Financial Development, Fiscal Policy, and Macroeconomic Volatility

Ji Hoon Park

PhD

University of York
Economics

November 2015

Abstract

This thesis examines empirically the effect of financial frictions and public debt on economic variables and seeks for an appropriate fiscal consolidation strategy.

First, the thesis explores the determinants of output volatility, especially the roles of financial development and government debt. The analysis, based on a panel of 127 countries over four decades, employs system GMM dynamic panel regression. According to the regression results financial development is estimated to have a non-linear effect on output volatility. Increased government debt levels are statistically associated with increased macroeconomic volatility. However, we need to interpret the results carefully due to endogeneity problems. The effect of the interactions between the two is insignificant.

Second, it analyses the role of financial frictions on economic fluctuations. When the three models are compared with the U.S. data along the second moments, the firm friction model helps in fitting some macroeconomic variables and outperforms the other models. In the impulse response functions, we find that financial frictions greatly amplify and propagate the effects of the exogenous shocks on economic variables. Specially, the firm friction model shows more persistent response than the bank friction model. In addition, the size of the response depends on the leverage in the model with financial frictions.

Third, the thesis considers how the effects of fiscal policy consolidation differ depending on alternative strategies. To do this, we develop an open economy DSGE model with an endogenous risk premium mechanism. The government consumption cut has larger negative effects on output than the government investment cut because of a complementarity with private consumption. The response of the tax hike is smaller than the expenditue cut because the tax hikes reduce more debts and the lower risk premium crowds in consumption and investment. Among three fiscal rules, the expenditure adjusted rule is the most effective for both preventing the economic downturn and reducing government debt.

Table of contents

Acknowledgements

I would like to express my sincere gratitude to my supervisor, Dr. Andrew Pickering. He has encouraged me and guided my work during my PhD period. When I encountered difficulties, he helped me to overcome it.

I would also like to thank professor Mike Wickens and Neil Rankin for serving as my thesis advisory group members. Their advice and comments on my research has been invaluable.

I would especially like to thank Korean government for providing the opportunity to study Economics and supporting me financially.

Finally, a special thanks to my family. Words can not express how grateful I am to my parents, parents-in-law. I would also like to thank to my wife, Hae-Yun, my son, Jinwoo, and my daughter, Sohyun. I could not spend time with them in a great holiday and had to head to the library. Without their sacrifice, this work might be impossible.

Declaration

I hereby certify that this thesis is entirely my own work. I have exercised reasonable care to ensure that this work is original. I also declare that the work has been carried out according to the requirements of the University's Regulations and Code of Practice for Research Degree Programmes. The work has not been taken from the work of others except that such material has been cited and acknowledged within the text.

Chapter 1

Introduction

The recent economic crisis since 2007 was mainly caused by financial instability. The losses in the mortgage market due to the bursting of the housing bubble in the U.S. were amplified into large turmoil in the financial market and the world economy suffered from a serious economic downturn (Brunnermeier, 2009). In order to get out of the economic crisis many countries around the world took extraordinary fiscal measures. However, the large fiscal stimulus packages and a slow ensuing recovery deteriorated the fiscal positions of many industrial countries. In turn, the concern over defaults of so called PIIGS countries (Portugal, Italy, Ireland, Greece, and Spain) deepened the global economic downturn since 2012.

Therefore, both financial and fiscal instability are thought as the most important causes of the recent economic crisis. This thesis attempts to analyse the impact of the two factors on economic variables and find an appropriate consolidation policy to overcome the fiscal crisis. The main contributions of this thesis are as follows. It empirically explores the effect of both financial development and government debt on output volatility. Second, it examines the role of financial frictions on economic fluctuations under New Keynesian economy. Lastly, it analyses the performance of various fiscal policy strategies to reduce government debt under an open economy dynamic stochastic general equilibrium (DSGE) model.

Chapter 2 empirically examines the determinants of output volatility, especially two specific factors - financial development and government debt. Financial development is traditionally considered to reduce output volatility. However, the recent financial crisis highlights the destabilising role of financial development because the repercussion of the crisis is remarkable in financially developed countries. Theoretically, larger financial development may imply higher leverage of economic agents, which propagate and amplify external shocks through financial frictions. Thus, this chapter revisits the relationship between financial development and output volatility utilising new dynamic dataset for 127 countries over the years 1971-2010. This chapter augments the previous literature by attempting to reconcile conflicting results on the relationship between financial development and output volatility using various model specification such as alternative regression methods, time horizons, and different measures of financial development.

Chapter 2 also contributes by examining the relationship between government debt and output volatility. There are several mechanisms that government debt can affect output volatility such as the next; (i) restricting the scope of fiscal and monetary policy, (ii) reducing the effectiveness of fiscal policy, (iii) increasing sovereign default risk, (iv) decreasing international confidence. Especially it becomes an important research area to find the effect of government debt on output volatility under the soaring government debt in many countries as the aftermath of the recent financial crisis. However, there has not been much discussion on this topic. Chapter 2 fills this gap.

Analysing jointly financial development and government debt, which is not tried so far is another contribution of this chapter. As the recent financial crisis suggests, both financial development and government debt are closely connected in the development of the crisis. For example, in Ireland and Spain bail-outs of unstable banking system triggered fiscal crisis by increasing government debt. In Greece and Italy unsustainable government debt destabilised the financial markets by raising doubts about banks with government bonds. In order to analyse the interrelation between financial development and government debt, we add an interaction term between the two in the baseline model.

The empirical analysis finds the following results. First, financial development affects output volatility in a non-linear fashion like the previous literature. In other words, financial development reduces output volatility up to a certain level. Above this level, economies become more unstable. However, the recent financial crisis lowered the critical level from 152.6 percent of GDP to 140.9 percent of GDP in the baseline model suggesting the fact that the destabilising role of private credit was strengthened during the crisis. Second, government debt levels increase output volatility in a linear way. However, as macroeconomic conditions can affect government debt, the result may be sensitive to endogeneity problem. Moreover, some robustness tests do not show the validity of the instruments for the consistency of the estimation. Therefore, we need to interpret carefully the relationship between government debt and output volatility. The effect of financial development and government debt on output volatility is robust among non-OECD countries. However, we cannot get reliable results for OECD members because the sample is too small. In addition, when we use lagged values of the two variables, the significant relationship disappears. The government's policy reaction may cause this result. Specifically, as the government can implement fiscal consolidation to cope with high levels of debt and raise the interest rate against abundant private credit, the economy becomes stable in the following period. Third, the interaction term between the two is statistically insignificant suggesting that financial development with higher government debt is not associated with economic instability. This is because private credit and government debt have different cyclicality.

Chapter 3 focuses on the financial sector. Since the recent financial crisis GDP values have showed very different time paths among impacted countries. Specifically, in the countries such as Spain and Iceland where experienced an abrupt increase of private credit before the crisis, GDP declined more than 10% and it didn't recover the pre-crisis level in 2013. On the other hand, the U.S. showed modest contraction and soon rebounded above the pre-crisis level. What is specially noteworthy is that the amount of private credit growth in the U.S. was not larger than other countries. Thus, it is possible to assume that financial frictions derived by the fast growth of private credit affect the amplification and the propagation of shocks. With this background the main purpose of this chapter is to investigate empirically the role of financial frictions on economic fluctuations. We adopt the DSGE model for this analysis. Standard DSGE models assume that there are no frictions in the financial sector. However, Bernanke et al. (1999) adopted financial frictions at the firm level and many papers have developed their mechanism. Recently, Gertler and Karadi (2011) explicitly model financial intermediaries as a source of financial frictions. They consider the fact that Bernanke et al. (1999) do not consider the financial intermediaries which are one of the most important disturbing factors in the recent financial crisis.

Given these approaches, Chapter 3 contributes to the existing papers by trying to identify the effect of financial frictions on the amplification and the persistence of economic fluctuations. Specifically, the main themes of this chapter are as follows: (i) to confirm the fact that financial frictions are relevant to the amplification and the persistence of economic fluctuations; (ii) to ask which type of financial frictions are more important in explaining the amplified and persistent fluctuation of economic variables; (iii) to analyse which type of financial frictions better match the economic fluctuations during the recent financial crisis. Chapter 3 compares three DSGE models to investigate these topics. The first model is the no friction model which means the basic model without financial frictions based on Smets and Wouters (2007). The second one is the model with financial frictions at the firm level following Bernanke et al. (1999). The third one is the model with financial frictions at the financial intermediaries level following Gertler and Karadi (2011). The three models are calibrated with the U.S. data for the period 1960Q1$\sim$2015Q4.

This chapter finds the following results. First, in the moment comparison the presence of financial frictions at the firm level improves the model's fit. This means that this financial friction is relevant for the U.S. data. Thus, the firm friction model outperforms the other models. However, the contribution of the financial frictions at the bank level to the model's fit is not sure. Second, in the impulse response functions incorporating financial frictions of either type amplifies and propagates the effect of exogenous shocks on the economic variables. As the exogenous shocks affect the credit market, the impact on investment and output can be expanded through the rise in the external finance premium. Third, the response of macroeconomic variables depends on the leverage in the model with financial frictions. Higher leverage in the firm or the bank causes more change in the external finance premium, and the impact on investment and output to the shocks is also expanded. However, the persistence of the response is larger in the model with financial frictions at the firm level - the firm friction model. The reason is that exogenous shocks in the firm friction model have persistent effects on investment through the serial effect on the firm's net worth. Therefore, the bank friction model with higher leverage is appropriate for explaining the recent financial crisis, while the firm friction model well describes the persistent crisis. These findings are another contribution of chapter 3.

Chapter 4 turns to the government debt issue. In order to examine the effect of fiscal consolidation strategies, we utilise an open economy DSGE model with various fiscal instruments. This model is based on the extended version of the ECB's New Area-Wide Model (NAWM) described by Coenen et al. (2013). Fiscal instruments include government consumption, government investment and lump-sum transfers in the expenditure side, and consumption tax, wage income tax, and capital income tax in the revenue side. We develop this framework in some ways. First, we introduce an endogenous risk premium in the DSGE model. Empirically the fall in the government debt to GDP ratio reduces the risk premium of government bonds. Thus, we assume that the interest rate faced by the government increases by the risk premium which correlates positively with the government debt levels. Second, this chapter contributes to the macroeconomic literature by attempting alternative fiscal rules. The baseline model assumes that government expenditures are adjusted according to the output and the debt ratio, and revenues are correlated with the debt ratio. However, there is no generally accepted fiscal rule unlike the monetary policy rule. As robustness test, two more rules - an expenditure adjusted rule and a tax adjusted rule - are introduced.

Simulation results show that the government consumption cut has the largest negative impact on output. Since we assume a complementarity between government consumption and private consumption, the effect of the government investment cut is less than the government consumption cut. The lump-sum transfers cut does not show a significant effect because it does not constitute the national income. The revenue based strategy has generally smaller effects on impact than the expenditure based strategy. Specially, capital income tax rather raises output in the short run. Non-Keynesian effect due to the endogenous risk premium causes this result. As the tax hike has more significant impact on the debt ratio and the risk premium, the response in investment and consumption is constrained. We can confirm this effect when the model without the risk premium is examined. When the risk premium is omitted, noticeable changes appear in the response of macroeconomic variables. As the non-Keynesian effect disappears, the response in the tax hike becomes larger than the expenditure cut. This result is consistent with the previous literature (e.g., Guajardo et al., 2014; Alesina et al., 2015). The fiscal rule also induces remarkable changes in the effect of the tax hike. As in the tax hike the debt ratio shows more change according to the implementation of alternative rules, the difference in the response of investment and consumption between two cases becomes relatively larger. This result suggests that it is necessary for us to pay attention to the relationship among economic variables such as the debt level, the fiscal rule, when we investigate the effect of fiscal consolidation. For example, when there is an obvious positive relationship between the risk premium and government debt, the tax hike is desirable. If the fiscal rule is only applied to the expenditure or the tax rate, the tax hike is better than the expenditure cut. In addition, when private consumption is a complement to government consumption, we need to avoid the government consumption cut and the consumption tax hike.

The thesis ends with a conclusion, future research areas.

Chapter 2

The determinants of output volatility: financial development and government debt

2.1. Introduction

Developing countries exhibit significantly greater output volatility than developed countries (Malik and Temple, 2009). Moreover, many papers have documented the fact that business cycle volatility has been related to lower growth in output, investment and consumption as volatility creates economic uncertainty (Ramey and Ramey, 1995; Aizenman and Marion, 1999; Loayza et al., 2007). Furthermore, assuming risk-averse agents and imperfect insurance in the economy, output volatility produces direct adverse real welfare effects.[1] An episode of extreme output volatility - the recent financial crisis[2] - impacted developed countries and researchers have since focussed attention on the welfare implications of output volatility. A better understanding of the causes of output volatility is essential for developed countries as well as developing countries.

Previous research has addressed the determinants of output volatility utilising different subsets of variables and data.[3] This chapter analyses two specific determinants of output volatility among others - financial development and government debt levels. First of all, the

[1] Aizenman and Powell (2003) show that a weak legal system combined with imperfect information leads to profound effects of volatility on production, employment and welfare. They suggest that legal and information problems explain why volatility has substantial effects on emerging market economies.

[2] Unsurprisingly, Sutherland and Hoeller (2012) find that large values for the volatility measures are typically related to deep recessions.

[3] Specifically, the effects of financial development on output volatility are analysed in Easterly et al. (2001), Denizer et al. (2002), Ferreira da Silva (2002), Lopez and Spiegel (2002), Kunieda (2008), Mallick (2009), and Dabla Norris and Srivisal (2013). The effects of trade (openness) variables are addressed in Bejan (2006), Cavallo (2007), and Di Giovanni and Levchenko (2009). Gali (1994), Fatas and Mihov (2001), Viren (2005), and Debrun et al. (2008) examine fiscal policy and government size. The role of institutions is studied in Acemoglu et al. (2003), Mobarak (2005), and Malik and Temple (2009).

role of financial development on output volatility is traditionally analysed using credit market imperfections and asymmetric information. Specifically, as a financial system develops in an economy, in principle, credit market imperfections and information asymmetries are eased (Tharavanij, 2007). In the economy, economic agents can diversify risk and manage effectively unexpected events (Dabla Norris and Srivisal, 2013). Accordingly, financial development may reduce output volatility. However, the recent financial crisis has triggered a different view on the role of financial development. Larger financial development may also imply higher leverage of economic agents, which propagates and amplifies external shocks through financial frictions (Bernanke et al., 1999; Gertler and Karadi, 2011). Thus, we revisit the relationship between financial development and output volatility in order to verify the adequacy of these arguments using new dynamic panel dataset for 127 countries over the years 1971-2010.

Concurrently, the past few years have witnessed significant increases in government debt in many countries as a result of the recent financial crisis. In addition, projections of standard measures of public debt relative to GDP for the next 30 years indicate that debt levels may be unsustainable for many countries (Cecchetti et al., 2010). High debt has the potential to restrict the scope for countercyclical fiscal policies, which may cause higher output volatility (Kumar and Woo, 2010). According to Reinhart and Rogoff (2009), government debt surges are also an antecedent to banking crises. Thus, it is necessary to examine whether the fiscal expansion seen in some countries during the recent financial crisis increases output at the sacrifice of more volatile economy in the future (Schurin, 2012). However, there has not been much discussion about the impact of government debt on output volatility. Therefore, one of the objectives of this chapter is to shed some light on this issue by investigating the impact of government debt on output volatility. In this context, we address a new empirical question: Is there a link between government debt levels and output volatility?

This chapter contributes to the literature by providing a rigorous analysis of the impacts of financial development and government debt on output volatility. It differs from earlier work in many significant ways. First, this chapter includes the recent financial crisis period to investigate the impact of the financial crisis on output volatility. The second contribution is a systematic analysis of the effect of government debt on output volatility. Furthermore, we examine jointly financial development and government debt using an interaction term between the two. Third, we try to reconcile conflicting results in the literature using a different regression method, different time horizons and an alternative measure of financial development.

The findings are as follows. First, financial development affects output volatility in a non-linear fashion. This is consistent with earlier work. Specifically, financial development will reduce output volatility up to a certain level (when private credit equals 140.9 percent of GDP in the regression using the sample of 65 countries). Above this level, economies on average become more volatile. Before the financial crisis this threshold value is higher - 152.6 percent of GDP - suggesting the strengthened destabilising role of private credit during the financial crisis. In addition, increased government debt levels are statistically associated with increased macroeconomic volatility. A one-standard deviation increase in the ratio of government debt to GDP - 53.2 percent of GDP in the sample - raises output volatility by about one percent. This connection is not non-linear unlike financial development. However, these results are not valid under some robustness tests. For example, when alternative time periods are used, Arellano-Bond tests for autocorrelation do not ensure the validity of the specification and the results. We also find totally different results when we use lagged values of the two. This conflicting result arises from endogeneity problems. Therefore, we need to interpret the results carefully. Third, the interaction between the two is statistically insignificant suggesting that financial development with fiscal problems is not related to economic instability.

The remainder of the chapter is organised as follows: Section 2.2 provides a review of the literature. Section 2.3 explains estimation methodologies and discusses the system Generalized Methods of Moments (system GMM). In Section 2.4, our dataset is described. Section 2.5 presents the main regression results and Section 2.6 provides a series of robustness checks. Section 2.7 concludes.

2.2. Literature review

2.2.1. Financial development and output volatility

A considerable literature has already examined the relationship between financial development and output volatility. Some papers have theoretically analysed their connections. Specifically, Aghion et al. (1999) show that economies with a high degree of physical separation between savers and investors, and capital market imperfections embodied in constraints on the amounts investors can borrow from savers, may fluctuate to a greater extent around the steady state growth path. In other words, those economies will tend to be more volatile. In contrast, when there exists a developed capital market, the economy converges to a stable growth path along which only exogenous shocks make the economy fluctuate.[4]

Acemoglu and Zilibotti (1997) also examine the link between financial development and output volatility by emphasising the role that diversification plays in reducing risk. They show that in early stages of development with scarcity of capital and the presence of indivisible projects, agents will not able to diversify away risk effectively because only a limited number of imperfectly correlated projects can be undertaken. This will make the

[4] Therefore, Aghion et al. (1999) suggest that financial market development may stabilise the economy (Spiliopoulos, 2010).

earlier stages of development highly volatile. As wealth builds up, however, economies can diversify risk better, increase investment, and reduce investment risk and volatility.

Aghion et al. (2007) find that financial development reduces macroeconomic volatility using a overlapping generation growth model in which firms engage in two types of investment: a short-term one and a long-term productivity enhancing one.[5]

However, financial development can also have a positive effect on output volatility. Wagner (2010) shows that diversification of risks *within* financial institutions increases the probability of *system* crises even though it alleviates each institution's individual risk.[6] Shleifer and Vishny (2010) also find that bank credit and real investment will be unstable when prices of securitised loans are variable. In their model, banks invest in securitised loans using their capital when asset prices are high because of high profitability of this investment in booms. Thus, real investment further increases with securitisation. However, banks are forced to sell their assets at lower prices in recessions. This accelerates price falls and there is much less investment. This mechanism implies that the real economy becomes more volatile with banks' securitisation.

On the basis of these theoretical predictions a number of empirical papers have attempted to examine whether financial development reduces output volatility. Some, but not all, empirical research support the stabilising role of financial development. Specifically, Ferreira da Silva (2002) finds that output, investment and consumption volatility are negatively related to all proxies of financial system development applying Generalized Methods of Moments (GMM) techniques on a panel data set of forty countries spanning the years

[5] Since it takes a longer time to complete, long-term investment has a higher liquidity risk as well as a relatively less procyclical return. Under complete financial markets, they show that long-term investment is countercyclical, thus mitigating volatility. But when there are tight credit constraints, long-term investment turns procyclical, thus amplifying volatility. Therefore, tighter credit leads to higher macroeconomic volatility.

[6] In his model with two banks, banks' risk becomes similar through more diversification and this increases the probability of simultaneous failure, i.e. a system crisis.

1960 to 1997.[7] Using the Fixed Effects (FE) methodology, with different control variables and aggregation periods, Denizer et al. (2002) also generally support a negative correlation between financial development and growth, consumption, and investment volatility.[8] They also show that the way in which the financial system develops matters.[9] Lopez and Spiegel (2002) also find a significantly negative relationship between financial development and income volatility from a cross-country panel spanning the years 1960 to 1990, using the system GMM estimation with time and country fixed effects.[10] Their results also suggest that financial development alleviates economic fluctuations in the long run.

In addition, some papers find evidence for a non-linear relationship between financial development and output volatility. The non-linear relationship means that financial system development reduces volatility up to a limit, but thereafter reduces stability. For example, Easterly et al. (2001) find that financial system development is significantly associated with less volatility, but the relationship is non-linear in a panel of 60 countries over the periods 1960–1997.[11] Their point estimates suggest that output volatility begins to in-

[7] Ferreira da Silva (2002) uses a diverse set of proxies to measure the financial system development: (i) the ratio of a country's liquid liabilities to its GDP (ii) the ratio of the assets of deposit money banks to the total assets of the financial system (iii) the ratio of the claims to the non-financial private sector divided by the total domestic credit or the ratio of the claims to the non-financial private sector devided by the GDP (iv) the growth rate of the financial sector real GDP. The three indicators, (ii) $\sim$ (iv) are from King and Levine (1993).

[8] Denizer et al. (2002) use panel data from 70 countries for the period 1956 to 1998. They also use the four measures from King and Levine (1993) as the financial development indicators.

[9] Particularly, the role of banks in the financial sector has explanatory power for the output, consumption, and investment volatility, whereas the ratio of credit supplied to the private sector is only important in explaining consumption volatility.

[10] Lopez and Spiegel (2002) measure volatility as the square of the change in income per capita unlike other papers. They also get the indicators of financial development from King and Levine (1993).

[11] Easterly et al. (2001) evaluate the impact of many factors such as financial system development, trade (financial) openness, price flexibility and policy volatility on growth volatility using OLS and 2SLS. For the measure of the financial system development, they use the ratio of credit to private sector to GDP. They also use a range of instrumental variables including indicators for legal origin, initial GDP per capita, the urban share of the population, life expectancy, the standard deviation of terms of trade changes, indicators of oil and other commodity exporters, and a measure of political stability because the ratio of credit to the private sector to GDP is found to be endogenous. Their empirical results find that trade (financial) openness seems to play much role in explaining output volatility, but wage rigidities is not significant determinant of volatility.

crease when the credit to the private sector reaches 100 percent of GDP. Recently, Dabla Norris and Srivisal (2013) also find strong evidence of a non-linear relationship between financial development and the volatility of output, consumption, and investment using a 110-country panel dataset over the periods 1974–2008.[12] Specifically, financial development has a beneficial role in dampening volatility, but only up to a certain level. At high levels (again, over 100 percent of GDP), financial development magnifies consumption and investment volatility.

On the other hand, other papers do not find a negative relationship between financial development and output volatility. For example, Acemoglu et al. (2003) suggest that distortionary macroeconomic policies are symptoms of underlying institutional problems rather than being the ultimate causes of economic volatility.[13] They find that financial aspects become insignificant for explaining volatility once the effect of institutions are taken into account. Beck et al. (2006) investigate the channels through which financial development potentially affects output volatility using a panel of 63 countries over the years 1960–1997 and also do not find a strong and robust relationship between financial development and growth volatility.[14] Specifically, they find inflation volatility intensifies output volatility in countries with low level of financial development, but no effect in the countries with better financial system using OLS regressions. They also find weak evidence for a restraining effect of financial system development on the impact of terms of

[12] Dabla Norris and Srivisal (2013) evaluate financial development by the aggregate private credit provided by deposit money banks and other financial institutions as a share of GDP. They also consider three indicators measured as a share of GDP – total liquid liabilities, depository banks' assets, and total deposits in financial institutions – following King and Levine (1993).

[13] Acemoglu et al. (2003) use the constraint on the executive variable as the indicator of institutions in order to develop the argument that the fundamental cause of post-war instability is institutional. And they use data on the mortality rates of soldiers, bishops, and sailors stationed in the colonies between the 17th and 19th centuries as the instrumental variable for institutions to tackle the reverse causality problem.

[14] Their indicator of financial system development is private credit, the claims on the private sector by financial intermediaries as share of GDP.

trade volatility.[15]

Tharavanij (2007) also investigates the effect of capital market development and financial development on volatility together and finds that financial development is almost always insignificant.[16] He suggests that output and investment volatility are negatively related to measures of capital market development using panel data covering 44 countries from 1975 to 2004.[17] In addition, there is some evidence that capital market development also lowers consumption volatility. Unlike other research, Mallick (2009) separately estimates the effect on different parts of volatility - business cycle volatility and long-run volatility - and finds that financial development affects only business cycle volatility and does not affect long-run volatility. Since total volatility is composed of business cycle volatility and long-run volatility, the effect of financial development on total volatility is argued to be weak.

Another strand of literature empirically studies the relationship between credit cycles and economic crises. For example, Schularick and Taylor (2012) find that lagged credit growth turns out to be highly significant as a predictor of financial crises using an annual dataset of 14 developed countries over the years 1870–2008. Based on a similar dataset, Jorda et al. (2012) also find that higher rate of change of bank credit is associated with a deeper recession implying that larger credit booms are followed by deep recessions and sluggish recoveries.

---

[15] However, the FE regressions show somewhat different results. In particular, they show more significant results for the interaction of terms of trade volatility and private credit, whereas less significant results for the interaction of inflation volatility with private credit.

[16] Specifically, when output volatility and consumption volatility are used, financial development is always insignificant. Nonetheless, this paper presents the evidence of a significant negative relationship between financial development and investment volatility.

[17] This paper uses the ratio of private sector credit to GDP and the ratio of liquid liabilities to GDP as the indicator of financial development. Also it apply both the value of shares traded on domestic exchanges divided by the total value of listed shares (Turnover Ratio) and the ratio of value of tatal shares traded on the stock market divided by GDP over the claims of the banking sector on the private sector as a share of GDP (Structure Activity index) as the measure of capital market development.

In summary, previous work has established substantial theoretical and empirical grounds to understand the relationship between financial development and output volatility. Based on these studies, financial development generally reduces output instability up to the certain level. Above the level, economies become more unstable. However, we still have open questions. First of all, we don't know how the relationship between financial development and output volatility has changed during the recent financial crisis. Existing studies generally investigate the pre-crisis period. However, the recent financial crisis ended the so-called Great Moderation[18] in the developed countries and larger financial sectors in some developed countries may considerably affect economic outcome, especially economic stability. Second, some studies find a weak relationship between financial development and output volatility. The difference of conclusions, however, remains unclear. Third, the number of sample countries is not sufficient. Panel data comprise 116 countries[19] at most in existing papers and most studies have 40˜70 countries in the sample. According to these questions, we develop the empirical analysis on the effects of financial development on output volatility in following way. First, we expand the length of the sample period into the recent financial crisis. Thus, we can examine the effect of the recent financial crisis on output volatility using panel data over the years 1971–2010. Second, we attempt to consolidate conflicting results among the existing work. The difference of conclusions may result from the measures of financial development considered, the sets of controls, aggregation periods, country samples, and the estimation techniques employed (Dabla Norris and Srivisal, 2013). For example, among the studies which show conflicting conclusions Beck et al. (2006) utilise the FE regression instead of the system GMM regression. Ace-

[18] The U.S. entered a period of great moderation with the long and large decline in output volatility since 1980s (Blanchard and Simon, 2001). This decline in output volatility was shown in other developed countries. Barrell and Gottschalk (2004) also examine the causes of the decline of the output gap volatility in the G7.

[19] Mallick (2009) includes 116 countries in some regressions. Recently, Dabla-Norris and Srivisal (2013) employs the panel data for 110 countries.

moglu et al. (2003) also use the ratio of real M2 to GDP as a measure of the importance of financial intermediation instead of the ratio of private sector credit to GDP generally used. Tharavanij (2007) add the measure of capital market development and find more private credit is not associated with less output volatility. We, thus, investigate whether different specifications cause different results or not as robustness tests. Third, we increase the number of sample countries compared to the previous work. Our panel is composed of 127 countries and this helps to obtain reliable results.

2.2.2. Government debt and output volatility

The effect of government debt on macroeconomic stability is unclear. On the one hand, due to the automatic stabilisers and discretionary fiscal policy reacting to a negative shock, increased government debt may mitigate the propagation of a shock during recession, thereby contributing to macroeconomic stability. However, on the other hand, high levels of government debt can increase output volatility through a variety of mechanisms. First, high government debt constrains fiscal and monetary policy by causing large fiscal consolidation or temporary monetary loosening (Pescatori et al., 2014). Second, increased government debt in itself may raise macroeconomic volatility because fiscal policy to reduce output volatility becomes less effective at high government debt levels (Sutherland and Hoeller, 2012).[20] Third, government debt also increases output volatility by increasing a probability of sovereign default. Since defaults are associated with deep recessions, higher government debt is linked to output volatility through default risks.[21] Fourth, government debt increases output volatility by the impact on international confidence (Elmendorf and

[20] Sutherland and Hoeller (2012) show that high government debt levels reduce the effectiveness of fiscal policy because higher sovereign default risk at very high debt levels may reduce investment.

[21] Also, external debt as a share of GDP is higher when countries default according to Mendoza and Yue (2012). This explains the relationship between government debt and output volatility because external debt takes up a considerable part of government debt.

Mankiw, 1998). International investors may worry about high government debt levels. It can cause a significant outflow of foreign capital and make the economy unstable.

Some papers theoretically analyse the effect of government debt on volatility using the dynamic stochastic general equilibrium (DSGE) framework. For instance, Corsetti et al. (2013) analyse a 'sovereign risk channel' through which higher public debt negatively affects private-sector financing costs and show that the sovereign risk may exacerbate macroeconomic instability in the DSGE model proposed by Curdia and Woodford (2009).[22] Schurin (2012) also shows that output becomes more volatile when countries have significant amounts of government debt because the risk premium on government bonds is countercyclical and the economy substantially becomes unstable with rising risk of default.

Meanwhile, some research finds that high government debt statistically weakens growth, sometimes in a non-linear manner (e.g., Caner et al., 2010; Kumar and Woo, 2010; Checherita and Rother, 2010; and Cecchetti et al., 2011).[23] However, there are not many papers which statistically examine the effect of government debt on output volatility. Spiliopoulos (2010)[24] includes short term and long term government debt as determinants of macroeconomic volatility within a cross-section of 50 countries over the period 1974–1989 and find the ratio of short term debt to GDP is an important correlate of output volatility.[25]

[22] Specifically, an upward shift of the government deficit raises the risk premium on public debt and, through the sovereign risk channel, this drives up private borrowing costs, unless higher risk premium is neutralized by relaxed monetary policy. Then, sovereign risk tends to exacerbate the effects of cyclical shocks.

[23] Specifically, Reinhart and Rogoff (2010) find that above 90 percent of debt to GDP ratio growth rates fall considerably more. However, Herdon, Ash, and Pollin (2014) raise objection to their result showing that the relationship between government debt and GDP growth varies by time periods and country.

[24] Spiliopoulos (2010) has some characteristics in the methodology. This paper employs Bayesian Model Averaging techniques. This also uses the downside semideviation of GDP growth rates – the standard deviation of GDP growth rates below the mean growth over the time period – as a measure of volatility, instead of using the standard deviation of GDP per capita growth rates like other studies.

[25] However, the direction of relationship is ambiguous. The short term debt is found to have positive effect on output volatility, but long term debt negatively affects volatility. He concludes that the effect of long term debt is inconclusive because including only long term debts lowers an inclusion probability into

Sutherland and Hoeller (2012) examine simple bivariate relationships between various debt measures and macroeconomic volatility using OECD countries' quarterly data. They find that increase in government debt results in higher output volatility, though private sector debt levels are not strongly and robustly associated with output volatility. However, their probit estimation reveals that the effect of more government debts on the probability of a recession occurring is negative and strong. Pescatori et al. (2014) focus on advanced economies and can not find non-linear relationship between government debt and output volatiity. However, they suggest a positive relationship, even if there is the large inter-quartile range. In particular, above 56 percent of debt to GDP ratio a relatively higher output volatility exists.

Like this, it is not clear whether government debt makes an economy unstable. Furthermore, existing literature does not systematically analyse the relationship between government debt and output volatility. First of all, previous work does not correct for possible endogeneity. Second, the sample period[26] and the number of sample countries[27] are not sufficient to get reliable results like previous subsection. Thus, we improve the current understanding of the relationship between government debt and output volatility in following way. First, we employ dynamic panel methodology, the system GMM regression to alleviate the endogeneity problem. We also use lagged values of government debt in the robustness section so that we investigate the relationship between government debt at the beginning of a period and subsequent output volatility. Second, we expand the length of the sample period using panel data over the years 1971–2010. In addition, we increase the number of countries and our panel is composed of 65 countries.

0.26 in the Bayesian Model Averaging techniques.

[26] Spiliopoulos (2010) excludes the recent financial crisis period. Sutherland and Hoeller (2012) only include 15 years (1995-2010) in the sample period.

[27] Spiliopoulos (2010) includes 50 countries and Sutherland and Hoeller (2012) only include OECD countries in the sample.

2.2.3. Interactions between financial development and government debt

As stated above, existing literature analyses the effect of financial development and government debt on output volatility separately. However, the two factors may interact and affect jointly output volatility in a particular way. The recent crisis especially shows that analysing private credit and government debt separately is not appropriate (Jorda et al., 2013). For example, when the real estate bubble collapsed in Ireland and Spain, a banking system became unstable. Bail-outs of the banking system abruptly increased government debt and turned into a sovereign debt crisis. In addition, unsustainable government debt in Greece and Italy raised doubts about banks with government bonds.

Using a statistical toolkit relied on local projection approach Jorda et al. (2013) clearly show that the recovery from economic crisis can be delayed if high levels of government debt and a private credit overhang occur simultaneously based on the analysis of 150 crises in 17 advanced countries since 1870. However, they find that adding the interactions between the two in the logit model does not increase the generation probability of financial crisis. This result can be explained by differences in the cyclicality of private credit and government debt. Private credit seems to be pro-cyclical while government debt shows counter-cyclical in developed countries. Except for Jorda et al. (2013), it's not easy to find related studies in this area. Thus, we improve their research to examine the effect of the interactions between financial development and government debt on output volatility. First, we employ the system GMM regression instead of the logit model because we are not interested in the generation probability of financial crisis, but output volatility. Second, we increase the number of countries to 65 countries. Lastly, we expand the number of control variables. Jorda et al. (2013) do not consider other control variables, while we include various control variables such as exchange rate, trade, inflation and institution.

2.3. Econometric methodology

2.3.1. Methodology

Previous empirical work and the recent financial crisis motivate the following hypotheses. First, the theory and previous evidence suggest that we should expect to find a non-linear relationship between financial development and output volatility. A second hypothesis is that government debt levels may increase output volatility. Third, the interactions between financial development and government debt are associated with higher output volatility. In order to examine these hypotheses we use the system GMM dynamic panel regression by Arellano and Bond (1991), Arellano and Bover (1995), and Blundell and Bond (1998). We also compute Arellano-Bond standard errors which are robust to heteroskedasticity and autocorrelation.

The baseline panel regression specification is as follows:

$$\begin{aligned} VOL_{i,t} &= \alpha VOL_{i,t-1} + \beta_1 FD_{i,t} + \beta_2 FD_{i,t}^2 \\ &\quad + \gamma_1 GD_{i,t} + \gamma_2 GD_{i,t}^2 + \delta FD_{i,t} \times GD_{i,t} + \lambda X_{i,t} + u_t + \mu_i + \epsilon_{i,t} \end{aligned} \tag{2.1}$$

where VOL is a measure of output volatility at time t for country i; FD is a measure of financial development; GD is a measure of the government debt level; X is a set of other variables; u_t is the time-specific fixed effect; μ_i is the country-specific fixed effect; and $\epsilon_{i,t}$ is the error term. We examine the effects of financial development and government debt on output volatility simultaneously.[28] We also include the lagged dependent variable in the system GMM dynamic panel regression in order to control a persistent effect of the

[28] We also examine the effect of financial development omitting government debt and the effect of government debt omitting a measure of financial development as the robustness check.

dependent variable.

The above equation is based on Dabla Norris and Srivisal (2013). We include a linear and a squared terms of private credit to test the non-linear impact of financial development on output volatility and expect that the linear term, $\beta_1 < 0$, and the quadratic term, $\beta_2 > 0$ according to Dabla Norris and Srivisal (2013). However, we extend their work in the following ways: (i) our equation includes the measure of government debt to examine its impact on output volatility (ii) the interaction term between financial development and government debt is included. Regarding government debt, we use GD to examine the effect of government debt levels. A positive sign on γ_1 would indicate a magnifying role of government debt levels on output volatility. In order to examine the existence of a non-linear relationship between government debt and output volatility we add a quadratic term, GD^2.[29] Lastly, we include the interaction term between the two, $FD \times GD$, to examine jointly the effect of private credit and government debt on output volatility.

We consider two more regression specifications according to "General-to-Specific Approach". First, a parsimonious specification I excludes the quadratic term of government debt and the interaction term. Second, in order to maintain the number of available observations a parsimonious II excludes government debt related terms. The two more regression specifications are as follows.

$$VOL_{i,t} = \alpha VOL_{i,t-1} + \beta_1 FD_{i,t} + \beta_2 FD^2_{i,t} + \gamma_1 GD_{i,t} + \lambda X_{i,t} + u_t + \mu_i + \epsilon_{i,t} \tag{2.2}$$

$$VOL_{i,t} = \alpha VOL_{i,t-1} + \beta_1 FD_{i,t} + \beta_2 FD^2_{i,t} + \lambda X_{i,t} + u_t + \mu_i + \epsilon_{i,t} \tag{2.3}$$

[29] An assumption of a non-linear relationship between government debt and output volatility is not based on a prediction of the theory or previous research. However, it is meaningful to test this assumption under the non-linear relationship between government debt and economic growth shown in the literature.

2.3.2. System GMM

As stated above, we adopt the system GMM dynamic panel regression. Some previous papers use the FE panel regression. The FE panel regression deals with the omitted variables bias resulting from the correlation between country specific fixed effects and the independent variables in the pooled OLS. However, the use of the system GMM regression instead of the FE panel regression can be justified as follows. The FE panel regression still has the measurement error bias and the endogeneity problem - both output volatility and financial development (or government debt) jointly respond to some other unobserved factors - which are inherent in the OLS.[30] Specifically, a serious difficulty arises with the FE model in the context of a dynamic panel data model particularly in the small number of time periods and large number of individuals context (Nickell, 1981). This arises because the demeaning process which subtracts the individual's mean value of dependent variables and each explanatory variables from the respective variable creates a correlation between regressor and error. The bias arises even if the error process is i.i.d. If the error process is autocorrelated, the problem is even more severe given the difficulty of deriving a consistent estimate of the AR parameters in that context. One solution to this problem involves taking first differences of the original model. Arellano and Bond (1991) begin by differencing all regressors using the GMM. And they find that the lagged dependent variables are valid instruments in the differenced equations. Specifically, Arellano and Bond (1991) propose the difference GMM estimator with following moment conditions[31]

$$E\left[VOL_{i,t-s}(\epsilon_{i,t}-\epsilon_{i,t-1})\right] = 0 \; for \; s \geq 2, t = 3, \ldots, T, \tag{2.4}$$

$$E\left[Y_{i,t-s}(\epsilon_{i,t}-\epsilon_{i,t-1})\right] = 0 \; for \; s \geq 2, t = 3, \ldots, T, \tag{2.5}$$

[30] See Kumar and Woo (2010).

[31] This explanation partly follows Kunieda (2008).

where Y indicates explanatory variables other than the lagged dependent variables. However, the lagged dependent variables are poor instruments for the regression if the explanatory variables follow a random work (Blundell and Bond, 1998). In order to correct this problem, Arellano and Bover (1995), and Blundell and Bond (1998) assume that first differences of instrument variables are uncorrelated with the fixed effects. This allows us to introduce more instruments, and increases efficiency (Roodman, 2006). Specifically, lagged differences of dependent variables are included as instruments. This assumption is explained by following moment conditions

$$E\left[(VOL_{i,t-s} - VOL_{i,t-s-1})(\mu_i + \epsilon_{i,t})\right] = 0 \ for \ s = 1 \tag{2.6}$$

$$E\left[(Y_{i,t-s} - Y_{i,t-s-1})(\mu_i + \epsilon_{i,t})\right] = 0 \ for \ s = 1. \tag{2.7}$$

We can obtain consistent and efficient estimators with these four moment conditions. These estimators are called as the system GMM estimators.

According to this approach we utilise the lagged levels of the regressors as the instruments for the regression in differences and the lagged first differences of the corresponding variables as the instruments for the regression in levels. However, the system GMM can generate numerous instruments and this causes some problems (Roodman, 2009).[32] Roodman (2009) suggests two main techniques to limit the number of instruments in the system GMM. The first is to use only certain lags instead of all available lags for the instruments. The second method collapses the instrument matrix. We combine the two approaches collapsing the instruments and using only the two-period lags of the dependant variable, the

[32] Specifically, the problems of too many instruments are as follows. First, it can overfit endogenous variables. Second, it violates a Hansen test of overidentification.

valid latest one.

However, above discussion is reasonable only under the hypothesis that explanatory variables are weakly endogenous[33] (Dabla Norris and Srivisal, 2013). Thus, to cope with the endogeneity problem we substitute the lagged levels of private credit and government debt for the contemporaneous levels in the robustness checks.

2.4. Data

Our panel dataset spans 40 years from 1971[34] to 2010 for 127 countries (40 high-income, 58 middle-income, and 29 low-income countries).[35] The number of our sample countries is larger than previous research. However, data for some regressors used in the regressions - especially, government debt - are not available for many countries for the whole period. Therefore, the sample size reduces to 65 countries for which data for all variables are available (27 high-income, 34 middle-income, and 4 low-income countries). Appendix shows the list of countries included in the sample. We include the recent financial crisis periods because output volatility potentially related to both increasing private credit and government debt during the financial crisis is an important part of this chapter.[36] The data set comprises eight non-overlapping five-year periods (1971–75, 1976–80, ..., 2001–05, 2006–10).[37] To check the robustness of our results we also consider alternative time horizon - 3 year periods (1971–73, 1974–76, ..., 2007–10).

Our measure of output volatility is the standard deviation of the annual growth rate of real GDP per capita.[38] The GDP data are taken from release 7.1 of the Penn World Table

[33] Weakly endogeneity means that explanatory variables are not correlated with future values of the error term.

[34] We choose 1971 as the first year because of data availability.

[35] Regarding income levels of countries, we follow World Bank classification.

[36] Previous research does not include the recent financial crisis periods. For example, Dabla Norris and Srivisal (2013) stop in 2008.

[37] A panel dataset transforming the time series data into five-year periods is now standard in the literature (Dabla-Norris and Srivisal, 2013).

[38] Previous research such as Dabla Norris and Srivisal (2013) also use the same measure.

(PWT), due to Heston et al. (2012). We use the chain-weighted real output series named RGDPCH in PWT 7.1, and measure annual growth rates using log differences.

The measure of financial development is "Private credit", defined as the ratio of domestic credit supplied to the private sector by depository banks and other financial institutions to GDP.[39] Private credit is the most commonly used indicator of financial development (e.g., Easterly et al., 2001; Beck et al., 2006; Tharavanij, 2007; Mallick, 2009). Other papers also use alternative measures such as total liquid liabilities, depository banks' assets, and total deposits in financial institutions from Levine and King (1993). As in previous work alternative measures from Levine and King (1993) show similar results with private credit. Thus, we don't consider these alternative measures.[40] However, we consider "Money" as another measure of financial development because Acemoglu et al. (2003) find different results using this measure. Money is defined as the ratio of real M2 to GDP. On the other hand, we examine whether an inclusion of the measure of capital market development changes the importance of financial development or not as a robustness test. Following Tharavanij (2007), we employ two measures: "Structure activity index" and "Turnover ratio". Turnover ratio is defined as the value of shares traded on domestic stock market divided by the total value of listed shares. And structure activity index is defined as the ratio of value of total shares traded on the stock market divided by GDP over the domestic credit provided by banking sector as percentage of GDP.[41] In addition, we use the ratio of total (domestic and external) gross central government debt to GDP from Reinhart and Rogoff (2011) as the indicator of government debt levels.

[39] Particularly, domestic credit to private sector indicates financial resources supplied to the private sector, such as through loans, purchases of nonequity securities, and the trade credits and other accounts receivable, that certify a claim for repayment (Tharavanij, 2007).

[40] Levine and King (1993) also indicate problems in these alternative measures. In specific, these measures do not differentiate between the liabilities of various financial institutions, and may not be closely related to financial services such as risk management and information processiong.

[41] Turnover ratio is identified as an absolute measure of capital market, whereas structure activity index relatively measures stock market activity compared to banks (Tharavanij, 2007).

Clearly, it is necessary to control for other variables which can affect output volatility in order to estimate the impact of financial development and government debt on output volatility more precisely. As controls we include a number of variables that have shown to be associated with output volatility in the literature. First of all, this includes beginnings-of-period real GDP per capita to control for economic size.[42] We also consider the standard deviation of real exchange rates changes to control for foreign exchange shocks, as exchange rate changes can affect production and consumption decisions.[43]

Other control variables, measured as averages within each 5-year period, include trade openness[44], as measured by the ratio of exports plus imports to GDP, the ratio of government consumption expenditure to GDP[45]. Also, we include an index of the type of political regime (Polity index)[46] which captures the institutionalised qualities of the governing authority, and may have a bearing on economic stability.[47] Finally, the standard deviation of inflation can be used as an indirect measure of the strength of monetary policy regimes.[48][49]

[42] A number of papers such as Easterly et al. (2001) use initial GDP per capita as control variables and find that developing countries tend to undergo much more output volatility than developed countries.

[43] Denizer et al. (2002) also attempts to control for macroeconomic shocks by including the standard deviation of the exchange rate and find that greater exchange rate volatility is related to more GDP volatility. The next series of papers that investigate output volatility (e.g., Ferreira da Silva, 2002; Kunieda, 2008; Dabla Norris and Srivisal, 2013) follow this method by incorporating the standard deviation of the exchange rate.

[44] The effects of trade openness on output volatility are addressed in Bejan (2006), Cavallo (2007), and Di Giovanni and Levchenko (2009). They show significantly destabilising role of trade openness.

[45] Rodrik (1998) argues that the government plays a risk-reducing role in economies exposed to external risk by providing social insurance. Tharavanij (2007) includes this variable as a control variable besides Dabla Norris and Srivisal (2013).

[46] This index is taken from Polity-IV dataset and ranges from -10 (hereditary monarchy) to +10 (consolidated democracy).

[47] For example, Mobarak (2005) finds that higher levels of democracy is more stable.

[48] We use the standard deviation of inflation, while other studies such as Dabla Norris and Srivisal (2013) include the level of inflation. This is because the former is more significant variable than the latter (Denizer et al., 2002). Dabla-Norris and Srivisal (2013) also find that the level of inflation has insignificant effect on output volatility. Blanchard and Simon (2001) find that the level of inflation is insignificant in explaining changes in output volatility. Among the related work, Beck et al. (2006) and Kunieda (2008) use the volatility of inflation as control variables.

[49] We omit a measure of financial openness unlike Dabla Norris and Srivisal (2013) because some papers such as Buch et al. (2005) do not show significant relationship between financial openness and output volatility.

The definition and sources for all variables are given in Appendix.

Table 2.1 reports summary statistics of all variables. There are some important points. Output volatility is decreasing with income level. There are also differences in financial development. High income countries tend to have deeper financial system, measured by private credit to GDP ratio. Another measure of financial development, money, also shows similar pattern depending on the income level. And two measures of capital market, structure activity index and turnover ratio, are increasing with the income level. However, the ratio of government debt to GDP is clearly decreasing with the income level. It is the highest for the low income countries, while it is almost half in the high income countries.

Table 2.1. Summary statistics (5-year panel)

Variable	Obs	Mean	Std. Dev.	Low income	Middle income	High income
Output volatility	989	1.99	1.91	2.41	2.06	1.55
Private credit	898	41.25	39.61	13.38	32.17	74.22
Money	866	53.25	144.22	42.67	44.74	77.59
Structure Activity index	353	18.12	174.95	3.86	17.73	20.45
Turnover ratio	308	47.63	53.58	15.25	33.99	66.11
Government debt	485	53.78	53.20	90.60	56.41	46.11
Initial GDP	989	3.60	0.58	2.87	3.55	4.24
Real exchange rate volatility	976	67.16	372.88	138.01	8.94	4.14
Domocracy	977	1.80	7.19	-2.32	0.90	6.36
Trade openness	915	73.50	47.14	55.72	73.71	86.28
Inflation volatility	958	41.28	410.50	55.66	54.54	9.87
Government spending	909	15.91	6.30	13.66	15.02	18.82

Figure 2-1 illustrates the behavior of output volatility over the sample period. The data roughly show a downward trend. However, output volatility increased for the 2006–2010 period, especially for the high income countries. For example, volatility in the high income countries doubled that in the first half of 2000s. The notable exception is the low income countries, where output volatility decreased recently though relative to historic high levels. Thus, during the period 2006–2010 they became more stable than the high income countries. This reflects the fact that the financial crisis mostly impacted developed countries.

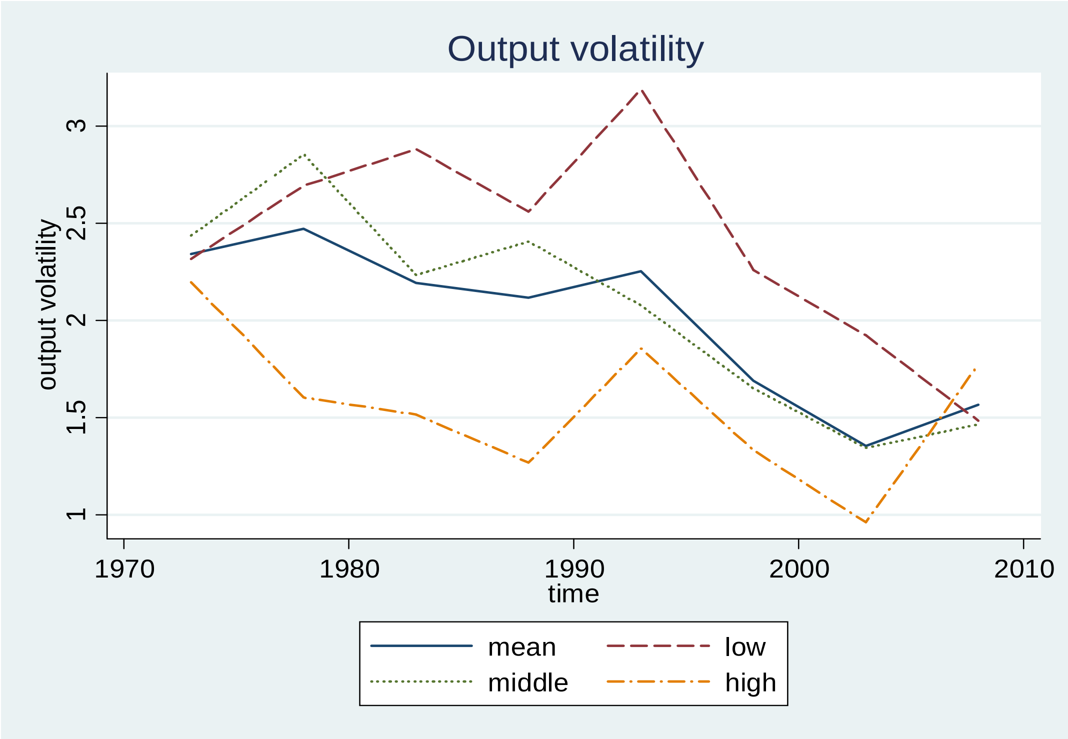

Figure 2-1. Output volatility

The mean ratio of private credit to GDP has consistently increased over the last four decades (Figure 2-2). However, the magnitude of increase varies with income levels. Specifically, the low income countries have remained at similar levels and the middle income countries exhibit a moderate increase of private credit, whilst there was a dramatic rise of private credit in the high income countries, especially in the 2000s. This increase of private credit may be associated with the recent financial crisis in developed countries following previous research such as Reinhart and Rogoff (2009).

