Essays on Sovereign Debt Holdings and Macro-Financial Linkages

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Declaration

I certify that the thesis I have presented for examination of the doctoral degree in Economics at the University of Sheffield is my own work. I am aware of the University's Guidance on the Use of Unfair Means. I warrant that this dissertation does not, to the best of my knowledge, infringe the rights of any third party. The copyright of this thesis rests with the author.

This dissertation contains approximately 49,610 words including appendices, references, footnotes and has 41 figures.

Miroslava Quiroga Treviño
September 2022

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Abstract

This thesis consists of three essays that analyse sovereign debt holdings in the balance sheets of the financial sector, which comprises both financial institutions and a central bank. The first essay deals with how sovereign leverage can have an impact on economic activity through a balance sheet channel of fiscal policy and studies the implications on credit markets and real economic activity when banks are subject to minimum capital requirements. By employing a dynamic stochastic general equilibrium model (DSGE) estimated with Bayesian techniques for the European periphery, this work highlights that the financial sector, being the largest holder of sovereign debt, propagates the effects of a debt-financed fiscal policy on the real business cycle through credit displacement and investment contraction.

The second essay examines European bank exposures to domestic sovereign debt and the implications on real activity under a recomposition in their balance sheets. The research focuses on the transmission channel of fiscal shocks on credit supply and capital formation in six of the largest European Monetary Union countries using a Structural Bayesian Panel Vector Autoregressor (SBPVAR) from 2003-2019. Results suggest that debt shocks increased the exposure of domestic financial institutions to sovereign debt and instigated credit displacement, leading to lower capital formation in European economies, where the effects appeared more pronounced for peripheral economies.

The final essay develops a DSGE model to analyse the impact of Large Scale Asset Purchases (LSAPs) of government securities on financial and real variables to analyse the effect on economic activity using the European Union as the case of study. Regulatory measures capturing macroprudential regulation set a limit on the minimum capital ratios that financial institutions must meet which in turn influence credit provision. This essay analyses the interaction of fiscal, monetary and macroprudential policies and suggests that unconventional monetary measures alleviate pressures on the banking sector that consequently incites credit provision. By increasing demand of government securities, the central bank eases banks' balance

sheets, reducing the cost for financial intermediaries which further pass that into lower credit costs for private firms to incentivize their investment decisions. The model features occasionally binding constraints to evaluate the role of LSAPs in the presence of the Zero Lower Bound (ZLB) for short term rates, showing that the effects on the economy are amplified when the lower bound binds.

The results of this thesis suggest that to the extent that the banking sector generates a primary market for sovereign bonds, it leads to a lower credit supply, which is reflected in lower levels of credit and investment. On the other hand, unconventional measures in the form of LSAPs implemented by central banks, lead to relax the balance sheet of commercial banks, which facilitates credit to the productive sector and minimizes the crowding out effect of the debt on private investment.

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Chapter 1

Introduction

Following the financial crisis in 2008, economies began to implement expansionary policies to face the economic slowdown. Two years later in 2010, without having recovered from the consequences brought by the economic crisis, Europe faced a debt crisis which was characterized by high deficits in the European economies and increased levels of public debt. Thus, the global financial and debt crisis led to high levels of public debt in European economies, taking them to historically high levels. In fact, prior to the financial crisis, debt levels were around 60% of GDP and although some austerity measures were implemented to decrease the deficit after the crisis, debt remained at very high levels above 100% as of 2019.

One of the reasons why the crisis proved to be costly, particularly in Europe, was due to the connection between the sovereign and banking sector. As debt financed fiscal policy remained one of the most active policies in recent decades by allowing countries to face economic downturn, the increasing levels of government debt led to increased bond holdings by domestic banks, which became a burden to the real economy. Banks' debt holdings from sovereigns showed a strong home bias, particularly in the periphery European countries and in Germany (Feyen and Zuccardi (2019)). In Europe, this post-recession period was characterized by an increase in sovereign debt holdings by domestic financial institutions (Gennaioli et al (2018); Bocola (2016), Bolton and Jeanne (2011)) and by a contraction in the issuance of new credit to productive sector (Crosignani (2017), Gennaoioli et al (2014), Broner et al (2014)). Thus, as a result of a contraction in the supply of credit due to higher costs for borrowing, the effects on the real economy were through a lower capital formation (Acharya et al (2014); For italian case: Balduzzi et al (2018) and Cingano et al (2016)).

With debt issuance pressuring the domestic financial system, the effects of these measures acted to contract credit in the European economies and permeated to the real economy given that credit is essential to facilitate the productive investment of an economy. The financial crisis showed that interactions between credit markets and the rest of the economy are relevant for explaining macroeconomic fluctuations in what came to be defined as *Macro-Financial linkages*.[1] The Macro-Financial linkages describe the relationship that exists between the real economy and the financial sector, where shocks in the real sector can spread through financial markets and amplify economic fluctuations, or shocks from the financial sector can lead to the amplification of macroeconomic fluctuations. In this regard, studying government indebtedness becomes relevant given that to the extent that sovereign leverage has repercussions on the financial sector, it can affect the levels of credit and investment in economic activity.

This context in which the European and the global economy faced the post-recession period led to the need for macroeconomic policies -monetary policy, fiscal policy and macroprudential policy-, to act together and seek stability in financial markets. New policy regulations were implemented in the international financial sector to limit the propagation of shocks from the financial sector to the real economy. These measures in terms of macroprudential regulation aimed at mitigating the costs associated with financial instability at a macroeconomic level. The Basel committee proposed changes under Basel III regulation to increase capital requirements and strengthen their balance sheets by improving EU banks capital ratios (Bank for International Settlements (2011) and Basel Committee (2017)).

For its part, following the crisis, central banks responded by lowering interest rates by relying on conventional monetary policy to stimulate the economy. In Europe the expansionary monetary policy led the short-term rates reaching the zero lower bound (ZLB). The European Central Bank since then has relied on the use of unconventional monetary policy by employing Large-Scale Asset Purchase (LSAP) programs for long-term securities under different programs to support the transmission channels of monetary policy and guarantee financial stability. These in turn expanded the balance sheets of the central bank where *public sector* purchases account for around 80% of total Asset purchases.[2]

[1] See Claessens and Kose (2018) for an in-depth survey of the literature.

[2] The history of cumulative purchase breakdowns under the Asset Purchase Program (APP) can be found in the ECB's official website under the monetary policy asset purchase instruments.

The financial crisis thus reawakened interest among policy makers and academics in understanding the role of public debt and the interaction with Monetary Financial Institutions (MFI). In accordance with the definition of the ECB for MFI, they comprise: 1) deposit-taking corporations and 2) central banks of the EU Member States and the European Central Bank. This thesis analyses how sovereign leverage can have an impact on economic activity by the interaction with the financial system, which comprises both *financial institutions* and *central banks*. The first two essays (found in Chapters 2 and 3) focus on the holdings of sovereign debt by banks which act as deposit-taking corporations subject to capital requirements, whereas the last essay (Chapter 4), focuses on the central bank holdings of long-term debt to understand unconventional monetary policy implemented following the debt crisis in Europe.

The thesis adopts an integrated approach by drawing on both theoretical and empirical research to address the effects of fiscal indebtedness along the business cycle through bond holdings in the financial sector. Below is an overview of three essays that comprise the following chapters of the thesis.

1.1 Overview of the 1st Essay

Debt-Financed Fiscal Policy and Financial Exposure: A Balance Sheet Channel of Fiscal Policy

What are the effects of a debt-financed government spending shock on credit supply and capital formation, when the banking sector must generate the primary bond market? This research is motivated by the events that followed the financial crisis where national governments in the European Union applied expansionary fiscal policies by increased indebtedness, having repercussions in their domestic financial sector who acted as the main holder of sovereign debt. The chapter studies the effects of fiscal policy financed with debt and proposes a mechanism for understanding one of the channels of contagion between banks and sovereigns. In particular, the connection between sovereign bond holdings on bank balance sheets and the effects seen during the European debt crisis on low levels of corporate lending. To address the evidence of financial sector being exposed to government debt, this chapter features a two-region general equilibrium model, estimated with Bayesian techniques. We use data from the European Periphery: Greece, Italy, Ireland, Portugal, and Spain; which experienced exceptionally high levels of indebtedness and debt holdings in their domestic banks. The model incorporates heterogeneous agents that differ

in their degree of impatience giving a role for financial intermediation in the steady state and two financial frictions on both sides of the credit markets: (i) borrowing constrained agents subject to collateral constraints to access credit and (ii) banks subject to minimum capital requirements which incur a cost for deviating from it. This work contributes to the literature by providing a theoretical framework to examine the hypothesis that the banks that were most exposed to domestic public debt did so at the expense of corporate lending. The transmission mechanism in the model suggests that when banks increase their sovereign debt holdings, deviations from the capital-to-asset ratio set by financial regulation generate a cost to the banking sector, which in turn influences credit supply. What happens in the model is that the supply of credit contracts, increasing borrowing rates. Consequently, firms facing collateral constraints, when faced with higher borrowing rates need to pledge more collateral to be granted credit by financial institutions. This chapter highlights that the financial sector, being the largest holder of sovereign debt, propagates the effects of a debt-financed fiscal policy on the real business cycle through credit displacement.

1.2 Overview of the 2nd Essay

Sovereign Debt Exposure in Europe: A Bayesian Panel-VAR analysis of Macro-Financial Linkages

How does credit and investment react to debt shocks in the European Monetary Union and are there asymmetric effects on credit to enterprises and investment across countries? This study analyses the interaction between fiscal policy and banks' sovereign exposures in influencing credit supply by studying the transmission of shocks generated in six of the largest European Monetary Union countries (EMU-6) and its effects on real economic activity. The chapter estimates a Structural Bayesian Panel Vector Autoregressor model that allows for the inclusion of a cross-sectional dimension in the study of debt-financed fiscal shocks on real and financial variables, and which accounts for heterogeneities present at the country level to explain Macro-Financial linkages in the EMU-6. The contribution of Chapter 3 lies in the use of panel data to analyse the effects of the proposed channel in the DSGE model in the previous chapter, but allows to capture country heterogeneity that is not exploited in the theoretical framework. Moreover, it contributes to the literature by providing new empirical evidence on the transmission of debt fiscal policy shocks to real economic activity in the European monetary union and by quantifying the balance sheet channel of fiscal policy. The main results that emerge from this chapter

suggest that under a debt shock, the re-composition in the balance sheets of financial institutions negatively impacted the provision of credit and investment in EMU with the highest credit crunches observed in those economies with more exposure to Sovereign Debt Holdings, in particular the periphery economies. This chapter shows the macroeconomic implications of public debt for the European countries in the presence of macro-financial linkages by first showing the mechanism holds for the pool of EMU-6 countries. Further, the research continues by comparing heterogeneity at different levels: by splitting the sample in blocks of stressed (periphery)/non stressed(core) countries as has been suggested in the literature; and by analysing the mechanism allowing for heterogeneity at the country level.

1.3 Overview of the 3rd Essay

Public Large Sale Asset Purchases and Financial Stability

How do LSAP programs of Public Debt play a role in business cycles to achieve financial stability and how does it compare when facing the ZLB? In the current context in which the central banks own a big share of domestic public debt in their balance sheets, understanding the role played by fiscal authorities and central bank's balance sheet in achieving financial stability is crucial. In the previous two essays, reference was made to the fact that the greater public indebtedness generated pressure on commercial banks as they were exposed to sovereign bonds in their balance sheets. This chapter analyzes how central banks increase the holding of public bonds in their balance sheets to facilitate liquidity in the market. By employing a DSGE model with nominal rigidities to give a role to monetary policy effects on real activity, Chapter 4 proposes a mechanism of transmission through which LSAP of government securities influence real activity by easing wholesale firms' investment constraints and lowering the cost faced by financial institutions subject to capital requirements. The chapter models the European Union as the case of study and regulatory measures capturing macroprudential regulation set a limit on the minimum capital ratios that financial institutions must meet which in turn influence credit provision. This chapter contributes by including fiscal, monetary and macroprudencial policies and allowing for unconventional monetary policy to play a role for providing financial stability, as observed in the post-crisis period when the European Central Bank faced the ZLB constraint. The model proposes a richer framework to analyse the fiscal policy implications on financial markets and how the central bank can act to counteract pressures in the financial intermediation process. The results that emerge from this work indicate that as the central bank buys government bonds, it eases balance

sheets of banks which in return can provide liquidity to firms seeking to borrow. The public asset purchase program lowers long term real rates used as reference for real investments which in turn allow firms to finance their investment at a cheaper rate. Moreover, results show that in the presence of the ZLB for short term rates, the effects on the economy are amplified.

1.4 Organisation of this Thesis

The following chapters present the three essays that analyse the dynamics of sovereign debt holdings in the balance sheets of the financial sector on investment decisions. Chapter 2 proposes a DSGE model estimated with Bayesian techniques for the aggregate European periphery to analyse how sovereign leverage can have an impact on economic activity through the asset holdings in the financial sector by its effect on credit. This work highlights that the financial sector, by acting as the primary holder of sovereign debt, propagates the effects of a debt-financed fiscal policy on the real business cycle by crowding out investment. Chapter 3 delves deeper into the topic by studying the transmission channel of fiscal shocks on credit supply and capital formation for the European Monetary Union using a Structural Bayesian Panel Vector Autoregressor with quarterly data from 2003 to 2019. Results suggest that debt shocks increased the exposure of domestic financial institutions to sovereign debt and instigated credit displacement, leading to lower capital formation in European economies, where effects appeared more pronounced for peripheral economies. Chapter 4 develops a DSGE model using the European Union as the case of study to analyse the impact of LSAP of government bonds to incentivize credit and investment. The model features occasionally binding constraints to evaluate the role of LSAPs in the presence of the ZLB for short term rates, showing that the effects on the economy are amplified when the lower bound binds. Chapter 5 provides a conclusion to the thesis that summarises the work of each chapter and main findings and policy implications that emerge from each.

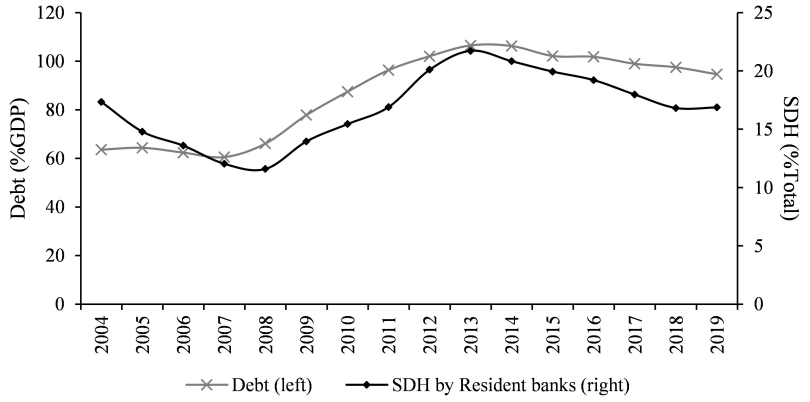
Chapter 2

Debt-Financed Fiscal Policy and Financial Exposure: A Balance Sheet Channel of Fiscal Policy

2.1 Introduction

Following the financial crisis in 2008, the national governments of the European economies applied expansionary fiscal policies through increased indebtedness. In Europe, as shown in Figure 2.1, the increase in government debt enlarged the balance sheets of financial institutions by increasing their holdings of domestic government securities.

Figure 2.1 Government Debt and Sovereign Exposure of Financial Institutions

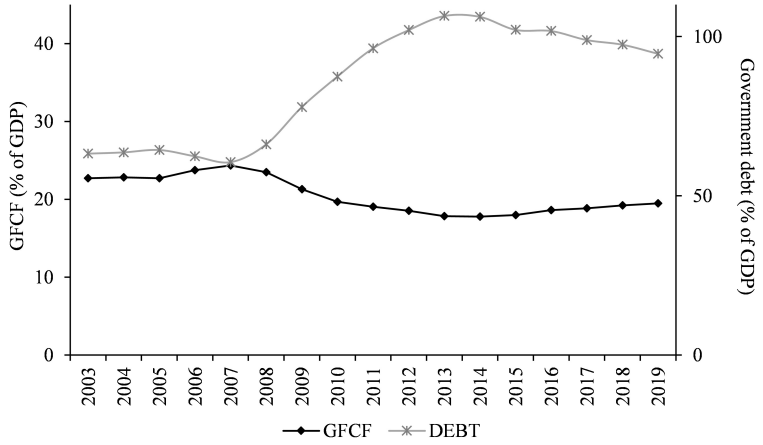


Government consolidated debt (gray) as percentage of GDP and Sovereign Debt Holdings (SDH) by Resident Financial Institutions (black) as a share of Total sovereign debt issuance. Source: Bruegel database by Merler and Pisani-Ferry (2012) and Macroeconomic and sectoral statistics by the ECB. The economies included are: Germany, Finland, France, Netherlands, Greece, Ireland, Italy, Portugal and Spain.

Debt-Financed Fiscal Policy and Financial Exposure: A Balance Sheet Channel of Fiscal Policy

Government borrowing became a main concern given governments could over-borrow, amplifying the problems for the financial sector, especially when it acts as main holder of most government securities (see Appendix A.4). Furthermore, during the periods of economic downturn following the financial and debt crisis, bank credit in Europe slumped. For firms in Europe, where loans by financial institutions are a relevant source for financing their activity, this was reflected in lower levels of investment and fixed capital formation as shown below.

Figure 2.2 Sovereign Indebtedness and Fixed Capital Formation in Europe



Government consolidated debt (red) and Gross Fixed Capital Formation (black) as percentage of GDP. Source: Macroeconomic and sectoral statistics – Statistical Data Warehouse of the European Central Bank. The economies included are: Germany, Finland, France, Netherlands, Greece, Ireland, Italy, Portugal and Spain.

The credit crunch and fall in investment in Europe was more severe in those economies with higher debt levels and banks not sufficiently capitalized as was the case for the European Periphery. In response to the crisis, the Basel committee on Banking Regulation and Supervision (BCBS) established new changes to the existing international *macroprudential* regulatory framework on more strict capital adequacy rules in aims of reducing the systemic risk of the financial system and mitigating the costs associated with financial instability. The proposed changes under Basel III regulation increased capital requirements for financial institutions already established under Basel I and II, to have banks increase their Tier 1 capital and additional buffers, leading the capital requirements to increase to a total of 13%. In this regard, new policy regulations were implemented in the international financial sector to limit the propagation of shocks from the financial sector to the real economy.

The financing of the fiscal stimulus has since raised questions on how fiscal policy should be implemented given the already high levels of public debt the European economies face and its effect on the real economy through investment contraction. This chapter analyzes how sovereign leverage can have an impact on economic activity, mainly through the asset holding channel in the financial sector. In particular, this work answers the question: What are the effects of debt-financed fiscal policy on credit supply and capital formation, when the domestic banking sector act as the primary sovereign bond market?

To answer this question, a two-region dynamic stochastic general equilibrium model (DSGE) is estimated with Bayesian techniques for the aggregated European periphery covering the period of 2003-2019. To address the evidence of the financial sector being exposed to sovereign debt, a model in which banks play an important role is required. This work relies on an International Real Business Cycle model with an added banking sector which is highly exposed to domestic sovereign debt holdings in response to an expansionary fiscal shock to analyze the outcomes on real activity by its effects on lending and investment.[1] Moreover, as the financial crisis prompted a general interest in better understanding how international capital regulation drives bank behaviour, this chapter builds upon the work of Gerali (2010) and the open economy extension made by Kamber and Thoenissen (2013) to account for minimum capital requirements. However, this chapter extends their model to incorporate a fiscal authority as an economic agent and the holdings of government securities in the balance sheets of financial intermediaries. This allows to study the transmission mechanism of fiscal policy shocks in the presence of financial frictions in the banking sector that are more in line with the regulation imposed internationally to maintain minimum capital requirements.

The chapter contributes to the literature by proposing a model that considers a balance sheet channel of sovereign exposure to explain the effects of debt financed fiscal policy on real economic activity. In particular, this work proposes a financial sector that is subject to minimum capital requirements and that responds to an increase in bond holdings offering a richer specification compared to existing literature. The model incorporates two financial frictions on both, the supply and demand side of the credit market: (i) Borrowing constrained agents, who need to pledge collateral to access credit from the financial sector, and (ii) Banks subject to minimum capital

[1]For the purpose of this work, the banking sector models only what the ECB considers as Monetary Financial Institutions (MFI) other than the central bank, which are credit institutions involved in lending and deposit taking. Non-MFI thus are not considered in this work as they do not offer deposits or close substitutes to deposits to the public.

requirements, which will pay a cost from deviating from it. The innovation comes from the inclusion of sovereign debt in the balance sheet of financial institutions which causes deviations in their capital-to-asset ratios. In the model, the decision to maintain capital is based on the macroprudential regulation imposed by Basel Committee in order to mitigate systemic risk.

Additionally, the model features heterogeneous agents that differ in their degree of impatience giving a role for financial intermediation in the steady state. Because the model considers two types of households, in order for the credit market to function, one of them has to save for the other one to borrow. Thus, there is a need to make sure that entrepreneurs do not delay spending and rapidly accumulate wealth to the point where they don't need to borrow anymore, which would give no role to financial intermediaries to play a role in the transmission of shocks to the real economy. This is important as the global financial crises highlighted the need to incorporate the financial structure of the economy into models and the absence of a formal description of financial markets or frictions would impede the analysis of policy considerations that happen through the banking sector.

To address this, we follow Iacoviello (2005) and assume that entrepreneurs discount the future more than the saving consumers (or patient households). This means that entrepreneur's return to savings is greater than the interest rate, which implies a binding borrowing constraint. It is because of the different time preference, that saving households will always save and borrowing households will always borrow in steady state and its neighbourhood.[2] This assumption helps to create a clear distinction between savers and borrowers to allow for banks to operate as financial intermediaries. However, the assumption that households are more patient than entrepreneurs is a simplifying assumption and although in Iacoviello (2005) the borrowing constraints makes impatient entrepreneurs be borrowers and not savers, other models have also studied borrowing constrained entrepreneurs which are required to incur in savings to access credit. For instance, Cagetti and De Nardi (2006) also model borrowing constrained entrepreneurs to explain wealth inequality in a life-cycle model, although not modelling explicitly a financial sector. The borrowing constraints in their work limit the ability of entrepreneurs with low wealth to access credit. For entrepreneurs, the need to accumulate assets to have borrowing capacity is what makes them want to increase savings. The mechanism they propose suggest that in order to expand

[2]In that way, households can smooth their consumption intertemporally by receiving a risk-free rate for their savings, while the consumption of entrepreneurs is subject to the amount of loans they can obtain given the value of their collateral in the form of physical capital. The spread between the two rates is the margin obtained by the financial institutions for acting as intermediary.

their firms, entrepreneurs must increase savings, which generates greater wealth that can be inherited by their offspring, allowing new generations to have enough wealth to access funds to invest and further increase their wealth. In this chapter, to maintain consistency to the original model by Kamber and Thoenissen (2013), infinitely lived households are assumed and entrepreneurs are not forced to save to use their wealth as collateral to access credit. Instead, to access credit, entrepreneurs need to provide collateral to financial intermediaries, which is a fraction of the value of the future installed capital. The financial sector then plays a relevant role in the transmission and propagation of shocks to the real economy to explain the increase in banking sovereign exposure in Europe that resulted in a decrease in credit and investment.

The remainder of this paper is structured as follows. Section 2.2 presents an overview of the relevant literature, Section 2.3 presents the model description, Section 2.4 presents the data used in the estimation under Bayesian techniques, Section 2.5 discusses the results of this work and Section 2.6 concludes.

2.2 Relevant Literature

In the past decades and as public leverage reached high levels post great recession, questions on the effects of public debt issuance have become more relevant to study. In Europe, the period that followed the financial and debt crises coincided with a strong upsurge of domestic bank's sovereign exposures. This in turn makes banks highly vulnerable to changes in fiscal policy when it is carried out through borrowing. In this regard, some literature has explored the causes of this growth in Banks' exposure to domestic sovereign debt (see for example Cooper and Nikolov (2018), Farhi and Tirole (2014) on diabolic loop; Marco and Macchiavelli (2014) and justify the debt bias by a *moral suasion* channel; and Battistini et al (2014) on the *systemic risk* channel). Although this chapter addresses not the *cause* but rather the *implications* of having a high exposure to domestic debt in the years following the crisis, it is important to highlight the strong home bias by European banks and in particular in the European periphery (Feyen and Zuccardi (2019)).

Another branch of the literature has tried to analyse the role of domestically held debt on the balance sheet of financial institutions, and its amplification to real economic activity. In this regard, theoretical contributions like that of Bolton and Jeanne (2011) who analyse a model with financial intermediation and show that sovereign default may prompt a banking crisis when holding large amounts

of government bonds. There are a number of papers that consider the effects of sovereign debt on the ability of banks to lend. Firstly, Becker and Ivashina (2017) find a connection between accumulation of domestic sovereign debt and contraction of bank credit supply. Additionally, Gennaoioli et al (2014) find that government defaults affect the balance sheets of domestic banks ending up in declines in private credit. Also, Broner et al (2014) find that during the European debt crisis large amount of debt owned by domestic financial institutions, reduced investment by lending reallocation from private to public borrowing, and Padilla (2018) for instance finds evidence of banks largely exposed to government debt reduce credit and affect output when governments default. In addition to this, Pérez (2015) also finds that defaults have an effect on balance sheets of banks, affecting investment.

Ample evidence suggests that turmoil in financial sector deters economic activity by a credit contraction, leading to lower investment and consumption. In the empirical ground, effects of sovereign exposure of banks and effects on credit is vast. For instance Gennaioli et al (2018), find that banks hold large proportions of government bonds and that it affects lending by using panel data at bank-level of 20,000 banks for 191 countries from 1998-2012. For the European case, Acharya et al (2018) using bank and firm-level data from 2006 to 2012, analyze the bank-firm relationships and find that during the euro crisis, lending contraction affected investment mainly of those firms affiliated to highly exposed banks to sovereign debt. Likewise, Altavilla et al (2017), find that bank's exposures amplified the impact of sovereign stress on bank lending to domestic firms in the Euro area from 2007 to 2015 and find that effects of domestic government policies are transmitted through the banking sector. For the Italian case in particular: Bofondi et al (2018) use firm level data to analyze the effects of credit supply for Italian firms during the European debt crisis and find increased rates for new loans, affecting the credit supply and consequently real activity. Also Bottero et al (2020) analyzes credit contraction to firms due sovereign holdings in bank's balance sheets and its propagation effects of financial shocks using Italian data. Moreover, De Bruyckere et al (2013) analyze the contagion between bank and sovereign default risk in Europe between 2007–2012 and find that at the country level, the debt ratio is the most important driver of contagion.

Moreover, the implementation of the Basel accords gave rise to ample interest in the literature focusing on the consequences of bank capital requirements and lending behaviour by credit institutions. A large body of the literature suggests that capital requirements excert great influence in the credit supply of financial institutions subject to those requirements. In particular, the literature postulates that banks adjust their lending to changes in the actual (observed) capital-to-asset

ratio and the desired capital ratios imposed by regulation. De Jonghe et al (2020) support this view by finding that the increase in the required and actual capital, leads to a credit contraction to firms by shrinking banks' balance sheets. Also finding that bank characteristics are relevant for explaining the size of the contraction. They suggest that smaller and less profitable banks tend to be the ones with higher credit contractions. Similarly, Mésonnier & Monks (2014) and more recently Groop et al (2019) find that this contraction in lending is associated with higher capital requirements imposed by European Banking Authority (EBA) in the Capital Exercise which accounted for 50 percent of the banking sectors in each EU Member State in 2011.[3] Fraisse and Thesmar (2020), find that bank capital requirements affect corporate borrowing in France which further depresses employment and investment, where fixed assets fall by 1.1% and capital expenditures by 2.7% (when there is a 1 percent increase in capital requirements). Aiyar et al (2014) also finds that credit contraction due to tighter capital requirements affects regulated banks in the United Kingdom (UK), although unregulated banks act as a substitute source of credit to firms, thus increasing lending. Bridges et al (2014) and Francis and Osborne (2012) have similar findings of capital requirements on credit supply in the UK.

This chapter relates to the literature that studies the links between sovereign debt and exposure of the domestic banking sector and focuses in analyzing the observed increase in public debt in Europe that resulted in a decrease in credit and investment. In line with the above and motivated by persistent high levels of post-crisis debt, this work extends the open economy model by Kamber and Thoenissen (2013) to give a role to debt securities in bank intermediation and account for the international capital regulatory framework in financial institutions. The next section delves deeper into the model to address this issue.

2.3 Model Description

This model features a two-region international Real Business Cycle model where each region will be denoted by a superscript j to indicate that equations correspond to each region j= home (h) or foreign (f). The world population is divided in the two regions where $[0, n)$ belongs to the home economy and the remaining share $[n, 1]$ belongs to the foreign economy. Apart from the relative prices each economy faces,

[3]The EBA announced in October 2011 the need for banks to reinforce their capital positions by increasing their capital buffer against sovereign debt exposures by June 2012. The exercise was aimed at restoring confidence in the euro area banking sector to withstand shocks during the Sovereign debt crisis.

agents in the two countries are identical, so the model assumes similar equations for the domestic and foreign agents.

Each economy $j = (h, f)$ is described by the following 5 types of agents: (i) patient households that consume, supply labour and save in the form of deposits (ii) impatient households (entrepreneurs) who acquire loans and invest in physical capital while subject to a borrowing constraint (iii) a productive sector that uses capital and labour as inputs for the production of goods (iv) an integrated banking sector which incurs intermediation costs when deviating from capital requirements consistent with macroprudential regulation [4] and (v) fiscal entity that issues debt and collects taxes to finance public spending.

This chapter builds upon the work of Gerali (2010) and the open economy extension made by Kamber and Thoenissen (2013) to consider capital requirements for financial institutions. However, the model is extended by introducing a fiscal authority as an economic agent and incorporating the holdings of government securities in the balance sheets of the banking sector. This allows to study the transmission mechanism of fiscal policy shocks in the presence of financial frictions in financial intermediation. Additionally, the model features heterogeneous agents that differ in their degree of impatience giving a role for financial intermediation in the steady state following Iacoviello (2005). As such, total consumption (C_t) is split between *patient* consumers (c_t^P)and *impatient* consumers (a.k.a. entrepreneurs) (c_t^E), which is reflected in their higher rate of time preference (discount factor). It is because of the different time preference, that saving households will always save and borrowing households will always borrow, giving a role to the financial sector in the steady state and its neighbourhood.

2.3.1 Household

In each economy $j = (h, f)$ The representative patient household maximizes utility given by:

$$E_t \sum_{t=0}^{\infty} \{\beta^t U(c_t^{Pj}, l_t^j)\} \tag{2.1}$$

[4]The Basel Committee introduced capital requirements in Basel I and II to all banking institutions. The Basel III legislation targeted global systemically important banks (G-SIBs), also known as *too-big-to-fail banks* as any instability in those financial institutions would further threaten the stability of the financial system. In this sense, the fact that the banking sector does not distinguish between the size of the banking institutions and seeks to model the banking sector as a whole, is consistent with the regulation being focused on systematic financial stability.

where E_t is the expectation operator, β is the intertemporal discount factor, c_t^P denotes total patient household consumption of goods bundling together consumption of domestic and foreign produced goods, and l_t denotes worked hours.[5] The utility function has the properties for consumption: $U_c' > 0$ and $U_c'' < 0$; for labour: $U_l' < 0$, $U_l'' < 0$.

Households in each economy j save what remains after consumption c_t in the form of bank deposits d_t, for which they obtain a return of $d_t r_{t-1}$. Moreover, they receive wage w_t for supplying labour l_t to the goods producer, and pay taxes to the fiscal authority T_t. Under a general equilibrium framework, households receive dividends for owning productive firms (defined as Π_t^G) and dividends from owning the banks (defined as Π_t^B). Thus, the budget constraint faced by the representative patient household is given by:

$$c_t^{Pj} + d_t^j = w_t^j l_t^j + d_t^j(1 + r_{t-1}) + \Pi_t^{Gj} + \Pi_t^{Bj} - T_t^j \tag{2.2}$$

Equation 2.2 states that consumption and savings of the patient household must be equal to wage income, returns on deposits, dividend payments from owning firms and banks and tax payments to local government. The household for the j economy chooses its path for consumption c_t^P, labour supply l_t and savings d_t to maximize utility subject to 2.2, yielding the following optimization conditions:

$$\lambda_t = U_{ct}^{'Pj} \tag{2.3}$$

$$U_{lt}^{'j} = \lambda_t^j w_t^j \tag{2.4}$$

$$\lambda_t^j = E_t \lambda_{t+1}^j \beta(1 + r_t) \tag{2.5}$$

Equation 2.3 equates marginal utility of consumption to the Lagrange multiplier, equation 2.4 provides the decision of the household to supply labour, while equation 2.5 shows optimal savings decision by the household which is a function of the return on deposits obtained from saving at the financial institutions.[6]

[5] Section A.1 explains the aggregation of home and foreign produce goods in an international setup.

[6] For this model, households do not choose bonds, they only make deposits in the bank and it is the bank who chooses the composition of assets in its balance sheet.

2.3.2 Entrepreneurs

Entrepreneurs in each j economy seek to increase their lifetime consumption as shown in Equation 2.6.[7] However, as opposed to households who work and save to consume, entrepreneurs need to invest to generate capital (which they rent as a source of income) and for that they need to borrow from financial institutions. Yet, to access loans (q_t) from banks, they are restricted to the value of their collateral given by their holdings of physical capital. Consequently, entrepreneurs must decide on the optimal stock of physical capital (k_t), which allows to derive an explicit expression for the price of capital, which enters entrepreneurs borrowing constraint.

Entrepreneurs maximize utility given by:

$$E_t \sum_{t=0}^{\infty} \beta_t^E U(c_t^{Ej}) \tag{2.6}$$

Subject to.

$$c_t^{Ej} = \rho_t k_{t-1}^j - i_t^j + q_t^j - (1 + r_{t-1}^q)\epsilon_t q_{t-1}^j \tag{2.7}$$

$$k_t^j = (1-\delta)k_{t-1}^j + s\left(\frac{i_t^j}{k_{t-1}^j}\right)k_{t-1}^j \tag{2.8}$$

$$(1 + r_t^q)q_t^j E_t\epsilon_{t+1} = \chi\varphi_{t+1}^j k_t^j(1-\delta) \tag{2.9}$$

Equation 2.7 shows the budget constraint faced by entrepreneurs, indicating that consumption depends on income from the capital rented to the intermediate goods producers $\rho_t k_{t-1}$, new credit from banking institutions q_t minus the interest paid on already granted loans in previous periods $(1 + r_{t-1}^q)q_{t-1}$ and investments incurred in the present period i_t.[8] Equation 2.8 simply indicates the standard law of motion of physical capital where δ is the depreciation rate. Furthermore, it faces investment costs $s(.) = s(\frac{i_t}{k_{t-1}})$, such that in the steady state $s(.) = \delta$ and $s'(.) = 1$. The cost depends on the amount of investment (new capital to be installed) relative to the capital already installed. Finally, Equation 2.9 represents the collateral constraint for entrepreneurs. This constraint indicates that to access credit (LHS of

[7] Similar to the patient households, β^E captures the inter-temporal discount factor specific to entrepreneurs, although given entrepreneurs are more impatient than household savers, this implies $\beta^E < \beta$. The difference in the discount factors of the two types of agents, as well as the assumption that the shocks are small enough, make it possible to impose that the borrowing constraint always binds (see Iacoviello (2005)). This prevents entrepreneurs from postponing consumption to be completely self-financed leading to a non-binding constraint.

