 month but the issuance of this type of bond is very limited and not continues.
- Risk weight on loan is computed by dividing the total risk-weighted asset in the Capital Adequacy Requirement computation by the total loan.
- Capital to weighted loan ratio is calculated by dividing the total bank equity with the risk-weighted asset.

6.4.6 Distribution of Deposit Outflows

Figure 6.3 presents the distribution fit of deposit outflows in Indonesia. I use quarterly data from 205Q3 - 2017Q4. Deposit outflows is computed as the negative growth of quarterly deposits. Therefore, the positive value means there is deposit outflows, and negative values means there is deposit inflows.The distribution fit is produced using additional tool in Matlab : "Find the Best Distribution" tool version 1.2.0.0 (467 KB) by Yoav Aminov.

6.4.7 Derivation of Consumption Equivalent

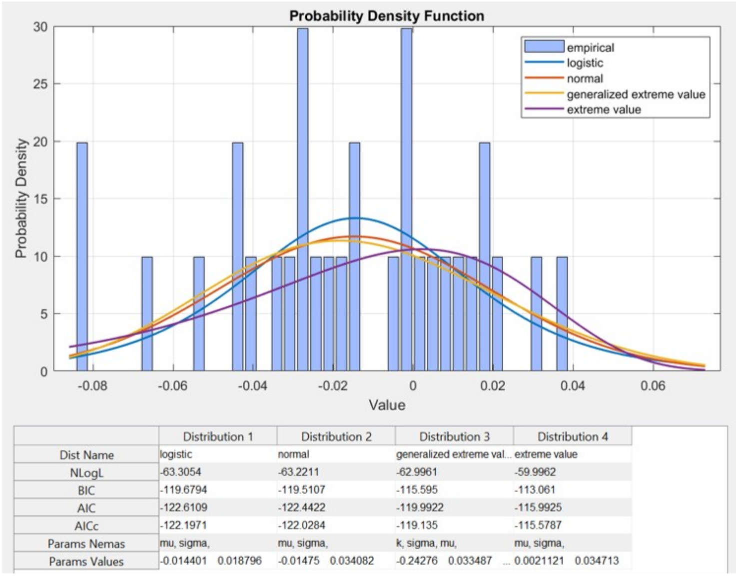
Household

Households' welfare in the baseline case (constant liquidity rule):

$$W^0 = \sum_{t=0}^{\infty} \beta_P^t \left[(1 - a^P) \log \left(c_t^{P,0} - a^P c_{t-1}^{P,0} \right) - \frac{l_t^{P,0 \, 1+\phi}}{1 + \phi} \right]$$

Households' welfare in the optimal case (countercyclical liquidity rule):

$$W^{opt} = \sum_{t=0}^{\infty} \beta_P^t \left[(1 - a^P) \log \left(c_t^{P,opt} - a^P c_{t-1}^{P,opt} \right) - \frac{l_t^{P,opt \, 1+\phi}}{1 + \phi} \right]$$



	Distribution 1	Distribution 2	Distribution 3	Distribution 4
Dist Name	logistic	normal	generalized extreme val...	extreme value
NLogL	-63.3054	-63.2211	-62.9961	-59.9962
BIC	-119.6794	-119.5107	-115.595	-113.061
AIC	-122.6109	-122.4422	-119.9922	-115.9925
AICc	-122.1971	-122.0284	-119.135	-115.5787
Params Nemas	mu, sigma,	mu, sigma,	k, sigma, mu,	mu, sigma,
Params Values	-0.014401 0.018796	-0.01475 0.034082	-0.24276 0.033487 ...	0.0021121 0.034713

Figure 6.3: Distribution of Deposit Outflows

Consumption equivalent ζ^P is fraction of c_t^0 that households willing to give away in order to obtain the benefits of the optimal policy.

$$W^0((1+\zeta^P)\, c^{P,0}, l^{P,0}) = W^{opt}(c^{P,opt}, l^{P,opt})$$

Then we can derive ζ^P as follows:

$$\sum_{t=0}^{\infty} \beta_P^t \left[(1-a^P) \log \left[(1+\zeta^P) c_t^{P,0} - a^P (1+\zeta^P) c_{t-1}^{P,0} \right] - \frac{l_t^{P,0 1+\phi}}{1+\phi} \right] = W^{opt}$$

$$\Leftrightarrow \sum_{t=0}^{\infty} \beta_P^t \left[(1-a^P) \log \left[(1+\zeta^P) \left(c_t^{P,0} - a^P c_{t-1}^{P,0} \right) \right] - \frac{l_t^{P,0 1+\phi}}{1+\phi} \right] = W^{opt}$$

$$\Leftrightarrow \sum_{t=0}^{\infty} \beta_P^t \left[(1-a^P) \log(1+\zeta^P) + (1-a^P) \log \left(c_t^{P,0} - a^P c_{t-1}^{P,0} \right) - \frac{l_t^{P,0 1+\phi}}{1+\phi} \right] = W^{opt}$$