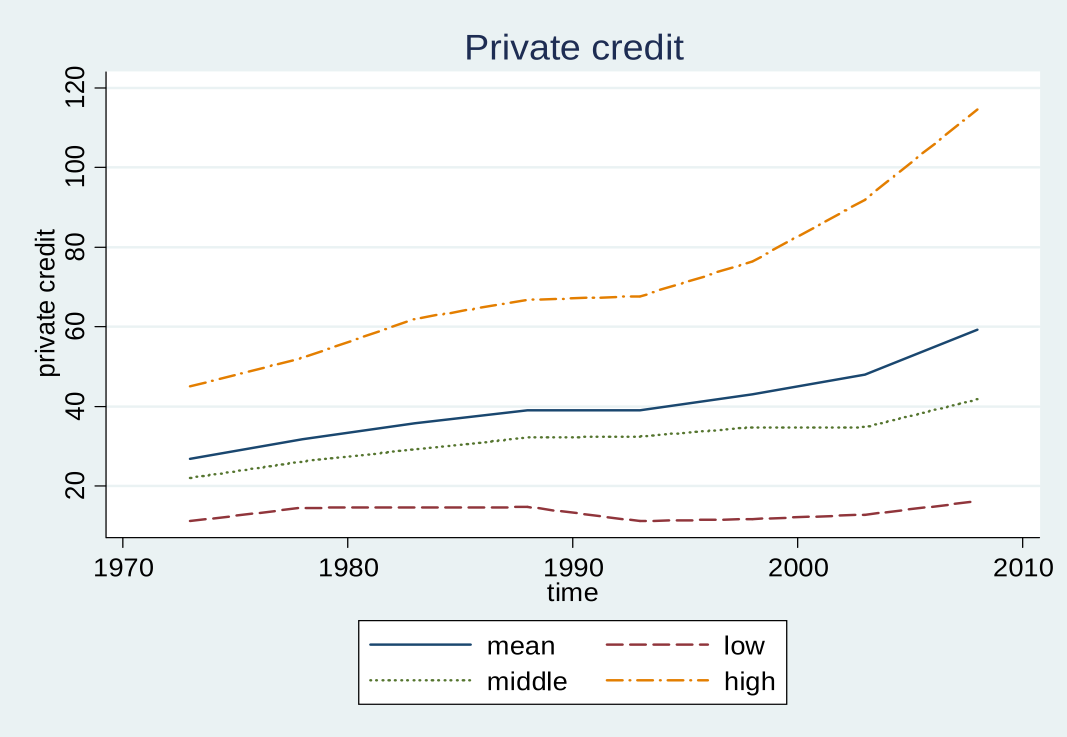

Figure 2-2. Private credit

The mean government debt levels in Figure 2-3 display a significant increase until the 1980s followed by a downsizing. The middle and low income countries exhibit strikingly similar time trends throughout. However, the debt of the high income countries has consistently risen over the last four decades.[50] Finally, a turnaround of the ordering showed up recently. The debt of the high income countries was larger than the lower income level

[50]Contrary to expectations, the debt ratio of the high income countries showed a quite smooth increase during the recent financial crisis. This is because the abrupt increase of government debt is confined to some Eurozone countries and United States.

countries. This reversal presumably implies that developed countries adapted vigorous fiscal policy to overcome the financial crisis.

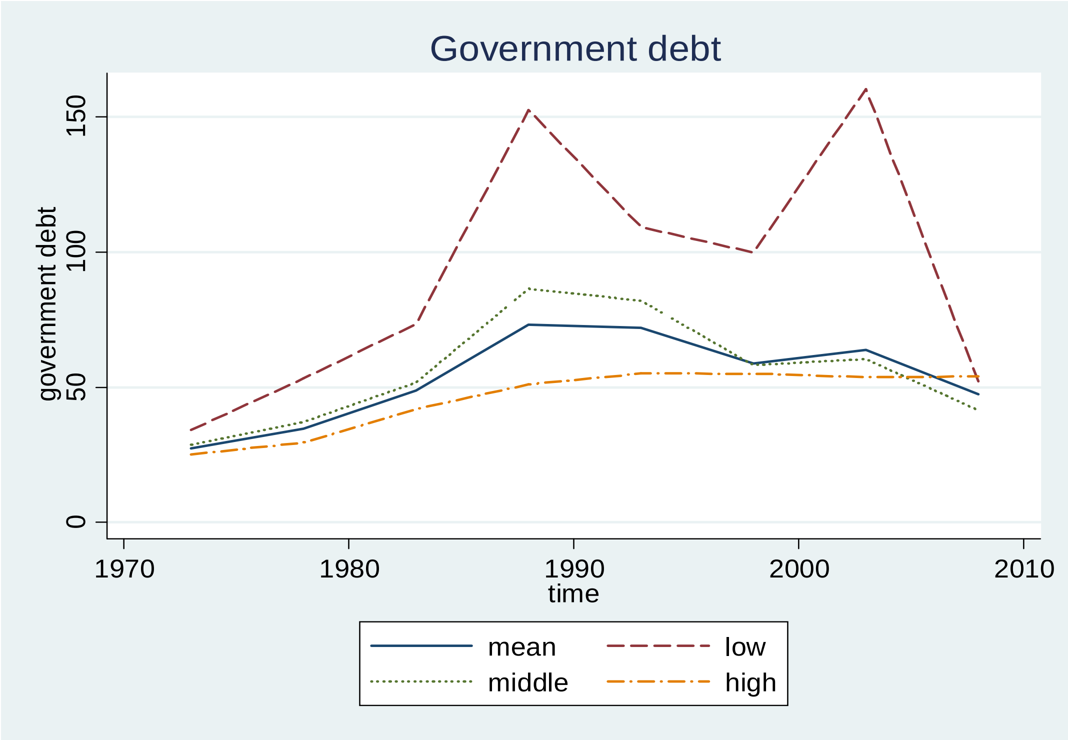

Figure 2-3. Government debt

In addition, in order to examine the relative impact of the various factors, Table 2.2 presents bivariate correlations of output volatility and the variables of interest - those relating to financial development, government debt, initial GDP, openness, democracy and policies. The result shows that private credit is negatively associated with output volatility in raw terms, but that government debt is correlated with output volatility. Money is negatively correlated with output volatility. As a correlation between private credit and money is also high, the relationship between money and output volatility may be presumably similar to that between private credit and output volatility. Regarding control variables, higher levels of initial GDP and democracy are associated with reduced output volatility. Exchange rate volatility, trade openness, inflation volatility and government spending are positively associated with output volatility, but the degree is not that big.

Table 2.2. Five-year panel correlations between variables

Variable	Output volatility	Private credit	Money	Gov. debt	Initial GDP
Output volatility	1				
Private credit	-0.3353	1			
Money	-0.2556	0.8189	1		
Gov. debt	0.1173	-0.1401	0.0489	1	
Initial GDP	-0.2254	0.7138	0.6099	-0.1239	1
Exchange rate volatility	0.0293	-0.0208	-0.0179	0.1066	-0.0656
Democracy	-0.3039	0.4731	0.4067	0.0150	0.5501
Trade openness	0.0802	0.1962	0.2743	0.2763	0.2355
Inflation volatility	0.0625	-0.1289	-0.0660	0.1310	-0.0494
Gov. spending	0.0385	0.3402	0.3534	0.1593	0.3396

Variable	Exchange rate volatility	Democracy	Trade openness	Inflation volatility	Gov. spending
Exchange rate volatility	1				
Democracy	-0.0084	1			
Trade openness	-0.0040	0.0687	1		
Inflation volatility	-0.0033	-0.0007	-0.0585	1	
Gov. spending	-0.0789	0.1073	0.3642	-0.0223	1

2.5. Regression results

This section shows regression results of the determinants of output volatility, focussing on the roles of financial development and government debt. We begin with simple cross-section regressions and then move on to the system GMM dynamic panel regression.

2.5.1. Cross-section regression results

We start with a preliminary regression to examine the effect of financial development and government debt on output volatility using averages across countries over the period 1971–2010 presented in Table 2.3. To evaluate the relative impact of financial development and government debt we regress output volatility against a variety of regressors. Column (1) presents the baseline cross-country regression including both financial development and government debt. Regarding the connection between financial development and output volatility we find that the sign of the linear term is negative and statistically significant at the 5% significance level. This is consistent with Dabla Norris and Srivisal (2013). However, government debt levels are not found to significantly affect output volatility in Column (1). This result is different from previous papers such as Spiliopoulos (2010) and Sutherland and Hoeller (2012).[51]

In order to increase the sample size, in Column (2) of Table 2.3 we only examine the relationship between financial development and output volatility eliminating government debt.[52] The empirical result shown in Column (2) is the same as discussed above. Private credit is displayed to significantly affect output volatility implying that financial development does expose a country to reduced output volatility.[53]

Since the regression results discussed above have many limitations, their interpretation is problematic. For example, certain time periods in our data may be associated with greater

[51] This difference comes from aggregation periods, country samples, and the estimation techniques. Specifically, Spiliopoulos (2010) employs Bayesian Model Averaging technigues with 50 countries from the period 1974–1989.

[52] Our sample includes observations on 126 countries in Column (2). However, our sample size reduces to 64 countries when government debt is included in Column (1).

[53] This result is also similar to a simple reduced-form cross-section regression of Dabla Norris and Srivisal (2013).

financial development and reduced volatility or there may be certain country-specific characteristics associated with increased financial development and decreased volatility (Denizer et al., 2002). Also both output volatility and financial development (or government debt) may jointly respond to some other unobserved factors due to the endogeneity problem. To address this matter, we employ the system GMM dynamic panel regression. We also use the lagged variables of financial development and government debt to tackle the endogeneity problem in the robustness test.

Table 2.3. The result of cross-section regression

Regression type	(1)		(2)	
Private credit	-0.7899099	(-2.32)**	-1.366163	(-2.76)***
Government debt	-0.1183789	(-0.34)		
Initial GDP	0.0581523	(0.22)	0.4487283	(1.56)
Exchange rate volatility	0.00000114	(6.01)***	0.000000972	(5.75)***
Democracy	-0.0472881	(-2.71)***	-0.0785791	(-3.03)***
Trade openness	0.5590275	(2.06)**	1.551415	(2.77)***
Inflation volatility	0.0005986	(1.42)	-.0002276	(0.98)
Government spending	0.0849353	(0.12)	0.5241861	(0.86)
Intercept	2.038762	(2.71)***	-.4783477	(-0.46)
R^2	0.5264		0.2749	
Observations	64		126	

Note: t-values in parentheses

Levels of significance: *** 1 percent, ** 5 percent, * 10 percent

2.5.2. System GMM results

We now advance to the system GMM regression.[54] The estimated effects of financial development and government debt on output volatility are presented in Table 2.4. The baseline regression shown in Column (1) is based on the equation (2.1). We find that the linear term of private credit enters negatively and the quadratic term enters positively. Both terms are also significant at the conventional level. This implies that the relationship between financial development and output volatility is U-shaped, i.e., in early stages of financial development, as the financial system matures in an economy, it has a stabilising effect. However, as the financial system develops above a certain level, output volatility begins to increase. Our findings confirm previous studies (e.g., Easterly et al., 2001; Dabla-Norris and Srivisal, 2013).

In Column (2) of Table 2.4 we eliminate insignificant variables according to the equation (2.2).[55] Our main results of the U-shaped connection between private credit and output volatility still hold. The level of significance of private credit is especially much higher. In addition, when we eliminate government debt related terms to increase the sample size in Column (3) following the equation (2.3), the result is similar to the above ones.

This U-shaped volatility suggests that there is an optimal financial development. What is the theoretical rationale of the optimal financial development? As a financial system develops, households can smooth consumption opportunities and firms can diversify production possibilities. Since agents anticipate less shock in normal times, this financial deepening contributes to the stabilisation of the economy. However, this positive effect happens only up to the threshold. As the development of the financial system becomes deeper than the threshold, higher leverage of private sector will exacerbate risk through several channels, especially in crisis times.[56] Credit overhang, thus, contributes to exacerbating a slowdown

[54] We allow output volatility to follow an AR(1) process.

[55] In Column (2), the quadratic term of government debt and the interaction term are omitted.

[56] For example, lower interest rate resulting from more private credit will lower the quality of investments and again increase the average risk of investment (Spiliopoulos, 2010). In addition, financial accelerator

into a recession and may cause output instability. According to the mechanism given above, countries under the high leverage of private sector are increasingly vulnerable to negative shocks and financial development begins to affect negatively economic stability by amplifying shocks to the economy (Easterly et al., 2001).

From the equation (2.1), the threshold at which the effect of financial system on output volatility changes from negative to positive is calculated as $(-\beta_1/2\beta_2)$ (Dabla-Norris and Srivisal, 2013). The threshold estimated from the system GMM regression is 174.4 percent of GDP in Column (1). However, it drops to 140.9 percent and 129.9 percent of GDP in Columns (2) and (3), respectively.[57] Above the threshold, financial development does not act as a stability mechanism any longer. During the recent financial crisis many countries, especially developed countries, exceeded this threshold. Specifically, there are 15 countries from our sample on the basis of the regression in Column (3). The list is as follows: Cyprus, Denmark, Ireland, Japan, Korea, Luxembourg, Netherlands, New Zealand, Portugal, South Africa, Spain, Sweden, Switzerland, United Kingdom, United States. Our result suggests that those countries may need to reduce private credit to stabilise the economy.

The relationship between government debt and output volatility is shown in Column (1) of Table 2.4. The result shows that the linear term of government debt levels enters negatively whilst the quadratic term enters positively. However, the both terms are not significant at the conventional level suggesting that the connection between government

mechanisms in crisis times are also likely to be stronger under larger private credit (Jorda et al., 2012). Paul Krugman in the New York Times (July 10, 2014) especially proposes that the recent financial crisis is a kind of "balance sheet recession". Under high debt levels people become aware of its riskiness at some point. Thus, creditors demand to pay back the debt and debtors cannot but decrease their consumption for deleveraging. This simultaneous reduction of consumption may result in a depression. And this lower income will again cut consumption. This chain effect will further amplify the economic downturn. On the other hand, financial frictions also result from balance sheets of financial intermediaries (Gertler and Karadi, 2011). Bankruptcy of the firms with the high leverage ratio in recession gives a negative impact on the financial institutions and this reduces their ability and willingness to lend to the firms. Some firms can not help giving up investment due to a shortage of funds and this may aggravate the slowdown.

[57] Dabla-Norris and Srivisal (2013) show that the threshold value is 147 percent of GDP. Our threshold estimate is less than theirs on the basis of the equation of Column (3) which is similar to their one.

debt and output volatility does not appear to be non-linear. Therefore, contrary to financial development, there may be no limit at which the impact of government debt levels on output volatility changes its sign.

However, government debt enters with a positive sign and is significant at the 5% confidence level in the parsimonious regression shown in Column (2) of Table 2.4. This result suggests that larger government debt will be statistically associated with higher output volatility. Specifically, a one-standard deviation increase in government debt to GDP - 53.2 percent of GDP in the sample - raises output volatility by about one percent. This is basically consistent with previous work such as Spiliopoulos (2010), and Sutherland and Hoeller (2012) which find a significant destabilising role of government debt.

In Column (1), we include the interaction term between private credit and government debt according to the baseline equation (2.1). The interaction term between the two has a positive sign, but is not statistically significant at the conventional level. This result means that financial development with fiscal problems is not significantly related to economic instability. As explained in subsection 2.2.3, the difference in the cyclicality of private credit and government debt may cause this insignificant result. During the boom private credit tends to increase, whilst government debt decreases in developed countries. Therefore, it is difficult to generalise some Eurozone cases explained in the section 2.1.

We need to check the validity of the instruments for the consistency of the estimation. We utilise two specification tests following the literature. The first is an Arellano-Bond test for autocorrelation which examines the hypothesis of no second-order serial correlation in the first-differenced error terms. We find that we cannot reject the null hypothesis (p-value $= 0.262$). The second test is the Hansen test of over-identifying restrictions, which analyses the moment conditions. Table 2-4 shows that we cannot reject the null hypothesis that the full set of orthogonality conditions are valid (p-value $= 0.458$).

Table 2.4. The result of system GMM (full sample, 5-year panel, 1971~2010)			
Regression type	(1)	(2)	(3)
Lagged dependent variable	-0.0415752 (-0.58)	-0.0313347 (-0.43)	0.07517 (0.65)
Private credit	-6.889294 (-2.29)**	-5.361302 (-2.81)***	-5.54377 (-2.84)***
Private credit square	1.975202 (2.91)***	1.903188 (3.00)***	2.133435 (3.36)***
Government debt	-2.034902 (-1.32)	1.034569 (2.38)**	
Government debt square	0.6129722 (1.30)		
Interaction term	0.7390806 (0.92)		
Initial GDP	2.433177 (2.03)**	2.312843 (1.82)*	0.2508624 (0.59)
Exchange rate volatility	0.000156 (1.83)*	0.0001612 (1.84)*	0.0002073 (2.15)**
Democracy	0.0424812 (1.00)	0.0421137 (1.04)	-0.0108528 (-0.43)
Trade openness	0.5415663 (0.78)	0.3554796 (0.51)	2.220773 (1.73)*
Inflation volatility	0.0002368 (1.13)	0.0002308 (1.11)	-0.0000555 (-0.53)
Government spending	1.141744 (1.09)	1.147794 (1.09)	1.677045 (1.76)*
Intercept	-6.200321 (-1.20)	-9.058235 (-1.74)*	-2.399298 (-1.07)
Number of countries	65	65	127
Observations	406	406	765
Time dummies	Yes	Yes	Yes
Number of instruments	21	19	18
A-B AR(2) test *p*-values[1)]	0.262	0.235	0.159
Hansen test *p*-values[2)]	0.458	0.430	0.551

Note : Heteroskedasticity and autocorrelation consistent t-statistics are in parentheses.

Levels of significance: *** 1 percent, ** 5 percent, * 10 percent.

1) The null hypothesis is that the first-differenced errors exhibit no second-order correlation.

2) The null hypothesis is that the instruments used are not correlated with the residuals.

2.5.3. Effect of country group

In this subsection, we divide the complete sample into OECD member and non-member countries.[58] This analysis is done under the assumption that we can understand the determinants of output volatility more accurately among homogenous groups. Table 2.5 – 2.6 display the effect of private credit and government debt on output volatility in OECD and non-OECD countries, respectively.[59] In Table 2.5, the coefficients of private credit and government debt become insignificant. Specifically, we can't find the U-shaped relationship between financial development and output volatility. The linearly positive relationship between government debt and macroeconomic volatility also disappears. This result means that the rise in private credit and government debt do not significantly make the economy unstable in the developed countries. The interaction term between the two variables is statistically insignificant as ever. To understand this result we need to be reminded of the fact that the small number of time periods and large number of individuals context is an appropriate precondition for the system GMM. As the sample size is not sufficiently big to get reliable results in this analysis, this should be carefully interpreted.

In contrast, we find the non-linear relationship between private credit and output volatility in non-OECD countries as shown in Table 2.6. This is consistent with Dabla and Srivisal (2013). Government debt also has a positive and significant correlation with output volatility in Column (2). The interaction term shows insignificant coefficients. Thus, the main results shown in Table 2.4 are valid for low-income and middle-income countries. Both the Hansen test and the A-B AR(2) test do not reject the validity of the instruments in Table 2.6.

[58] Countries are divided according to OECD membership in 1975 because some middle income countries has become OECD member since then and homogenous character among member countries is weakened.

[59] Two tables consist of 3 columns like Table 2.4 : (1) the baseline regression by the equation (2.1) (2) the parsimonious regression I by the equation (2.2) (3) the parsimonious regression II by the equation (2.3)

Table 2.5. The result of system GMM (OECD, 5-year panel, 1971~2010)			
Regression type	(1)	(2)	(3)
Lagged dependent variable	-0.0488405 (-0.59)	-0.0327831 (-0.42)	-0.0751011 (-0.95)
Private credit	-0.3207905 (-0.14)	0.4888672 (0.51)	0.3333053 (0.33)
Private credit square	0.1339466 (0.61)	0.1166148 (0.52)	0.165213 (0.74)
Government debt	-2.537687 (-1.43)	-0.1525859 (-0.61)	
Government debt square	0.5366649 (1.66)*		
Interaction term	0.4436177 (0.40)		
Initial GDP	-1.549785 (-0.86)	-1.984548 (-1.16)	-1.839711 (-1.29)
Exchange rate volatility	0.0000967 (1.26)	0.0000992 (1.06)	0.0000832 (0.96)
Democracy	0.0407347 (0.70)	0.0424981 (0.71)	0.0303262 (0.53)
Trade openness	1.854083 (1.35)	1.737656 (1.31)	1.541673 (1.34)
Inflation volatility	0.0513296 (3.15)***	0.0518711 (3.13)***	0.0517224 (3.45)***
Government spending	3.047362 (1.81)*	3.029821 (2.01)**	2.642733 (1.85)*
Intercept	1.021202 (0.12)	0.6549986 (0.08)	0.8629506 (0.12)
Number of countries	22	22	23
Observations	152	152	159
Time dummies	Yes	Yes	Yes
Number of instruments	21	19	18
A-B AR(2) test p-values1)	0.109	0.129	0.125
Hansen test p-values2)	0.311	0.376	0.302

Note : Heteroskedasticity and autocorrelation consistent t-statistics are in parentheses.

Levels of significance: *** 1 percent, ** 5 percent, * 10 percent.

1) The null hypothesis is that the first-differenced errors exhibit no second-order correlation.

2) The null hypothesis is that the instruments used are not correlated with the residuals.

Table 2.6. The result of system GMM (non-OECD, 5-year panel, 1971∼2010)			
Regression type	(1)	(2)	(3)
Lagged dependent variable	-0.0584749 (-0.80)	-0.0491241 (-0.67)	0.0740315 (0.65)
Private credit	-12.65243 (-3.39)***	-9.638859 (-3.83)***	-6.308893 (-2.63)***
Private credit square	3.671152 (3.69)***	3.512048 (3.67)***	2.528936 (3.01)***
Government debt	-2.670936 (-1.56)	1.032281 (1.89)*	
Government debt square	0.5226936 (0.94)		
Interaction term	1.420174 (1.32)		
Initial GDP	2.285053 (1.62)	2.014615 (1.37)	0.2609372 (0.59)
Exchange rate volatility	0.0001464 (1.85)*	0.0001539 (1.88)*	0.0002033 (2.12)**
Democracy	0.0422501 (0.93)	0.0423024 (0.97)	-0.0083907 (-0.33)
Trade openness	1.504686 (1.76)*	1.105674 (1.44)	2.458787 (1.73)*
Inflation volatility	0.0002205 (1.04)	0.0002174 (1.05)	-0.000061 (-0.60)
Government spending	0.8725147 (0.74)	0.7609676 (0.67)	1.452299 (1.41)
Intercept	-1.287515 (-0.23)	-4.713997 (-0.85)	-2.325263 (-0.92)
Number of countries	43	43	104
Observations	254	254	606
Time dummies	Yes	Yes	Yes
Number of instruments	21	19	18
A-B AR(2) test p-values[1)]	0.705	0.593	0.142
Hansen test p-values[2)]	0.595	0.562	0.686

Note : Heteroskedasticity and autocorrelation consistent t-statistics are in parentheses.

Levels of significance: *** 1 percent, ** 5 percent, * 10 percent.

1) The null hypothesis is that the first-differenced errors exhibit no second-order correlation.

2) The null hypothesis is that the instruments used are not correlated with the residuals.

2.5.4. Effect of lagged variables

Contemporaneous values of private credit and government debt are used in the main regressions in Table 2.4. In this subsection, we use lagged values of private credit and government debt to examine the relationship between financial development (or government debt) at the beginning of a period and subsequent output volatility. This specification also helps to alleviate endogeneity problems (Denizer et al., 2002).

We find a statistically insignificant relationship between output volatility and lagged private credit in Table 2.7.[60]. Furthermore, the both terms of private credit do not display expected signs. This result suggests that the established levels of financial development do not significantly affect output volatility in the following period. This is consistent with Denizer et al. (2002). According to them, this is because private credit is linked to monetary policy. When private credit is likely to increase, the central bank reacts by monetary contraction. Both changes in private credit and monetary policy actions affect the following period's output volatility. Financial development with smoother business cycle does not show up because it is difficult to separate the effect of monetary policy from the total size of private credit. The interaction term between the two also reveals an insignificant coefficient. However, in Column (2) we find a significant and negative relationship between government debt and output volatility suggesting that larger government debt in the previous period is statistically associated with lower output volatility in the following period. This is obviously different from the main result in Table 2.4. This difference may be related to the mechanism linking government debt to output volatility explained in Section 2.2. Countries with high government debt are under policy constraint. They may be pressured to reduce debt and cut interest rates. This fiscal consolidation and expansionary monetary policy in the previous period reduce output volatility in the following period.

[60] The regression structure of Table 2.7 is the same as the main regressions in Table 2.4.

Table 2.7. The result of system GMM (lagged variables, 5-year panel, 1971∼2010)

Regression type	(1)	(2)	(3)
Lagged dependent variable	0.0670775 (0.83)	0.0591536 (0.74)	0.0759762 (0.63)
Lagged private credit	3.247894 (1.63)	1.615907 (1.18)	-1.029204 (-0.63)
Lagged credit square	-0.4876631 (-1.20)	-0.408862 (-1.01)	0.6183748 (1.18)
Lagged government debt	-1.464436 (-0.56)	-1.257768 (-2.97)***	
Lagged debt square	0.4668215 (0.72)		
Interaction term	-0.8118995 (-0.96)		
Initial GDP	2.59891 (1.90)*	2.444689 (1.77)*	0.1787402 (0.49)
Exchange rate volatility	0.000000417 (2.39)**	0.00000042 (3.51)***	0.000000378 (4.10)***
Democracy	0.035449 (0.70)	0.0433949 (0.85)	-0.0191786 (-0.72)
Trade openness	0.4150452 (0.39)	0.3878794 (0.37)	1.647385 (1.18)
Inflation volatility	0.0001178 (0.63)	0.0001202 (0.65)	0.0000162 (0.18)
Government spending	0.7161189 (0.58)	0.6383277 (0.54)	1.477145 (1.83)*
Intercept	-11.62158 (-1.61)	-9.652008 (-1.55)	-3.787688 (-1.09)
Number of countries	65	65	127
Observations	395	395	743
Time dummies	Yes	Yes	Yes
Number of instruments	21	19	18
A-B AR(2) test p-values[1)]	0.863	0.907	0.135
Hansen test p-values[2)]	0.999	1.000	0.610

Note : Heteroskedasticity and autocorrelation consistent t-statistics are in parentheses.

Levels of significance: *** 1 percent, ** 5 percent, * 10 percent.

1) The null hypothesis is that the first-differenced errors exhibit no second-order correlation.

2) The null hypothesis is that the instruments used are not correlated with the residuals.

2.6. Robustness checks

This section provides a series of sensitivity checks to investigate whether the system GMM regression results shown in Table 2.4 are robust or not depenidng on the specification of the regression. First, to account for conflicting results in the previous literature, we use the FE panel regression instead of the system GMM regression. Second, we consider two alternative time horizons. Third, we exclude the period 2008–2010 over the sample period to examine the effect of the recent financial crisis. Fourth, we use M2 instead of private credit as the measure of financial development. Lastly, we examine the effect of financial development on output volatility when capital market development is included.

2.6.1. FE regression results

As mentioned before, the FE panel regression has a few limitations. However, we also introduce the FE panel regression to reconcile conflicting results in the previous literature. Table 2.8 contains the FE regression results of output volatility using the measures of financial development and government debt. In the baseline regression shown in Column (1) of Table 2.8, the linear term of private credit enters negatively and is significant at the 1% significance level. And the quadratic term enters positively and is also significant at the 1% significance level. This result displays the U-shaped effect of private credit on output volatility confirming the results of the system GMM regression.[61] In Columns (2) and (3)[62], the non-linear relationship between financial development and output volatility remains robust.[63] This non-linear relationship in the FE regression is a new finding because

[61] This also means that economies with fully developed or poorly developed financial system seem to be unstable, while economies with financial development of an intermediate level seem to be stable.

[62] In Column (2), we eliminate the insignificant regressors - the quadratic term of government debt and the interaction term like the system GMM regression. Similarly, in Column (3), we omit government debt from the regressors.

[63] For reference, the estimated threshold values of financial development in the FE regression are 139.8 percent, 150.4 percent and 132.7 percent of GDP in Columns (1)~(3), respectively.

previous work such as Lopez and Spiegel (2002) which employ the FE panel regression do not examine the non-linear connection between financial development and volatility.[64] Beck et al. (2006) even do not find the significant impact of financial development on output volatility in the FE panel regression.[65]

Regarding the effect of government debt levels on output volatility, in Column (1), the signs of the linear and the quadratic terms are positive, but the both terms are not significant at the conventional level. This confirms the fact that the relationship between government debt and output volatility is not non-linear. However, when the insignificant variables are omitted in Column (2), the sign of government debt is positive and significant at the 1% confidence level. These results for the relationship between government debt and output volatility are broadly similar to the result of the system GMM regression suggesting that government debt will statistically amplify output volatility. However, the effect of government debt on output volatility is smaller than the system GMM regression result. Specifically, a one-standard deviation increase in government debt to GDP raises output volatility by about 0.68 percent.

In Column (1), the interaction term between financial development and government debt has a negative sign unlike the system GMM regression. However, it is still statistically insignificant at the conventional level. This result, thus, supports the fact that financial development with larger government debt does not significantly affect output volatility.

[64] As explained in the literature review, some papers find the non-linear relationship. However, Easterly et al. (2001) use OLS and 2SLS, while Dabla-Norris and Srivisal (2013) use the system GMM.

[65] Beck et al. (2006) have a different study approach with ours as follows: (i) the time horizon (ii) the number of sample period (iii) the number of sample country. These factors can cause different conclusions.

Table 2.8. The result of FE regression (full sample, 5-year panel, 1971~2010)			
Regression type	(1)	(2)	(3)
Private credit	-3.763651 (-2.74)***	-4.07619 (-3.80)***	-2.699936 (-2.68)***
Private credit square	1.345873 (4.25)***	1.355286 (4.43)***	1.017506 (3.11)***
Government debt	0.7609571 (0.94)	0.6762186 (4.04)***	
Government debt square	0.0664181 (0.24)		
Interaction term	-0.1765178 (-0.43)		
Initial GDP	-0.4063447 (-0.56)	-0.4110385 (-0.57)	-0.1480925 (-0.42)
Exchange rate volatility	0.0001612 (1.79)*	0.0001625 (1.80)*	0.0001173 (1.15)
Democracy	-0.0089834 (-0.52)	-0.0076752 (-0.49)	-0.0170615 (-1.14)
Trade openness	0.9561339 (1.77)*	0.9825451 (1.84)*	1.039015 (1.55)
Inflation volatility	0.0004033 (1.57)	0.0004007 (1.56)	0.0000451 (0.30)
Government spending	0.5321367 (0.87)	0.4999447 (0.81)	0.20374 (0.32)
Intercept	2.967246 (1.21)	3.308734 (1.29)	2.670585 (1.84)*
Number of countries	65	65	127
Observations	454	454	848
Time dummies	Yes	Yes	Yes
R^2	0.2299	0.2294	0.1058

Note : Heteroskedasticity and autocorrelation consistent t-statistics are in parentheses.

Levels of significance: *** 1 percent, ** 5 percent, * 10 percent.

2.6.2. Different time horizon

The main regression in Table 2.4 is based on eight non-overlapping five-year periods. It is necessary to test how the result changes when alternative time horizons are applied. In this section, we consider shorter three-year periods.[66] Table 2.9 presents the robustness test results to the three-year periods. The non-linear relationship between financial development and output volatility considerably changes with the alternative time horizon in Columns (1) and (2). In other words, the U-shaped connection between financial development and output volatility is not consistent with the different time horizon. However, the U-shaped relationship again appears and the both terms become significant at the conventional level in Column (3).

When we examine the relationship between government debt and output volatility, we also find that the results are consistent with the main regressions. When the quadratic term of government debt and the interaction term are omitted in Column (2), government debt displays the significant and positive relationship with output volatility. However, we need to pay attention to the simultaneity in the determination of output volatility and government debt. Changes in macroeconomic conditions generally affect government debt through the budget deficit and thus more sensitive to endogeneity problems (Fatas and Mihov, 2003). Therefore, when the system GMM regression partly controls endogeneity problems, the regression results may produce different results depending on the time horizon. This suggests that we need to interpret carefully the relationship between government debt and output volatility.

In addition, the interaction term between financial development and government debt shows an insignificant sign in Column (1).[67] Therefore, this result confirms the fact that there is no unambiguous relationship between financial development with the fiscal problem and output volatility.

[66] We also estimate longer seven-year periods. However, we do not report the estimation result because the validity of the instruments is not certain. The A-B AR(2) test result rejects the null hypothesis. This problem in the longer time horizon comes from the fact that the number of time periods is relatively small compared to the number of sample.

[67] Furthermore, unlike the main result, the sign of the interaction term becomes negative in the 3-year panel regression shown in Table 2.9.

Table 2.9. The result of system GMM (full sample, 3-year panel, 1971~2010)

Regression type	(1)	(2)	(3)
Lagged dependent variable	0.0033334 (0.06)	0.0030834 (0.05)	0.1360813 (1.88)*
Private credit	1.12891 (0.75)	-0.01835 (-0.01)	-5.085878 (-2.57)**
Private credit square	0.2723035 (0.69)	0.3350841 (0.79)	2.198607 (3.03)***
Government debt	1.103542 (0.65)	1.0297 (2.66)***	
Government debt square	0.2405196 (0.63)		
Interaction term	-0.5462189 (-0.64)		
Initial GDP	0.0738547 (0.03)	0.2938376 (0.14)	-0.259477 (-0.12)
Exchange rate volatility	0.0001284 (3.62)***	0.0001327 (3.76)***	0.0001673 (3.89)***
Democracy	-0.0048607 (-0.19)	-0.0041826 (-0.17)	-0.0098234 (-0.54)
Trade openness	0.999148 (1.31)	1.09666 (1.47)	2.429333 (2.42)**
Inflation volatility	0.0001123 (1.58)	0.0001084 (1.57)	-0.0001244 (-0.94)
Government spending	0.2162828 (0.20)	0.1935616 (0.18)	-0.8729403 (-0.72)
Intercept	-5.422125 (-0.66)	-5.424958 (-0.67)	0.7468372 (0.08)
Number of countries	65	65	126
Observations	691	691	1297
Time dummies	Yes	Yes	Yes
Number of instruments	26	24	23
A-B AR(2) test p-values[1)]	0.601	0.584	0.150
Hansen test p-values[2)]	0.802	0.850	0.641

Note : Heteroskedasticity and autocorrelation consistent t-statistics are in parentheses.

Levels of significance: *** 1 percent, ** 5 percent, * 10 percent.

1) The null hypothesis is that the first-differenced errors exhibit no second-order correlation.

2) The null hypothesis is that the instruments used are not correlated with the residuals.

2.6.3. Effect of the financial crisis

The baseline panel data set spans 40 years from 1971 to 2010 including the recent financial crisis. As a robustness check, in Table 2.10 we exclude the period 2008–2010 over the sample period to account for the effect of the recent financial crisis.[68] Regarding private credit, the empirical results shown in Columns (1)-(2) of Table 2.10 are the same as the main regression results. Thus, we still find the U-shaped relationship between private credit and output volatility. The threshold value of private credit is 152.6 percent of GDP in Columns (2). This value is higher than Dabla-Norris and Srivisal (2013) which use a similar time period (1974-2008). This value is slightly higher than the one from the main regression model in Table 2.4 suggesting the financial crisis since 2008 has lowered the threshold value of private credit. As many developed countries which have increased private credit before the crisis have experienced the recession, the recent financial crisis seems to accelerate an instabilising role of private credit on the economic performance.[69]

On the other hand, the both terms of government debt do not show significant and expected signs in Column (1). Similarly, the interaction term between the two does not significantly affect output volatility. However, a positive and statistically significant relationship between government debt and output volatility appears in Column (2). This result means that government debt levels are a statistically important factor affecting output volatility before the crisis. However, the effect of government debt on output volatility is larger than the main regression result. Specifically, a one-standard deviation increase in government debt to GDP raises output volatility by about 1.31 percent.

[68] As above Column (1) is the baseline model. Column (2) eliminates the quadratic term of government debt and the interaction term. Column (3) omits all the variables related to government debt.

[69] An interesting point is that the both terms of financial development lose significance despite the expected signs in Column (3) of Table 2.10. Since many developing countries are added to the sample in Column (3), private credit is not assumed to have a clear relationship with output volatility in developing countries before the financial crisis.

Table 2.10. The result of system GMM (full sample, 5-year panel, 1971∼2007)

Regression type	(1)	(2)	(3)
Lagged dependent variable	0.0077849 (0.08)	0.0138001 (0.14)	0.0459709 (0.41)
Private credit	-6.594568 (-2.21)**	-5.542502 (-2.37)**	-2.971983 (-1.22)
Private credit square	1.870563 (2.32)**	1.815884 (2.28)**	1.080343 (1.34)
Government debt	-0.66616 (-0.29)	1.307947 (3.32)***	
Government debt square	0.3695962 (0.79)		
Interaction term	0.5013391 (0.64)		
Initial GDP	3.832314 (2.48)**	3.780662 (2.45)**	0.2885093 (0.63)
Exchange rate volatility	0.0001392 (3.53)***	0.0001503 (3.74)***	0.0001737 (4.35)***
Democracy	0.0437677 (1.03)	0.0427823 (1.03)	-0.0054593 (-0.20)
Trade openness	0.6274247 (0.78)	0.5123016 (0.63)	2.437381 (1.84)*
Inflation volatility	0.0002348 (1.16)	0.0002333 (1.16)	-0.0000102 (-0.10)
Government spending	1.291548 (1.28)	1.291357 (1.28)	2.122281 (2.59)**
Intercept	-12.74001 (-1.86)*	-14.78554 (-2.26)**	-4.103952 (-1.52)
Number of countries	65	65	126
Observations	344	344	651
Time dummies	Yes	Yes	Yes
Number of instruments	20	18	17
A-B AR(2) test p-values[1)]	0.728	0.771	0.144
Hansen test p-values[2)]	0.899	0.912	0.526

Note : Heteroskedasticity and autocorrelation consistent t-statistics are in parentheses.

Levels of significance: *** 1 percent, ** 5 percent, * 10 percent.

1) The null hypothesis is that the first-differenced errors exhibit no second-order correlation.

2) The null hypothesis is that the instruments used are not correlated with the residuals.

2.6.4. Alternative measure of financial development

So far we have considered private credit from banks and other financial institutions. Previous research obtains very similar results on the impact of financial development on output volatility with alternative measures of financial development.[70] However, Acemoglu et al. (2003) use real M2 as a measure of financial development and do not find any strong evidence supporting weak financial system as a main cause of output volatility. In order to examine their conclusion, we use M2 instead of private credit. Table 2.11 presents this robustness test.[71] In Columns (1)-(3), the linear and the quadratic terms of money no longer are statistically significant. Moreover, the both terms do not show expected signs in Columns (1)-(2). Therefore, more quantity of money is not associated with less output volatility, and they do not show the U-shaped relationship. This is because each measure of financial development captures a different aspect of it (Denizer et al., 2002). Specifically, M2 measures the overall size of the financial system. Private credit is a measure of the magnitude to which financial services are provided to the private sector. These results are consistent with Acemoglu et al. (2003). Thus, the relationship between financial development and output volatility seems to depend on the measure of financial development.

Regarding government debt and the interaction term, the results shown in Table 2.11 are similar to the above result. Specifically, higher government debt is statistically associated with economic instability. The relationship between government debt and output volatility is not U-shaped. In addition, the interaction term between money and government debt does not have the significant effect on output volatility.

[70] Specifically, these measures are as follows: (i) the ratio of total liquid liabilities to GDP (ii) the ratio of depository banks' assets to GDP (iii) the ratio of total deposits in financial institutions to GDP.

[71] As above Column (1) is the baseline regression. Column (2) eliminates the quadratic term of government debt and the interaction term. Column (3) omits all the variables related to government debt.

Table 2.11. The result of system GMM (M2, 5-year panel, 1971~2010)

Regression type	(1)	(2)	(3)
Lagged dependent variable	-0.0000904 (-0.00)	-0.0016574 (-0.02)	0.1000289 (0.86)
Money	0.6014445 (0.21)	0.9814117 (0.45)	-3.651366 (-1.22)
Money square	-0.2504855 (-0.55)	-0.2503992 (-0.53)	0.8988728 (1.13)
Government debt	-1.700796 (-0.61)	0.9946844 (2.31)**	
Government debt square	0.7370902 (1.30)		
Interaction term	0.2199488 (0.19)		
Initial GDP	2.855689 (2.32)**	2.900044 (2.30)**	0.2550774 (0.61)
Exchange rate volatility	0.0001613 (1.75)*	0.0001664 (1.78)*	0.0002178 (2.13)**
Democracy	0.0256583 (0.53)	0.0252239 (0.54)	-0.0195414 (-0.79)
Trade openness	-0.2597566 (-0.26)	-0.3105336 (-0.30)	1.618036 (1.23)
Inflation volatility	0.0002576 (1.20)	0.0002457 (1.14)	-0.000015 (-0.10)
Government spending	1.322288 (1.02)	1.360669 (1.07)	2.028321 (2.14)**
Intercept	-11.35788 (-1.82)*	-13.91781 (-2.30)**	-1.321426 (-0.42)
Number of countries	65	65	127
Observations	374	376	731
Time dummies	Yes	Yes	Yes
Number of instruments	21	19	18
A-B AR(2) test p-values[1)]	0.277	0.226	0.147
Hansen test p-values[2)]	0.517	0.404	0.313

Note : Heteroskedasticity and autocorrelation consistent t-statistics are in parentheses.

Levels of significance: *** 1 percent, ** 5 percent, * 10 percent.

1) The null hypothesis is that the first-differenced errors exhibit no second-order correlation.

2) The null hypothesis is that the instruments used are not correlated with the residuals.

2.6.5. Inclusion of other controls

When capital market development and financial development are taken together, financial development loses a significant role on output volatility (Tharavanij, 2007). We also consider two measures of capital market development, structure activity index and turnover ratio, to examine this conclusion in our model. Tables 2.12[72] shows this regression result. We find a negative and significant relationship between capital market development and output volatility, irrespective of used measures of capital market development. This result means that capital market development is statistically associated with decreased output volatiity.

However, the relationship between financial development and output volatility changes a bit. Specifically, we still find the U-shaped relationship between private credit and output volatility in Columns (1)-(2). However, the both terms become insignificant. This result suggests that private credit is not significantly associated with output volatility. These results show that capital market development has dampening roles of output volatility and relatively tends to reduce the importance of financial development on output volatility confirming the results of Tharavanij (2007).

However, the Hansen test result is not available in Table 2.12 meaning that the instruments may be correlated with the residuals. Still, the A-B AR(2) test ensures the validity of the result. Thus, we need to interpret this result carefully under the endogeneity problem.

[72] Since we focus on the relationship between financial development and output volatility in this subsection, we use only the parsimonious regression II based on the equation (2.3).

Table 2.12. The result of system GMM (capital market development, 5-year sample, 1971~2010)

Regression type	(1)	(2)
Lagged dependent variable	0.0708556 (0.94)	0.0695865 (0.84)
Private credit	-3.216731 (-1.42)	-2.988061 (-1.43)
Private credit square	1.104743 (1.63)	1.035363 (1.56)
Initial GDP	2.027224 (2.09)**	3.222734 (2.00)**
Exchange rate volatility	0.0001966 (2.08)**	0.000208 (2.21)**
Democracy	-0.0355002 (-1.27)	-0.0557387 (-1.92)*
Trade openness	1.678433 (1.98)**	0.8158557 (0.79)
Inflation volatility	0.0007871 (5.79)***	0.0006761 (0.81)
Government spending	0.9847128 (0.71)	0.1220348 (0.07)
Structure activity index	-0.4812238 (-2.69)**	
Turnover ratio		-0.535844 (-2.48)**
Intercept	-8.166077 (-1.71)*	-
Countries	85	85
Observations	345	299
Time dummies	Yes	Yes
Number of instruments	17	17
A-B AR(2) test *p*-values1)	0.539	0.586
Hansen test *p*-values2)	-	-

Note : Heteroskedasticity and autocorrelation consistent t-statistics are in parentheses.

Levels of significance: *** 1 percent, ** 5 percent, * 10 percent.

1) The null hypothesis is that the first-differenced errors exhibit no second-order correlation.

2) The null hypothesis is that the instruments used are not correlated with the residuals.

2.7. Conclusion

During the recent financial crisis both private credit and government debt rose in many countries and these factors amplified the crisis. This phenomenon has made a lot of researchers take interests in their economic impact. In this light, this chapter attempts to improve the current understanding of the determinants of output volatility beyond the existing literature. Specifically, this chapter addresses the effects of financial development and government debt on output volatility. It expands the length of time-series by including the recent financial crisis and increases the number of sample countries by a panel of 127 countries. Methodologically, we utilise a number of econometric techniques and also examine the non-linear relationship as well as the effect of the interaction of the two factors.

This chapter finds solid evidence that higher financial system development mitigates output volatility following previous researches. There is also some consistent evidence of non-linearity - the effect of financial development on output volatility changes from negative to positive beyond the certain level. The robustness test shows that the main results are valid irrespective of the regression method, the sample period. Our estimated threshold value of private credit is 140.9 percent of GDP in the sample of 65 countries. We find that during the financial crisis this threshold value becomes lower than before suggesting the strengthened destabilising role of private credit. Therefore, many advanced countries need to reduce private credit in order to stabilise their economies because they exceeded the threshold during the recent financial crisis. When we use a measure of capital market development to reconcile conflicting results in the literature, the effect of financial development on output volatility diminishes. This means that capital market development plays a similar role with financial development. However, the impact of capital market development should be interpreted carefully because the Hansen test result is not available.

In addition, our result shows the significant and positive relationship between government debt levels and output volatility meaning that larger government debt is statistically associated with higher output volatility. This means that the highest government debt levels which are unparalleled in history may act as the destabilising factor of the economy. However, some robustness tests do not show the validity of the instruments for the consistency of the estimation. For example, using longer time periods, A-B AR(2) test result rejects the null hypothesis of no second-order serial correlation in the first differenced errors. This result especially suggests that the relationship between government debt and output volatility should be interpreted carefully given endogeneity. Further empirical research is certainly necessary to gain confidence in the role of government debt on output volatility. Especially, in order to control endogeneity problems, we need to find an appropriate instrumental variable for government debt.

In some European countries, the financial crisis and the fiscal crisis escalated further each other. Thus, we also examine the effect of the interactions between private credit and government debt on output volatility. However, the interaction term between the two does not significantly affect output volatility throughout our analysis suggesting that financial development with fiscal problems is not related to the economic instability. Different cyclicality between private credit and government debt causes this result. Therefore, we cannot generally apply some Eurozone countries' case to other countries. In addition, when we use the lagged values of private credit and government debt, the two factors do not significantly affect output volatility. As higher private credit or government debt makes the government take counter policies, the economy in the following period can be stabilised.

Appendix

A. List of countries

High income country		Low income country	
Australia*	Korea, Rep.*	Bangladesh	Mozambique
Austria*	Luxembourg	Benin	Nepal
Bahrain	Netherlands*	Burkina Faso	Niger
Belgium*	New Zealand*	Burundi	Rwanda
Canada*	Norway*	Cambodia	Sierra Leone
Chile*	Oman	Cent. African Rep.*	Togo
Croatia	Poland*	Chad	Uganda
Cyprus	Portugal*	Comoros	Zambia*
Czech Rep.	Russia*	Congo. Dem. Rep.	Zimbabwe*
Denmark*	Saudi Arabia	Ethiopia	
Equa. Guinea	Slovak Republic	Gambia, The	
Estonia	Slovenia	Guinea	
Finland*	Singapore*	Guinea-Bisau	
France*	Spain*	Haiti	
Germany*	Sweden*	Kenya*	
Greece*	Switzerland*	Liberia	
Ireland*	Trinidad&Tobago	Madagascar	
Israel	United Kingdom*	Malawi	
Italy*	United States*	Mali	
Japan*	Uruguay*	Mauritania	

Middle income country		
Albania	Fiji	Pakistan
Algeria*	Gabon	Panama*
Angola	Ghana*	Papua New Gui.
Argentina*	Guatemala*	Paraguay*
Bhutan	Guyana	Peru*
Bolivia*	Honduras*	Philippines*
Botswana	Hungry*	Romania*
Brazil*	India*	Senegal
Bulgaria*	Indonesia*	Sri Lanka*
Cameroon	Iran	South Africa*
Cape Verde	Jamaica	Sudan
China*	Jordan	Suriname
Colombia*	Lebanon	Swaziland
Congo, Rep.	Lesotho	Syria
Costa Rica*	Malaysia*	Thailand*
Djibouti	Mauritius*	Tunisia*
Dominican Rep.*	Mexico*	Turkey*
Ecuador*	Morocco*	Venezuela*
Egypt*	Namibia	
El Salvador*	Nicaragua*	

Note : * indicates countries for which data for all variables are available.

B. Variables used in regression analysis

Variables	Description	Source
Output volatility	Standard deviation of annual growth of real, chain-weighted GDP per capita	Penn World Table 7.1
Private credit	Private credit supplied by depository banks and other financial institutions as percentage of GDP	World Bank WDI
Money	Money and quasi money (M2) as percentage of GDP	World Bank WDI
Structure Activity Index	The ratio of value of total shares traded on the stock market divided by GDP over the domestic credit provided by banking sector as percentage of GDP	World Bank WDI
Turnover ratio	The total value of shares traded divided by the average market capitalization for the period	World Bank WDI
Government debt	Total gross central government debt as percentage of GDP	Reinhart and Rogoff (2011)
Real exchange rate volatility	Stnadard deviation of real exchange rate in unit of national currency per US dollar	IMF IFS
Democracy	Index ranging from -10 (autocratic regimes) to +10 (democratic regimes)	Polity IV Project
Trade openness	Sum of exports and imports as a share of GDP	World Bank
Inflation volatility	Standard deviation of average consumer prices. Average consumer prices are year-on-year changes.	IMF WEO
Government expenditure	All government current expenditure for purchases of goods and services as percentage of GDP	World Bank WDI

Chapter 3

The role of financial frictions in the propagation of shocks

3.1. Introduction

The financial market turmoil beginning in 2007 has led to the most severe financial crisis since the Great Depression with large repercussions for the real economy (Brunnermeier, 2009).[73] Of course, financial crises are nothing new. They have been around since the development of money and financial markets. Financial crises have continued to thrive through the ages, and they plague countries to this day (Kindleberger, 1993; Reinhart and Rogoff, 2009). Therefore, issues relating to financial stability have always been part of macroeconomics, but they have often been introduced as mainly of historical interest, or generally of relevance to emerging markets.[74] However, the recent crisis has made it plain that even in economies like the United States, significant disruptions of financial intermediation remain a possibility (Woodford, 2010).

Figure 3-1 displays quarterly time series for real GDP of some OECD countries from 2008 to 2013.[75] The GDP values are expressed as percentages of GDP in the second quarter of 2008. This figure shows that GDP values have decreased since the financial crisis in 2008. However, GDP values show different time paths depending on the countries.

[73] Many economists have also attributed the economic downturn of the Great Depression to the failure of financial markets. For example, see Fisher (1933), Keynes (2006), Minsky (2008), and Brunnermeier and Sannikov (2012).

[74] Since the 1990s, emerging markets have become increasingly integrated into global financial markets. Contrary to what was widely predicted by policymakers and economic theorists, their access to international markets has turned out to be very volatile, with frequent periods of market closures (Fostel and Geanakoplos, 2008).

[75] We also collect a quarterly GDP data from OECD database.

For example, Estonia's GDP declined by nearly 20% in the third quarter of 2009 and still didn't recover the pre-crisis level. Spain and Iceland did not show an abrupt fall like Estonia. However, their economies did not improve and became worse over time. On the contrary, United States experienced a modest contraction compared to other countries and surpassed the pre-crisis level from 2011. This is similar to Germany. A variety of factors can induce this different time paths of GDP. However, we note financial frictions derived by an abrupt increase of private credit. In Spain, Estonia, and Iceland private credit increased at an unprecedented speed before the crisis, while U.S and Germany did not experience such exceptional case.[76] Thus, it is possible to assume that financial frictions affect the amplification and the propagation of external shocks. The main purpose of this chapter is to investigate whether or not such a relationship exists.