[8] It is not assumed that entrepreneurs incur a production process but that it faces a cost of transforming investment into capital. Thus, transforming investment into capital is not done immediately and adds persistence to the process of capital accumulation.

the equation), entrepreneurs need to provide collateral (RHS of the equation), which is a fraction χ of the market value of the future installed capital after depreciation $\varphi_{t+1}\ k_t(1-\delta)$ and ϵ captures an exogenous credit shocks that follow an AR(1) process.

Overall, these set of equations indicate that to increase consumption, entrepreneurs must invest in the generation of capital (which they rent as a source of income) and at the same time is the future value of the installed capital what allows the entrepreneur to gain access to bank credit to invest. In this sense, the entrepreneur maximizes his consumption subject to the constraints in (2.7- 2.9) by choosing its consumption path c_t, how much capital to acquire in the next period k_t, how much to invest i_t and how much borrowing q_t is required to finance investment. The optimization process yields the following order conditions for the entrepreneur:

$$\lambda_t^{Ej} = U_{ct}^{'Ej} \tag{2.10}$$

$$\varphi_t^j = \left(s'\left(\frac{i_t^j}{k_{t-1}^j} \right) \right)^{-1} \tag{2.11}$$

$$\Lambda_{t,t+1}^j (1 + r_t^q)\epsilon_{t+1} = 1 - \Delta_t^j (1 + r_t^q)\epsilon_{t+1} \tag{2.12}$$

$$\varphi_t^j = E_t \Lambda_{t,t+1}^j [E_t \rho_{t+1}^j + E_t \varphi_{t+1}^j (1-\delta)] + \Delta_t^j \chi E_t \varphi_{t+1}^j (1-\delta) \tag{2.13}$$

where $\Lambda_{t,t+1} = \frac{\beta^E E_t \lambda_{t+1}^E}{\lambda_t^E}$ denotes the real stochastic discount factor, φ is the multiplier associated to the capital stock dynamics and Δ_t is the multiplier associated with the collateral restrictions. Equation 2.10 equates the lagrange multiplier of the entrepreneur's budget constraint to the marginal utility of consumption. Equation 2.11 indicates that investment decision is such that the market value of the installed capital φ equals the additional replacement cost $s'(.)$. Equation 2.12 describes the borrowing decision for entrepreneurs, which is a function of the interest rate on loans r_t^q, and Equation 2.13 shows the decision of how much capital to acquire next period. The current value of installed capital should be the discounted future value adjusted for depreciation and the return from renting future capital to the intermediate goods producer. This implies that the entrepreneur has the incentive to increase investment to the extent that the cost of transforming investment into capital allows them to increase the value of capital in the future. Given this, the investment decisions depend on the Q ratio (φ), which measures the market value of a firm to replacement costs of installed capital.

2.3.3 Goods Producer

The problem for the final goods producer in each economy j is to determine the use of factors of production: capital and labour, taking payment of factors as given. The goods producer rents capital from the entrepreneurs for ρ_t, and hires labour provided by the patient household at wage w_t, to produce output y_t using a Cobb Douglas technology with constant returns of scale:

$$y_t^j = A_t^j k_{t-1}^{j,\alpha} l_t^{j,1-\alpha} \tag{2.14}$$

where α takes values $[0, 1]$ and A_t captures total factor productivity, which follows an exogenous AR(1) process of the form: $A_t^j = \rho_a A_{t-1}^j + \upsilon_{gt}$, with ρ_a denoting the autoregressive coefficient and υ_t being the i.i.d. normal innovation.

Profits for the goods producer are given by:

$$\Pi_t^{Gj} = y_t^j - w_t^j l_t^j - \rho_t^j k_{t-1}^j \tag{2.15}$$

Equation 2.15 indicates that profits of the representative goods producer come from the difference between revenues from selling output y and the cost of renting factors of production. The maximization of profits for the goods producer yields the following optimal conditions:

$$A_t^j (1-\alpha) \left(\frac{k_{t-1}^j}{l_t^j} \right)^{\alpha} = w_t^j \tag{2.16}$$

$$A_t^j (\alpha) \left(\frac{l_t^j}{k_{t-1}^j} \right)^{1-\alpha} = \rho_t^j \tag{2.17}$$

Indicating that for the representative goods producer within economy j, the demand schedules are given by equations 2.16 and 2.17, linking the payment of factors to their respective marginal product.

2.3.4 Government

For the j economy, the standard government's budget constraint faced by the fiscal authority is given by:

$$G_t^j = T_t^j + b_t^j - b_{t-1}^j (1 + r_{t-1}) \tag{2.18}$$

where G_t is government expenditure, considered as government *final consumption* expenditure, T_t are non-distortionary taxes, b_t are government bonds and $(1 + r_{t-1})$ represent the interest payments on its outstanding debt. The government spending is chosen exogenously and is assumed to follow an AR(1) process: $G_t^j = \rho_{gt} G_{t-1}^j + \upsilon_{gt}$, where ρ_g captures the persistence of the shock and υ_{gt} is the i.i.d. normal innovation.

In each economy, the fiscal authority finances spending with a mix of non-distortionary taxes T_t and by issuing government bonds $\Delta b_{t,t-1}$. The tax revenue raised by the government each period follows a standard fiscal policy rule as that of Leeper(1991):

$$\frac{T_t^j}{\bar{T}} = \phi \left[\frac{b_{t-1}^j r_{t-1}}{\bar{br}} \right] \tag{2.19}$$

The policy rule indicates that tax collection is a function of debt such that at least the interest on outstanding debt must be replayed where $\bar{T}$ and $\bar{br}$ show deviations from its steady state values. Thus, taxes are a function of debt and include an adjustment parameter ϕ that is positive and $\phi > 1$, allowing for a non-explosive system.[9]

2.3.5 Financial Sector

Commercial banks in each economy are modelled as an aggregated financial sector following Kamber and Thoenissen (2013). The function of the banking sector is to channel funds from patient households to entrepreneurs (impatient households), seeking to invest in the generation of capital. Thus, patient households provide resources to the bank in the form of deposits that are then used to supply credit to (impatient) entrepreneurs who are subject to collateral constraints.

The balance sheet constraint for financial institutions in each economy j, specifies that total assets Q_t must equal liabilities in the form of interbank borrowing/deposits D_t and bank's capital K_t^B:

$$Q_t^j = D_t^j + K_t^{Bj} \tag{2.20}$$

The loans made by the banking sector are denoted by $Q_t^j = q_t^j + b_t^j$, where q_t^j are loans to domestic entrepreneurs and b_t^j are bonds issued by the local government, thus lending to the fiscal authority. For an international banking sector for deposits

[9] Because debt cannot explode given the terminal condition (no debt at the end of time), an increase in government debt will imply an increase in taxes in future periods such that $T_t = \phi b_{t-1} r_{t-1}$, where $\phi > 1$ to have a steady state solution. Further, Appendix A.6 presents a special case of Ricardian equivalence to explain the relevance of debt holdings in the banking sector.

and interbank borrowing, the difference between the two are defined as the net foreign asset positions $NFA_t^j = d_t^j - D_t^j$.

Furthermore, the bank accumulates capital (or net worth) according to the law of motion:

$$K_t^{Bj} = (1 - \delta^B)K_{t-1}^{Bj} + \Pi_t^{Bj} \tag{2.21}$$

Bank's objective is to maximize the discounted sum of cash flows where profits are derived from the difference between the inflows and outflows for financial intermediaries.[10]

$$\begin{aligned}\Pi_t^{Bj} = E_t \sum_{t=0}^{\infty} \beta^t \Big[& q_{t-1}^j (1 + r_{t-1}^q)\epsilon_t - q_t^j + b_{t-1}^j (1 + r_{t-1}) - b_t^j + \\ & D_t^j - D_{t-1}^j (1 + r_{t-1}) + K_t^{Bj} - K_{t-1}^{Bj} - C^b(.) \Big]\end{aligned} \tag{2.22}$$

Equation 2.22 shows the standard cash flow equation for banks. This enables households to smooth consumption intertemporally by receiving a risk-free rate $(1 + r)$ for their savings, while $(1 + r^q)$ denotes the loan rate faced by entrepreneurs. The banking sector which operates under perfect competition, takes these rates as given. Moreover, an extension is considered to incorporate a cost related to the capital positions of the bank $C^b(.)$.

$$C^b(.) = \frac{\kappa}{2}\left(\frac{K_{t-1}^{Bj}}{Q_{t-1}^j} - z\right)^2 K_{t-1}^{Bj} \tag{2.23}$$

where κ is an adjustment cost parameter that is positive, the capital-to-asset ratio of financial institutions is given by $\frac{K_{t-1}^B}{Q_{t-1}}$ with Q being total assets as defined by Equation (2.20), and where z denotes the capital-to-asset ratio in the steady state that is exogenous and is calibrated to be consistent with Basel regulation.[11]

The banking sector faces a quadratic cost function in Equation (2.23) that penalizes deviations from the exogenous steady state capital-to-asset ratio. This ratio aims to capture the capital requirement regulation internationally agreed for credit institutions under the different flavours of Basel, to cover unexpected losses for depositors and stakeholders from increased leverage. Furthermore, this friction in

[10] Future profits of banks are discounted using the patient household's discount factor given they are owned by these agents.

[11] This parameter is not dynamic but static, and as such, it only accounts for the mandatory conservation buffer under Basel III but leaves out the seasonal buffer under Basel III (an additional countercyclical buffer of 2.5% for good time periods).

the credit supply side allows to understand how the exposure to sovereign debt by the banking sector has effects on private credit.

The maximization problem of the financial intermediaries consist of choosing the credit supply that maximizes the discounted sum of cash flows given by Equation 2.22, subject to Equations 2.20, 2.21 and 2.23, yielding the following condition:

$$Sp_t = \kappa\left(z - \frac{K_t^{Bj}}{Q_t^j}\right)\left(\frac{K_t^{Bj}}{Q_t^j}\right)^2 \tag{2.24}$$

Equation 2.24 describes the credit supply of financial institutions where spread Sp_t captures the difference between loans and risk free rate: $Sp_t = (1+r_t^q)E_t\epsilon_{t+1} - (1+r_t)$. In other words, this spread captures the margin for intermediation, which is the difference between what banks charge for lending and what they must pay back to depositors.

This condition states that any deviations from this capital-to-asset ratio relative to the steady state, generates a cost to the banking sector, which in turn have an effect on the credit supply in the economy. When facing a shock, banks respond by adjusting the level of loans either by increasing or reducing the supply of credit, which in turn leads to an increase in credit rates. It is precisely the deviation from capital-to-asset ratio (z) that has banks incur a regulation cost and generate a change in the spread between the loan and deposit rates. By affecting the credit supply, this then translates into lending rates faced by borrowers who see their investment decisions affected, having effects in real activity.

2.3.6 Consolidated constraint of the economy

Production within each economy $j = (h, f)$ must comply with the consolidated budget constraint given by:

$$P_t^j y_t^j = C_t^j + i_t^j + G_t^j + \delta K_{t-1}^{Bj} + NFA_t^j - NFA_{t-1}^j(1 + r_{t-1}) \tag{2.25}$$

Where C_t corresponds to the aggregate consumption in each j economy given by that of the patient household and entrepreneurs $C_t^j = c_t^{Pj} + c_t^{Ej}$. The net foreign assets are defined as $NFA_t^j = d_t^j - D_t^j$ domestically held assets in the form of deposit savings and the borrowing from the global banks from the domestic banks, the next section delves deeper in the topic.

2.3.7 Market Clearing conditions

This work models a two-region open economy model with the two economies defined as: home (the reference economy) and foreign (which represents the rest of the world). For the purposes of this work, the home economy has the superscript h and the foreign economy has the superscript f.

Asset market

Equilibrium in the asset market depends on the economy's initial net foreign asset position (NFA_t), so the following condition is required to clear the asset market in an open economy setting:

$$NFA_t^h = -NFA_t^f \tag{2.26}$$

In order to consider the interest rate premium in smaller to larger open economies, a small bond holding cost Ω is included:

$$(1 + r_t) = (1 + r_t^*)\frac{rs_t}{rs_{t-1}} - \Omega NFA_t \tag{2.27}$$

where r_t denotes the interest rate faced by the home economy, r^* is the foreign economy interest rate and rs is the real exchange rate between the home h and the foreign f economy. A positive NFA position means that the economy is a net lender, whereas a negative NFA indicates that it is a net borrower. When the home economy acts as a borrower, it then faces a higher interest rate by the amount indicated by the bond holding cost. When the home economy acts as lender in the international market, it receives an interest rate that is lower. [12]

Goods market

To ensure that the goods market clears in an international setting, the final demand of each j economy should pair the total global output produced. The demand functions of each j economy for goods produced domestically X_{Ht}^j and abroad X_{Ft}^j is given by:

Demand for goods produced in region H

$$X_{Ht}^h = X_t^h \nu \left(\frac{P_t^h}{P_{Ht}}\right)^\theta \tag{2.28}$$

$$X_{Ht}^f = X_t^f \nu^* \left(\frac{P_t^f}{P_{Ht}}\right)^\theta \tag{2.29}$$

[12] This is analogus to what is modelled in Kamber and Thoenissen (2013) following debt elastic interest rate in open economy models by Schmitt-Grohe and Uribe (2003) and Bodenstein (2011).

Demand for goods produced in region F

$$X_{Ft}^{h} = X_{t}^{h}(1-\nu)\left(\frac{P_{t}^{h}}{P_{Ft}}\right)^{\theta} \tag{2.30}$$

$$X_{Ft}^{f} = X_{t}^{f}(1-\nu^{*})\left(\frac{P_{t}^{f}}{P_{Ft}}\right)^{\theta} \tag{2.31}$$

Where X_t^j - (C_t^j, i_t^j,K_t^{Bj}, G_t^j) denotes the total demand for the j^{th} region, (ν) is the share of the home-produced good in final demand and (ν^*) is the share of home-produced good in foreign final demand. P_{Ht} indicates the price of goods produced in the home economy (H) while P_{Ft} denotes the price of goods produced in the foreign economy (F) and θ is the elasticity of substitution between home and foreign goods.[13] This means that the demand for each producing region (H, F) depends on the relative price of domestically produced goods and the share of j-produced goods in final demand for each region.

Hence, the first set of equations indicate that the production in the home economy H consumed locally (Eq. 2.28) and consumed abroad (Eq. 2.29) are a share of the home-produced good in home's final demand (ν) or home-produced good in foreign final demand (ν^*) and the relative prices of home produced goods to total prices in the respective j economy.

In the case of goods produced in the foreign economy (F) the same logic applies, that is, Equation 2.30 indicates the production of goods produced in economy F for export to economy h depends on relative prices and the share of foreign produced goods in final demand of economy h. For its part, the Equation 2.31 indicates the production of goods produced in the foreign economy F for consumption in the same economy, which therefore represents the share of foreign produced goods in the foreign economy $(1-\nu)$ in the final demand for goods in the economy f, multiplied by its relative price.

Finally, the following equations ensure that the final goods market clears:

$$ny_{t}^{h} = nX_{Ht}^{h} + (1-n)X_{Ht}^{f} \tag{2.32}$$

$$(1-n)y_{t}^{f} = (1-n)X_{Ft}^{f} + nX_{Ft}^{h} \tag{2.33}$$

[13]The superscript (lowercase) denotes where the final demand comes from [home (h) or foreign (f), while the subscript (uppercase) denotes where the good is produced [produced at Home (H) or the Foreign (F) economy].

Where n denotes the size of economy h and y^j denotes total output produced in each economy (where production is indicated by the subscript :H,F). For each j economy, the first term of the RHS of the equation indicates the local demand for domestically produced goods while the second term denotes the foreign demand for domestically produced goods (exports). Moreover, in a model with unequal region sizes, it is useful to redefine the shares in terms of country sizes(n) and openness to trade (γ). Following De Paoli (2009), the relationship is given in such a way that $\nu = 1-(1-n)\gamma$ for the home economy and $\nu^* = n\gamma$ for the foreign economy.[14]

2.4 Estimation of the model

Using the log-linearized version around the steady state of the model presented in section 2.3, Bayesian estimation techniques are used to analyse the business cycle characteristics of the model.[15] The two j regions in the estimation exercise are the aggregate periphery countries: Greece, Italy, Ireland, Portugal and Spain (GIIPS) as the smaller region defined as home (h) and the United States (US) as the large foreign region (f). The European periphery economies are chosen as credit contractions and high levels of sovereign debt holdings by domestic financial institutions were more pronounced (see discussion in section 2.2). To account for the foreign economy, data on the United States is used to capture the rest of the world given its big share of world production. The relative size of the home region n, is calibrated as the share of the GIIPS region measured by the GDP of the GIIPS block and the remaining share $(1-n)$ corresponds to that of the GDP of the US.

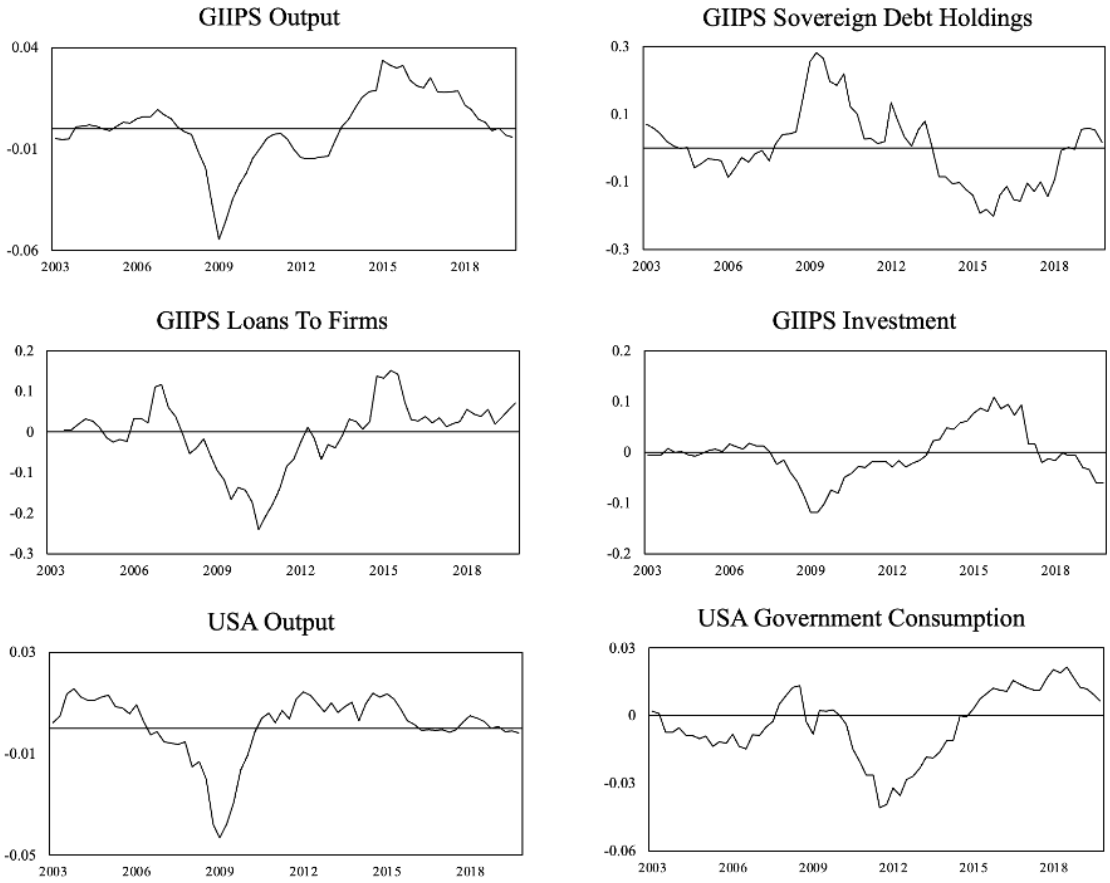
2.4.1 Data

The model is estimated using the cyclical component of six data series on output, government spending, investment, loans to Firms and sovereign debt holdings by financial institutions. The estimation sample ranges over the period 2003Q1:2019Q4 (68 quarters), which also captures the rise in public debt and the rise in sovereign debt holdings following the financial and debt crises in Europe.

[14] When the share of domestically-produced goods is greater in the home than in the foreign economy, that means ($\nu > \nu^*$), home bias happens. In other words, households in the h economy have home bias towards their own produced goods.

[15] Although estimation can be performed through Maximum Likelihood (ML) or Bayesian techniques, a Bayesian approach allows to use prior information to identify parameters in the model, unlike a full information approach through ML.

Figure 2.3 Observable Variables Used in Estimation



Source. Obtained using data from OECD and ECB. Notes: The graphs present the observable variables used in the Bayesian estimation of the baseline DSGE model. The data presented are the cyclical component under the Hamilton filter. The GIIPS variables correspond to the sum of real values of all the peripheral economies. The horizontal axis identifies the quarterly period while the vertical axis shows the percentage deviation from the trend. The series has 68 observations with quarterly frequency 2003Q1: 2019Q4.

The data series are transformed to real terms with base year 2015 and the trend is eliminated using the Hamilton filter to estimate the linearized model (Figure 2.3) plots the real variables constructed as indicated above under Hamilton Filter.[16] The variables for GIIPS correspond to the sum of real values of all the peripheral economies before the log transformation. The data sources and transformations can be found in Appendix A.3.

2.4.2 Calibration and Estimation

Some structural parameters are calibrated whilst others are estimated through Bayesian techniques. Well established parameters in the literature have been calibrated. From a Bayesian point of view, calibration of the model parameters suggests a strong prior belief on the parameter values.[17] On the other hand, the parameter estimation aims to improve the measurement of the magnitude and persistence of the shock experienced by the peripheral European region under study by relying on additional information derived from the data. Also, estimations are made for other key parameters as the elasticity of substitution and trade openness, which shed light on the dynamics between the European periphery and the United States. Tables 2.1 and 2.2 show the calibrated and estimated parameters used in the estimation of the linearized model. The rest of the model parameters are derived from the model as indicated in Appendix A.2.

Calibrated Parameters: For the baseline calibration of the model a discount factor of 0.99 is established for the household utility function which equates an annual interest rate of 4 percent , whereas for entrepreneurs, the discount factor is set to 0.98, indicating an annual discount rate of 8 percent.[18] The difference in the discount factor implies that some agents are more patient than others, which allows to generate the demand for intermediation by the financial sector in the steady state. For the Cobb–Douglas production function, share of capital input in intermediate goods

[16]Because the posterior distribution of the structural parameters is sensitive to the choice of trend removal/cycle extraction, the method chosen will affect the analysis. To see how the results change with a different method for detrending the data, Appendix A.5 compares results using Hamilton filter (baseline choice) with one-sided HP filter.

[17]Bayesian estimation is an approach that lies between calibration and Maximum Likelihood estimation, since in the absence of prior information (or flat priors), the estimate converges to Maximum Likelihood where the results are data-driven. In the opposite case in which the priors are correct and no additional information is added with the data used for the estimation, the results then converge back to calibration, since the prior mean is typically cantered around calibrated values from existing studies.

[18]Among recent literature that consider differences in discount factors and use similar values are: Gallegati et al (2019) set the impatient discount factor to .98; Jensen et al (2018) set it to 0.97; Batini et al (2019) sets entrepreneurs' discount factor to 0.98.

production α is set to 0.3 as a standard value from the RBC literature. Additionally, a standard capital depreciation rate $\delta = 0.025$ is used, which is equivalent to a 10 percent yearly rate. For the financial sector, a capital-to-asset ratio is set at 0.105 in the steady state consistent with Gerali et al (2010) and Kamber and Thoenissen (2013). Since there is no modelling of the seasonal buffer under Basel III, this work only accounts for the mandatory conservation buffer and so the capital-to-asset ratios is set to 10.5%.[19] The loans to valuation χ is set to 0.3 taken from other studies that set a value ranging from [0.3-0.38].[20] For the Steady state ratios, G/Y is set to 41% consistent with the share of general government expenditure to GDP from 2007-2018. Bond holdings are set such that $\frac{b}{y} > 0$, to allow for bond holdings in the steady state.[21]

Table 2.1 Calibrated Parameters

Description	**Param**	**Value**
Discount Factor for Patient Household	β	0.990
Discount Factor for Impatient Entrepreneur	β^E	0.980
Elasticity of Substitution in Production	α	0.300
Physical capital Depreciation Rate	δ	0.025
Capital to Asset Ration for financial intermediaries	z	0.105
The loans to valuation	χ	0.300
Gov. Expenditure share	$\frac{g}{y}$	0.410
Steady state Debt share	$\frac{b}{y}$	0.100

Estimated Parameters: Six persistence parameters and standard deviations of the shocks are estimated, along with 3 model parameters relying on MCMC algorithm under Bayesian methods. Given priors must be independent of the data, the model parameters on investment adjustment cost, elasticity of substitution and trade openness were set in line with calibrated values in Kamber and Thoenissen (2013).

[19] For a bank to be considered well capitalized according to Basel III regulation, *total* capital ratio must be at least 8% and the total minimum capital adequacy ratio, including the capital conservation buffer should be of 10.5%. The latter includes the total capital requirement of 8 percent with the 2.5% capital conservation buffer.

[20] Other authors that set values similar to this are: Christensen et al (2007), who set it to 0.32, for firms who can borrow against business capital calibrated for Canada, Chadha and Corrado (2012) set the capital as collateral as 0.2 in their model. Gertler and Karadi (2009) calibrate the fraction of capital that can be diverted to 0.383; Gallegati et al (2019) set the value of loan-to-value for entrepreneurs to 0.5 ; Batini et al (2019) sets entrepreneurs loan-to-value ratio to 0.38.

[21] When dealing with variables that take on a zero steady state, such as the stock debt or other assets, one cannot linearize them around their steady state. In such cases, it becomes necessary to introduce some convenient variable that is non-zero in the steady state. Standard in the literature is to consider the non-zero ratio, such as $\frac{b}{y}$ which must be positive and is set to 10% to prevent high indebtedness levels in steady state.

Table 2.2 Estimated parameters

Description	**Param**	**Prior**	**Mean**	90% HPD interval		**PDF**	**PstDev**
Model Parameters							
Adjustment Costs	s(.)	1.00	0.7229	0.1909	1.2583	Γ	0.5000
EoS Home vs Foreign Goods	θ	1.00	1.2429	0.6595	1.8881	Γ	0.5000
Openness to Trade	γ	0.30	0.3086	0.2925	0.3253	β	0.0100
AR(1) Coefficients							
Technology	ρ^{a}	0.7000	0.7843	0.6809	0.8967	β	0.1000
Foreign Technology Shock	ρ^{a*}	0.7000	0.7279	0.6069	0.8591	β	0.1000
Default Shock	ρ^{ϵ}	0.7000	0.6981	0.5467	0.8746	β	0.1000
Foreign Default Shock	$\rho^{\epsilon*}$	0.7000	0.4572	0.3086	0.6152	β	0.1000
Government Spending	ρ^{g}	0.7000	0.6615	0.5002	0.8256	β	0.1000
Foreign Gov. Spending	ρ^{g*}	0.7000	0.6874	0.5277	0.8372	β	0.1000
Standard Deviations							
Technology	σ_{a}	1.0000	0.2700	0.2296	0.3062	Γ^{-1}	0.5000
Foreign Technology Shock	σ_{a*}	1.0000	0.3691	0.2961	0.4430	Γ^{-1}	0.5000
Default shock	σ_{ϵ}	1.0000	0.2527	0.2261	0.2774	Γ^{-1}	0.5000
Foreign Default shock	$\sigma_{\epsilon*}$	1.0000	0.2924	0.2432	0.3371	Γ^{-1}	0.5000
Government Spending	σ_{g}	1.0000	0.2353	0.2261	0.2471	Γ^{-1}	0.5000
Foreign Government Spending	σ_{g*}	1.0000	0.2353	0.2261	0.2477	Γ^{-1}	0.5000

The table shows results from the bayesian estimation parameters. Column 1 describes the estimated parameters and column 2 shows the corresponding symbol. The rest of the columns show the mean values for the priors and posteriors, the 90% HPD interval, the distribution functions where: β Beta, Γ Gamma, and $\Gamma - 1$ Inverse Gamma; and the posterior deviation (obtained after 50,000 iterations). Draws from posterior distribution of the parameters are obtained using Metropoli-Hastings algorithm and convergence of the MCMC was assessed.

For the parameters controlling the persistence of the shock processes, standard priors were chosen for the parameters of persistence and standard deviations. I assume a Beta distribution with uniform mean 0.7 and uniform standard deviation 0.1. For the conditional standard deviations of the shock processes, we follow what is standard in literature and assign an Inverted Gamma distribution, to guarantee a positive standard deviation. As observed in Table 2.2, the posteriors exhibit a variation from its corresponding priors, suggesting that data can reveal some information relative to the prior. Likewise, technology shocks are the most persistent source of fluctuations, and in general shocks appear persistent except for the default shock abroad.

2.5 Results

To understand the effects of indebtedness on real economic activity, this section presents the impulse-response functions of the effects of an exogenous shock on government spending from the estimation of the linearised model in section 2.3.

2.5.1 Debt dynamics on the credit markets

The interest of this chapter lies in understanding the dynamics of public debt and its effects on the real economy. Figure 2.4 shows the effects of a debt financed fiscal shock when the financial institutions acquire government bonds. The open economy dynamic implies that an increase in government spending leads to a fall in national saving, reducing the supply of loanable funds and thereby instigating an increase in the real interest rate and a fall in the NFA positions of the home economy.[22] This further reduces consumption as higher interest rates on deposits increase household savings. Moreover, consumption falls as the increase in government spending has a negative income effect on Households given the higher tax burden. This further stimulates output as a negative income effect on Households given the higher tax burden, leads to an increase in Labour supply, increasing aggregate supply. [23]

However, the question this chapter answers is what are the effects of debt-financed fiscal policy on credit supply and capital formation, when the domestic banking sector act as the primary bond market? As has been observed in Europe and other economies, the banking sector has acted as a relevant bondholder which has had effects on real economic activity. Figure 2.4 highlights what happens on the credit market under a debt-financed fiscal shock for the estimated model.

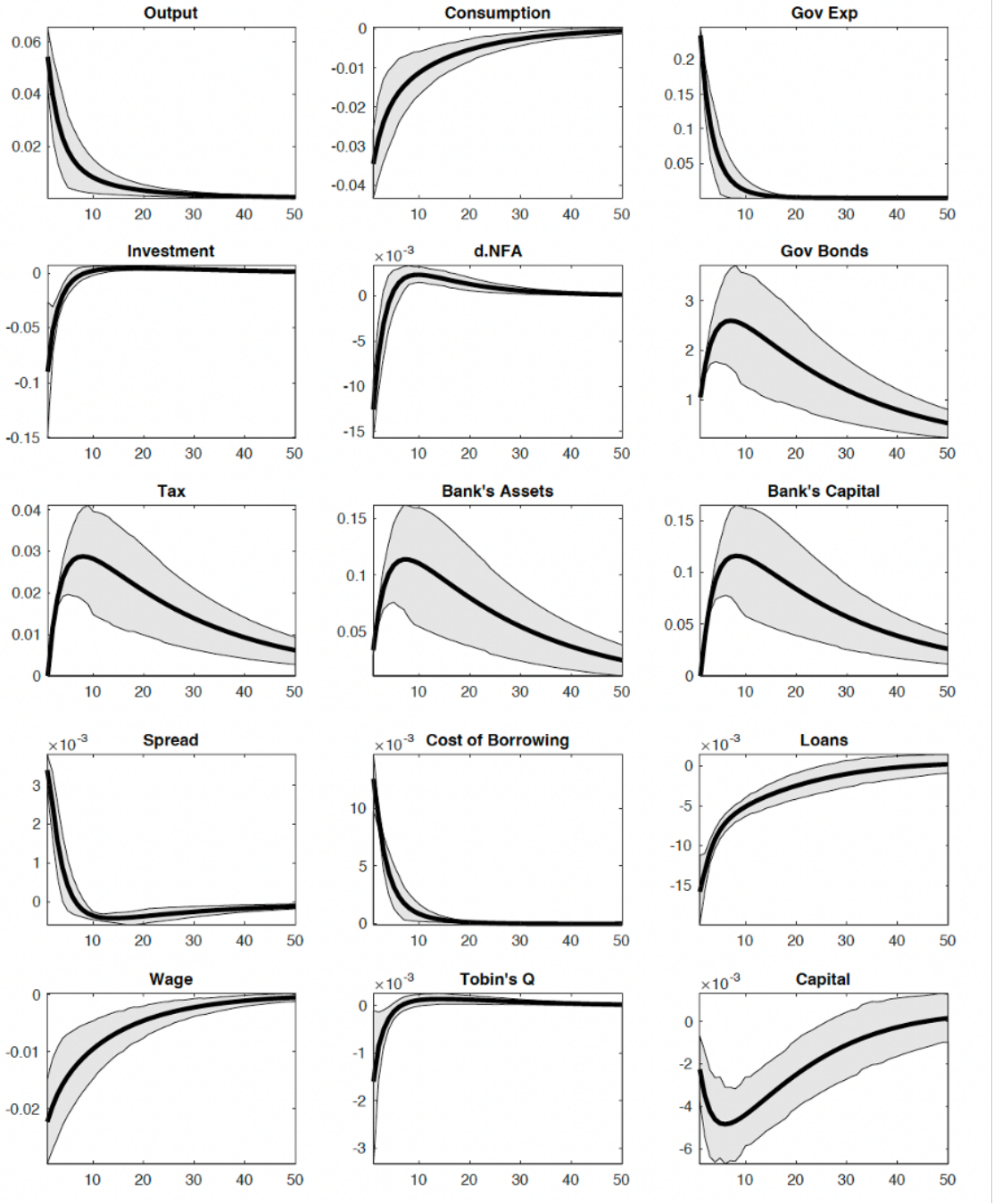
Understanding the mechanism of transmission

To understand the dynamics in the credit market and the effects on investment of a public spending shock, one must first understand the dynamics on both sides of the credit market. On the *supply side* of credit, the bonds issued by the fiscal authority are absorbed by the financial sector, increasing the asset side of the balance sheet. The debt financed government spending shock directly affects the capital-to-asset ratio of banks, weakening their financial positions. That is, as bonds are absorbed by the banking sector, the increased assets in the bank's balance sheet led to the banking sector having to raise more capital to meet capital requirements. Because bank capital doesn't respond immediately to an increase in the bank's assets, this causes capital-to-asset ratio to deviate from the minimum capital requirements set by international regulation. The banks to be able to generate more capital, must increase their profits (see Equation 2.21). Therefore, they must decide the optimal level of loans to the private sector that allows them to meet the capital

[22] As there is a fall in net capital outflows, this reflects in a positive capital account and a fall in the current account in the balance of payments

[23] The higher labour supply however leads to a fall in wages.