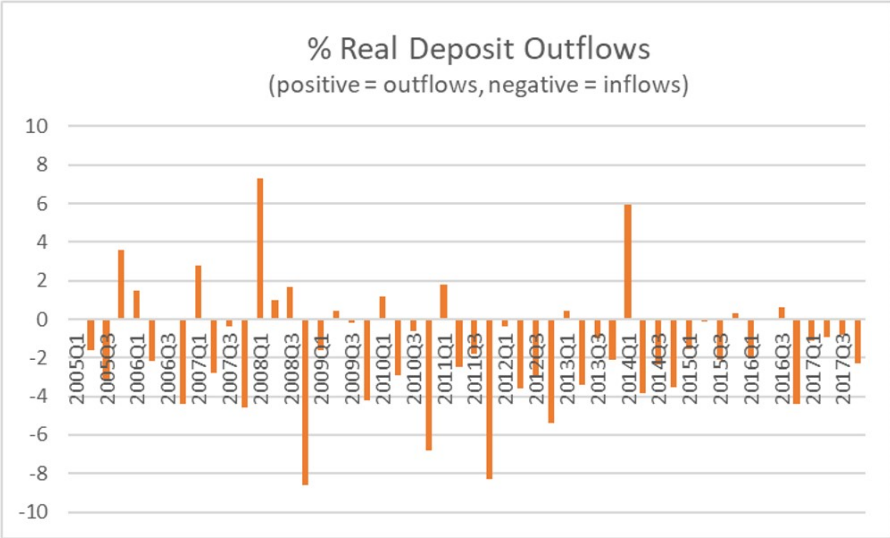


Figure 6.4: Data of Deposit Outflows

$$\Leftrightarrow \sum_{t=0}^{\infty} \beta_P^t \left[(1-a^P)\log(1+\zeta^P)\right] + \sum_{t=0}^{\infty} \beta_P^t \left[(1-a^P)\log\left(c_t^{P,0} - a^P c_{t-1}^{P,0}\right) - \frac{l_t^{P,0\,1+\phi}}{1+\phi}\right] = W^{opt}$$

$$\Leftrightarrow \sum_{t=0}^{\infty} \beta_P^t \left[(1-a^P)\log(1+\zeta^P)\right] + W^0 = W^{opt}$$

$$\Leftrightarrow \frac{(1-a^P)}{1-\beta_P}\log(1+\zeta^P) + W^0 = W^{opt}$$

$$\Leftrightarrow \log(1+\zeta^P) = \frac{1-\beta_P}{(1-a^P)}\left(W^{opt} - W^0\right)$$

$$\Leftrightarrow (1+\zeta^P) = \exp\left[\frac{1-\beta_P}{(1-a^P)}\left(W^{opt} - W^0\right)\right]$$

$$\Longleftrightarrow \zeta^P = \exp\left[\frac{1-\beta_P}{(1-a^P)}\left(W^{opt} - W^0\right)\right] - 1. \tag{6.219}$$

Entrepreneur

Entrepreneurs' welfare in the baseline case (constant liquidity rule):

$$W^0 = \sum_{t=0}^{\infty} \beta_E^t \log(c_t^{E,0} - a^E c_{t-1}^{E,0})$$

Entrepreneurs' welfare in the optimal case (countercyclical liquidity rule):

$$W^{opt} = \sum_{t=0}^{\infty} \beta_E^t \log(c_t^{E,opt} - a^E c_{t-1}^{E,opt})$$

Using the similar approach as before, we can compute consumption equivalent ζ^E as follows:

$$\sum_{t=0}^{\infty} \beta_E^t \log((1+\zeta^E)(c_t^0 - a^E c_{t-1}^0)) = W^{opt}$$

$$\Leftrightarrow \sum_{t=0}^{\infty} \beta_E^t \log(1+\zeta^E) + \sum_{t=0}^{\infty} \beta_E^t \log(c_t^{E,0} - a^E c_{t-1}^{E,0}) = W^{opt}$$

$$\Leftrightarrow \frac{\log(1+\zeta^E)}{1-\beta_E} + W^0 = W^{opt}$$

$$\Leftrightarrow \log(1+\zeta^E) = (1-\beta_E)\left(W^{opt} - W^0\right)$$

$$\Leftrightarrow (1+\zeta^E) = \exp\left((1-\beta_E)\left(W^{opt} - W^0\right)\right)$$

$$\Leftrightarrow \zeta^E = \exp\left((1-\beta_E)\left(W^{opt} - W^0\right)\right) - 1. \tag{6.220}$$