Researchers began to investigate how financial imperfections could be introduced into the existing macroeconomic models such as the dynamic stochastic general equilibrium (DSGE) models. The standard DSGE models like Christiano et al. (2005) and Smets and Wouters (2003, 2007) assume that there are no frictions in the financial sector. Thus, these models cannot reflect financial market disruptions. However, the DSGE literature on the financial system has been expanding in recent times. The literature offers different approaches to incorporating financial frictions. The first approach is to model financial frictions at the firm level following Bernanke et al. (1999). Many papers have adopted this approach (Christensen and Dib, 2008; De Graeve, 2008; Queijo von Heideken, 2009; Nolan and Thoenissen, 2009). However, this approach emphasises credit market constraints on non-financial borrowers and treats financial intermediaries largely as a veil (Gertler and Kiyotaki, 2010). The second approach is to explicitly model the financial intermediaries as

[76] Since 2000, just before the financial crisis the amount of privae credit has more than doubled in Estonia, Spain, and Iceland. However, its growth was not noticeable in the U.S. In Germany private credit rather declined.

a source of financial frictions. Gertler and Karadi (2011) and Gertler and Kiyotaki (2010) adopt this approach with the presence of a moral hazard problem between the depositors and the financial intermediaries.

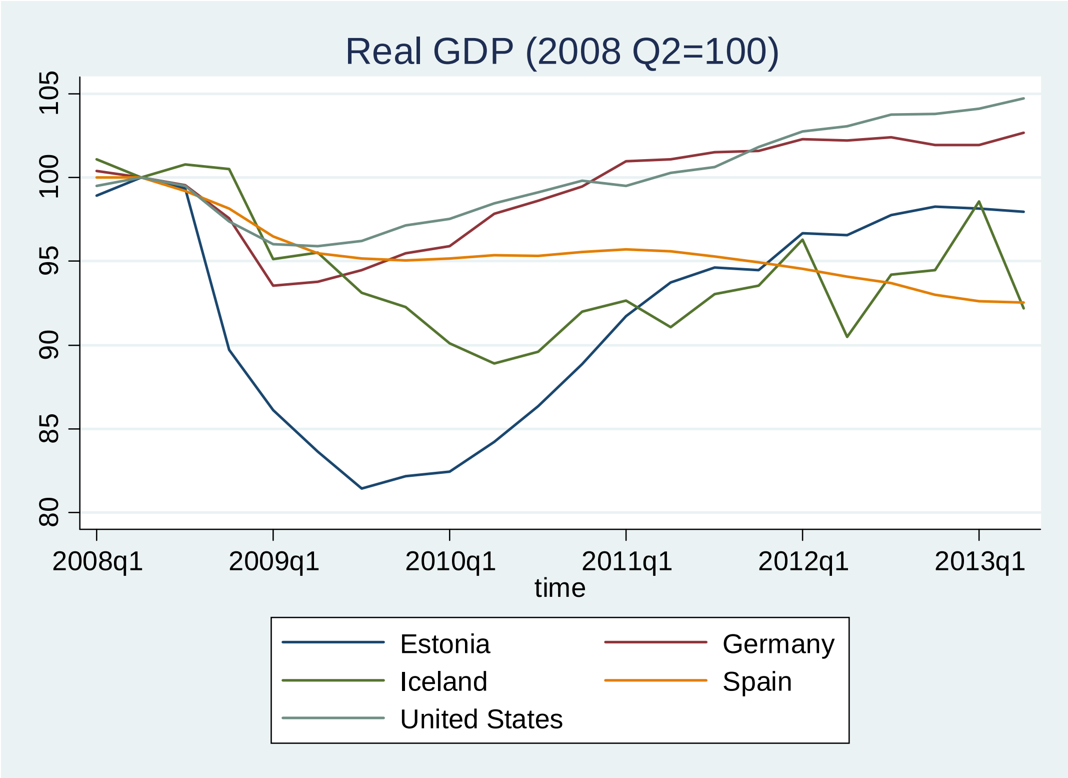

Figure 3-1. Quarterly time series of real GDP during the recent financial crisis

Given these alternative approaches, the main themes of this chapter are: (i) to confirm the fact that financial frictions are relevant to the amplification and the persistence of economic fluctuations; (ii) to ask which type of financial frictions are more important in explaining the amplified and persistent fluctuation of economic variables; (iii) to analyse which type of financial frictions better match the economic fluctuations during the recent financial crisis. This chapter compares three DSGE models to examine these issues. The first model is the basic model without financial frictions (henceforth the no friction model).

The second model is the model with financial frictions at the firm level (henceforth the firm friction model). The last one is the model with financial frictions at the financial intermediaries level (henceforth the bank friction model). The no friction model is based on Smets and Wouters (2007) model. Smets and Wouters (2007) extended the basic DSGE model by adding habit formation in consumption, investment adjustment costs, variable capital utilisation, sticky wages, and price indexation to past inflation.[77] The firm friction model incorporates financial frictions following Bernanke et al. (1999). In this model financial frictions come from a costly state verification framework a la Townsend (1979), in which lenders must pay a fixed "auditing cost" to observe an individual borrower's realised return. This drives "the external finance premium" (the difference between the cost of funds raised externally and the opportunity cost of funds internal to the firm). The key mechanism of the model is that the external finance premium depends inversely on the firm's net worth.[78] Lastly, the bank friction model incorporates financial frictions following Gertler and Karadi (2011). In the Gertler and Karadi (2011) model, the source of financial frictions is the balance sheets of financial intermediaries. To motivate why the condition of intermediary balance sheets influences the flow of credit, they introduced an agency problem between the intermedaries and the depositors. The agency problem induces an endogenously determined leverage ratio, which has the effect of tying overall credit flows to the intermedaries' capital. The comparison among the three models is conducted using the moment comparison and the impulse response function analysis. Thus, the three models are calibrated with the U.S. data for the period 1960Q1$\sim$2015Q4. We also investigate how the

[77] However, we leave out some elements like sticky wages in Smets and Wouters (2007) model since labour market variables are not our main interest.

[78] Specifically, this mechanism arises if there is a shock that affects the firm's net worth. If a shock has a negative impact on the net worth, the firm will need to borrow much more for a given investment. However, a higher leverage ratio means a more risk for the lenders, and they will demand a higher premium. This increased cost will lower investment and the price of capital. This fall in the price of capital again decreases the firm's net worth, and this causes an increase in the external finance premium. Thus, these effects amplify and propagate the original contraction in the economy.

three models respond to exogenous shocks such as a monetary policy shock, a technology shock, a capital quality shock, a government spending shock, and wealth shocks.

Our main findings are as follows. First, in the moment comparison the introduction of financial frictions originating in the firm improves the fitting with the U.S. data. Thus, the firm friction model outperforms the other models. However, the bank friction model displays mixed results. It generates more volatility for investment and less volatility for consumption. For the cross-correlation with GDP it is not preferred to the no friction model. Second, the impulse response functions show that incorporating financial frictions of either type greatly amplifies and propagates the effects of most exogenous shocks on economic variables. However, we find an attenuator effect of financial frictions on the technology shock in the firm friction model. In particular, the response of output to the technology shock is stronger in the no friction model than the firm friction model. The decline in the marginal product of capital due to the technology shock reduces investment, thus, the firm's loan. The firm's leverage improves and the external finance premium also drops. As investment rebounds, the response of output is reduced compared to the no friction model. Third, the response to the exogenous shocks depends on the leverage. In our baseline set-up, the response of output is greater in the bank friction model than the firm friction model. This result can differ when other values of the firm's leverage or the bank's leverage are used. Higher value of the leverage expands the response of output to the shock. Fourth, the responses of output in the firm friction model are more persistent because the shock causes the chain reaction of investment. The fall in the firm's net worth to the shock also reduces investment and the level of capital. The firm's net worth further declines and continuously induces investment to fall. On the other hand, in the bank friction model output is adjusted much faster. The fall in the bank's net worth to the shock raises the external finance premium and decreases investment. However, as higher finance premium reduces the demand for the loan, this limits the fall in the finance premium. Thus, investment and output soon rebounds. Therefore, we may infer that the bank friction model with high leverage is appropriate for explaining deeper financial crises, whereas the firm friction model can capture both the magnitude and the persistence of economic downturns. Specially, the high leverage of the banks before the recent financial crisis might aggravate the repercussion of the crisis.

This chapter is organised as follows. In Section 3.2, we summarise related literature. Section 3.3 introduces the three DSGE models. Section 3.4 discusses the calibration and compares the response of the three models to five standard shocks. Section 3.5 checks robustness of the results and Section 3.6 concludes.

3.2. Literature review

The discussion of the importance of financial frictions in the amplification and the persistence of economic fluctuations to the exogenous shocks comes from Bernanke and Gertler (1989). They showed that the presence of asymmetric information in credit markets can give the balance sheet conditions of borrowers a role to play in the business cycle through their impact on the external finance premium. The procyclical nature of firm net worth leads the wedge between the cost of external finance and internal funds, the external finance premium, to fall during booms and to rise during recessions. Carlstrom and Fuerst (1997) demonstrated the quantitative importance of the Bernanke and Gertler (1989) mechanism, finding that it can produce a hump-shaped output response to shocks in an otherwise standard real business cycle model. The propagation brought about by financial frictions allows the model to better match the data, but it does not amplify the response of output.[79]

[79] Carlstrom and Fuerst (1997) compared the real business cycle (RBC) model and the agency-cost model with financial frictions. The RBC model shows a jump in investment and output to a positive productivity

Bernanke et al. (1999) also showed that the financial accelerator mechanism both amplifies the impact of shocks and provides a quantitatively important mechanism that propagates shocks at business cycle frequencies.[80] Queijo von Heideken (2009) also indicated that financial frictions are relevant for both the U.S. and the Euro area using Bayesian estimation techniques and the financial market structure can play an important role in the transmission mechanism of shocks.[81] Nolan and Thoenissen (2009) found that a shock to the financial accelerator mechanism is very tightly linked with the onset of recessions, more so than total factor productivity shock or monetary shock.[82]

However, other research differs on the significance of the financial accelerator mechanism. For example, Christensen and Dib (2008) showed that the role of the financial accelerator mechanism a la Bernanke et al. (1999) in investment fluctuations depends on the nature of the shocks.[83] In particular, the financial accelerator mechanism dampens the rise of investment following a positive technology shock and an investment-efficiency shock while that mechanism significantly amplifies and propagates the impact of monetary policy, money demand, and preference shocks on investment and the price of capital.[84] De

shock. Capital doesn't have a role in the RBC model. However, in the agency-cost model, the entrepreneurial net worth has an impact on the dynamics of the variables. A technology shock increases the net worth and this boosts the demand for capital. The increase of demand for capital forces up the price of capital and this chokes off investment demand. Therefore, on impact, output is muted compared to the RBC model and the model's dynamics hereafter follows the RBC model.

[80] However, the empirical success of the costly external finance model lies partly in the fact that more investment requires more borrowing for a fixed amount of internal funds (Gomes et al., 2003).

[81] Queijo von Heideken (2009) studied an extended version of Bernanke et al. (1999) model with other frictions that are justified to be important to fit the data. These include price indexation to past inflation, sticky wages, habit formation in consumption and variable capital utilisation.

[82] Nolan and Thoenissen (2009) included a shock which is located in the entrepreneurial sector - the source of the financial accelerator mechanism - to the financial accelerator model of Bernanke et al. (1999) and compared the response of the shock with total factor productivity or monetary shock.

[83] Christensen and Dib (2008) extended Bernanke et al. (1999) with two features: (i) the debt contracts are written in terms of the nominal interest rate reflecting the nature of debt contracts in developed economies; (ii) the monetary policy is characterized by a modified Taylor rule under which the monetary authority adjusts short-term nominal interest rates in response to inflation, output, and money-growth changes. They estimated this model for the U.S. using maximum likelihood method and presented evidence in favor of the financial accelerator mechanism.

[84] This result is partly due to the aggressive response of the monetary authority to output variations when

Graeve (2008) also found that the responses of investment and output are substantially lower in the model with financial frictions conditional on an investment supply shock and a productivity shock.[85] Therefore, it can be concluded that the effect of the external finance premium is strongly dependent on the assumptions such as nominal rigidities, adjustment costs, and the kind of exogenous shocks while the introduction of the external finance premium generally improves the fit of economic data characteristics such as the degree and the persistence of economic fluctuations (Brazdik et al., 2011).

The models with financial frictions explained above were constructed without an explicit role for financial intermediation. In other words, the focus was primarily on the demand side of credit. However, the aim of explaining specific features of the financial crisis motivated researchers to introduce financial intermediaries into DSGE models. Some papers have investigated the role of a banking sector in monetary policy analysis by including a banking sector in the model. The pioneering model introducing financial intermediaries into the DSGE models is Goodfriend and McCallum (2007). The banking sector is introduced to describe the interaction and differences between various types of interest rates to determine how much the central bank is misled by relying on a standard model without the banking sector.[86] The next important contribution to the literature comes from Curdia and Woodford (2009). They developed a New Keynesian model with a banking sector and found that including the credit channel in the model does not fundamentally

---

the financial accelerator is included.

[85] De Graeve (2008) appended the financial friction of Bernanke et al. (1999) model to a baseline DSGE model like Christiano et al. (2005) or Smets and Wouters (2003, 2007) in order to study fluctuations in the external finance premium.

[86] Goodfriend and McCallum (2007) also demonstrated the competitive banking market setup creates two opposite external finance premium effects. The first is called the banking attenuator effect since the banking sector attenuates a monetary policy shock because the external finance premium grows in booms and drops in recessions. On the other hand, the banking accelerator effect arises from the fact that the monetary policy shock raises the opportunity cost of investment, therefore the marginal product of capital and the price of capital have to increase. They argued that for reasonable parameter values the attenuator effect is stronger and the external finance premium is procyclical.

change optimal monetary policy.[87] More recently, Gertler and Karadi (2011) and Gertler and Kiyotaki (2010) applied a similar mechanism to financial intermediation. They developed a DSGE model with financial intermediaries that face endogenously determined balance sheet constraints and showed that a decrease of the financial intermediaries' net worth disrupts lending and borrowing in a way that raises the external financial premium with spillover effects in the real economy.[88] Villa and Yang (2011) also estimated a model with financial intermediaries for the U.K economy and suggested that financial frictions play an important role in explaining U.K business cycles.[89]

On the other hand, some papers proposed DSGE models with leverage constraints both in the firm and in the bank (e.g. Gerali et al., 2010; Meh and Moran, 2010; Rannenberg, 2012). Gerali et al. (2010) assumes imperfect competition in the banking sector and sticky interest rates and the amount of lending to entrepreneurs is constrained by entrepreneurs' holding of capital. Their model can rationalise an attenuator mechanism on the role of banks in the business cycle to a monetary policy shock and a technology shock, whereas the financial intermediation may introduce additional volatility to the business cycle for the consequence of shocks originating in credit markets. Meh and Moran (2010) introduced two moral hazard problems to study the role of bank capital for the transmission

[87] Curdia and Woodford (2009) produced two different interest rates - the interest rate available to savers and the interest rate that borrowers pay for the loan - to show the result.

[88] Gertler and Karadi (2011) and Gertler and Kiyotaki (2010) introduced an agency problem between intermediaries and their depositors. This agency problem endogenously constrains intermediary leverage ratios, which have the effect of tying overall credit flows to the net worth of the intermediary sector. Gertler and Kiyotaki (2010) also introduced an inter-bank market. The disruption to the inter-bank market besides the agency problem has impacts on real activities. Gertler and Karadi (2011) showed that the intermediary balance sheet mechanism produces a modest amplification of declines in output and investment relative to the conventional DSGE model. Gertler and Kiyotaki (2010) did not explicitly compare models and used this model to assess the impact of three forms of intervention: (i) a direct lending by the Central Bank to households; (ii) an indirect lending through increased lending in the interbank market; (iii) the government acquisiton of private banks.

[89] Specially, Villa and Yang (2011) showed that the banking sector shock explains about half of the fall in output during the recent recession.

of macroeconomic shocks.[90] They showed that the presence of this bank capital channel of tranmission amplifies and propagates the effects of technology shocks on output, investment and inflation but has a more limited role for the effects of monetary policy shocks. Rannenberg (2012) combined the costly state verification problem between firms and banks following Bernanke et al. (1999) with the moral hazard problem between banks and depositors following Gertler and Karadi (2011) and compared the model with the Bernanke et al. (1999) type model. His modification amplifies the response of the overall economy to the shocks and better matches U.S data compared to the Bernanke et al. (1999) type model.

This chapter is closely related to Villa (2013). It also compared three models in order to analyse whether financial frictions are empirically relevant and, if so, which type of financial frictions is preferred by the data.[91] However, this chapter and Villa (2013) differ in several respects as follows. First, we calibrate the three models to the U.S. data including the financial crisis period, whilst Villa (2013) estimates the models to the Euro Area during the pre-crisis period. Second, for the result of the moment comparison Villa (2013) finds that the introduction of either type of financial frictions improves the model's fit and the bank friction model outperforms the firm friction model. However, our result shows that the firm friction model fits the data better than the bank friction model. Third, in the results of the impulse responses function the firm friction model shows more persistent

[90] Two moral hazard problems are as follows. The first moral hazard occurs between entrepreneurs and banks. Entrepreneurs may choose projects with a low probability of success to raise their private benefits. As a monitoring mechanism, banks demand entrepreneurs to invest their net worth when lending to them. And the second moral hazard happens between banks and investors. Investors cannot monitor entrepreneurs so they deposit funds at banks. However, banks may not rightly monitor since monitoring is private and costly. Therefore, investors require banks to invest their net worth in entrepreneurs' projects. This mechanism means that the dynamics of bank capital affect how much banks can lend, and the dynamics of entrepreneurial net worth influence how much entrepreneurs can borrow.

[91] The three models are as follows: (i) Smets and Wouters (2007) model (SW model); (ii) a SW model with financial frictions originating in non-financial firms a la Bernanke et al. (1999), (SWBGG model); (iii) a SW model wih financial frictions originating in financial intermediaries, a la Gertler and Karadi (2011), (SWGK model).

responses of output and investment to the shocks, while the bank friction model shows much faster adjusted responses. In addition, the two models with financial frictions display more amplified responses with higher leverage. This result is one of our important contribution because it is not definitely mentioned in Villa (2013).

3.3. The models

This section presents the three DSGE models: the no friction model, the firm friction model and the bank friction model. The no friction model is a closed-economy DSGE model similar to that of Smets and Wouters (2007). The model we consider is the framework of the DSGE model with monopolistic competition and nominal price rigidities. And in the firm friction model we incorporate the financial accelerator largely following Bernanke et al. (1999) while the bank friction model is similar to that of Gertler and Karadi (2011). In all the models the economy is populated by a representative household, capital producers, intermediate goods firms, final goods producers, and the policy maker. And in the bank friction model financial intermediaries are added to the economy.

3.3.1. The no friction model (Smets and Wouters, 2007)

3.3.1.1. Households

There is a continuum of households where the population measures to unity. Households are infinitely-lived and consume intertemporally and intratemporally over differentiated goods provided by final goods firms. Further, households provide labour service to intermediate goods firms. The representative household derives utility from consumption C_t, and labour supply L_t. Thus, households' preferences are given by the expected utility function

$$E_t \left\{ \sum_{i=0}^{\infty} \beta^i \left[\ln \left(C_{t+i} - hC_{t+i-1} \right) - \frac{\chi}{1+\varphi} \left(L_{t+i} \right)^{1+\varphi} \right] \right\} \tag{3.1}$$

where a discount rate $\beta \in (0, 1)$, a habit parameter $h \in (0, 1)$, a relative utility weight of labour $\chi > 0$, and an inverse Frisch elasticity of labour supply $\varphi > 0$. The representative household's utility is separable in consumption and leisure and allows for habit formation in consumption following Smets and Wouters (2007). The household saves by depositing funds with financial intermediaries and by buying government bonds. Both of these assets have a maturity of one quarter, yield a gross real risk-free return R_t from $t-1$ to t. In the equilibrium considered here, these assets are both riskless and are thus perfect substitutes and earn the same interest rate. Let W_t be the real wage rate, Π_t net distributions from ownerships of both non-financial and financial firms, T_t lump sum taxes, and B_{t+1} the total quantity of short term debt the household acquires. Then their budget constraint is given by

$$C_t = W_t L_t + \Pi_t - T_t + R_t \, B_t - B_{t+1} \tag{3.2}$$

Maximisation of households' preferences (3.1) subject to the budget constraint (3.2) gives the following first order conditions with respect to C_t, L_t, B_t:

$$C_t : \lambda_t = \left(C_t - hC_{t-1} \right)^{-1} - \beta h E_t \left(C_{t+1} - hC_t \right)^{-1} \tag{3.3}$$

$$L_t : \lambda_t W_t = \chi L_t^{\varphi} \tag{3.4}$$

$$B_t : 1 = E_t \beta \Lambda_{t,t+1} R_{t+1} \tag{3.5}$$

where λ_t denotes the Lagrangian multiplier associated with the budget constraint and $\Lambda_{t,t+1} = \frac{\lambda_{t+1}}{\lambda_t}$.

3.3.1.2. Capital producers

At the end of period t, competitive capital producers purchase the stock of depreciated capital from intermediate goods firms and then repair depreciated capital and produce new capital. The new and re-furbished capital is then sold back to intermediate goods firms and any profits are transfered to households. We assume that the value of a unit of new capital is Q_t and the cost of replacing depreciated capital is unity. We also suppose that there are flow adjustment costs associated with producing new capital and there are no adjustment costs associated with refurbishing capital following Christiano et al. (2005). A representative capital producer's accumulation technology is given by

$$K_{t+1} = \xi_t K_t + I_{nt} \tag{3.6}$$

where K_t is capital stock, $I_{nt} \equiv I_t - \delta(U_t)\xi_t K_t$ is net capital created, and ξ_t is a stochastic shock to the quality of capital following an autogressive process

$$\ln \xi_t = \rho_\xi \ln \xi_{t-1} + \eta_t^\xi, 0 < \rho_\xi < 1, \eta_t^\xi \sim N(0, \sigma_\xi) \tag{3.7}$$

Thus, $\xi_t K_t$ is the effective quantity of capital at period t. The capital quality shock ξ_t is introduced to capture economic depreciation or obsolescence of capital (Gertler and Karadi, 2011). And U_t is the utilisation rate of capital and $\delta\left(U_t\right)$ is the depreciation rate depending on the utilisation rate of capital. The depreciation rate is as follows:

$$\delta\left(U_t\right)=\delta_{ss}+\frac{\left(R_{ss}+EFP_{ss}\right)-\left(1-\delta_{ss}\right)}{\left(1+\zeta\right)*\mu}U_t^{1+\zeta} \tag{3.8}$$

where δ_{ss} is the steady state depreciation rate, R_{ss} is the steady state gross real risk-free interest rate, EFP_{ss} is the steady state external finance premium, μ is the price mark-up and ζ is the elasticity of marginal depreciation with respect to utilisation rate.

Therefore, $\delta\left(U_t\right)\xi_t K_t$ is the quantity of capital refurbished. Investment adjustment costs are also given by

$$f(\frac{I_t}{I_{t-1}})=\frac{\eta}{2}\left[\frac{I_t}{I_{t-1}}-1\right]^2, f\left(1\right)=f^{'}\left(1\right)=0 \text{ and } f^{''}\left(1\right)>0 \tag{3.9}$$

where I_t is gross capital created and η means inverse elasticity of net investment to the price of capital. The function f summarises the technology that transforms current and past investment into installed capital for use in the following period (Christiano et al., 2005). Then, real expected profits of the capital producer are given by

$$\max E_t\sum_{\tau=t}^{\infty}\beta^{T-t}\Lambda_{t,\tau}\left\{\left(Q_\tau-1\right)I_{n\tau}-f\left(\frac{I_{n\tau}}{I_{n\tau-1}}\right)I_{n\tau}\right\} \tag{3.10}$$

The first order condition for investment gives the following relation for net investment assuming all capital producers choose the same net investment rate.

$$Q_t=1+f\left(\cdot\right)+\frac{I_{nt}}{I_{nt-1}}f^{'}\left(\cdot\right)-E_t\beta\Lambda_{t,t+1}(\frac{I_{nt+1}}{I_{nt}})^2 f^{'}\left(\cdot\right) \tag{3.11}$$

From the equation (3.11), the price of capital goods is equal to the marginal cost of investment goods production.

3.3.1.3. Intermediate goods firms

Intermediate goods firms hire labour and combine it with capital and produce wholesale goods that are finally sold to final goods producers in a perfectly competitive market. These firms are risk-neutral and have a finite horizon. At the end of period t, each intermediate goods firm i buys capital K_{it} from capital producers at a given price Q_t and produces output Y_{it}, using the capital and labour L_{it}. Then production technology is given by the following Cobb-Douglas technology:

$$Y_{it} = A_t \left(U_t \xi_t K_{it}\right)^{\alpha} L_{it}^{1-\alpha} \tag{3.12}$$

where A_t denotes total factor productivity and follows an AR(1) process:

$$\ln A_t = \rho_A \ln A_{t-1} + \eta_t^A, 0 < \rho_A < 1, \eta_t^A \sim N(0, \sigma_A) \tag{3.13}$$

and α is effective capital share. Let P_{mt} be the price of intermediate goods output. We assume that the replacement price of used capital is unity. Then, the first order conditions are as follows:

$$K_{it} : P_{mt} \alpha \frac{Y_{it}}{U_t} = \delta' \left(U_t\right) \xi_t K_{it} \tag{3.14}$$

$$L_{it} : P_{mt} \left(1 - \alpha\right) \frac{Y_{it}}{L_{it}} = W_t \tag{3.15}$$

With the assumption of perfect capital markets, the return to capital is equal to the gross real risk-free interest rate.

$$E_t \beta^i \Lambda_{t,t+1+i} R_{kt+1+i} = E_t \beta^i \Lambda_{t,t+1+i} R_{t+1+i} \tag{3.16}$$

where R_{kt} is the return to capital from $t-1$ to t.

3.3.1.4. Final goods producers

In order to introduce monopolistic competition in the goods market, this model comprises a retail sector. Final goods producers purchase intermediate goods Y_{it} at the market price P_{mt} and re-package those goods into retail output Y_{ft} that are sold in a monopolisticly competitive market. It takes one unit of intermediate good to make a unit of retail good, i.e. $Y_{it} = Y_{ft}$. Final output Y_t is a constant elasticity substitution composite of a continuum of mass unity of differentiated final goods firms that use intermediate output as the sole input. The final output composite is given by

$$Y_t = \left[\int_0^1 Y_{ft}^{(\varepsilon-1)/\varepsilon} df \right]^{\varepsilon/(1-\varepsilon)} \tag{3.17}$$

where Y_{ft} is output by final goods producer f and ε is the elasticity of substitution. From cost minimisation by users of final output, Y_{ft} is given by

$$Y_{ft} = \left(\frac{P_{ft}}{P_t} \right)^{-\varepsilon} Y_t \tag{3.18}$$

where $P_t = \left[\int_0^1 P_{ft}^{1-\varepsilon} df \right]^{1/(1-\varepsilon)}$ is the aggregate price index.

Final goods producers are subject to nominal rigidities following Calvo (1983) and Yun (1996). Specifically, only a fraction $1 - \gamma_P$ of firms is allowed to adjust its price each period. Those firms not allowed to optimise its price can index its price to the lagged inflation at a rate r_P. Denoting the optimal price as P_t^*, final goods producers decide the price as follows:

$$\max E_t \sum_{i=0}^{\infty} \gamma^i \beta^i \Lambda_{t,t+1} \left[\frac{P_t^*}{P_{t+i}} \Pi_{k=1}^i \left(1 + \pi_{t+k-1}\right)^{r_P} - P_{mt+i} \right] Y_{ft+i} \tag{3.19}$$

where π_t is the rate of inflation from $t-1$ to t. The first order conditions are given by

$$E_t \sum_{i=0}^{\infty} \gamma^i \beta^i \Lambda_{t,t+1} \left[\frac{P_t^*}{P_{t+i}} \Pi_{k=1}^{i} \left(1+\pi_{t+k-1}\right)^{r_P} - \mu P_{mt+i} \right] Y_{ft+i} = 0 \tag{3.20}$$

with the price mark-up $\mu = \frac{1}{1-1/\varepsilon}$. Thus, the aggregate price index evolves as follows:

$$P_t = \left[(1-\gamma) \left(P_t^*\right)^{1-\varepsilon} + \gamma \left(\Pi_{t-1}^{\gamma_P} P_{t-1} \right)^{1-\varepsilon} \right]^{1/(1-\varepsilon)} \tag{3.21}$$

3.3.1.5. Monetary policy and equilibrium

We assume that the monetary authority sets risk-free nominal interest rate $R_{n,t}$ to stabilise output and inflation according to a simple Taylor rule of the form

$$\log\left(\frac{R_{n,t}}{R}\right) = (1-\rho)\left[\kappa_\pi \log\left(\frac{\Pi_t}{\Pi}\right)_t + \kappa_y \log\left(\frac{Y_t}{Y_t^*}\right)\right] + \rho\left(\frac{R_{n,t-1}}{R}\right) + \eta_t^R \quad \kappa_\pi > 1,\ \kappa_y \geq 0 \tag{3.22}$$

with an interest rate smoothing parameter $\rho \in [0,1)$ and $\eta_t^R \sim N(0, \sigma_R)$ is an exogenous shock to monetary policy (Gertler and Karadi, 2011). The strength of the monetary authority's reaction to fluctuations of inflation and output is determined by the inflation coefficient κ_π and the output gap coefficient κ_y, where we impose the Taylor principle as $\kappa_\pi > 1$ (Taylor, 1993). The following Fisher equation shows the relation between nominal and real interest rates.

$$1 + R_{n,t} = R_t \frac{E_t P_{t+1}}{P_t} \tag{3.23}$$

Output consists of comsumption, investment, investment adjustment cost, and government spending. Thus, the economy-wide resource constraint is given by

$$Y_t = C_t + I_t + f\left(\frac{I_{nt}}{I_{nt-1}}\right) I_{nt} + G_t \tag{3.24}$$

The term G_t represents a government spending shock that follows an AR(1) process:

$$\ln G_t = \rho_G \ln G_{t-1} + \eta_t^G, 0 < \rho_G < 1, \eta_t^G \sim N(0, \sigma_G) \tag{3.25}$$

3.3.2. The firm friction model (Bernanke et al., 1999)

The introduction of financial frictions at the firm level changes the set-up of intermediate goods firms compared to the no friction model explained above. The firm friction model is identical to the no friction model otherwise. Intermediate goods firms are, in fact, the key for the working of the financial accelerator mechanism since financial frictions arise from asymmetric information in the relationship between borrowers (i.e. intermediate goods firms) and lenders (i.e. a financial intermediary who ultimately represents household and thus need not be modeled explicitly). In this subsection, we leave out the explanation of households, capital producers and final goods firms, since these parts are the same as the no friction model.[92] Then, we show the set-up of intermediate goods firms.

3.3.2.1. Intermediate goods firms

Intermediate goods firms produce goods in a perfectly competitive market following the no friction model. This optimisation problem is identical to that in the no friction model described by equations (3.12) - (3.15). Given that the firm earns zero profits, it pays out the ex post return to capital to the financial intermediary. Accordingly, R_{kt+1} is given by

[92] Therefore, we maintain some frictions - habit formation in consumption, variable capital utilisation and price indexation to past inflation - unlike Bernanke et al. (1999).

$$R_{kt+1} = \frac{\left[P_{mt+1}\alpha\frac{Y_{t+1}}{\xi_{t+1}K_{t+1}} + Q_{t+1} - \delta\left(U_{t+1}\right)\right]\xi_{t+1}}{Q_t} \tag{3.26}$$

Following Bernanke et al. (1999), we assume that each firm survives until the next period with probability θ_e and his expected lifetime is equal to $1/(1-\theta_e)$. This assumption ensures that intermediate goods firm's net worth will never be enough to fully finance the acquisiton of capital. Thus, they buy the capital from capital goods producers using both their net worth and loans from financial intermediaries. We also assume the existence of an agency problem between intermediate goods firms and intermediaries. Intermediate goods firms can costlessly observe their returns. However, the intermediaries have to pay monitoring costs to observe the realised output of the firms. This is a costly state verification framework a la Townsend (1979). Thus, entrepreneurs cannot borrow at the riskless rate and have to pay the external finance premium.

In particular, the ex post gross return of intermediate goods firm j is $\omega^j R_{kt+1}$, where ω^j is an idiosyncratic shock to intermediate goods firm j's return. The variable ω^j is i.i.d. cross time and cross the intermediate goods firms, with cumulative density function $F(\omega)$, and $E\left\{\omega^j\right\} = 1$. The auditing cost is assumed to equal a proportion μ of the realised gross return to intermediate goods firm's capital. Intermediate goods firm j has his own net worth N^j_{t+1} at the end of t and has to borrow an amount L^j_{t+1} to acquire capital goods. Thus, the above relationship is given by

$$L^j_{t+1} = Q_t K^j_{t+1} - N^j_{t+1} \tag{3.27}$$

where L^j_{t+1} is an amount of loan at the end of t. And the intermediary faces an opportunity cost of funds between t and $t+1$ equal to the stochastic return on the portfolio of loans to intermediate goods firms, R_{t+1}.

Given $Q_t K_{t+1}^j$, L_{t+1}^j, and R_{t+1}, the optimal contract may be characterized by a gross non-default loan rate, R_{jt+1}^L, and a threshold value of the idiosyncratic shock ϖ^j, such that for values of the idiosyncratic shock greater than or equal to ϖ^j, the intermediate goods firm is able to repay the loan at the contractual rate, R_{jt+1}^L. That is, ϖ^j is defined by

$$\varpi^j R_{kt+1} Q_t K_{t+1}^j = R_{jt+1}^L L_{t+1}^j \tag{3.28}$$

If $\omega^j < \varpi^j$, the intermediate goods firm cannot pay the contractual return and declares default. The value of ϖ^j and R_{jt+1}^L under the optimal contract are determined by the requirement that households receive expected returns equal to the opportunity costs of their funds. Accordingly, the loan contract must satisfy

$$\left[1 - F\left(\varpi^j\right)\right] R_{jt+1}^L L_{t+1}^j + (1-\mu)\int_0^{\varpi^j} \omega^j R_{kt+1} Q_t K_{t+1}^j dF\left(\omega^j\right) = R_{t+1} L_{t+1}^j \tag{3.29}$$

Combining equations (3.27) and (3.28) with equation (3.29) yields the following expression for ϖ^j:

$$\left\{\left[1 - F\left(\varpi^j\right)\right]\varpi^j + (1-\mu)\int_0^{\varpi^j} \omega^j dF\left(\omega^j\right)\right\} R_{kt+1} Q_t K_{t+1}^j = R_{t+1}\left(Q_t K_{t+1}^j - N_{t+1}^j\right). \tag{3.30}$$

Given the state-contingent debt form of the optimal contract, the expected return to the intermediate goods firm may be expressed as

$$E\left\{\int_{\varpi^j}^{\infty} \omega^j R_{kt+1} Q_t K_{t+1}^j dF\left(\omega^j\right) - \left(1 - F\left(\varpi^j\right)\right)\varpi^j R_{kt+1} Q_t K_{t+1}^j\right\} \tag{3.31}$$

Combining this relation with equation (3.30) allows us to simplify intermediate goods firm's objective to maximisation of

$$E\left\{\left[1-\mu\int_0^{\varpi^j}\omega^j dF\left(\omega^j\right)\right]R_{kt+1}/E\left(R_{kt+1}\right)\right\}E\left(R_{kt+1}\right)Q_tK_{t+1}^j - R_{t+1}\left(Q_tK_{t+1}^j - N_{t+1}^j\right) \tag{3.32}$$

The formal investment and contracting problem then reduced to choosing K_{t+1}^j and a schedule for ϖ^j to maximise equation (3.32), subject to the set of state-contingent constraints implied by equation (3.30).

We assume $E\left\{R_{kt+1}/R_{t+1}\right\} \geq 1$ because the intermediate goods firms purchase capital in the competitive equilibrium. Thus, the first-order condition yields the following relation for optimal capital purchases:

$$Q_tK_{t+1}^j = \psi\left(E\left\{R_{kt+1}/R_{t+1}\right\}\right)N_{t+1}^j, \text{ with } \psi(1)=1, \psi'\left(\cdot\right)>0 \tag{3.33}$$

Equation (3.33) can be expressed as a different way.

$$E\left\{R_{kt+1}\right\} = s\left(\frac{N_{t+1}^j}{Q_tK_{t+1}^j}\right)R_{t+1}, \qquad s'\left(\cdot\right)<0 \tag{3.34}$$

As shown in the above equation, the premium over the risk-free rate the intermediary demands is a negative function of the share of intermediate goods firm's capital investment that is financed by his net worth.

Following Christensen and Dib (2008), intermediate goods firm's net worth at the end of period t is given by

$$N_{t+1} = \theta_e V_t + (1-\theta_e)N_t^e \tag{3.35}$$

where V_t is the equity held by intermediate goods firms at $t-1$ who are still in business at the period t and N_t^e is the transfer that newly entering intermediate goods firms receive from the firms who depart from the market. Here, intermediate goods firm's equity is given by

$$V_t = R_{kt+1}Q_{t-1}K_t - \left(R_{t+1} + \frac{\mu \int_0^{\varpi} \omega R_{kt+1}Q_{t-1}K_t dF(\omega)}{Q_{t-1}K_t - N_{t-1}} \right) (Q_{t-1}K_t - N_{t-1}) \qquad (3.36)$$

3.3.3. The bank friction model (Gertler and Karadi, 2011)

We add financial intermediaries to the no friction model in order to verify the role of financial frictions at the bank level. With the introduction of the financial intermediaries the set-ups of households and intermediate goods firms are a little modified. The bank friction model is similar to the no friction model except the set-ups of the financial intermediaries, households and the intermediate goods firms.

3.3.3.1. Households

The optimisation problem of households in the bank friction model is similar to ones in the two models explained above. However, within each household there are two types of members like Gertler and Karadi (2011). A banker manages a financial intermediary. At any moment in time the fraction f of the household members are workers and the fraction $1-f$ are bankers. We assume that bankers have a finite horizon to avoid the possibility of full self-financing of all investment. In particular, a banker at $t-1$ survives at the period t with probability θ. Thus, each period the fraction $1-\theta$ of bankers fail and become workers. The same number of workers become bankers, keeping the relative proportion of each type of members constant. New bankers receive a transfer from households.

3.3.3.2. Financial intermediaries

Financial intermediaries lend funds obtained from households to non-financial firms. In addition, financial intermediaries in this model are meant to capture the entire banking sector, i.e., investment banks as well as commercial banks (Gertler and Karadi, 2011).[93] Let S_{jt} be the quantity of financial claims on non-financial firms that the intermediary holds; Q_t^b the relative price of each claim; N_{jt}^b the net worth that intermediary j has at the end of period t; and B_{jt+1} the amount of deposits the intermediary obtains from households. The financial intermediary's balance sheet is then given by

$$Q_t^b S_{jt} = N_{jt}^b + B_{jt+1} \tag{3.37}$$

Household deposits with the intermediary at time t pay the non-contingent real gross return R_{t+1} at $t+1$. And the intermediary earns the stochastic return R_{kt+1} on the assets over this period. Both R_{kt+1} and R_{t+1} will be determined endogenously. Then the intermediary's net worth is given by

$$\begin{aligned} N_{jt+1}^b &= R_{kt+1} Q_t^b S_{jt} - R_{t+1}\, B_{jt+1} && (3.38) \\ &= \left(R_{kt+1} - R_{t+1}\right) Q_t^b S_{jt} + R_{t+1}\, N_{jt}^b && (3.39) \end{aligned}$$

Any growth in net worth above the riskless return depends on the premium $R_{kt+1} - R_{t+1}$ the intermediary earns on his assets, as well as his total assets, $Q_t^b S_{jt}$. Since the intermediary will not fund assets with a discounted return less than the discounted cost of borrowing, for the intermediary to operate in period t, this constraint can be expressed by

$$E_t \beta^i \Lambda_{t,t+1+i} \left(R_{kt+1+i} - R_{t+1+i}\right) \geq 0 \tag{3.40}$$

[93] Thus, we use financial intermediaries mixed with banks.

where $\beta^i \Lambda_{t,t+i}$ is the stochastic discount factor which the intermediary at t applies to earnings at $t+i$ and $i \geq 0$. With perfect capital markets, the relation always holds with equality. So the risk adjusted premium is zero. With imperfect capital markets, however, the premium may be positive due to limits on the intermidiary's ability to obtain funds. So long as the intermediary can earn a risk adjusted return that is greater than or equal to the return the household can earn on its deposits, it pays for the banker to keep building assets until exiting the industry. Thus, the objective function of the intermediary can be given by

$$\begin{aligned} V_{jt} &= \max E_t \sum_{i=0}^{\infty} (1-\theta)\, \theta^i \beta^{i+1} \Lambda_{t,t+1+i} \left(N^b_{jt+1+i} \right) \\ &= \max E_t \sum_{i=0}^{\infty} (1-\theta)\, \theta^i \beta^{i+1} \Lambda_{t,t+1+i} \left[(R_{kt+1+i} - R_{t+1+i})\, Q^b_t S_{jt} + R_{t+1+i}\, N^b_{jt+i} \right] \end{aligned} \tag{3.41}$$

where V_{jt} is the expected terminal wealth of the bank j. To the extent the discounted risk adjusted premium in any period, $\beta^i \Lambda_{t,t+i}\ (R_{kt+1+i} - R_{t+1+i})$, is positive, the intermediary will want to expand its assets indefinitely by borrowing additional funds from households. Following Gertler and Karadi (2011), we introduce the moral hazard problem between the bankers and households. We assume that after collecting deposits, the banker can choose to divert some of funds for his own consumption. Specifically, the banker can divert fraction $0 \leq \lambda^b \leq 1$ of funds. In this case, the depositor can force the intermediary into bankrupcy and recover the remaining fraction $1 - \lambda^b$ of funds. This implies that lenders are willing to supply funds to the banker if the following incentive constraint is satisfied:

$$V_{jt} \geq \lambda^b Q^b_t S_{jt} \tag{3.42}$$

In the above inequality V_{jt} is what the banker would lose by diverting a fraction of funds and $\lambda^b Q_t S_{jt}$ means the gain from doing so.

From the equation (3.41) we can express V_{jt} as follows:

$$V_{jt} = \nu_t Q_t^b S_{jt} + \eta_t N_{jt}^b \tag{3.43}$$

with

$$\nu_t = E_t \left\{ (1-\theta) \beta \Lambda_{t,t+i} \left(R_{kt+1} - R_{t+1} \right) + \beta \Lambda_{t,t+i} \theta x_{t,t+1} \nu_{t+1} \right\} \tag{3.44}$$

$$\eta_t = E_t \left\{ (1-\theta) \beta \Lambda_{t,t+i} R_{t+1} + \beta \Lambda_{t,t+i} \theta z_{t,t+1} \eta_{t+1} \right\} \tag{3.45}$$

where $x_{t,t+1} \equiv Q_{t+1}^b S_{jt+1} / Q_t^b S_{jt}$, is the gross growth rate in assets between t and $t+1$, and $z_{t,t+1} \equiv N_{jt+1}^b / N_{jt}^b$ is the gross growth rate of net worth. The variable ν_t means the expected discounted marginal gain to the banker of expanding assets $Q_t^b S_{jt}$ by a unit, holding N_{jt}^b constant, and while η_t has the interpretation of the expected discounted value of having another unit of N_{jt}^b, holding the assets $Q_t^b S_{jt}$ constant. Using (3.43) we can show the incentive constraints (3.42) as

$$\nu_t Q_t^b S_{jt} + \eta_t N_{jt}^b \geq \lambda^b Q_t^b S_{jt} \tag{3.46}$$

If this constraint binds, we can obtain following relationship between the bank's assets and the bank's net worth:

$$Q_t^b S_{jt} = \frac{\eta_t}{\lambda^b - \nu_t} N_{jt}^b = \phi_t N_{jt}^b \tag{3.47}$$

where ϕ_t is the banker's leverage ratio.[94] Holding constant net worth, expanding the assets raises the banker's incentive to divert funds. The equation (3.47) limits the intermediaries' leverage ratio to the point where the banker's incentive to cheat is exactly balanced by the cost. Therefore, the moral hazard problem yields an endogenous capital constraint on the intermediary's ability to expand the assets.

Combining (3.47) with (3.39) allows to express the evolution of the banker's net worth as

$$N^b_{jt+1} = \left[\left(R_{kt+1} - R_{t+1} \right) \phi_t + R_{t+1} \right] N^b_{jt} \tag{3.48}$$

In addition, it follows that

$$z_{t,t+1} = N^b_{jt+1} / N^b_{jt} = \left(R_{kt+1} - R_{t+1} \right) \phi_t + R_{t+1} \tag{3.49}$$

$$x_{t,t+1} = Q^b_{t+1} S_{jt+1} / Q^b_t S_{jt} = \left(\phi_{t+1} / \phi_t \right) \left(N^b_{jt+1} / N^b_{jt} \right) = \left(\phi_{t+1} / \phi_t \right) z_{t,t+1} \tag{3.50}$$

All the components of ϕ_t depend only on economy wide variables. This allows for total aggregation across the intermediaries, obtaining

$$Q^b_t S_t = \phi_t N^b_t \tag{3.51}$$

where $Q^b_t S_t$ denotes the aggregate quantity of intermediary assets and N^b_t reflects aggregate intermediary net worth. In the general equilibrium of our model, variation in N^b_t, will induce fluctuations in overall asset demand by intermediaries.[95]

[94] An interpretation of this condition is as follows (Gertler and Karadi, 2011). With frictionless competitive capital markets, intermediaries will expand borrowing to the point where rates of return will adjust to ensure ν_t is zero. However, the moral hazard problem between the banker and household may place limits on this arbitrage. Specifically, the intermediary's loans are constrained by its net worth.

[95] This mechanism of financial frictions at the bank level also arises if there is a shock that affects the bank's net worth. If a shock has a negative impact on the net worth, the bank has to decrease the loans

N_t^b consists of the net worth of existing intermediaries, N_{et}^b, and the one of new bankers, N_{nt}^b.

$$N_t^b = N_{et}^b + N_{nt}^b \tag{3.52}$$

N_{et}^b is given by

$$N_{et}^b = \theta \left[\left(R_{kt} - R_t \right) \phi_{t-1} + R_t \right] N_{t-1}^b \tag{3.53}$$

because bankers in business in period $t-1$ did not die at t with the ratio θ. We also suppose that the funds the household gives its new banker equal to a small fraction of the value of assets that exiting bankers had intermediated in their final operating period. Assuming that the exit probability is i.i.d., the final period assets of exiting bankers at t is $(1-\theta) Q_t^b S_{t-1}$. Thus, we suppose that each period the household gives $\iota / (1-\theta)$ of this value to its entering bankers.[96] Accordingly, in the aggregate,

$$N_{nt}^b = \iota Q_t^b S_{t-1} \tag{3.54}$$

Combining equations (3.53) and (3.54) gives the equation of motion for N_t^b.

$$N_t^b = \theta \left[\left(R_{kt} - R_t \right) \phi_{t-1} + R_t \right] N_{t-1}^b + \iota Q_t^b S_{t-1} \tag{3.55}$$

3.3.3.3. Intermediate goods firms

The optimisation problems of intermediate goods firms follow the above two models, de-

to the firms. The leverage ration expands the contraction of the loans. This fall of the loans will lower investment, thus output.

[96] Here, ι is a parameter for the transfer to the entering bankers.

scribed by equations (3.12) - (3.15), (3.26).

The firm finances its capital acquisition by obtaining funds from intermediaries. To acquire the funds, the firm issues S_t claims equal to the number of units of capital acquired K_{t+1} and prices each claim at the price of a unit of capital Q_t^b. That is, $Q_t^b K_{t+1}$ is the value of capital acquired and $Q_t^b S_t$ is the value of claims against this capital as follows:

$$Q_t^b K_{t+1} = Q_t^b S_t \tag{3.56}$$

3.4. Calibration and model comparison

3.4.1. Calibration

The three models are calibrated with U.S. data over the period from 1960Q1~2015Q4. The data includes real GDP, real consumption, real private investment, inflation. The parameters which are not recognised in the dataset or are linked to target values of the variables are calibrated following the previous literature. In the no friction model, we generally use conventional parameters according to Bernanke et al. (1999), and Gertler and Karadi (2011). The discount factor, β, is 0.99, meaning a quarterly steady state real interest rate of 1%. The steady state depreciation rate, δ_{ss}, is 0.025, implying an annual depreciation rate of 10%. The capital share, α, is 0.33, corresponding to one third of the total income. The elasticity of substitution between goods, ε, is equal to 4.167 and the government expenditure share is equal to 0.2. Also, we normalise the steady state utilisation rate U_{ss} at unity. Other parameters are calibrated in accordance with the estimates reported in Primiceri et al. (2006), as in Gertler and Karadi (2011). These parameters are as follows: the habit parameter h, the elasticity of marginal depreciation with respect to the utilisation rate ζ, the investment adjustment parameter η, the relative utility weight on labor χ, the Frisch elasticity of labor supply φ^{-1}, the price rigidity parameter γ, and the price indexing parameter γ_P. For the monetary policy rule, we also use the conventional Taylor rule parameters. And for the exogenous shocks, we use quite persistent values but the shock to the quality of capital following Gertler and Karadi (2011).

Regarding the parameters for the firm friction model the survival probability of intermediate goods firms θ_e follows Bernanke et al. (1999). We adopt the estimate used in De Graeve (2008) for the steady state capital to net worth ratio K/N and the elasticity of the external finance premium s.[97] The steady state external finance premium EFP_{ss} is also modified following Gertler and Karadi (2011) to increase the comparability of the three models.

The parameters related to the financial sector - the survival probability of the banks θ, the fraction of capital that can be diverted λ, and the proportional transfer to entering banks ι - are selected following Gertler and Karadi (2011). These parameters are decided to obtain following three target values. Specifically, the target of the bank's capital to net worth ratio is calibrated as 4 according to the aggregate data.[98] The steady state interest rate target is the pre-2007 spreads between mortgage rates and government bonds and between BAA corporate versus government bonds. The average horizon of the banks is set to a decade. Tables 3.1 and 3.2 show the parameter values for the three models.

[97] The previous literature with financial frictions at the firm level mostly calibrated the steady state capital to net worth as 2 (e.g., Bernanke et al., 1999; Christensen and Dib, 2008). However, De Graeve (2008) estimated this parameter using Bayesian methods. This estimate may be more reasonable because the U.S. macroeconomic data used in his paper covers the period 1954 to 2004. Therefore, we use 1.42 as the steady state capital to net worth ratio in the firm friction model. In section 3.5, we check an impact of the capital to net worth ratio using the conventional value 2.

[98] The bank's leverage ratio was extraordinarily high during the recent financial crisis. The leverage ratio is at the range of 25~30 for investment banks, and 15~20 for commercial banks. However, these high ratio mainly reflects housing finance (Gertler and Karadi, 2011).