Figure 2.4 Government Spending Shock



Responses to a 1 S.D. government spending shock. Impulse response functions obtained at posterior means computed from estimation and 90% HPD intervals. Vertical axis is in percentage deviations from steady state and horizontal axis is measured in quarters.

requirements (capital-to-asset ratio) given the greater credit to the government.[24] Financial intermediaries can only increase their profit and capital by initially reducing credit. Consequently, financial institutions react by contracting the credit supply to firms, trying to maintain the spreads they obtain from intermediation, to offset these higher costs. The effect of higher bond holdings by financial institutions then acts to contract the credit supply, further rising the lending rates to firms as depicted by the increase in the cost of borrowing, which in turn introduces a higher spread between the loan rate and the risk-free (savings) rate.

On the *demand side* of credit, the increase in the spread affects the firms' decision to borrow. An entrepreneur's decision to borrow is affected by the spread, since it implies higher costs for borrowing (see equation 2.9). By facing higher borrowing costs, firms in turn reduce the demand for loans which affects their investment decisions and thus capital formation in the economy. This happens as higher cost of borrowing causes the entrepreneurs to need to pledge more collateral to access credit. The fact that entrepreneurs are subject to binding collateral constraints, causes that when the value of the installed capital (Q ratio) decreases, the collateral that is used to acquire loans decreases, leading to lower borrowing capacity.[25] Therefore the presence of financial frictions both in supply and demand side of the credit market help capture the connection between sovereign bond holdings on bank balance sheets and the effects on low levels of corporate lending.

In order to compare results in Figure 2.4 which allows banks to acquire sovereign debt, Figure 2.5 presents the impulse responses of the counterfactual exercise in which there is *no financial intermediation for government debt*. This counterfactual scenario, causes the mechanism that plays a role in financial intermediation to be different. The main difference is shown in the response of investment, where the absence of a modelled sovereign exposure mechanism acts as a crucial factor preventing the emergence of a crowding out effect. Although the mean posterior shows a similar contraction in investment, the credible intervals suggest that the model cannot provide strong evidence for the presence or absence of a crowding out effect under higher sovereign debt exposure by banks.[26]

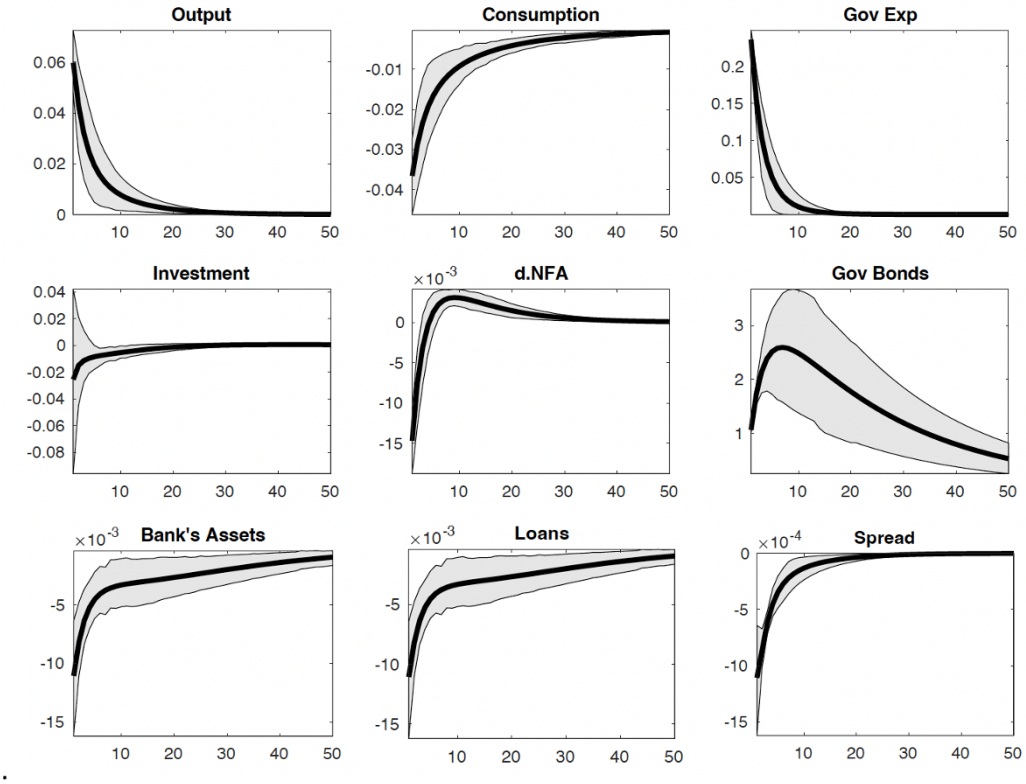
[24] As stated in subsection 2.3.5, banks require a positive spread between loan and policy rate, which increases bank's profits, to supply loans. Equation 2.23 imposes a cost on increased assets. Ergo, the bank incurs a quadratic cost whenever the capital-to-assets ratio moves away from the set ratio z, which reduces profits.

[25] The reason why the productive sector is affected in its collateral comes from the relationship between the investment and Q-ratio. An increase (decrease) implies a looser (tighter) borrowing constraint for entrepreneurs, thus increasing (decreasing) their investment.

[26] The credible interval suggests there is a 90% probability that the true(unknown) estimate would lie within the bands around the mean posterior, given the evidence provided by the observed data.

In the case of financial intermediation of debt, the spread increases as higher debt in the balance sheets increase in the cost for the banking sector, interpreted as higher capital requirements. The higher spread between loans rate and risk-free rate, leads to lower investment and capital formation. However, Figure 2.5 shows the effect on the spread is negative. This because of higher deposit rates that occur due to the increase in public spending, reducing the credit spread and contracting the bank capital generated from retained earnings. Consequently, this leads to a lower credit supply to be able to compensate for the fall in the spread. In fact, the bank's assets are reduced by the amount that loans fall as sovereign holdings do not enter the balance sheets of financial institutions even though debt rises in response to the government spending shock.

Figure 2.5 Responses to a Debt-financed Government Spending Shock under No Financial intermediation of Sovereign Bonds

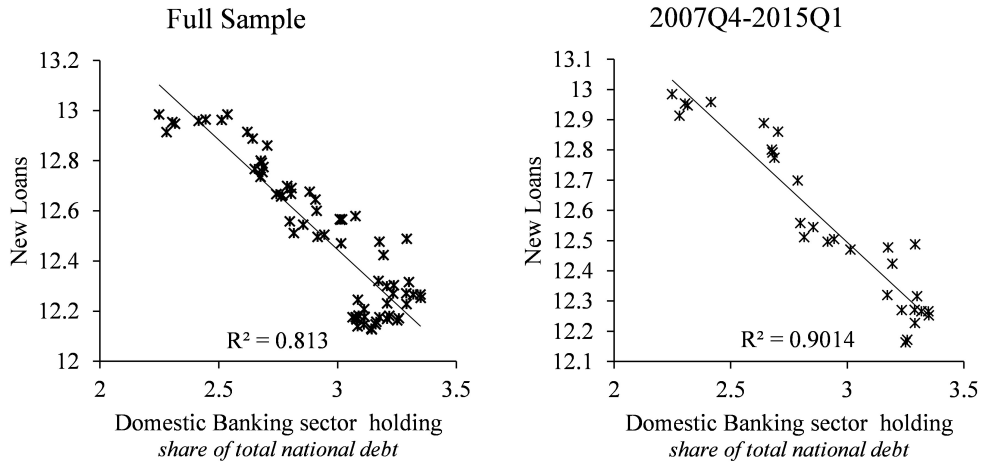


Responses to a 1 S.D. government spending shock. The figure shows the effects of a government spending shock with no financial intermediation for government debt. Impulse response functions obtained at posterior means computed from estimation and 90% HPD intervals. Vertical axis is in percentage deviations from steady state and horizontal axis is measured in quarters.

Debt dynamics during the crisis period

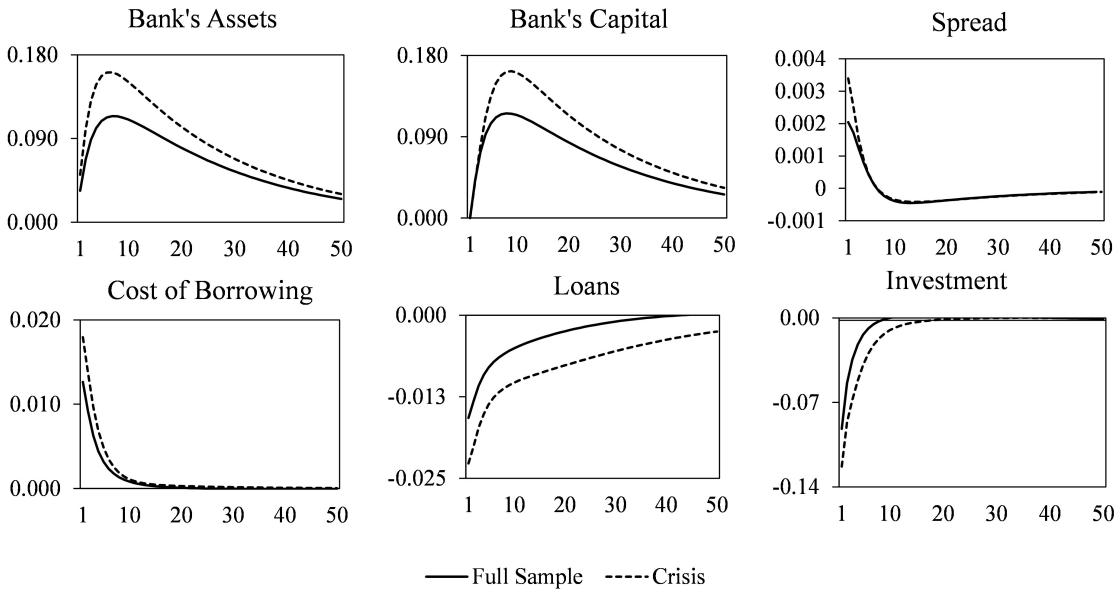
The analysis of *debt-financed* fiscal policy is extended to understand how it changes by restricting the estimation sample period to 2007Q4:2015Q1. The period captures the rise in public debt (as percentage of GDP) and the rise in sovereign debt holdings during the European sovereign debt crisis. Additionally, looking at the data used in the estimation, Figure 2.6 presents the correlation between sovereign debt holdings and credit to the private sector which reflects a higher R^2 for the sub-sample period. To focus explicitly on debt dynamics in the financial sector, the analysis focuses in understanding how fiscal expansionary shock affects: 1) *total assets* acquired by financial institutions, 2) responses in *bank's capital*, 3) the effects on *loans*, 4) the *cost of borrowing* for firms, 5) the *spread* between the loan and risk-free rate, and 6) the effects on real activity by understanding the effects on *investment*. When analyzing the effects of the same shock for the subsample, as expected, the mechanism shows higher effects during the European debt crisis period than when a longer period is considered as shown in Figure 2.7. Particularly during the crisis, debt issuance was higher which led to more debt being acquired as part of banks' assets compared to the full period. The increase in the spread is also higher because of the contraction in the credit supply, leading to a higher cost of borrowing. Consequently, investment shows larger effects for the crisis period.

Figure 2.6 Correlations of Sovereign Debt Holdings and Loans to Firms in the European Periphery (GIIPS)



Note: variables in natural logarithm form. Source: own estimates with data from ECB- Statistical Data warehouse. The aggregate of periphery countries include: Greece, Ireland, Italy, Portugal and Spain (GIIPS).

Figure 2.7 Effects of different sub-sample period [2007Q4:2015Q1]



Responses to a 1 S.D. government spending shock on selected variables. Impulse response functions obtained at posterior means computed from estimation. Vertical axis is in percentage deviations from steady state and horizontal axis is measured in quarters.

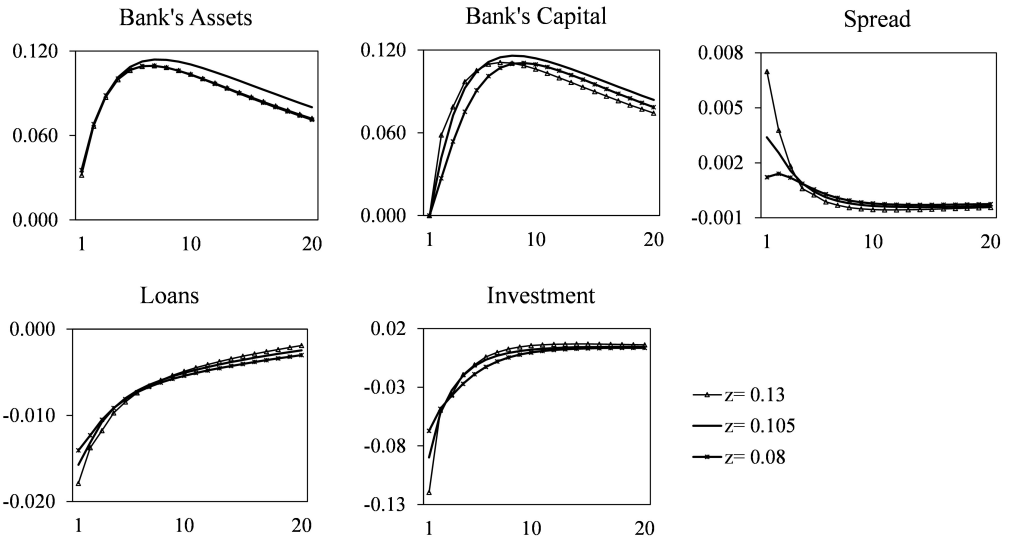
Capital requirements and effects on Investment

Given the relevance of capital requirements in explaining frictions in the credit supply side that further transfer to real economic activity, the effects of a fiscal expansion under different capital requirements to banking institutions are also analyzed. The baseline model has assumed so far a capital-to-asset ratio of 10.5%. Figure 2.8 simulates a change in the regulation to account for lower and higher capital requirements to see the implications on investment, where the values are chosen to be consistent with Basel regulation. The international standards required banks to meet a minimum ratio of regulatory capital which, until the financial crisis of 2008–2009, corresponded to an 8% Under Basel I and II. However the reforms that followed the financial crisis under Basel III regulation, set the new measures could increase the total capital requirements to up to 13% with the inclusion of additional buffers.[27]

While the shock in public spending financed with debt has similar effects in terms of the composition of observed assets and capital, which corresponds to the first two graphs in Figure 2.8, what changes are the capital-to-asset requirements in the steady state imposed as macroprudential regulation. The model dynamics indicate that

[27]More precisely, the minimum ratio of capital to risk-weighted assets went from 8% under Basel II to 10.5% under Basel III and adds up to 13 percent under the countercyclical buffer.

Figure 2.8 Effects of different capital requirements to Banking Institutions



Responses to a 1 S.D. government spending shock on selected variables. Impulse response functions obtained at posterior means computed from estimation. Vertical axis is in percentage deviations from steady state and horizontal axis is measured in quarters.

impacts of higher capital requirements imply higher costs for the banking sector as it requires more capital when it increases its assets. This consequently puts upward pressure on the bank spread and contracts credit to a greater extent and consequently reduces investment as constrained entrepreneurs face higher borrowing costs.[28]

2.6 Concluding Remarks

The post-recession period in Europe was characterized by higher debt levels, increased sovereign debt holdings by domestic financial institutions and by a contraction in the issuance of credit to productive sector. This in turn highlighted the crucial role of frictions in the credit market for propagating economic shocks. Given the nature of the financial crisis and that it was propagated through the financial sector, understanding the different policies at play during the period following the economic turmoil of 2008 has become relevant to understand the macroeconomic implications. As such, motivated by persistent high levels of post-crisis debt, and in order to account for the international regulatory framework that financial institutions face, this chapter develops a DSGE model estimated with Bayesian techniques to analyze

[28]These results are consistent with a branch of literature that has documented changes in capital requirements and contraction in lending: Bottero(2020) ; Fraisse & Thesmar (2020) ; De Jonghe et al (2020) ; Bridges et al (2014); Gropp et al (2019), Cohen and Scatigna (2016), among others.

the effects of debt-financed fiscal policy on credit supply and capital formation when the financial institutions act as sovereign debt holders.

This work contributes to the literature by proposing a model that considers a balance sheet channel of sovereign exposure. The model features a financial sector that is subject to minimum capital requirements and that responds to an increase in bond holdings offering a richer specification compared to existing literature. By incorporating financial frictions on both, the supply and demand side of the credit market and accounting for heterogeneous agents that differ in their degree of impatience, financial intermediation takes on a relevant role to explain fluctuations in real activity. It demonstrates through a theoretical framework that the introduction of financial intermediation with capital buffers, generates a channel to explain the differentiated effects in real economic activity. Moreover, this chapter adds to the existing literature in understanding *one of the channels* of contagion between banks and sovereigns and provides new evidence on the balance sheet channel that has been studied to explain market imperfections on the supply side for macro-financial linkages.

The results that emerge from this work propose that when the fiscal authority issues government debt to finance expenditure, the asset side of the bank's balance sheet expands. This expansion in the assets side of the bank balance sheet coupled with banks facing capital requirement costs of intermediation, contracts the credit supply and increases credit spreads. In turn, entrepreneur's decision to borrow is affected by higher borrowing costs and the need to pledge more collateral to access credit, negatively affecting investment and capital formation decisions. This happens as the fiscal policy financed through indebtedness depresses access to credit, as a result of a substitution effect between loans and bonds in the restructuring of the balance sheet. Thus, to the extent that bank's assets are increased by ownership of government securities, the loans to the private sector are reduced, leading to a lower capital formation in the economy and depressing investment. The *conclusion* that emerges from this work is that bank's exposure to sovereign debt, propagates the transmission through changes in their credit supply and amplifies the effects on capital formation in the real economy. Moreover, the findings suggest that during a sub-sample period (2007Q4-2015Q1) which covers the period of the financial and debt crisis in Europe, these effects are more pronounced. In performing the robustness checks for the model under a different filtering strategy, the results do not vary significantly, indicating the model is robust to filtering.

It should however be noted that the aim of this work is not to say that debt policy is bad. In fact, facilitating liquidity to the public sector helps stimulate economic activity through expansionary fiscal stimulus. However, it is important to emphasize the fact that economies that are limited to accessing funding through the domestic sector have implications for domestic financial institutions. In particular, the aim of this chapter is to highlight that there are trade-offs that emerge from having high exposure of the banking sector to sovereign debt on private investment. the mechanism provides a rationale to understand why credit contractions led to lower investment in European peripheral economies as has been documented in the empirical literature (see Section 2.2).

In terms of policy implications, it becomes crucial to seek to implement policy measures that help mitigate the frictions present in the financial sector. In an economy like the European one with a high dependence of companies on bank credit as a source of liquidity, any shock that affects the ability of the financial sector to grant credit can affect investment levels and lead to adverse consequences for the economy.[29] This chapter argued the relevance of the banking sector to propagate macroeconomic policy shocks. These shocks may be in the form of greater regulations for the banking sector in terms of capital requirements or may simply be associated with macroeconomic policy that has direct repercussions on the banking sector's balance sheets. To the extent that banks cannot adjust immediately to shocks hitting the economy, it could lead to them having to adjust their credit provision further affecting investment in the economy. Another point that becomes relevant is in line with the negative effects that banking regulation has on credit provision (see Thamae and Odhiambo (2021) for an extensive review of the literature). To the extent that banking regulation limits credit availability in traditional banking institutions, companies that cannot access credit may migrate to unregulated markets as an alternative source of financing, leading to greater fragility in the financial sector.

[29]As suggested in the work by Priftis and Zimic (2021), the credit response to a government spending shock depends to a great extent on how the debt is financed. Countries like the United States, whose debt is held by foreign economies, can borrow without significantly crowding out domestic investment. The difference with the peripheral economies in Europe is that the uncertainty following the financial crisis but in particular following the episode of the sovereign debt crisis, limited the credit these governments could obtain abroad.

Appendix A

A.1 International final demand

Each component of the final demand vector X_t^j can be decomposed in such a way that: $\mathbf{X}_t^j = \mathbf{A}(X_{Ht}^j, X_{Ft}^j)$ where $\mathbf{X}$ -(C_t^j, i_t^j,K_t^{Bj}, G_t^j) - denotes total final demand of goods, bundling together both home X_{Ht}^j and foreign X_{Ft}^j goods, while $\mathbf{A}$ is the Armington aggregator. Each component of final demand is a CES aggregate of home and foreign produced goods.[1] Next, I define the CES index along with the corresponding price index for each region $j = (h, f)$:

For the home economy (h)

$$X_t^h = [\nu^{\frac{1}{\theta}} {X_{Ht}^h}^{\frac{\theta-1}{\theta}} + (1-\nu)^{\frac{1}{\theta}} {X_{Ft}^h}^{\frac{\theta-1}{\theta}}]^{\frac{\theta}{\theta-1}} \tag{A.1.1}$$

$$P_t^h = [(\nu P_{Ht}^{1-\theta}) + ((1-\nu)P_{Ft}^{1-\theta})]^{\frac{1}{1-\theta}} \tag{A.1.2}$$

For the foreign economy (f)

$$X_t^f = [\nu^{*\frac{1}{\theta}} {X_{Ht}^f}^{\frac{\theta-1}{\theta}} + (1-\nu^*)^{\frac{1}{\theta}} {X_{Ft}^f}^{\frac{\theta-1}{\theta}}]^{\frac{\theta}{\theta-1}} \tag{A.1.3}$$

$$P_t^f = [(\nu^* P_{Ht}^{1-\theta}) + ((1-\nu^*)P_{Ft}^{1-\theta})]^{\frac{1}{1-\theta}} \tag{A.1.4}$$

Where θ is the elasticity of substitution between home and foreign goods and ν is the share of the home-produced good in final demand. The superscript (lowercase) denotes where the final demand comes from [home (h) or foreign (f), while the subscript (uppercase) denotes where the good is produced [produced at Home (H) or the Foreign (F) economy].[2] This indicates that the final demand goods in each

[1] Each of the components of final demand vector $\mathbf{X}$, are isomorphic in the way they are bundled and priced. In other words (sounding less fancy but perhaps clearer), they all are aggregated by a CES function and priced as described.

[2] As an example, if the final demand component is consumption for j=h: c_t^h is made up of c_{Ht}^h (goods demanded at home and produced at Home) and c_{Ft}^h (goods demanded at home and produced in Foreign country (imported goods).

economy j=(h,f) are an aggregate of goods *produced* at Home (H) and abroad (F) depending on the share ν. Similarly, the prices faced by the domestic economy are also a component of prices of domestic goods and foreign goods weighted by the relative weight of home-produced good in final demand.

All relative prices can be expressed as combinations of the terms of trade and the price of country. For this work no distinction is made between tradable and non-tradable goods, assuming all goods are traded in the international market. Terms of trade (TOT) measured as the price of imports (expressed in units of home economy) relative to the price of exports (expressed in units of home economy), can be defined as a function of the price index:

$$TOT_t = \frac{P_{Ft}}{s_t P^f_{Ht}} \tag{A.1.5}$$

Where s_t is the nominal exchange rate. Because the law-of-one-price holds, the price of goods produced in domestic economy P_{Ht} equal the prices of goods in foreign economy times the exchange rate: $P_{Ht} = s_t P^f_{Ht}$, the TOT can be written as:

$$TOT_t = \frac{P_{Ft}}{P_{Ht}} \tag{A.1.6}$$

Thus, the relative prices expressed as combinations of the terms of trade are defined as:

$$\frac{P^h_t}{P_{Ht}} = \left[\nu + (1-\nu)TOT_t^{1-\theta}\right]^{\frac{1}{1-\theta}} \tag{A.1.7}$$

$$\frac{P^f_t}{P_{Ht}} = \left[\nu^* + (1-\nu^*)TOT_t^{1-\theta}\right]^{\frac{1}{1-\theta}} \tag{A.1.8}$$

$$\frac{P^h_t}{P_{Ft}} = \left[\nu TOT_t^{\theta-1} + (1-\nu)\right]^{\frac{1}{1-\theta}} \tag{A.1.9}$$

$$\frac{P^f_t}{P_{Ft}} = \left[\nu^* TOT_t^{\theta-1} + (1-\nu^*)\right]^{\frac{1}{1-\theta}} \tag{A.1.10}$$

Following Kamber and Thoenissen (2013), the terms of trade (TOT_t) and the real exchange rate (rs_t), which are the two relative prices in international models, are related by the degree of openness to trade (γ) in the linearized form as follows: $\hat{rs}_t = (1-\gamma)\hat{TOT}_t$. The hat indicates the log linear deviations from steady state. Notice that in the extreme case of the economy being fully open to trade ($\gamma = 1$) the real exchange rate is constant.

A.2 Specifications

The model presented in section 2.3 is log-linearized and used to derive the system of equations that describes the equilibrium. The system is written in stationary form, where the variables are measured in deviations from the non-stochastic steady state. A deterministic steady-state in this model is defined, so that a zero-growth steady state is assumed $X_t = X_{t-1} = X$ for any variable X in the model. Appendices A.2.1 and A.2.2 describe the steady state and log-linearized equations. The model is defined in generalized state-space form $E_t X_{t+1} = AX_t$ and impulse response functions are used to simulate effects of shocks.

A.2.1 Steady State

In the steady state, shocks are constant and equal to one, and all real variables are constant over time. The steady state of the model is defined by the following equations:

$$\frac{c^P}{y} = 1 + \frac{q}{y}(\frac{1}{\beta} - 1) - \delta^B \frac{K^B}{y} - \rho\frac{k}{y} - \frac{T}{y} \tag{A.2.1}$$

$$\frac{w}{c} = \eta \tag{A.2.2}$$

$$\lambda_t = \frac{1}{c^P} \tag{A.2.3}$$

$$\frac{1}{\beta} = (1 + r) \tag{A.2.4}$$

$$\frac{y}{k} = \left(\frac{k}{l}\right)^{\alpha-1} = \frac{\rho}{\alpha} \tag{A.2.5}$$

$$\left(\frac{\rho}{\alpha}\right)^{\frac{\alpha}{\alpha-1}}(1 - \alpha) = w \tag{A.2.6}$$

$$\frac{k}{l} = \left(\frac{\rho}{\alpha}\right)^{\frac{1}{\alpha-1}} \tag{A.2.7}$$

$$\frac{c^E}{y} = \rho\frac{k}{y} - \frac{i}{y} - r^q\frac{q}{y} \tag{A.2.8}$$

$$S\left(\frac{i}{k}\right) = \delta \tag{A.2.9}$$

$$S'\left(\frac{i}{k}\right) = 1 \tag{A.2.10}$$

$$\frac{q}{k} = \beta\chi(1-\delta) \tag{A.2.11}$$

$$\frac{1}{c^E} = \lambda^E \tag{A.2.12}$$

$$\beta - \beta^E = \Delta \tag{A.2.13}$$

$$\rho = \frac{1}{\beta^E}[1 - \Delta\chi(1-\delta)] - (1-\delta) \tag{A.2.14}$$

$$\frac{D}{Q} = 1 - z \tag{A.2.15}$$

$$\frac{q}{Q} = 1 - \frac{b}{Q} \tag{A.2.16}$$

$$\Pi^B = K^B \frac{1-\beta}{\beta} \tag{A.2.17}$$

$$\frac{T}{y} = \frac{G + br^b}{y} \tag{A.2.18}$$

$$\frac{c}{y} = 1 - \frac{d^B K^B}{y} - \frac{i}{y} - \frac{G}{y} \tag{A.2.19}$$

A.2.2 Log-Linear System

Variables with hats are used to denote log-deviations (or percentage deviations) from its steady state value. To simplify the nomenclature and limit the extension of this appendix, this section omits the introduction of superscripts $j = (h, f)$ for each region described in section 3 of the main text. However, the reader must assume that a block of similar equations for each of the agents corresponds to each economy.

HOUSEHOLDS:

$$\hat{y}_t = \hat{c^P}_t \frac{c^H}{d} + \frac{d}{y}\Big[\hat{d}_t - \hat{d}_{t-1}(1+r_t)\Big] + \frac{pk}{y}(\hat{p}_t + \hat{k}_{t-1}) + \hat{T}_t \, \frac{T}{y} \tag{A.2.20}$$

$$-\hat{c}_t^P = \hat{\lambda}_t \tag{A.2.21}$$

$$\hat{\lambda}_t + \hat{w}_t = 0 \tag{A.2.22}$$

$$\lambda_{t+1} + \widehat{(1+r_t)} = \hat{\lambda}_t \tag{A.2.23}$$

$$\widehat{1+r_t} = \widehat{1+r_t^*} + (1-\gamma)\left[\widehat{TOT}_{t+1} - \widehat{TOT}_t\right] + \hat{\epsilon}_{t+1}^{IR} - bhc^* \, \frac{\delta \, NFA}{y} \tag{A.2.24}$$

GOODS PRODUCERS:

$$\hat{y}_t = \hat{A}_t + \hat{k}_{t-1} \, \alpha + \hat{l}_t(1-\alpha) \tag{A.2.25}$$

$$\hat{w}_t = \widehat{TOT}_t(n-1)\gamma + \hat{y}_t - \hat{l}_t \tag{A.2.26}$$

$$\hat{p}_t = (n-1) \, \gamma \, \widehat{TOT}_t + \hat{y}_t - \hat{k}_{t-1} \tag{A.2.27}$$

ENTREPRENEURS:

$$\hat{c}_t^E \, \frac{c^E}{y} = (\hat{p}_t + \hat{k}_{t-1}) \, \frac{pk}{y} - \hat{i}_t \, \frac{i}{y} + \hat{q}_t \, \frac{q}{y} - [\widehat{(1+r^q)}_{t-1} + \epsilon_t] \, (1+r^q) \, \frac{q}{y} - \hat{q}_{t-1} \, (1+r^q) \, \frac{q}{y} \tag{A.2.28}$$

$$\hat{k}_t = (1-\delta) \, \hat{k}_{t-1} + \delta \, \hat{i}_t \tag{A.2.29}$$

$$(\widehat{1+r_t^q}) + \hat{\epsilon}_{t+1} + \hat{q}_t = \hat{\varphi}_{t+1} + \hat{k}_t \tag{A.2.30}$$

$$-\hat{c}_t^E = \hat{\lambda}_t^E \tag{A.2.31}$$

$$\hat{\varphi}_t = \left[\hat{k}_{t-1} - \hat{i}_t\right] s''(\cdot)\ \frac{i}{k} \tag{A.2.32}$$

$$\beta^E\ \hat{\lambda}^E = \beta^E\ \hat{\lambda}_{t+1}^E + \hat{\Delta}_t \Delta + \beta(\widehat{1+r_t^q}) + \beta\ \hat{\epsilon}_{t+1} \tag{A.2.33}$$

$$\hat{\varphi}_t = \left[\hat{\lambda}_{t+1}^E - \hat{\lambda}_t^E\right]\ \left[\beta^E\ (p+(1-\delta)\right] + \hat{p}_{t+1}\ p\ \beta^E + \hat{\varphi}_{t+1}\left[1-\beta^E\ p\right] + \hat{\Delta}_t\ \Delta\chi(1-\delta) \tag{A.2.34}$$

FINANCIAL SECTOR:

$$\hat{\Pi}_t^B = \frac{1}{1-\beta}\ \frac{Q}{K^B}\ \frac{q}{Q}\left[(\widehat{1+r_{t-1}^q}) + \hat{\epsilon}_t\right] + \frac{b}{K^B}\ \frac{1}{1-\beta}(\widehat{1+r_{t-1}}) - \frac{D}{K^B}\ \frac{1}{(1-\beta)}(\widehat{1+r_{t-1}}) + K_{t-1}^B \tag{A.2.35}$$

$$\hat{Q}_t = \hat{D}_t\ \frac{D}{Q} + \hat{K}_t^B\ \frac{K^B}{Qi} \tag{A.2.36}$$

$$\hat{Q}_t = \hat{q}_t\ \frac{q}{Q} + \hat{b}_t\ \frac{b}{Q} \tag{A.2.37}$$

$$\hat{K}_t^B - \hat{K}_{k-1}^B(1-\delta^B) = \hat{\Pi}_t^B \tag{A.2.38}$$

$$\frac{1}{\beta}\left[(\widehat{1+r_t^q}) + \hat{\epsilon}_{t+1} - (\widehat{1+r_t})\right] = \kappa\ z^3\left[\hat{Q}_t - \hat{K^B}_t\right] \tag{A.2.39}$$

$$\hat{c}_t\ \frac{c}{y} + \frac{\delta NFA}{y} + \hat{i}_t\ \frac{i}{y} + \hat{G}_t\ \frac{G}{y} = (n-1)\ \gamma\ T\hat{O}T_t + y_t - \delta^B\ \hat{K}_{t-1}^B\ \frac{K^B}{y} + \frac{\delta NFA}{y}\left(\frac{1}{\beta}\right) \tag{A.2.40}$$

GOVERNMENT:

$$\hat{G}_t\ \frac{g}{y} = \hat{T}_t\ \frac{T}{y} + \hat{b}_t\ \frac{b}{y} - \hat{b}_{t-1}\ \frac{b}{y}\ \left(\frac{1}{\beta}\right) - (\widehat{1+r_{t-1}})\ \frac{b}{y}\ \left(\frac{1}{\beta}\right) \tag{A.2.41}$$

MARKET CLEARING:

$$\begin{aligned} y_t^h = v\Big[\hat{c}_t\frac{c}{y} + \frac{i}{y}\hat{i}_t + \delta^B\ \frac{K^B}{y}\ \widehat{K_{t-1}^B} + \hat{G}_t\ \frac{g}{y}\Big] \\ +(1-v)\Big[\hat{c}_t^*\ \frac{c}{y} + \hat{i}_t^*\ \frac{i}{y} + \delta^B\ \frac{K^B}{y}\ \widehat{K_{t-1}^{B*}} + \hat{G}_t^*\ \frac{g}{y}\Big] \\ +\{\widehat{TOT}\ \theta(v)(1-v)\}\Big[\frac{c}{y} + \frac{i}{y} + \delta^B\ \frac{K^B}{y} + \frac{g}{y}\Big] \\ +\{\widehat{TOT}\ \theta(1-v^*)(1-v)\}\Big[\frac{c}{y} + \frac{i}{y} + \delta^B\ \frac{K^{B*}}{y} + \frac{g}{y}\Big] \end{aligned} \tag{A.2.42}$$

$$\begin{aligned} y_t^f = v^*\Big[\hat{c}_t\frac{c}{y} + \frac{i}{y}\hat{i}_t + \delta^B\ \frac{K^B}{y}\ K_{t-1}^B + \hat{G}_t\ \frac{g}{y}\Big] \\ +(1-v^*)\Big[\hat{c}_t^*\ \frac{c}{y} + \hat{i}_t^*\ \frac{i}{y} + \delta^B\ \frac{K^{B*}}{y}\ K_{t-1}^{B*} + \hat{G}_t^*\ \frac{g}{y}\Big] \\ -\{\widehat{TOT_t}\ \theta(v^*)(v)\}\Big[\frac{c}{y} + \frac{i}{y} + \delta^B\ \frac{K^B}{y} + \frac{g}{y}\Big] \\ -\{\widehat{TOT_t}\ \theta(1-v^*)(v^*)\}\Big[\frac{c}{y} + \frac{i}{y} + \delta^B\ \frac{K^{B*}}{y} + \frac{g}{y}\Big] \end{aligned} \tag{A.2.43}$$

A.3 Data Sources

For each periphery country i, the variables are:

- GDP^i : Gross domestic product (expenditure approach) - Millions of Euros, current prices, quarterly levels, seasonally adjusted. Source: Quarterly National Accounts, Organisation for Economic Co-operation and Development (OECD) Stats.