Social Welfare

Total social welfare is defined as:

$$W_t = (1-\beta_P)\, W_t^P + (1-\beta_E)\, W_t^E.$$

Using the definition of W_t^P and W_t^E in equation 4.73 and equation 4.74, we can define social welfare in the baseline case as:

$$W_t^0 = \left[\begin{array}{c} (1-\beta_P) \sum_{t=0}^{\infty} \beta_P^t \left[(1-a^P) \log \left(c_t^{P,0} - a^P c_{t-1}^{P,0} \right) - \frac{l_t^{P,0 \, 1+\phi}}{1+\phi} \right] \\ + (1-\beta_E) \sum_{t=0}^{\infty} \beta_E^t \log (c_t^{E,0} - a^E c_{t-1}^{E,0}) \end{array} \right],$$

and social welfare in the optimal case as:

$$W_t^{opt} = \left[\begin{array}{c} (1-\beta_P) \sum_{t=0}^{\infty} \beta_P^t \left[(1-a^P) \log \left(c_t^{P,opt} - a^P c_{t-1}^{P,opt} \right) - \frac{l_t^{P,opt \, 1+\phi}}{1+\phi} \right] \\ + (1-\beta_E) \sum_{t=0}^{\infty} \beta_E^t \log (c_t^{E,opt} - a^E c_{t-1}^{E,opt}) \end{array} \right].$$

Consumption equivalent ζ is fraction of c_t^P and c_t^E that households and entrepreneurs willing to give away in order to obtain the benefits of the optimal policy. The concept of the consumption equivalent in this case follows:

$$W^0((1+\zeta)\, c_t^{P,0}, l_t^{P,0}, (1+\zeta)\, c_t^{E,0}) = W^{opt}(c_t^{P,opt}, l^{P,opt}, c_t^{E,opt}).$$

Therefore, I can derive ζ as follows:

$$\left[\begin{array}{c} (1-\beta_P) \left\{ \sum_{t=0}^{\infty} \beta_P^t \left[\begin{array}{c} (1-a^P) \log \left(\begin{array}{c} (1+\zeta)\, c_t^{P,0} \\ -a^P (1+\zeta)\, c_{t-1}^{P,0} \end{array} \right) \\ -\frac{l_t^{P,0 \, 1+\phi}}{1+\phi} \end{array} \right] \right\} \\ + (1-\beta_E) \left\{ \begin{array}{c} \sum_{t=0}^{\infty} \beta_E^t \log ((1+\zeta)\, c_t^{E,0} \\ -a^E (1+\zeta)\, c_{t-1}^{E,0}) \end{array} \right\} \end{array} \right] = W^{opt}(c_t^{P,opt}, l^{P,opt}, c_t^{E,opt})$$

$$\Leftrightarrow \left[\begin{array}{c} (1-\beta_P) \left\{ \sum_{t=0}^{\infty} \beta_P^t \left[\begin{array}{c} (1-a^P) \log \left((1+\zeta) \left(c_t^{P,0} - a^P c_{t-1}^{P,0} \right) \right) \\ -\frac{l_t^{P,0 \, 1+\phi}}{1+\phi} \end{array} \right] \right\} \\ + (1-\beta_E) \left\{ \sum_{t=0}^{\infty} \beta_E^t \log \left((1+\zeta) \left(c_t^{E,0} - a^E c_{t-1}^{E,0} \right) \right) \right\} \end{array} \right] = W^{opt}(c_t^{P,opt}, l^{P,opt}, c_t^{E,opt})$$

$$\Leftrightarrow \begin{bmatrix} (1-\beta_P)\sum\limits_{t=0}^{\infty}\beta_P^t \begin{bmatrix} (1-a^P)\log(1+\zeta) \\ +(1-a^P)\log\left(c_t^{P,0}-ac_{t-1}^{P,0}\right) \\ -\frac{l_t^{P,0}{}^{1+\phi}}{1+\phi} \end{bmatrix} \\ +(1-\beta_E)\sum\limits_{t=0}^{\infty}\beta_E^t \begin{pmatrix} \log(1+\zeta) \\ +\log\left(c_t^{E,0}-a^E c_{t-1}^{E,0}\right) \end{pmatrix} \end{bmatrix} = W^{opt}(c_t^{P,opt}, l^{P,opt}, c_t^{E,opt})$$