Table 3.1. Common parameter values for the three models

Name	Definition	Value	Source
β	Discount factor	0.99	Bernanke et al. (1999)
h	Habit parameter	0.815	Gertler and Karadi (2011)
χ	Relative utility weight of labour	3.409	Gertler and Karadi (2011)
φ	Inverse Frisch elasticity of labour supply	0.276	Gertler and Karadi (2011)
U_{ss}	Steady state capital utilisation rate	1.0	Gertler and Karadi (2011)
δ_{ss}	Steady state depreciation rate	0.025	Bernanke et al. (1999)
R_{ss}	Steady state gross real risk-free rate	$1/\beta$	Bernanke et al. (1999)
η	Investment adjustment parameter	1.728	Gertler and Karadi (2011)
α	Effective capital share	0.330	Gertler and Karadi (2011)
ζ	Elasticity of marginal depreciation	7.2	Gertler and Karadi (2011)
ε	Elasticity of substitution	4.167	Gertler and Karadi (2011)
γ	Probability of keeping prices fixed	0.779	Gertler and Karadi (2011)
γ_p	Measure of price indexation	0.241	Gertler and Karadi (2011)
ρ	Smoothing parameter of Taylor rule	0.8	Gertler and Karadi (2011)
κ_π	Inflation coefficient of Taylor rule	1.5	Gertler and Karadi (2011)
κ_y	Output gap coefficient of Taylor rule	0.125	Gertler and Karadi (2011)
ρ_ξ	Persistence of shock to quality of capital	0.66	Gertler and Karadi (2011)
ρ_A	Persistence of total factor productivity shock	0.9	Gertler and Karadi (2011)
ρ_G	Persistence of government spending shock	0.95	Bernanke et al. (1999)
$\frac{G}{Y}$	Steady state ratio of government expenditures	0.20	Bernanke et al. (1999)

Table 3.2. Parameter values for financial frictions

Name	Definition	Firm friction	Bank friction	Source
θ_e	Survival probability	0.972	-	Bernanke et al. (1999)
θ	Survival probability of bankers	-	0.972	Gertler and Karadi (2011)
EFP_{ss}	Steady state finance premium (basis point)	100	100	Gertler and Karadi (2011)
K/N	Steady state capital to net worth ratio	1.42	-	De Greave (2008)
K/N^b	Steady state capital to net worth ratio of bank	-	4	Gertler and Karadi (2011)
s	Elasticity of financial premium	0.06	-	De Greave (2008)
λ	Fraction of capital divertable	-	0.381	Gertler and Karadi (2011)
ι	Transfer to the entering bankers	-	0.002	Gertler and Karadi (2011)

3.4.2. Comparison of business cycle moments

We compare the cyclical properties of the data generated by the three models to the empirical U.S. data to discuss the goodness of fit of each model. The real variables considered are GDP, personal consumption expenditures, non-residential investment and inflation rate. The financial variables considered are interest rate for the three models, the firm's net worth for the firm friction model and the bank's net worth for the bank friction model.[99]

[99] Data source is as follows : (1) GDP, personal consumption expenditures, non-residential investment : NIPA table from Bureau of Economic Analysis (2) inflation : GDP deflator in NIPA table (3) interest rate : Effective Federal Fund Rate from Federal Reserve Bank of St. Louis (4) firm's net worth : sum of "Nonfarm nonfinancial corporate business; net worth" and "Nonfarm nonfinancial corporate business; proprietors equity in noncorporate business" in Flow of Funds Account of the Federal Reserve Board (5) bank's net worth : Tangible Common Equity calculated using Federal Deposit Insurance Corporation's "Quarterly Banking Profile"

All the empirical data is detrended using the Hodrick-Prescott filter.

Table 3.3 reports the relative standard deviations to GDP of some selected variables. The firm friction model fits the data better in terms of relative volatility of consumption and investment. The bank friction model generates considerably more volatility than the other two models for investment, although the relative volatility of consumption is too low compared to the data. The three models generate similar standard deviation of inflation and real interest rate. However, for the former the three models well capture the data, whilst for the latter they fail to replicate the value in the data. The relative volatility of the net worth in the two models with financial frictions is much higher than in the data, although the firm friction model comes closer to the data.

Table 3.3. Standard deviations relative to GDP

Variable	Data	No friction	Firm friction	Bank friction
GDP	1	1	1	1
Consumption	0.82	1.11	0.70	0.40
Investment	3.11	5.08	4.77	5.69
Inflation	0.18	0.19	0.15	0.15
Interest rate	1.02	0.14	0.10	0.12
Net worth (Firm)	2.21		4.51	
Net worth (Bank)	2.06			10.21

In Table 3.4 the comparison of the cross-correlation with GDP reveals the firm friction model gets closer to the data. The firm friction model fits the data better than the other two models in terms of all the related variables. The no friction model is preferred to the bank friction model when compared to the data. The firm friction model performs similarly well at matching the correlation of the net worth with GDP compared to the bank friction model. However, the bank friction model generates a strong procyclicality of the bank net worth, whilst this variable is mildly countercyclical in the data.

Table 3.4. Correlations with GDP

Variable	Data	No friction	Firm friction	Bank friction
GDP	1	1	1	1
Consumption	0.90	0.47	0.63	0.32
Investment	0.86	0.74	0.90	0.97
Inflation	0.35	0.30	0.35	0.61
Interest rate	0.65	0.39	0.57	0.90
Net worth (Firm)	0.70		0.92	
Net worth (Bank)	-0.15			0.84

Table 3.5 also displays the autocorrelation coefficients of order 1. The three models reproduces similar values of the autocorrelations for the related variables. The variables such as consumption and inflation are more autocorrelated in the three models than in the data. Regarding GDP and interest rate the firm friction model and the no friction model match well with the autocorrelation observed in the data. Regarding inflation, there is not a unique model to successfully replicate the dynamics in the data.

Table 3.5. Autocorrelations

Variable	Data	No friction	Firm friction	Bank friction
GDP	0.86	0.85	0.87	0.89
Consumption	0.87	0.95	0.95	0.96
Investment	0.91	0.89	0.87	0.90
Inflation	0.48	0.68	0.66	0.73
Interest rate	0.83	0.85	0.83	0.91
Net worth (Firm)	0.92		0.71	
Net worth (Bank)	0.72			0.66

Overall, even if not all the moments are replicated by the models, the introduction of financial frictions originating in the firm improves the model's fitting with the U.S. data. However, whether the introduction of financial frictions at the bank level is preferred in the data or not is not certain. Thus, the firm friction model outperforms the bank friction model. This result is not consistent with the literature such as Villa (2013) which finds that the bank friction model is empirically relevant and it fits the data better than the firm friction model in the estimation with the Euro Area data for the pre-crisis period. The repercussion on the financial market in the U.S. during the financial crisis may cause the discrepancy.

3.4.3. Comparison of impulse responses

This section presents the impulse responses of key macroeconomic variables to the structural shocks in the three models. Figures 3-2 to 3-6 examine five shocks - monetary policy shock, technology shock, capital quality shock, government spending shock, and wealth shocks - in order to highlight how the presence of financial frictions affects the movement of economic variables and the transmission mechanism of these shocks. We particularly emphasise both the magnitude and the persistence of the responses of economic variables such as output, consumption and investment. All the shocks are set to produce a downturn. Each variables' response is expressed as the percentage deviation from its steady-state level.[100]

3.4.3.1. Monetary policy shocks

Figure 3-2 presents the responses of the three models to a temporary negative monetary policy shock. The monetary shock is 25 basis point increase in the short term interest rate. The directions of the impact responses are similar among the three models, since in all the models an increase in the nominal interest rate has negative effects on investment and, thus, output. However, the strengths of the responses are different. The presence of financial frictions implies a significant amplification and propagation of the monetary policy shock on macroeconomic variables, since the responses of these variables in the two models with financial frictions are greater than the no friction model and persist for longer. The response of output is strongest in the bank friction model with a trough of -0.69%, reached in quarter 3,[101] while it is weakest in the no friction model, where the trough of output equals -0.27%. The response of output in the firm friction model is in between the two models, with a trough of -0.37%. Note that the path of output in the no friction model remains persistently above the paths of output in the two models with financial frictions. The difference in the output response across the three models is mainly caused by the investment response. The trough of investment is -3.93% in the bank friction model,

[100] Version 4.3.1 of Dynare toolbox for Matlab is used for the computations.

[101] The larger response of output to the monetary policy shock in the bank friction model compared to the no friction model is in line with euro area evidence by Maddaloni et al. (2011). They found that when the impact of the monetary policy shock on changes in credit supply related to the bank's balance sheet is neutralized, the response of GDP to the monetary policy shock is reduced by 50% in a vector autoregressive (VAR) analysis.

-1.95% in the firm friction model and -1.24% in the no friction model, while the paths of consumption are similar across the three models.

The transmission mechanisms of monetary policy are also different among the three models. Following the shock, the nominal interest rate rises and output, investment, consumption, labour supply, and inflation fall on impact. This is the standard interest rate channel of monetary policy transmission (Villa, 2013). In the models with financial frictions, however, the transmission mechanism of the monetary policy shock is also enhanced through its impact on credit markets. In the firm friction model, the decline in the price of capital due to the tightening of monetary policy causes a fall in the net worth of intermediate goods firms, and the external finance premium rises (Bernanke et al., 1999). This mechanism further reinforces the contraction in capital and investment. In the bank friction model, due to the negative effects on investment, the assets of intermediaries decrease as well. At the same time the fall in asset prices worsens financial intermediaries' balance sheets. The fall in profits makes financial intermediaries increase the lending rate more than the increase in the deposit rate, in order to restore profits. Hence the external finance premium rises. The increase in financing costs causes a further decline in loans and investment (Villa, 2013). Thus, the reason why the response of output to the monetary policy shock is stronger in the models with financial frictions than the no friction model is well understood.

To understand why output responds more strongly to the monetary policy shock in the bank friction model than in the firm friction model, it is useful to examine the response of the bank's and the firm's net worths, the external finance premium, and the price of capital in the two models (Rannenberg, 2012). In specific, the external finance premium increases by 0.70% in the bank friction model and 0.12% in the firm friction model, respectively. More a significant decline of the return to capital in the bank friction model in turn causes a stronger drop in the price of capital and the bank's net worth. The stronger drop in the bank's net worth itself contributes to the stronger increase in the external finance premium in the bank friction model, since it implies a stronger increase in the bank leverage, which increases the external finance premium. Finally, the stronger decline in the price of capital causes the stronger contraction of investment observed in the bank friction model.[102] However, the validity of this result depends on the leverage. When the firm's leverage is higher, the response of output in the firm friction model can be larger than the bank friction model. We examine the effect of the leverage in the robustness section.

The result for the monetary policy shock is generally consistent with earlier literature. In particular, most earlier papers showed the significance of the financial accelerator mechanism to the monetary policy shock (e.g. Bernanke et al., 1999; Christensen and Dib, 2008; Queijo von Heideken, 2009). However, De Graeve (2008) found that the investment response in the model with financial frictions is no longer uniformly greater than the model where financial frictions are shut off, even if the investment response is amplified.[103]

For the accelerator effect of financial frictions at the intermediaries level our result does not accord to some papers (e.g. Goodfriend and McCallum, 2007; Gerali et al., 2010). In particular, Goodfriend and McCallum (2007) recognised that the negative monetary policy decreases the demand for bank deposits, thereby tending to reduce the external finance premium for a givern value of assets in the economy. This attenuates the effect

[102] Above result is related to the fact that external funding is more expensive than using internal resources (Banerjee, 2002; De Graeve, 2008). This is due to the increase in the costs of lenders, who have to evaluate the prospects of success of the investment projects and monitor the borrower's conduct. For a better fit of the data, thus, models should try to account for the observed positive premium on external funds (Brazdik et al., 2011).

[103] De Graeve (2008) pointed out that the form of adjustment costs causes this difference. In other words, he used investment adjustmet costs while other papers used capital adjustment costs. In his model, temporary fluctuations in the external finance premium will have less impact on the economy compared to the model with capital adjustment costs since changing the flow of investment is costly. However, we find that the firm friction model consistently displays stronger responses of investment and output to the monetary policy shock than the no friction model despite investment adjustment costs. This result confirms that financial frictions at the firm level strengthen the amplification and the propagation of economic fluctuations.

of the monetary policy that weakens output. In Gerali et al. (2010), the introduction of a banking sector also attenuates the impact of the monetary policy tightening. This result largely comes from sticky interest rates, which reduce the response of retail loan rates, thus, lessening the contraction in loans, consumption and investment. However, other papers showed that financial frictions at the intermediaries level have amplification effects on output and investment for the monetary policy shock like our paper (e.g. Meh and Moran, 2010; Gertler and Karadi, 2011; Rannenberg, 2012).[104]

Unlike the above-mentioned literature we also find that in the bank friction model the response of output to the monetary policy shock is adjusted faster than the firm friction model even if the responses of output are persistent in the two models.[105] This result suggests an interesting finding that the bank friction model has relatively a shorter recession to the monetary policy shock, whereas the firm friction model shows persistent recession to the same shock. This difference comes from the persistent response of investment to the shock in the firm friction model.[106] What causes these different responses of investment in the two models with financial frictions? First of all, some frictions incorporated in the three models - variable capital utilisation and habit formation in consumption - contribute to the persistent response of output. For example, Christiano et al. (2005) suggested that variable capital utilisation is important to explain output persistence in response to monetary shock.[107] Dotsey and King (2006) also showed the importance of variable capital

[104] Rannenberg (2012) also showed the amplification effect of financial frictions despite the rise in the bank's net worth. This is associated with two assumptions. One is the maturity of contracts and the other is the absence of traded assets from the bank's portfolio. Unexpected entrepreneurial defaults don't have the impact with the one quarter maturity of contracts and the loss in value of assets don't affect the bank's profit with the absence of traded assets.

[105] After 10 years, output in the two models is still below their steady state. However, output in the bank friction model becomes greater in 17 quarters than the firm friction model, whereas the maximum decrease of output in the bank friction model is almost twice as large as that the firm friction model.

[106] Investment in the bank friction model becomes positive in 17 quarters, whereas in the firm model investment remains negative for 10 years.

[107] Christiano et al. (2005) used a model that incorporates price and wage rigidities, habit formation in consumption, adjustment cost in investment and variable capital utilisation and found that wage rigidity

utilisation for output persistence.[108] And Bouakez et al. (2005) found that habit formation in consumption increases output persistence through its effect on labour supply.[109] Nolan and Thoenissen (2009) also found that habits in consumption helps to generate persistent responses in a number of macro aggregates following certain shocks.

These frictions which are helpful to output persistence equally apply to the three models in this section. However, the firm friction model discussed here has another persistence mechanism besides the common ones. In the firm friction model the temporary shock has much stronger persistence through the feedback effect of tightened financial frictions. In particular, in the firm friction model a negative monetary policy shock decreases the firm's net worth which in turn increases financial frictions and forces the firm to invest less. This results in a lower level of capital and decreases the firm's net worth in the following period. This fall again leads to lower investment and lowers the net worth in the following periods (Brunnermeier et al., 2012). According to this mechanism, the shock to the firm's net worth induces persistent effects in the firm friction model. However, the bank friction model has a restricted persistence mechanism compared to the firm friction model. In the bank friction model, as explained above the decreased net worth of the bank increases the external finance premium and this lowers investment. Again, lower investment causes declines in bank earnings and thus bank capital decreases in subsequent periods, which

---

and variable capital utilisation are important factor for output persistence. According to their results, habit formation and investment adjustment costs play a much smaller role than variable capital utilisation in promoting output persistence. To understand their mechanism it is notable for firms to set prices as a mark-up over marginal costs. The major components of marginal costs are wages and the rental rate of capital. By allowing the service of capital to decrease after a negative monetary policy shock, variable capital utilisation helps dampen the lagre fall in the rental rate of capital that would otherwise happen. This in turn reduces the fall in marginal costs and, hence, prices. The resulting inertia in inflation means that the fall in nominal spending that happens after the negative monetary policy shock generates a persistent fall in real output.

[108] They constructed a model incorporating variable capital utilisation, materials input, and labour flexibility and indicated that these three features are mutually reinforcing and magnifying output persistence.

[109] In particular, habit formation induces households to adjust their labour supply more gradually to achieve a smoother and more persistent consumption profile than under time-separable preferences.

propagates the negative effect of the shock until the trough. But decreased investment means a reduced demand for the bank's assets. This less demand for the bank's assets rather lowers the external finance premium and investment rebounds with the decrease in financing costs.[110] And this increase in investment contributes to the recovery of the bank's net worth. Through this process the effect of financial frictions is mitigated and investment or output can be adjusted faster in the bank friction model. Thus, the bank friction model shows less persistent responses of output and investment than the firm friction model, since there is no feedback effect of tightened financial frictions and the mitigating mechanism of financial frictions rather works. This finding suggests that the main objective of financial frictions at the firm level is to capture the extent and the persistence of fluctuation in aggregate output, whereas introducing financial frictions at the bank level into the DSGE models has been motivated mainly by the aim of explaining specific features of the financial crisis (Brazdik et al., 2011).

[110] This reaction of investment is displayed as the fast adjustment after the trough.

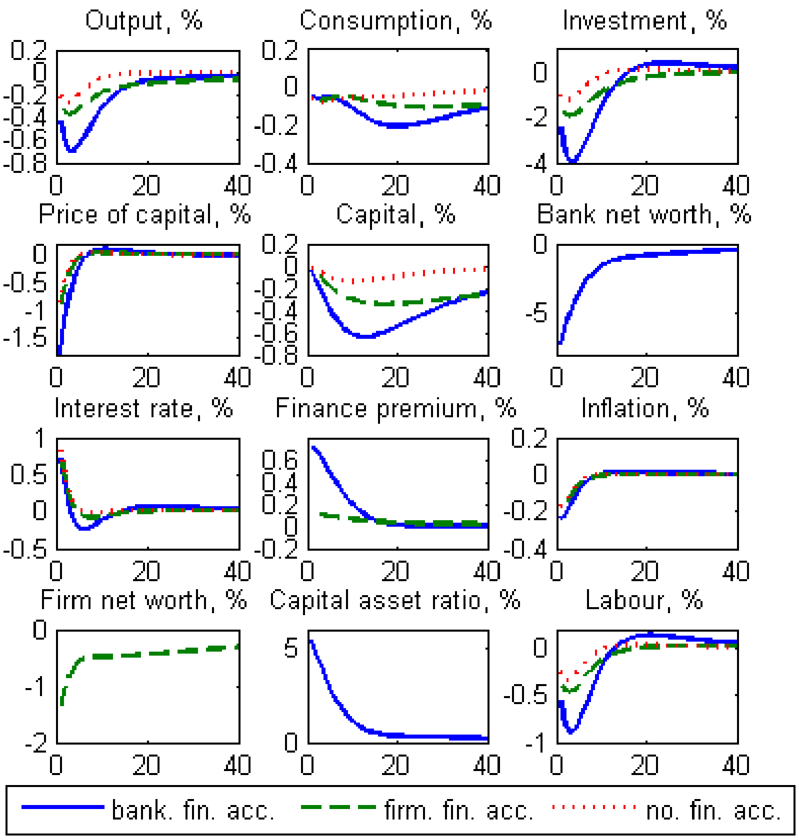

Figure 3-2. Response to monetary policy shock

3.4.3.2. Technology shocks

Figure 3-3 displays the responses of the three economies to a contractionary transitory technology shock. The technology shock is a negative one percent innovation in total factor productivity, with a quarterly autoregressive factor of 0.95. The technology shock has a direct impact on output by making factors less productive, and leads to an increase in prices due to the contraction in aggregate supply (Villa, 2013). Since the Taylor rule is operating, the nominal interest rate rises as shown in Figure 3-3. Investment and consumption decline due to the contraction in output. In the firm friction model, the external finance premium does not show a definite rise and a fall in investment is less than the no friction model. However, in the bank friction model this shock also implies a decrease in asset prices, which worsens the financial intermediaries' balance sheet. Such a deterioration makes the financial intermediaries willing to push up the external finance premium to increase profits. The increase in the financing cost, further reduces the loan demand by the intermediate goods firms, which enhances the downturn in investment and asset prices.

The response of output is stronger in the bank friction model than in the firm friction model all the time. In specific, the trough of output is -0.88% shown in quarter 5 in the bank friction model and -0.59% reached in quarter 6 in the firm friction model. The stronger decline in the bank friction model is mainly caused by a drop in investmet displaying the trough of -3.82% and -1.89%, respectively. The response of output in the no friction model is between the two models with the trough of -0.76%. The no friction model, of course, does not have the effect through the firm's net worth or the financial intermediaries' balance sheet, since the premium is fixed at zero.

The reason for the weaker output response of the firm friction model compared to the no friction model lies in the effect of entrepreneurial leverage (Rannenberg, 2012)[111]. In particular, the technology shock reduces the marginal product of capital. Thus, investment decreases and this causes the capital stock to fall. As the firms demand less loans, their leverage declines. This persistently lowers the external finance premium. This attenuates the fall of investment due to the negative technology shock, thus, output in the firm friction

[111] On the other hand, De Graeve (2008) showed that the main reason for the weaker responses is the form of adjustment costs because investment adjustment costs are more dynamic than capital adjustment costs. In particular, if investment is negative today, it will be negative for an extended period, in order to minimise costs related to changing its flow. In case of the negative productivity shock, investment which is low for a long time, means that the capital stock is much less than the firm's net worth, thereby decreasing borrowing needs. This results in a drop in the external finance premium. Investment will be higher in all periods, since long lasting negative investment will not be costly due to a low future premium for external finance.

model relative to the no friction model.

We also find that the response of output in the bank friction model is adjusted faster than the no friction model in spite of the persistent response of output in the three models.[112] This fact also results from the faster adjustment of investment in the bank friction model like the monetary shock.[113] This difference may be explained by the mitigating mechanism of financial frictions introduced in the section 3.3.2.1. Particularly the two models with financial frictions have the same frictions which contribute to output persistence such as variable capital utilisation and habit formation in consumption. However, the persistence of output and investment in the bank friction model is restricted due to the mitigating mechanism of financial frictions. Another interesting finding is that the firm friction model doesn't show the most persistent responses of output and investment.[114] In the firm friction model, the negative technology shock again has persistent effects through the feedback effect of tightened financial frictions.[115] However, as the fall in the marginal productivity reduces the firm's loan, the rise in the external finance premium is restrained. This partially offsets the persistent decrease of investment. After all, the degree of output persistence in the firm friction model is similar to the no friction model.

The result for the technology shock in the firm friction model is consistent with earlier literature (e.g. Christensen and Dib, 2008; De Graeve, 2008[116]; Rannenberg, 2012; Villa,

[112] After 10 years, output is still below its steady state in the three models.

[113] Investment in the bank model becomes greater than the no friction model in 10 quarters, whereas its trough in the bank friction model is much larger than the no friction model.

[114] The values of output and investment in the firm friction model remain above those in the bank friction model all the periods. The reversal of the values between the two models like the monetary policy shock doesn't turn up.

[115] The shock in period t decreases the wage and therefore the current firm's net worth. This raises borrowing frictions and leads to decreased investment for period $t+1$. The lower investment reduces output in period $t+1$ and therefore the wage which means a lower net worth for the next generation of the firms. The next generation also invests less and the effect persists further (Brunnermeier et al., 2012).

[116] In De Graeve (2008), a smaller response of investment in the model with financial frictions is offset by a greater consumption response, leading to similar output response over the different models. However, in our setting, the response of consumption in the firm friction model is also smaller than the no friction model, resulting in much smaller output response in the firm friction model.

2013). However, in Bernanke et al. (1999), a positive productivity shock decreases the external finance premium and thus boosts investment compared to the model without financial frictions. In addition, this chapter shows consistent results with earlier papers for financial frictions at the intermediaries level (e.g. Meh and Moran, 2010; Gertler and Karadi, 2011; Rannenberg, 2012; Villa, 2013). Gerali et al. (2010) found that the responses of consumption and output are attenuated, while the response of investment is amplified with imperfectly competitive banks and sticky interest rate setting. To understnd this result, it is helpful to consider how their model's assumption changes the transmission mechanism of financial frictions at the bank level.[117]

[117] The amplification mechanism of investment in Gerali et al. (2010) is as follows. With imperfectly competitive banking, the rise in the policy rate to the technology shock triggers a larger rise in loan rates. Investment is decreased both by the technology worsening and by more difficult access to credit.

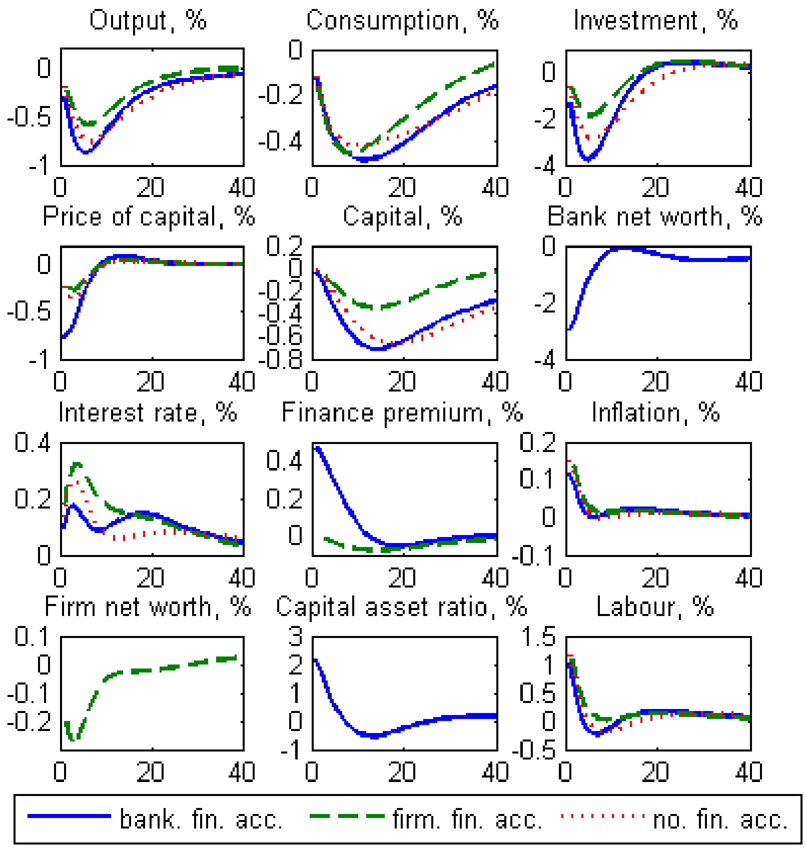

Figure 3-3. Response to technology shock

3.4.3.3. Capital quality shocks

Figure 3-4 shows the effects of a capital quality shock in the three models. The initiating shock is a five percent decline in capital quality, with a quarterly autoregressive factor of 0.66. In the no friction model, this shock causes a decrease in the price of capital, which leads to a fall in investment and, hence, output. In the firm friction model, the shock also implies the fall in the price of capital. But a change in the price of capital has another effect besides the decline of investment. The firm's net worth decreases due to the lower return on capital. This effect causes a rise in the external finance premium. This should cause more contraction in investment. Thus, the response of output is amplified compared to the no friction model. The bank friction model also generates two additional effects. Firstly, the retrenchment in investment leads to a lower demand for the assets of the financial intermediaries, affecting in turn their profits. Secondly, the net worth of the financial intermediaries decreases because of the lower return on capital.[118] These two additonal effects act in the direction of reducing investment and output. Thus, the presence of financial frictions at the bank level generates two additional economic contraction effects and the response to the capital quality shock is the strongest in the bank friction model. In specific, the trough of output is -7.36% of quarter 4 in the bank friction model, -4.11% of quarter 4 in the firm friction model and -2.69% of quarter 3 in the no friction model. The differences in the output declines across the three models are also caused by the decline of investment. The trough of investment is -35.12% in the bank friction model, -15.73% in the firm friction model and -8.07% in the no friction model.

The output declines to the capital quality shock are very persistent in the three models.[119] However, we also find that typically in the bank friction model the response of output is adjusted faster than the other two models like the monetary policy shock and the technology shock.[120] The faster adjustment in the bank friction model is mainly caused by the response of investment.[121] The explanations introduced in the earlier section equally apply to the

[118] The capital quality shock can be translated directly into a shock to the banks' balance sheet in the bank friction model, since the capital is identical to the assets of financial intermediaries. Thus, Gertler and Karadi (2011) and Gertler and Kiyotaki (2010) regard an exogenous decline in capital quality as the initiating feature of the current crisis.

[119] After 10 years, they are still below their steady states.

[120] Output gradually increases after the trough in the no friction model and the firm friction model, but the bank friction model displays an abrupt rise after the trough. For example, the response of output in the firm friction model is greater than the bank friction model in 13 quarters, whereas the value of the trough in the bank friction model is almost twice as large as that in the firm friction model.

[121] While the response of investment in the firm friction model remains around the steady state since 14 quarters, investment in the bank friction model rebounds right away from the trough and increases to the value of 10.35% in 5 years.

capital quality shock.[122]

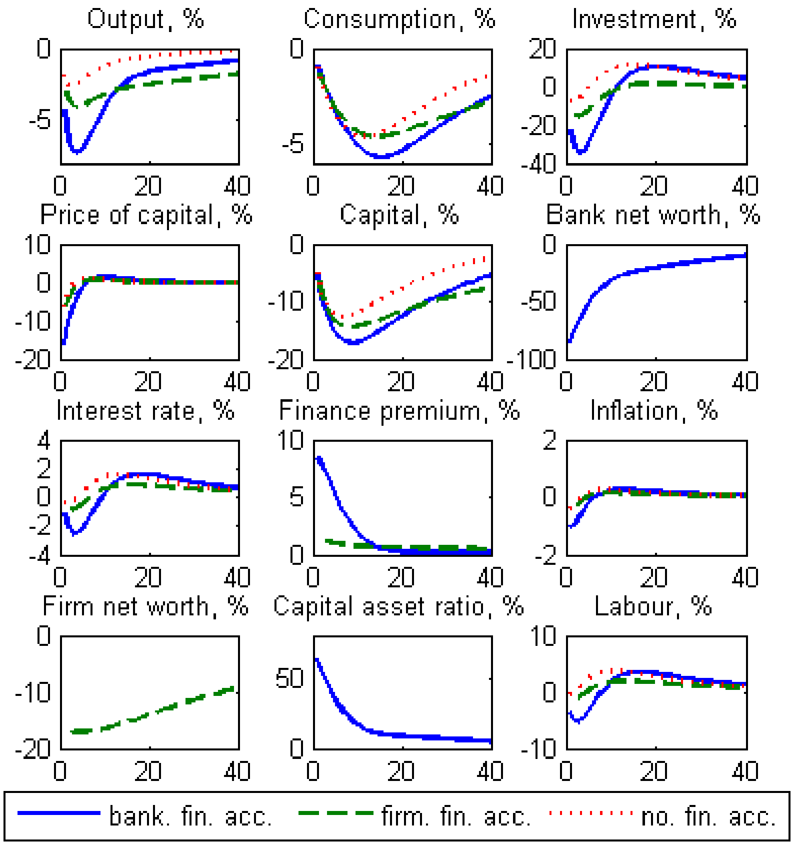

Figure 3-4. Response to capital quality shock

3.4.3.4. Government spending shocks

Figure 3-5 displays the effects of a government spending shock in the three models. The responses of economic variables are generally similar among the three models, but the order

[122] In sum, some frictions - variable capital utilisation and habit formation in consumption - identically apply to the three models. However, in the firm friction model the feedback effect of tightened financial frictions contributes to more persistent responses of output and investment. And the faster adjustment in the bank friction model results from the mitigating mechanism of financial frictions.

of the output response is different from other shocks. The instant response of output to a negative government spending shock is the same among the three models. The trough of output is -0.21% in the firm friction model, -0.20% in the bank friction model and the no friction model. However, the response of output in the firm friction model are persistently larger than the bank friction model and the no friction model. This difference results from the response of investment because the response of consumption is similar among the three models. And the difference of the investment response comes from the fact that the crowding-out effect of investment due to the negative government spending shock is the smallest in the firm friction model (Rannenberg, 2012).[123] We find from Figure 3-5 that investment also increases in the no friction model, since the capital stock rises. However, in the firm friction model, the external finance premium rises, since the net worth of the intermediate goods firm persistently decreases and the capital stock declines. This limits the increase in investment even if there is the crowding-out effect of investment. In the bank friction model, the capital asset ratio of the bank increases persistently, since the bank's net worth falls and the capital stock doesn't show any change. This movement restricts the increase of investmen due to the crowding-out effect. However, the degree of the investment contraction in the bank friction model is smaller than the firm friction model as we can find out from the fact that the external finance premium rather decreases in the bank friction model. Finally, in the bank friction model the response of output to the government spending shock is adjusted faster than other models, even though the difference is not that large compared to other shocks.

[123] When the government spending increases, the crowding-out effect decreases private investment and consumption. Accordingly, the crowding-out effect increases private investment and consumption with the reduction of government spending.

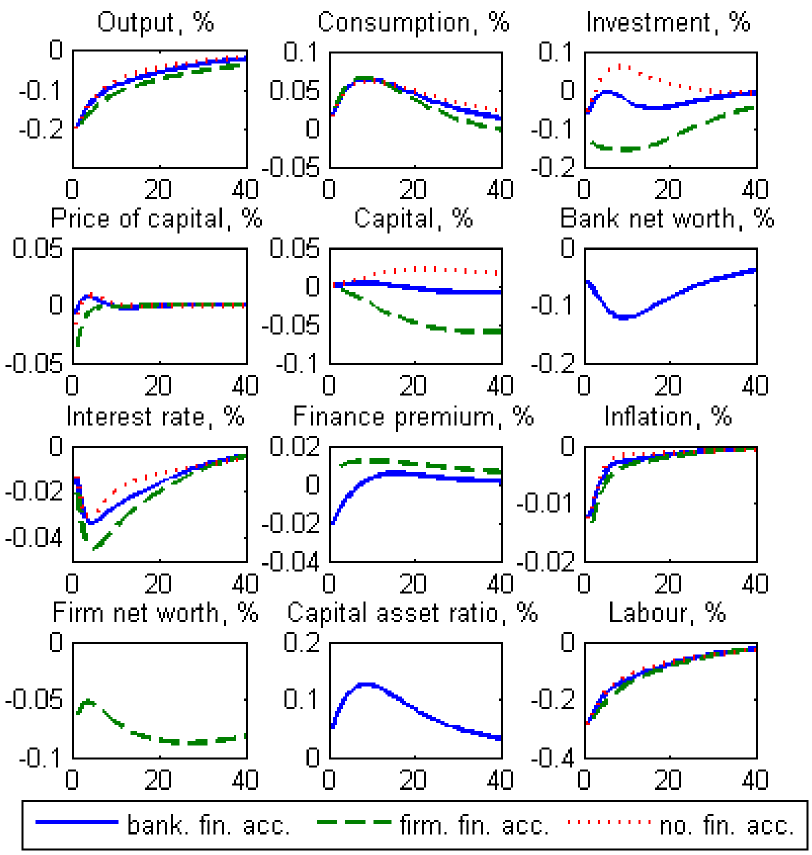

Figure 3-5. Response to government spending shock

3.4.3.5. Wealth shocks

We now consider the effects of financial shocks that lead to exogenous declines in the bank's net worth or in the firm's net worth.[124] The shock to the firm's net worth has been used in the numerous models with financial frictions at the firm level (e.g. Christiano et al., 2010;

[124] Following Holmstrom and Tirole (1997), the shock to the bank's net worth might be interpreted as a credit crunch, since it is caused by sudden deteriorations in the balance sheets of the banks due to asset losses and the bank reduces the loan to non-financial firms.

Nolan and Thoenissen, 2009).[125] Recent upheavals in financial markets worldwide, characterised by growing asset losses and dramatic reductions in profits of financial institutions, appear to reflect disturbances of this kind (Meh and Moran, 2010).

Figure 3-6 jointly displays both the response to the bank's net worth shock in the bank friction model and the one to the firm's net worth shock in the firm friction model. The wealth shock is a negative one percent shock in the firm's net worth or in the bank's net worth, respectively. Output declines in both models, but the response of the firm friction model is much stronger than that of the bank friction model. And this difference mainly results from a stronger decline in investment.[126] Specially, the responses of output and investment in the firm friction model are deeper and more persistent than the bank friction model, whereas the instant responses are similar between the two models. In the firm friction model, the reduction of the firm's net worth increases the firm's leverage, since the intermediate goods firms need to borrow more to fund their capital stock. This increase in leverage causes a rise in the external finance premium, thus a drop in the price of capital, which reinforces the initial drop in the net worth. This further lowers investment. The decline of the bank's net worth, meanwhile, increases capital asset ratio of the bank, and this increases the external finance premium, since increased bank's leverage requires a higher profitability. The implied increase in the financing cost causes a contraction of the price of capital, thus, investment, and output.

Then, what makes the greater responses of output and investment in the firm friction model than the bank friction model? This difference is related to the mechanism which

[125] Christiano et al. (2010) suggested that this shock reflects irrational exuberance or asset price bubble, since it raises the firm's net wealth independently of movements in fundamentals. And Nolan and Thoenissen (2009) interpreted this shock as a shock to the efficiency of contractual relations between borrowers and lenders.

[126] The trough of output is -0.30% and the one of investment is -1.94% in the firm friction model. In the bank friction model, output declines in response to the shock and reaches a trough of -0.17% in quarter 4. The output contraction is mainly driven by a drop in investment, which declines by 0.52% on impact and reaches a trough of -1.09% in quarter 4.

causes more persistent responses of output and investment in the firm friction model. Particularly in the firm friction model the negative shock to the firm's net worth increases financial frictions and forces the firm to invest less. This results in a lower level of capital and further reduces the firm's net worth in the following period. This fall again leads to lower investment and lowers the net worth in the following periods. However, the bank friction model doesn't have this kind of mechanism. In the bank friction model, as explained in section 3.4.2.1 the decreased net worth of the bank increases the external finance premium and this lowers investment. But decreased investment means a fall of the demand for the loan. This decreased demand for the loan rather lowers the external finance premium and investment rebounds with the decrease in financing costs. And this increase of investment contributes to the recovery of the bank's net worth. Through this process the effect of financial frictions is mitigated and the bank friction model shows less persistent and lighter responses of output and investment than the firm friction model.

The importance of the shock to the firm's net worth explained above is consistent with Nolan and Thoenissen (2009). And this chapter shows that the shock to the bank's net worth reduces both output and inflation in the bank friction model. By contrast, in the models of Gerali et al. (2010) and Meh and Moran (2010) this shock lowers output, but increases inflation. This different response of inflation in these papers is connected to the movement of wages. The contraction at the bank's net worth causes the firms to raise labour demand to increase capital utilisation, pushing up wages. The higher wages and financing costs result in the increase in inflation.[127] Empirical studies on the macroeconomic effects of this wealth shock have mixed results. While Maddaloni et al. (2011), for the euro area, found that their proxy for a shock to bank capital moves output and inflation in the same direction, Fornari and Stracca (2012) also found that a negative shock to bank capital

[127] In contrast, in our bank friction model the labour demand falls following the reduction in investment and this pushes down wages. This lower wages contribute to the decrease in inflation.

persistently reduces output, but do not find a statistically significant and robust decline of inflation.

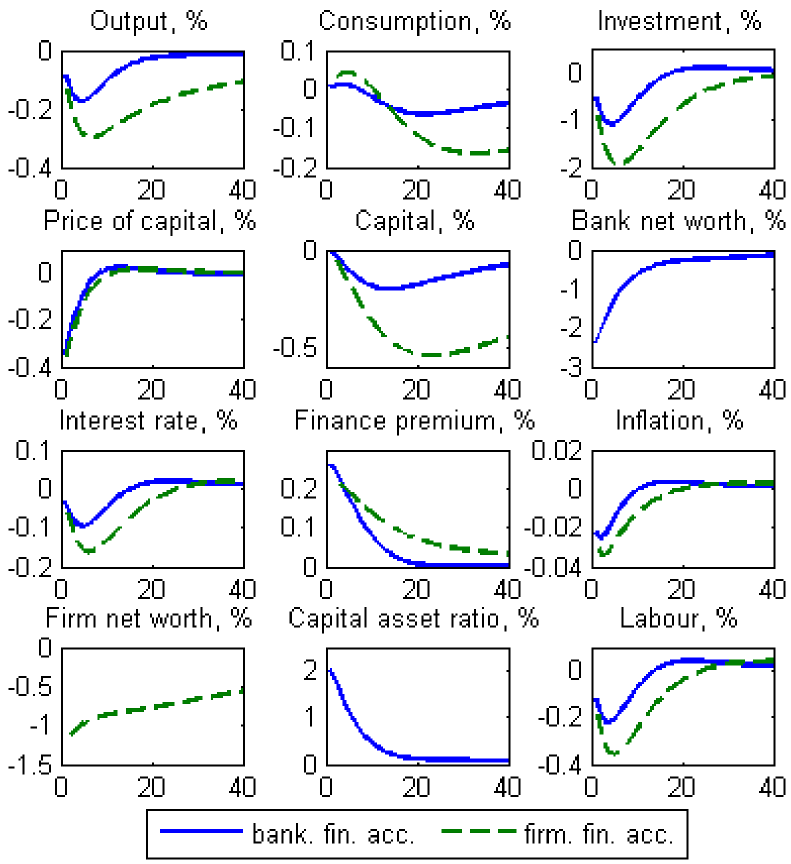

Figure 3-6. Response to wealth shocks

3.5. Robustness analysis

This section assesses the robustness of our main findings regarding the dynamics of the three models. We modify the baseline model and apply the five shocks to the three models as in the previous section. Figures 3-7 to 3-10 display the responses of output, consumption and investment to the five standard shocks in the modified models.

3.5.1. No habit formation in consumption

Figure 3-7 presents an impact of no habit formation in consumption. For this purpose, we set the value of habit parameter as zero. We find that on impact the response of consumption is larger than before. Thus, the the maximum decrease of output is larger than the baseline model and the timing of the trough is faster. However, the patterns of the amplification and the persistence found in section 3.4 are not modified because habit formation in consumption equally applies to the three models. This result confirms that our findings are not influenced by the specification of habit formation in consumption.

3.5.2. Constant capital utilisation

Figure 3-8 shows the impact of constant capital utilisation. As explained in section 3.4. the variable capital utilisation we adopted contributes to the persistence of the responses in output and investment. We also introduced the variable depreciation rate considering this variable capital utilisation. This subsection investigates the sensitivity of our key findings without the variable capital utilisation and the variable depreciation rate. Thus, we redo the exercises of the section 3.4 setting the values of $U = 1$ and $\delta = 0.025$. We also find that the responses of investment and output a little decrease, whereas the role of financial frictions affecting the amplification and the persistence of economic fluctuations is unchanged. Therefore, Figure 3-8 also suggests that our findings are robust to the specification of the capital utilisation and the depreciation rate.

3.5.3. Alternative monetary policy rule

To examine the robustness of financial frictions to the specification of monetary policy, we change the specification of the monetary policy rule (3.22). Instead of using the standard Taylor rule, we set the smoothing parameter ρ to zero and all other coefficients of the rule unchanged. Using this monetary policy rule, Figure 3-9 shows the responses of the three models to the five exogenous shocks. We find that our findings are also robust to the specification of the monetary policy rule, as financial frictions continue to play a key role in amplifying and propagating shocks: the responses of output and investment in the bank friction model display more amplified declines following the shocks and those in the firm friction model exhibit more persistent declines than other two models, much like they did in Figures 3-2 – 3-5. The main difference between Figure 3-9 and Figures 3-2 – 3-5 is that the magnitude of the responses is much smaller in Figure 3-9 because an initial impact in interest rate is not transmitted to the next periods under the alternative monetary policy rule.

3.5.4. Higher value of the steady state capital to asset ratio

In this subsection, we examine the effect of the firm's leverage. The steady state capital to asset ratio K/N governs the financial accelerator effect in the firm friction model because it directly affect the equation (3.35) - (3.36). To assess the sensitivity of our results to the value of the steady state capital to asset ratio, we use a higher value of 2 instead of 1.42, implying 50% of the firm's capital expenditure is externally financed. Figure 3-10 displays the responses of the three economies to the shocks according to the modified steady state capital to asset ratio. We find that in this Figure the responses of investment and output in the firm friction model are greater than the baseline model described in Figures 3-2 – 3-5. This deeper response of output mainly comes from investment. When the firms heavily depend on the external funding, the shock to the firm's net worth expands the rise in the external finance premium. This further aggravates investment and output. Thus, the responses in the firm friction model are more amplified and more persistent than the bank friction model. This finding shows the amplification of responses to the exogenous shocks heavily depends on the extent of leverage. In addition, this result suggests that the bank friction model with high leverage is appropriate for explaining the recent financial crisis. The bank's high leverage contributes to amplifying and propagating the repercussion of the crisis.

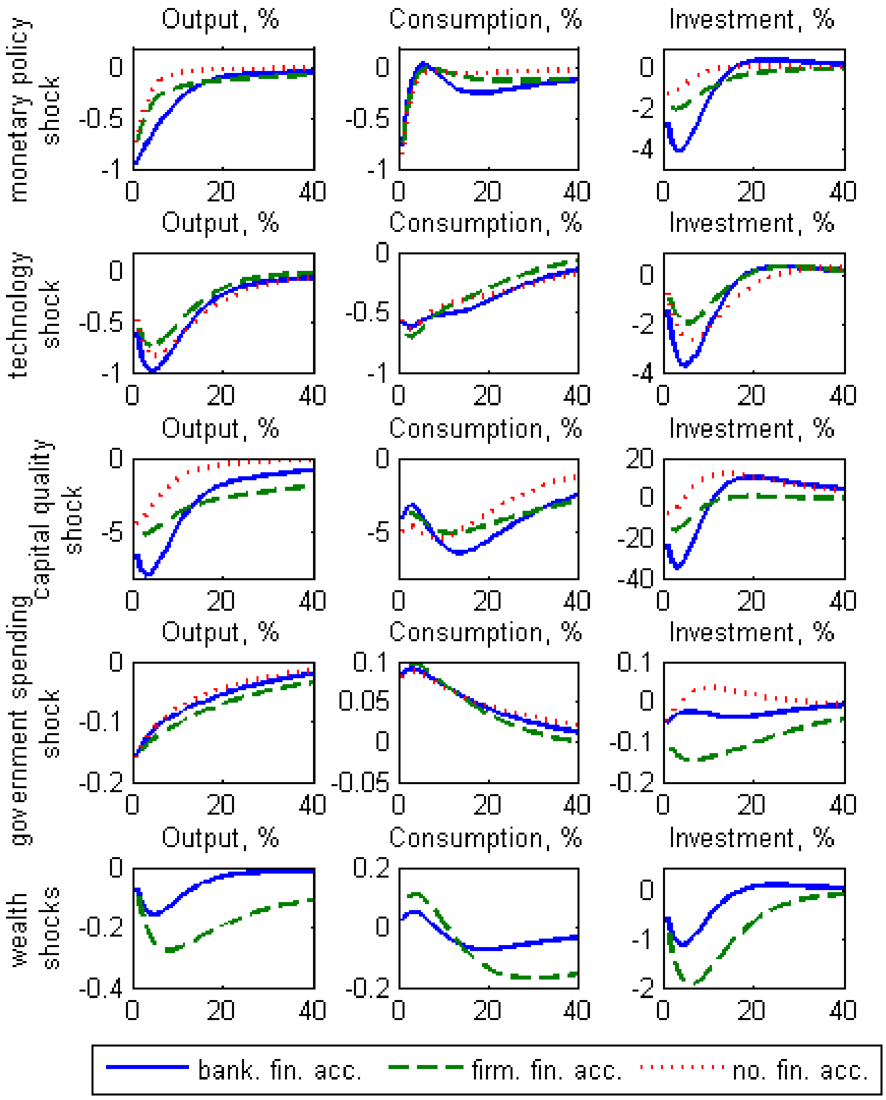

Figure 3-7. Impact of no habit formation in consumption

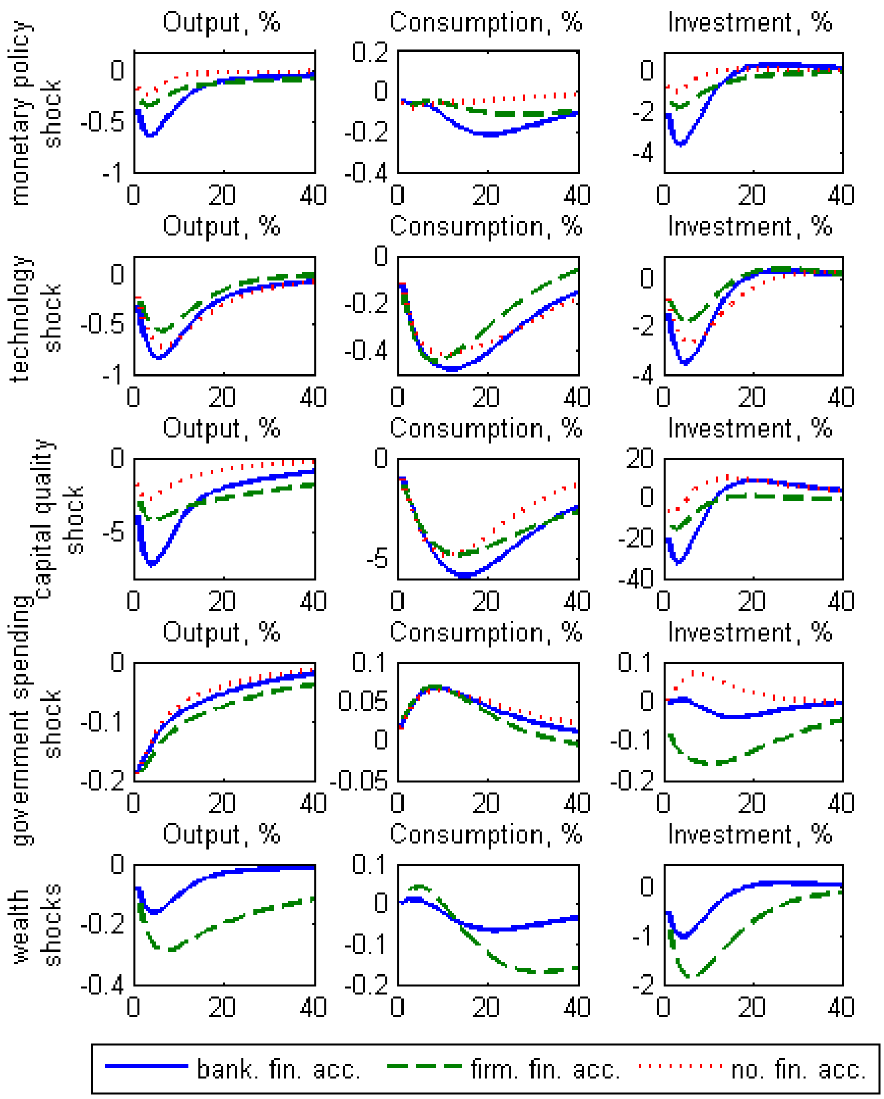

Figure 3-8. Impact of constant capital utilisation

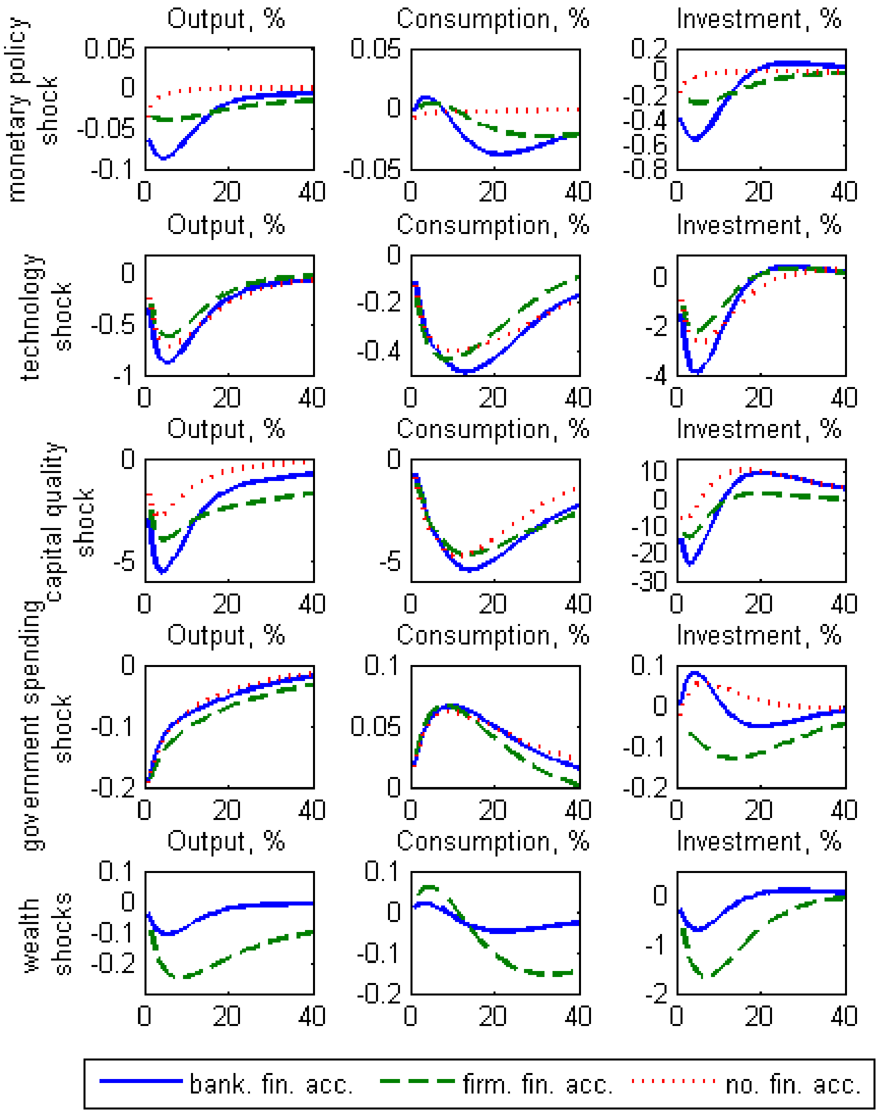

Figure 3-9. Impact of parameter of the Taylor rule

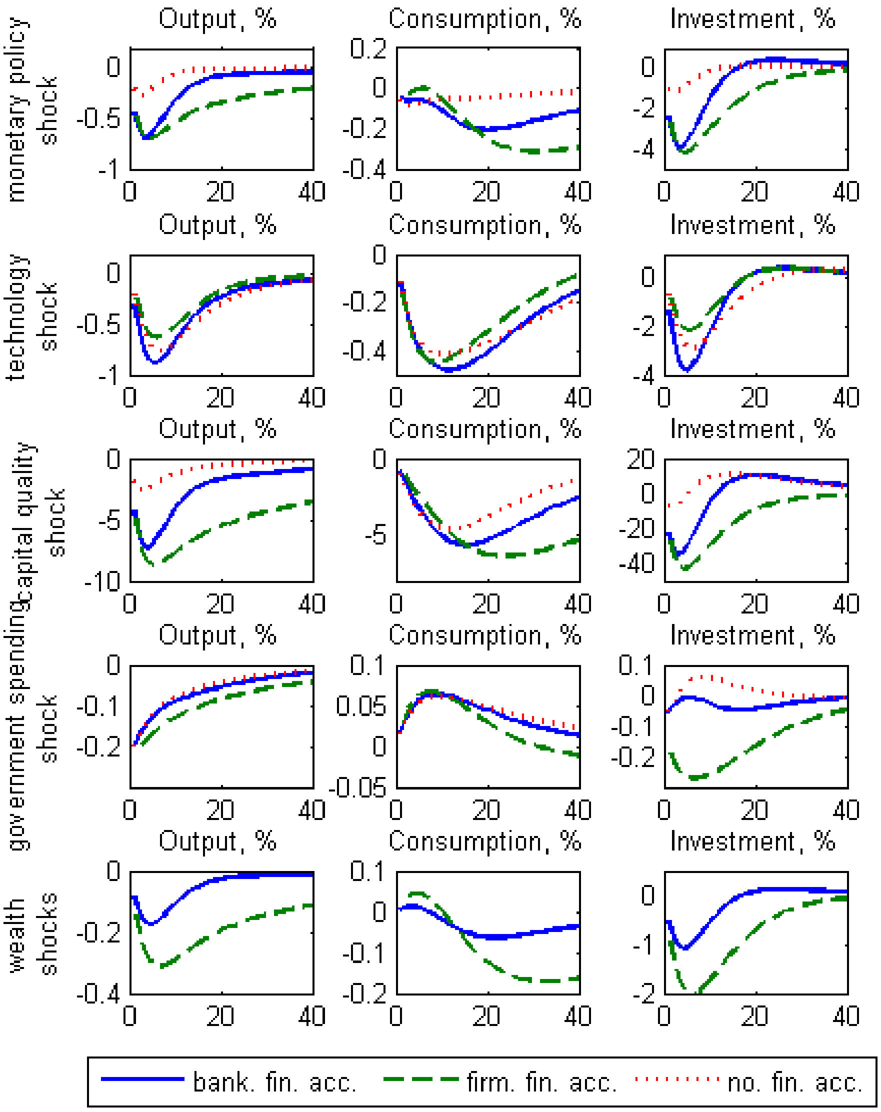

Figure 3-10. Impact of capital to net wealth ratio

3.6. Conclusion

The repercussion of the recent financial crisis varied across the countries. In specific, Estonia's GDP declined by roughly 20%, whereas U.S. and Germany experienced relatively modest economic contraction. Also, Spain still did not overcome the economic crisis, while U.S. and Germany soon rebounded surpassing the pre-crisis level of GDP in 2011. We pay attention to financial frictions as the cause of these differences because in the countries which experienced the abrupt and persistent economic slump private credit considerably increased before the crisis. We try to analyse the relationship between the economic fluctuation and financial frictions in the DSGE model. The idea is whether financial frictions in the DSGE model are crucial to account for the fluctuations of economic variables or not. To this purpose, we introduce the models which embed Bernanke et al. (1999) financial accelerator or Gertler and Karadi (2011) model into the standard DSGE framework. This chapter compares the three DSGE models - the no friction model, the firm friction model, and the bank friction model - according to the moment comparison and the impulse response functions analysis. The three models are calibrated with the U.S. data for the period 1960Q1$\sim$2015Q4. In the impulse response functions we introduce five exogenous shocks such as monetary policy shock, technology shock, capital quality shock, fiscal policy shock and wealth shock to analyse the importance of financial frictions on the magnitude and the persistence of fluctuations in economic activity.