- GC^i : General government final consumption expenditure - Millions of Euros, current prices, quarterly levels, seasonally adjusted. Source: Quarterly National Accounts, Organisation for Economic Co-operation and Development (OECD) Stats.

- FCF^i : Gross fixed capital formation - Millions of Euros, current prices, quarterly levels, seasonally adjusted. Source: Quarterly National Accounts, Organisation for Economic Co-operation and Development (OECD) Stats.

- NL^i: New Loans - Millions of Euros, current prices, quarterly levels, seasonally adjusted (using the Eviews' X-12 filter) - Monetary Financial institutions, Total Loans other than revolving loans to Non-Financial Corporations (Outstanding amount) Source: ECB- Statistical Data warehouse.

- SDH i : Sovereign debt holdings by domestic credit institutions – Millions of Euros quarterly levels, seasonally adjusted (using the Eviews' X-12 filter). Source: Historical country level data retrieved from Merler and Pisani-Ferry (2012)

For the United States, the variables are:

- GDP: Gross domestic product (expenditure approach) - Millions of Dollars, current prices, quarterly levels, seasonally adjusted. Source: Quarterly National Accounts, Organisation for Economic Co-operation and Development (OECD) Stats.

- GC : General government final consumption expenditure - Millions of Dollars, current prices, quarterly levels, seasonally adjusted. Source: Quarterly National Accounts, Organisation for Economic Co-operation and Development (OECD) Stats.

Deflators:

- $GDP\_deflator^i$: Gross Domestic Product - Deflator base 2015, Seasonally Adjusted. Source: Quarterly National Accounts, Organisation for Economic Co-operation and Development (OECD) Stats.
- $GC\_deflator^i$: General government final consumption expenditure - Deflator-2015=100, Seasonally Adjusted. Source: Quarterly National Accounts, Organisation for Economic Co-operation and Development (OECD) Stats.
- $FCF\_deflator^i$: Gross fixed capital formation - Deflator - 2015=100, Seasonally Adjusted. Source: Quarterly National Accounts, Organisation for Economic Co-operation and Development (OECD) Stats.

Definition of data variables

The time series are constructed as follows:

$$Y_t^{obs} = LN\left(\frac{(GDP_t)}{GDP\_deflator_t}\right) * 100 \tag{A.3.1}$$

$$G_t^{obs} = LN\left(\frac{(GC_t)}{GC\_deflator_t}\right) * 100 \tag{A.3.2}$$

$$I_t^{obs} = LN\left(\frac{(FCF_t)}{FCF\_deflator_t}\right) * 100 \tag{A.3.3}$$

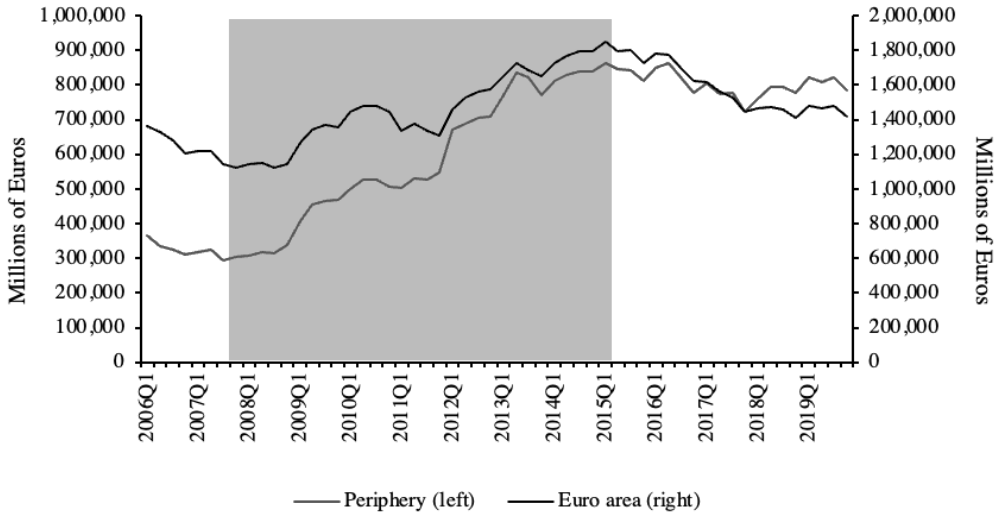
$$NL_t^{obs} = LN\left(\frac{(NL_t)}{GDP\_deflator_t}\right) * 100 \tag{A.3.4}$$

$$SDH_t^{obs} = LN\left(\frac{(SDH_t)}{GDP\_deflator_t}\right) * 100 \tag{A.3.5}$$

A.4 Supporting Figures: Sovereign Debt in European Financial Institutions

In Europe, the financial and sovereign debt crisis (2008-2014) coincided with a strong upsurge of domestic bank's sovereign exposures. Figure A.1 shows the Holdings of debt securities issued by the General Government reported by Credit Institutions in the Euro Area. As shown in the figure, the European banks increased their debt holdings in their balance sheets, particularly the periphery countries.

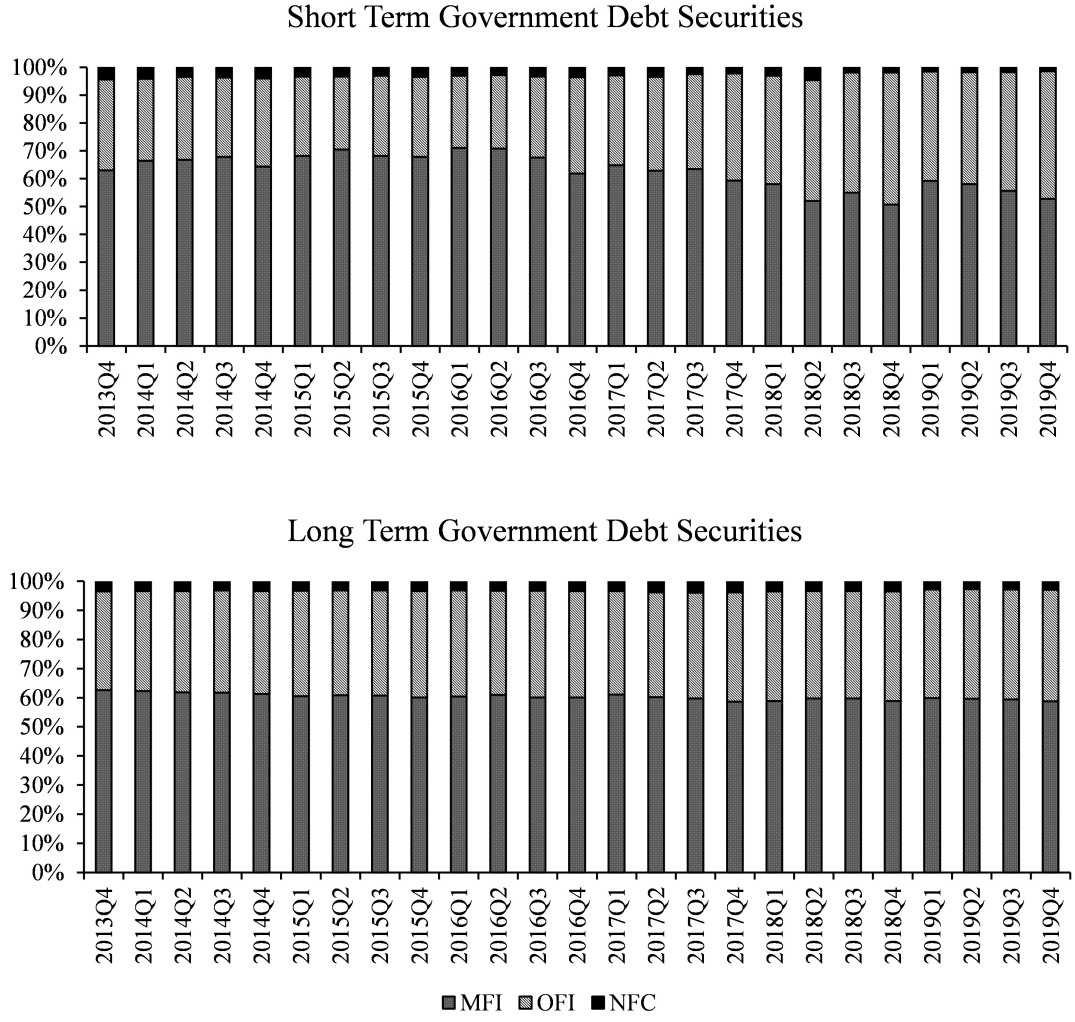
Figure A.1 Holdings of debt securities issued by Euro Area General Government reported by credit institutions



Euro area outstanding amounts at the end of the period reported by credit institutions. Units: Millions of Euros. Source: Statistical Data Warehouse - Balance Sheet Items (BSI) database. Periphery countries are: Greece, Ireland, Italy, Portugal and Spain. The Euro Area includes the 19 member states (changing composition).

To this day, banks in the Euro area still concentrate large amounts of this government debt in its balance sheets. Figure A.2 shows the share of debt securities issued by the general government of European Area held by Financial and Non-Financial Institutions. The financial sector is decomposed into Monetary Financial Institutions (MFI) and Other Financial Institutions (OFI). As shown, most of the government debt lies in the hands of the financial sector, where the percentage exceeds 95%. Besides, MFI account for 58% of sovereign holdings for short-term debt (under 1 year) while for long-term debt (over 1 year) it amounts 37%. This in turn makes banks highly vulnerable to changes in fiscal policy when it is carried out through borrowing.

Figure A.2 Debt Securities Issued by General Government of European Countries

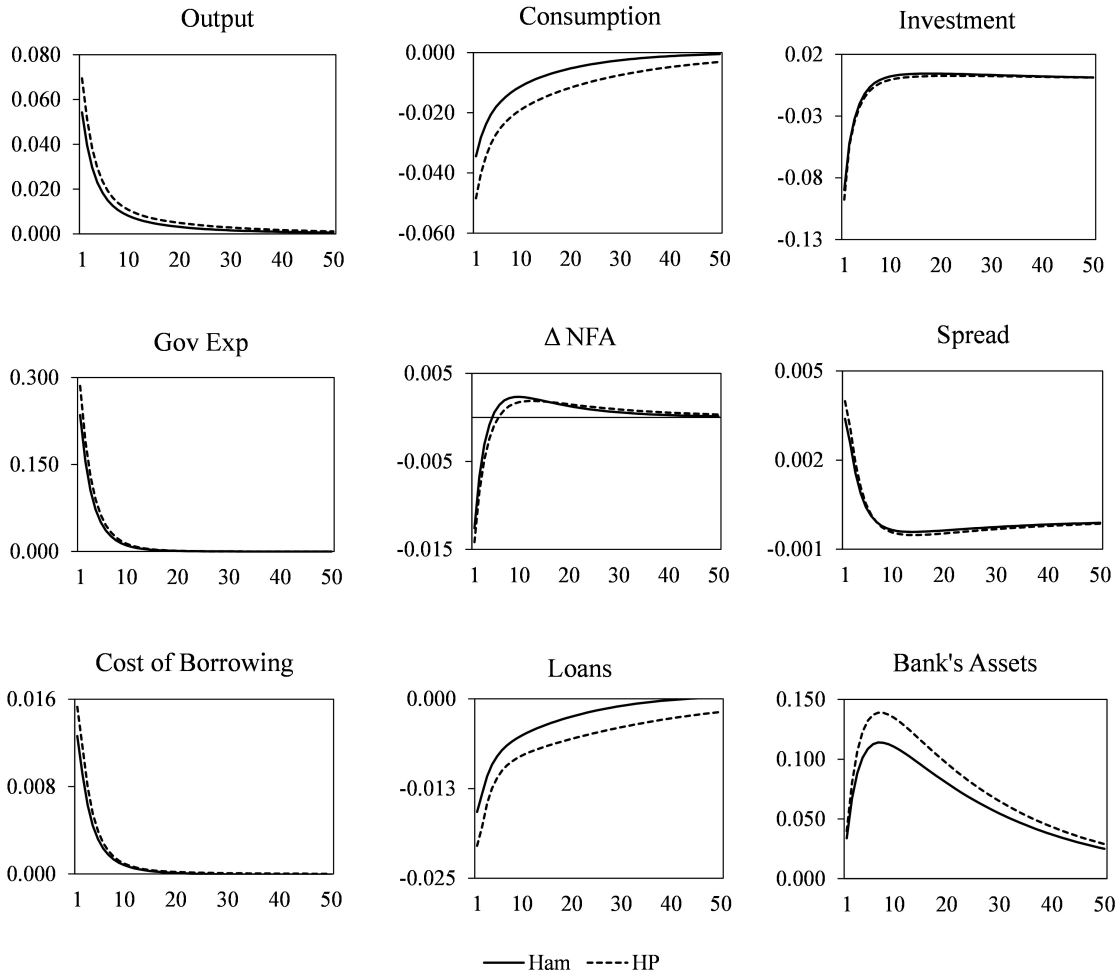


Share of debt securities issued by the General Government in Euro Area. Financial Sector comprises Monetary Financial Institutions (MFI) and Other Financial Institutions (OFI). The latter includes corporations engaged in financial leasing, financial vehicle corporations created to be holders of securitised assets, financial holding corporations, dealers in securities and derivatives, venture capital corporations and development capital companies. The countries included are: Germany, Finland, France, Netherlands, Greece, Ireland, Italy, Portugal and Spain. Source: Eurosystem-Securities Holdings Statistics by European Central Bank. Series available from 2013Q4.

A.5 Filtering Sensitivity

Because the posterior distribution of the structural parameters is sensitive to the choice of trend removal/cycle extraction, the chosen method will affect the analysis. Figure A.3 shows how the results change with a different method for detrending the data. We compare results using Hamilton filter, which is the baseline choice, with one-sided HP filter. The reason for choosing the one-sided HP filter instead of a normal HP filtering comes from the fact that the use of an HP filter takes the form of a backward-looking state space form which is not consistent with the model solution where agents have information available up to period t. Given the data is quarterly, the smoothing parameter is set equal to 1600.

Figure A.3 Effects of different extraction methods



Responses to a 1 S.D. government spending shock on selected variables. Impulse response functions obtained at posterior means computed from estimation. Vertical axis is in percentage deviations from steady state and horizontal axis is measured in quarters.

A.6 The Ricardian equivalence: a special case

The Ricardian Equivalence (RE) first proposed by David Ricardo and later supported by Barro's work in 1974 postulates that the level of government debt is *irrelevant*. By "irrelevant," Ricardian equivalence suggests that tax-financed policy has the same *equilibrium dynamics* as the debt-financed policy. [3] The fact that this theory considers debt levels to be *irrelevant* to explain equilibrium makes the exercise itself interesting to later understand how this equivalence is broken, generating differentiated effects. One may wonder if the Ricardian Equivalence holds in the real world, and the answer is most likely not.[4] The Ricardian Equivalence only holds under certain assumptions.[5] Nonetheless, the intuition derived from the Ricardian Equivalence is valuable for understanding fiscal policy, in particular when the objective of this work lies in explaining *sovereign debt relevance* in the transmission mechanisms of fiscal policy to real activity.

According to Ricardian Equivalence, the effects of fiscal policy do not depend on the way in which government expenditure is financed. This section shows how financial intimidation of sovereign debt securities generate a mechanism for a debt-financed government expansion to produce differentiated effects on macroeconomic real activity versus a tax-financed fiscal expansion. The analysis focuses on the effects of an exogenous shock that increases government spending under two different financing schemes: (i) tax-financed and (ii) debt-financed. The model allows us to consider the Ricardian Equivalence exercise as a special case embedded in the model when ϕ takes the value of 2. It is easy to show that when $\phi = 2$ it is possible to compare a model without debt such that $G = T$, with one that allows debt and

[3] Regardless of the increase in Government spending being financed with the tax/debt mix, households would react as if the government balances its budget every period, or in other words, the household only cares about the present discounted value of its tax obligations, but because present discounted value (PDV) of taxes equals the PDV of government spending, the time path is irrelevant.

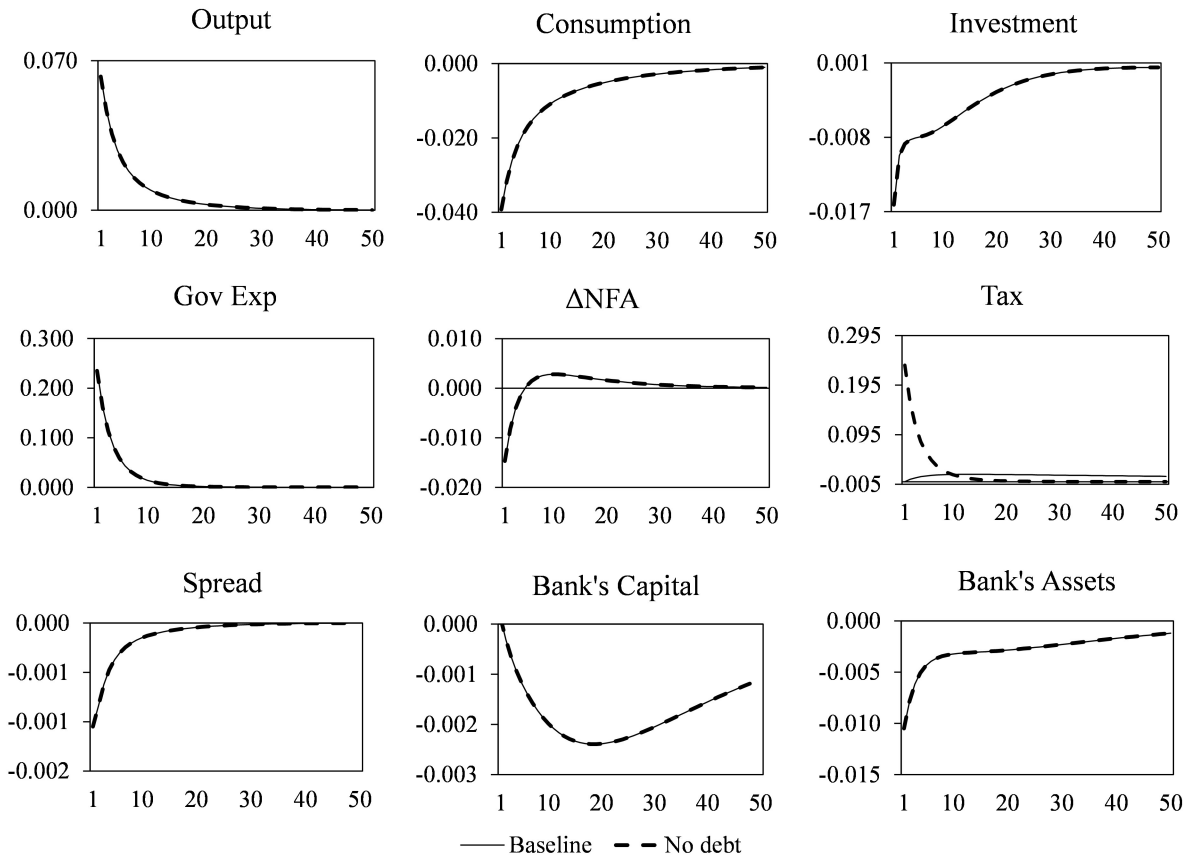
[4] This theory has led to extensive research on testing the predictions of the Ricardian Equivalence. At the empirical level, some papers find evidence that the predictions of the Ricardian holds (see eg. Mosikari and Eita (2017); Marzouk and Oukhallou 2017; Haug 2019) while others find mixed evidence (see eg. Panjer et al 2019; Eichler and Pyun 2017; Nickel and Vansteenkiste (2008)) or no evidence at all (see Adji and Alm (2016)). However, this literature does not test the different fiscal policy financing schemes.

[5] To establish the equivalence of taxes and deficits, the following assumptions must hold: "(1) successive generations are linked by altruistically motivated transfers; (2) capital markets either are perfect, or fail in specific ways; (3) the postponement of taxes does not redistribute resources within generations; (4) taxes are nondistortionary; (5) the use of deficits cannot create value (that is, through bubbles); (6) consumers are rational and farsighted; and (7) the availability of deficit financing as a fiscal instrument does not alter the political process." See Douglas Bernheim (1987) for an extensive discussion.

where taxes react to pay interest on outstanding debt as established in section 2.3.4.

In aims of showing how the sovereign exposures of financial sector lead to a differentiated effects in the financing of the government expenditure, first an exercise is presented in which the banking sector *does not absorb government debt*, showing with the model that in the absence of a banking sector that absorbs sovereign debt, the Ricardian Equivalence holds.

Figure A.4 Ricardian Equivalence



Responses to a 1 S.D. government spending shock. Impulse response functions obtained at posterior means computed from estimation. Vertical axis is in percentage deviations from steady state and horizontal axis is measured in quarters. A debt-financed government expenditure (solid line) follows the government budget constraint defined in section 2.3.4, whereas a tax-financed fiscal policy (dashed line) assumes no debt is modelled in the economy such that the present discounted value of expenditure is that of taxes. When the financial sector does not hold sovereign debt, the *equilibrium dynamics* do not change, confirming the predictions by the Ricardian Equivalence.

Figure A.4 illustrates a government expenditure shock when the banking sector does not generate the primary bond market. A *debt-financed* government expenditure follows Eq.2.18 whereas a *tax-financed* government expenditure assumes no debt is

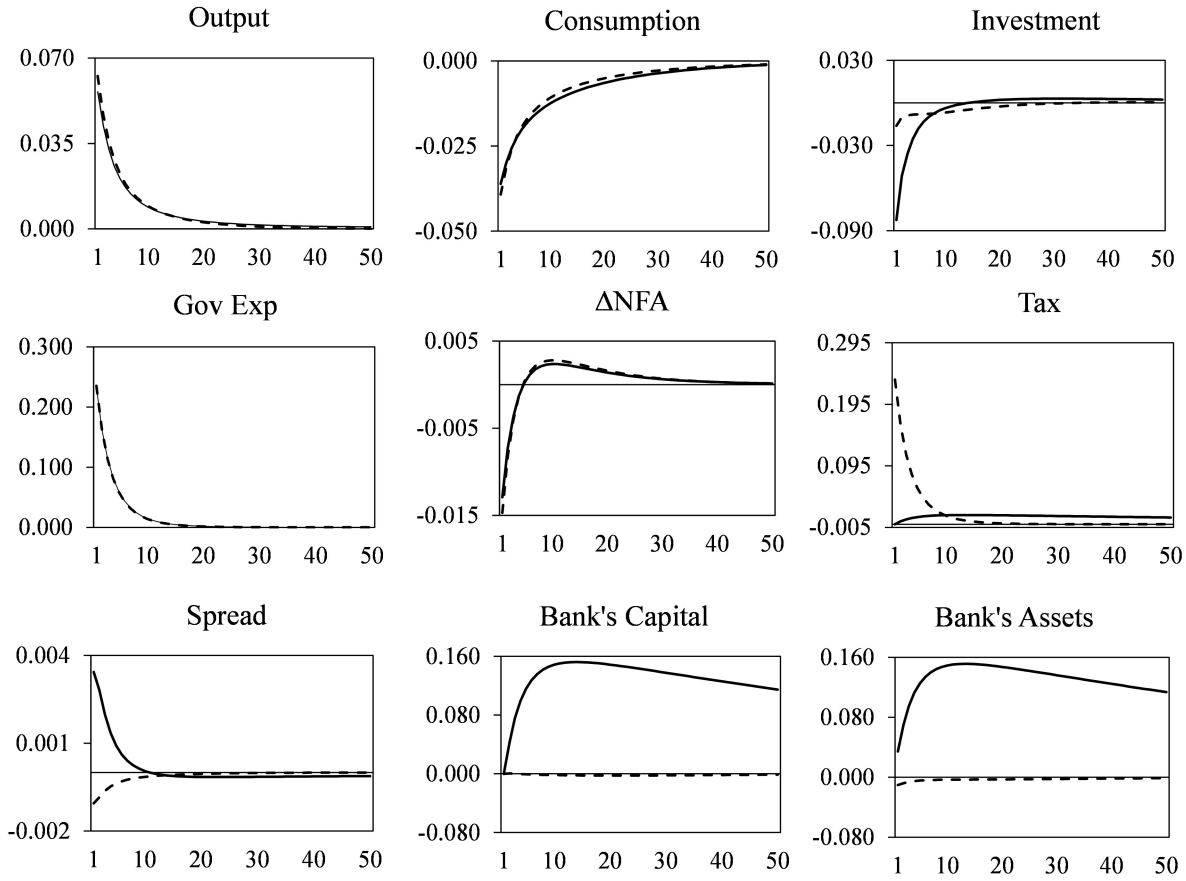
modelled in the economy such that the present discounted value of expenditure G is that of taxes. From Figure A.4 ,it can be shown that the taxes / debt mix does not produce differentiated effects. In fact, the only change observed is in the tax response. When spending is *tax-financed* (dashed line), taxes have the same behaviour as that of the shock to government spending because the present discounted value of G equals that of taxes, $G = T$. On the other hand, when spending is *debt-financed* (solid line), the tax response follows the behaviour of the bond issuance and the speed of adjustment will depend on the value of ϕ. This happens because when the government incurs a deficit, it borrows to finance the difference between the expenses and collected taxes from households. However, the increase in government debt will imply an increase of taxes in future periods such that $T_{t+1} = \phi b_t r_t$.[6] This indicates that as suggested by the RE, if taxes are lump sum, the mix between debt and tax finance is irrelevant for understanding government expenditure dynamics.

The previous figure highlights how to the extent that the banking sector does not absorb the sovereign bonds, the debt/tax mix does not generate differentiated effects, maintaining the Ricardian Equivalence (RE). If debt does not have differentiated effects to a tax-financed scheme, then the aim of proposing a *debt channel* would be irrelevant and limiting the analysis to changes in G_t (without specifying how spending is financed) would suffice. However, as has been observed in Europe and other economies, the banking sector has acted as a relevant bondholder which has had effects on real economic activity.

Figure A.5 shows the effects of the *same shock* to government spending under both financing schemes. In this exercise however, the banking sector is allowed to hold government securities in its balance sheet. Figure A.5 presents the Impulse Responses like those on Figure A.4. The *dashed line* displays the effects of a shock to government spending when it is financed with taxes, while the *solid line* shows the responses on each variable when the expenditure is financed with debt. The main difference in the equilibrium dynamics comes from the way in which the government spending shock affects the banking sector. In the debt financed scenario, the balance sheets of financial institutions respond to the shock abruptly as the debt is absorbed by the banks. For its part, the spread increases since higher assets on the balance sheet imply higher costs for the financial sector, which is reflected in lower investment levels.

[6]Because debt cannot explode given the terminal condition (no debt at the end of time), an increase in government debt will imply an increase in taxes in future periods such that $T_t = \phi b_{t-1} r_{t-1}$, where $\phi > 1$ to have a steady state solution.

Figure A.5 Government Spending Shock when Financial Sector Holds Sovereign Debt



Responses to a 1 S.D. government spending shock. Impulse response functions obtained at posterior means computed from estimation. Vertical axis is in percentage deviations from steady state and horizontal axis is measured in quarters. The dashed line displays the effects under tax financed scheme whirls the solid line shows the effects under debt financed scheme.

As shown in the Figure A.5, with the introduction of a banking sector that generates a primary market for domestic bonds, the tax/debt mix pose differentiated equilibrium effects and breaks the Ricardian Equivalence. This in turn suggests the way in which Government expenditure (G) is financed matters and that debt has a relevant channel to propagate the effects of fiscal policy into real activity.

Chapter 3

Sovereign Debt Exposure in Europe: A Bayesian Panel-VAR analysis of Macro-Financial Linkages

3.1 Introduction

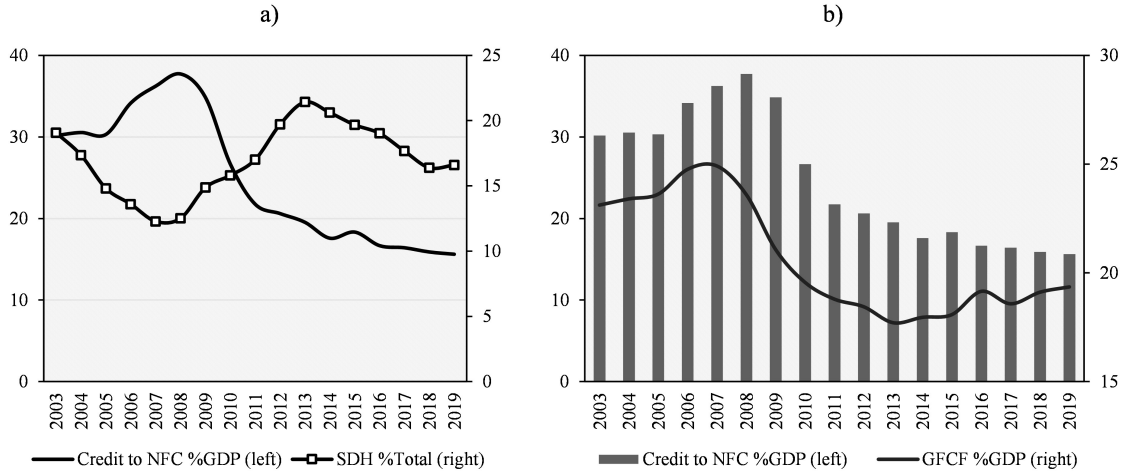
Macro-financial linkages refer to the interactions between the real economy and the financial sector. In particular, the connection between the two causes shocks from the real economy to be propagated through the financial markets, amplifying the effects in the economy. These linkages emerge from the dependence of borrowing agents on bank credit, and this holds especially true in Europe, where bank loans represent around 50% of the external financing for non-financial corporations (See e.g. Altavilla et al (2019) and Reichlin (2014)). Thus, banks play a central role in the propagation and amplification of economic fluctuations, especially when the ability to provide credit is hindered by changes in macroeconomic conditions. As such, the presence of these macro-financial linkages suggests that macroeconomic policies that affect the financial sector can lead to credit market disruptions to be transmitted to the real economy.

In this chapter, the focus is to understand how government debt affects the real economy through the banking sector by impacting the supply of credit to European firms. The channel here examined focuses on the supply side of credit the market, were the emphasis is placed on the role of banks acting as credit providers. Thus, debt financed fiscal policy, via its direct effects on the balance sheets of financial

institutions, can limit the access to financial services to other borrowers. Furthermore, the dependence of firms on financial institutions for accessing credit has implications for the real economy by affecting their investment decisions.

By way of illustration, Panel a) in Figure 3.1 shows how bank credit granted to enterprises shrank, while the holding of sovereign bonds by domestic banks increased in European Monetary economies. Besides, the fall in credit to non-financial corporations was also accompanied by a contraction in investment (panel b).

Figure 3.1 Credit, Debt Holdings and investment



Source: Loans to Non-MFI Debt are obtained from European Central Bank's Statistical Data warehouse, Sovereign debt holdings are retrieved from Merler and Pisani-Ferry (2012) and Gross fixed capital formation is obtained from the OECD. Period covers 2003-2019 on quarterly basis. countries include: France, Germany, Greece, Ireland, Italy and Spain.

Large strands of the literature have documented that in the years that followed the financial and debt crisis, the contagion channels between banks and sovereigns intensified in Europe. A strand of the literature has documented these macro-financial linkages by exploiting granular microdata at bank and firm level. For example, De Marco (2019) finds that in Europe, credit volumes and interest rates on loans were affected by bank exposures to sovereign debt and that small and young firms were mainly affected. Blundell-Wignall and Slovik (2010) carry out a study considering 91 banks in EU countries, where they document that most of the sovereign debt is held on the banking books of banks and that the period over which domestic banks increased their holdings of local sovereign debt was also characterized by contraction in the issuance of new bank credit in Europe. Acharya et al (2018) find

that banks' sovereign holdings reduced the probability of firms getting access to loans in particular by poor capitalized banks. This in turn having an effect on investment, employment, and sales growth these firms. In the same line, Altavilla et al (2016) find that bank exposures had an effect on lending to domestic companies in the European economy using data for 226 eurozone banks from 2007 to 2015. They find that bank exposures to sovereign debt amplified the impact of sovereign stress on banks through a credit contraction to domestic firms and credit contraction by banks from stressed countries to other economies. Popov and Van Horen (2015) argue that during the European debt crisis, credit contraction by European banks with bond holdings of periphery economies was greater than that of banks with no debt holdings of those countries. Specifically, they find that large holdings of periphery sovereign debt decreased lending by 21.3% relative to banks with less holdings of periphery debt. Bottero et al (2020) find that in the context of the European debt crisis, the shock to the banks' debt holdings in Italy was transmitted to Italian firms through a credit contraction. Italian financial institutions with larger exposure to government bonds tightened their credit supply affecting mainly small and medium enterprises' investment and employment decisions. Along the same lines, Bofondi et al (2018) finds that Italian banks tightened credit during European debt crisis sovereign by reducing credit supply and increasing rates. Cingano et al (2016) also studies the case of Italy at the firm level and finds that if credit was not reduced following the financial crisis, investment expenditure would have been higher at the firm level. Another study based on data for Italian banks was made by Albertazzi et al(2014) who find that sovereign spreads significantly affect the cost of borrowing for firms and households and causes a reduction in loan growth; in particular, they find that a 1% increase in the sovereign spread decreases annual lending growth by 1 percentage point for households and 0.7 for firms. Grandi et al (2020) do it for the French case for more than 60.000 firms and found that banks most exposed to risky sovereign debt reduced lending more than those less exposed to government bonds and also found firms having to face higher loan rates for accessing credit.

The literature on macro-financial linkages is extensive and still increasing to better understand the potential contagion between sovereigns and banks to the real economy. Although various mechanisms exist through which macro-financial linkages occur, this chapter seeks to empirically test the balance sheet recomposition that occurs when banks are hit by shocks that directly affect their balance sheets. Particularly, we study the *balance sheet channel of fiscal policy* by focusing on the supply side dynamics of the market. The mechanism follows that described in Chapter 2, where sovereign debt exposure in domestic banks led to contractions in credit and

investment. The intuition that goes behind this mechanism is that when the financial intermediaries cannot raise additional resources to acquire government debt, these purchases are made at the expense of other assets such as corporate lending, further leading to lower investment. However, debt shocks generate asymmetric responses on the domestic real economy and the DSGE model is silent when accounting for multi-country heterogeneity derived from structural characteristics of the European economies.

In the European Union, even though monetary policy may be the same within the monetary area, fiscal policy has idiosyncratic dynamics in each country and therefore the study of fiscal policy and its effects on each country becomes relevant to understand the cross-country heterogeneities. Hence, the implementation of fiscal policies in each of the economies that comprise the EMU, leads to the idiosyncratic components becoming more relevant to explain the effects on real economic activity. In particular, where each country is subject to different institutional frameworks for its fiscal policy, the analysis of the effects of public indebtedness in each country becomes relevant to understand the underlying macro-financial linkages present within the monetary union.