$$\Leftrightarrow \begin{bmatrix} \left[(1-\beta_P)\sum\limits_{t=0}^{\infty}\beta_P^t(1-a^P)\log(1+\zeta)\right] \\ +\left[(1-\beta_P)\sum\limits_{t=0}^{\infty}\beta_P^t(1-a^P)\log\left(c_t^{P,0}-a^P c_{t-1}^{P,0}\right)\right] \\ -(1-\beta_P)\frac{l_t^{P,0}{}^{1+\phi}}{1+\phi} \\ +(1-\beta_E)\sum\limits_{t=0}^{\infty}\beta_E^t\log(1+\zeta) \\ +\left(1-\beta^E\right)\sum\limits_{t=0}^{\infty}\beta_E^t\log\left(c_t^{E,0}-a^E c_{t-1}^{E,0}\right) \end{bmatrix} = W^{opt}(c_t^{P,opt}, l^{P,opt}, c_t^{E,opt})$$

$$\Leftrightarrow \begin{bmatrix} \left[(1-\beta_P)\sum\limits_{t=0}^{\infty}\beta_P^t(1-a^P)\log(1+\zeta)\right] \\ +W^0(c_t^{P,0}, l^{P,0}, c_t^{E,0}) \\ +(1-\beta_E)\sum\limits_{t=0}^{\infty}\beta_E^t\log(1+\zeta) \end{bmatrix} = W^{opt}(c_t^{P,opt}, l^{P,opt}, c_t^{E,opt})$$

$$\Leftrightarrow \begin{bmatrix} (1-\beta_P)\sum\limits_{t=0}^{\infty}\beta_P^t(1-a^P)\log(1+\zeta) \\ +(1-\beta_E)\sum\limits_{t=0}^{\infty}\beta_E^t\log(1+\zeta) \end{bmatrix} = W^{opt}(c_t^{P,opt}, l^{P,opt}, c_t^{E,opt}) - W^0(c_t^{P,0}, l^{P,0}, c_t^{E,0})$$

$$\Leftrightarrow \begin{bmatrix} (1-\beta_P)(1-a^P)\log(1+\zeta)\sum\limits_{t=0}^{\infty}\beta_P^t \\ +(1-\beta_E)\log(1+\zeta)\sum\limits_{t=0}^{\infty}\beta_E^t \end{bmatrix} = W^{opt}(c_t^{P,opt}, l^{P,opt}, c_t^{E,opt}) - W^0(c_t^{P,0}, l^{P,0}, c_t^{E,0})$$

$$\Leftrightarrow \left[\begin{array}{c} (1-\beta_P)\,(1-a^P)\log\left(1+\zeta\right)\frac{1}{1-\beta_P} \\ +\,(1-\beta_E)\log\left(1+\zeta\right)\frac{1}{1-\beta^E} \end{array} \right] = W^{opt}(c_t^{P,opt}, l^{P,opt}, c_t^{E,opt}) - W^0(c_t^{P,0}, l^{P,0}, c_t^{E,0})$$

$$\Leftrightarrow \left[\begin{array}{c} (1-a^P)\log\left(1+\zeta\right) \\ +\log\left(1+\zeta\right) \end{array} \right] = W^{opt}(c_t^{P,opt}, l^{P,opt}, c_t^{E,opt}) - W^0(c_t^{P,0}, l^{P,0}, c_t^{E,0})$$

$$\Leftrightarrow (2-a^P)\log\left(1+\zeta\right) = W^{opt}(c_t^{P,opt}, l^{P,opt}, c_t^{E,opt}) - W^0(c_t^{P,0}, l^{P,0}, c_t^{E,0})$$

$$\Leftrightarrow \log\left(1+\zeta\right) = \frac{W^{opt}(c_t^{P,opt}, l^{P,opt}, c_t^{E,opt}) - W^0(c_t^{P,0}, l^{P,0}, c_t^{E,0})}{(2-a^P)}$$

$$\Leftrightarrow \zeta = \exp\left[\frac{W^{opt}(c_t^{P,opt}, l^{P,opt}, c_t^{E,opt}) - W^0(c_t^{P,0}, l^{P,0}, c_t^{E,0})}{(2-a^P)}\right] - 1 \qquad (6.221)$$