Our main results are as follows. First of all, the introduction of financial frictions at the firm level improves the model's fit, whilst the introduction of financial frictions at the bank level shows mixed results. Thus, the firm friction model is perferred by the data according to the comparison of the second moments.

Second, in the impulse response functions the introduction of financial frictions, either at the firm level or at the financial intermediaries level, amplifies and propagates the fluctuation of economic variables. This is because exogenous shocks affect the credit market. In the firm friction model, the fall in the price of capital due to the exogenous shock reduces the firm's net worth and the external finance premium rises. Capital and investment further decrease. This amplifies the original response of output. In the bank friction model, the fall in investment due to the exogenous shock reduces the bank's asset. The bank raises the lending rate to restore the profit and the external finance premium rises. This further reduces loans. The negative impact on investment accelerates the fall of output. However, the firm friction model does not show the accelerator effect on output and investment to the technology shock. The entrepreneurial leverage causes this difference. The fall in the marginal product of capital due to the technology shock decreases investment, thus, the firm's loan. The improved leverage ratio reduces the external finance premium and affects positively both investment and output.

Third, the model with higher leverage displays more amplified responses of output and investment to the exogenous shocks. When we introduce higher values of the leverage in the subsection 3.5.4, we confirm that the response of output is extended.

Fourth, the firm friction model shows more persistent responses than the bank friction model. This is because the feedback effect of tightened financial frictions works. The fall of the firm's net worth owing to the exogenous shock makes the firm invest less. This reduces capital, hence, the firm's net worth. More contraction of the firm's net worth sequentially decreases investment and output. However, in the bank friction model the decline of investment due to the exogenous shock reduces the demand for the loan and the external finance premium falls. Thus, investment and output have not decreased any more and soon rebound.

In the impulse response functions analysis our sensitivity analysis shows that our findings are robust to the modifications of the model such as habit formation in consumption, variable capital utilisation and the monetary policy rule. To sum up, the comparison shows that the effect of shocks on macroeconomic variables is strongly dependent on the assumptions made about the type of financial frictions, and the source of shocks. However, it can be concluded that the bank friction model with high leverage may better capture the amplification of fluctuations of macroeconomic variables to the shocks and the firm friction model may better capture the persistence of fluctuations to the shocks.

Appendix

A. The linearized model

In this appendix we provide the log-linear form of the model. We represent all transformed variables by lower-case letters. We also define the steady state value of a variable by dropping the time subscript t and indicate the logarithmic deviation from its steady-state value by a hat (‘$\widehat{\ }$’).

A1. The no friction model

$$\begin{aligned} & r_k k\left(\widehat{r}_{k,t+1}+\widehat{q}_t+\widehat{k}_{t+1}\right) \\ = \; & \alpha p_m y\left(\widehat{p}_{m,t+1}+\widehat{y}_{t+1}\right)+k\left(\widehat{q}_{t+1}+\widehat{\xi}_{t+1}+\widehat{k}_{t+1}\right)-\delta k\left(\widehat{\delta}_{t+1}+\widehat{\xi}_{t+1}+\widehat{k}_{t+1}\right)\end{aligned} \tag{A1.1}$$

$$\widehat{y}_t=\widehat{a}_t+\alpha\left(\widehat{u}_t+\widehat{\xi}_t+\widehat{k}_t\right)+(1-\alpha)\,\widehat{l}_t \tag{A1.2}$$

$$\widehat{p}_{m,t}+\widehat{y}_t-\widehat{u}_t=\zeta\widehat{u}_t+\widehat{\xi}_t+\widehat{k}_t \tag{A1.3}$$

$$\widehat{i}_{nt}=i\widehat{i}_t-\delta k\left(\widehat{\delta}_t+\widehat{\xi}_t+\widehat{k}_t\right) \tag{A1.4}$$

$$\widehat{q}_t=\eta\frac{\left(\widehat{i}_{nt}-\widehat{i}_{nt-1}\right)}{i}-\beta\eta\frac{\left(\widehat{i}_{nt+1}-\widehat{i}_{nt}\right)}{i} \tag{A1.5}$$

$$k\widehat{k}_t=k\widehat{k}_{t-1}+k\widehat{\xi}_t+\widehat{i}_{nt} \tag{A1.6}$$

$$\widehat{\lambda}_t = -\frac{\left(\widehat{c}_t - h\widehat{c}_{t-1}\right)}{\left(\left(1-\beta h\right)\left(1-h\right)\right)} - \beta h\left(\widehat{c}_{t+1} - h\widehat{c}_t\right) \tag{A1.7}$$

$$\widehat{\Lambda}_t = \widehat{\lambda}_t - \widehat{\lambda}_{t-1} \tag{A1.8}$$

$$\widehat{\Lambda}_{t+1} + \widehat{r}_{t+1} = 0 \tag{A1.9}$$

$$y\widehat{y}_t = c\widehat{c}_t + i\widehat{i}_t + g\widehat{g}_t \tag{A1.10}$$

$$\widehat{p}_{m,t} + \widehat{y}_t - \widehat{l}_t = -\widehat{\lambda}_t + \chi\widehat{l}_t \tag{A1.11}$$

$$\widehat{mc}_t + \widehat{p}_{m,t} = 0 \tag{A1.12}$$

$$\widehat{\pi}_t = \frac{1}{1+\beta\gamma_P}\left(\beta\widehat{\pi}_{t+1} + \gamma_P\widehat{\pi}_{t-1} - \frac{\left(1-\beta\gamma\right)\left(1-\gamma\right)}{\gamma}\widehat{p}_{m,t}\right) \tag{A1.13}$$

$$\widehat{r}_{n,t} = \widehat{r}_t + \widehat{\pi}_{t+1} \tag{A1.14}$$

$$\widehat{r}_{n,t} = \rho\widehat{r}_{n,t-1} + \left(1-\rho\right)\left(\kappa_\pi\widehat{\pi}_t + \kappa_y\widehat{y}_t\right) + \widehat{\eta}_t^R \tag{A1.15}$$

$$\widehat{r}_{k,t} = \widehat{r}_t \tag{A1.16}$$

$$\widehat{\xi}_t = \rho_\xi \widehat{\xi}_{t-1} + \widehat{\eta}_t^\xi \tag{A1.17}$$

$$\widehat{a}_t = \rho_A \widehat{a}_{t-1} + \widehat{\eta}_t^A \tag{A1.18}$$

$$\widehat{g}_t = \rho_G \widehat{g}_{t-1} + \widehat{\eta}_t^G \tag{A1.19}$$

A2. The firm friction model

$$\begin{aligned} & r_k k \left(\widehat{r}_{k,t+1} + \widehat{q}_t + \widehat{k}_{t+1}\right) \\ = \quad & \alpha p_m y \left(\widehat{p}_{m,t+1} + \widehat{y}_{t+1}\right) + k \left(\widehat{q}_{t+1} + \widehat{\xi}_{t+1} + \widehat{k}_{t+1}\right) - \delta k \left(\widehat{\delta}_{t+1} + \widehat{\xi}_{t+1} + \widehat{k}_{t+1}\right) \end{aligned} \tag{A2.1}$$

$$\widehat{y}_t = \widehat{a}_t + \alpha \left(\widehat{u}_t + \widehat{\xi}_t + \widehat{k}_t\right) + (1-\alpha)\,\widehat{l}_t \tag{A2.2}$$

$$\widehat{p}_{m,t} + \widehat{y}_t - \widehat{u}_t = \zeta \widehat{u}_t + \widehat{\xi}_t + \widehat{k}_t \tag{A2.3}$$

$$\widehat{i}_{nt} = i \widehat{i}_t - \delta k \left(\widehat{\delta}_t + \widehat{\xi}_t + \widehat{k}_t\right) \tag{A2.4}$$

$$\widehat{q}_t = \eta \frac{\left(\widehat{i}_{nt} - \widehat{i}_{nt-1}\right)}{i} - \beta \eta \frac{\left(\widehat{i}_{nt+1} - \widehat{i}_{nt}\right)}{i} \tag{A2.5}$$

$$k\widehat{k}_t = k\widehat{k}_{t-1} + k\widehat{\xi}_t + \widehat{i}_{nt} \tag{A2.6}$$

$$\widehat{\lambda}_t = -\frac{(\widehat{c}_t - h\widehat{c}_{t-1})}{((1-\beta h)(1-h))} - \beta h(\widehat{c}_{t+1} - h\widehat{c}_t) \tag{A2.7}$$

$$\widehat{\Lambda}_t = \widehat{\lambda}_t - \widehat{\lambda}_{t-1} \tag{A2.8}$$

$$\widehat{\Lambda}_{t+1} + \widehat{r}_{t+1} = 0 \tag{A2.9}$$

$$y\widehat{y}_t = c\widehat{c}_t + i\widehat{i}_t + g\widehat{g}_t \tag{A2.10}$$

$$\widehat{p}_{m,t} + \widehat{y}_t - \widehat{l}_t = -\widehat{\lambda}_t + \chi\widehat{l}_t \tag{A2.11}$$

$$\widehat{mc}_t + \widehat{p}_{m,t} = 0 \tag{A2.12}$$

$$\widehat{\pi}_t = \frac{1}{1+\beta\gamma_P}\left(\beta\widehat{\pi}_{t+1} + \gamma_P\widehat{\pi}_{t-1} - \frac{(1-\beta\gamma)(1-\gamma)}{\gamma}\widehat{p}_{m,t}\right) \tag{A2.13}$$

$$\widehat{r}_{n,t} = \widehat{r}_t + \widehat{\pi}_{t+1} \tag{A2.14}$$

$$\widehat{r}_{n,t} = \rho\widehat{r}_{n,t-1} + (1-\rho)(\kappa_\pi\widehat{\pi}_t + \kappa_y\widehat{y}_t) + \widehat{\eta}_t^R \tag{A2.15}$$

$$\widehat{r}_{k,t+1} - \widehat{r}_{t+1} = s\left(\widehat{n}_{t+1} - \widehat{q}_t - \widehat{k}_{t+1}\right) \tag{A2.16}$$

$$\widehat{n}_{t+1} = \theta_e r_k \left(\frac{k}{n}\right)\left(\widehat{r}_{k,t+1} - \widehat{r}_t\right) + \widehat{r}_t + \widehat{n}_{t+1} + \widehat{\eta}_t^N \tag{A2.17}$$

$$\widehat{\xi}_t = \rho_\xi \widehat{\xi}_{t-1} + \widehat{\eta}_t^\xi \tag{A2.18}$$

$$\widehat{a}_t = \rho_A \widehat{a}_{t-1} + \widehat{\eta}_t^A \tag{A2.19}$$

$$\widehat{g}_t = \rho_G \widehat{g}_{t-1} + \widehat{\eta}_t^G \tag{A2.20}$$

A3. The bank friction model

$$\begin{aligned} & r_k k\left(\widehat{r}_{k,t+1} + \widehat{q}_t + \widehat{k}_{t+1}\right) \qquad \text{(A3.1)} \\ = \; & \alpha p_m y\left(\widehat{p}_{m,t+1} + \widehat{y}_{t+1}\right) + k\left(\widehat{q}_{t+1} + \widehat{\xi}_{t+1} + \widehat{k}_{t+1}\right) - \delta k\left(\widehat{\delta}_{t+1} + \widehat{\xi}_{t+1} + \widehat{k}_{t+1}\right) \end{aligned}$$

$$\widehat{y}_t = \widehat{a}_t + \alpha\left(\widehat{u}_t + \widehat{\xi}_t + \widehat{k}_t\right) + (1-\alpha)\,\widehat{l}_t \tag{A3.2}$$

$$\widehat{p}_{m,t} + \widehat{y}_t - \widehat{u}_t = \zeta \widehat{u}_t + \widehat{\xi}_t + \widehat{k}_t \tag{A3.3}$$

$$\widehat{i}_{nt} = i\widehat{i}_t - \delta k \left(\widehat{\delta}_t + \widehat{\xi}_t + \widehat{k}_t\right) \tag{A3.4}$$

$$\widehat{q}_t = \eta \frac{\left(\widehat{i}_{nt} - \widehat{i}_{nt-1}\right)}{i} - \beta\eta \frac{\left(\widehat{i}_{nt+1} - \widehat{i}_{nt}\right)}{i} \tag{A3.5}$$

$$k\widehat{k}_t = k\widehat{k}_{t-1} + k\widehat{\xi}_t + \widehat{i}_{nt} \tag{A3.6}$$

$$\widehat{\lambda}_t = -\frac{(\widehat{c}_t - h\widehat{c}_{t-1})}{((1-\beta h)(1-h))} - \beta h (\widehat{c}_{t+1} - h\widehat{c}_t) \tag{A3.7}$$

$$\widehat{\Lambda}_t = \widehat{\lambda}_t - \widehat{\lambda}_{t-1} \tag{A3.8}$$

$$\widehat{\Lambda}_{t+1} + \widehat{r}_{t+1} = 0 \tag{A3.9}$$

$$y\widehat{y}_t = c\widehat{c}_t + i\widehat{i}_t + g\widehat{g}_t \tag{A3.10}$$

$$\widehat{p}_{m,t} + \widehat{y}_t - \widehat{l}_t = -\widehat{\lambda}_t + \chi\widehat{l}_t \tag{A3.11}$$

$$\widehat{mc}_t + \widehat{p}_{m,t} = 0 \tag{A3.12}$$

$$\widehat{\pi}_t = \frac{1}{1+\beta\gamma_P}\left(\beta\widehat{\pi}_{t+1} + \gamma_P\widehat{\pi}_{t-1} - \frac{(1-\beta\gamma)(1-\gamma)}{\gamma}\widehat{p}_{m,t}\right) \tag{A3.13}$$

$$\widehat{r}_{n,t} = \widehat{r}_t + \widehat{\pi}_{t+1} \tag{A3.14}$$

$$\widehat{r}_{n,t} = \rho \widehat{r}_{n,t-1} + (1-\rho)\left(\kappa_\pi \widehat{\pi}_t + \kappa_y \widehat{y}_t\right) + \widehat{\eta}_t^R \tag{A3.15}$$

$$\begin{aligned} \nu \widehat{\nu}_t \quad = \quad & (1-\theta)\,\beta\left(r_k \widehat{r}_{k,t+1} - r\widehat{r}_{t+1}\right) + (1-\theta)\,\beta\left(r_k - r\right)\widehat{\Lambda}_{t+1} \\ & +\beta\theta x \nu\left(\widehat{\Lambda}_{t+1} + \widehat{x}_{t+1} + \widehat{\nu}_{t+1}\right) \end{aligned} \tag{A3.16}$$

$$\eta \widehat{\eta}_t = (1-\theta)\,\beta \Lambda r\left(\widehat{\Lambda}_{t+1} + \widehat{r}_{t+1}\right) + \beta\theta z\eta\left(\widehat{\Lambda}_{t+1} + \widehat{z}_{t+1} + \widehat{\eta}_{t+1}\right) \tag{A3.17}$$

$$\lambda^b \phi \widehat{\phi}_t - \phi\nu\left(\widehat{\phi}_t + \widehat{\nu}_t\right) = \eta\widehat{\eta}_t \tag{A3.18}$$

$$z\widehat{z}_t = \phi\left(r_k \widehat{r}_{k,t+1} - r\widehat{r}_{t+1}\right) + \phi\left(r_k - r\right)\widehat{\phi}_t + r\widehat{r}_{t+1} \tag{A3.19}$$

$$\widehat{x}_t = \widehat{\phi}_{t+1} - \widehat{\phi}_t + \widehat{z}_t \tag{A3.20}$$

$$\widehat{q}_t + \widehat{k}_{t+1} = \widehat{\phi}_t + \widehat{n}_t^b \tag{A3.21}$$

$$\widehat{n}_t^b = \frac{n_e^b}{n^b}\widehat{n}_{et}^b + \frac{n_n^b}{n^b}\widehat{n}_{nt}^b \tag{A3.22}$$

$$\widehat{n}_{et}^b = \widehat{z}_t + \widehat{n}_{t-1}^b \tag{A3.23}$$

$$\widehat{n}_{nt}^b = \widehat{q}_t + \widehat{k}_t + \widehat{\xi}_t \tag{A3.24}$$

$$\widehat{\xi}_t = \rho_\xi \widehat{\xi}_{t-1} + \widehat{\eta}_t^\xi \tag{A3.25}$$

$$\widehat{a}_t = \rho_A \widehat{a}_{t-1} + \widehat{\eta}_t^A \tag{A3.26}$$

$$\widehat{g}_t = \rho_G \widehat{g}_{t-1} + \widehat{\eta}_t^G \tag{A3.27}$$

Chapter 4

The Effects of alternative fiscal consolidation strategies

4.1. Introduction

In the recent financial crisis, many countries around the world have taken extraordinary fiscal measures in order to stimulate their economies with the hope of boosting demand and limiting job losses. The launch of large-scale fiscal stimulus packages has triggered a lively debate in both academic and policy circles about the effectiveness of fiscal policy. However, there is no consensus among economists on the effects of fiscal policy on GDP (Zubairy, 2014). On the one hand, some researches find that the fiscal stimulus is effective at the zero lower bound (e.g. Woodford, 2010; Christiano et al., 2011; Eggertsson, 2011; Erceg and Linde, 2014). On the other hand, other works insist that the effects of the fiscal stimulus programs are reduced because of significant implementation lags and financing problems (e.g. Cogan et al., 2010; Drauzburg and Uhlig, 2011)

Apart from the aggregate effectiveness of fiscal stimulus, the large fiscal stimulus packages and a slow ensuing recovery have put severe strains on the fiscal positions of many industrial countries. Figure 4-1 displays the general government gross debt to GDP ratio in selected countries from 2000 to 2018.[128] Ireland and Spain show a fall in the debt ratio before the crisis, whereas the ratio slightly increases in the U.S., the U.K., Greece, and Portugal. However, the government debt begins to deteriorate rapidly in all countries without exception after the financial crisis. The debt ratio is predicted to decrease mildly around 2015, but it is still higher than the pre-crisis level. Since most developed countries

[128] Its source is the IMF World Economic Outlook (2013). The values after 2012 are forecasts.

have fiscal pressure in social security related to the aging problem, increasing public debt may jeopardise economic stability (IMF, 2009). Furthermore, as shown in some countries' example, public debt surge can cause a sharp increase in sovereign debt spread.[129] They, thus, cannot help taking immediate and significant actions to decrease public debt. In this context, how public debt can be reduced has become a main policy issue in most countries and many researchers become interested in this topic.

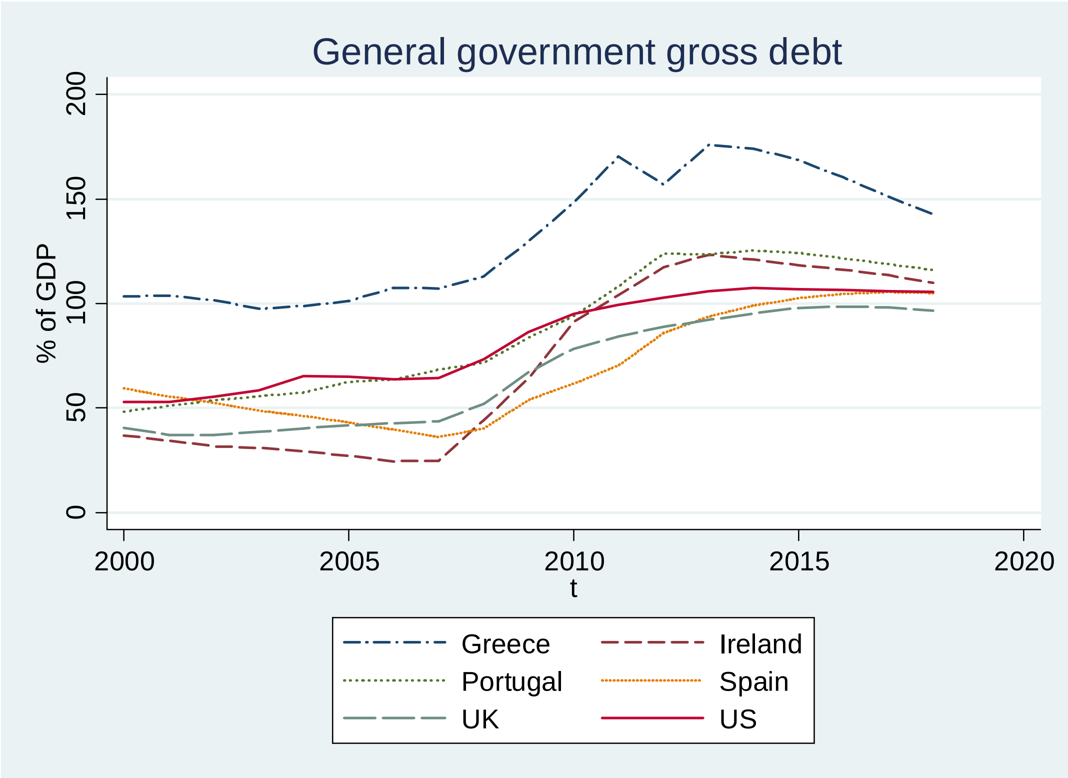

Figure 4-1. General government gross debt in some countries

Most developed countries are already reducing their public debt. However, their 'austerity' has varied across nations. The Economist (May 26, 2012)[130] shows that fiscal consoli-

[129] For example, in 2006 Greece's debt to GDP ratio stood at 108%, and the spread of its 10-year bond at 409 basis points (bps). In 2010, Greece's debt to GDP ratio was 148%, and the 10-year spread was 909 bps.

[130] The Economist uses forecast change in government primary balance 2011-2013 according to the OECD's

dation is mainly done by cutting government spending. For example, Greece is supposed to cut the government spending in order to decrease public debt. European countries such as the U.K., Spain, Portugal, and Ireland follow a similar pattern. However, Italy largely adopts the revenue increase for fiscal consolidation. The U.S., and Australia take a similar position.

We analyse the effects of an array of different fiscal actions to consolidate public debt using an open economy dynamic stochastic general equilibrium (DSGE) model with a variety of fiscal instruments. Many previous papers examine the effects of government expenditure cut and tax hike in the DSGE model (Stahler and Thomas, 2012; Almeida et al., 2013; Cogan et al., 2013). Above all, the main structure of this model is based on the extended version of the ECB's New Area-Wide Model (NAWM) described by Coenen et al. (2013).[131] However, we develop this framework for fiscal policy analysis in three important ways. First, our model builds in a new dimension by endogenising government bond premia. The risk premium of government bond is positively associated with the expected debt to GDP ratio (Laubach, 2009; 2010). The relationship between two variables becomes more manifest during the recent financial crisis (Laubach, 2010; Schuknecht, 2010). Some euro area countries case, especially, suggests that we need to consider the effects of variable risk premia of government bonds on economic variables in the process of fiscal consolidation. Second, our model has a more extended fiscal policy block. We consider both expenditure and revenue based policies to conduct the fiscal consolidation strategy. Specifically, the expenditure based policy includes a cut in government consumption, government investment, and lump-sum transfers, whereas the revenue based policy covers a

Economic Outlook.

[131] The basic NAWM is an an open-economy DSGE model estimated for the euro area. Christoffel et al. (2008) describe the model in detail. Coenen et al. (2013) extend the basic NAWM as follows. First, households fall into two categories: Ricardian and non-Ricardian households. Second, a complementarity between government consumption and private consumption is assumed. Third, a time-to-build technology for public capital is adopted. Fourth, fiscal instruments react to changes in public debt and output.

hike in consumption tax, wage income tax, and capital income tax.[132] Therefore, we can simulate diverse fiscal measures which are implemented to decrease government debt and quantify their consequences. Third, we consider a relatively rich description of fiscal policy rules. Following Bohn (1998) most papers on fiscal policy assume the fiscal rule to prevent the public debt from increasing infinitely. In particular, since allowing more fiscal tools to respond to public debt in the model is the best suitable for the data according to Leeper et al. (2010), we define fiscal policy rules on all fiscal instruments.

Our another contribution is a variety of robustness checks within the model. First of all, we provide evidence on how the endogenous risk premium of government debts has consequences for the stimulative effects of fiscal consolidation. For this, we analyse whether the endogenous risk premium causes the difference in the effect of fiscal consolidation or not. Also we simulate different fiscal rules. Unlike monetary policy, since there is no widely accepted specification for the fiscal policy rule, this chapter not only incorporates dynamic adjustments of fiscal instruments in response to the level of economic activity and to the state of government debt, but also tries to understand how the effects of fiscal consolidation strategies depend on the interaction with the fiscal policy rule. In additon, we test the consumption substitution effect mentioned by Benk and Jakab (2012). According to a complementary relationship between private consumption and public consumption the effect of fiscal policy differs. However, their relationship varies depending on the paper. Some papers find that it is substitute (Forni et al., 2010), while others find that it is complementary (Leeper et al., 2009). Thus, we analyse the effects of the complementarity of both private consumption and government consumption on fiscal consolidation with different parameterisations.

The main results can be summarised as follows. For the expenditure based policies,

[132] Coenen et al. (2013) introduce capital income tax in their model, but the tax rate is constant. However, we allow the capital income tax rate to change.

the cut in government consumption is the most damaging in the short run. The cut in government investment has smaller contractionary effects than the cut in government consumption unlike previous literature. This is related to the complementarity between government consumption and private consumption. The reduction in lump-sum transfers has relatively small negative effect on output because it is not a determinant of output. With regard to the tax hike, we find that the hike in consumption tax has a larger negative effect on output than other distortionary taxes in the short run. However, negative effects of other tax hikes are bigger than consumption tax in the long run. In particular, the increase in capital income tax has a permanent dampening effect on output by impeding private investment. Regarding robustness tests, the response of macroeconomic variables to the consolidation strategies under alternative risk premium schemes and alternative fiscal policy rules varies considerably, especially for distortionary taxes.

The remainder of this chapter is structured as follows. In Section 4.2 we summarise previous related literature. Section 4.3 presents a detailed description of the model, while Section 4.4 reports calibration of parameters and steady state values of variables. In Section 4.5 we investigate the effects of alternative fiscal consolidation strategies. Section 4.6 provides robustness checks regarding other types of models and parameterisations. Finally, Section 4.7 concludes.

4.2. Literature review

4.2.1. Fiscal consolidation

Previous literature examining fiscal consolidation can be divided into three categories. First, some works compare the effects of fiscal policy shocks through the cut in government expenditures and the rise in tax rates (Stahler and Thomas, 2012; Almeida et al., 2013; Cogan et al., 2013). Stahler and Thomas (2012) find that a reduction in the public sector wage bill is the least damaging, whereas a cut in government investment is the most damaging.[133] Almeida et al. (2013) find that in a small euro area economy like Portugal, fiscal consolidation with a permanent reduction in government expenditure causes short-run costs, whereas output increases and welfare improves in the long run. In addition, they show that fiscal consolidation involving a tax reform which changes the tax burden from wage income to consumption raises its gain. Cogan et al. (2013) find that GDP increases in both the short run and the long run according to fiscal consolidation plans with the mix of government expenditure reductions and labour tax cuts in the U.S.[134]

Second category is the so-called narrative approach that examines a wide range of policy documents to identify fiscal adjustment motivated by a desire to reduce the budget deficit (Leigh et al., 2010; Guajardo et al., 2014; Alesina et al., 2015). Guajardo et al. (2014)[135] and Alesina et al. (2015) focus on 17 developed countries during 1978-2009. In addition, Alesina et al. (2015) construct fiscal plans with a 3-years horizon. This method is based on the belief that the simulation of a multi-year fiscal plan is proper than of individual fiscal shocks to evaluate the effects of fiscal consolidation. The two papers show similar results. These investigations find that fiscal consolidation generally has contractionary effects on output. They also suggest that the increase in taxation is much more costly, in terms of output losses, than the cut in government spending. The two papers agree with the fact that private investment makes this difference between the two types of fiscal consolidation. However, they show different views on the importance of the monetary policy. Guajardo et al. (2014) suggest that more negative effect of the tax hike can be explained by accompanying monetary policy. In particular, the degree of monetary easing

[133] Stahler and Thomas (2012) develop a medium scale DSGE model with a two-country monetary union for fiscal policy simulations. They calibrate the model to Spain and the European Monetary Union.

[134] They present three causes of this "expansionary austerity": (i) lower expected taxes due to the reduction of government expenditure increase consumption even in the short run. (ii) the present cut in the labour tax rate stimulates employment and production. (iii) a reduction in exchange rate raises net exports.

[135] Leigh et al. (2010) are mostly similar to Guajardo et al. (2014).

is higher following spending cuts that following tax hikes. However, Alesina et al. (2015) reject this explanation through both the constraint of the Euro area and a counterfactual experiment of zero policy rate. They insist that this is because Guajardo et al. (2014) is based on the analysis of isolated shocks rather than plans.

Lastly, other papers analyse the consequences of a permanent reduction in the debt ratio (Coenen et al., 2008; Forni et al., 2010; Erceg and Linde, 2013). Specifically, Coenen et al. (2008) examine the effects of the permanent cut in the targeted debt ratio through expenditure or revenue-based policy.[136] They find that fiscal consolidation causes macroeconomic costs such as declines in output and consumption in the short run. Among various fiscal strategies, the negative effect of the government consumption cut is larger than the transfers cut. However, the macroeconomic effects become positive in the long run when the resulting fiscal surplus due to the reduction in government debt is used to reduce distortionary taxes. Forni et al. (2010) find that the permanent reduction of both expenditures and taxes is the best fiscal consolidation scenario by estimating the macroeconomic impacts of permanently decreasing the debt ratio in Germany and Belgium. Erceg and Linde (2013) examine the effects of a 25% reduction in the long run debt target using a two country DSGE model. Their results vary depending on the constraints on monetary policy and exchange rate adjustment. Under an independent monetary policy, government spending cuts are much less costly than tax hikes. This is because the government spending cut lowers the interest rate further and causes exchange rate depreciation, whilst the labour tax hike induces a relatively modest fall of the interest rate and exchange rate appreciation. However, in a currency union, the labour tax hike has smaller negative effects on the economy than the government spending cut in the short run. This is caused by two

[136] They use a two country open economy model of the euro area, which is based on the NAWM. In the model, expenditure-based consolidation includes transfers and government consumption. In addition, revenue-based consolidation operates through changes in either consumption tax or labour income tax.

factors - a constraint on interest rate adjustment and fixed nominal exchange rates. Even so, because real interest rates and real exchange rates gradually move toward their flexible price levels, the tax hike is more costly in the long run. This result, thus, means trade-offs between the short and the long-run effects of fiscal consolidation strategies.

We adopt the first approach in this chapter and compare how the effects of fiscal consolidation change depending on fiscal policy tools. Especially, we focus on which fiscal instrument is the least damaging impact on output and the most effective to reduce public debt.

4.2.2. Fiscal instruments

All models investigating fiscal consolidation have in common a consumption tax, a wage income tax and lump-sum taxes on the revenue side as well as government consumption and lump-sum transfers on the expenditure side.[137] However, the specific structures of fiscal block are different depending on the characteristics of models. In Forni et al. (2010), total government revenues are composed of four taxes including the above and capital income tax. They add public employment in government expenditures, but do not consider government investment. Stahler and Thomas (2012) segment the government expenditures side by differentiating public consumption, public investment, and the public sector wage bill. On the other hand, Almeida et al. (2013) consider an employers' social security contribution and corporate income tax on the revenues side. Cogan et al. (2013) also introduce a variety of taxes, but the expenditure side is relatively simple by only considering government consumption and transfers.

Based on these papers, our model has a wider array of fiscal instruments on both the expenditure and revenue side. In particular, the government finances its expenditure

[137] An exception is Erceg and Linde (2013). They consider only two fiscal instruments: a wage income tax hike and a government spending cut.

requirements with lump-sum tax and three types of distortionary taxes, over consumption, wage income and capital income. We consider social security contribution of both employees and employers, but do not analyse their effect because it is similar to wage income tax. In regard to the government expenditure, we take account of three instruments such as government consumption, government investment, and lump-sum transfers. Based on the extended fiscal framework, we examine the transmission mechanism of these fiscal measures and compare their relative merits.

4.2.3. Fiscal rule

Bohn (1998) finds on the basis of U.S. data that the government takes corrective actions by increasing the primary budget surplus in response to the accumulation of public debt. Since then most research associated with fiscal policy has assumed a fiscal rule to prevent the debt ratio from increasing infinitely. Leeper et al. (2010) emphasise the importance of the fiscal rule in order to accurately predict the impacts of fiscal policy stating "Understanding which fiscal instruments have historically responded to debt and how quickly they have done so is essential to accurately predict the impacts of fiscal policy."

However, since there is no widely accepted specification for the fiscal policy rule, there are various forms of the fiscal rule. Some literature only adjust a fiscal instrument following the rule (Coenen et al., 2008; Furceri and Mourougane, 2010; Erceg and Linde, 2010; Almeida et al., 2013; Cogan et al., 2013). Coenen et al. (2008) suppose a simple rule that the government changes one among fiscal instruments - i) on the expenditure side transfers and government consumption ii) on the revenue side consumption tax and labour income tax - according to debt. Furceri and Mourougane (2010) rely on a lump-sum tax which is less detrimental to growth because it does not affect saving and labour supply decision. In their set-up, the lump-sum tax is adjusted according to the debt ratio. Erceg and Linde (2010) introduce a fiscal rule that labour income tax responds to both the debt and the deficit. Almeida et al. (2013) consider a fiscal rule which one of fiscal instruments responds to both tax revenues and the debt. Lump-sum taxes are adjusted according to the debt in Cogan et al. (2013). Erceg and Linde (2013) assume that government spending or labour income tax is adjusted according to government debt and deficit.

Other papers further develop the fiscal rule and allow all fiscal instruments to be adjusted (Forni et al., 2010; Leeper et al., 2010). For example, Forni et al. (2010) assume that all fiscal items respond to the debt, public deficit, and GDP growth. Leeper et al. (2010) not only specify fiscal rules for more instruments, but also estimate four scenarios' fitness for the U.S. data.[138] According to them, the model allowing more fiscal instruments to respond to debt is the best suitable for the time series data.

Like this, there is no generally accepted fiscal policy rule. Thus, we consider various fiscal rules. Our model basically assumes that government expenditures are adjusted according to the variation of output and government debt. However, tax rates only depend on the debt ratio because the coefficients on output gap are insignificant according to Forni et al. (2009). Moreover, we simulate alternative fiscal rules as a robustness test following Leeper et al. (2010). One rule is that only the government expenditures are adjusted and the other is that only the distortionary taxes are adjusted.

4.2.4. Non-Keynesian effect

If indirect responses of private consumption and private investment overwhelm a direct negative effect of fiscal consolidation, the economy becomes expansionary in spite of fiscal consolidation. This favorable effect is labelled as a "non-Keynesian effect" in some papers because it contrasts with the traditional Keynesian view. Benk and Jakab (2012) present some channels to explain possible non-Keynesian effects. Among them, the mechanisms

[138] Four scenarios of the fiscal rule are as follows: (i) four items such as government spending, lump-sum transfers, capital income tax, and labour income tax respond to debt (ii) only capital and labour income taxes respond (iii) only lump-sum transfers respond (iv) only government spending responds.

which are related to this chapter are expectation channel, risk premium channel, and consumption substitution effects.

4.2.4.1. Expectation channel

Since the present fiscal consolidation reduces the probability of a future fiscal contraction, households increase their consumption (Benk and Jakab, 2012). However, this expectation effect is limited under a marked fraction of non-Ricardian households[139]. Many previous research departs from standard neoclassical models and adopts non-Ricardian households (Coenen and Straub, 2005; Gali et al., 2007; Furceri and Mourougane, 2010; Erceg and Linde, 2010; Coenen et al., 2013).[140] An increase in the share of non-Ricardian households raises the negative impact of fiscal consolidation on output. For example, Erceg and Linde (2010) find that the negative impact of a coordinated cut in government expenditures is larger when the ratio of non-Ricardian households is higher. We follow the assumption of the two types of households in the model.

4.2.4.2. Endogenous risk premium of bonds

The fall in the debt ratio through fiscal consolidation may reduce a risk default premium of government bonds. A decrease in real interest rate associated with this effect stimulates private investment and increases output (Benk and Jakab, 2012). Many previous literature has examined the effects of fiscal variables on the risk premium of government bonds, but their results are mixed. However, some papers find significant results. For example, using U.S. data Laubach (2009) finds that one percentage point increase in the deficit to

[139] Households who do not have any assets, and just consume their current labour income are called as various names: non-Ricardian households, rule-of-thumb households, hand-to-mouth households. On the other hand, households who have full access to capital markets are called as Ricardian or optimising households. We use Ricardian and non-Ricardian households throughout this chapter.

[140] Ricardian equivalence does not hold with the two types of households since non-Ricardian households do not anticipate the future tax burden (Coenen et al., 2008).

GDP ratio raises the risk premium by about 25 basis points, and one percentage point increase in the debt ratio adds 3 to 4 basis points to the risk premium. Laubach (2010) analyses cross-sectional relationships between fiscal stance and the risk premium using a panel of 10 euro area countries and finds that the effect of fiscal position depends on circumstances. Specifically, before 2008 a one percentage point increase in the surplus to GDP ratio decreases the risk premium by at most 3 basis points, and the effect of the debt ratio is 0.3 basis points at most. However, during the recent financial crisis, the effect becomes larger significantly. A one percentage point reduction in the surplus ratio increases the risk premium by 20 basis points, and a percentage point increase in the debt ratio increases it by 0.8 basis points. Schuknecht et al. (2010) also find that coefficients for the deficit ratio are 3-4 times higher and for the debt ratio 7-8 times higher during the recent financial crisis than earlier using the data of 15 EU countries.[141]

Previous work develops DSGE models with endogenous government bond yields to examine the effects of fiscal policy. The real interest rate is allowed to increase with a rise in the debt target in Coenen et al. (2008).[142] Furceri and Mourougane (2010) develop a closed economy DSGE model with endogenous government bonds yields. Specifically, the risk premium reflects market expectations on public debt (or public deficit) and it is calibrated following Laubach (2009). Erceg and Linde (2010) also allow credit spreads to depend inversely on the deficit and the debt to examine a possibility of output expansion by fiscal consolidation. On the other hand, Almeida et al. (2013) simply model the risk premium as a shock following an AR (1) process.

Following these approaches, we allow for the endogenous response of the risk premium.

[141] Specifically, one percentage increase in the deficit ratio raises the spread by 3.49 basis points before the crisis, but the effect is 12.64 basis points during the crisis. Similarly, an increase in the debt ratio by one percentage point results in the risk premium by 1.25 basis points during the crisis, whereas the effect is 0.16 basis points before the crisis.

[142] They use relatively a small coefficient implying that a one percentage-point fall in the debt ratio leads to a one basis point reduction in the interest rate.

In order to capture marked increases of the risk premium in a number of euro area countries during the recent financial crisis, we assume that the risk premium reacts to the future path of the debt ratio. As a robustness test, we examine how the impact of various fiscal consolidation strategies on macroeconomic variables changes when the endogenous risk premium is omitted.

4.2.4.3. Consumption substitution effects

Bouakez and Rebei (2007) analyse the consequences of a complementary relationship between private consumption and public consumption on the response of economic variables to a positive government spending shock. According to their results, lower values of the elasticity of substitution tend to further increase private consumption. Specifically, when the elasticity is set to 1, the government spending shock causes a larger crowding-out effect on private consumption. However, when the elasticity is 0.25, the complementarity effect dominates the negative wealth effect and private consumption is crowded-in in spite of the increase of government spending. If government consumption has a substitution effect with private consumption, a cut in government consumption may increase private consumption, thus, output.

Some models have incorporated a substitutability between private and public consumption. For example, Forni et al. (2010) also assume higher degree of substitutability between private and public consumption. However, other literature finds that the relationship between government consumption and private consumption may be complementary (Leeper et al., 2009; Coenen et al., 2013). In this case, fiscal consolidation through the cut in government consumption further worsens the economic situation.[143]

[143] Ni (1995) estimates substitutability between private consumption and government consumption and find that inconclusive result. Specifically, the estimates depend on the specification of utility function and the measurement of interest rates.

In our model, government consumption is assumed to have a complementary relationship with private consumption following Coenen et al. (2013). In addition, we test the robustness of our results with different values of complementarity between private and government consumption.

4.3. The model (Coenen et al., 2013)

This section describes our model. The model is based on Coenen et al. (2013), but it is a little different. Many previous papers examine the effects of fiscal consolidation utilising the DSGE model (Stahler and Thomas, 2012; Almeida et al., 2013; Cogan et al., 2013). Above all, this model is based on the extended version of the ECB's NAWM described by Coenen et al. (2013). The basic structure of the model is as follows. There are two countries, a home country and a foreign country. We focus mainly on the home country. In the home country, there are households, firms, a government. Households are divided into two types, Ricardian and non-Ricardian households. There are two forms of firms. Specifically, within the home country, domestic intermediate goods firms produce wholesale goods that are sold to both domestic and foreign markets using labour and capital under monopolistic competition. And domestic final goods producers combine domestic intermediate goods and imported intermediate goods into a private consumption good, a private investment good, and a public consumption good in a perfectly competitive market. Finally, the government is composed of a fiscal authority which implements fiscal policy and a monetary authority which sets the nominal interest rate.

However, we develop the framework for fiscal policy analysis in three important ways. First, our model builds in a new dimension by endogenising government bond premia as a function of the expected debt to GDP ratio. This allows us to examine the effects of variable risk premia of government bonds on economic variables in the process of fiscal consolidation.

Second, our model has a more developed fiscal policy block. On the government expenditure side, we include the cut in government consumption, government investment and lump-sum transfers. On the fiscal revenues side, we cover the hike in consumption tax, wage income tax and capital income tax. Therefore, we can simulate diverse fiscal measures which are implemented to decrease government debt and quantify their consequences. Third, we develop a relatively rich description of fiscal policy rules. Specifically, we define fiscal policy rules on all fiscal instruments because allowing more fiscal measures to respond to public debt in the model is the best suitable for the data following Leeper et al. (2010).

In this section we describe the households, the domestic firms, and the government shortly. Appendix presents their detailed set-up and structures of the foreign firms.

4.3.1. Households

Households consume consumption goods and investment goods and supply differentiated labour services to domestic firms. We introduce non-Ricardian households in the form of rule-of-thumb consumers, following Gali et al. (2007). To this end, we assume that there is a continuum of households, indexed by $h \in [0,1]$, which is split into two groups: (i) Ricardian households, indexed by $i \in (\omega, 1]$, who accumulate physical capital and have access to financial markets and (ii) non-Ricardian households, indexed by $j \in [0, \omega)$, who do not. As a result, the former group of households can smooth consumption intertemporally by trading domestic and foreign bonds, whereas the latter simply consume their after-tax disposable income.

Furthermore, we suppose that government consumption is a complement with private consumption following Leeper et al. (2009), as in Coenen et al. (2013). The consumption bundle $\widetilde{C}_{h,t}$ of household h is given by

$$\widetilde{C}_{h,t} = (\alpha_G^{1/\nu_G} C_{h,t}^{(1-1/\nu_G)} + (1-\alpha_G)^{1/\nu_G} G_t^{(1-1/\nu_G)})^{\nu_G/(\nu_G-1)} \tag{4.1}$$

where $\alpha_G \in [0,1]$ is a share of the household's consumption of private goods, $C_{h,t}$, $\nu_G > 0$ measures the elasticity of substitution between private consumption, $C_{h,t}$, and government consumption, G_t.[144]

4.3.1.1. Ricardian households

Each Ricardian household i derives its utility from purchases of the private consumption good, $C_{i,t}$ and supplies of the labour services provided to firms, $N_{i,t}$. The household's lifetime utility function takes the form

$$E_t \left\{ \sum_{k=0}^{\infty} \beta^k \epsilon^C_{t+k} \left[\ln(\widetilde{C}_{i,t+k} - \kappa \widetilde{C}_{t+k-1}) - \frac{1}{1+\zeta} (N_{i,t+k})^{1+\zeta} \right] \right\} \tag{4.2}$$

where $\beta \in (0,1)$ is a discount rate, $\kappa \in (0,1)$ is an external habit formation parameter in consumption, $\widetilde{C}_{t-1}$ is the lagged economy-wide aggregate consumption bundle, and $\zeta > 0$ is an inverse Frisch elasticity of labour supply. The variable ϵ^C_t is also a general preference shock and follows an autogressive process given by

$$\ln \epsilon^C_t = \rho_{\epsilon^C} \ln \epsilon^C_{t-1} + \eta^{\epsilon^C}_t, 0 < \rho_{\epsilon^C} < 1, \eta^{\epsilon^C}_t \sim N(0, \sigma_{\epsilon^C}) \tag{4.3}$$

Then their budget constraint is given by

$$\begin{aligned} & (1+\tau^C_t)P_{C,t}C_{i,t} + P_{I,t}I_{i,t} + \frac{B_{i,t+1}}{R_{g,t}} + \frac{S_t B^*_{i,t+1}}{[1-\Gamma_{B^*}(s_{B^*,t+1})]R^*_t} + T_{i,t} \\ = \; & (1-\tau^N_t - \tau^{W_h}_t)W_{i,t}N_{i,t} + [(1-\tau^K_t)R_{K,t} + \tau^K_t \delta P_{I,t}]K_{i,t} + (1-\tau^D_t)D_{i,t} + TR_{i,t} \\ & + B_{i,t} + S_t B^*_{i,t} + \Xi^B_{i,t} + \Xi^{B*}_{i,t}, \end{aligned} \tag{4.4}$$

[144] $\nu_G \to 0$ means that government and private consumptions are perfect complements; $\nu_G \to \infty$ indicates that the two are perfect substitutes; and $\nu_G \to 1$ gives the Cobb-Douglas case.

where $P_{C,t}$ and $P_{I,t}$ denote the prices of a unit of the private consumption good $C_{i,t}$ and the investment good $I_{i,t}$, respectively. $W_{i,t}$ indicates the wage rate for the labour services provided to firms, $N_{i,t}$; the capital services, $K_{i,t}$, is rented to firms for the rental rate, $R_{K,t}$; and $D_{i,t}$ represents the dividend paid by the household-owned firms. $R_{g,t}$[145] and R_t^* denote the respective returns on domestic government bonds, $B_{i,t+1}$, and internationally traded foreign bonds, $B_{i,t+1}^*$.[146] The latter are denominated in foreign currency and, thus, their domestic value depends on the nominal foreign exchange rate S_t. τ_t^C indicates the consumption tax rate that is levied on the household's consumption purchases; and τ_t^N, τ_t^K, and τ_t^D are the tax rates levied on the different sources of the households's income; wage income, capital income, and dividend income, respectively. We assume that the physical capital depreciation, $\delta P_{I,t} K_{i,t}$, is exempted from taxation. $\tau_t^{W_h}$ is the household's contribution to social security. The term $T_{i,t}$ and $TR_{i,t}$ denote lump-sum taxes and lump-sum transfers, respectively. When taking a position in the international bond market, the household encounters an external financial intermediation premium.

$$\Gamma_{B^*}(s_{B^*,t+1}) = \gamma_{B^*}\left(\exp\left(\frac{S_t B_{t+1}^*}{P_{Y,t}Y_t}\right) - 1\right) \tag{4.5}$$

where $s_{B^*,t+1} = S_t B_{i,t+1}^* / P_{Y,t} Y_t$ is holdings of internationally traded foreign bonds expressed in domestic currency relative to domestic nominal output.[147] The incurred intermediation premia are rebated in the form of lump-sum payments, $\Xi_{i,t}^B$ and $\Xi_{i,t}^{B*}$.

[145] One of the main features of the model is that Ricardian households make economic decisions by the interest rate on government bonds rather than the policy rate. The spread between the returns on government bonds and the policy rate is a function of the level of government debt. The central bank sets the policy interest rate by a Taylor rule (4.36). The interest rate on government bonds is decided by the endogenous risk premium mechanism (4.37).

[146] Coenen et al. (2013) assume that there is a wedge between the nominal interest rate set by the monetary authority and the return acquired by the households by an exogenous domestic risk premium shock. Since this wedge is invariable over time, capital income tax rate is also constant. However, our model leaves out this wedge and allows for changes of capital income tax rate.

[147] This specification implies that, in the steady-state, households have no incentive to hold foreign bonds and the economy's net foreign asset position is zero (Christoffel et al., 2008).