This chapter answers the question: How does credit and investment react to debt shocks in the European Monetary Union? and analyses the asymmetric effects on credit to enterprises and investment across countries. To analyse the impact of debt-financed fiscal policy, this work estimates a Bayesian Panel Vector Autoregressors (PVAR) model where real and financial variables modelled for the largest 6 economies in the European Monetary Union (EMU-6), that together account for 80 percent of the GDP of the 19 countries that comprise the union. Panel VARs serve a useful tool when analyzing the transmission of idiosyncratic shocks across units and time. They follow a similar logic to that of typical VARs but allow for the inclusion of a cross-sectional dimension, making them a more powerful tool to account for heterogeneities across the economic systems under study. The use of Panel VARs allow to model both, the common effects present across European MU countries while allowing for individual behaviours of countries or groups of countries to be analyzed. Moreover, relying on a panel estimation reduces biases that may arise from aggregating groups into a single time series. Additionally, as the use of a panel contains more information and more variability in the data, it presents a more efficient estimate compared to a unit time series or cross-sectional estimates.

The contribution of this document is to expand with empirical evidence the theoretical model described in chapter 2 to understand the macro-financial linkages that arise with changes in public debt policies. Because VARs are reduced form models, identification restrictions motivated by economic theory are needed to better understand policy implications. The theoretical model provides a logic for understanding the transmission mechanism of debt shocks on credit to enterprises and investment through financial intermediation. However, it is also true that DSGE models still face difficulties in accounting for heterogeneity across different countries and asymmetries in the responses of similar shocks that are not explicitly modelled. Thus, this chapter links panel VARs to the DSGE model described in the previous chapter to explain how public debt has effects on the real economy and it does so by extending the analysis to consider the heterogeneity that exists across the largest EMU countries. Moreover, a second contribution of this chapter is that it broadens the existing literature assessing the effects of public debt shocks on the supply side of credit to understand the role played by financial institutions in shaping macroeconomic outcomes through its effects on investment. The main differences of this work compared with the existing literature lie in that no other work has tried to analyse the effects debt shocks on bank's balance sheet recomposition to explain the impact on credit and investment for European economies to quantify the balance sheet channel of fiscal policy.

The rest of this chapter is structured as follows: Section 3.2 describes the empirical framework used for this work; Section 3.3 presents the data used in the model estimation and discusses the identification employed; Section 3.4 presents the results under different specifications and Section 3.5 concludes.

3.2 Empirical Framework

Following seminal work by Canova and Pappa (2007), when the time dimension (T) and cross sectional dimension (N) are of moderate size and dynamic heterogeneity is alleged, partial pooling allows to better the quality of the estimates of the coefficients in the model. This work relies on a standard format which leads to partial pooling by a random coefficient Panel VAR (PVAR) model with hierarchical priors, allowing for cross-subsectional heterogeneity. The PVAR model includes N countries, with n endogenous variables, and p lags over T periods. The model for each i country is then defined as:

$$y_{it} = \sum_{k=1}^{p} A_i^k y_{i,t-k} + \epsilon_{it} \quad ; \quad \epsilon_{it} \sim \mathcal{N}(0, \Sigma_i) \tag{3.2.1}$$

Under this estimator the matrix of dynamic coefficients A_i^k is assumed to be country specific and $\Sigma_{ii,t} = \mathbf{E}(\epsilon_{it}\epsilon'_{is}) = 0$ for $i \neq j$ and takes the form of Σ_i diagonal elements of the matrix ($\Sigma = I_n \otimes \Sigma_i$). This imposes country specific heterogeneity in the impact coefficients and residuals in the panel which should be assumed if the purpose is to allow each country to respond differently to debt shocks. In compact form and stacked over T periods, equation 3.2.1 is defined as:

$$Y_i = \bar{X}_i \beta_i + \epsilon_i \tag{3.2.2}$$

where Y_i is a vector of order nTx1, the matrix $\bar{X}_i$ is of order nTx $n(np)$ capturing the lagged coefficients of the k^{th} lags of endogenous variables. The vector β_i is of order $n(np)$x1 containing the transpose of row j of the endogenous coefficients $A_i^{k(j)}$, and the vector of residuals ϵ_i is of order nTx1. The random effects model states that for each country i, the vector β_i is such that:

$$\beta_i = b + b_i \tag{3.2.3}$$

where b is the vector of order npx1 and b_i is treated as random for the country i with mean zero and a constant variance. This thus implies :

$$\beta_i \sim \mathcal{N}(b, \Sigma_b) \tag{3.2.4}$$

where 3.2.4 indicates that the PVAR coefficients differ across countries. By considering β_i as an exchangeable prior to derive the posterior distribution, Bayesian techniques can be employed to identify the random coefficient in 3.2.4 utilizing either the Zellner and Hong (1989) or the hierarchical prior approach proposed by Jarocinski (2010). The methodology employed in this work adopts the latter, following the framework established by Jarocinski (2010).The choice of identification lies in that the hierarchical prior approach allows to estimate not only β_i, but the rest of the parameters assumed to be known under the Zellner and Hong (1992) approach. This implies that under a hierarchical approach, $\Sigma_i = [\Sigma_1, \Sigma_2, \ldots, \Sigma_N]$ and the common mean and covariance coefficients (b and Σ_b) are also estimated as they are treated as random variables. This allows for a richer specification of the model because although β_i (for i = 1,...,N) is still estimated in the model, the means and covariance coefficients are obtained as the posterior median for the specified hyperparameters. The complete posterior distribution for the model $\pi(\beta, b, \Sigma_b, \Sigma \mid y)$ is proportional

to:

$$\pi(\beta, b, \Sigma_b, \Sigma \mid y) \propto \pi(y \mid \beta, \Sigma)\pi(\beta \mid b, \Sigma_b)\pi(b)\pi(\Sigma_b)\pi(\Sigma) \tag{3.2.5}$$

where the first term is the likelihood function of the data, the second is the conditional prior distribution for β on the two hyperparameter, b and Σ_b, for which hyperpriors are defined as $\pi(b)$ $\pi(\Sigma_b)$, respectively. The final term is the prior of Σ for the Σ_i matrix.

The parameters and hyperparameters follow standard values from macroeconomic literature and Gibbs sampler for the hierarchical prior allow to derive the posterior distribution for the model. In particular, the selected form for b and Σ are diffuse priors, allowing for the posterior distributions to rely less on the prior information and capture the underlying data structure. For Σ_b which is the full covariance matrix defined as $\Sigma_b = (\lambda_1 \otimes I_q)\ \Omega_b$, the specified $\lambda_1 \sim\ \mathcal{IG}(s_0/2, v_0/2)$ follows an Inverse Gamma distribution with shape $s_0/2$ and scale $v_0/2$. The priors for s_0 and v_0 are set to be weakly informative as standard in the literature by using values of 0.001 for both, as suggested by Jarocinski (2010) and Gelman (2006). This allows to obtain a posterior of structural differences in the responses to debt shocks which endogenously weights country specific and average cross sectional information.[1] The covariance matrix Ω_b has an off-diagonal elements are zeros as no covariance is assumed between terms in β_i. The variance of parameters in β_i that relate endogenous variables to their own lags is given by: $\sigma^2_{aii} = \left(\frac{1}{l^{\lambda_3}}\right)^2$, where l is the lag considered by the coefficient and λ_3 is the scaling parameter that controls the speed at which coefficients for lags greater than 1 converge to zero. For the cross-lag coefficients the variance is given by $\sigma^2_{aij} = \left(\frac{\sigma_i^2}{\sigma_j^2}\right)\left(\frac{\lambda_2}{l^{\lambda_3}}\right)^2$, where λ_2 represents a cross-variable variance parameter. The way to obtain the scaling parameters controlling for the relative coefficient sizes on variables i and j ($\sigma_i^2 \mid \sigma_j^2$), is by fitting the autoregressive models by OLS for all n endogenous variables in the model and obtaining the st. deviations. Since the variance is assumed common across countries, the autoregressive models are calculated by pooling the data of all the units for each endogenous variable. The cross-variable weighting parameter (λ_2) is set to 0.5 to give more weighting to the i^{th} variable lags than lags of other variables, and the lag decaying parameter (λ_3) is set to 1 as suggested by Dieppe et al (2016). The posterior distribution of the parameters rely on Gibbs sampler numerical methods.

[1] Its worth noting that if $\lambda_1 = 0$, then β_i take identical values of b (pooled estimates). However when $\lambda_1 \to \infty$ coefficients for each country collapse into their individual OLS estimates by country. To allow for information sharing across countries, intermediate values of λ_1 that can provide a good balance between pooled and individual estimates can be achieved by choosing an inverse Gamma distribution for λ_1 with weakly informative priors standard in literature (see Canova and Ciccarelli (2013)).

3.3 Data

The dataset consists of quarterly macroeconomic and financial variables that are available from 2003q1 to 2019q4.[2] The model focuses on six of the largest countries in the European Monetary Union (EMU-6): Germany, France, Greece, Ireland, Italy, and Spain. These countries were selected based on the availability of data for a balanced panel throughout the period of study.[3]The real variables included are debt and gross fixed capital formation (both as a share of GDP) and the financial variables include Sovereign debt holdings by domestic banking sector, loans to Non-Financial Corporations (NFC), and cost of borrowing for NFC.

The General Public Sector Debt as a share of GDP is derived from the Public Sector Debt database from the Organisation for Economic Co-operation and Development (OECD) which includes quarterly information on for the period of analysis (2003Q1-2019Q4). For the historical country-level Sovereign Debt Holdings (SDH) by the banking sector, the data is retrieved from Merler and Pisani-Ferry (2012).[4] This dataset on sovereign bond holdings collects data of the specific country's national authorities for 10 European countries (Belgium, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal, Spain) the UK and the USA. The data is expressed as a share of total debt issued by domestic authorities and is broken down by holding sector (resident and non-resident banks) to each specific country on quarterly frequency. This dataset is useful as it compiles publicly available data provided by national authorities that generally differs across countries, allowing for a more comparable cross-country analysis.

The cost-of-borrowing indicator is estimated by the ECB and is publicly available in their website based on interest rate statistics of monetary financial institutions. This variable allows for cross-country comparability and accurately measures the borrowing costs for firms in European countries. This chapter uses the cost-of-

[2]The time set is consistent with the introduction of the single currency in the European Monetary Union and excludes the period characterized by the corona-virus (COVID-19) pandemic as it presents a different kind of shock in the economy.

[3]The selection of countries for this chapter was based on the availability of data for sovereign debt holdings by Merler and Pisani-Ferry (2012), given the implication of domestic banks' exposure to explain the mechanisms through which credit conditions are affected. From the countries in their dataset, only those with available data for the period 2003-2019 were considered for a balanced panel estimation. For Portugal, data on domestic banks' sovereign exposure are available from 2008, while for the Netherlands, annual data on sovereign debt exposure would need to be interpolated to capture the period 2003-2007, potentially adding noise to the series. Including these countries considerably reduces the sample size for the estimation. For its part, Belgium only has availability on an annual basis on sovereign debt exposure and lacks quarterly data.

[4]The remaining percentage is held by Central Banks, Other Public Institutions, Other Residents that are not the banking sector.

borrowing indicator for NFC which is derived as a weighted-average of short-term and long-term loan rates to NFC and that takes into account the financial structure of businesses.

The volume of bank loans to NFC is obtained from Statistical data warehouse from European Central Bank and it covers the period 2003-2019. The variable includes the total outstanding amounts of business volumes of loans that are classified as new agreements between a non-financial corporation and a bank. Existing loan contracts that are extended and no renegotiation of the terms and conditions takes place, are not considered.[5] In this regard, the loan volumes include only new financial contracts or renegotiated contracts. Data is provided on a monthly basis and aggregated on a quarterly basis by adding the monthly flows. This dataset considers the loans to new businesses both those up to and over 1 million Euro and is divided by the GDP of the respective country. Finally, Gross fixed capital formation as a percentage of gross domestic product is obtained from the Organisation for Economic Co-operation and Development (OECD). The data for gross fixed capital formation and Gross Domestic product are obtained in current prices and seasonally adjusted on a quarterly frequency.

The fact that each variable comes from the same source for all the N units at the cross-sectional level, helps reduce measurement errors introduced in the estimation of PVAR models that encompass different sources.[6]

3.3.1 Data discussion and Identification strategy

To emphasize the effects on the *supply side of credit*, balance sheets elements are included in this work. It should be noted that in order to try to identify the effects of a debt shock on the supply-side of credit, there are different factors to consider, which are described next.

Debt, investment and credit to NFC are measured as a proportion of GDP, which controls for changes in economic activity on these variables. Considering credit and investment as a proportion of GDP allows to consider how, following the financial crisis, the countries in the region experienced sharp falls in economic activity that consequently lead to a lower demand for credit and lower investment. In particular,

[5]The relevance of using this variable seeks to reflect the fact that since amounts are outstanding at the end of the period, existing loans could have been preserved, reflecting higher volumes at the end of the period. However, the granting of new credit contracts seeks to reflect the fact that scenarios such as the financial and debt crisis had implications for credit supply and demand, reflecting to a better extent the liquidity of the banking sector.

[6]Summary statistics of the variables used can be found in Appendix B.

after the financial crisis, it can be argued that demand and supply for credit fell. On the *demand side*, the economic contraction led by itself to a lower demand for credit by companies to carry out the investment. Moreover, on the *supply side* the lower economic activity has implications based on the borrower's capacity for loan repayment. Although disentangling the effects arising from demand and supply in the credit markets presents a problem in itself since supply and demand are not directly observed, controlling credit and investment variables by GDP allows these factors to be considered when there are periods of low economic activity on both sides of the credit market, so that the focus remains on the balance sheet channel that is explored in this chapter.[7]

For its part, the bank holdings of domestic sovereign debt are retrieved from from Merler and Pisani-Ferry (2012). The fact that during the debt crisis, the yields on risky periphery sovereign bonds reduced their market value for banking institutions holdings, considering this variable measured as share of total debt issuance by domestic governments allows to mitigate possible market valuation changes in the balance sheets of financial institutions. Finally, the cost of borrowing presents the cost of credit for NFC. In order to be consistent with Chapter 2, the relevant rate for companies is the real interest rate, so the cost of borrowing, which is measured as a rate weighted by the percentage of short- and long-term credits by financial institutions towards NFCs, is defined as a real rate by removing inflation ($i^q - \pi$) captured by the Harmonised Index of Consumer Prices (HICP) for each country. This also allows considering changes in (conventional) monetary policy on its direct effect on the cost of borrowing, while also allowing to consider the effects that monetary policy has on inflation. This is relevant since the period of study covers the post-crisis where the European Central Bank responded by lowering monetary policy interest rates and remained in the effective lower bound since 2015. Furthermore, the credit easing packages and other non conventional monetary measures implemented since 2015 also had effects on loan rates from financial institutions. This chapter does not model monetary policy explicitly. However, most of the impact of the monetary policy rate is indirectly embedded in the cost of borrowing for financial institutions, and the fact that all economies under the study are subject to the same monetary shocks allows to focus on disentangling the effects of fiscal shocks on the credit channel.

[7]The identification on the responses are based on a theoretical framework that gives a role to financial frictions present on the demand side (entrepreneurs) subject to collateral constraints and the supply side (the financial sector). In order to control for frictions in the balance sheets of borrowers, apart from considering loans as a share of GDP to account for changes in economic activity, the loans considered reflects only those under new credit standards, where credit standards reflect the borrower characteristics like balance sheet conditions.

Identification strategy

To analyse the effects of sovereign debt on financial institutions' balance sheets and investment, the variables included in Equation 3.2.1 are:

$$y_{it} = [debt_{it}, sdh_{it}, loans_{it}^{NFC}, cob_{it}^{NFC}, I_{it}]' \tag{3.3.1}$$

where $debt_{it}$ represents the debt to GDP ratio for country i, sdh_{it} accounts for sovereign debt holdings by the domestic banking sector for country i, $loans_{it}^{NFC}$ measure the credit to NFC in each country i, cob_{it}^{NFC} captures the cost of borrowing for NFC and I_{it} is the gross fixed capital formation in the country i.

As identification is required for meaningful interpretation of structural impulse response functions (IRFs), this work relies on a Choleski recursive identification strategy for analysing the effects of debt shocks on real and financial variables in the European countries.[8] The ordering of the variables is established in Equation 3.3.1 which implies: (i) debt does not react contemporaneously to shocks to other variables in the system, (ii) SDH are contemporaneously affected by debt shocks by acting as the primary market for government debt (iii) loans to NFC reacts contemporaneously to debt shocks and sovereign debt holdings given that the restructuring of the asset-side of the balance sheets of financial institutions has repercussions on credit levels, however it does not respond contemporaneously to changes in credit or investment rates. This ordering then imposes an identification of the supply side of credit to be consistent with the DSGE model presented in Chapter 2. (iv) The cost of borrowing responds as a consequence of the public debt shocks that lead to the restructuring of the banks' balance sheets. The changes in the supply of credit would then lead to lending rates responding contemporaneously to shocks, and finally (v) investment doesn't impact contemporaneously the rest of the variables. Under the specified ordering this imposes zero restrictions on the upped diagonal coefficients of the contemporaneous relationships between endogenous variables based on theoretical ground.

3.4 The Effects of Debt Shocks in EMU

As a starting point for the analysis, the first subsection explores the transmission mechanism of debt shocks by relying on the pooled estimator, to understand the

[8] A discussion on the choice of identification and alternative identification strategies can be found in Appendix B.1.

effects of the debt shocks for the European countries as a whole. Then the second subsection allows for block heterogeneity to understand the debt shock implications for core and stressed periphery countries in the balance sheets of financial institutions and investment. A third exercise analyses the same effects when cross subsectional heterogeneities are introduced in the estimation of each country-level VAR. This implies that dynamic coefficients and residuals are allowed to be country specific, to analyse country heterogeneities. The PVAR model relies on Bayesian techniques to estimate the model parameters and produce impulse response functions to analyse the effects of a debt shock on financial (volumes and prices) and real variables. To validate the estimated Bayesian PVAR, all models presented in this section are checked to satisfy the stability condition and no roots lie outside the unit circle.[9] Uncertainty around the parameters and impulse responses are reported under a 68% credible interval.

3.4.1 What is the average effect of a debt shock in the European Monetary Union ?

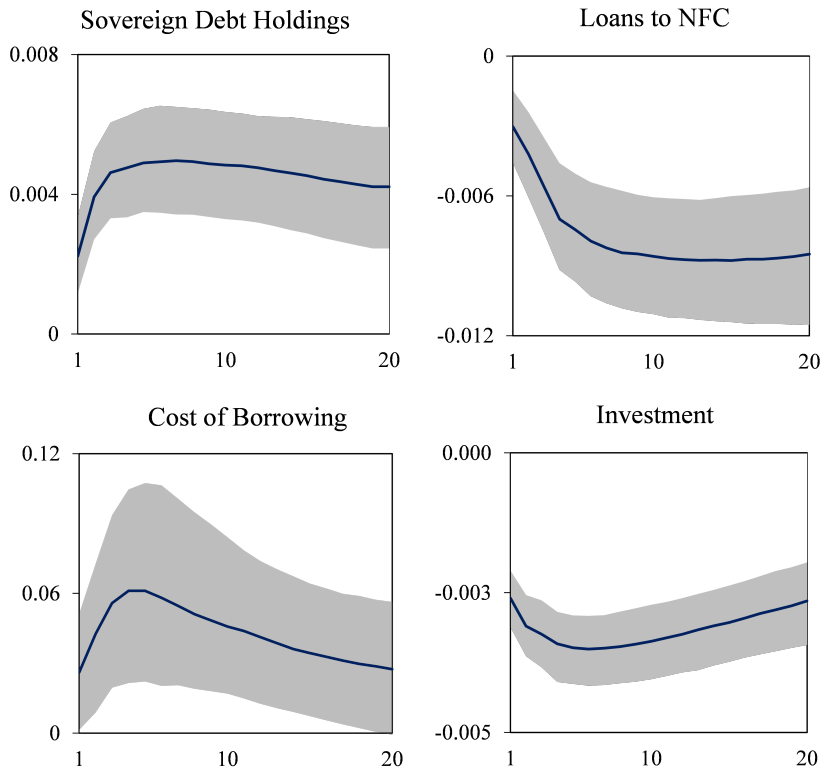
The objective of this chapter is to study how debt shocks have real economic impacts in Europe using a panel of Euro Area countries. The underlying mechanism is aimed at showing how shocks in the debt holdings by financial intermediaries affect the supply of credit and lead to crowding out of investment. To analyse the average effect of a debt shock in the EMU countries, this section relies on a pooled estimator which allows for an overall response to a shock in debt levels in the European economies as a whole. The pooled estimator of the model is obtained by relaxing the properties cross-subsectional heterogeneity where the matrix of dynamic coefficients A_i^k is assumed to be homogeneous across units and $\Sigma_{ii} = \mathbf{E}(\epsilon_i \epsilon_i') = 0$ for $i \neq j$ takes the form of Σ^c diagonal elements of the matrix ($\Sigma_t = I_n \otimes \Sigma^c$). The estimation of the coefficients β and Σ^c are obtained through Bayesian techniques following a normal-Wishart identification strategy.[10]

Figure 3.2 shows the structural impulse responses to a one standard deviation debt shock on the pooled sample of monetary union countries. As observed in Figure 3.2, a debt shock increases SDH by domestic banks in the EMU-6 economies. Likewise, the balance sheet recomposition is shown on the effects on credit levels

[9]The stability condition on the fitted Bayesian PVAR is required to reformulated as a Moving Average representation on which assumptions about the covariance matrix can be imposed.

[10]The prior for β is assumed to be a multivariate normal and the prior for the variance covariance matrix Σ^c is inverse Wisheart, where the residual variance terms for each of the n endogenous variables $(\sigma_1^2, \sigma_2^2, \sigma_3^2, \sigma_4^2, \sigma_5^2)$ are obtained from a pooled sample of the N countries.

Figure 3.2 European MU response to a 1 s.d. Government Debt Shock



Median responses to a one standard deviation shock of government debt under a pooled estimator based on 5,000 iteration runs. The y axis identifies the median responses in percentage points with 68% credible intervals. The horizontal axis indicates time in quarters.

to the private sector when banks purchase domestic sovereign debt. Moreover, the effect on the cost of borrowing responds positively to shocks in the public debt due to restructuring in the balance sheets of the banking sector causing a contraction in credit supply and leading to higher borrowing rates, which are relevant for NFC to incur in investment. The impact on credit supply is measured through both, lower credit volumes and higher cost of borrowing to NFC. As documented by De Marco (2019), the negative response of loan volumes with higher interest rates on loans suggests that the sovereign debt holding shocks had a negative effect on the supply of credit. Finally, investment presents a contraction for the European economies that follows from a debt shock. In the face of a higher cost of borrowing, following the balance sheet restructuring in the financial sector, a debt shock crowds out investment.

What these results suggest is that for the pool of EMU-6 countries a debt shock influences the balance sheet of banks by increasing the debt holdings and displacing credit to NFC. The effects on the borrowing rates are consistent with a credit contraction, which causes firms to reduce investment in response to higher costs to borrow.

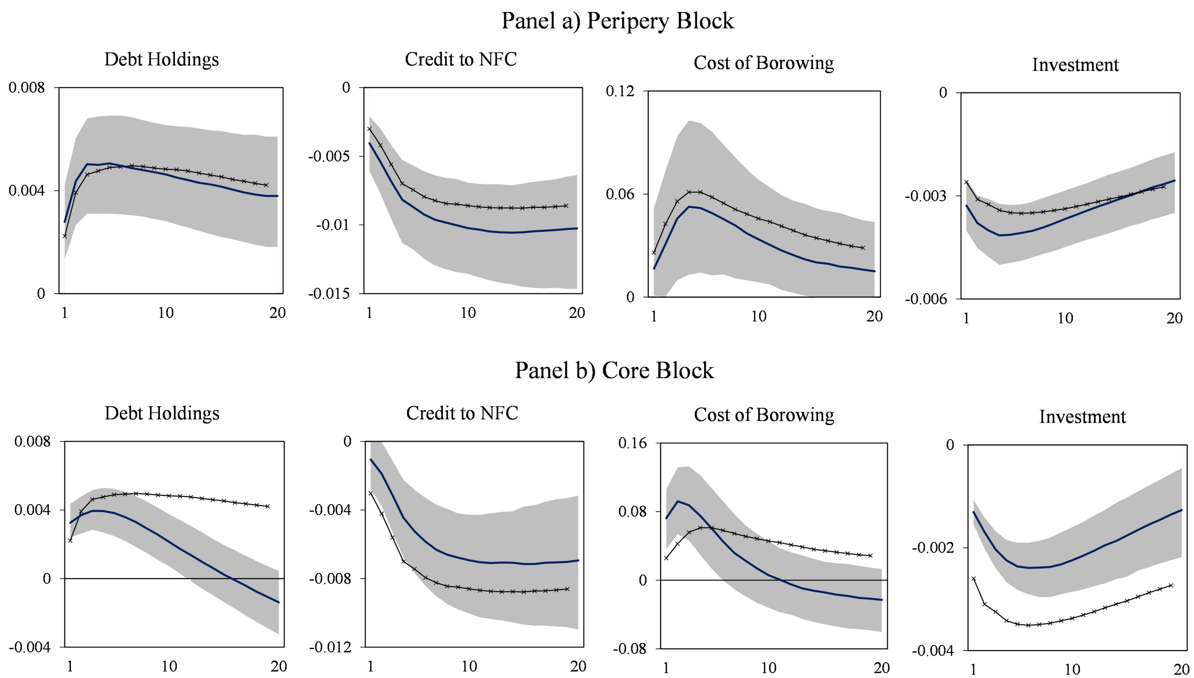
3.4.2 How does credit and investment react to debt shocks in countries subject to higher fiscal/financial stress?

Fiscal policy shocks may generate asymmetric responses on countries with higher public debt levels, especially when banks in those economies are highly exposed to the sovereign debt being issued. The literature suggests that the member states mainly exposed to debt holdings were those in the European periphery with higher debt levels and growing deficits. To study the effects of regional debt shocks, the panel is split into 2 groups: core countries (Group 1) and Periphery Countries (Group 2). Although the group composition is exogenously determined, the split between financial/sovereign stressed European periphery and the core European economies is well established in the literature.[11]

Here the interest lies in examining impulse responses between blocks that may be assumed to have common characteristics reflecting binary heterogeneity (two groups) to examine the extent of cross-block heterogeneity and group convergence. A panel VAR is estimated for core and stressed periphery countries, allowing for slope and contemporaneous impact matrix to be different across blocks, but common within blocks. The assumption for relaxing the cross-subsectional heterogeneity feature of the panel lies in that countries within each group are expected to react in similar ways to structural economic shocks. Under a pooled estimator, restrictions of this type obtain the average responses of each of the groups of countries (core/periphery) which the empirical literature considers to be homogeneous in their dynamics. The debt shock is identified by Choleski recursive methods for the two blocks and an average impulse response function for each block is obtained.

[11]The financial and debt crises in Europe led to economies within the same monetary union reacting heterogeneously between groups as those exposed to financial/sovereign stress (periphery) while other European economies were not (core), See for example De Cicarelli et al (2013), Marco (2019), Asimakopoulos et al (2018).

Figure 3.3 Periphery/Core response to a 1 s.d. Government Debt Shock



Median responses (solid) to a one standard deviation shock of government debt under a pooled estimator based on 5,000 iteration runs. The y axis identifies the median responses in percentage points with 68% credible intervals. The horizontal axis indicates time in quarters. The stared line displays the average effect for the pool of countries.

Figure 3.3 displays the responses to a debt shock of debt holdings by domestic banks, credit to NFC, lending rates and investment between the heterogeneous blocks. Moreover, in aims of comparison the stared line displays the average effects for the pool of countries to analyze how allowing for block heterogeneity leads to different responses in credit and investment in the face of a debt shock with respect to the average response under a pooled estimation for all EMU-6 countries.

Although the responses for the groups are of a similar nature to those observed in the aggregate, the response in SDH by domestic banks is higher in the peripheral block. This confirms prior findings in the literature given the dynamics observed during the sovereign debt crisis where the increase in holdings of domestic government bonds was higher for the European periphery. Credit falls in both blocks, confirming previous findings in the literature on credit contraction under sovereign exposure in European economies (see e.g. Becker and Ivashina (2018), Kalemli-Özcan et al (2018), Bottero et al (2020)). The effects however appear larger in the peripheral economies compared to the core block, which can be observed in the data (see Figure B.2) and are to be expected given the higher responses in debt holdings of financial institutions. Once again, the positive response of credit rates and the contraction in credit volumes allows to infer a contraction in the supply of credit. Furthermore, investment falls on both blocks although the contraction it is of lesser magnitude for the core block.[12]

In general, what is reflected in these results is how, when considering block difference, heterogeneous responses are observed in terms of blocks. The persistence of the effects, in particular the effects of sovereign exposure and cost of borrowing, seem to be highly influenced by the peripheral dynamics. The effects on credit and investment on the other hand show how relative to the pool of EMU-6 countries (stared line) credit and investment fall more for the periphery, while for the core economies the responses of both are above the stared line which implies smaller effects in credit and investment.

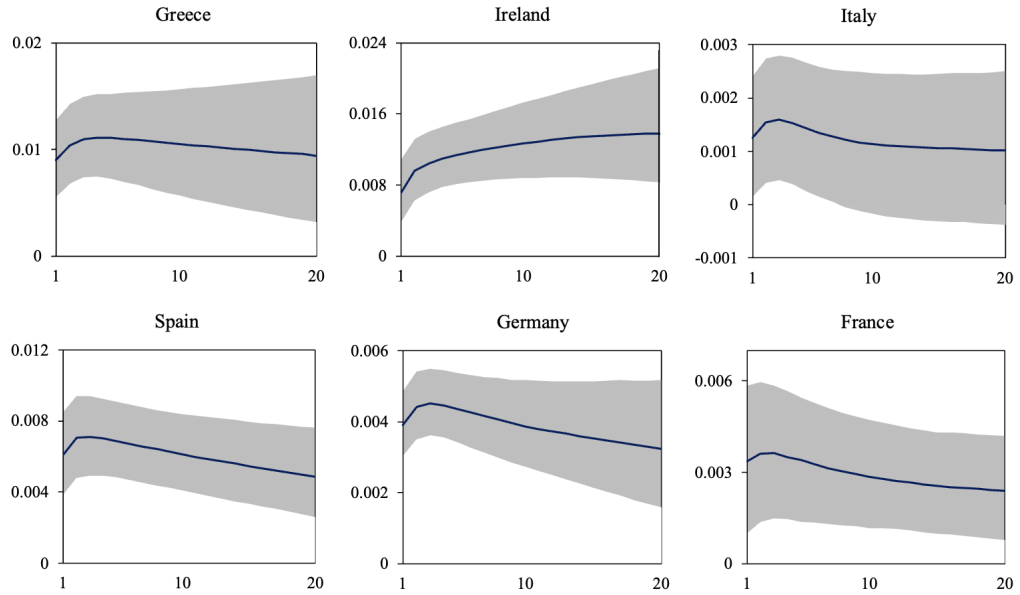
[12]Figure B.4 shows the correlations by block which further support these results.

3.4.3 Are there asymmetric effects on credit to enterprises and investment across European MU countries?

So far, the aggregate effects have been shown for the economies of the monetary union and a distinction has been made between blocks (core/periphery) to understand the effects of the on credit and investment levels. This section examines the asymmetric effects on credit to firms and investment across the EMU-6 countries. Although the regional integration in the euro area would suggest synchronized business cycles, the fiscal responses and financial fragilities present at the country level within the union can lead to heterogeneous responses to debt shocks. The structural responses to a debt shock are identified by imposing the same Choleski decomposition in all countries as defined in section 3.3.1. The autocorrelation coefficient was defined as 0.7 for the EMU-6 panel of countries and the priors for the estimation are those defined in section 3.2. Under a random estimator, restrictions of this type obtain the cross-sectional response for each country. These symmetric identification restrictions imply that even though the response to a debt shock is different in each of the EMU-6 countries, the nature of the disturbances is independent of the country and the underlying mechanism of the balance sheet channel is assumed the same for all units.

When allowing for cross-subsectional heterogeneity, debt shocks have positive effects on SDH by domestic financial institutions in all EMU-6 economies as shown in Figure 3.4. The highest acquisition of domestic debt in the bank's balance sheets are observed in Greece, Ireland and Spain where in the face of debt shocks, debt holdings by banks in Greece increase by 0.9%, 0.7% in Ireland, 0.6% in Spain. This difference in responses to the core economies like Germany and France which show a 0.3% increase in debt holdings by domestic banks could be associated with the ease of core countries to finance debt in other markets and need not to immediately saturate the local banking system. In the case of Italy, the response of sovereign debt exposure seems to be the smallest among all countries after a positive shock in domestic public debt, which is not surprising since domestic debt exposure by domestic banks is low in Italy compared to the other peripheral economies. However, the adjustment in credit is greater in impact than that of other countries, as shown in Figure 3.5.

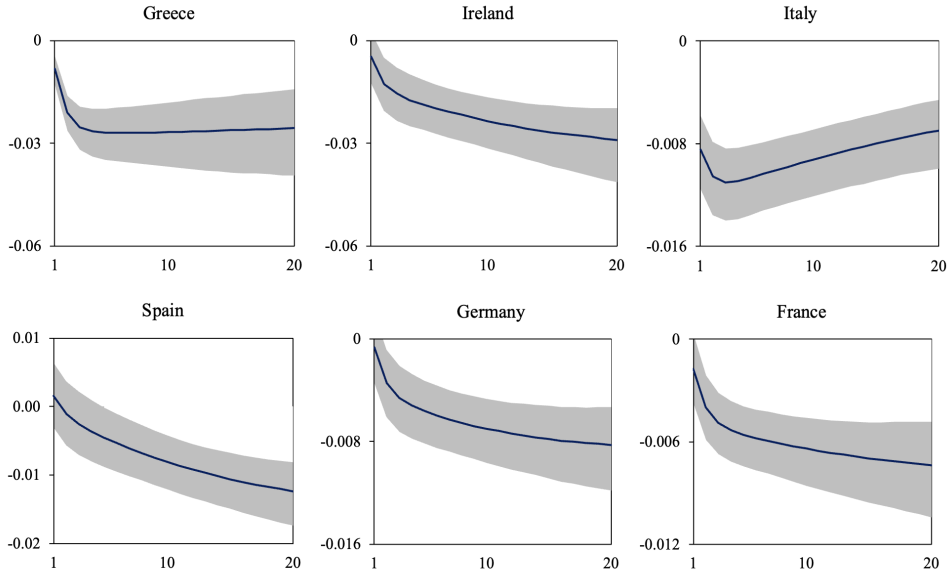
Figure 3.4 Response of Bank's Sovereign Holdings to a Government Debt Shock



Median responses to a one standard deviation shock of government debt based on 5,000 iteration runs. The y axis identifies the median responses in percentage points with 68% credible intervals. The horizontal axis indicates time in quarters.

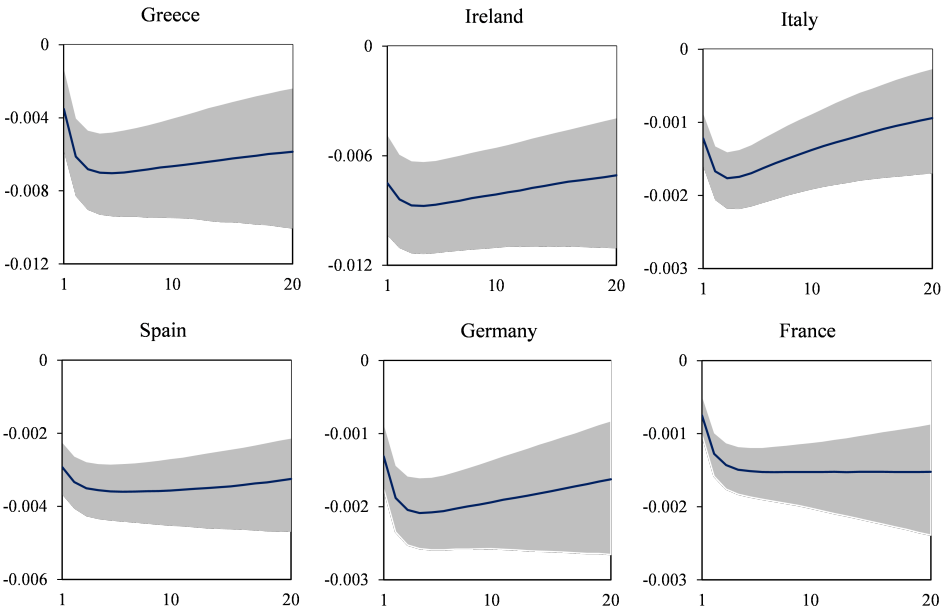
Figure 3.5 shows what corresponds to the effect of a debt shock on credit to NFC. Debt shocks displace credit to the productive sector were once again the responses in each country present heterogeneous behaviour. On impact, the economies that respond immediately are Italy with a contraction in credit of 0.8%, followed by Greece (with 0.8%). The rest of the economies take a quarter to adjust lending to the debt shock whereas Spain seems to take longer to significantly show a response . The difference in the responses of credit to non-financial corporations could be explained by the ability of the banking sector to deal with new debt purchases on their balance sheets. As defined in Chapter 2, the effects on credit depend on the increase in asset holdings on bank balance sheets and the room left to acquire debt without immediately crowding out credit. In this sense, one factor explaining the difference in response could reflect the capital of financial institutions in each country to face balance sheet expansions when increasing holding of sovereign bonds. Cross-country differences in lending can also suggest underlying structural aspects as well as disparities in the characteristics of borrowers and lenders in each country like differences in bank products offered to firms, heterogeneity in bank's collateral requirements, institutional regulatory frameworks, capitalization of domestic banks, among others not explicitly modelled.

Figure 3.5 Response of Credit to Enterprises to a Government Debt Shock



Median responses to a one standard deviation shock of government debt based on 5,000 iteration runs. The y axis identifies the median responses in percentage points with 68% credible intervals. The horizontal axis indicates time in quarters.

Figure 3.6 Response of Investment to a Government Debt Shock



Median responses to a one standard deviation shock of government debt based on 5,000 iteration runs. The y axis identifies the median responses in percentage points with 68% credible intervals. The horizontal axis indicates time in quarters.

Finally, Figure 3.6 presents the effects of a public debt shock on investment in European economies. The crowding out of investment is shown for all economies although higher effects are perceived for Ireland, Greece and Spain where on impact a debt shock leads to a contraction of 0.7%, 0.4%, 0.3% respectively of Investment to GDP. Although in all the countries, investment contracts, when comparing the contraction in credit to the contraction in investment, asymmetric responses are observed in terms of how under debt shocks, the credit displacement affects investment at the country level. In part, the asymmetric response is due to different responses on the credit rate (see Figure B.3 in Appendix). However, it also reflects the composition of borrowers by firm size or even to the predominant composition of the banking sector in each country (both in terms of size of banks and in the capitalization in the face of greater holdings of sovereign bonds in their balance sheets), reflecting different effects on investment in each country.

The findings of this section further support that the mechanism of transmission is observed across countries as suggested by the DSGE model, however, the heterogeneous responses suggest that mechanisms that are not captured in the theoretical model may account for the heterogeneity that exists across the EMU-6 countries here studied. In this regard, the empirical results of this work show that beyond the balance sheet channel of fiscal policy, there are still country-specific elements that affect the transmission of the shock, making the PVAR approach relevant to broaden the understanding of the mechanism across countries and further supporting the results that granular data exploit in micro-analysis. In particular, the fact that the banking sector encloses a degree of heterogeneity in each country, can be explained by several factors that the DSGE model does not directly capture: 1) diversity in credit development in each country or 2) financial fragility (vulnerability of a financial sector) in the face of public debt shocks in bank balance sheets.

3.5 Concluding Remarks

This paper empirically tests the balance sheet channel of fiscal policy by studying the relationship between sovereign debt shocks and responses in the balance sheets of financial institutions (sovereign debt holdings and loans to enterprises) which are transmitted to the real economy by investment contraction. It does so by exploiting a Bayesian Structural Panel Vector Autoregression model to analyse cross-subsectional relationships among six of the largest EMU countries over the period 2003Q1-2019Q4, to analyse heterogeneous responses across countries.

The main results that emerge from this work suggest that (a) the evolution of the bank's balance sheets influences the bank lending channel of fiscal policy for European economies. The chapter shows that under a debt shock, the re-composition in the balance sheets of financial institutions negatively impacted the provision of credit and investment in EMU; (b) The highest credit crunches and fall in investment were observed in those economies with more exposure to SDH, in particular the periphery economies. Although at the aggregate level for the European economies the channel is maintained, when a distinction is made by block, higher responses are observed in periphery countries and same insight holds when country heterogeneity is allowed in the model. The robustness of the mechanism comes from different ways of accounting for heterogeneity in the panel, by pooled average responses in the EMU, by block heterogeneity and by country specific dynamics. Moreover, despite a prevailing channel of debt-financed fiscal policy, the differences in responses across countries could also be associated with the regulatory framework and institutional characteristics that are idiosyncratic to each country.

The contribution of this work is twofold: (i) contributes to the literature by providing new empirical evidence on the transmission of fiscal policy shocks to real economic activity in the European countries by relying on a theoretical framework explored in a DSGE model[13], and (ii) analyses how sovereign debt has effects on real activity in European countries and highlights the macro-financial linkages that exist within the Euro Area and the heterogeneity in responses to fiscal debt shocks. This paper reviews the macroeconomic implications of public debt for the European countries in the presence of macro-financial linkages by first showing the mechanism holds for the pool of EMU countries, but also emphasising heterogeneity at different levels: by splitting the sample in blocks of stressed (periphery)/non stressed(core) countries as has been suggested in the literature; and by analysing the mechanism allowing for heterogeneity at the country level.

The results have important implications for the design of policy to understand the effects of debt-financed fiscal policy when it leads to increased bond holdings by financial institutions. As the European union has a primarily bank-based financial system, the changes in the composition of bank's balance sheets can have substantial

[13]As identified by Canova and Ciccarelli (2013), when a VAR omits relevant information about the optimization problems of economic agents, it is possible that the innovations obtained from a SVAR lack the characteristics presented in the theoretical models. Thus, the fact that there is a cross sectional dimension specified in the Panel VAR estimation on its own does not help to solve the fundamental problem of not having states of the economy that are not modelled in the empirical framework.

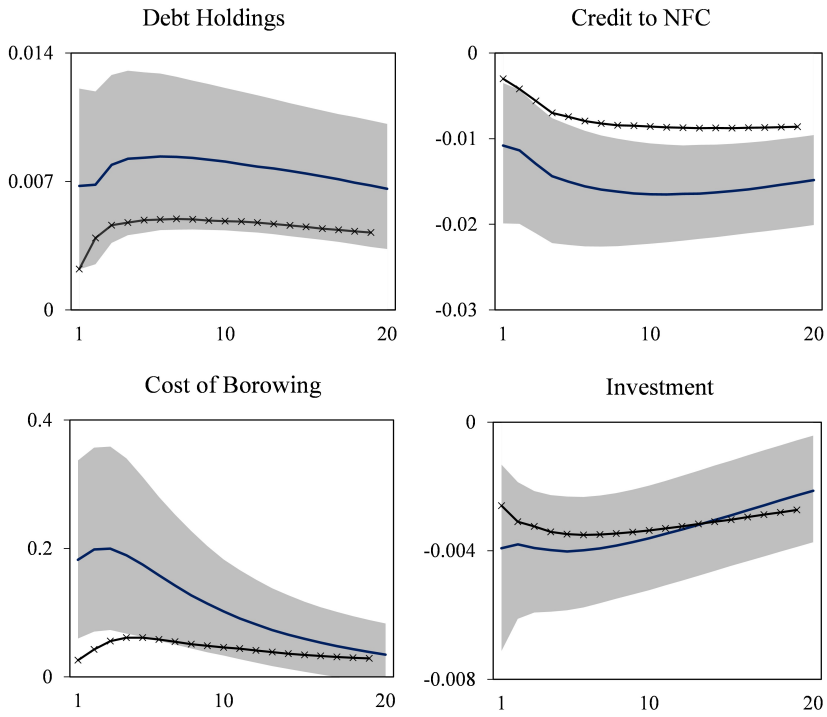
repercussions in the transmission of macroeconomic policy. Thus, to the extent that banks remain the main suppliers of credit in the European economy, shocks that affect their liquidity provision may pose a source of risk as impact to the private sector may disrupt economic activity. In this regard, the effects of debt issuance on borrowing and investment depend on a well-functioning credit market. Moreover, despite the commonalities within the EMU countries, a degree of heterogeneity in macro-financial linkages remains in their response to debt financed fiscal policy on credit and investment. Plausible reasons for this lie in the idiosyncratic components like country specific legal frameworks and fragilities present in the credit markets (in terms of size of banks and firms) which are outside the scope of this work.

Appendix B

B.1 Identification Discussion

The baseline approach considered is a recursive approach which implies a causal ordering of the model variables as described in section 3.3.1. The choice for identification allows data to drive the direction and magnitude of the response by imposing a causal ordering as suggested by the mechanism explored in Chapter 2. However, the literature offers alternative approaches for potential identification, such as an identification by sign restrictions. As pointed out by Fry and Pagan (2007), sign restrictions are not superior to other identification strategies in SVARs such as the recursive identification approach by Choleski. Despite the popularity of sign restrictions as means to identifying VARs, the Choleski recursive approach provides less restrictive for our purpose of modelling a credit supply contraction. This is because we aim at estimating the effects of a debt shock on the credit supply, and imposing a sign restriction identification involves imposing restrictions on the variables of interest (borrowing costs and loans to NFC) to capture the crowding out effect on investment. In such case, only the persistence on the variables would be tested. Figure B.1 provides an illustration of the responses to a debt shock under a sign restriction approach for the pooled estimation. The sign restrictions are imposed on impact for all the variables such that sovereign debt holdings respond positively to debt shocks, loans respond negatively and the interest rate responds by increasing to identify the effects on credit supply. The results suggest responses similar in magnitude and persistence to those obtained by Choleski decomposition (starred line) to further support the balance sheet channel of debt-financed fiscal policy. Yet, because the response of loans and cost of borrowing is driven by the sign restriction, only the persistency is being examined.

Figure B.1 Shock to Government Debt -Sign Restrictions



Responses to a one standard deviation shock of government debt under a sign restriction identification. The y axis identifies the median responses in percentage points with 68% credible intervals. Starred line displays the median responses obtained under the pooled estimation under Choleski recursive identification for comparison. The horizontal axis indicates time in quarters.

Another potential identification scheme could be by relying on a proxy VAR that identifies the shock without imposing theoretical structure or ordering of the variables. Instead, under such approach, an instrument is constructed as a proxy measure of the shock of interest. This identification does not impose the timing restrictions that are implicit in the recursive identification by Choleski. Also, the narrative approach has advantages over the sign identification which also impose some restrictions based on theory. For this work, an additional benefit with respect to sign identification would be that to be able to identify a credit supply contraction, one would need to directly impose restrictions on the variables of interest, for example the cost of borrowing (positive) and loans (negative). Yet, the challenge for the narrative proxy VAR approach lies in being able to find an appropriate instrument for identifying the shock of interest. In such framework, proxy variables require the exogeneity and relevance conditions to be met. This implies the method relies on external instruments to identify the exogenous shock. For the relevance of the instrument, it must be correlated to the shock one wants to identify but should not be correlated to other shocks. In practice however, proxies may suffer from a

weak instrument problem, produced by low relevance. Future work could focus on investigating potential instruments for detecting government debt shocks.

B.2 Data

This subsection presents the sources for the data and summary statistics at country level over the period 2003Q1 - 20019Q4.

Table B.1 Sources of the Data

Variable	**Source**
General Public Sector Debt (% GDP)	OECD
Sovereign Debt Holdings	Merler and Pisani-Ferry (2012)
Cost-of-Borrowing indicator	European Central Bank (ECB)
Bank Loans to Non-Financial Corporations	European Central Bank (ECB)
Gross fixed capital formation (% GDP)	OECD

Table B.2 Descriptive statistics

Public Debt as a share of GDP

	Germany	France	Greece	Ireland	Italy	Spain
Mean	70.03	94.16	153.30	70.11	122.08	76.12
Max	82.37	112.32	192.89	129.33	137.77	107.20
Min	59.82	73.33	107.47	26.16	104.66	40.72
St. Dev	6.65	14.74	34.27	34.17	12.68	26.12

Sovereign Debt Holdings by Domestic Banking Sector

	Germany	France	Greece	Ireland	Italy	Spain
Mean	30.77	10.80	16.60	23.16	17.02	24.65
Max	42.00	19.00	31.34	45.09	24.46	35.92
Min	23.04	5.00	8.90	2.09	11.45	15.10
St. Dev	4.59	3.51	4.21	13.55	4.05	5.61

Loans to Non-Financial Corporations as a share of GDP

	Germany	France	Greece	Ireland	Italy	Spain
Mean	29.25	13.58	5.94	22.15	28.72	58.02
Max	49.48	20.29	21.46	78.03	44.72	101.29
Min	21.99	9.14	0.06	2.75	20.88	26.55
St. Dev	6.34	2.32	3.67	20.18	6.12	25.45

Cost of Borrowing to Non-Financial Corporations

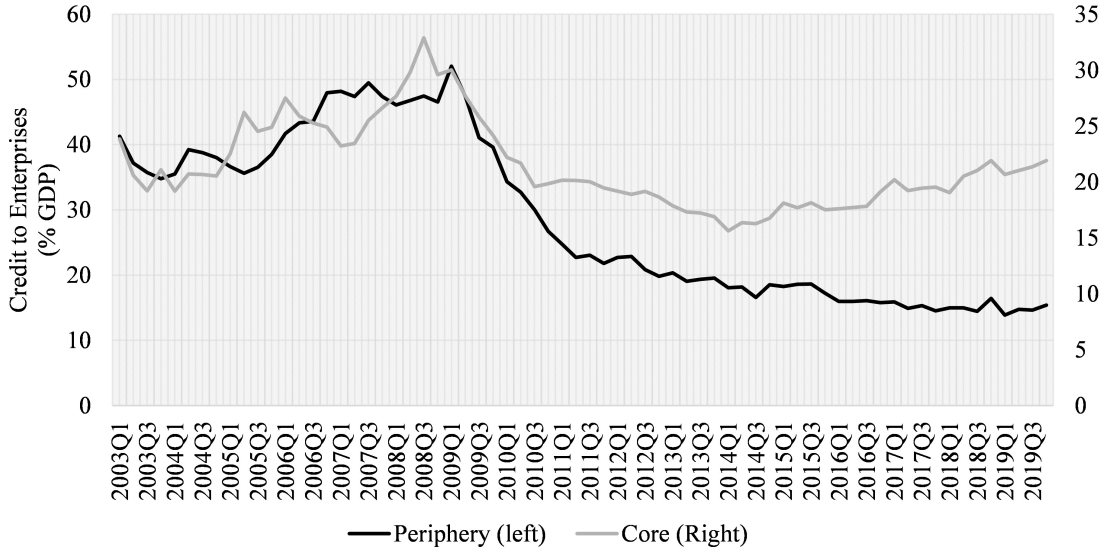
	Germany	France	Greece	Ireland	Italy	Spain
Mean	1.74	1.28	3.69	2.79	1.94	1.36
Max	3.69	3.68	8.18	5.71	3.92	4.04
Min	0.58	1.09	0.12	0.28	0.14	0.74
St. Dev	1.21	1.01	1.94	1.11	0.98	1.33

Gross Fixed Capital Formation as a share of GDP

	Germany	France	Greece	Ireland	Italy	Spain
Mean	20.02	22.27	16.68	23.15	19.25	22.61
Max	21.53	23.82	29.75	32.01	22.09	30.13
Min	18.69	21.01	9.57	15.68	16.65	17.23
St. Dev	0.67	0.72	6.14	4.61	1.81	4.74

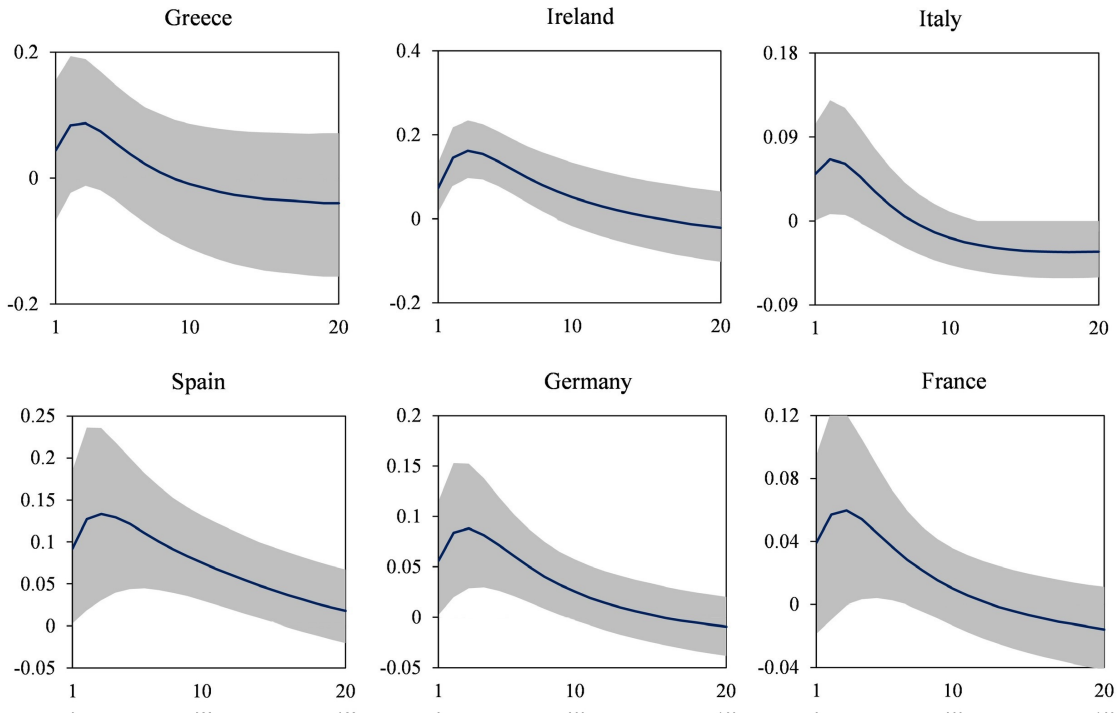
B.3 Supporting Figures

Figure B.2 New credit to NFC (% GDP)



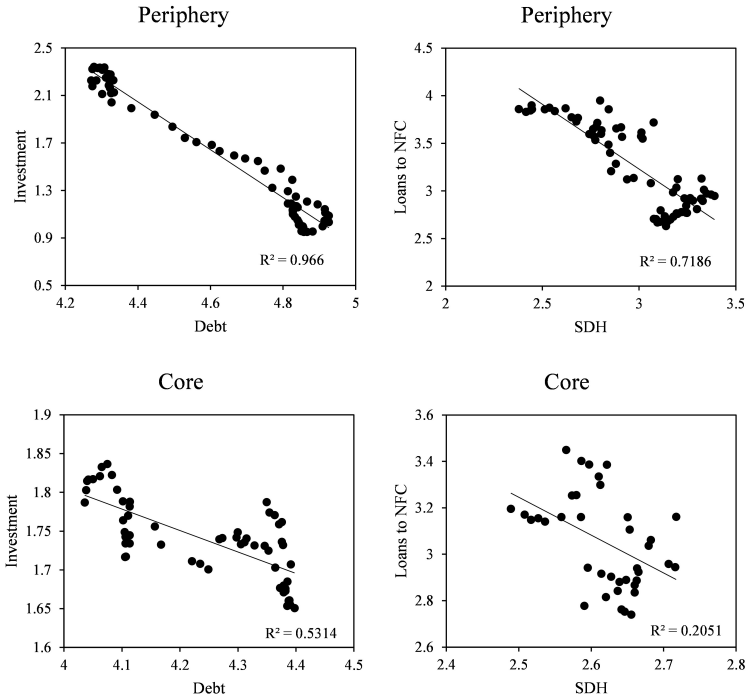
Source: European Central Bank's Statistical Data warehouse. Core countries include: France and Germany. Periphery countries include: Greece, Ireland, Italy and Spain.

Figure B.3 Response of Cost of Borrowing for NFC to a 1 s.d. Shock to Government Debt



Median responses to a one standard deviation shock of government debt based on 5,000 iteration runs. The y axis identifies the median responses in percentage points with 68% credible intervals. The horizontal axis indicates time in quarters.

Figure B.4 Block-correlations



Source: Debt to GDP is obtained from European Central Bank's Statistical Data warehouse, Sovereign debt holdings are retrieved from Merler and Pisani-Ferry (2012) and loans to Non-MFI Debt are obtained from European Central Bank's Statistical Data warehouse. Variables defined in log-levels from 2003-2019 on quarterly basis. Core countries include: France and Germany. Periphery countries include: Greece, Ireland, Italy and Spain.

Chapter 4

Public Large Sale Asset Purchases and Financial Stability

4.1 Introduction

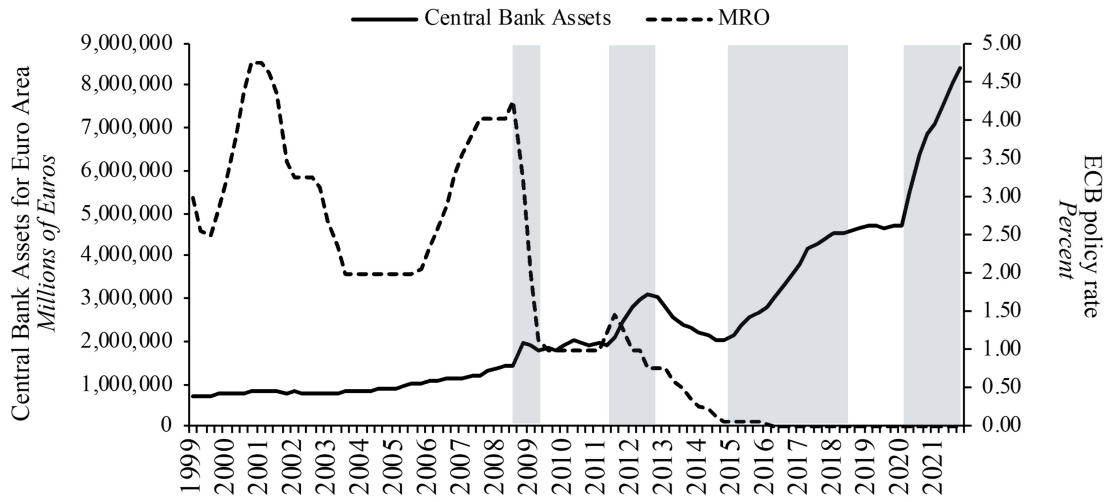
Prior to the financial crisis of 2008, the main tool that Central Banks had to influence economic activity was the short-term interest rate. Conversely, following the crisis and in aims to contain the recession and stimulate economic activity, central banks responded by lowering interest rates. In advanced economies, the short-term policy rate cuts reached the zero lower bound (ZLB) which left no room for conventional monetary policy to manoeuvre. In response, Central Banks began undertaking unconventional monetary policies, with Large-Scale Asset Purchase programs (LSAPs) being a key *unconventional tool* for trying to provide liquidity to the market.[1]

The European Central Bank (ECB) began to purchase long-term assets to handle the provision of liquidity in the financial markets. As a result of these unconventional policies, the balance sheets of the ECB expanded to record levels. As shown in Figure 4.1, asset purchases were implemented by the ECB since 2009 to deal with the effects of the financial crisis, although the use of this tool was not aggressively used given that when the financial crisis hit in 2008, the policy rate in Europe was still positive, leaving some room for conventional monetary policy to still operate.[2]

[1]For instance, the Federal Reserve implemented since 2008 Q1 Q2 Q3; similarly the Bank of England starting on 2009 and the Bank of Japan were amongst the first central banks to implement these policies in what at the time were considered unconventional monetary policies.

[2]As opposed to what happened in the United States, who hit the lower bound at the end of 2008, the EU took longer to implement unconventional monetary policies.

Figure 4.1 Central Bank Assets and Policy Rate in the Euro Area



Central Bank Assets for Euro Area (11-19 Countries) are quarterly averages measured in Millions of Euros (left). The MRO rate measured in percent (right) is the ECB Main Refinancing Operations Rate. For the period 2000-2008 where the MRO fixed is not reported, the series are derived from the average between ECB Deposit Facility Rate and ECB Marginal Lending Facility Rate for Euro Area, which are the other two rates used by ECB as policy rates. Sources: Federal Reserve Bank of St. Louis.

Two years after the crisis hit, an episode of turmoil in Europe during the Sovereign Debt Crisis caused the ECB to respond by using unconventional measures and announced an asset purchase program in response to the high risk of insolvency of the banking sector (2011-2012). The Securities Market Program (SMP) was mainly implemented with the purpose of aiding stressed countries (periphery countries) during the European sovereign debt crisis. Specifically, this program was active in impaired bond markets where core economies faced lower yields and periphery economies were facing higher risk premia.[3] This program was implemented by 2011 and terminated in September 2012 following a governing council decision. The assets under the program were kept in the ECB's balance sheets and run off until maturity.

[3]In particular the Securities market program as argued by Eser and Schwaab (2013) was to aid the monetary policy transmission mechanism for countries with struggling bond markets given the high risk perception and lower demand for those securities and try to bring into line with the rest of the European countries, like peripheral ones. This makes the SMP differ in the conditions where it was implemented as LSAP implemented in countries like the United States, the United Kingdom were facing lower risk premia perceived in the international markets. See Eser and Schwaab (2013) for a discussion on the effects of this particular program.

Although purchases of long-term assets by the ECB had already been implemented since 2009 as a response to the financial and sovereign debt crisis, these purchases were small and short lived. It was until the ECB's policy rate reached the *effective lower bound* by mid 2014[4], that purchases of long-term assets were widely used as a policy tool. The European Central Bank since then has relied on the use of unconventional monetary policy by employing Open Market Operations for Long-Term securities under different programs to support the transmission channels of monetary policy and guarantee financial stability.

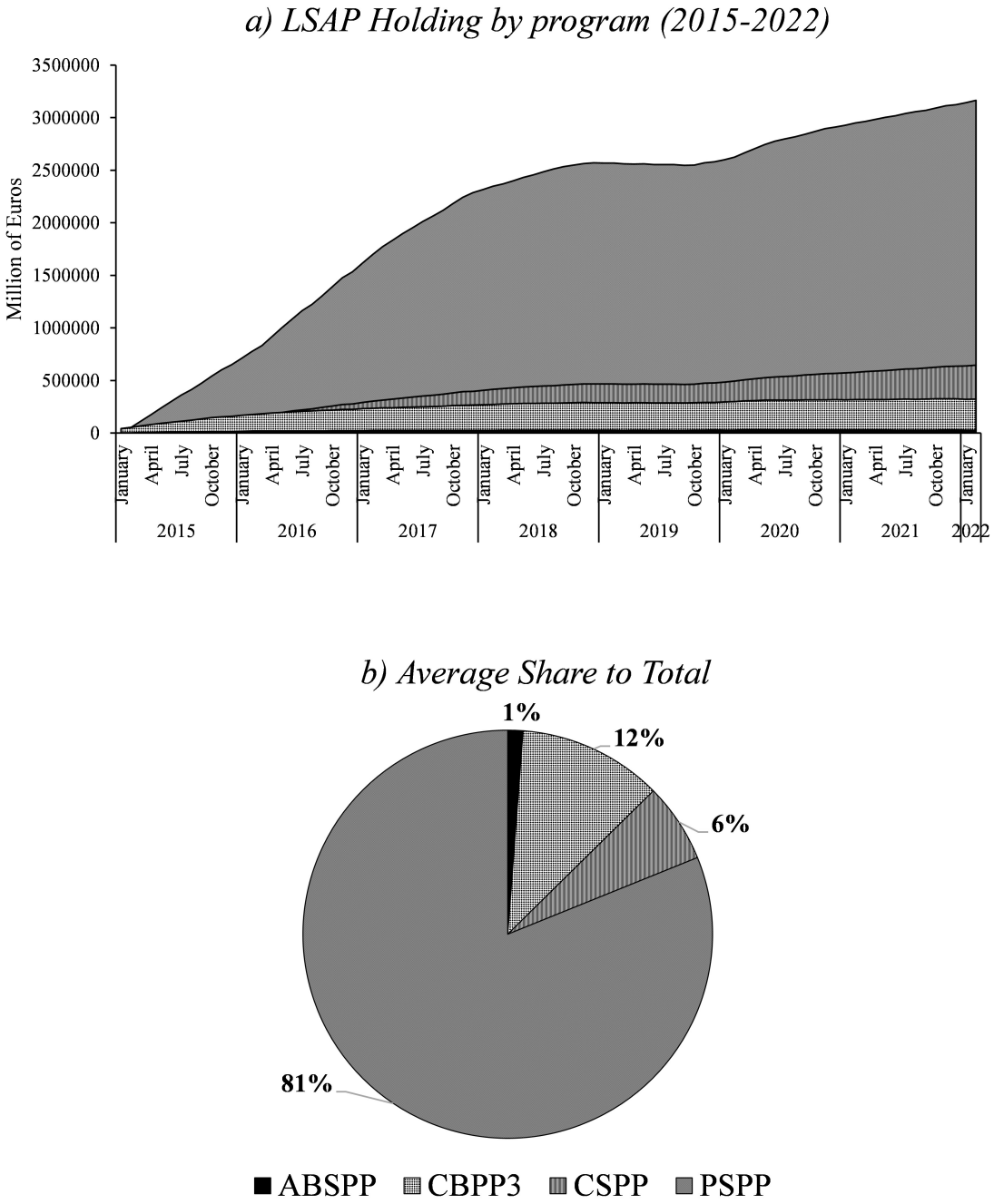
The ECB currently implements these measures under the Asset Purchases Programme (APP). This program is subdivided into 4 categories: 1) corporate sector purchase program (CSPP), 2) public sector purchase program (PSPP), 3) asset-backed securities purchase program (ABSPP) 4) the third covered bond purchase program (CBPP3). Figure 4.2 panel a), illustrates how these programs have evolved since APP was implemented in 2015. As shown in the figure, long-term government bonds (PSPP) represent the main type of asset held by the central monetary institution under the asset purchase program. When taken as a share of total assets in the APP program, the Public Sector purchase program accounts for around 80% of total Asset purchases (see panel b).

In the current context in which the central banks own a big chunk of domestic public debt in their balance sheets, understanding the role played by fiscal indebtedness and central bank's balance sheet in achieving financial stability is crucial. Although numerous definitions exist for *financial stability*, they all agree in that financial stability aims at allowing the financial system to operate smoothly for all agents interacting through it. That is, that financial markets allow borrowers and savers with the resources they need to invest and participate in a functioning economy. Given its multidisciplinary nature, *financial stability* for the purpose of this work is defined as improving credit conditions in the economy through the financial system.

Thus, the objective of this work is to study how these LSAP have worked out to achieve financial stability. This chapter answers the question: How do LSAP programs of public debt affect the business cycles to achieve financial stability? and how does this compare when facing the ZLB?

[4]That is, as the ECB Deposit Facility Rate went below zero and the MRO fixed rate was 0.05.

Figure 4.2 History of cumulative net purchases by program under the APP



End of month asset holdings by program in Millions of Euros: Asset-backed securities purchase programme (ABSPP), Covered bond purchase programme 3 (CBPP3), Corporate Sector purchase programme (CSPP) and Public sector purchase programme(PSPP). Source: European Central Bank (ECB).

To answer these questions, this chapter proposes a model that incorporates 3 different policies: 1) Government expenditure, which has been an active post-recession policy and has been used to support real activity in times where monetary policy faced difficulties; 2) Unconventional monetary policies, particularly in the form of LSAP as part of the central bank's toolkit to try to achieve financial stability when facing the effective lower bound in the short term policy rates; and 3) Macroprudential policies that account for capital requirements of financial institution which had to be reinforced post crisis and have been present in regulatory framework since for trying to mitigate systemic risk. All these ingredients mixed up together, make for a richer framework to analyze business cycle fluctuations. Furthermore, to understand the effects under the ZLB the model employs Occasionally Binding Constraints (OBC) to compare the effects to normal times, that is, when the short-term rates are not constrained to zero.

The main results of the chapter show that by increasing demand of government securities through the implementation of LSAP, the central bank eases commercial banks' balance sheets, reducing the cost for financial intermediaries which further pass that into lower credit costs for private firms to incentivize their investment decisions. Moreover, results show that in the presence of the ZLB for short term rates, the effects on the economy are amplified.In this chapter, different channels of transmission to real activity are considered: (i) the effects of LSAP programs on asset prices and long-term yields (ii) pass through effects of public bond rates to credit rates and (iii) rebalancing of banks' balance sheets to allow commercial banks to expand the credit supply and provide liquidity to the private sector.

The contribution to the literature is twofold: On the one hand it contributes to the literature that aims at understanding macro-financial linkages, an area that exploded following the crisis as a criticism to economists for poorly modelling the channels of transmission of financial intermediation to real activity. On the other hand, it contributes to the literature by incorporating a mix of policies to study those linkages. The real innovation in the model is the inclusion of macroprudencial policy in the framework, to account for financial frictions present in financial intermediation. This chapter builds upon the work of Sims and Wu (2021) whose model includes financial frictions in the banking sector a la Gertler and Karadi (2013).They model a banking sector where financial frictions are modelled through moral hazard and bankers can abscond with a proportion of assets from financial institutions which justifies the existence for banks to hold capital. Thus, banks face an incentive constraint such that the capital they hold should be at least that of

the proportion of assets that banks will take and not repay. This friction however does not capture the main reason why in reality, banks must hold capital. This paper fills the gap by incorporating macroprudential regulation to account for capital requirements present in financial intermediation. Regulatory measures capturing macroprudential regulation set a limit on the minimum capital ratios that financial institutions must meet which in turn influence credit provision. Capital requirements for financial institutions influence the margins (or spreads) financial institutions get out of intermediation. By allowing segmentation and intermediation, the financial sector plays a key role in the model. In this model, segmentation occurs because economic agents do not interact with each other, and all financial interactions happen through the financial sector. Therefore, companies and the government must access credit through financial institutions and the central bank must act through banks to finance both agents when implementing unconventional monetary policy. Same holds for households, which turn to financial institutions to deposit their savings and obtain a return which is derived from the profit margins of credit institutions. Thus, allowing for segmentation and intermediation is what gives the financial sector a role for transmission of shocks to the real economy.