Finally, the law of motion for capital stock is given by

$$K_{i,t+1} = (1-\delta)K_{i,t} + \epsilon_t^I \left(1 - \Gamma_I \left(I_{i,t}/I_{i,t-1}\right)\right) I_{i,t}, \tag{4.6}$$

where δ is the depreciation rate of the capital stock and ϵ_t^I is an investment-specific technology shock. An adjustment cost function in investment, $\Gamma_I\left(I_{i,t}/I_{i,t-1}\right)$, is given by the form

$$\Gamma_I\left(I_{i,t}/I_{i,t-1}\right) = \frac{\gamma_I}{2}\left(\frac{I_{i,t}}{I_{i,t-1}} - g_z\right)^2 \tag{4.7}$$

where $\gamma_I > 0$ is the adjustment cost parameter in investment and g_z represents the economy's trend growth rate in the steady state.

Maximisation of households' preferences (4.2) subject to the budget constraint (4.4) gives the following first order conditions with respect to $\widetilde{C}_{i,t}$, $I_{i,t}$, $K_{i,t+1}$, $B_{i,t+1}$, and $B^*_{i,t+1}$:

$$\widetilde{C}_{i,t} : (1+\tau_t^C)\Lambda_{i,t} = \epsilon_t^C(\widetilde{C}_{i,t} - \kappa\widetilde{C}_{t-1})^{-1} \tag{4.8}$$

$$\begin{aligned} I_{i,t} \quad : \quad p_{I,t} = {} & Q_{i,t}\epsilon_t^I\left(1 - \Gamma_I\left(I_{i,t}/I_{i,t-1}\right) - \Gamma_I'\left(I_{i,t}/I_{i,t-1}\right)\frac{I_{i,t}}{I_{i,t-1}}\right) \\ & + \beta E_t\left[\frac{\Lambda_{i,t+1}}{\Lambda_{i,t}} Q_{i,t+1}\epsilon_{t+1}^I \Gamma_I'\left(I_{i,t}/I_{i,t-1}\right)\frac{I_{i,t}^2}{I_{i,t-1}^2}\right] \end{aligned} \tag{4.9}$$

$$K_{i,t+1} : Q_{i,t} = \beta E_t\left[\frac{\Lambda_{i,t+1}}{\Lambda_{i,t}}((1-\delta)Q_{i,t+1} + (1-\tau_{t+1}^K)r_{K,t+1} + (\tau_{t+1}^K\delta - (1-\tau_{t+1}^K))p_{I,t+1}\right] \tag{4.10}$$

$$B_{i,t+1} : \beta R_{g,t} E_t \left[\frac{\Lambda_{i,t+1}}{\Lambda_{i,t}} \Pi_{C,t+1}^{-1} \right] = 1 \tag{4.11}$$

$$B_{i,t+1}^{*} : \beta(1 - \Gamma_{B^{*}}(s_{B^{*},t+1})) R_t^{*} E_t \left[\frac{\Lambda_{i,t+1}}{\Lambda_{i,t}} \Pi_{C,t+1}^{-1} \frac{S_{t+1}}{S_t} \right] = 1 \tag{4.12}$$

where $\Lambda_{i,t}/P_{C,t}$ and $\Lambda_{i,t}Q_{i,t}$ denote the Lagrangian multiplier associated with the budget constraint (4.4) and the capital accumulation equation (4.6)[148], respectively, $p_{I,t} = P_{I,t}/P_{C,t}$ is the relative price of the investment good, $r_{K,t+1} = R_{K,t}/P_{C,t}$ is the real rental rate of capital, and $\Pi_{C,t+1} = P_{C,t+1}/P_{C,t}$ the inflation rate of the consumption good. In equilibrium, with all households choosing identical allocations, the combination of the first-order conditions with respect to the holdings of domestic and internationally traded bonds, (4.11) and (4.12), yields a risk-adjusted uncovered interest parity (UIP) condition, reflecting the assumption that the return on internationally traded bonds is subject to an exteranl financial intermediation premium.

4.3.1.2. Non-Ricardian households

Each non-Ricardian household j has the same utility function, equation (4.2), with the Ricardian household. However, the non-Ricardian households fully consume after-tax disposable income and lump-sum transfers because they do not invest in physical capital and trade bonds. Thus, their budget constraints are given by

$$(1 + \tau_t^{C}) P_{C,t} C_{j,t} + T_{j,t} = (1 - \tau_t^{N} - \tau_t^{W_h}) W_{j,t} N_{j,t} + TR_{j,t} \tag{4.13}$$

[148] Here, $\Lambda_{i,t}$ represents the shadow price of a unit of the consumption good; that is, the marginal utility of consumption out of income. Similarly, $Q_{i,t}$ measures the shadow price of a unit of the investment good; that is, Tobin's Q.

4.3.1.3. Wage setting

We assume that monopolistically competitive unions set the wages for the two types households following Coenen and Straub (2005), as in Coenen et al. (2013). Each firm also decides how much labour to hire given the wage, and allocate labour uniformly across households, independently of their type. Therefore, the wages for both types of households are the same, $W_{i,t} = W_{j,t} = W_t$, and the amounts of labour for the two types of households are also identical, $N_t = N_{i,t} = N_{j,t}$.

Each household h supplies its differentiated labour inpus $N_{h,t}$ in monopolistically competitive markets. Wage is adjusted according to staggered wage contracts a la Calvo (1983). Unions are permitted to optimally adjust its nominal wage $W_{h,t}$ in a given period t with probability $1 - \xi_W$. All unions that are allowed to reset their wages in a given period t choose the same wage $\widetilde{W}_t = \widetilde{W}_{h,t}$. Those unions which are not permitted to optimally reset their wages partially adjust their wages to productivity developments and inflation:

$$W_{h,t} = g_{z,t} \Pi^{\dagger}_{C,t} W_{h,t-1}, \tag{4.14}$$

where $g_{z,t}$ indicates the rate of labour productivity growth and $\Pi^{\dagger}_{C,t} = \Pi^{\chi_W}_{C,t-1} \overline{\Pi}_t^{1-\chi_W}$ means a geometric average of past consumer price inflation, $\Pi_{C,t-1} = P_{C,t-1}/P_{C,t-2}$, and the monetary authority's inflation target, $\overline{\Pi}_t$. The weight of past inflation is determined by the indexation parameter χ_W.

Each union h who is allowed to optimally reset its wage contract in period t maximises its utility function (4.2) subject to the demand for its labour inputs and the wage-indexation scheme (4.14). Thus, the first-order condition for the union' optimal wage-setting decision is given by

$$E_t \left[\sum_{k=0}^{\infty} (\xi_W \beta)^k \left(\Lambda_{t+k} (1 - \tau^N_{t+k} - \tau^{W_h}_{t+k}) g_{z,t,t+k} \frac{\Pi^{\dagger}_{C;t,t+k}}{\Pi_{C;t,t+k}} \frac{\widetilde{W}_t}{P_{C,t}} - \varphi^W_{t+k} \epsilon^N_{t+k} (N_{h,t+k})^{\varsigma} \right) N_{h,t+k} \right] = 0, \tag{4.15}$$

where Λ_{t+k} indicates the marginal utility out of income (equal across all households), $g_{z,t,t+k} = \Pi^k_{s=1} g_{z,t+s}$, $\Pi^{\dagger}_{C;t,t+k} = \Pi^k_{s=1} \Pi^{\chi_W}_{C,t+s-1} \overline{\Pi}^{1-\chi_W}_{t+s}$, $\Pi_{C;t,t+k} = \Pi^k_{s=1} \Pi_{C,t+s-1}$ and φ^W_t denotes the markup of the real after-tax wage.

Aggregate labour N_t is decided by the following equation

$$N_t = \left[\int_0^1 (N_{h,t})^{1/\varphi^W_t} \, dh \right]^{\varphi^W_t} \tag{4.16}$$

Given equation (4.14) and equation (4.15), the aggregate wage index W_t evolves according to

$$W_t = \left[\xi_W \left(g_{z,t} \Pi^{\dagger}_{C,t} W_{h,t-1} \right)^{1/1-\varphi^W_t} + (1 - \xi_W) \left(\widetilde{W}_t \right)^{1/1-\varphi^W_t} \right]^{1-\varphi^W_t}. \tag{4.17}$$

4.3.1.4. Aggregation

Most aggregate variables are given by a weighted average of the equivalent variables for each consumer type. Thus, aggregate consumption and aggregate labour services are given by

$$C_t = (1 - \omega) C_{i,t} + \omega C_{j,t}, \tag{4.18}$$

$$N_t = (1 - \omega) N_{i,t} + \omega N_{j,t} \tag{4.19}$$

Similarly, aggregate lump-sum taxes and lump-sum transfers[149] are given by

$$T_t = (1-\omega)T_{i,t} + \omega T_{j,t} \tag{4.20}$$

$$TR_t = (1-\omega)TR_{i,t} + \omega TR_{j,t} \tag{4.21}$$

Since only Ricardian households invest on physical capital and trade in bonds, aggregate holdings of bonds, aggregate investment and the physical capital are given by

$$B_{t+1} = (1-\omega)B_{i,t+1} \tag{4.22}$$

$$I_t = (1-\omega)I_{i,t} \tag{4.23}$$

$$K_{t+1} = (1-\omega)K_{i,t+1} \tag{4.24}$$

4.3.2. Domestic intermediate goods firms

At the end of period t, each intermediate goods firm $f \in [0,1]$ produces a differentiated intermediate good $Y_{f,t}$, using physical capital $\widetilde{K}_{f,t}$ and labour services $N_{f,t}$. according to the following Cobb-Douglas technology:

$$Y_{f,t} = \epsilon_t \left(\widetilde{K}_{f,t}\right)^{\alpha} (z_t N_{f,t})^{1-\alpha} - z_t \psi \tag{4.25}$$

[149] Coenen et al. (2013) assume that lump-sum taxes are levied on Ricardian households and a distribution of lump-sum transfers is favorable to non-Ricardian households. However, we adopt a different structure because an analysis of redistribution policy is not our objective. Cogan et al. (2013) stay in line with our model.

where ϵ_t denotes transitory technology shock that affects total factor productivity and follows an AR(1) process:

$$\ln \epsilon_t = \rho_\epsilon \ln \epsilon_{t-1} + \eta_t^\epsilon, 0 < \rho_\epsilon < 1, \eta_t^\epsilon \sim N(0, \sigma_\epsilon) \tag{4.26}$$

and the variable z_t denotes a permanent technology shock that augments the productivity of labour permanently. The rate of labour-augmenting productivity $g_{z,t} = z_t/z_{t-1}$ follows a serially correlated process and determines the model's balanced growth path. The parameter α is effective capital share and the term $z_t\psi$ is fixed costs of production.

Physical capital $\widetilde{K}_{f,t}$ is a constant-returns-to-scale (CES) aggregate of private capital services $K_{f,t}$ and the public capital stock $K_{G,t}$

$$\widetilde{K}_{f,t} = (\alpha_K^{1/\nu_K}(K_{f,t})^{(1-1/\nu_K)} + (1-\alpha_K)^{1/\nu_K}(K_{G,t})^{(1-1/\nu_K)})^{\nu_K/(\nu_K-1)} \tag{4.27}$$

where α_K is a share of private capital services, and the parameter ν_K denotes the elasticity of substitution between private capital services and the public capital stock.[150]

We adopt a time-to-build technology for public capital following Leeper et al. (2009), as in Coenen et al. (2013). We, thus, assume that it takes L periods to complete government investment and add the public capital stock. The law of motion for public capital is then given by

$$K_{G,t+1} = (1-\delta_G)\, K_{G,t} + A_{I_{G,t-L+1}} \tag{4.28}$$

where δ_G denotes the depreciation rate of the public capital stock. $A_{I_{G,t-L+1}}$ is the authorised budget for government investment in period $t - L + 1$. Government investment that

[150] $\nu_K \to 0$ implies perfect complements, $\nu_K \to \infty$ gives perfect substitutes, and $\nu_K \to 1$ yields the Cobb-Douglas case.

is actually implemented is defined by

$$I_{G,t} = \sum_{n=0}^{L-1} b_n A_{I_{G,t-n}} \tag{4.29}$$

with $\sum_{n=0}^{L-1} b_n = 1$, and enters the government budget constraint, as well as the economy's aggregate resource constraint.

We assume that the domestic intermediate goods firm charges different prices at home and abroad, setting prices in domestic currency regardless of the market of destination. In both markets, prices are adjusted following staggered price contracts of Calvo (1983).[151] Therefore, the aggregate price index of product sold domestically $P_{H,t}$ is given by this equation:

$$P_{H,t} = \left[(1 - \xi_H) \left(\widetilde{P}_{H,t} \right)^{1/1-\varphi_t^H} + \xi_H \left(\Pi_{H,t-1}^{\chi_H} \overline{\Pi}_t^{1-\chi_H} P_{H,t-1} \right)^{1/1-\varphi_t^H} \right]^{1-\varphi_t^H} \tag{4.30}$$

Also the aggregate price index of product sold abroad $P_{X,t}$ is given by a similar equation:

$$P_{X,t} = \left[(1 - \xi_X) \left(\widetilde{P}_{X,t} \right)^{1/1-\varphi_t^X} + \xi_X \left(\Pi_{X,t-1}^{\chi_X} \overline{\Pi}_t^{1-\chi_X} P_{X,t-1} \right)^{1/1-\varphi_t^X} \right]^{1-\varphi_t^X} \tag{4.31}$$

Only a fraction $1 - \xi_H$ or $1 - \xi_X$ of the firms are permitted to re-set their prices each period. $\widetilde{P}_{H,t}$ and $\widetilde{P}_{X,t}$ are optimal prices in each market, respectively. φ_t^H and φ_t^X are price indexation parameters. We also assume that those firms which are not permitted to optimise its price can adjust their prices according to an average of past intermediate goods inflation and the inflation target of the domestic monetary authority $\overline{\Pi}_t$. χ_H and χ_X are indexation parameters determining the weight on past inflation.

4.3.3. Domestic final goods producers[152]

[151] A detailed explanation of price setting is found in Appendix A.
[152] Appendix C2 describes a structure of domestic final goods producers in detail.

The final goods firms produce three distinct non-tradable final goods by combining the domestically-produced intermediate goods with the imported intermediate goods, namely a private consumption good, Q_t^C, a private investment good, Q_t^I, and a public consumption good, Q_t^G.

The representative firm producing the non-tradable final private consumption goods and investment goods integrates a bundle of domestically-produced intermediate goods, H_t^C, with a bundle of imported foreign intermediate goods, IM_t^C, using the CES technology,

$$
\begin{aligned}
Q_t^X &= [\nu_X^{1/\mu_X} \left(H_t^X\right)^{1-1/\mu_X} \\
&\quad + (1-\nu_X)^{1/\mu_X} \left(\left(1-\Gamma_{IM^X}\left(IM_t^X/Q_t^X;\epsilon_t^{IM}\right)\right) IM_t^X\right)^{1-1/\mu_X}]^{\mu_X/\mu_X-1} \\
X &\in \{C, I\}
\end{aligned} \tag{4.32}
$$

where μ_X denotes the intra-temporal elasticity of substitution between the distinct bundles of domestic and foreign intermediate goods, while the parameter ν_X indicates the home bias in the production of the consumption goods and the investment goods. The final goods producers is subject to a cost $\Gamma_{IM^X}\left(IM_t^X/Q_t^X;\epsilon_t^{IM}\right)$ when varying the use of the bundle of imported goods in producing the consumption goods and the investment goods.

In contrast, the final public consumption good, Q_t^G, is produced by only using domestic intermediate goods; that is, $Q_t^G = H_t^G$.

4.3.4. Fiscal policy

The government budget constraint has the following form.

$$
\begin{aligned}
& P_{G,t}G_t + P_{I_G,t}I_{G,t} + B_t + TR_t \\
= \;& \tau_t^C P_{C,t}C_t + \left(\tau_t^N + \tau_t^{W_h} + \tau_t^{W_f}\right) W_t N_t + \tau_t^K (R_{K,t} - \delta P_{I,t})K_t \\
& + \tau_t^D D_t + B_{t+1}/R_{g,t} + T_t, \qquad (4.33)
\end{aligned}
$$

where G_t is government consumption, $I_{G,t}$ denotes government investment, and $\tau_t^{W_f}$ implies the rate of firms' contributions to social security. $P_{G,t}$ and $P_{I_G,t}$ also indicate the prices of a unit of the public consumption good and the public investment good, respectively. This budget constraint is based on Coenen et al. (2013). However, we develop the budget constraint allowing capital income tax rate to change. The government has three instruments on the expenditure side: the government consumption, G_t, the government investment, $I_{G,t}$, and the lump-sum transfers, TR_t. On the revenue side, it also has seven means: the consumption tax rate, τ_t^C, the wage income tax rate, τ_t^N, the capital income tax rate, τ_t^K, the dividend income tax rate, τ_t^D, the lump-sum taxes, T_t, the household's contribution to social security, $\tau_t^{W_h}$, and the firm's contribution to social security, $\tau_t^{W_f}$.

The fiscal rules in this chapter is similar to Coenen et al. (2013), but we amend their fiscal rules as follows: (i) in Coenen et al. (2013) fiscal instruments respond to a deviation from debt values implied by the steady state, whereas our model explicitly introduces the debt target and fiscal instruments respond to a gap between the actual debt ratio and the targeted ratio. (ii) Coenen et al. (2013) add to their fiscal rules the debt to GDP ratio and output gap.[153] However, we assume that tax rates only depend on the debt ratio following Forni et al. (2009). Forni et al. (2009) show that the coefficients relating tax rates to the output gap are insignificant.

All the fiscal instruments are assumed to follow simple feedback rules with a uniform

[153] However, for consumption tax they only allow for a persisence rule and a pre-announcement rule.

specification. Specifically, fiscal policy rules have following characteristics. First, all fiscal instruments react to their own lagged values. Second, there may be some automatic stabiliser component to movements in government expenditures. This is modelled as a contemporaneous response to deviations of output from the steady state. Third, all fiscal instruments are permitted to respond to the state of real government debt, B_t/P_t to prevent the debt from increasing infinitely. Fourth, we allow for pre-announcement effects following Leeper et al. (2013), as in Coenen et al. (2013). For government expenditure and tax rates, we assume that fiscal instruments adjust endogenously according to the rule:

$$X_t = X + \rho_X X_{t-1} + \theta_{X,B}(B_t - B_t^*) + \theta_{X,Y}(Y_t - Y) + (1 - \psi_X)\eta_t^X + \psi_X \eta_{t-1}^X, \tag{4.34}$$

for $X \in \left\{G, I_G, TR, \tau_t^C, \tau_t^N, \tau_t^K, T_t, \tau_t^{W_h}, \tau_t^{W_f}\right\}$, where variables without time subscript indicate corresponding steady state values, ρ_X is the smoothing parameter, B_t^* denotes the targeted debt ratio, $\theta_{X,B}$ measures the responsiveness of corresponding instrument to deviations in the debt ratio from its target value, $\theta_{X,Y}$ also means the responsiveness of these fiscal instruments to deviations in output from its steady state value, and ψ_X is a weight of pre-announcement effects. η_t^X is a shock of corresponding instrument and distributed i.i.d. $N(0,1)$.

The targeted debt ratio B_t^* follows an AR(2) process to reduce the debt gradually according to Erceg and Linde (2013). This logic is because an abrupt reduction of the debt may cause large adverse consequences on output. Thus, the targeted debt ratio evolves according to the following equation

$$B_{t+1}^* - B_t^* = \rho_{d_1}\left(B_t^* - B_{t-1}^*\right) - \rho_{d_2} B_t^* + \eta_t^{B^*} \tag{4.35}$$

where $0 \leq \rho_{d_1} < 1$ and $\rho_{d_2} > 0$.

4.3.5. Monetary policy

We assume that the monetary authority sets the nominal interest rate to stabilise output and inflation according to a simple Taylor rule

$$\begin{aligned} \log\left(R_t/R\right) &= \phi_R \log\left(R_{t-1}/R\right) + (1-\phi_R)\left[\log\left(\overline{\Pi_t}/\overline{\Pi}\right) + \phi_\Pi \log\left(\Pi_{C,t-1}/\overline{\Pi}_t\right) + \phi_Y \log Y_t\right] \\ &\quad + \phi_{\triangle\Pi} \log\left(\Pi_{C,t}/\Pi_{C,t-1}\right) + \phi_{\triangle Y} \log\left(Y_t/Y_{t-1}\right) + \eta_t^R, \end{aligned} \tag{4.36}$$

where r_t denotes the deviation of the nominal interest rate from its steady state value, r, $\Pi_{C,t} = P_{C,t}/P_{C,t-1}$ indicates the consumer price inflation, $\overline{\Pi}$ is the monetary authority's long run inflation objective. Similarly, y_t is output gap[154], and η_t^R is a serially uncorrelated shock to the nominal interest rate. Therefore, the monetary authority sets the nominal interest rate based on inflation rate, changes in inflation rate, and changes in the output gap.

4.3.6. Endogenous risk premium of government bonds

In order to take into account the effect of fiscal policy on the interest rate spread, we suppose that the spread between the interest rate on government bond and the nominal interest rate set by the monetary authority, in other words, a risk premium is a function of the government deficit and debt level. The risk premium on government bond is decided by the following equation.

$$R_{g,t} - R_t = \psi_b(B_{t+1} - B) + \psi_d(B_{t+1} - B_t) \tag{4.37}$$

[154] The output gap is defined as the deviation of aggregate output from the trend output level implied by the permanent technology shock.

4.3.7. Market clearing and aggregate resource constraint

In the markets for domestic intermediate goods, we obtain the following aggregate resource constraint in nominal terms:

$$P_{Y,t}Y_t = P_{H,t}H_t + P_{X,t}X_t, \tag{4.38}$$

Market clearing in the fully competitive final goods markets also implies: $Q_t^C = C_t$, $Q_t^I = I_t + \Gamma_I\left(I_{i,t}/I_{i,t-1}\right)K_t, Q_t^G = G_t$, $Q_t^{I_G} = I_{G,t}$.

Subsequently, combining the market clearing conditions for domestic intermediate goods and final goods results in the following representation of the nominal aggregate resource constraint (4.38):

$$\begin{aligned} P_{Y,t}Y_t &= P_{H,t}H_t + P_{X,t}X_t \\ &= P_{C,t}C_t + P_{I,t}\left(I_t + \Gamma_I\left(I_{i,t}/I_{i,t-1}\right)K_t\right) + P_{G,t}G_t + P_{I_G,t}I_{G,t} + P_{X,t}X_t \\ &\quad -P_{IM,t}\left(IM_t^C\frac{1-\Gamma_{IM^C}\left(IM_t^C/Q_t^C;\epsilon_t^{IM}\right)}{\Gamma_{IM^C}^{\dagger}\left(IM_t^C/Q_t^C;\epsilon_t^{IM}\right)} + IM_t^I\frac{1-\Gamma_{IM^I}\left(IM_t^I/Q_t^I;\epsilon_t^{IM}\right)}{\Gamma_{IM^I}^{\dagger}\left(IM_t^I/Q_t^I;\epsilon_t^{IM}\right)}\right), \end{aligned} \tag{4.39}$$

where the last equality has been obtained using the demand functions for the bundles of the domestic and foreign intermediate goods utilised in the production of the final consumption and investment goods, H_t^C and H_t^I as well as IM_t^C and IM_t^I, along with the prices of the two types of final goods, $P_{C,t}$ and $P_{I,t}$.

Finally, the terms of trade (defined as the domestic price of imports relative to the price of exports) are given by:

$$ToT_t = \frac{P_{IM,t}}{P_{X,t}}. \tag{4.40}$$

4.4. Calibration

For most parameter values we generally resort to previous literature such as Coenen et al. (2013). Table 4.1 reports chosen parameter values for preferences and technology. The discount factor, β, is 0.997, so that the steady state real interest rate is equal to 1.2% per annum, while on the nominal side, the steady state inflation rate is set to 1.9% on an annual basis. The inverse of the Frisch labour elasticity is equal to 2. The share of private consumption in the aggregate consumption bundle, α_G, is 0.75. The elasticity of substitution between private and government consumption goods, ν_G, is set to 0.29 meaning the two goods are strong complements.[155] And the share of non-Ricardian households, ω, is equal to 0.18.

Turning to the model's supply side, we set the capital share of output, α, to 30% and the depreciation rate of both private capital, δ, and public capital, δ_G, to 0.015, implying an annual depreciation rate of 6%. The elasticity of substitution between private and public capital is $\nu_K = 0.84$, giving rise to moderate complementarities in the composite capital stock. Furthermore, we assume $b_0 = 1$ with one period time to build for public capital and set the share of private investment in the aggregate investment bundle, $\alpha_G = 0.9$. In addition, we set the parameter for nominal wage stickiness ξ_W to 0.85, which means that nominal wages are fixed on average for 6.7 quarters. Regarding the domestic prices Calvo parameter, we set $\xi_H = 0.92$.[156]

[155] Bouakez and Rebei (2007) estimates the value of the elasticity of substitution as 0.332 based on U.S. data. Leeper et al. (2009) also find that $\nu_G = 0.33$ using U.S. data.
[156] These parameters are higher relative to previous researches.

Table 4.2 shows parameter values for both monetary policy and fiscal policy. Our calibration of the parameters of the monetary policy rule and the fiscal rule is generally based on the values estimated by Coenen et al. (2013). In particular, we set the parameters of the monetary policy rule such that $\phi_R = 0.86$, $\phi_\Pi = 1.73$, $\phi_{\triangle\Pi} = 0.20$, and $\phi_{\triangle Y} = 0.11$. We set $\psi_b = 0.05$, $\psi_d = 0$ following Erceg and Linde (2010). This suggests that one percentage point increase in the debt ratio raises the risk premium by 5 basis points.[157] As regards the fiscal sector, the feedback coefficients on government expenditures vary depending on fiscal instruments. For example, government investment has a marked feedback coefficient on government debt with $\theta_{I_G,B} = -0.18$, whereas the coefficient of government consumption to debt is set to be small with $\theta_{G,B} = -0.02$. The coefficients on output are not significant except government investmen with $\theta_{I_G,Y} = 0.55$. On the revenue side, the parameters of tax rates are set according to Forni et al. (2009).[158] In addition, the parameters of the debt target equation (4.35), ρ_{d_1} and ρ_{d_2} are set following Erceg and Linde (2013).

Table 4.3 shows steady state values. The expenditure shares of private consumption, private investment, government consumption, and government investment are set to, respectively, 57.5%, 18.3%, 21.5%, and 2.8% of nominal GDP, while the export and import shares are set to 16% following Coenen et al. (2013). The steady state tax rates are also calibrated according to Coenen et al. (2013). Regarding government debt, we assume the debt target ratio of 60% per annum.

[157] As mentioned in Erceg and Linde (2010), these coefficients are somewhat higher considering previous works. However, these high coefficients are appropriate for the analysis of fiscal consolidation during the crisis.

[158] Coenen et al. (2013) omit the feedback of consumption tax and capital income tax.

Table 4.1 Parameter values for preferences and technology		
Households		
β	0.997	Discount factor
κ	0.57	Habit parameter
ζ	2	Inverse Frisch elasticity of labour supply
α_G	0.75	Private consumption share in aggregate consumption
ν_G	0.29	Elasticity of substitution between private and government consumption
ω	0.18	Share of non-Ricardian households
ξ_W	0.85	Wages Calvo parameter
χ_W	0.53	Wages indexation
Intermediate goods firms		
α	0.3	Effective capital share
δ	0.015	Depreciation rate of private capital
δ_K	0.015	Depreciation rate of public capital
α_K	0.9	Private capital share in aggregate capital
b_0	1	Time to build parameter
ν_K	0.84	Elasticity of substitution between private and government investment
ξ_H	0.92	Domestic prices Calvo parameter
χ_H	0.82	Domestic prices indexation
γ_I	6.10	Investment adjustment costs
Final goods firms		
μ_C	1.98	Elasticity of substitution in consumption
μ_I	1.75	Elasticity of substitution in investment

Table 4.2. Parameter values for policy		
Monetary policy coefficient		
$\overline{\pi}$	1.9	Inflation target
ϕ_R,	0.86	Interest rate smoothing
ϕ_Π	1.73	Response on inflation
$\phi_{\triangle\Pi}$	0.20	Response to change in inflation
$\phi_{\triangle Y}$	0.11	Response to output growth
ψ_b, ψ_d	0.05, 0	Debt coefficient of risk premium
Fiscal policy coefficient		
$\theta_{G,B}$, $\theta_{G,Y}$, ρ_G, ψ_G	-0.02, 0.06, 0.77, 0.06	Government consumption
$\theta_{I_G,B}$, $\theta_{I_G,Y}$, ρ_{I_G}, ψ_{I_G}	-0.18, 0.55, 0.70, 0.93	Government investment
$\theta_{TR,B}$, $\theta_{TR,Y}$, ρ_{TR}, ψ_{TR}	-0.14, 0.10, 0.72, 0.81	Lump-sum transfers
$\theta_{\tau^C,B}$, $\theta_{\tau^C,Y}$, ρ_{τ^C}, ψ_{τ^C}	0.02, 0, 0.91, 0.31	Consumption tax
$\theta_{\tau^N,B}$, $\theta_{\tau^N,Y}$, ρ_{τ^N}, ψ_{τ^N}	0.0252, 0, 0.81, 0.11	Wage income tax
$\theta_{\tau^K,B}$, $\theta_{\tau^K,Y}$, ρ_{τ^K}, ψ_{τ^K}	0.0171, 0, 0.97, 0.0	Capital income tax
$\theta_{T,B}$, $\theta_{T,Y}$, ρ_T, ψ_T	0.07, 0, 0.68, 0.90	Lump-sum tax
$\theta_{\tau^{W_h},B}$, $\theta_{\tau^{W_h},Y}$, $\rho_{\tau^{W_h}}$, $\psi_{\tau^{W_h}}$	-0.01, -0.05, 0.74, 0.26	Employees' social security contribution
$\theta_{\tau^{W_f},B}$, $\theta_{\tau^{W_f},Y}$, $\rho_{\tau^{W_f}}$, $\psi_{\tau^{W_f}}$	0.01, -0.03, 0.69, 0.77	Employers' social security contribution
ρ_{d_1}, ρ_{d_2}	0.935, 0.0001	Autoregressive debt target

Table 4.3. Steady state values		
GDP components share		
$\frac{C}{Y}$	0.575	Proportion of private consumption
$\frac{I}{Y}$	0.183	Proportion of private investment
$\frac{G}{Y}$	0.215	Proportion of government consumption
$\frac{I_G}{Y}$	0.028	Proportion of government investment
$\frac{X}{Y}$	0.16	Proportion of export
$\frac{IM}{Y}$	0.16	Proportion of import
Tax rates		
τ^C	22.3	Consumption tax
τ^N	11.6	Wage income tax
τ^K	35.0	capital income tax
τ^{W_h}	12.7	Employees' social security contribution
τ^{W_f}	13.2	Employers' social security contribution
τ^D	0.0	Profit income tax
Fiscal policy		
B_Y	2.40	Government debt to GDP ratio

4.5. Effects of alternative fiscal policy strategies

This section estimates the macroeconomic effects of alternative fiscal consolidation strategies in the model explained above. We consider two fiscal consolidation strategies: the expenditure based strategy and the revenue based strategy. These strategies are simulated using a variety of fiscal instruments. The simulation results are assessed on a basis of impulse responses of key macroeconomic variables. All responses are reported as the percentage changes from their steady state.

4.5.1. Effects of the expenditure based strategy

Figures 4-2 – 4-3 show the dynamic responses of economic variables to the temporary fiscal policy shock under the expenditure-based strategy and the revenue-based strategy, respectively. The temporary fiscal policy shock is equivalent to a one-percentage point decline in the steady state output. Regarding simulations in this subsection, all dynamic responses are displayed for the first 10 years.

In Figure 4-2 we compare three fiscal instruments - government consumption, government investment and lump-sum transfers. In the short run the cut in government consumption is the most harmful to the economy because output immediately falls by 0.98%.[159] The reduction in government investment follows closely with the minimum value of -0.84%. The cut in lump-sum transfers does not show a noticeable effect with the trough of -0.01%. This is because the lump-sum transfers are not an element of aggregate output and do not directly reduce it. This result is contradictory to previous researches showing that the cut in government investment is the most damaging in GDP and employment (e.g., Stahler and Thomas, 2012). The response of consumption mainly causes this difference and the complementarity between private consumption and government consumption contributes to the disparity of consumption.[160] Of course, since the cut in government investment reduces the aggregate capital and negatively affects investment, it can be more damaging to the economy in the long run. On the other hand, the responses of the debt ratio are similar among the three fiscal instruments. The debt ratio remarkably falls on impact. According to the fiscal rule the government expenditures rise and the taxes fall. As the fiscal rule has a counterbalancing role on the debt ratio, it gradually approaches to the steady state. The reduction in the debt ratio also translates into a fall in the risk premium. For example, in

[159] Since the pre-announcement coefficient in government consumption is very low, most of the decline of output takes place immediately.

[160] See Section 4.6.3.1.

the government consumption cut an decrease in the debt ratio by 1.22% in 5 quarter leads to an improvement in the debt refinancing cost by 0.24% on impact.

The transmission mechanism of fiscal consolidation is also different among the three fiscal instruments. Starting with the government consumption, as government consumption returns to the steady state over time, output is adusted quickly[161] and turns positive in 7 years. In this case, the responses in consumption and net export contribute to the output recovery. Specifically, the decline in government consumption makes firms curtail production and this has a negative impact on wage and employment. Thus, non-Ricardian households who are not affected by the wealth effect reduce consumption in the short run. As the wage rate and employment get back to the steady state with the output recovery, their consumption improves. Ricardian households also reduce their consumption for quite some time. This is because the decline in income overwhelms the positive wealth effect due to the debt reduction. Combining the two types of consumption, the aggregate consumption falls. At the same time, the fall in output makes firms bring down prices and inflation rate falls. The drop in the inflation rate decreases production costs and domestic products become cheaper than foreign goods. This impact is displayed in an increase in the terms of trade. Both this deterioration in the terms of trade and a modest increase in the foreign exchange rate cause the increase in net export. In addition, real interest rates fall immediately, and investment increases modestly. The fall in the risk premium further reduces the real interest rates and contributes to the improvement in private investment.[162]

Regarding the effects of the temporary cut in government investment, the time path of output is similar to the cut in government consumption.[163] The debt ratio also displays a similar pattern. Private investment rises because the real interest rate significantly falls.

[161] For example, output declines by 0.52% after one year and 0.14% after two years

[162] See Section 4.6.1.

[163] There is a difference in instant responses between two shocks. The initial response of government investment is much muter because of a higher pre-announcement coefficient.

The increase is smaller than the government consumption cut. The complementarity between private and government investment causes this difference. In other words, the cut in government investment further decreases physical capital used by the firms and this offsets the positive effect of lower interest rates on private investment. However, there are remarkable differences in the dynamics of the constituents of output compared to government consumption. Private consumption increases on impact, but does not display a significant change since then. Non-Ricardian households decrease their consumption becaue of the fall in wage income, whilst Ricardian households' consumption increases as the positive wealth effect due to expected future tax cuts dominates. The effects on labour supply and wage rate mostly look similar to government consumption. This is because a lower accumulation in public capital reduces workers' productivity. A related reduction in the production possibility frontier also increases inflation in spite of the drop in the unit labour cost. Since the foreign exchange rate rises in the short run, the export also increases. The time path of import is similar to private consumption.

Now we analyse the effects of lump-sum transfers. The cut in transfers results in a small rise in output initially. Modest increases in private consumption and investment contribute to the economic expansion. The reduction in transfers has a remarkable dampening effect on non-Ricardian households' consumption. Their consumption gets better because of the recovery of transfers. For Recardian households, meanwhile, they slightly increase their consumption because the loss in transfers counteracts the positive wealth effect. Investment increases due to the fall in the real interest rate. Since the response of consumption is partly shared by the consumption of imported products, import displays a similar response to private consumption. The depreciation in the foreign exchange rate also increases the export.

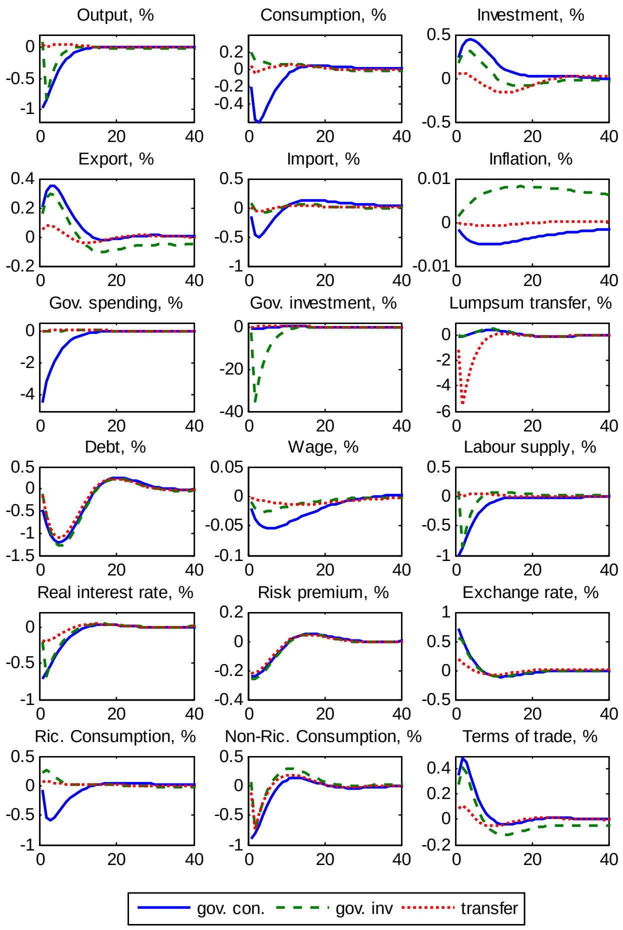

Figure 4-2. Effects of expenditure based strategy

4.5.2. Effects of the revenue based strategy

We now analyse the effects of the revenue based strategies. Figure 4-3 summarises the impulse response of positve shocks to the tax rate on, respectively, consumption, wage income, and capital income, all set in order to obtain a decrease in revenues equal to 1% of the steady state output. The effects of the revenue based strategies vary depending on the taxes. The strongest drop in output on impact is found for the consumption tax with the lowest value of -0.34% in quarter 2. The rise of the wage income tax reduces output by 0.30% on impact. In contrast, the hike of capital income tax increases output on impact. This is a kind of the non-Keynesian effect explained in section 4.2.4. The endogenous risk premium causes this economic expansion.[164] However, the increase of output gradually diminishes and output begins to decrease in quarter 22. The debt reduction effect is the strongest in the wage income tax in the short run, followed by the consumption tax and the capital income tax. As the fiscal rule raises the government expenditures and reduces the taxes, the debt ratio gradually comes to the steady state. However, in the wage income tax the debt ratio rather increases in 4 years. The risk premium appears to be similar to the dynamics of the debt ratio because the former is positively correlated with the latter.

Macroeconomic variables in each tax hike change as follows. First, regarding the consumption tax hike, the response of tax rate peaks at about 7.2%. The economic contraction mainly comes from a reduction in comsumption because the consumption tax raises the price of products.[165] The fall in output slightly dampens the employment and the wage rate also diminishes. The firms which face a decreasing demand of products cut prices and the inflation rate also starts to fall. This deflation improves the terms of trade. Depreciation in the foreign exchange rate with this favorable price effect results in an increase in the export. And the drop in private consumption and the improvement in the terms of trade reduce the import for quite some time. Private investment increases in the short and mid terms because the real interest rate generally falls.

Second, the initial rise in the wage income tax rate is nearly 12.1%. Private consumption

[164] See Section 4.6.1.

[165] The negative impact on consumption applies to two types of households. Non-Ricardian households reduce consumption by the maximum of 6.2%. Ricardian households expect the fall in the future tax rate and this positive wealth effect increases their consumption. However, as this effect is offset by the price effect of the tax hike, they also reduce private consumption.

decreases because the tax hike dampens households' income. Non-Ricardian households noticeably decrease their consumption.[166] Ricardian households rather raise consumption on impact because of the positive wealth effect. However, their consumption falls in quarter 30 because the effect of income loss dominates the wealth effect. The reduction in the public debt makes other tax rates fall through the fiscal rule. These effects contribute to a gradual rebound in consumption. The favorable movement of the real interest rate increases private investment. However, private investment becomes aggravated in quarter 9 because the rise in the debt ratio increases the risk premium in quarter 12. The fall in output reduces labour demand by the firms, and the aggregate employment also drops on impact. It soon begins to increase in the following period due to the improvement in investment. Wage slightly rises despite the fall in employment because the wage income tax hike also increases the gross demand wage by employees (Stahler and Thomas, 2012). In addition, the foreign exchange rate depreciates in the short run. As this movements of the foreign exchange rate determines the time path of the export, the export increases. The import generally falls. This time path of the import is similar to private consumption implying the demand of foreign products accounts for a substantial portion of the change in private consumption.

Third, the hike in capital income tax rate has a notable effect on investment. Private investment falls with the minimum value of -2.11% in quarter 10 because the firms utilise less capital in the production. Unlike investment, consumption slightly rises for the most periods. This is because the effect of capital income tax on comsumption is limited compared to other taxes. Specially, non-Ricardian households are not affected by the capital income tax rate[167], and their consumption does not show a notable change. In addition, higher tax burden makes Ricardian households choose consumption instead of investment.

[166] Specially, non-Ricardian consumption declines by 12.9% on impact.

[167] Thus, on the occasion of the change in capital income tax, non-Ricardian households contribute to stabilise output (Forni et al., 2009).

Thus, they increase consumption in spite of the fall in capital income. Inflation rate also increases slightly. For the response of employment, there are two conflicting effects. On the one hand, capital can be substituted with labour because of the higher tax rate. On the other hand, the decrease of production reduces employment. In this case, the employment persistently rises because the former effect is bigger than the latter one. Depreciation in the foreign exchange rate and the increase in the terms of trade raise net export in the short run. As a result, output increases temporarily owing to the increases in consumption and net export. However, output begins to decline in quarter 22 because the persistent decrease of investment shrinks the production capability and this has a negative impact on net export.

To list fiscal instruments in the order to have a bigger impact in output is as follows : (i) the government consumption cut (ii) the government investment cut (iii) the consumption tax hike (iv) the wage income tax hike (v) the lump-sum transfers cut (vi) the capital income tax hike. Between the expenditure based strategies and the revenue based strategies, much stronger impact on output is found for the former. This result is not consistent with the previous literature.[168] This distinction may result from the structure of the model such as the complementarity between private and government consumption, and the endogenous risk premium.[169] As the debt ratio increases, the real interest rate further rises through the endogenous risk premium. This worsens investment and increases the output loss. Since the change of the debt ratio is bigger in the tax hike, the effect of the endogenous risk premium is also more noticeable in the tax hike. Thus, when the endogenous risk premium is omitted, the result of fiscal consolidation is totally different.[170]

In addition, the revenue based strategies are more effective in the government debt

[168] The previous literature generally shows that the tax hike is much more detrimental to the economy (e.g., Guajardo et al., 2014; Alesina et al., 2015).

[169] We examine the impact of the structure of the model in the next section.

[170] See Chapter 4.6.1.

reduction. This suggests that the tax hike is superior to the expenditure based strategy. The tax hike is not only recommendable to decrease the government debt, but also has the advantage in preventing more serious economic downturn. However, we need to carefully interpret this result because its feasibility depends on the structure of the model.

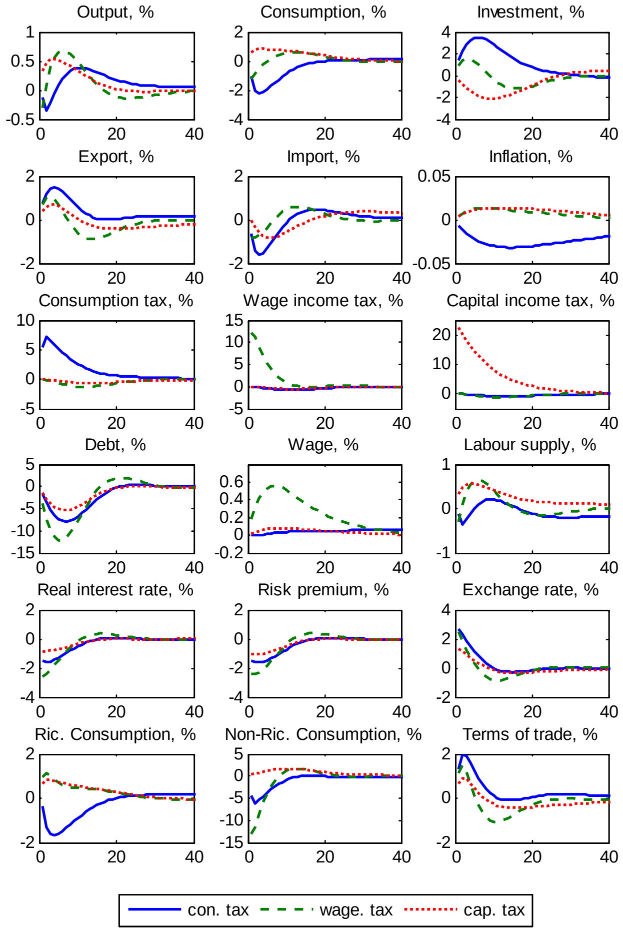

Figure 4-3. Effects of revenue based strategy

4.6. Robustness analysis

In this section, we provide additional robustness analysis regarding the structure and the parameterisation of the model. We begin by modifying the endogenous risk premium of government bonds which responds to the debt ratio. Then, we show that the fiscal rule is an important factor deciding the effects of fiscal consolidation. Finally, we investigate the sensitivity of our findings to the parameters determining the complementarity between government consumption and private consumption.

4.6.1. Endogenous risk premium of government bonds

In the baseline model, we assume that the interest rate faced by the government equals the policy rate set by the monetary authority plus the risk premium which depends positively on the government debt. In this subsection, we simulate the effect of fiscal consolidation to estimate the effects of the endogenous risk premium mechanism on economic variables when the mechanism is omitted. Figure 4-4 – 4-5 report the results of this experiment in the expenditure based strategy and the revenue based strategy, respectively.

We find that the effects of the risk premium schemes differ considerably depending on the fiscal instruments. Regarding the expenditure based strategies in Figure 4-4, the endogenous risk premium does not make significant impacts on output. Compared to Figure 4-2 the output contraction is bigger, but the difference is not noticeable. The troughs of each fiscal instrument are as follows: the government consumption cut is -1.05%; the government investment cut is -0.94%; the lump-sum transfers cut is -0.07%. The impact on the debt ratio is also similar to the baseline model. Even though the effects are not noticeable, the endogenous risk premium has favorable effects on investment and private consumption. In the short run, the endogenous risk premium based on the debt ratio falls. This stimulates investment and private consumption through the fall in the real interest rate. Thus, the endogenous risk premium reduces the output loss. This is labelled as the non-Keynesian effect by some papers.

Regarding the revenue based strategies in Figure 4-5, the endogenous risk premium makes notable differences. The output decrease is much bigger than the baseline model. Specifically, the consumption tax hike has the minimum value of -1.33%. The wage income tax hike also shows an amplified effect on output with the lowest value of -1.04%. The capital income tax hike reduces output with the trough of -0.26% unlike the baseline model. We find that the endogenous risk premium further crowds in private consumption and investment through the decline in the real interest rate. This difference comes from the time paths of the debt ratio. Since the debt ratio further declines, the risk premium also falls. Specifically, in Figure 4-4 the maximum decrease of the debt ratio is -1.29% with the government investment cut, and the risk premium falls by -0.26%. In contrast, in Figure 4-5 the value builds up to -12.04% with the wage income tax hike. When the endogenous risk premium is omitted, this favorable effect vanishes and the real interest rate bounds. Therefore, the existence of the endogenous risk premium has much more favorable effects on output in revenue based strategies.

In addition, when the risk premium is omitted, the scale of the impact on output among the fiscal instruments changes. Arranging the fiscal instruments in the order to have greater influence is as follows: (i) the consumption tax hike (ii) the government consumption cut (iii) the wage income tax hike (iv) the government investment cut (v) the capital income tax hike (vi) the transfers cut. The negative effect of the tax hike is larger than the expenditure based strategy when the risk premium mechanism is omitted. This result follows the previous literature (e.g., Guajardo et al., 2014; Alesina et al., 2015).[171] This suggests that the endogenous risk premium significantly affects the effect of the fiscal consolidation. This is also consistent with the notion that the response of private investment is very important for the effect of the fiscal consolidation.

[171] This confirms that the discrepancy between the baseline result in Section 4.5 and the previous literature is mainly caused by the endogenous risk premium mechanism.

Thus, there is a fiscal policy tradeoff. The tax hike is superior to the government expenditure cut for the reduction of the debt ratio. However, we need to take the possibility of more serious economic downturn with the tax hike.

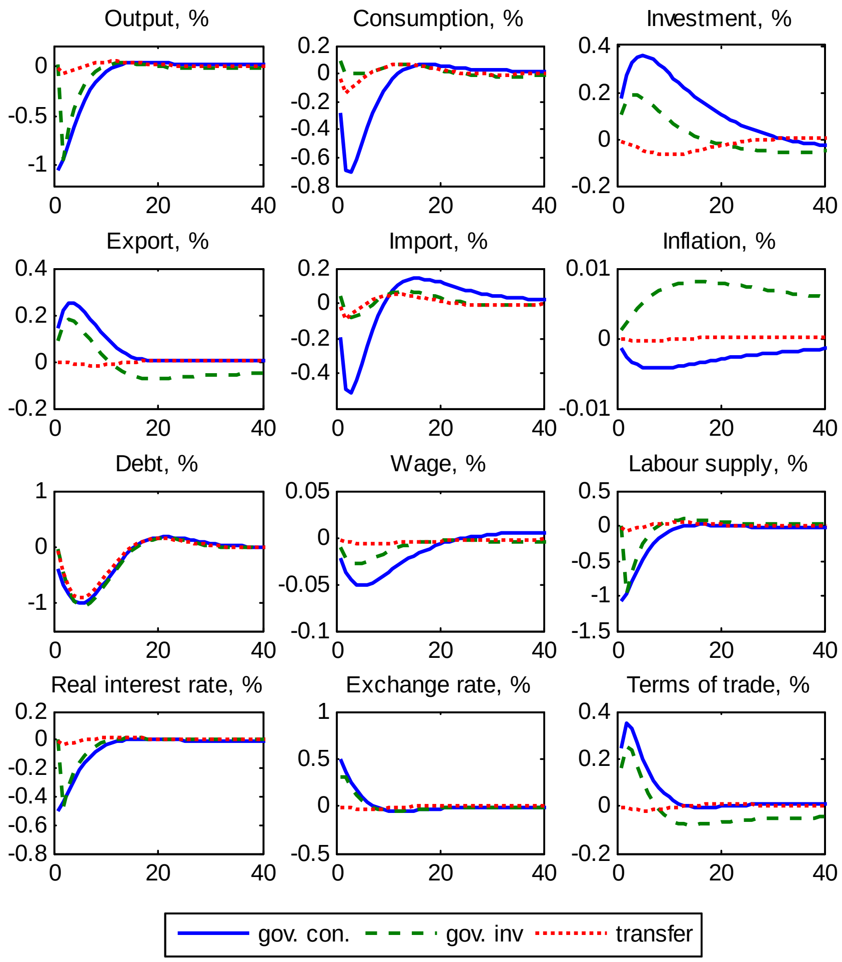

Figure 4-4. Effects of expenditure based strategy (no risk premium)

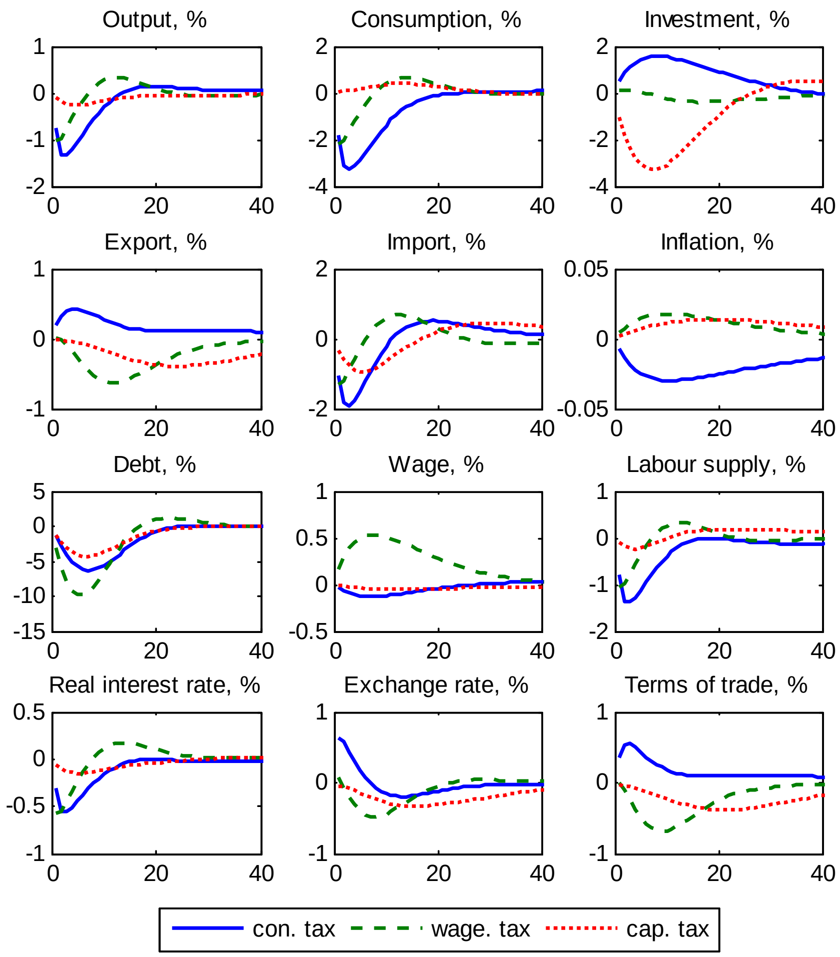

Figure 4-5. Effects of revenue based strategy (no risk premium)

4.6.2. Fiscal rule

Under our baseline calibration, the government expenditures respond to the evolution of both output and public debt, whereas the tax rates correlate with public debt. In this section, we simulate two more versions of the fiscal rule to analyse how adjustments in the fiscal rule affect the impact of fiscal consolidation on macroeconomic variables. First, only three government expenditures - government consumption, investment, and lump-sum transfers - are adjusted. Second, only three distortionary taxes - consumption tax, wage income and capital income taxes - are adjusted. Figure 4-6 – 4-7 plot the impulse responses following the expenditures adjusted rule, while Figure 4-8 – 4-9 illustrate the impulse responses following the taxes adjusted rule.