The remainder of the chapter is organized as follows: Section 4.2 covers some literature relevant for the discussion, Section 4.3 presents the model, Section 4.4 discusses the parameter calibration, Section 4.5 discusses the results, and Section 4.6 concludes.

4.2 Relevant Literature

The 2008 Financial crisis resulted in tighter credit conditions as banks faced liquidity shocks. As suggested in the empirical literature, credit conditions in the European economy were tighter and lending was reduced in the period succeeding the financial and debt crisis in Europe.[5] In response to this credit contraction, central banks provided large amounts of liquidity to the banking sector in attempt to stimulate bank lending.

There are different mechanisms through which LSAP can have an impact on the real economy, one of the transmission mechanisms is the *asset price channel*

[5]Altavilla et al (2019) in section 5 The impact of monetary policy on bank intermediation and profitability provides a full discussion and cite: "in Chart 24, the aggregate cost of borrowing indicator for both Non-financial corporations and households increased in the largest Euro area countries between 2010 and 2012 [...]After the credit-easing package was introduced in June 2014, the cost of borrowing indicators for both NFCs and households declined to historical lows."

in which the unconventional measures sought to increase the demand for assets and rise their respective price. Given the negative relationship between price and yields, this meant a reduction in long term yields. De Santis (2020) using data of 10 Euro area countries using monthly data from 2004- 2015, estimates a panel error correction model to explain Euro area countries' sovereign yields following large scale asset purchases. They find that unconventional policy reduced the 10-year Euro area yields by reducing both the risk-free rate and the credit risk component, with most of the impact happening between September 2014 and February 2015, when the APP program was announced. Abidi and Miquel-Flores (2018) use a regression discontinuity design framework to analyse the effects of LSAP of corporate assets using a sample of 1,300 bonds across 15 countries in the Euro area. They focus on the corporate sector purchase programme (CSPP) and find that the such program led to a decline in yields of corporate bonds and lowering the cost of borrowing for non-financial corporations in Europe after the program implementation. In the same lines Ertan et al (2020) study the CSPP and find that by reducing the cost of debt for eligible firms, it eases banks' balance sheets to increase the supply of credit to small and medium enterprises (SMEs). They argue that as large corporations have access to debt markets by increased demand by central banks, the SMEs are the beneficiaries of increased credit supply.

Recent empirical evidence shows that the pass-through of bonds rates to interest rates on corporate loans. In fact, Creel and Viennot (2013) analyse conventional and unconventional monetary policy transmission to interest rates in Europe for the period following the global financial crisis using monthly data from June 2007 to December 2012 to estimate a SVAR. They find evidence of pass-through from the ECB rate to interest rates through the supply side of credit. Altavilla et al. (2019) analyse how the unconventional monetary measures announced by mid 2014 had a pass-through of monetary policy to bank lending rates and provides evidence on effects on lending volumes. In fact, they find that Euro area banks informed that the APP led to increased loan volumes with the impact being stronger for banks with larger sovereign bond holdings.

Moreover, the *bank lending channel* implies an increase in the reserve supply that helps increase the supply of credit in the banking sector and promote greater liquidity towards the real economy through greater consumption and investment. Because investment decisions (house/mortgage investment for consumers or capital investment by firms) are typically based on long term interest rates, by reducing long term rates, the central bank can ease credit conditions and lead to higher levels

of investment. This, coupled with higher public spending led to increased output. Some literature has empirically addressed this, for instance, Gambetti and Musso (2017) who quantify the APP program of the ECB on real output and inflation using a SVAR model with time variation in the parameters from 2009 to 2016.They find significant impacts on output and inflation measured by real GDP and Harmonised Index of Consumer Prices (HICP) inflation. Although the effects they find show that the APP shock to real GDP becomes smaller after a year. They also find that one of the channels at work under the APP shock is through credit channel, by which asset purchases influence the supply of bank lending and lending rates. In particular, their findings suggest that this channel contributes to the decline in lending rates and increased loan volumes.

In this chapter, the approach taken is that of the banks' balance sheet channel where both changes in asset prices and lending channels are present. That is, the way in which the central bank LSAP policies have effects in the model is through: 1) changes in asset prices (thus yields) 2) pass through effects of public bond rates at credit rates and 3) rebalancing of banks' balance sheets so that commercial banks can lend to the private sector. This work argues that the propagation of the LSAP depends on the policy impact on banks cost that affects its lending conditions through changes in credit margins. Banks benefit from capital relief once central bank purchases the securities and at the same time lower yields make banks benefit from funding private sector which offers higher yields (this is a valuation channel effect).

The macroeconomic literature has for long recognized that financial intermediation plays a key role in economic fluctuations and the transmission of shocks to the real economy. Also, in response to the financial crisis, the international Basel regulation implemented additional policies on capital requirements to financial intermediaries, aiming to reduce the costs associated with financial instability. Vast literature on the empirical front has documented the relationship between bank capital and lending behaviour (See e.g. Francis and Osborne (2009), Bridges et al (2014) Košak et al (2015), Aiyar et al (2016), Roulet (2018), among others[6]).In the theoretical framework, the DSGE literature started incorporating capital requirements to account for capital regulation with the work by Gerali et al (2010) being pioneering for further

[6]See for example Albertazzi et al (2020) where the bank capital channel works by making it costly for banks to break the minimum capital requirements imposed by regulation. As equity/capital funding is more costly compared with other forms of funding, financial institutions tend to diminish the amount of capital in excess of what regulators require because capital requirements are associated to adjustment in lending.

studies. However, previous studies within the DSGE literature exploring the effects of unconventional monetary policy, such as Curdia and Woodford (2011), Gertler and Karadi (2011, 2013), Chen et al (2012), Schabert (2014), Carlstrom et al (2017), and Sims and Wu (2021), have not addressed the integration of macroprudential frameworks. This chapter links this literature and proposes an innovative DSGE framework to account for the structural general equilibrium effects of LSAP on real activity, while also recognizing the crucial role that macroprudential regulatory requirements can play in shaping the capital held by financial intermediaries.

In particular, this chapter builds upon the work of Sims and Wu (2021) whose model includes financial frictions in the banking sector a la Gertler and Karadi (2013) by introducing a moral hazard problem. They model a banking sector where bankers can abscond with a proportion of assets from financial institutions which justifies the existence for banks to hold capital.[7] This friction however does not capture the reason why in reality banks must hold capital. To accurately model the impact of capital regulation on financial institutions, this chapter deviates from the approach taken by Sims and Wu (2021) and instead reengineers the financial sector in the model. Specifically, the model incorporates macroprudential regulation on financial intermediaries subject to capital requirements, where deviations from targeted capital requirements imposed by prudential authorities is consistent with that described in Chapter 2 of this thesis. However, unlike Chapter 2, this chapter introduces a modification to the quadratic function that accounts for a term premia to capture the excess return in long-term assets compared to short-term yields, thus enabling a role for unconventional monetary measures to influence real activity. Additionally, the model considers government bonds to be a fraction of the spread on corporate bonds, which leads to an arbitrage condition capturing the relative risk of each asset derived from risk weighted assets needed to be backed up by capital as established by macroprudential regulatory requirements.

This work also relates to the literature that studies the effects of unconventional measures in the presence of the ZLB. As discussed in the previous section, LSAP were introduced by ECB since 2009 but aggressively used since from 2015 onwards once the short-term rates reached zero. As indicated by Gros et al (2015) the novelty of the programme implemented by the ECB in 2015 was in terms of the size of the LSAP rather than the use of long-term security purchases as a tool itself, with the difference mainly on the short-term rates being constrained to the ZLB. Significant work that

[7] In their model, banks face an incentive constraint such that the capital they hold should be at least that of the proportion of assets that banks will take and not repay.

comes from that of Woodford (2011), Christiano et al (2011) and Eggertsson (2011) predict government spending multipliers at the ZLB much larger than one. Moreover, on the empirical field recent research predicts larger responses when monetary policy is constrained by the lower bound on policy rates (see Morita (2015), Liu et al (2019), Klein and Winkler (2021), Bonam et al (2022).)

The following section presents the model that incorporates LSAP to influence long term rates through its effects on the banking system to stimulate real activity and allows to study the effects of a binding ZLB.

4.3 Model Description

As standard in literature, to allow for monetary policy to have real effects in the economy, this work employs a mid-size New Keysian DSGE model with Calvo nominal rigidities.[8] The nominal rigidities in the model allow to keep track of nominal variables so that an asset pricing channel can also be studied. The model closely follows the work by Sims and Wu (2021), to study the effects of LSAP programs on real activity. However, unlike their work, this chapter models financial frictions by incorporating regulatory capital requirements imposed to financial institutions. The inclusion of financial friction is consistent with that described in Chapter 2 to account for macro-prudential regulation present in the financial institutions, but extends it to account for a term premium on long term assets.[9] Furthermore, segmentation gives the financial sector a key role for transmission of shocks to the real economy as financial interactions occur through commercial bank's intermediation.

The model consists of the following agents in the economy: (i) household who saves in the form of deposits in financial institutions and supply labour to labour unions; (ii) a labour market which is made up of monopolistically competitive labour unions that demand labour from households and subsequently offer it to labour packers who further prepare it to be used by productive wholesale firms; (iii) capital

[8]Nominal rigidities arise because of the presence of retail firms with market power under monopolistic competition, who adjust prices with probability $(1-\phi_p)$ and monopolistically competitive labour unions adjusting wages with probability $(1-\phi_w)$. These rigidities will make the price and wage setting problem dynamic for retailers and labour unions.

[9]In response to the financial crisis, the international regulation under Basel implemented additional policies on capital requirements to the financial sector, aimed at reducing the costs associated with financial instability. The deviation from Sims and Wu (2021) follows the need to model the financial sector to account for the relevant capital regulation which applies to financial institutions and imposes capital requirements when adjusting their balance sheet positions.

owners that produce capital available for production; (iv) the production of goods in the model is divided into 3 components: a wholesale firm that produces output using capital and labour (from labour packers), to then resell it to the retailers who operate under monopolistic competition and set prices á la Calvo. Also, the wholesale firm issues corporate bonds to finance new investments; (v) the fiscal authority issues long term bonds to finance government expenditure; (vi) a monetary authority (Central bank) who sets the policy rate (rate on reserves) by a Taylor rule and when hitting the lower bound influences long term rates through LSAP; (vii) financial sector that is subject to regulation on minimum capital requirements.

4.3.1 Households

Households in the economy maximize utility subject to a budget constraint:

$$U_0 = \mathbf{E}_0 \sum_{t=0}^{\infty} \beta^t \left[ln(C_t - bC_{t-1}) - \chi \frac{L_t^{1+\eta}}{1+\eta} \right] \tag{4.3.1}$$

$$s.t.\ P_t C_t + D_t = MRS_t L_t + R_{t-1}^d D_{t-1} + DIV_t - P_t T_t \tag{4.3.2}$$

They consume C_t and save what is left from consumption in the form of bank deposits D_t, and supply labour L_t to labour unions for a remuneration MRS_t. Additionally, the households get dividends DIV_t from owning the non-financial and financial firms and pay lump sum taxes to the fiscal authorities.

Note that households can only save via short term debt through one-period deposits. The model implies that markets are segmented in the sense that households cannot hold long term bonds directly, but can access indirectly the long-term bonds market (where corporate and government bonds are traded) by providing deposits to intermediaries.[10]

Households then choose intertemporal consumption, how much to save and how much labour to supply to labour unions. The optimization process of households yields the following order conditions in real terms:

$$\mu_t = \frac{1}{C_t - bC_{t-1}} - \beta b\, \mathbf{E}_t \frac{1}{C_{t+1} - bC_t} \tag{4.3.3}$$

[10]Calmstrom et al (2017) calls market segmentation to the short term bond markets being segmented from the long term bond markets and only financial intermediaries can purchase long term debt.

$$\chi L_t^{\eta} = mrs_t \mu_t \tag{4.3.4}$$

$$1 = Rd_t \, \mathbf{E}_t \, \Lambda_{t+1} \Pi_{t+1}^{-1} \tag{4.3.5}$$

Where $\mu_t = \lambda_t^n P_t$ is the real marginal utility of consumption, the $mrs_t = \frac{MRS_t}{P_t}$ is the real remuneration for households, $\Lambda_{t,t+1} = \frac{\beta \mu_t}{mu_{t-1}}$ is the real stochastic discount factor and Π_{t+1} is gross inflation defined as $\frac{P_{t+1}}{P_t}$.

4.3.2 Labour Market

The way the labour market operates is through labour unions and is modelled following Sims and Wu (2021). On the first stage the labour union purchases labour from the household at MRS_t and sells it to a labour packer. Subsequently, the labour packer aggregates union labour to be ready for production and sell it to production firms at wage W_t. [11]

Labour Unions

On the first stage the labour unions, indexed by $h \, \epsilon \, [0, 1]$, purchase labour from the household at MRS_t and sell that labour to the packer at $W_t(h)$.

$$DIV_t^{LU}(h) = W_t(h) L_{d,t}(h) - MRS_t L_{d,t} \tag{4.3.6}$$

Note that because the demand function coming from the packagers comes from their optimization process, it's first needed to solve the optimization process of the packagers and use the demand for labour union in the dividend function for them to choose how much labour to demand from the household. Thus we first solve for the problem of labour packers and then come back to the optimization of labour unions.

Labour Packer

The labour packer converts union labour $L_{d,t}(h)$, into final labour available for production $L_{d,t}$ and sells it to production firms at nominal wage W_t.[12]
Labour packers choose how much labour from the unions to get in order to maximize their profit, given by:

$$W_t \left(\int_0^1 L_{d,t}(h)^{\frac{\epsilon_w - 1}{\epsilon_w}} \, dh \right)^{\frac{\epsilon_w}{\epsilon_w - 1}} - W_t(h) L_{d,t}(h) \tag{4.3.7}$$

[11] The reason to model the labour market this way is to keep heterogeneity out of the household problem and instead of a setup with heterogeneous households with insurance as in Erceg et al (2000) which in turn allows for more general preferences.

[12] It is assumed that labour packers operate under perfect competition and thus make no profit in equilibrium.

Equation 4.3.7 describes what the packer gets from selling the "ready-for-production" labour to firms minus the payement made to labour unions for the repackaged labour. Where the integral, defined as $L_{d,t}$, represent the CES function for accumulation of labour supplied by union h. Optimization process for labour packagers yields the demand for union labour (downward sloping implying imperfect substitutability of union labour) and wage index (as shown in equations 4.3.8 and 4.3.9):

$$L_{dt}(h) = \left[\frac{W_t(h)}{W_t} L_{d,t}\right] \tag{4.3.8}$$

$$W_t^{1-\epsilon_w} = \int_0^1 W_t(h)^{1-\epsilon_w}\, dh \tag{4.3.9}$$

Returning to Labour Unions

By incorporating the demand for labour union given by labour packers, we can rewrite equation 4.3.6 as follows:

$$DIV_t^{LU} = W_t(h)^{1-\epsilon_w} W_t^{\epsilon_w} L_{d,t} - MRS_t W_t(h)^{-\epsilon_w} W_t^{\epsilon_w} L_{d,t} \tag{4.3.10}$$

or in real terms:

$$div_t^{LU} = W_t(h)^{1-\epsilon_w} w_t^{\epsilon_w} L_{d,t} P_t^{\epsilon_w - 1} - mrs_t P_t^{\epsilon_w} W_t(h)^{-\epsilon_w} w_t^{\epsilon_w} L_{d,t} \tag{4.3.11}$$

Once we have incorporated the demand for labour from packers, we can analyse the decisions made by labour unions. Unions face wage rigidities *a la* Calvo in which every period they can adjust the nominal wage $W_t(h)$ with a probability of $1 - \phi_w$. Thus, labour unions choose the nominal wage $W_t(h)$ so as to maximize the present discounted value of their real dividends (div_t^{LU}) given the probability that the wage chosen today isn't adjusted and thus stays relevant in the future ϕ_w.

$$\mathbf{E}_t \sum_{j=0}^{\infty} \phi_w^j \Lambda_{t,t+j} \left[div_{t+j}^{LU}\right] \tag{4.3.12}$$

The optimization process yields the first order condition for the nominal wage:

$$W_t^{\#} = \frac{\epsilon_w}{\epsilon_w - 1} \frac{\mathbf{E}_t \sum_{j=0}^{\infty} \phi_w^j \Lambda_{t,t+j} mrs_{t+j} P_{t+j}^{\epsilon_w} w_{t+j}^{\epsilon_w} L_{d,t+j}}{\mathbf{E}_t \sum_{j=0}^{\infty} \phi_w^j \Lambda_{t,t+j} P_{t+j}^{\epsilon_w} w_{t+j}^{\epsilon_w} L_{d,t+j}} \tag{4.3.13}$$

Where the nominal wage $W_t(h)$ can be expressed as not depending on h as $W_t^{\#}$, implying that unions who get to update the wages do it for the same amount. The Equation 4.3.13 can be rewritten in real terms and recursive form as:

$$w_t^{\#} = \frac{\epsilon_w}{\epsilon_w - 1} \frac{f_{1,t}}{f_{2,t}} \tag{4.3.14}$$

where $w_t^{\#}$ is the real wage and :

$$f_{1t} = mrs_t w_t^{\epsilon_w} L_{d,t} + \phi_w \mathbf{E}_t \Lambda_{t,t+1} \Pi_{t+1}^{\epsilon_w} f_{1,t+1} \tag{4.3.15}$$

$$f_{2t} = w_t^{\epsilon_w} L_{d,t} + \phi_w \mathbf{E}_t \Lambda_{t,t+1} \Pi_{t+1}^{\epsilon_w - 1} f_{2,t+1} \tag{4.3.16}$$

4.3.3 Capital Producers

Capital producers in this model built *new* physical capital $\hat{I}_t$ by using/transforming unconsumed I_t, by means of the following production function:

$$\hat{I}_t = \left[1 - s\left(\frac{I_t}{I_{t-1}}\right)\right] I_t \tag{4.3.17}$$

Where s(.) is the adjustment cost (See Christiano et al (2005)) and is defined by:

$$s\left(\frac{I_t}{I_{t-1}}\right) = \frac{\psi_k}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2 \tag{4.3.18}$$

The function s(.) satisfies that: s(1) =s'(1)= 0 and s"(1) = $\psi_k \geq 0$. [13] Profits for the capital producers are given in real terms by the following function:

$$div_t^k = p_t^k \left[1 - s\left(\frac{I_t}{I_{t-1}}\right)\right] I_t - I_t \tag{4.3.19}$$

[13]The dynamics of the model are influenced by the adjustment cost parameter, ψ_k, but the steady state of the model does not depend on it.

The capital producers pick I_t to maximize the present discounted value of real profits, yielding the following equation:

$$p_t^k = \frac{1 - \mathbf{E}_t \, \Lambda_{t,t+1} p_{t+1}^k s'\left(\frac{I_{t+1}}{I_t}\right)\left(\frac{I_{t+1}}{I_t}\right)^2}{1 - s\left(\frac{I_t}{I_{t-1}}\right) - s'\left(\frac{I_t}{I_{t-1}}\right)\left(\frac{I_t}{I_{t-1}}\right)} \tag{4.3.20}$$

Where p_t^k is the price firms pay for new capital $\hat{I}_t$.

4.3.4 Production of Goods

The production of goods in the model consists of three parts. First, a wholesale firm produces output by choosing how much to acquire of each of the factors of production and how much corporate debt to issue in order to finance new investments. Subsequently, the wholesale firm sells output to a continuum of retailers who repackage wholesale output to finally be sold to a competitive final-good firm.

Wholesale Firm

The wholesale firm produces output using capital stock K_t accumulated by investing in new capital and labour purchased from the labour packer $L_{d,t}$ at W_t. The output is produced by the wholesale firm using a Cobb Douglas technology of the form:

$$Y_t^w = A_t (u_t K_t)^\alpha L_{d,t}^{1-\alpha} \tag{4.3.21}$$

Where u_t is defined as capital utilization decisions on the use of the capital stock by the firms, A_t is the total factor productivity that follows an AR(1) process in its log form: $ln(A_t) = \rho_A ln(A_{t-1}) + s_A \epsilon_{At}$. and where the capital stock evolves according to the law of motion given by:

$$K_{t+1} = \hat{I}_t + (1 - \delta(u_t))K_t \tag{4.3.22}$$

Where $\delta(u_t)$ is a utilization adjustment cost of the form: $\delta\,(u_t) = \delta_0 + \delta_1(u_t - 1) + \frac{\delta_2}{2}(u_t - 1)^2$; and in the steady state it has the following properties $\delta(1) = \delta_0$, $\delta'(1) = \delta_1$, and $\delta''(1) = \delta_2$. This aims at capturing the depreciation of capital that is the cost for firms for utilization on production.

Additionally, the wholesale firm issues corporate bonds to finance new investments but is subject to an investment-in-advance constraint which indicates that the expenditure (in nominal terms) on new investments cannot exceed new issuance of long term corporate bonds F_t^w.

$$P_t^k \hat{I}_t \leq Q_t(F_t^w - \kappa F_{t-1}^w) \tag{4.3.23}$$

Here, Q_t defines the price of corporate bonds issued by the wholesale firm, F_{t-1}^w is the coupon payment on current period t from past issuances and the parameter κ captures the decaying coupon payment parameter. We then write equation 4.3.23 as an equality by setting ψ as a fraction of new investment that is financed with corporate long term debt

$$\psi P_t^k \hat{I}_t = Q_t(F_t^w - \kappa F_{t-1}^w) \tag{4.3.24}$$

The nominal profits of the firm are then given by:

$$DIV_t^w = P_{wt} A_t (u_t K_t)^\alpha L_{d,t}^{1-\alpha} - W_t L_{d,t} - P_t^k \hat{I}_t - F_{t-1}^w + Q_t(F_t^w - \kappa F_{t-1}^w) \tag{4.3.25}$$

Which describes the income from selling wholesale output at price P_{wt} minus the expenditures on labour wage W_t (paid to labour packer) , new capital acquired from the capital producers at price P_t^k and the value of new long term bonds issued at Q_t. Dividends can be expressed in real terms as follows:

$$div_t^w = p_{wt} A_t (u_t K_t)^\alpha L_{d,t}^{1-\alpha} - w_t L_{d,t} - p_t^k \hat{I}_t - \frac{F_{t-1}^w}{P_t} + Q_t\left(\frac{F_t^w}{P_t} - \kappa \frac{F_{t-1}^w}{P_t}\right) \tag{4.3.26}$$

The wholesale firm maximizes the PDV of those dividends subject to the capital accumulation equation and investment in advance constraint. The firm thus chooses u_t, $L_{d,t}$, $\hat{I}_t$, K_{t+1} and F_t^w, where v_{1t} is the multiplier on the capital accumulation equation and v_{2t} is the multiplier on the loan in advance constraint, yielding the first order conditions:

$$w_t = (1-\alpha) p_{wt} A_t (u_t K_{t-1})^\alpha L_{d,t}^{-\alpha} \tag{4.3.27}$$

$$v_{1t} d'(u_t) = \alpha p_{wt} A_t (u_t K_t)^{\alpha-1} L_{d,t}^{1-\alpha} \tag{4.3.28}$$

$$v_{1t} = p_t^k (1 + \psi v_{2t}) \tag{4.3.29}$$

$$v_{1t} = \mathbf{E}_t \, \Lambda t, t+1 \Big[p_{t+1}^w A_{t+1} L_{d,t+1}^{1-\alpha} \alpha (u_{t+1} K_{t+1})^{\alpha-1} u_{t+1} + v_{1,t+1}(1 - \delta(u_{t+1})) \Big] \tag{4.3.30}$$

$$Q_t(1 + v_{2t}) = \mathbf{E}_t \, \Lambda_{t,t+1} \Pi_{t+1}^{-1} \Big[1 + \kappa Q_{t+1}(1 + v_{2,t+1}) \Big] \tag{4.3.31}$$

Equation 4.3.27 describes the labour demand coming from wholesale firms, equations 4.3.28- 4.3.30 are the first order conditions on capital utilization u_t, new capital $\hat{I}_t$ and capital stock K_{t+1} decisions , respectively. Note that equation 4.3.30 which is the euler equation of capital uses the real discount factor because capital is a real asset, whereas for the euler equation of bonds (equation 4.3.31) the relevant discount factor is nominal $\Lambda_{t,t+1}\Pi_{t+1}^{-1}$ as bonds are nominal assets.

As in Sims and Wu (2021), we define two auxiliary variables:

$$M_{1t} = 1 + v_{2t} \tag{4.3.32}$$

$$M_{2t} = 1 + \psi v_{2t} \tag{4.3.33}$$

Thus

$$\frac{M_{1t} - 1}{M_{2t} - 1} = \frac{1}{\psi} \tag{4.3.34}$$

So for positive values of loan in advance multiplier, the auxiliary variables M_1 and M_2 are grater than 1 which in turn will have an effect on equations 4.3.28-4.3.31. Thus, the proportion ψ of investment that must be financed by debt is a distortion that plays a role in the bond issuance, Investment decisions, capital stock and utilization of the wholesale firm.[14]

Rewriting equation 4.3.29 by introducing the auxiliary equations, it looks as follows:

$$v_{1t} = p_t^k M_2 t \tag{4.3.35}$$

Further, by substituting v_{1t} in eq. 4.3.28 (order condition of capital utilization), and eq. 4.3.30 (euler equation of capital), we get:

$$p_t^k M_{2t} \delta'(u_t) = \alpha p_{wt} A_t (u_t K_t)^{\alpha-1} L_{d,t}^{1-\alpha} \tag{4.3.36}$$

$$p_t^k M_2 t = \mathbf{E}_t \, \Lambda_{t,t+1} \Big[p_{t+1}^w A_{t+1} L_{d,t+1}^{1-\alpha} \alpha (u_{t+1} K_{t+1})^{\alpha-1} u_{t+1} + p_{t+1}^k M_2, t+1(1-\delta(u_{t+1})) \Big] \tag{4.3.37}$$

Finally, by setting M_{1t} in eq. 4.3.31 (euler equation of bonds), we get:

$$Q_t M_{1t} = \mathbf{E}_t \, \Lambda_{t,t+1} \Pi_{t+1}^{-1} \Big[1 + \kappa Q_{t+1} M_{2,t+1} \Big] \tag{4.3.38}$$

[14] For unconventional monetary policy in the form of LSAP to have an effect on real activity, the model requires ψ to be a non zero parameter so that changes in asset pricing have an impact on the firms decision to make investments. For practical purposes, is easy to see that setting ψ to zero makes equation 4.3.34 to be undefined.

From equation 4.3.38 its easy to see how if $M_{1t} = M_{2,t+1} = 1$, the interest rate on long term bonds would be the same as that of equation 4.3.5 from household decision to save, thus $E_t R^F_{t+1} = R^d_t$.

Rewriting the bond euler equation as:

$$M_{1t} = \mathbf{E}_t \, \Lambda_{t,t+1} \Pi^{-1}_{t+1} \left[\frac{1 + \kappa Q_{t+1}}{Q_t} + \frac{\kappa Q_{t+1}}{Q_t} \Big(M_{2,t+1} - 1 \Big) \right] \tag{4.3.39}$$

and defining the long term corporate bond yield as:

$$R^F_t = \frac{1 + \kappa Q_t}{Q_{t-1}} \tag{4.3.40}$$

we get the following expression:

$$M_{1t} = \mathbf{E}_t \, \Lambda_{t,t+1} \Pi^{-1}_{t+1} \left[R^F_{t+1} + \frac{\kappa Q_{t+1}}{Q_t} \Big(M_{2,t+1} - 1 \Big) \right] \tag{4.3.41}$$

So without a binding investment-in-advance constraint ($v_{2t} = 0$), auxiliary variable $M2 = 1$ and long term bond yields would be that of deposits (a flat yield curve).

$$1 = \mathbf{E}_t \, \Lambda_{t,t+1} \Pi^{-1}_{t+1} R^F_{t+1} \tag{4.3.42}$$

Equations 4.3.34- 4.3.38 describe the set of first order conditions of the wholesale firm that are relevant for the model dynamics. Given the optimal decisions on factors of production, new investments and bond issuance, the wholesale firm produces output to then be sold to retailers for repackaging who further sell it to the final goods firm.

Retailers and Final good production: Same as it was approached in the labour market, we work this backwards to first derive the demand from the final good firms to be included in the monopolistic competitive retailers decision to derive the optimal price set by retailers. Retailers in the model operate under monopolistic competition, facing a downward sloping demand coming from final-good firms and have a degree of market power that allows them to be price setters.

Final goods

The competitive final goods producer purchases and transforms/aggregates output from a continuum of retailers into a final good used for consumption and investment. It does so by employing a CES production technology where retail output $Y_t(f)$ is transformed into the final output good Y_t:

$$Y_t = \left(\int_0^1 Y_t(f)^{\frac{\epsilon_p - 1}{\epsilon_p}} \, df \right)^{\frac{\epsilon_p}{\epsilon_p - 1}} \tag{4.3.43}$$

The final goods producer operates under perfect competition and maximizes the income from selling final goods at price P_t and what its outflows from purchasing retail output at $P_t(f)$. Thus, the final good firms problem is to maximize that difference given by:

$$P_t \left(\int_0^1 Y_t(f)^{\frac{\epsilon_p - 1}{\epsilon_p}} \, df \right)^{\frac{\epsilon_p}{\epsilon_p - 1}} - P_t(f) Y_t(f) \tag{4.3.44}$$

Choosing the level of $Y_t(f)$ that maximizes the profit, the final goods producer generates the standard demand curve for goods (which is downward sloping) and an aggregate price index:

$$Y_t(f) = \left(\frac{P_t(f)}{P_t} \right)^{-\epsilon_p} Y_t \tag{4.3.45}$$

$$P_t^{1-\epsilon_p} = \int_0^1 P_t(f)^{1-\epsilon_p} \, df \tag{4.3.46}$$

Retailers

Monopolistic competition is characterized by many firms in the market. Thus, the model characterizes the monopolistically competitive firms as a continuum of retailers indexed by $f \, \epsilon \, [0; 1]$, who purchase wholesale output to then be repackaged for sale to final goods firms

Nominal profits for the retailers are:

$$DIV_t^R(f) = P_t(f) Y_t(f) - P_{wt} Y_t^w(f) \tag{4.3.47}$$

This expression indicates the profit made from selling repackaged wholesale output at price $P_t(f)$ to the final good firm minus what it pays to wholesale firm to acquire wholesale output $Y_t^w(f)$ at price P_{wt}. Thus, $P_t(f)$ is a fixed mark-up of wholesale price P_{wt}. By plugging the demand for retail output from final goods producers $Y_t(f)$ and rewriting the equation in real terms, real profits of retailers are

defined as:

$$div_t^R(f) = P_t(f)^{1-\epsilon_p} P_t^{\epsilon_p} Y_t - p_{wt} P_t(f)^{-\epsilon_p} P_t^{\epsilon_p} Y_t \tag{4.3.48}$$

Retailers are subject to price rigidities *a la* Calvo in which every period they can change the nominal prices charged to the final goods firm for the repackaged output, with probability $1 - \phi_p$. Thus, retailers choose price $P_t(f)$ so as to maximize the present discounted value of their real dividends (div_t^R) given the probability that the price chosen today isn't adjusted and thus stays relevant in the future ϕ_p.

$$\mathbf{E}_t \sum_{j=0}^{\infty} \phi_p^j \Lambda_{t,t+j} \left\{ div_{t+j}^R \right\} \tag{4.3.49}$$

The optimization process yields the first order condition for the nominal price set by retailers:

$$P_t^{\#} = \frac{\epsilon_p}{\epsilon_p - 1} \frac{\mathbf{E}_t \sum_{j=0}^{\infty} \phi_p^j \Lambda_{t,t+j} P_{t+j}^{\epsilon_p} p_{w,t+j} Y_{t+j}}{\mathbf{E}_t \sum_{j=0}^{\infty} \phi_p^j \Lambda_{t,t+j} P_{t+j}^{\epsilon_p - 1} Y_{t+j}} \tag{4.3.50}$$

Where $P_t(f)$ can be expressed as not depending on f implying all retailers set same price and defining it as $P_t^{\#}$. Further, 4.3.50 can be rewritten in real terms and recursive form as:

$$\Pi_t^{\#} = \frac{\epsilon_p}{\epsilon_p - 1} \frac{x_{1,t}}{x_{2,t}} \tag{4.3.51}$$

where $\Pi_t^{\#} = P_t^{\#} / P_t$, and x_{1t} and x_{2t} are defined as:

$$x_{1t} = p_{wt} Y_t + \phi_p \, \mathbf{E}_t \, \Lambda_{t,t+1} \Pi_{t+1}^{\epsilon_p} x_{1,t+1} \tag{4.3.52}$$

$$x_{2t} = Y_t + \phi_p \, \mathbf{E}_t \, \Lambda_{t,t+1} \Pi_{t+1}^{\epsilon_p - 1} x_{2,t+1} \tag{4.3.53}$$

4.3.5 Fiscal Authority

The fiscal authority consumes G_t and finances its expenditure by imposing a lump sum tax on the household T_t and by issuing long term debt b^G. The treasury additionally gets a lump sum transfer every period from the central bank T^{cb} for any profits made during the time period for holding assets. The budget constraint of the government is given by:

$$G_t = T_t + Q_t^B (b_t^G - \kappa b_{t-1}^G) - b_{t-1}^G + T_t^{cb} \tag{4.3.54}$$

Government spending is assumed to be exogenous and follows an AR(1) in its log form:

$$ln(G_t) = (1 - \rho_G)ln(G) + \rho_G ln(G_t - 1) + s_G \epsilon_{Gt} \tag{4.3.55}$$

Government bonds are held both by commercial banks b_t and central banks b_t^{cb}.

$$b_t^G = b_t + b_t^{cb} \tag{4.3.56}$$

Where b_t^G indicates the total real outstanding perpetual government debt and follows an exogenous AR(1) process: $ln(b_t^G) = (1 - \rho_B)ln(b^G) + \rho_B ln(b_{t-1}^G) + s_B \epsilon_{Bt}$. To avoid the introduction of multiple period bonds which would increase the number of variables to keep track in the model, government bonds are assumed to have the same structure as the perpetual corporate bonds with decaying coupon payouts following Sims and Wu(2021) and first proposed by Woodford (2001) to model different maturities of bonds.

4.3.6 Monetary Authority

In the model, the central bank conducts both, conventional monetary policy to affect short term rates following a standard Taylor rule and unconventional monetary policy in the form of LSAP. The monetary authorities set monetary policy such that short term rate (the rate of reserves) can hit the lower bound.

$$ln(R_t^{re}) = max\{0, ln(R_t^{TR})\} \tag{4.3.57}$$

The equation indicates that in normal times the central bank sets interest rate on reserves following a Taylor Rule for the short-term interest rate as follows:

$$\begin{aligned} ln(R_t^{TR}) = (1 - \rho_r)ln(R^{TR}) + \rho_r ln(R_{t-1}^{TR}) + \\ (1 - \rho_r)\Big[\phi_\Pi\Big(ln(\Pi_t) - ln(\Pi)\Big) + \phi_Y\Big(ln(Y_t) - ln(Y_{t-1})\Big)\Big] + \epsilon_{rt} \end{aligned} \tag{4.3.58}$$

The Taylor rule shows the persistence of interest rate $\rho_r \, \epsilon[0, 1]$, and responsiveness to inflation $\phi_\Pi > 0$ and output growth $\phi_Y > 0$, where central bank responds raising rates when inflation is above target or when output growth is too high.[15] However, if the short term rate under Taylor rule R^{TR} goes below zero, then the reserve rate is constrained to the ZLB. This can be thought of as the *shadow interest rate* as

[15] Following the baseline model by Sims and Wu (2021), output growth is used instead of output gap in the Taylor rule, under consideration of the observed reaction function used by central authorities and as theoretically desirable given the presence of nominal and financial frictions.

defined by Wu and Zhang (2019) , which represents the short-term nominal interest rate that the central bank would set given the conditions present in the economy if it was not constrained by the ZLB.[16] As such, this constraint aims at capturing that the central bank cannot use the reserves rate as part of the policy toolkit when the rate is zero allowing LSAP programs to play a role in trying to stabilize the real activity.