As in the baseline model shown in Figure 4-2, in Figure 4-6 and 4-8 the declines in government expenditures decrease both employment and output on impact. The government expenditure cut crowds in investment and its positive wealth effect leads Ricardian households' consumption to rise in the short run.[172] The debt ratio generally drops. This makes the real interest rate drop with decreasing risk premium. This raises investment and reduces the fall in output. In the two additional rules the economic contraction is relatively modest compared to the baseline result. However, the difference is negligible. As the absolute size of de-leveraging is small, there is little to create the difference.

In contrast, the effects of the revenue based srategies shown in Figure 4-7 and 4-9 are considerably different from the baseline result. Specially, we find that output increases in spite of the tax hike. This difference can be explained by the impact of the fiscal rule on the debt ratio. In the case of fiscal consolidation the fiscal rule makes the government expenditure rise and the tax rate fall. Thus, the level of deleverage relatively declines. Without one of the two fiscal rules, the debt ratio sharply declines in relative to the baseline result. This strengthens the positive wealth effect and spurs Ricardian households' consumption. Thus, the firms increase employment and this accelerates investment by increasing the productivity of capital. Also, the real interest rate considerably declines through the effect of the debt on the risk premium. This contributes to increasing investment. The surplus in net export also rises by the depreciation of the real exchange rate.

[172] An exception is government consumption. Ricardian households reduce private consumption because of the complementarity between government consumption and private consumption.

Ultimately, output increases persistently in spite of fiscal consolidation. In addition, we can find a little difference between the expenditure adjusted rule and the tax adjusted rule. The expenditure adjusted rule shows better economic performance than the tax adjusted rule. This is because the adjustment of the tax rate in the fiscal rule leads to more change in the debt ratio. Thus, in the expenditure adjusted rule the debt ratio declines further more than the tax adjusted rule and its non-Keynesian effect is relatively amplified.

In summary, the results imply that the fiscal rules significantly affect the effects of fiscal consolidation. This is consistent with Leeper et al. (2010). In addition, the influences of the fiscal rules are relatively stronger in the revenues based strategies than the expenditures based strategies.

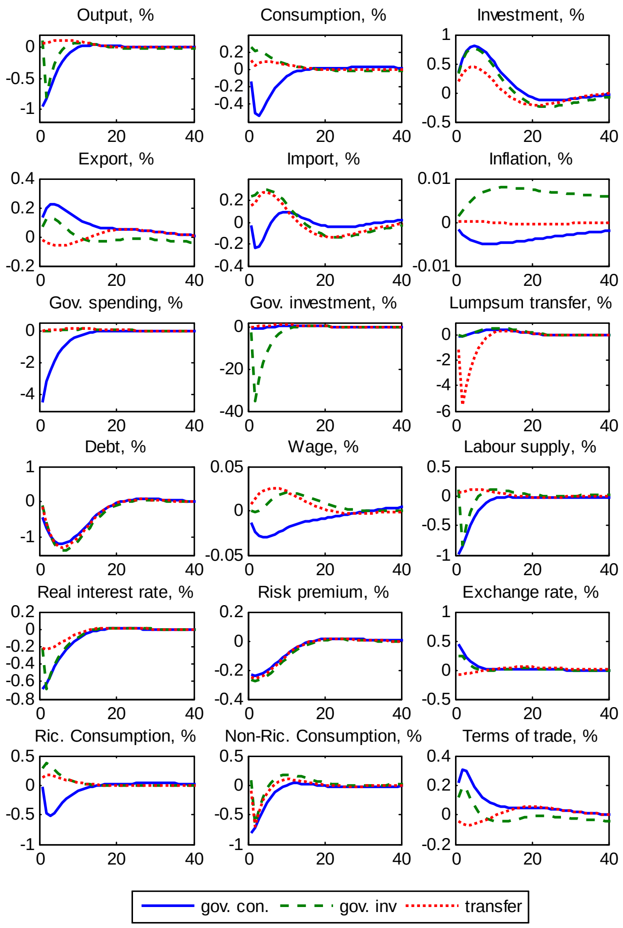

Figure 4-6. Effects of expenditure based strategy (expenditure adjusted rule)

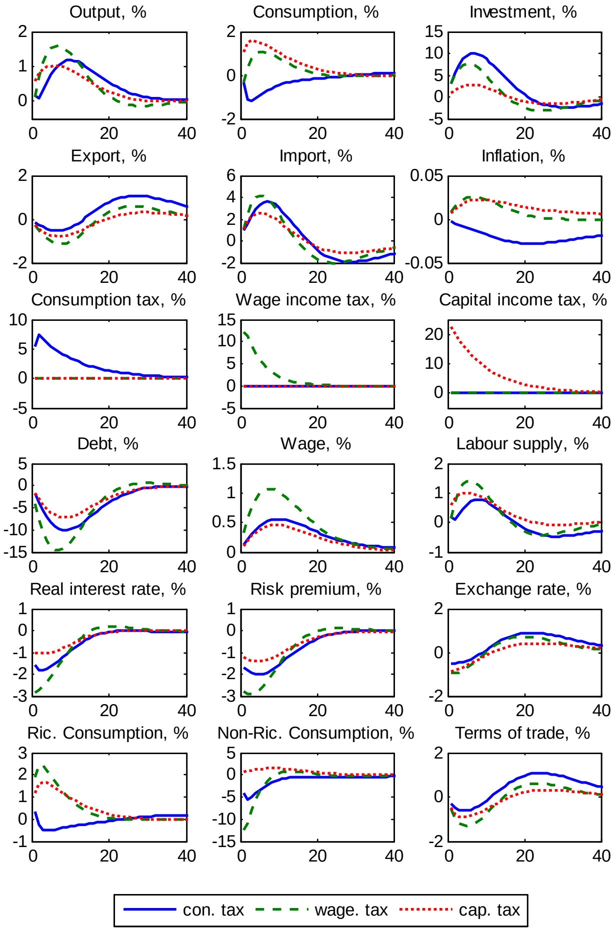

Figure 4-7. Effects of revenue based strategy (expenditure adjusted rule)

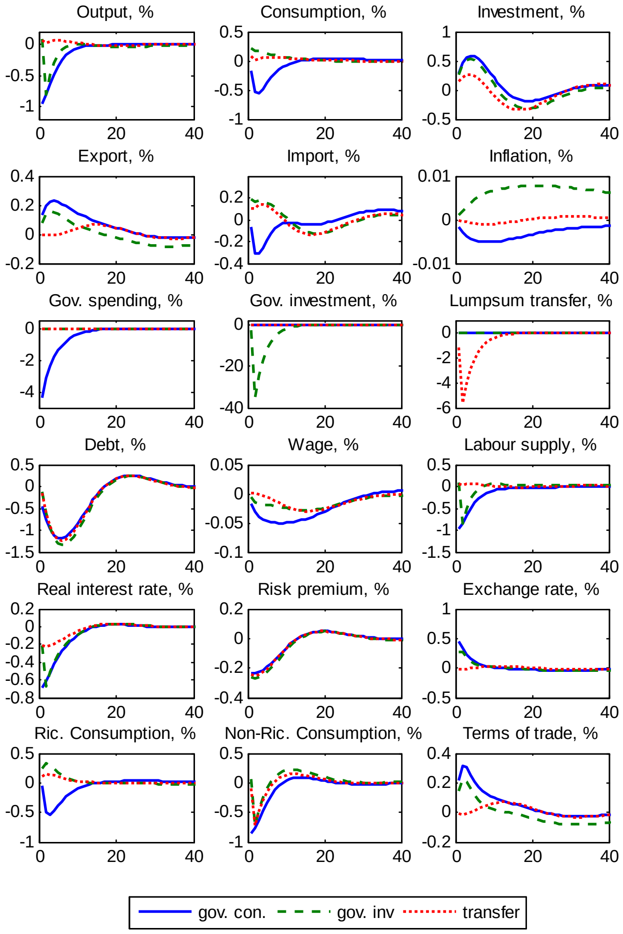

Figure 4-8. Effects of expenditure based strategy (tax adjusted rule)

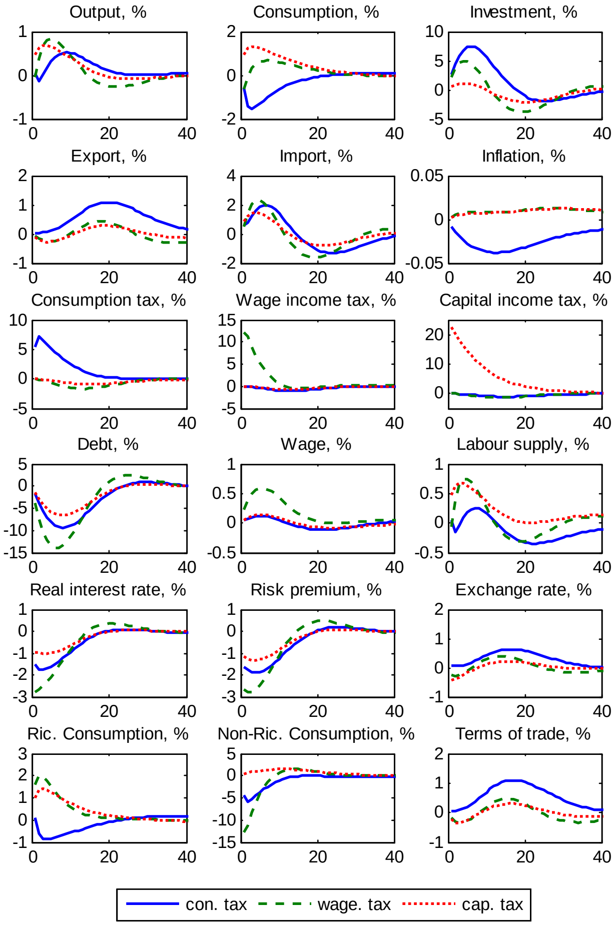

Figure 4-9. Effects of revenue based strategy (tax adjusted rule)

4.6.3. Impact of the relationship between private consumption and government consumption

The baseline model assumes that government consumption is a complement with private consumption. However, in this section we allow government consumption to be a less close complement or a substitute with private consumption to examine the effects of complementarity between private consumption and government consumption. Figure 4-10 displays the effects of the negative government consumption shock depending on different values of complementarity. We consider three different scenarios by setting the elasticity of substitution between private and government consumption, ν_G, to 0.29, 0.8, and 1.5, respectively. The bigger ν_G is, the larger crowding-out effect on private consumption the government consumption shock generates. Thus, when ν_G is set to 0.8, and 1.5, private consumption begins to increase in the short run. For higher values of ν_G, the cut in government spending raises the marginal utility of private consumption, which strengthens the positive wealth (Bouakez and Rebei, 2007). This reinforced wealth effect is illustrated in the increase in Ricardian households' consumption. On the other hand, higher values of ν_G alleviates an increase in investment. More increases in private consumption also cause a rise in the import. However, since the positive effect on consumption dominates other negative impacts, the degree of output reduction decreases with higher values of ν_G. Similarly, the degree of reduction in employment and wage decreases.

In addition, under higher values of ν_G, the effect of government consumption shock on output is rather less than other fiscal instruments. Specifically, as shown in Figure 4-11, when ν_G is calibrated to 0.8, the immediate effect on output is -0.60%. This value is smaller than the dampening effect of government investment with the lowest value of -0.80%. We find that the negative effects of the distortionary tax hike also become larger than before in Figure 4-12. Specifically, the consumption tax hike has the largest negative effect on output with the minimum value of -0.38%. The wage income tax hike has smaller contractive effects with the lowest values of -0.21.

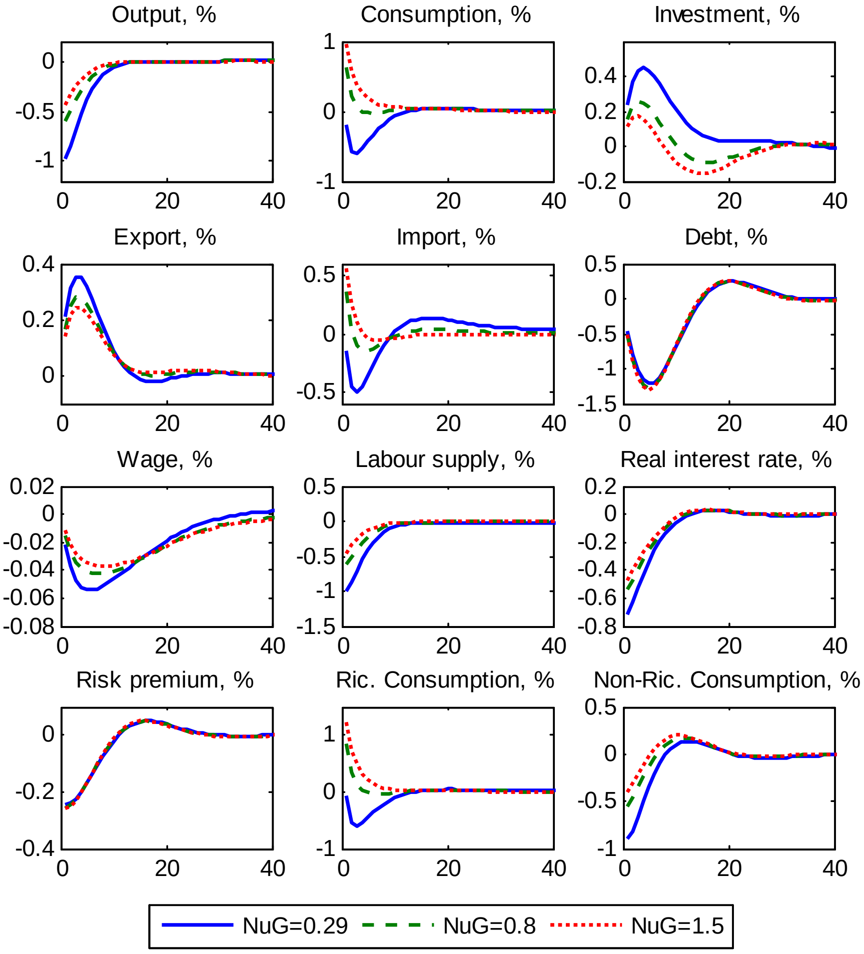

Figure 4-10. Effects of complementarity between private and government consumption

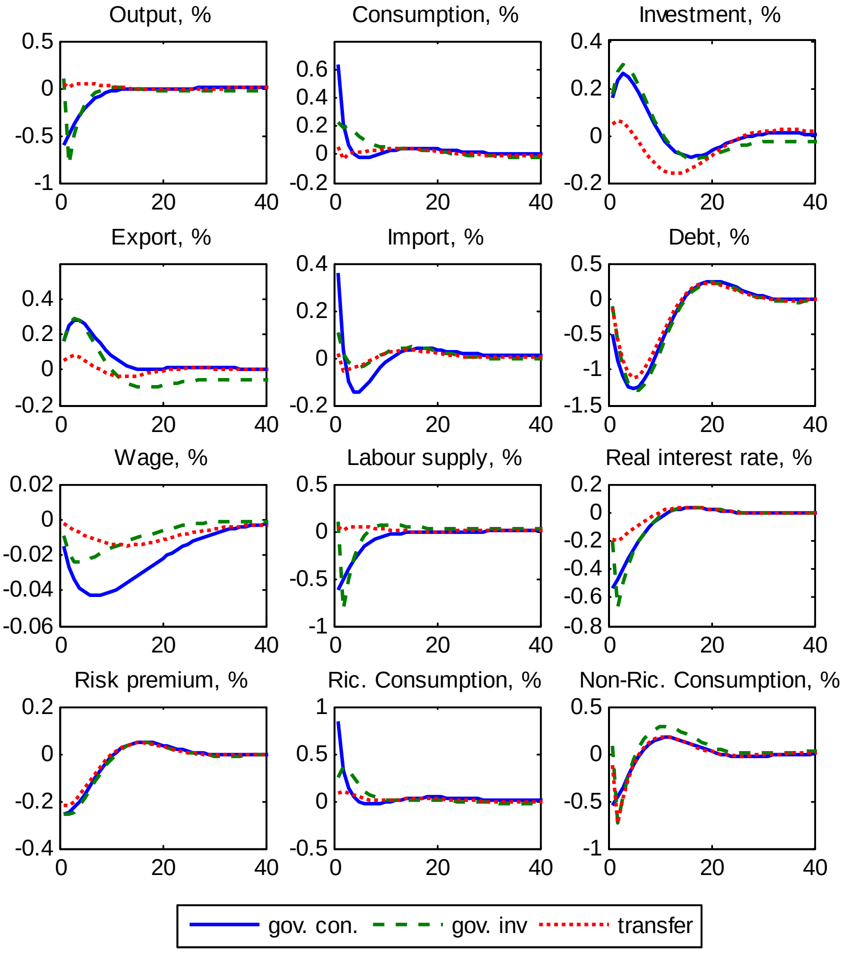

Figure 4-11. Effects of expenditure based strategy (weak complementarity)

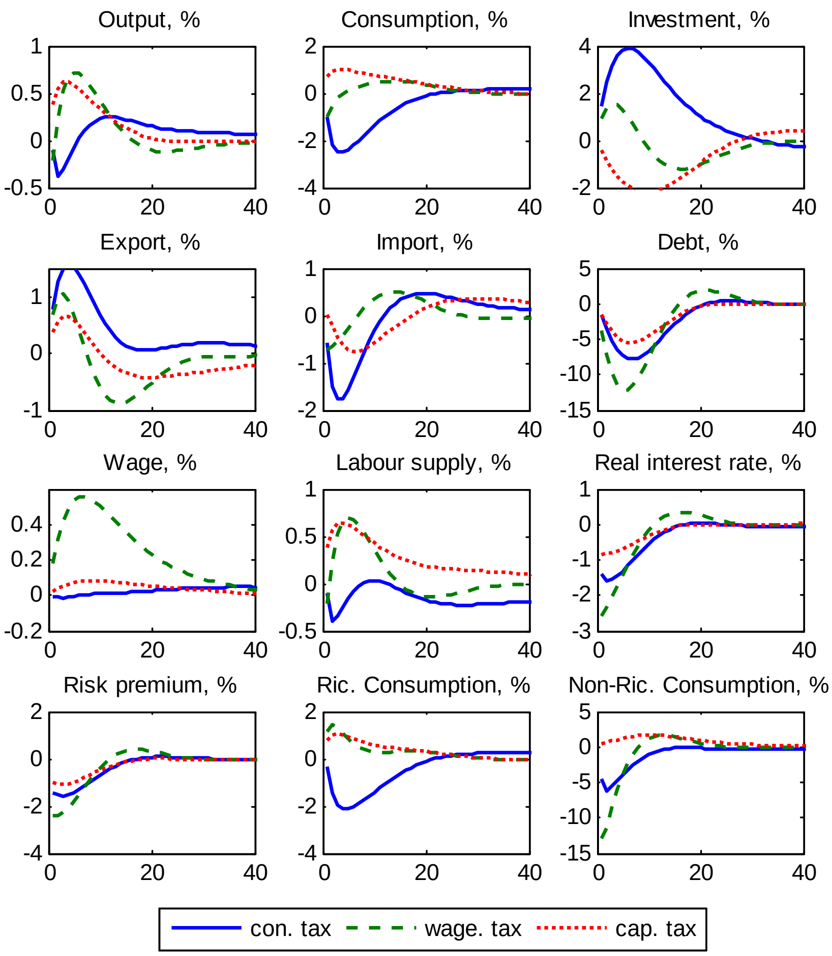

Figure 4-12. Effects of revenue based strategy (weak complementarity)

4.7. Conclusion

In this chapter, we examine the macroeconomic effects of alternative fiscal consolidation strategies. In order to achieve this objective, we develop the open economy DSGE model with a comprehensive fiscal block. The model is based on the ECB's NAWM described by Coenen et al. (2013), but it is a little different. We divide the fiscal expenditure side into government consumption, government investment, and lump-sum transfers. We also consider a variety of distortionary taxes on the fiscal revenues side. Our model incorporates the endogenous risk premium of government bonds and the fiscal rule. It is calibrated for the euro area.

We simulate the tax hike as well as the reduction of the government expenditure equivalent to a one percentage point of GDP to achieve fiscal consolidation. The results show that there are remarkable variations in the responses of macroeconomic variables following fiscal consolidation strategies. Fiscal consolidation is found to dampen the economy in the short run, but the magnitude of the effect varies across fiscal instruments. Specifically, the effect of the government consumption cut is worst in the short run. Even if the cut in government investment negatively affects the economy, its effect is less than government consumption. This result is associated with the complementarity between private consumption and government consumption. The tax hike also has smaller effects on impact than the government consumption cut. Among the taxes, the consumption tax hike has the largest negative impact on output in the short run. The wage income tax hike shows less reduction of output than the consumption tax hike. The capital income tax hike rather increases output in spite of fiscal consolidation. This is because the wealth effect due to higher tax burden on investment increases Ricardian households' consumption and the favorable movement of the exchange rate increases the net export.

We also find that both the endogenous risk premium and the fiscal rule have considerable influences over the effects of fiscal consolidation. Specially, the influence of these mechanisms is relatively stronger in the revenues based strategies than the expenditures based strategies. This is because in the revenue based strategies the debt ratio decreases more significantly than the expenditure based strategies. As the real interest rate falls with the endogenous risk premium, both private consumption and investment are crowded in.

Therefore, when the endogenous risk premium is excluded from the model, the effect of the revenue based strategies is larger than the expenditures based strategies. Specifically, the consumption tax cut has the largest negative impact on output unlike the baseline model.

In addition, the fiscal rule that only the government expenditures or the tax rates are adjusted is superior to the baseline fiscal rule because the economic downturn is smaller and the magnitude of the debt restructuring is larger. This result is associated with the fact that the number of the fiscal instruments responding to output and debt decreases and the non-Keynesian effect is strengthened in the two alternative fiscal rule. Furthermore, the expenditure adjusted rule is superior to the tax adjusted rule. The tax rates only respond to the debt ratio, whilst the expenditures respond to both output and the debt ratio. Thus, in the tax adjusted rule the non-Keynesian effect is constrained.

Appendix

A. The model appendix

Apart from the extensions by both Coenen et al. (2013) and our model, this model appendix follows mostly Christoffel et al. (2008), with minor changes to unify the notation.

A.1. Price setting of the domestic intermediate goods firms

The intermediate goods firm, taking the rental cost of capital, $R_{K,t}$, and the wage, W_t, as given, uses optimally capital and labour services and minimises total input cost $R_{K,t}\widetilde{K}_{f,t} + (1+\tau_t^{W_f})W_t N_{f,t}$ subject to the technology constraint (4.25). Defining as $MC_{f,t}$ the Lagrange multiplier associated with the technology constraint (4.25)[173], the first-order conditions of the firm's cost minimisation problem with respect to capital and labour inputs are given, respectively, by

$$\widetilde{K}_{f,t} : \alpha \frac{Y_{f,t} + z_t\psi}{\widetilde{K}_{f,t}} MC_{f,t} = R_{K,t} \tag{A1}$$

$$N_{f,t} : (1-\alpha)\,\frac{Y_{f,t} + z_t\psi}{N_{f,t}} MC_{f,t} = (1+\tau_t^{W_f})W_t \tag{A2}$$

or, more compactly,

$$\frac{\alpha}{1-\alpha}\frac{N_{f,t}}{\widetilde{K}_{f,t}} = \frac{R_{K,t}}{(1+\tau_t^{W_f})W_t} \tag{A3}$$

Marginal cost is given by a following equation because the firms face the same marginal cost[174].

[173] $MC_{f,t}$ can be interpreted as nominal marginal cost because it computes the shadow price of varying the use of capital and labour services (Christoffel et al., 2008).

[174] This is because all firms are subject to the same production technology and the same input prices.

$$MC_t = \frac{(R_{K,t})^{\alpha}\left(\left(1+\tau_t^{W_f}\right)W_t\right)^{1-\alpha}}{\epsilon_t z_t^{1-\alpha}\alpha^{1-\alpha}(1-\alpha)^{1-\alpha}} \tag{A4}$$

The firms are permitted to re-set their prices each period with probability $1-\xi_H$ or $1-\xi_X$, depending on whether the product is sold in the domestic or the foreign market. Defining as $P_{H,f,t}$ the domestic price of good f and as $P_{X,f,t}$ its foreign price, all firms that are permitted to reset their prices in a given period t choose the same price $\widetilde{P}_{H,t} = \widetilde{P}_{H,f,t}$ and $\widetilde{P}_{X,t} = \widetilde{P}_{X,f,t}$, depending on the market of destination. Those firms which are not permitted to optimise its price can adjust their prices according to an average of past intermediate goods inflation and the inflation target of the domestic monetary authority:

$$P_{H,f,t} = \Pi_{H,t-1}^{\chi_H}\overline{\Pi}_t^{1-\chi_H}P_{H,f,t-1}, \tag{A5}$$

$$P_{X,f,t} = \Pi_{X,t-1}^{\chi_X}\overline{\Pi}_t^{1-\chi_X}P_{X,f,t-1}. \tag{A6}$$

where $\Pi_{H,t-1} = P_{H,t-1}/P_{H,t-2}$, $\Pi_{X,t-1} = P_{X,t-1}/P_{X,t-2}$, $\overline{\Pi}_t$ is the inflation target, χ_H and χ_X are indexation parameters determining the weight on past inflation.

Each firm f that is allowed to optimally reset its domestic and foreign price in period t maximises the discounted sum of its expected nominal profits,

$$E_t\left[\sum_{k=0}^{\infty}\Lambda_{t,t+k}\left(\xi_H^k D_{H,f,t+k} + \xi_X^k D_{X,f,t+k}\right)\right], \tag{A7}$$

subject to the price-indexation schemes (A5) and (A6) and taking as given domestic and foreign demand for its differentiated output, $H_{f,t}$ and $X_{f,t}$. $D_{H,f,t}$ and $D_{X,f,t}$ are period t nominal profits yielded in the domestic and foreign markets, respectively, and are given by

$$D_{H,f,t} = P_{H,f,t}H_{f,t} - MC_tH_{f,t}, \tag{A8}$$

$$D_{X,f,t} = P_{X,f,t}X_{f,t} - MC_tX_{f,t}. \tag{A9}$$

These nominal profits are distributed as dividends to the households. Thus, the first order condition characterising the firm's optimal pricing decision for its output sold in the domestic market is given by

$$E_t\left[\sum_{k=0}^{\infty}\xi_H^k\Lambda_{t,t+k}\left(\Pi_{H,t+k}^{\dagger}\widetilde{P}_{H,t} - \varphi_{t+k}^H MC_{t+k}\right)H_{f,t+k}\right] = 0 \tag{A10}$$

where we replace the equation (A5), noting that $P_{H,f,t+k} = \Pi_{H,t,t+k}^{\dagger}\widetilde{P}_{H,t}$ with $\Pi_{H,t,t+k}^{\dagger} = \Pi_{s=1}^{k}\Pi_{H,t+s-1}^{\chi_H}\overline{\Pi}_{t+s}^{1-\chi_H}$. This equation means that the optimal price is adjusted to equate the firm's discounted sum of expected revenues to the discounted sum of expected marginal cost. In the absence of price staggering ($\xi_H = 0$), the factor φ_t^H is a time-varing markup of the price charged in domestic markets over nominal marginal cost, indicating the degree of monopoly power on the part of the intermediate goods firm.

We obtain a similar condition for its output sold in the foreign market:

$$E_t\left[\sum_{k=0}^{\infty}\xi_X^k\Lambda_{t,t+k}\left(\Pi_{X,t+k}^{\dagger}\widetilde{P}_{X,t} - \varphi_{t+k}^X MC_{t+k}\right)X_{f,t+k}\right] = 0 \tag{A11}$$

where the equation (A6) also is substituted with a equation showing that $P_{X,f,t+k} = \Pi_{X,t,t+k}^{\dagger}\widetilde{P}_{X,t}$ with $\Pi_{X,t,t+k}^{\dagger} = \Pi_{s=1}^{k}\Pi_{X,t+s-1}^{\chi_X}\overline{\Pi}_{t+s}^{1-\chi_X}$.

On the basis of equation (A5) and equation (A10), respectively, the aggregate price index $P_{H,t}$ is decided by this equation:

$$P_{H,t} = \left[(1-\xi_H) \left(\widetilde{P}_{H,t} \right)^{1/1-\varphi_t^H} + \xi_H \left(\Pi_{H,t-1}^{\chi_H} \overline{\Pi}_t^{1-\chi_H} P_{H,t-1} \right)^{1/1-\varphi_t^H} \right]^{1-\varphi_t^H} \tag{A12}$$

Also $P_{X,t}$ is given by a similar equation:

$$P_{X,t} = \left[(1-\xi_X) \left(\widetilde{P}_{X,t} \right)^{1/1-\varphi_t^X} + \xi_X \left(\Pi_{X,t-1}^{\chi_X} \overline{\Pi}_t^{1-\chi_X} P_{X,t-1} \right)^{1/1-\varphi_t^X} \right]^{1-\varphi_t^X} \tag{A13}$$

A.2. Domestic final goods producers

The representative firm producing the non-tradable final private consumption good, Q_t^C, integrates a bundle of domestically-produced intermediate goods, H_t^C, with a bundle of imported foreign intermediate goods, IM_t^C, using a constant-returns-to-scale (CES) technology,

$$Q_t^C = \left[\nu_C^{1/\mu_C} \left(H_t^C \right)^{1-1/\mu_C} + (1-\nu_C)^{1/\mu_C} \left(\left(1 - \Gamma_{IM^C} \left(IM_t^C / Q_t^C ; \epsilon_t^{IM} \right) \right) IM_t^C \right)^{1-1/\mu_C} \right]^{\mu_C/\mu_C - 1} \tag{A14}$$

where μ_C denotes the intratemporal elasticity of substitution between the distinct bundles of domestic and foreign intermediate goods, while the parameter ν_C indicates the home bias in the production of the consumption goods.

The final goods producers incur a cost $\Gamma_{IM^C} \left(IM_t^C / Q_t^C ; \epsilon_t^{IM} \right)$ when varying the use of the bundle of imported goods in producing the consumption good,

$$\Gamma_{IM^C} \left(IM_t^C / Q_t^C ; \epsilon_t^{IM} \right) = \frac{\gamma_{IM^C}}{2} \left(\left(\epsilon_t^{IM} \right)^{-1/\gamma_{IM^C}} \frac{IM_t^C / Q_t^C}{IM_{t-1}^C / Q_{t-1}^C} - 1 \right)^2 \tag{A15}$$

with the import adjustment cost parameter $\gamma_{IM^C} > 0$. As a result, the import share is relatively unresponsive in the short run to changes in the relative price of the bundle of imported goods, while the level of imports is permitted to jump in response to changes in overall demand. We will refer to ϵ_t^{IM} as an import demand shock.

Defining as $H_{f,t}^C$ and $IM_{f^*,t}^C$ the use of the differentiated output produced by the domestic intermediate goods firm f and the differentiated output supplied by the foreign exporter f^*, respectively, we have

$$H_t^C = \left[\int_0^1 \left(H_{f,t}^C\right)^{1/\varphi_t^H} df\right]^{\varphi_t^H}, \tag{A16}$$

$$IM_t^C = \left[\int_0^1 \left(IM_{f^*,t}^C\right)^{1/\varphi_t^*} df\right]^{\varphi_t^*}, \tag{A17}$$

where the markup parameters in the markets for domestic and imported intermediate goods φ_t^H, $\varphi_t^* > 1$ are inversely related to the intra-temporal elasticities of substitution between differentiated outputs supplied by the domestic firms and the foreign exporters, respectively, with $\varphi_t^H/(\varphi_t^H - 1) > 1$ and $\varphi_t^*/(\varphi_t^* - 1) > 1$.

With nominal prices for the differentiated goods f and f^* being set in monopolistically competitive markets, the final goods firm takes their prices $P_{H,f,t}$ and $P_{IM,f^*,t}$ as given and chooses the optimal use of the differentiated goods f and f^* by minimising the expenditure for the bundles of differentiated goods, $\int_0^1 P_{H,f,t}H_{f,t}^C$ and $\int_0^1 P_{IM,f^*,t}IM_{f^*,t}^C$, subject to the aggregation constraints (A16) and (A17). This yields the following demand equations for the differentiated goods f and f^*:

$$H_{f,t}^C = \left(\frac{P_{H,f,t}}{P_{H,t}}\right)^{-\varphi_t^H/\varphi_t^H-1} H_t^C, \tag{A18}$$

$$IM_{f^*,t}^C = \left(\frac{P_{IM,f^*,t}}{P_{IM,t}}\right)^{-\varphi_t^*/\varphi_t^*-1} IM_t^C, \tag{A19}$$

where $P_{H,t} = \left[\int_0^1 (P_{H,f,t})^{1/1-\varphi_t^H} df\right]^{1-\varphi_t^H}$, $P_{IM,t} = \left[\int_0^1 (P_{IM,f^*,t})^{1/1-\varphi_t^*} df\right]^{1-\varphi_t^*}$ are the aggregate price indexes for the bundles of domestic and imported intermediate goods, respectively.

Next, taking the price indexes $P_{H,t}$ and $P_{IM,t}$ as given, the consumption goods firm chooses the combination of the domestic and foreign intermediate goods bundles H_t^C and IM_t^C that minimises $P_{H,t}H_t^C + P_{IM,t}IM_t^C$ subject to aggregation constraint (A14).

$$H_t^C = \nu_{C,t}\left(\frac{P_{H,t}}{P_{C,t}}\right)^{-\mu_C} Q_t^C, \tag{A20}$$

$$IM_t^C = (1-\nu_{C,t})\left(\frac{P_{IM,t}}{P_{C,t}\Gamma^{\dagger}_{IM^C}\left(IM_t^C/Q_t^C;\epsilon_t^{IM}\right)}\right)^{-\mu_C}\frac{Q_t^C}{1-\Gamma_{IM^C}\left(IM_t^C/Q_t^C;\epsilon_t^{IM}\right)}, \tag{A21}$$

where $P_{C,t} = \left[\nu_{C,t}\left(P_{H,t}\right)^{1-\mu_C} + (1-\nu_{C,t})\left(\frac{P_{IM,t}}{\Gamma^{\dagger}_{IM^C}\left(IM_t^C/Q_t^C;\epsilon_t^{IM}\right)}\right)^{1-\mu_C}\right]^{1/1-\mu_C}$ is the price of a unit of the private consumption good and $\Gamma^{\dagger}_{IM^C}\left(IM_t^C/Q_t^C;\epsilon_t^{IM}\right) = 1-\Gamma_{IM^C}\left(IM_t^C/Q_t^C;\epsilon_t^{IM}\right) - \Gamma'_{IM^C}\left(IM_t^C/Q_t^C;\epsilon_t^{IM}\right)IM_t^C$.

The representative firm producing the non-tradable final private investment good, Q_t^I, is modelled in an analogous manner. Specifically, the firm combines its purchase of a bundle of domestically-produced intermediate good, H_t^I, with the purchase of a bundle of imported foreign intermediate goods, IM_t^I, using a constant returns to scale (CES) technology,

$$Q_t^I = \left[\nu_I^{1/\mu_I}\left(H_t^I\right)^{\mu_I-1/\mu_I} + (1-\nu_I)^{1/\mu_I}\left(\left(1-\Gamma_{IM^I}\left(IM_t^I/Q_t^I;\epsilon_t^{IM}\right)\right)IM_t^I\right)^{\mu_I-1/\mu_I}\right]^{\mu_I/\mu_I-1}, \tag{A22}$$

where μ_I denotes the intra-temporal elasticity of substitution between the distinct bundles of domestic and foreign intermediate inputs, while the parameter ν_I measures the home bias in the production of the investment good. All other variables related to the production of the investment good – import adjustment cost, $\Gamma_{IM^I}\left(IM_t^I/Q_t^I;\epsilon_t^{IM}\right)$: the optimal demand for firm-specific and bundled domestic and foreign intermediate goods, $H_{f,t}^I$, H_t^I and $IM_{f^*,t}^I$, IM_t^I, respectively; as well as the price of a unit of the investment good, $P_{I,t}$ – are defined or derived in a manner analogous to that for the consumption good.

In contrast, the non-tradable final public consumption good, Q_t^G, is assumed to be a composite made only of domestic intermediate goods; that is, $Q_t^G = H_t^G$ with

$$H_t^G = \left[\int_0^1 \left(H_{f,t}^G\right)^{1/\varphi_t^H} df\right]^{\varphi_t^H}. \tag{A23}$$

Hence, the optimal demand for the differentiated intermediate good f is given by

$$H_{f,t}^G = \left(\frac{P_{H,f,t}}{P_{H,t}}\right)^{-\varphi_t^H/\varphi_t^H-1} H_t^G, \tag{A24}$$

and the price of a unit of the public consumption good is $P_{G,t} = P_{H,t}$.

Aggregating across the three final goods firms, we obtain the following aggregate demand equation for domestic and foreign intermediate goods f and f^*.

$$H_{f,t} = H_{f,t}^C + H_{f,t}^I + H_{f,t}^G = \left(\frac{P_{H,f,t}}{P_{H,t}}\right)^{-\varphi_t^H/\varphi_t^H-1} H_t, \tag{A25}$$

$$IM_{f^*,t} = IM_{f^*,t}^C + IM_{f^*,t}^I = \left(\frac{P_{IM,f^*,t}}{P_{IM,t}}\right)^{-\varphi_t^*/\varphi_t^*-1} IM_t, \tag{A26}$$

where $H_t = H_t^C + H_t^I + H_t^G$ and $IM_t = IM_t^C + IM_t^I$.

A.3. Foreign intermediate goods firms

Each foreign intermediate goods firm f^* sells its differentiated good $Y^*_{f^*,t}$ in domestic market under monopolistic competition, setting the price in local (thata is, domestic) currency, as in Betts and Devereux (1996). Again, there is sluggish price adjustment due to nominal rigidities following Calvo (1983) and Yun (1996). Specifically, only a fraction $1-\xi^*$ of the foreign intermediate goods firms is allowed to adjust its price each period and has access to the following indexation scheme with parameter χ^*:

$$P_{IM,f^*,t} = \Pi_{IM,t-1}^{\chi^*} \overline{\Pi}_t^{1-\chi^*} P_{IM,f^*,t-1}, \tag{A27}$$

where $P_{IM,f^*,t} = P^*_{X,f^*,t}$ and $\Pi_{IM,t-1} = P_{IM,t-1}/P_{IM,t-2}$ with $P_{IM,t} = P^*_{X,t}$. Here, we have utilised the fact that, with foreign exporters setting prices in domestic currency, the price of the intermediate good imported from abroad (the import price index of the home country) is equal to the price changed by the foreign exporter in the home country (the export price index of the foreign country).

Each foreign exporter f^* receiving permission to optimally reset its price in period t maximises the discounted sum of its expected nominal profits,

$$E_t \left[\sum_{k=0}^{\infty} \Lambda^*_{t,t+k} (\xi^*)^k D^*_{f^*,t+k}/S_{t+k} \right], \tag{A28}$$

subject to the price-indexation schemes (A27) and the domestic (import) demand for its differentiated output, $IM_{f^*,t} = X^*_{f^*}$, where period t nominal profits (net of fixed costs) $D^*_{f^*,t}$ is given by

$$D^*_{f^*,t} = P_{IM,f^*,t} IM_{f^*,t} - MC^*_t IM_{f^*,t} \tag{A29}$$

with $MC^*_t = S_t \left(P_{O,t}\right)^{\omega^*} \left(P^*_{Y,t}\right)^{1-\omega^*}$ representing the foreign exporter's nominal marginal cost. The latter is defined as a simple geometric average of the price of oil, $P_{O,t}$, and foreign prices, $P^*_{Y,t}$, with ω^* measuring the share of oil in imports.

Hence, we obtain the following first order condition characterising the foreign exporter's optimal pricing decision for its output sold in the domestic market.

$$E_t\left[\sum_{k=0}^{\infty}(\xi^*)^k\,\Lambda^*_{t,t+k}\left(\Pi^{\dagger}_{IM,t+k}\widetilde{P}_{IM,t}-\varphi^*_{t+k}MC^*_{t+k}\right)IM_{f^*,t+k}/S_{t+k}\right]=0, \tag{A30}$$

where we have substituted the indexation scheme (A27), noting that $P_{IM,f^*,t+k}=\Pi^{\dagger}_{IM,t,t+k}\widetilde{P}_{IM,t}$ with $\Pi^{\dagger}_{IM,t,t+k}=\Pi^k_{s=1}\Pi^{\chi^*}_{IM,t+s-1}\overline{\Pi}^{1-\chi^*}_{t+s}$.

The associated aggregate index of price contracts for the differentiated products sold in domestic markets evolves according to

$$P_{IM,t}=\left[(1-\xi^*)\left(\widetilde{P}_{IM,t}\right)^{1/1-\varphi^*_t}+\xi^*\left(\Pi^{\chi^*}_{IM,t-1}\overline{\Pi}^{1-\chi^*}_t P_{IM,t-1}\right)^{1/1-\varphi^*_t}\right]^{1-\varphi^*_t}. \tag{A31}$$

A.4. Foreign retail firms

We assume that a representative foreign retail firm combines the purchases of the differentiated goods, $X_{f,t}$, that are produced by the domestic intermediate goods firm f and sold abroad, using a constant returns to scale technology,

$$X_t=\left[\int_0^1 (X_{f,t})^{1/\varphi^X_t}\,df\right]^{\varphi^X_t}, \tag{A32}$$

where the parameter φ^X_t is inversely related to the intratemporal elasticity of substitution between the differentiated goods supplied by the domestic firms, with $\varphi^X_t/(\varphi^X_t-1)>1$.

With nomianl prices for the exported intermediate goods f being set in producer currency under monopolistic competition, the foreign retailer takes its input prices $P_{X,f,t}/S_t$ as given and decides on the optimal use of the differentiated inputs by minimising the expenditure for the bundle of differentiated goods, $\int_0^1 P_{X,f,t}/S_t X_{f,t}df$, aubject to the aggregation constraint (A32). This yields the following demand equation for the differentiated good f:

$$X_{f,t} = \left(\frac{P_{X,f,t}}{P_{X,t}}\right)^{-\varphi_t^X/\varphi_t^X-1} X_t, \tag{A33}$$

where $P_{X,t} = \left[\int_0^1 (P_{X,f,t})^{1/1-\varphi_t^X} df\right]^{1-\varphi_t^X}$ is the aggregate price index for the bundle of exported domestic intermediate goods in producer currency.

The retailer takes the aggregate price index $P_{X,t}$ as given and supplies the quantity of the export bundle, X_t, that satisfies foreign demand. The latter is given by an equation similar in structure to the domestic import equation,

$$X_t = \nu^* \left(\frac{P_{X,t}/S_t}{P_{X,t}^{c,*}\Gamma_X^\dagger\left(X_t/Y_t^{d,*};\epsilon_t^X\right)}\right)^{-\mu^*} \frac{Y_t^{d,*}}{1-\Gamma_X\left(X_t/Y_t^{d,*};\epsilon_t^X\right)} \tag{A34}$$

with μ^* denoting the price elasticity of exports. Here ν^* represents the export share of the domestic intermediate goods firms, which captures the foreign non-price related preferences for domestic goods. The variable $P_{X,t}^{c,*}$ denotes the price of foreign firms that are competing with the domestic firms in their export markets, $Y_t^{d,*}$ is a measure of overall foreign demand, and $\Gamma_X\left(X_t/Y_t^{d,*};\epsilon_t^X\right)$ is an adjustment cost function given by

$$\Gamma_X\left(X_t/Y_t^{d,*};\epsilon_t^X\right) = \frac{\gamma^*}{2}\left(\left(\epsilon_t^X\right)^{-1/\gamma^*}\frac{X_t/Y_t^{d,*}}{X_{t-1}/Y_{t-1}^{d,*}} - 1\right)^2 \tag{A35}$$

and $\Gamma_X^\dagger\left(X_t/Y_t^{d,*};\epsilon_t^X\right) = 1-\Gamma_X\left(X_t/Y_t^{d,*};\epsilon_t^X\right) - \Gamma_X'\left(X_t/Y_t^{d,*};\epsilon_t^X\right)X_t$.

A.5. Market clearing and aggregate resource constraint

A.5.1. Market clearing in the markets for domestic intermediate goods

Each intermediate goods producer f acts as price setter in domestic and foreign monopolistically competitive markets. Hence, in equilibrium the supply of its differentiated output needs to equal domestic and foreign demand,

$$Y_{f,t} = H_{f,t} + X_{f,t} \tag{A36}$$

Aggregating over the continuum of firms f, we obtain the following aggregate resource constraint:

$$\begin{aligned} Y_t &= \int_0^1 Y_{f,t} df = \int_0^1 H_{f,t} df + \int_0^1 X_{f,t} df \\ &= \int_0^1 \left(\frac{P_{H,f,t}}{P_{H,t}}\right)^{-\varphi_t^H/\varphi_t^H-1} H_t dt + \int_0^1 \left(\frac{P_{X,f,t}}{P_{X,t}}\right)^{-\varphi_t^X/\varphi_t^X-1} X_t dt \\ &= \breve{s}_{H,t} H_t + \breve{s}_{X,t} X_t, \end{aligned} \tag{A37}$$

where the variables $\breve{s}_{H,t} = \int_0^1 \left(\frac{P_{H,f,t}}{P_{H,t}}\right)^{-\varphi_t^H/\varphi_t^H-1} dt$, $\breve{s}_{X,t} = \int_0^1 \left(\frac{P_{X,f,t}}{P_{X,t}}\right)^{-\varphi_t^X/\varphi_t^X-1} dt$ measures the degree of price dispersion across the differentiated goods f sold either domestically or abroad.

Given the optimal price setting strategies for intermediate goods firms, the two measures of price dispersion evolve according to

$$\breve{s}_{H,t} = (1-\xi_H)\left(\frac{\widetilde{P}_{H,t}}{P_{H,t}}\right)^{-\varphi_t^H/\varphi_t^H-1} + \xi_H \left(\frac{\Pi_{H,t}}{\Pi_{H,t-1}^{\chi_H}\overline{\Pi}_t^{1-\chi_H} P_{H,t-1}}\right)^{-\varphi_t^H/\varphi_t^H-1} \breve{s}_{H,t-1}, \tag{A38}$$

$$\breve{s}_{X,t} = (1-\xi_X)\left(\frac{\widetilde{P}_{X,t}}{P_{X,t}}\right)^{-\varphi_t^X/\varphi_t^X-1} + \xi_X \left(\frac{\Pi_{X,t}}{\Pi_{X,t-1}^{\chi_X}\overline{\Pi}_t^{1-\chi_X} P_{X,t-1}}\right)^{-\varphi_t^X/\varphi_t^X-1} \breve{s}_{X,t-1}, \tag{A39}$$

where $\widetilde{P}_{H,t}$ and $\widetilde{P}_{X,t}$ denote the optimal price contracts chosen by those firms that have received permission to reset their prices in their home and foreign markets in period t, and $\Pi_{H,t} = P_{H,t}/P_{H,t-1}$ and $\Pi_{X,t} = P_{X,t}/P_{X,t-1}$.

Similarly, in nominal terms we have

$$\begin{aligned} P_{Y,t}Y_t &= \int_0^1 P_{H,f,t}H_{f,t}df + \int_0^1 P_{X,f,t}X_{f,t}df \\ &= H_t \int_0^1 P_{H,f,t}\left(\frac{P_{H,f,t}}{P_{H,t}}\right)^{-\varphi_t^H/\varphi_t^H-1} dt + X_t \int_0^1 P_{X,f,t}\left(\frac{P_{X,f,t}}{P_{X,t}}\right)^{-\varphi_t^X/\varphi_t^X-1} dt \\ &= P_{H,t}H_t + P_{X,t}X_t, \end{aligned} \tag{A40}$$

where the second to last equality has been obtained using the aggregate demand relationships for the domestic intermediate goods sold in home and foreign markets, and , while the last equality has been obtained using the properties of the aggregate price indexes $H_{f,t}$ and $X_{f,t}$.

Finally, as regards aggregate intermediate goods firms' profits, we have

$$\begin{aligned} D_t &= \int_0^1 D_{H,f,t}df + \int_0^1 D_{X,f,t}df \\ &= P_{H,t}H_t + P_{X,t}X_t - MC_t\left(\breve{s}_{H,t}H_t + \breve{s}_{X,t}X_t + \psi z_t\right) \end{aligned} \tag{A41}$$

or, written as profit share,

$$s_{D,t} = \frac{D_t}{P_{Y,t}Y_t} = 1 - \frac{MC_t}{P_{Y,t}}\frac{\breve{s}_{H,t}H_t + \breve{s}_{X,t}X_t + \psi z_t}{Y_t}. \tag{A42}$$

A.5.2. Market clearing in the markets for imported intermediate goods

Each foreign exporter f^* acts as price setter for its differentiated output in domestic monopolistically competitive markets. Hence, in equilibrium the supply of its differentiated output needs to equal demand, $IM_{f^*,t}$. Aggregating over the continuum of firms f^*, we have

$$\begin{aligned}\int_0^1 IM_{f^*,t}df^* &= \int_0^1 \left(\frac{P_{IM,f^*,t}}{P_{IM,t}}\right)^{-\varphi_t^*/\varphi_t^*-1} IM_t df^* \\ &= \breve{s}_{IM,t} IM_t, \end{aligned} \tag{A43}$$

where the variable $\breve{s}_{IM,t} = \int_0^1 \left(\frac{P_{IM,f^*,t}}{P_{IM,t}}\right)^{-\varphi_t^*/\varphi_t^*-1} df^*$ measures the degree of price dispersion across the differentiated goods f^*. Given the optimal price setting strategies for foreign exporters, the measure of price dispersion evolves according to

$$\breve{s}_{IM,t} = (1-\xi^*)\left(\frac{\widetilde{P}_{IM,t}}{P_{IM,t}}\right)^{-\varphi_t^*/\varphi_t^*-1} + \xi^*\left(\frac{\Pi_{IM,t}}{\Pi_{IM,t-1}^{\chi^*}\overline{\Pi}_t^{1-\chi^*}P_{IM,t-1}}\right)^{-\varphi_t^*/\varphi_t^*-1}\breve{s}_{IM,t-1},$$

where $\widetilde{P}_{IM,t}$ denotes the optimal price contracts chosen by those exporters that have received permission to reset their prices in period t, and $\Pi_{IM,t} = P_{IM,t}/P_{IM,t-1}$.

A.5.3. Market clearing in the final goods markets

Market clearing in the fully competitive final goods markets implies:

$$Q_t^C = C_t, \tag{A44}$$

$$Q_t^I = I_t + \Gamma_u(u_t)K_t, \tag{A45}$$

$$Q_t^G = G_t. \tag{A46}$$

Subsequently, combining the market clearing conditions for domestic intermediate goods and final goods results in the following representation of the nominal aggregate resource constraint (A40):

$$\begin{aligned}
P_{Y,t}Y_t &= P_{H,t}H_t + P_{X,t}X_t \\
&= P_{C,t}C_t + P_{I,t}\left(I_t + \Gamma_u(u_t)K_t\right) + P_{G,t}G_t + P_{X,t}X_t \\
&\quad - P_{IM,t}\left(IM_t^C \frac{1-\Gamma_{IM^C}\left(IM_t^C/Q_t^C;\epsilon_t^{IM}\right)}{\Gamma^{\dagger}_{IM^C}\left(IM_t^C/Q_t^C;\epsilon_t^{IM}\right)} + IM_t^I \frac{1-\Gamma_{IM^I}\left(IM_t^I/Q_t^I;\epsilon_t^{IM}\right)}{\Gamma^{\dagger}_{IM^I}\left(IM_t^I/Q_t^I;\epsilon_t^{IM}\right)} \right),
\end{aligned} \tag{A47}$$

where the last equality has been obtained using the demand functions for the bundles of the domestic and foreign intermediate goods utilised in the production of the final consumption and investment goods, H_t^C and H_t^I as well as IM_t^C and IM_t^I, along with the prices of the two types of final goods, $P_{C,t}$ and $P_{I,t}$.

A.5..4. Market clearing in the domestic government bond market

The equilibrium bolding of domestic government bonds evolove over time according to the fiscal authority's budget constraint, reflecting the fiscal authority's need to issue debt in order to finance its debt.

As a given point in time , the supply of internationally traded foreign bonds is fully elastic and matches the (net) holding of foreign bonds accumulated by domestic households,

$$B_t^* = \int_0^1 B_{h,t}^* dh. \tag{A48}$$

A.5.5. Net foreign assets, trade balance and terms of trade

The domestic economy's net foreign assets equal the economy wide net holdings of foreign bonds (denominated in foreign currency) and evolve according to

$$(R_t^*)^{-1} B_{t+1}^* = B_t^* + \frac{TB_t}{S_t}, \tag{A49}$$

where $TB_t = P_{X,t}X_t - P_{IM,t}IM_t$ is the domestic economy's trade balance. For reporting purposes, the net foreign assets, as well as the trade balance, are conveniently expressed as a share of domestic output, with $s_{B^*,t+1} = S_t B_{t+1}^*/P_{Y,t}Y_t$ and $s_{TB,t} = TB_t/P_{Y,t}Y_t$, respectively.

Finally, the terms of trade (defined as the domestic price of imports relative to the price of exports) are given by:

$$ToT_t = \frac{P_{IM,t}}{P_{X,t}}. \tag{A50}$$

B. The linearized model

In this appendix we provide the log-linear form of the model. We represent all transformed variables by lower-case letters. We also define the steady state value of a variable by dropping the time subscript t and indicate the logarithmic deviation from its steady-state value by a hat ('$\widehat{\ }$').

$$\widehat{\lambda}_t = -\frac{1}{1-\kappa g_z^{-1}}\widehat{\widehat{c}}_t + \frac{\kappa g_z^{-1}}{1-\kappa g_z^{-1}}\widehat{\widehat{c}}_{t-1} - \frac{\kappa g_z^{-1}}{1-\kappa g_z^{-1}}\widehat{g}_{z,t} - \frac{1}{1+\tau^C}\widehat{\tau}_t^C + \widehat{\epsilon}_t^C \tag{B1}$$

$$\begin{aligned}\widehat{p}_{I,t} &= \widehat{Q}_t + \widehat{\epsilon}_t^I + \gamma_I g_z^2 \left(\beta \left(E_t \left[\widehat{i}_{t+1}\right] - \widehat{i}_t\right)\right) \\ &\quad - \left(\widehat{i}_t - \widehat{i}_{t-1}\right) + \beta E_t \left[\widehat{g}_{z,t+1} - \widehat{g}_{z,t}\right]\end{aligned} \tag{B2}$$

$$\begin{aligned}\widehat{q}_t &= \frac{\beta(1-\delta)}{g_z} E_t\left[\widehat{q}_{t+1}\right] + E_t\left[\widehat{\lambda}_{t+1}\right] - \widehat{\lambda}_t - E_t\left[\widehat{g}_{z,t+1}\right] \\ &\quad - \frac{\beta\left(1-\tau^K\right)}{g_z} E_t\left[\frac{1}{1-\tau^K}\widehat{\tau}_{t+1}^K - \widehat{R}_{K,t+1}\right] + \frac{\beta\delta p_I}{g_z} E_t\left[\tau^K \widehat{p}_{I,t+1} + \widehat{\tau}_{t+1}^K\right]\end{aligned} \tag{B3}$$

$$E_t\left[\widehat{\lambda}_{t+1}\right] - \widehat{\lambda}_t - E_t\left[\widehat{g}_{z,t+1}\right] + \widehat{r}_{g,t} - E_t\left[\widehat{\pi}_{C,t+1}\right] = 0 \tag{B4}$$

$$\widehat{r}_{g,t} - \widehat{r}_t^* = E_t\left[\widehat{s}_{t+1}\right] - \widehat{s}_t + E_t\left[\widehat{\pi}_{Y,t+1} - \widehat{\pi}_{Y,t+1}^*\right] - \gamma_{B^*}\widehat{s}_{B^*,t+1} \tag{B5}$$

$$\begin{aligned}\widehat{k}_{t+1} &= (1-\delta)\, g_z^{-1}\widehat{k}_t - (1-\delta)\, g_z^{-1}\widehat{g}_{z,t} \\ &\quad + \left(1-(1-\delta)\, g_z^{-1}\right)\widehat{\epsilon}_t^I + \left(1-(1-\delta)\, g_z^{-1}\right)\widehat{i}_t\end{aligned} \tag{B6}$$

$$\begin{aligned}\widehat{w}_t &= \frac{\beta}{1+\beta}E_t\left[\widehat{w}_{t+1}\right] + \frac{1}{1+\beta}\widehat{w}_{t-1} + \frac{\beta}{1+\beta}E_t\left[\widehat{\pi}_{C,t+1}\right] \\ &\quad - \frac{1+\beta\chi_W}{1+\beta}\widehat{\pi}_{C,t} + \frac{1}{1+\beta}\widehat{\pi}_{C,t-1} - \frac{\beta(1-\chi_W)}{1+\beta}E_t\left[\widehat{\pi}_{C,t+1}\right] + \frac{1-\chi_W}{1+\beta}\widehat{\pi}_{C,t} \\ &\quad - \frac{(1-\beta\xi_W)(1-\xi_W)}{(1+\beta)\,\xi_W\left(1+\frac{\varphi^W}{\varphi^W-1}\zeta\right)}\left(-\frac{\widehat{\tau}_t^N + \widehat{\tau}_t^{W^h}}{1-\tau^N-\tau^{W^h}} + \widehat{w}_{t+1} - \widehat{\epsilon}_t^N + \varsigma\widehat{N}_t - \widehat{\lambda}_t - \widehat{\varphi}_t^W\right)\end{aligned} \tag{B7}$$

$$\widehat{y}_t = \left(1+\psi y^{-1}\right)\left(\widehat{\epsilon}_t + \alpha\left(\widehat{\bar{k}}_t - \widehat{g}_{z,t}\right) + (1-\alpha)\,\widehat{n}_t\right) \tag{B8}$$

$$\widehat{r}_{K,t} = \widehat{g}_{z,t} + \widehat{n}_t + \left(1+\tau^{W_f}\right)^{-1}\widehat{\tau}_t^{W_f} + \widehat{w}_t - \widehat{\bar{k}}_t \tag{B9}$$

$$\begin{aligned}
(\widehat{\pi}_{H,t} - \widehat{\bar{\pi}}_t) &= \frac{\beta}{1+\beta\chi_H}E_t\left[\widehat{\pi}_{H,t+1} - \widehat{\bar{\pi}}_{t+1}\right] + \frac{\chi_H}{1+\beta\chi_H}(\widehat{\pi}_{H,t-1} - \widehat{\bar{\pi}}_t) \\
&\quad + \frac{\beta\chi_H}{1+\beta\chi_H}\left(E_t\left[\widehat{\bar{\pi}}_{t+1} - \widehat{\bar{\pi}}_t\right]\right) + \frac{(1-\beta\xi_H)(1-\xi_H)}{\xi_H(1+\beta\chi_H)}\left(\widehat{mc}_t - \widehat{p}_{H,t} + \widehat{\varphi}_t^H\right)
\end{aligned} \tag{B10}$$

$$\begin{aligned}
(\widehat{\pi}_{X,t} - \widehat{\bar{\pi}}_t) &= \frac{\beta}{1+\beta\chi_X}E_t\left[\widehat{\pi}_{X,t+1} - \widehat{\bar{\pi}}_{t+1}\right] + \frac{\chi_X}{1+\beta\chi_X}(\widehat{\pi}_{X,t-1} - \widehat{\bar{\pi}}_t) \\
&\quad + \frac{\beta\chi_X}{1+\beta\chi_X}\left(E_t\left[\widehat{\bar{\pi}}_{t+1} - \widehat{\bar{\pi}}_t\right]\right) + \frac{(1-\beta\xi_X)(1-\xi_X)}{\xi_X(1+\beta\chi_X)}\left(\widehat{mc}_t - \widehat{p}_{X,t} + \widehat{\varphi}_t^X\right)
\end{aligned} \tag{B11}$$

$$\begin{aligned}
(\widehat{\pi}_{IM,t} - \widehat{\bar{\pi}}_t) &= \frac{\beta^*}{1+\beta^*\chi^*}E_t\left[\widehat{\pi}_{IM,t+1} - \widehat{\bar{\pi}}_{t+1}\right] + \frac{\chi^*}{1+\beta^*\chi^*}(\widehat{\pi}_{IM,t-1} - \widehat{\bar{\pi}}_t) \\
&\quad + \frac{\beta^*\chi^*}{1+\beta^*\chi^*}\left(E_t\left[\widehat{\bar{\pi}}_{t+1} - \widehat{\bar{\pi}}_t\right]\right) \\
&\quad + \frac{(1-\beta^*\xi^*)(1-\xi^*)}{\xi^*(1+\beta^*\chi^*)}\left(\widehat{s}_t + \widehat{p}_{Y,t} - \widehat{p}_{IM,t} + \omega^*\widehat{p}_{O,t} + \widehat{\varphi}_t^*\right)
\end{aligned} \tag{B12}$$

$$\begin{aligned}\widehat{q}_t^C &= \nu_C^{1/\mu_C}\left(\frac{h^C}{q^C}\right)^{1-1/\mu_C}\widehat{h}_t^C + (1-\nu_C)^{1/\mu_C}\left(\frac{im^C}{q^C}\right)^{1-1/\mu_C}\widehat{im}_t^C \\ &+\frac{1}{\mu_C-1}\left(\nu_C^{1/\mu_C}\left(\frac{h^C}{q^C}\right)^{1-1/\mu_C} - \frac{\nu_C}{1-\nu_C}(1-\nu_C)^{1/\mu_C}\left(\frac{im^C}{q^C}\right)^{1-1/\mu_C}\right)\widehat{\nu}_{C,t}\end{aligned} \tag{B13}$$

$$\begin{aligned}\widehat{p}_{C,t} &= \nu_C\left(\frac{p_H}{p_C}\right)^{1-\mu_C}\widehat{p}_{H,t} + (1-\nu_C)\left(\frac{p_{IM}}{p_C}\right)^{1-\mu_C}\left(\widehat{p}_{IM,t} - \widehat{\Gamma}^{\dagger}_{IM^C,t}\right) \\ &+\frac{\nu_C}{1-\mu_C}\left(\left(\frac{p_H}{p_C}\right)^{1-\mu_C} - \left(\frac{p_{IM}}{p_C}\right)^{1-\mu_C}\right)\widehat{\nu}_{C,t}\end{aligned} \tag{B14}$$

$$\begin{aligned}\widehat{q}_t^I &= \nu_I^{1/\mu_I}\left(\frac{h^I}{q^I}\right)^{1-1/\mu_I}\widehat{h}_t^I + (1-\nu_I)^{1/\mu_I}\left(\frac{im^I}{q^I}\right)^{1-1/\mu_I}\widehat{im}_t^I \\ &+\frac{1}{\mu_I-1}\left(\nu_I^{1/\mu_I}\left(\frac{h^I}{q^I}\right)^{1-1/\mu_I} - \frac{\nu_I}{1-\nu_I}(1-\nu_I)^{1/\mu_I}\left(\frac{im^I}{q^I}\right)^{1-1/\mu_I}\right)\widehat{\nu}_{I,t}\end{aligned} \tag{B15}$$

$$\begin{aligned}\widehat{p}_{I,t} &= \nu_I\left(\frac{p_H}{p_I}\right)^{1-\mu_I}\widehat{p}_{H,t} + (1-\nu_I)\left(\frac{p_{IM}}{p_I}\right)^{1-\mu_I}\left(\widehat{p}_{IM,t} - \widehat{\Gamma}^{\dagger}_{IM^I,t}\right) \\ &+\frac{\nu_I}{1-\mu_I}\left(\left(\frac{p_H}{p_I}\right)^{1-\mu_I} - \left(\frac{p_{IM}}{p_I}\right)^{1-\mu_I}\right)\widehat{\nu}_{I,t}\end{aligned} \tag{B16}$$

$$\widehat{im}_t = \frac{im^C}{im}\widehat{im}_t^C + \frac{im^I}{im}\widehat{im}_t^I \tag{B17}$$

$$\widehat{x}_t = \widehat{\nu}^*_t - \mu^* \left(\widehat{p}_{X,t} - \widehat{p}_{Y,t} - \widehat{s}_t - \widehat{p}^C_{X,t} - \left(-\gamma^* \left(\left(\widehat{x}_t - \widehat{y}^*_t\right) - \left(\widehat{x}_{t-1} - \widehat{y}^*_{t-1}\right)\right)\right)\right) + \widehat{y}^*_t \tag{B18}$$

$$\widehat{r}_t = \phi_R \widehat{r}_{t-1} + (1-\phi_R)\left[\widehat{\overline{\pi}}_t + \phi_\Pi \left(\widehat{\pi}_{C,t} - \widehat{\overline{\pi}}\right) + \phi_Y \widehat{y}_t\right] + \phi_{\triangle\Pi}\left(\widehat{\pi}_{C,t} - \widehat{\pi}_{C,t-1}\right) + \phi_{\triangle Y}\left(\widehat{y}_t - \widehat{y}_{t-1}\right) + \widehat{\eta}^R_t \tag{B19}$$

$$\widehat{y}_t = \frac{h}{y}\left(\frac{h^C}{h}\left(\widehat{q}^C_t - \mu_C\left(\widehat{p}_{H,t} - \widehat{p}_{C,t}\right)\right) + \frac{h^I}{h}\left(\widehat{q}^I_t - \mu_I\left(\widehat{p}_{H,t} - \widehat{p}_{I,t}\right)\right) + \frac{h^G}{h}\widehat{h}^G + \frac{h^{I_G}}{h}\widehat{h}^{I_G}\right) + \frac{x}{y}\widehat{x}_t \tag{B20}$$

$$\begin{aligned}
\widehat{p}_{Y,t} + \widehat{y}_t \quad = \quad & \frac{p_C c}{p_Y y}\left(\widehat{p}_{C,t} + \widehat{c}_t\right) + \frac{p_I i}{p_Y y}\left(\widehat{p}_{I,t} + \widehat{i}_t\right) + \frac{p_I k g_z^{-1}}{p_Y y}\gamma_{u,1}\widehat{u}_t \\
& + \frac{p_G g}{p_Y y}\left(\widehat{p}_{G,t} + \widehat{g}_t\right) + \frac{p_{I_G} i_G}{p_Y y}\left(\widehat{p}_{I_G,t} + \widehat{i_{G}}_t\right) + \frac{p_X x}{p_Y y}\left(\widehat{p}_{X,t} + \widehat{x}_t\right) \\
& - \left(\frac{p_{IM} im^C}{p_Y y}\left(\widehat{p}_{IM,t} + \widehat{im}^C_t - \widehat{\Gamma}^\dagger_{IM^C,t}\right) + \frac{p_{IM} im^I}{p_Y y}\left(\widehat{p}_{IM,t} + \widehat{im}^I_t - \widehat{\Gamma}^\dagger_{IM^I,t}\right)\right)
\end{aligned} \tag{B21}$$

$$\begin{aligned}
\left(R^*\right)^{-1}\widehat{b}^*_{t+1} \quad = \quad & g_z^{-1}\left(\overline{\Pi}^*_Y\right)^{-1}\widehat{b}^*_t + \frac{p_X x}{s p_Y}\left(\widehat{p}_{X,t} + \widehat{x}_t - \widehat{s}_t - \widehat{p}_{Y,t}\right) \\
& - \frac{p_{IM} im}{s p_Y}\left(\widehat{p}_{IM,t} + \widehat{im}_t - \widehat{s}_t - \widehat{p}_{Y,t}\right)
\end{aligned} \tag{B22}$$

$$
\begin{aligned}
& p_G g\left(\widehat{p}_{G,t}+\widehat{g}_t\right)+p_{I_G} i_G\left(\widehat{p}_{I_G,t}+\widehat{i_G}_t\right)+\frac{b}{\pi g_z^{-1}}\left(\widehat{b}_t-\widehat{\pi}_{C,t}-\widehat{g}_{z,t}\right)+tr\widehat{tr}_t \qquad \text{(B23)}\\
= \;& \frac{p_C c}{p_Y y}\left(\widehat{\tau}_t^C+\tau^C\left(\widehat{p}_{C,t}+\widehat{c}_t-\widehat{p}_{Y,t}-\widehat{y}_t\right)\right)\\
& +\frac{wN}{p_Y y}\left(\widehat{\tau}_t^N+\widehat{\tau}_t^{W_h}+\widehat{\tau}_t^{W_f}+\left(\tau^N+\tau^{W_h}+\tau^{W_f}\right)\left(\widehat{w}_t+\widehat{N}_t-\widehat{p}_{Y,t}-\widehat{y}_t\right)\right)\\
& +\frac{r_K k g_z^{-1}}{p_Y y}\left(\widehat{\tau}_t^K+\tau^K\left(\widehat{u}_t+\widehat{r}_{K,t}+\widehat{k}_t-\widehat{g}_{z,t}-\widehat{p}_{Y,t}-\widehat{y}_t\right)\right)\\
& -\frac{p_I k g_z^{-1}}{p_Y y}\left(\delta\widehat{\tau}_t^K+\tau^K\gamma_{u,1}\widehat{u}_t+\tau^K\delta\left(\widehat{p}_{I,t}+\widehat{k}_t-\widehat{g}_{z,t}-\widehat{p}_{Y,t}-\widehat{y}_t\right)\right)\\
& +\frac{b}{r_g}\left(\widehat{b}_{t+1}-\widehat{r}_{g,t}\right)+\widehat{s}_{T,t}
\end{aligned}
$$

$$\widehat{\tilde{c}}_t=\alpha_G^{1/\nu_G}\left(\frac{c}{\tilde{c}}\right)^{1-1/\nu_G}\widehat{c}_t+(1-\alpha_G)^{1/\nu_G}\left(\frac{g}{\tilde{c}}\right)^{1-1/\nu_G}\widehat{g}_t \qquad \text{(B24)}$$

$$\widehat{\tilde{k}}_t=\alpha_K^{1/\nu_K}\left(\frac{k}{\tilde{k}}\right)^{1-1/\nu_K}\widehat{k}_t+(1-\alpha_K)^{1/\nu_K}\left(\frac{k_G}{\tilde{k}}\right)^{1-1/\nu_G}\widehat{k}_{G,t} \qquad \text{(B25)}$$

$$\widehat{k}_{G,t+1}=\frac{(1-\delta_G)}{g_z^{-1}}\widehat{k}_{G,t}+\frac{(1-\delta_G)}{g_z^{-1}}\widehat{g}_{z,t}+\left(1-\frac{(1-\delta_G)}{g_z^{-1}}\right)\left(\widehat{a}_{I_G,t}-\widehat{g}_{z,t}\right) \qquad \text{(B26)}$$

$$\widehat{i}_{G,t}=\frac{1}{b_0+b_1 g_z^{-1}}\left(b_0\widehat{a}_{I_G,t}+b_1 g_z^{-1}\widehat{a}_{I_G,t-1}-b_1 g_z^{-1}\widehat{g}_{z,t}\right) \qquad \text{(B27)}$$

$$\widehat{c}_t=(1-\omega)\frac{c_i}{c}\widehat{c}_{i,t}+\omega\frac{c_j}{c}\widehat{c}_{j,t} \qquad \text{(B28)}$$

$$\widehat{tr}_t=\frac{(1-\omega)}{tr}\widehat{tr}_{i,t}+\frac{\omega}{tr}\widehat{tr}_{j,t} \qquad \text{(B29)}$$

$$\begin{aligned}
&\left(1+\tau^{C}\right)c_{j}\left(\frac{1}{1+\tau^{C}}\widehat{\tau}^{C}+\widehat{c}_{j,t}\right)+\widehat{s}_{T,t} \\
=\quad &\left(1-\tau^{N}-\tau^{W_h}\right)wN\left(\widehat{w}_{t}+\widehat{N}_{t}-\frac{1}{1-\tau^{N}-\tau^{W_h}}\right)\left(\widehat{\tau}^{N}+\widehat{\tau}^{W_h}\right)+\widehat{tr}_{j,t} \qquad \text{(B30)}
\end{aligned}$$

$$\widehat{d}_{t}^{*}-\widehat{d}_{t-1}^{*}=\rho_{d1}\left(\widehat{d}_{t-1}^{*}-\widehat{d}_{t-2}^{*}\right)-\rho_{d2}\widehat{d}_{t-1}^{*}-\widehat{\epsilon}_{t}^{d^{*}} \qquad \text{(B31)}$$

$$\widehat{r}_{g,t}-\widehat{r}_{t}=\psi_{b}\widehat{b}_{t+1} \qquad \text{(B32)}$$

$$\widehat{T0T}_{t}=\widehat{p}_{IM.t}-\widehat{p}_{X.t} \qquad \text{(B33)}$$

Chapter 5
Conclusion

This thesis empirically contributes to the macroeconomic analysis on both financial frictions and government debt emphasised during the recent economic crisis.

Chapter 2 examines how both financial development and government debt affect output volatility utilising the system GMM panel regression. Conventionally financial development is thought to stabilise the economy. With regard to government debt there was no systematic analysis. However, the recent financial crisis highlights the destabilising role of the two factors. Thus, this chapter attempts to revisit the relationship between these economic variables and output volatility. Besides, this chapter adds several new issues on the determinants of output volatility. It analyses the effect of the interaction of the two factors on output volatility. This is based on some European countries' case suggesting both the financial crisis and the fiscal crisis are closely connected. In addition, we examine the impact of both private credit and government debt at the beginning of the period on the following period's output volatility using the lagged values of the two macroeconomic factors. It also divides the sample countries according to OECD membership and examines whether or not the income level affects the result.

The estimation establishes the following results. First, higher financial development reduces output volatility. However, above the certain threshold it rather increases economic instability suggesting the non-linear relationship. The estimated threshold gets lower from 152.6 % to 140.9% when the recent financial crisis periods are included. It suggests that the destabilising role of private credit was strengthened during the recent financial crisis. Second, we find that increased government debt levels are statistically associated with increased macroeconomic volatility. This relationship is not estimated to be non-linear unlike financial development. However, as macroeconomic variables can affect government debt, there is also the possibility of endogeneity. Therefore, it is necessary to interpret carefully the relationship between government debt and output volatility. Third, the interaction term between the two does not significantly affect output volatility. This is because the private credit is pro-cyclical, whilst government debt is counter-cyclical. Thus, regarding some European countries' case as general may be a bit hasty. Furthermore, lagged values of the two variables do not affect significantly output volatility. When we also divide the sample countries, non-OECD countries show similar results with the total sample. However, in OECD countries the significant results wholly disappear. We need to acknowledge the fact that the sample is too small to get reliable results for the OECD countries.

These conclusions have meaningful policy implications. Many developed countries may need to decrease private credit levels to stabilise their economies because their private credit levels exceed the estimated threshold during the recent financial crisis. In addition, we find that government debt can destabilise the economy. However, it would be premature to recommend the reduction of government debt given endogeneity. Thus, we need to develop appropriate instrumental variables for government debt to tackle the endogeneity problem.

Chapter 3 investigates how financial frictions empirically amplify and propagate economic fluctuations. This chapter is based on the empirical assumption that the repercussion of the recent financial crisis is related to financial frictions. Specifically, GDP values have showed different time paths depending on countries since 2008. Estonia's GDP declined by nearly 20% in the third quarter of 2009 and still didn't recover the pre-crisis level. This is similar to other countries such as Spain and Iceland. However, the U.S. experienced a modest economic contraction compared to other countries and surpassed the pre-crisis level from 2011. Germany also showed a similar pattern. The interesting fact is that Estonia and Spain experienced the abrupt rise in private credit before the crisis. In contrast, there was the modest increase of private credit in the U.S. and Germany. In order to examine the impact of financial frictions, this chapter compares three DSGE models - the no friction model, the firm friction model, and the bank friction model - according to the comparison of the second moments and the impulse response functions analysis. The three models are calibrated with the U.S. data for the period 1960Q1∼2015Q4.

The results of the moment comparison reveal that the introduction of financial frictions at the firm level improves the model's fit. However, the introduction of financial frictions at the bank level generates mixed impacts on the model's fit. And the firm friction model is the most preferred model by the data.

The impulse responses to the exogenous shocks in the three models show following important results. First, financial frictions, either at the firm level or at the financial intermediaries level, amplify and propagate the fluctuation of economic variables to the exogenous shocks. The impact on credit market gives rise to this difference. As the shock induces the firm's or the bank's net worth to fall and increases the risk premium, investment and output further declines in the models with financial frictions. Second, the response of macroeconomic variables in the model with financial frictions depends on the leverage. We find that higher leverage in the firm or the bank increases the repercussion of the shock. Its impact is displayed in the rise of the risk premium. Thus, investment and output more significantly respond to the shock. Third, the firm friction model displays more persistent responses than the bank friction model. The fall in the firm's net worth to the shock causes the continuous deterioration in investment and output through the response of the risk premium. Therefore, the result suggests that the bank friction model with high leverage is appropriate for explaining a deeper financial crisis, whilst the firm friction model well explains much longer financial crisis.

However, this analysis also has some limitations. This chapter assumes a closed economy and calibrates parameter values. However, most countries except the U.S. are open economies. Thus, when we adopt an open economy DSGE model and estimate the parameter values based on the data, the above results may be different. These issues can be interesting future research areas.

Chapter 4 attempts to find which fiscal consolidation strategy minimises the economic recession and maximises the reduction of government debt. For this purpose, the open economy DSGE model based on Coenen et al. (2013) is utilised. We develop this model by introducing the endogenous risk finance premium and various fiscal rules. In addition, we apply rich fiscal instruments as follows; (i) the cut in government consumption, government investment, and lump-sum transfers, (ii) the hike in consumption tax, wage income tax, and capital income tax. This chapter argues that the effect of the government consumption cut on output is the worst in the baseline model. Some assumptions of the model give rise to this result. The effect of the government investment cut is less than the government consumption cut because the complementarity between private consumption and government consumption expands the effect of the government consumption cut. As this assumption also affects the ranking of a series of tax hikes, the impact of the consumption tax hike on output is the largest among distortionary taxes. However, the effect of the tax hike is generally smaller than the expenditure cut because of the endogenous risk premium. The effect of this mechanism is noticeable in the revenue based strategies because the fall in the debt ratio is larger than in the expenditure based strategies. The model with the endogenous risk premium crowds in private consumption and investment due to the fall in the real interest rate. Thus, this alleviates the recession and accelerates the debt reduction. The capital income tax hike rather increases output in the short run due to this non-Keynesian effect. The endogenous risk premium makes a remarkable change in the ranking of the fiscal instruments based on the response of output. In the model without this mechanism the effect of the tax hike becomes larger than the expenditure based strategies. This result follows the previous literature (e.g., Guajardo et al., 2014; Alesina et al., 2015). Specially, the consumption tax cut has the largest negative impact on output.

Chapter 4 also examines how the fiscal rule significantly affects the impact of fiscal consolidation strategies on economic variables. Its effect is also noticeable in the tax hike like the risk premium mechanism. Compared to the baseline rule the number of the fiscal instruments responding to output and debt decreases in the two alternative rules such as the expenditure adjusted rule and the tax adjusted rule. Thus, the debt ratio and the risk premium move more than in the baseline model and this strengthens the non-Keynesian effect by raising private consumption and investment. As a result, the two optional rules are more effective in both the alleviation of economic recession and the reduction of government debt. Moreover, the expenditure adjusted rule is better than the tax adjusted rule. As the adjustment of the tax rate in the fiscal rule leads to more change in the debt ratio, in the expenditure adjusted rule the debt ratio declines further more than in the tax adjusted rule and its non-Keynesian effect is relatively amplified.

This chapter finds that the effect of fiscal consolidation can differ according to the assumption of the model. This result suggests that we need to pay attention to the economic situation before the choice of the fiscal consolidation strategy. In addition, this chapter can be developed in the following ways. First, some European countries like Greece and Italy show that the risk premium of the government bonds does not respond linearly to the debt ratio. Specially, when investors realised the default risk, the risk premium skyrocketed. Thus, when we apply the default risk to the endogenous risk premium mechanism, more accurate analysis may be possible. Second, we calibrate the coefficients of the fiscal rule according to the previous literature. As the coefficients can differ depending on countries, it is necessary to estimate those coefficients. We leave these topics in future research.

References

[1] Acemoglu, Daron, Simon Johnson, James Robinson, and Yunyong Thaicharoen (2003) Institutional causes, macroeconomic symptoms: crises and growth. *Journal of Monetary Economics* 50(1): 49-123.

[2] Acemoglu, Daron and Fabrizio Zilibotti (1997) Was Prometheus unbound by chance? risk, diversification, and growth. *Journal of Political Economy* 105(4): 709-751.

[3] Aghion, Philippe, Abhijit Banerjee, and Thomas Picketty (1999) Dualism and macroeconomic volatility. *The Quarterly Journal of Economics* 114(4): 1359-1397.

[4] Aizenman, Joshua and Nancy Marion (1999) Volatility and investment: interpreting evidence from developing countries. *Economica* 66(262): 157-1179.

[5] Aizenman, Joshua and Andrew Powell (2003) Volatility and financial intermediation. *Journal of International Money and Finance* 22(5): 657-679.

[6] Alesina, Alberto, Carlo Favero, and Francesco Giavazzi (2015) The output effect of fiscal consolidation plans. *Journal of International Economics* 96: S19-S42.

[7] Almeida, Vanda, Gabriela Castro, Ricardo Mourinho Felix, and Jose R Maria (2013) Fiscal consolidation in a small euro-area economy. *International Journal of Central Banking* 9(4): 1-38.

[8] Arellano, Manuel and Stephen Bond (1991) Some test of specification for panel data: Monte carlo evidence and an application to employment equations. *The Review of Economic Studies* 58(2): 277-297.

[9] Arellano, Manuel and Olympia Bover (1995) Another look at the instrumental variable estimation of error-components models. *Journal of Econometrics* 68(1): 29-51.

[10] Banerjee, Abhijit (2003) Contracting constraints, credit markets and economic development. *Advances in Economics and Econometrics: Theory and Applications, Eight World*

Congress (Vol. 3, p1). Cambridge University Press.

[11] Barell, Ray and Sylvia Gottschalk (2004) The volatility of the output gap in the G7. *National Institute Economic Review* 188(1): 100-107.

[12] Beck, Thorsten, Mattias Lundberg, and Giovanni Majnoni (2006) Financial intermediary development and growth volatility: Do intermediaries dampen or magnify shocks? *Journal of International Money and Finance* 25(7): 1146-1167.

[13] Bejan, Maria (2006) Trade openness and output volatility (No. 2759). *University Library of Munich, Germany.*

[14] Benk, Szilard and Zoltan Jakab (2012) Non-Keynesian effects of fiscal consolidation: An analysis with an estimated DSGE model for the Hungarian economy (No. 945). *OECD Publishing.*

[15] Bernanke, Ben S. and Mark Gertler (1989) Agency costs, net worth, and business fluctuations. *The American Economic Review* 79(1): 14-31.

[16] Bernanke, Ben S., Mark Gertler, and Simon Gilchrist (1999) The financial accelerator in a quantitative business cycle framework. *Handbook of Macroeconomics* 1: 1341-1393.

[17] Blanchard, Olivier and John Simon (2001) The long and large decline in US output volatility. *Brookings Papers on Economic Activity* 2001(1): 135-174.

[18] Blundell, Richard and Stephen Bond (1998) Initial conditions and moment restrictions in dynamic panel data models. *Journal of Econometrics* 87(1): 115-143.

[19] Bohn, Henning (1998) The behavior of US public debt and deficits. *The Quarterly Journal of Economics* 113(3): 949-963.

[20] Bouakez, Hafedh, Emanuela Cardia, and Francisco J Ruge-Murcia (2005) Habit formation and the persistence of monetary shocks. *Journal of Monetary Economics* 52(6): 1073-1088.

[21] Bouakez, Hafedh and Nooman Rebei (2007) Why does private consumption rise after

a government spending shock? *Canadian Journal of Economics* 40(3): 954-979.

[22] Brazdik, Frantisek, Michal Hlavacek, and Ales Marsal (2011) Survey of research on financial sector modeling within DSGE models: What central banks can learn from it. *Czech Journal of Economics and Finance* 62(3): 252-277.

[23] Brunnermeier, Markus K. (2009) Deciphering the liquidity and credit crunch 2007-2008. *The Journal of Economic Perspectives* 23(1): 77-100.

[24] Brunnermeier, Markus K. and Yuliy Sannikov (2014) A macroeconomic model with a financial sector. *The American Economic Review* 104(2): 379-421

[25] Buch, Claudia M., Jorg Dopke, and Christian Pierdzioch (2005) Financial openness and business cycle volatility. *Journal of International Money and Finance* 24(5): 744-765.

[26] Calvo, Guillermo A. (1983) Staggered prices in a utility maximizing framework. *Journal of Monetary Economics* 12(3): 383-398.

[27] Caner, Mehmet, Thomas Grennes, and Fritzi Koehler-Geib (2010) Finding the tipping point when sovereign debt turns bad (No. 5391). *The World Bank*.

[28] Carlstrom, Charles T. and Timothy S Fuerst (1997) Agency costs, net worth, and business fluctuations: A computable general equilibrium analysis. *The American Economic Review*, 893-910.

[29] Cavallo, Eduardo Alfredo (2008) Output volatility and openness to trade: A reassessment. *Economia*, 105-152.

[30] Cecchetti, Stephen G., Madhusudan Mohanty, and Fabrizio Zampolli (2010) The future of public debt: Prospects and implications (No. 300). *Bank for International Settlements*.

[31] Cecchetti, Stephen G., Madhusudan Mohanty, and Fabrizio Zampolli (2011) The real effects of debt (No. 352). *Bank for International Settlements*.

[32] Checherita, Cristina and Philipp Rother (2010) The impact of high and growing government debt on economic growth: An empirical investigation for the Euro Area. *European*

Central Bank Working Paper Series 1237.

[33] Christensen, Ian and Ali Dib (2008) The financial accelerator in an estimated new Keynesian model. *Review of Economic Dynamics* 11(1): 155-178.

[34] Christiano, Lawrence J., Martin Eichenbaum, and Charles L Evans (2005) Nominal rigidities and the dynamic effects of a shock to monetary policy. *Journal of Political Economy* 113(1): 1-45.

[35] Christiano, Lawrence J., Martin Eichenbaum, and Sergio Rebelo (2011) When is the government spending multiplier large? *Journal of Political Economy* 119(1): 78-121.

[36] Christiano, Lawrence J., Roberto Motto, and Massimo V Rostagno (2010) Financial factors in economic fluctuations. *European Central Bank Working Paper Series* 1192.

[37] Christoffel, Kai Philipp, Gunter Coenen, and Anders Warne (2008) The New Area-Wide Model of the euro area: A micro founded open economy model for forecasting and policy analysis. *European Central Bank Working Paper Series* 944.

[38] Coenen, Gunter, Matthias Mohr, and Roland Straub (2008) Fiscal consolidation in the euro area: Long-run benefits and short-run costs. *Economic Modelling* 25(5): 912-932.

[39] Coenen, Gunter and Roland Straub (2005) Does government spending crowd in private consumption? theory and empirical evidence for the euro area. *International Finance* 8(3): 435-470.

[40] Coenen, Gunter, Roland Straub, and Mathias Trabandt (2013) Gauging the effects of fiscal stimulus packages in the euro area. *Journal of Economic Dynamics and Control* 37(2): 367-386.

[41] Cogan, John F, Tobias Cwik, John B Taylor, and Volker Wieland (2010) New Keynesian versus old Keynesian government spending multipliers. *Journal of Economic Dynamics and Control* 34(3): 281-295.

[42] Cogan, John F, John B Taylor, Volker Wieland, and Maik H Wolters (2013) Fiscal

consolidation strategy. *Journal of Economic Dynamics and Control* 37(2): 404-421.

[43] Corsetti, Giancarlo, Keith Kuester, Andre Meier, and Gernot J Muller (2013) Sovereign risk, fiscal policy, and macroeconomic stability. *The Economic Journal* 123(566): 99-132.

[44] Curdia, Vasco, and Michael Woodford (2009) Credit frictions and optimal monetary policy (No. 278). *Bank for International Settlements.*

[45] Dabla-Norris, Era and Narapong Srivisal (2013) Revisiting the link between finance and macroeconomic volatility. *International Monetary Fund Working Papers* 13/29.

[46] De Graeve, Ferre (2008) The external finance premium and the macroeconomy: US post-WWII evidence. *Journal of Economic Dynamics and Control* 32(11): 3415-3440.

[47] Debrun, Xavier, Jean Pisani-Ferry, and Andre Sapir (2008) Government size and output volatility: Should we foresake automatic stabilization? *International Monetary Fund Working Papers,* 1-53.

[48] Denizer, Cevdet A, Murat F Iyigun, and Ann Owen (2002) Finance and macroeconomic volatility. *Contributions in Macroeconomics* 2(1).

[49] Dotsey, Michael and Robert G King (2006) Pricing, production, and persistence. *Journal of the European Economic Association* 4(5): 893-928.

[50] Drautzburg, Thorsten and Harald Uhlig (2011) Fiscal stimulus and distortionary taxation (No. w17111). *National Bureau of Economic Research.*

[51] Easterly, William, Roumeen Islam, and Joseph E Stiglitz (2001) Shaken and stirred: Explaining growth volatility. *Annual World Bank conference on development economics* (vol. 2000): 191-211.

[52] Eggertsson, Gauti B (2011) What fiscal policy is effective at zero interest rate? *In NBER Macroeconomics Annual 2010, Volumn 25* (pp. 59-112). University of Chicago Press.

[53] Erceg, Christopher J and Jesper Linde (2010) Asymmetric shocks in a currency union

with monetary and fiscal handcuffs. *NBER International Seminar on Macroeconomics 2010* (pp. 95-135). University of Chicago Press.

[54] Erceg, Christopher J and Jesper Linde (2013) Fiscal consolidation in a currency union: Spending cuts vs. tax hikes. *Journal of Economic Dynamics and Control* 37(2): 422-445.

[55] Erceg, Christopher J and Jesper Linde (2014) Is there a fiscal free lunch in a liquidity trap? *Journal of the European Economic Association* 12(1): 73-107.

[56] Fatas, Antonio and Ilian Mihov (2001) Government size and automatic stabilizers: International and intranational evidence. *Journal of International Economics* 55(1): 3-28

[57] Fatas, Antonio and Ilian Mihov (2003) The case for restricting fiscal policy discretion. *The Quarterly Journal of Economics* 118(4): 1419-1447.

[58] da Silva, Gesele Ferreira (2002) The impact of financial system development on business cycles volatility: Cross-country evidence. *Journal of Macroeconomics* 24(2): 233-253.

[59] Fisher, Irving (1933) The debt-deflation theory of great depressions. *Econometrica* 1(4): 337-357.

[60] Fornari, Fabio and Livio Stracca (2012) What does a financial shock do? First international evidence. *Economic Policy* 27(71): 407-445.

[61] Forni, Lorenzo, Andrea Gerali, and Massimiliano Pisani (2010) The macroeconomics of fiscal consolidation in euro area countries. *Journal of Economic Dynamics and Control* 34(9): 1791-1812.

[62] Forni, Lorenzo, Libero Monteforte, and Luca Sessa (2009) The general equilibrium effects of fiscal policy: Estimates for the euro area. *Journal of Public Economics* 93(3): 559-585.

[63] Fostel, Ana and John Geanakoplos (2008) Leverage cycles and the anxious economy. *The American Economic Review* 98(4): 1211-1244.

[64] Furceri, Davide and Annabelle Mourougane (2010) The effects of fiscal policy on out-

put: A DSGE analysis. *OECD Economics Department Working Papers* (No. 770). OECD Publishing.

[65] Gali, Jordi (1994) Government size and macroeconomic stability. *European Economic Review* 38(1): 117-132.

[66] Gali, Jordi, J. David Lopez-Salido, and Javier Valles (2007) Understanding the effects of government spending on consumption. *Journal of the European Economic Association* 5(1): 227-270.

[67] Gerali, Andrea, Stefano Neri, Luca Sessa, and Federico M Signoretti (2010) Credit and banking in a DSGE model of the euro area. *Journal of Money, Credit and Banking* 42(s1): 107-141.

[68] Gertler, Mark and Peter Karadi (2011) A model of unconventional monetary policy. *Journal of Monetary Economics* 58(1): 17-34.

[69] Gertler, Mark and Nobuhiro Kiyotaki (2010) Financial intermediation and credit policy in business cycle analysis. *Handbook of Monetary Economics* 3(3): 547-599.

[70] Giovanni, Julian di and Andrei A Levchenko (2009) Trade openness and volatility. *The Review of Economics and Statistics* 91(3): 558-585.

[71] Gomes, Joao F, Amir Yaron, and Lu Zhang (2003) Asset prices and business cycles with costly external finance. *Review of Economic Dynamics* 6(4): 767-788.

[72] Goodfriend, Marvin and Bennett T McCallum (2007) Banking and interest rates in monetary policy analysis: A quantitative exploration. *Journal of Monetary Economics* 54(5): 1480-1507.

[73] Guajardo, Jaime, Daniel Leigh, and Andrea Pescatori (2014) Expansionary austerity? International evidence. *Journal of the European Economic Association 12.4*: 949-968.

[74] Herdon, Thomas, Michael Ash, and Robert Pollin (2014) Does high public debt consistently stifle economic growth? A critique of Reinhart and Rogoff. *Cambridge Journal*

of Economics 38(2): 257-279.

[75] Heston, Alan and Robert Summers (2012) Penn world table version 7.1. *Center for International Comparisons of Production, Income and Prices at the University of Pennsylvania.*

[76] Holmstrom, Bengt and Jean Tirole (1997) Financial intermediation, loanable funds, and the real sector. *The Quarterly Journal of Economics* 112(3): 663-691.

[77] Horton, Mark A, Paolo Mauro, and Manmohan S Kumar (2009) The state of public finances: A cross-country fiscal monitor. *International Monetary Fund.*

[78] Jorda, Oscar, Moritz HP Schularick, and Alan M Taylor (2011) When credit bites back: Leverage, business cycles, and crises (No. w17621). *National Bureau of Economic Research.*

[79] Jorda, Oscar, Moritz HP Schularick, and Alan M Taylor (2013) Sovereigns versus banks: credit, crises, and consequences (No. w19506). *National Bureau of Economic Research.*

[80] Keynes, John Maynard (2006) General theory of employment, interest and money. *Atlantic Books.*

[81] Kindleberger, Charles P (1993) A financial history of western europe. *OUP Catalogue.*

[82] King, Robert G and Ross Levine (1993) Finance, entrepreneurship, and growth. *Journal of Monetary Economics* 32(3): 513-542.

[83] Kumar, Manmohan and Jaejoon Woo (2010) Public debt and growth (No 10/174). *International Monetary Fund.*

[84] Kunieda, Takuma (2008) Financial development and volatility of growth rates: new evidence. *MPRA Paper 11341.* University Library of Munich, Germany.

[85] Laubach, Thomas (2009) New evidence on the interest rate effects of budget deficits and debt. *Journal of the European Economic Association* 7(4): 858-885.

[86] Laubach, Thomas (2010) Fiscal policy and interest rate: The role of sovereign default risk. *NBER International Seminar on Macroeconomics 2010* (pp. 7-29). University of Chicago Press.

[87] Leeper, Eric M, Michael Plante, and Nora Traum (2010) Dynamics of fiscal financing in the United States. *Journal of Econometrics* 156(2): 304-321.

[88] Leeper, Eric M, Todd B Walker, and Shu-Chun Susan Yang (2010) Government investment and fiscal stimulus in the short and long run. *Journal of Monetary Economics* 57(8): 1000-1012.

[89] Leeper, Eric M (2013) Fiscal foresight and information flows. *Econometrica* 81(3): 1115-1145.

[90] Leigh, Daniel, Pete Devries, Charles Freeman, Jaime Guajardo, Douglas Laxton, and Andrea Pescatori (2010) Will it hurt? Macroeconomic effects of fiscal consolidation. *World Economic Outlook*: 93-124.

[91] Loayza, Norman V, Romain Ranciere, Luis Serven, and Jaume Ventura (2007) Macroeconomic volatility and welfare in developing countries: An introduction. *The World Bank Economic Review* 21(3): 343-357.

[92] Lopez, Jose A and Mark M Spiegel (2002) Financial structure and macroeconomic performance over the short and long run (No. 2002-05). *Federal Reserve Bank of San Francisco.*

[93] Maddaloni, Angela, Matteo Ciccarelli, and Jose-Luis Peydro (2014) Trusting the bankers: A new look at the credit channel of monitoring policy. *Review of Economic Dynamics.*

[94] Malik, Adeel and Jonathan RW Temple (2009) The geography of output volatility. *Journal of Development Economics* 90(2): 163-178.

[95] Mallick, Debdulal (2009) Financial development, shocks, and growth volatility (No.

17799). *University Library of Munich, Germany.*

[96] Meh, Cesaire A and Kevin Moran (2010) The role of bank capital in the propagation of shocks. *Journal of Economic Dynamics and Control* 34(3): 555-576.

[97] Mendoza, Enrique G and Vivian Z Yue (2012) A general equilibrium model of sovereign default and business cycles. *The Quarterly Journal of Economics* 127(2): 889-946.

[98] Minsky, Hyman P and Henry Kaufman (2008) Stabilizing an unstable economy (Vol. 1). New York: McGraw-Hill.

[99] Mobarak, Ahmed Mushfiq (2005) Democracy, volatility, and economic development. *Review of Economics and Statistics* 87(2): 348-361.

[100] Ni, Shawn (1995) An empirical analysis on the substitutability between private consumption and government purchases. *Journal of Monetary Economics* 36(3): 593-605.

[101] Nickell, Stephen (1981) Biases in dynamic models with fixed effects. *Econometrica: Journal of the Econometric Society*, 1417-1426.

[102] Nolan, Charles and Christoph Thoenissen (2009) Financial shocks and the US business cycle. *Journal of Monetary Economics* 56(4): 596-604.

[103] Pescatori, Andrea, Damiano Sandri, and John Simon (2014) Debt and growth: Is there a magic threshold? (No. 14/34). *International Monetary Fund.*

[104] Primiceri, Giorgio E, Ernst Schaumburg, and Andrea Tambalotti (2006) Intertemporal disturbances (No. w12243). *National Bureau of Economic Research.*

[105] Queijo von Heidenken, Virginia (2009) How important are financial frictions in the United States and the euro area? *The Scandinavian Journal of Economics* 111(3): 567-596.

[106] Ramey, Garey and Valerie A Ramey (1995) Cross-country evidence on the link between volatility and growth. *The American Economic Review* 85(5): 1138-1151.

[107] Rannenberg, Ansgar (2012) Asymmetric information in credit markets, bank leverage cycles and macroeconomic dynamics. *National Bank of Belgium Working Pape*r (No. 224).

[108] Reinhart, Carmen M and Kenneth S Rogoff (2009) This time is different: Eight centuries of financial folly. Princeton University Press.

[109] Reinhart, Carmen M and Kenneth S Rogoff (2010) Growth in a time of debt. *The American Economic Review* 100(2): 573-578.

[110] Reinhart, Carmen M and Kenneth S Rogoff (2011) From financial crash to debt crisis. *The American Economic Review* 101(5): 1676-1706.

[111] Roodman, David (2006) How to do xbound2: An introduction to difference and system GMM in stata. *Center for Global Development Working Paper* 103.

[112] Roodman, David (2009) A note on the theme of too many instruments. *Oxford Bulletin of Economics and Statistics* 71(1): 135-158.

[113] Schuknecht, Ludger, Jurgen von Hagen, and Guido Wolswijk (2011) Government bond risk premiums in the EU revisited: The impact of the financial crisis. *European Journal of Political Economy* 27(1): 36-43.

[114] Schularick, Moritz and Alan M Taylor (2012) Credit booms gone burst: Monetary policy, leverage cycles, and financial crises, 1870-2008. *The American Economic Review* 102(2): 1029-1061.

[115] Schurin, Matt (2012) Government debt and macroeconomic volatility. *mimeo.*

[116] Scheifer, Andrei and Robert W Vishny (2010) Unstable banking. *Journal of Financial Economics* 97(3): 306-318.

[117] Smets, Frank and Raf Wouters (2003) An estimated dynamic stochastic general equilibrium model of the euro area. *Journal of the European Economic Association* 1(5): 1123-1175.

[118] Smets, Frank and Raf Wouters (2007) Shocks and frictions in US business cycles: A Bayesian DSGE approach. *The American Economic Review* 97(3): 586-606

[119] Spiliopoulos, Leonidas (2010) The determinants of macroeconomic volatility: A

Bayesian model averaging approach (No. 26832). *University Library of Munich, Germany.*

[120] Stahler, Nikolai and Carlos Thomas (2012) FiMod-A DSGE model for fiscal policy simulations. *Economic Modelling* 29(2): 239-261.

[121] Sutherland, Douglas and Peter Hoeller (2012) Debt and macroeconomic stability: An overview of the literature and some empirics (No. 1003). *OECD Publishing.*

[122] Taylor, John B (1993) Discretion versus policy rules in practice. *Carnegie-Rochester Conference Series on Public Policy* (Vol. 39). Elsevier.

[123] Tharavanij, Piyapas (2007) Capital market and business cycle volatility. *Monash University Economics Discussion Paper.*

[124] Townsend, Robert M (1979) Optimal contracts and competitive markets with costly state verification. *Journal of Economic Theory* 21(2): 265-293.

[125] Villa, Stefania (2013) Financial frictions in the euro area: A Bayesian assessment. *ECB Working Paper* 1521, 1-39.

[126] Villa, Stefania and Jing Yang (2011) Financial intermediaries in an estimated DSGE model for the United Kingdom (No. 431). *Bank of England.*

[127] Viren, Matti (2005) Government size and output volatility: Is there a relationship? *Bank of Finland Discussion Paper* 8.

[128] Wagner, Wolf (2010) Diversification at financial institutions and system crises. *Journal of Financial Intermediation* 19(3): 373-386.

[129] Woodford, Michael (2010) Financial intermediation and macroeconomic analysis. *The Journal of Economic Perspectives* 24(4): 21-44.

[130] Woodford, Michael (2010) Simple analytics of the government expenditure multiplier (No. w15714). *National Bureau of Economic Research.*

[131] Yun, Tack (1996) Nominal price rigidity, money supply endogeneity, and business cycles. *Journal of Monetary Economics* 37(2): 345-370.

[132] Zubairy, Sarah (2014) On fiscal multipliers: Estimates from a median scale DSGE model. *International Economic Review* 55(1): 169-195.