The literature makes a distinction between different types of LSAP, calling acquisitions of long term government bonds quantitative easing (QE) and purchases of long term corporate debt as Credit Easing (CE), which is maintained in this work. The central bank in the model incurs in both, purchasing of corporate bonds f_t^{cb} and government bonds b_t^{cb}. The central bank's balance sheet in real terms is given by the following expression:

$$Q_t f_t^{cb} + Q_t^B b_t^{cb} = re_t \tag{4.3.59}$$

where the $Q's$ in front of each of the assets are the prices for corporate and government bonds, respectively. Equation 4.3.59 indicates that the central bank can hold corporate bonds or government bonds and it finances this with reserves (re) which constitute the money base in the model with no cash. Because the central bank has monopoly power over the monetary base (unlike commercial banks), it can increase the size of its balance sheet by issuing reserves.[17] Furthermore, the bond holdings by LSAP are considered exogenous, following exogenous AR(1) processes:

$$f_t^{cb} = (1 - \rho_f) f^{cb} + \rho_f f_{t-1}^{cb} + s_f \epsilon_{ft} \tag{4.3.60}$$

$$b_t^{cb} = (1 - \rho_b) b^{cb} + \rho_b b_{t-1}^{cb} + s_b \epsilon_{ft} \tag{4.3.61}$$

Given corporate and government bonds, reserves adjust automatically to make the balance sheet of the central bank hold. Each asset in the balance sheet yields a return: Private bonds f_t yield a return of R_t^F, government bonds b_t yield a return of R_t^B and reserves re_t have a rate of R_t^{re} which is set by monetary authorities either

[16] This work doesn't break the equivalence between the deposit and policy rate. The model imposes the Zero Lower Bound on the short-term policy rate and in equilibrium, this rate is equal to the interest rate on short-term deposits (so the ZLB is imposed on both). Sims and Wu (2021) in their paper incorporate reserve requirements so that the deposit and policy rates are not equal. This work so far rules out the introduction of negative interest rates as a tool for monetary policy.

[17] The interests to be paid on reserves (base money) allows for a realistic feature as at the end of the maintenance period, the ECB pays banks interest on their minimum reserve holdings – the interest rate is equivalent to the main refinancing operation (MRO) rate which is the policy rate (R^{re} in this chapter). Blot et al (2017) discuss the fact that ECB liabilities were mostly banknotes (currency) before the financial crisis, whereas after 2009 the main liabilities correspond to bank reserves, mainly as deposit facilities.

by a Taylor rule or constrained to zero depending on whether it hits the bound or not. The monetary authority receives returns on its assets and pays back interest on reserves (its liabilities) as shown in the following equation:

$$T_t^{cb} = (R_t^F - R_{t-1}^{re})Q_{t-1}f_{t-1}^{cb} + (R_t^B - R_{t-1}^{re})Q_{t-1}^B b_{t-1}^{cb} \tag{4.3.62}$$

This equation indicates that the central bank earns a spread over its asset holdings. However, as central banks are non-profit institutions, all earnings on asset holdings are given back to the Treasury each period in the form of a lump sum transfer T_t^{cb}.

4.3.7 Banking Sector

Bank intermediation happens through maturity transformation as they take short term liabilities (deposits from households) to fund long term assets. The financial intermediaries in the model fund both, wholesale firms and the government by acquiring corporate and government long term bonds. It is worth noting that consumption works through short term interest rates whereas investment depends on long term rates which captures the liquidity transformation in which the financial sector engages. [18]

The balance sheet constraint of the bank is given by:

$$Q_t f_t + Q_t^B b_t + re_t = d_t + n_t \tag{4.3.63}$$

Equation 4.3.63 indicates that banks hold in their balance sheets three kinds of assets: 1) long-term corporate bonds f_t at price Q_t; 2) long term government bonds b_t) at price Q_t^B; and 3) bank reserves re_t which are held on account with the central bank. Moreover, financial institutions finance those assets with deposits from the households d_t and capital of their own n_t.

The bank's capital or net worth (n_t), follows the law of motion of net worth which is accumulated through retained earnings:

$$n_t = \Pi_t^{-1}\Big[(1-\delta^b)n_{t-1}\Big] + div_t^B \tag{4.3.64}$$

[18] In the model, households act as savers and the wholesale firms and fiscal authorities act as borrowers. Households are not borrowing for mortgages in this model, as that is out of the scope of this work. If modelled however, it would react similar to investment as they would depend on long term rates further moving output in the same direction.

The profits of banks (div_t^B) are generated by gaining a difference between the return on assets and cost of liabilities, minus the capital needed for the current period:

$$div_t^B = \Pi_t^{-1}\left[R_t^F Q_{t-1} f_{t-1} + R_t^B Q_{t-1}^B b_{t-1} + R_{t-1}^{re} re_{t-1} - R_{t-1}^d d_{t-1}\right] - n_t \quad (4.3.65)$$

The interest rate on reserves R_{t-1}^{re}, which is set by the monetary authority, and the deposits rate, R_{t-1}^d, which is determined in equilibrium, are both known in $t-1$. The Bond yields for corporate and government debt follow: $R_t^F = \frac{1+\kappa Q_t}{Q_{t-1}}$ and $R_t^B = \frac{1+\kappa Q_t^B}{Q_{t-1}^B}$, respectively.

Including the balance sheet constraint (equation 4.3.63) we get the following expression, which shows how profits for financial intermediaries are created by obtaining a spread between long and short term rates: [19]

$$div_t^B = \Pi_t^{-1}\left[(R_t^F - R_{t-1}^d)Q_{t-1}f_{t-1} + (R_t^B - R_{t-1}^d)Q_{t-1}^B b_{t-1} + (R_{t-1}^{re} - R_{t-1}^d)re_{t-1} + R_{t-1}^d n_{t-1}\right] - n_t \quad (4.3.66)$$

The bank maximizes the expected discounted value of its profits (div_t^B) and will face a quadratic cost for deviating from the exogenous target leverage ratio (ϕ), which allows to consider the implications and costs associated with regulatory capital requirements:

$$\boldsymbol{Max}\, \mathbf{E}_t \Lambda_{t,t+1}\left\{div_{t+1}^B - C^b\left(\frac{Q_t f_t + \Delta Q_t^B b_t}{n_t} - \phi\right)n_t\right\} \quad (4.3.67)$$

The quadratic cost function for capital requirements is defined as:[20]

$$C^b(.) = \kappa_1^b\left[\frac{Q_t f_t + \Delta Q_t^B b_t}{n_t} - \phi\right] + \frac{\kappa_2^b}{2}\left[\frac{Q_t f_t + \Delta Q_t^B b_t}{n_t} - \phi\right]^2 \quad (4.3.68)$$

The formulation of the cost function for capital deviations in this case is so that there is a base spread given by the parameter κ_1^b, which gives a role to financial intermediation in the steady state. Without a positive yield curve, financial intermediaries would play no role as banks would earn no margin for intermediation. The

[19] The last term ($R_{t-1}^d n_{t-1}$) measures cost savings from financing with net worth as opposed to deposits.

[20] In the steady state, the capital requirements do not deviate from ϕ^b, which means that the cost is irrelevant, but the marginal cost allows for a spread to still hold so that there is no flat yield curve implied in the steady state. Thus, the function $C^b(.)$ satisfies that in the steady state: $C^b(.) = 0$, $C^{b\,\prime}(.) = \kappa_1^b$ and $C^{b\,\prime\prime}(.) = \kappa_2^b$.

modelling of bank capital requirements plays a key role on credit supply given that Bank capital is adjusted slowly through the accumulation of retained earnings. Thus, a reduction of bank profits because of reduced spreads, puts pressure on the capital requirements banks must hold to ensure credit provision.[21]

As shown in Equation 4.3.68, the requirements of government debt needed to be backed by bank's capital are less by the amount of Δ than for corporate debt.[22] This captures the fact that banks require less capital for having assets such as treasury bonds, causing higher deviations of the leverage ratio relative to steady state value (ϕ) when banks acquire corporate bonds than when acquiring government bonds. This allows for a distinction between corporate risk and government bond risk to be considered without the need to use non-linear models.

The optimization problem of the financial intermediaries yields the following order conditions for corporate, government bonds and reserves respectively:

$$\mathbf{E}_t\, \Lambda_{t+1}\Pi_{t+1}^{-1}(R_{t+1}^F - R_t^d) = \mathbf{E}_t\, \Lambda_{t+1}\Pi_{t+1}^{-1}\left[\kappa_1^b + \kappa_2^b\left(\frac{Q_t f_t + \Delta Q_t^B b_t}{n_t} - \phi^b\right)\right] \tag{4.3.69}$$

$$\mathbf{E}_t\, \Lambda_{t+1}\Pi_{t+1}^{-1}(R_{t+1}^B - R_t^d) = \Delta\, \mathbf{E}_t\, \Lambda_{t+1}\Pi_{t+1}^{-1}\left[\kappa_1^b + \kappa_2^b\left(\frac{Q_t f_t + \Delta Q_t^B b_t}{n_t} - \phi^b\right)\right] \tag{4.3.70}$$

$$\mathbf{E}_t\, \Lambda_{t+1}(R_t^{re} - R_t^d)\Pi_{t+1}^{-1} = 0 \tag{4.3.71}$$

Because the reserve rate (R^{re}) and deposit rate (R^d) are known when expectations are formed, equation 4.3.71 can be defined as $R_t^{re} = R_t^d$. Moreover, equations 4.3.69 and 4.3.70 lead to the arbitrage condition expression which indicates that the spread of government bonds to short term rates is a fraction Δ of the spread on corporate bonds. Thus, the parameter Δ will depend on the relative spread between government bonds and corporate bonds.[23]

[21] If banks earned no excess returns (that is, if the spreads =0), banks wouldn't accumulate net worth. So long as the banks can earn those returns, they will opt to accumulate net worth to take advantage of the credit spreads as opposed to the case where they earned no excess returns.

[22] This means that when the holding of corporate bonds increases in the bank's balance sheet, the costs for the banking sector are higher than having government bonds, since the increases of the former are 1:1.

[23] If $\Delta = 1$, the government bond yield would be equal to that of the corporate bond, implying that both types of bonds are perfect substitutes and have the same level of risk.

Without the presence of financial frictions, long and short rates would not be different (what is to say a flat yield curve), and the central bank wouldn't be able to influence economic activity by using LSAP. If the rates were equal, we would have the case where the financial markets are frictionless in the sense that the banks acquire assets to the point where the discounted return on each asset (R^F and R^B) equals the discounted cost of deposits (R^d) and no spread will be generated. However, the presence of the cost in the optimization process allows for the friction to have an effect on lending spreads.

Hence, if the central bank faces a ZLB on the short-term policy rate ($R_t^{re} = 0$), then the way the central bank can opt to facilitate credit and attain financial stability is by using unconventional monetary policy that affects long term rates on government bonds R^B and corporate bonds R^F. However its worth noting that the fact that $\Delta < 1$, when monetary authorities implement long scale asset purchases (LSAP) in the form of private bonds, excess returns are higher when compared to purchases of government debt (see Figure C.2 in Appendix.).

4.3.8 Market Clearing Conditions

Goods market

In equilibrium, because retailers repackage wholesale output (Y_t^w), the supply of wholesale output equals aggregate demand for retail output,Y_t aggregated for the continuum of f retailers.

$$Y_t^w = \int_0^1 Y_t(f)\, df = Y_t \int_0^1 \frac{P_t(f)}{P_t}^{-\epsilon_p} df = Y_t v_t^p \tag{4.3.72}$$

where v_t^p is a measure of price dispersion which can be written recursively as:

$$v_t^p = (1-\phi_p)\left(\Pi_t^{\#}\right)^{-\epsilon_p} + \phi_p \Pi_t^{\epsilon_p} v_{t-1}^p \tag{4.3.73}$$

where the aggregate price level or Inflation in the model evolves as follows:

$$1 = (1-\phi_p)(\Pi_t^{\#})^{1-\epsilon_p} + \phi_p \Pi_t^{\epsilon-1} \tag{4.3.74}$$

Labour Market

Because households supply labour to labour unions, in equilibrium household supply L_t equals aggregate demand for labour unions output,$L_{d,t}$ aggregated for the continuum of h indexed unions.

$$L_t = \int_0^1 L_{d,t}(h)\, dh = L_{d,t} \int_0^1 \frac{w_t(h)}{w_t}^{-\epsilon_w} dh = L_{d,t} v_t^w \tag{4.3.75}$$

where v_t^w is a measure of wage dispersion, which measures the wedge between household labour supply and labour used for production and which can be written recursively as:

$$v_t^w = (1-\phi_w)\left(\frac{w_t^{\#}}{w_t}\right)^{-\epsilon_w} + \phi_w \left(\frac{w_t}{w_{t-1}}\right)^{\epsilon_w} \Pi_t^{\epsilon_w} v_{t-1}^w \tag{4.3.76}$$

where the aggregate real wage in the model evolves according to:

$$w_t^{1-\epsilon_w} = (1-\phi_w)(w_t^{\#})^{1-\epsilon_w} + \phi_w \Pi_t^{\epsilon_w - 1} w_{t-1}^{1-\epsilon_w} \tag{4.3.77}$$

Bonds Market

Market-clearing conditions for long term bonds imply that the supply of long term perpetual debt issued by the wholesale firm (f_t^w) and long term perpetual government bonds (b_t^G) are in hands of the banking sector or the monetary authority:

$$f_t^w = f_t + f_t^{cb} \tag{4.3.78}$$

$$b_t^G = b_t + b_t^{cb} \tag{4.3.79}$$

Aggregated conditions for all agents in the model allow to have the market clearing condition for the economy. The aggregate resource constraint is defined as:

$$Y_t = C_t + I_t + G_t \tag{4.3.80}$$

The equations that make up the equilibrium of the model are in Appendix C.1.

4.4 Calibration

The model described in the previous section is calibrated to analyse the effects of different exogenous shocks on real activity. The model parameters take on relatively standard values retrieved from the literature or have been adapted to be consistent with data from the European case. The calibrated parameters are presented in Table 4.1 and the steady state of the model is defined in Appendix C.2.

As it is standard in literature, the parameter α measuring the share of capital in the production function is set to $\frac{1}{3}$, the discount factor β is set to 0.995, implying an annual steady state real interest rate of 2 percent; and the steady state capital depreciation $\delta_0 = 0.025$. Additionally, following Sims and Wu(2021) $\delta_2 = 0.01$, suggesting a volatile capital utilization by wholesale firms. The habit formation parameter b is set to 0.80 and inverse Frisch elasticity is set to 1.[24] Finally, κ is set to $1 - 40^{-1}$ to indicate a ten year duration (or 40 quarters) for both corporate and public bonds. For the shock processes, all AR(1) persistence parameters are set to 0.9 and all the st. deviations of the shock are set to 0.01. The values on AR(1) parameter of the exogenous corporate ρ_f and government bond ρ_b purchases by the monetary authority are set to 0. 97.

Table 4.1 Calibrated parameters

Parameters	*Description*	*Value*
α	Capital share	1/3
β	Discount factor	0.995
δ_0	Steady state capital depreciation for wholesale firms	0.025
δ_2	Squared term capital adjustment cost	0.01
b	Habit formation parameter	0.80
ψ	Fraction of investment financed with corporate debt	0.80
ψ_k	Investment adjustment cost faced by Capital producers	2
ϕ_p	price stickiness	0.75
ϕ_w	wage stickiness	0.75
ϵ_p	price markup	11
ϵ_w	wage markup	11
η	Frisch elasticity	1
κ	Coupon decay parameter for long term assets	$1 - 40^{-1}$
ρ_r	Taylor rule interest Rate Smoothing parameter	0.8
ϕ_Π	Taylor rule Inflation coefficient	1.5
ϕ_Y	Taylor rule Output coefficient	0.15
sr	Taylor rule parameter	0.0025
g	Government spending share of output	0.5
by	Steady state government debt / Y	0.8
b^{cs}	Central bank balance sheet / Y	0.1
$bcbG$	Percentage of Central Bank balance sheet government bond holdings	0.9

[24]The inverse Frisch elasticity describes how responsive is the labour supply to changes in the real wage. Lower calibrated values of inverse Frisch elasticity imply more willingness of people to work if real wage increases. Sensitivity analysis for this parameter is provided in Figure C.4.

Following Sims and Wu (2021) firms are set to finance 80% of their new investments by issuing corporate debt so ψ= 0.80. However different values of the parameter are provided in Figure C.3 to see the sensitivity of the model to different parameter values. The investment adjustment cost ψ_k is set = 2. We also follow them by setting the price ϕ_p and wage stickiness ϕ_w to 0.75, which captures a year between changes in prices (for retailers) and wages (for labour unions). Moreover, $\epsilon_p = \epsilon_w$=11, indicating mark-ups in the price and wage steady state of 10 %. The Taylor rule parameters are standard, set to: $\rho_r = 0.8$, $\phi_\Pi = 1.5$, $\phi_Y = 0.15$ and $s_r = 0.0025$.

Some parameters have been adjusted to adapt to the European case: Parameter κ_1^b is calibrated targeting a steady state excess return (or spread) of private bonds over the MRO deposit rate ($R^F - R^d$) , of 430 basis points (annualized).[25] Moreover, parameter Δ is set to 1/3, implying a third of the spread for observed for government bonds (10 year bond yields) over the deposit rate ($R^B - R^d$), which corresponds to the average spread ratio of corporate (BAA) and long term bonds with respect to short rate (MRO) for the period 2000-2021. In particular, the average spread for corporate BAA over the short rate is 4.3, while that of 10 year bond yields is of 1.4 percent (see Figures C.5 and C.6). Additionally, the government spending share of output is set to 50% of output in steady state and government debt is set to 80 percent of output.[26] The central bank's balance sheet is assumed to be 10 % of output in the steady state. Furthermore, we set 90 % of central bank's assets to be government bonds. By not considering the CBPP3 program, for which there is no mechanism in the model, the purchase of government debt would be approximately 90% of total APP program implemented by ECB, whereas that of corporate debt would be the remaining 10 %.

4.5 Results

This section shows the effects on real activity and other financial and macroeconomic aggregates of (i) a government spending shock that doesn't affect the financial sector, and *two* shocks that do affect financial institutions: (ii) a debt-financed fiscal policy shock (where debt is acquired by financial institutions) and (iii) a public LSAP shock by monetary authorities (where central bank acquires the public debt issued).

[25]This is consistent with the average spread of 4.3 percent between Moody's Seasoned Baa Corporate Bond Yield and short term (MRO fixed) rate for ECB from 2000-2021. This spread of 0.043 works in the same fashion as the spread $(1 + spr^F)^{1/4}$ that is targeted in Sims and Wu(2021), although they find that the spread is 3 percent annualized for the United States.

[26]We use an average government spending of around 50 percent for the period 2000-2020 and the average consolidated value of debt to GDP of European 19 countries for the same period.

We first analyze each scenario under *normal times* (when the ZLB on short term policy rate doesn't bind) and then compare the responses to a regime where the ZLB is binding to understand the implications of a constrained short term policy rate. This allows the use of LSAP not to be restricted to ZLB, giving flexibility to the model for analyzing the effects of unconventional monetary policy even when rates may be in positive territory.

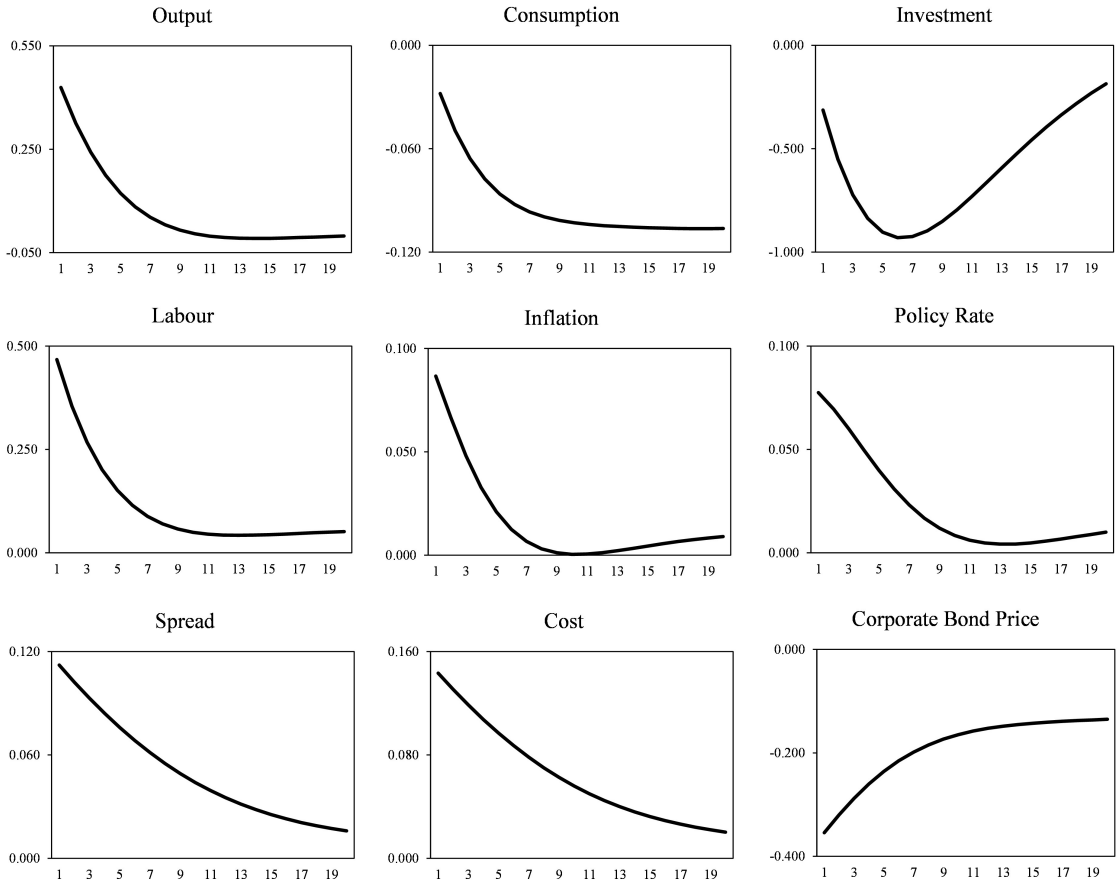
4.5.1 Indebtedness Under Financial Intermediation

This section shows the effects on real activity and other financial and macroeconomic aggregates of a government spending shock and a debt fiscal policy shock. The differentiated effect between the government spending shock and the shock financed with the issuance of long-term public debt comes from who acts as the sovereign debt holder.[27] Figure 4.3 depicts the dynamic response functions following a government spending shock. The effect of a fiscal expansion generates an increase in aggregate demand, thereby increasing output in the economy in line with standard literature. Given the government spending shock has a positive effect on aggregate demand, this puts pressure on the price level. Under conventional monetary policy the reaction of the monetary authority is to increase the policy rate (as stated by the Taylor rule) to fight inflationary pressures. Furthermore, the effects of higher short-term rates lead to increased savings in the economy, decreasing consumption. Likewise, this increase in the interest rate leads to an increase in employment levels derived from an increase in labour supply (substitution effect of leisure), and increased labour demand by firms seeking to increase production. However, consumption is mainly affected by the increase in taxes to finance spending. Given debt is set exogenously, the fiscal expansion implies increased taxation to households acting as the driver of consumption's response.

The increase in economic activity makes companies seek to increase their investment levels. However, as stated in equation 4.3.24, to finance new investment, firms are subject to an investment-in-advance constraint which implies that part of the investment must be financed through issuance of long-term corporate bonds. The fall in the price of bonds leads companies to consequently see their investment reduced. The government spending shock in the model shows a crowding out effect on consumption and investment.

[27] It should be kept in mind that because the Ricardian Equivalence doesn't hold, a government debt shock and a government spending shock produce differenciated effects.

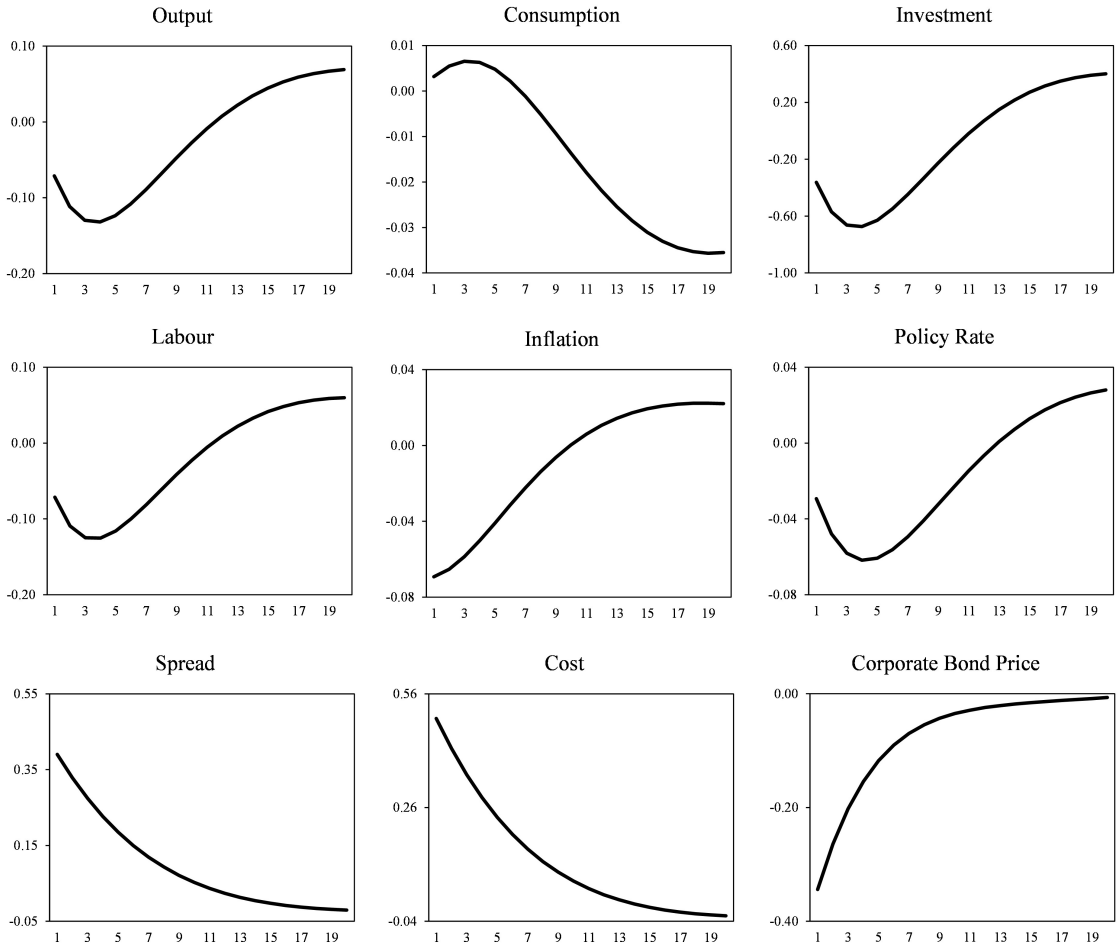
Figure 4.3 Government spending shock



Responses to a 1 percent government spending exogenous shock in percentage deviations from steady state. Horizontal axis is measured in quarters.

Figure 4.4 shows the dynamic response following a debt shock. In a similar way to the results of Chapter 2 and 3, debt issuance puts pressure on the bank's balance sheets. As new assets are held in bank's balance sheets, financial institutions subject to capital requirements face higher cost for holding assets. Balance-sheet constrained financial institutions and capital requirements faced by them, create a credit spread that end up affecting the firm decisions and in turn affect real economic activity. Moreover, the effects on real activity are transmitted to the real economy by the wholesale firms who take on investment to further stimulate real activity. When banks hold sovereign debt, there is a trade-off between government financing and firm financing, reducing in turn the credit to the productive sector.

Figure 4.4 Debt financed fiscal spending



Responses to a 1 percent debt exogenous shock in percentage deviations from steady state. Horizontal axis is measured in quarters.

The figure shows higher costs for financial institutions, leading to an increase in credit rates for companies, causing a fall in the price of bonds, which limits the investment capacity of companies given the investment-in-advance constraint. The higher costs faced by financial institutions end up pushing up the credit spreads and reducing investment of the wholesale firm. Moreover, the fall in investment further leads to a contraction in output which has deflationary consequences in the economy.

4.5.2 LSAP Shock/ long term government perpetual debt purchases by monetary authorities

Large Scale Asset Purchases of public debt indicate an exogenous increase in central bank's sovereign debt holding, where purchases of government bonds are financed by creating reserves.[28] In the previous section, under a debt shock, financial intermediaries acted as the holders of public debt which in turn contracted credit to the private sector (firms) as the tightening of the balance sheet constraint crowds out banks' purchases of corporate bonds. In this section, public debt is absorbed by the central bank through asset purchases to analyse how the liquidity situation improves when the central bank intervenes, by allowing to stimulate investment and real activity.[29] Because banks are faced with a balance sheet constraint, as monetary authority acquires some of the government debt issued by the fiscal authority, that would otherwise be acquired by the banks, it allows to free up space on the balance sheet of financial institutions to finance other assets such as corporate debt.

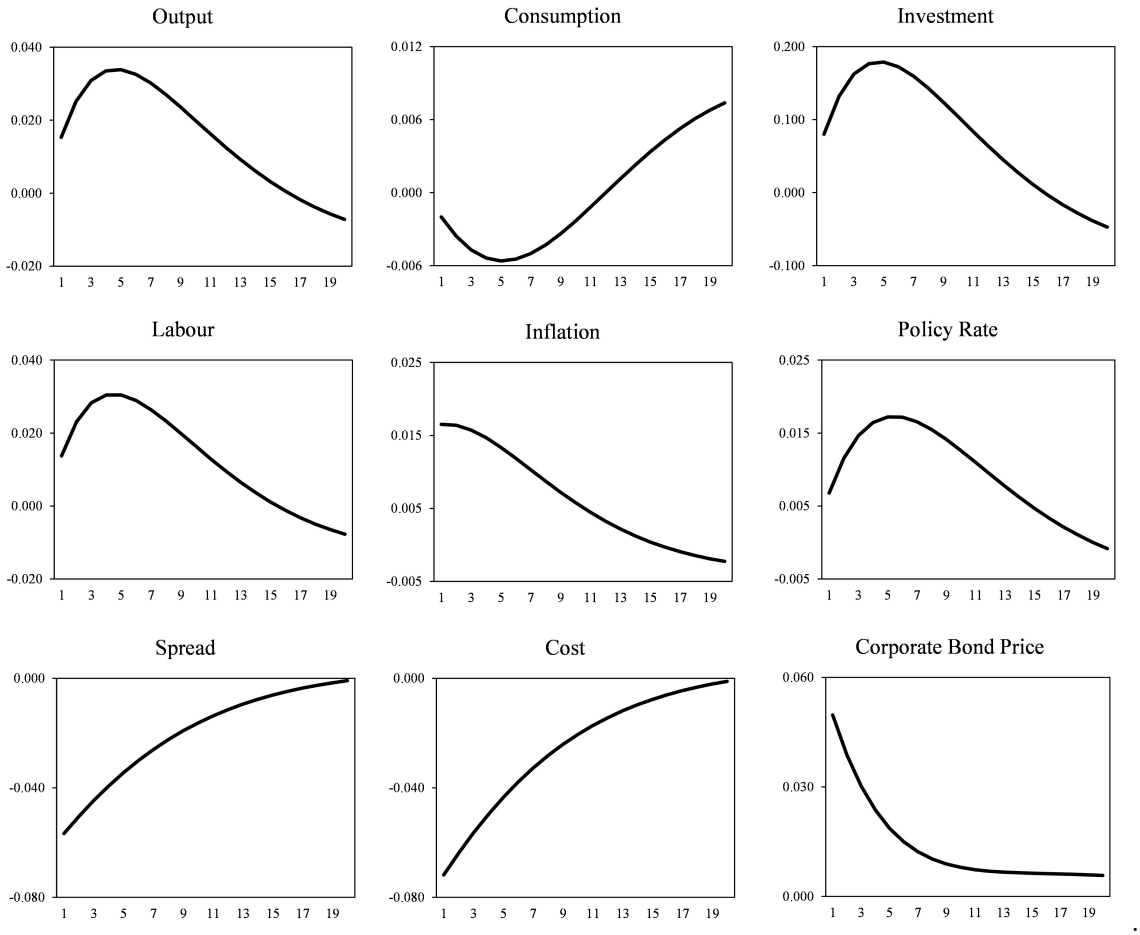
As shown in figure 4.5, the cost for financial institutions falls and reduces the interest rate on corporate debt which reduces the spread. This in turn means that debt issuing firms (the wholesale firms) can increase investment as higher debt prices imply a looser loan-in advance constraint, thus increasing real activity.[30] So, by having the central bank absorbing public assets, the cost for financial institutions is reduced thus increasing the supply of private credit, which allows them to increase investment and real activity. Also, under an active LSAP policy, output increases as aggregate demand is stimulated, pushing up price levels in the economy. This in turn, following the Taylor rule, causes the monetary authority to react by raising the policy rate as inflation rises, reducing consumption. As LSAP works by increasing the assets held by the central bank through reserve issuance, these additional reserves are being funded with additional deposits in financial institutions.

[28]The model allows for an increase in the purchase of public or corporate debt by monetary authorities. Corporate bond holdings by the central bank, here defined as Credit Easing (CE) policy, have the same responses of a LSAP shock, although with larger magnitude because the banks' balance sheet is less constrained in the capital requirements for government bonds by Δ, which is set to one-third. See Figure C.2 for a comparison of both policies.

[29]It should be understood as a LSAP shocks where the central bank is purchasing *existing* long term government debt B^{cb} and the shock does not simulate debt shock.

[30]If wholesale firm didn't have this constraint such that $\psi = 0$, unconventional monetary policy effects on bond prices wouldn't have an effect on real activity through increase investment and its effects on aggregate demand. It is in fact that firms are constrained to finance new investments by debt issuance that causes changes in corporate bond prices to impact firms decision to invest.

Figure 4.5 Public LSAP / Quantitative easing shock



Responses to a 1 percent public QE exogenous shock in percentage deviations from steady state. QE is defined as an exogenous increase in central bank government debt holdings in its balance sheet. Horizontal axis is measured in quarters.

The transmission mechanism: The implementation of Large Scale Asset Purchases by the central banks aims at lowering long-term rates through purchases of bonds by increasing demand for those assets. This form of unconventional monetary policy has real effects through the presence of financial frictions in the intermediation process, the existence of market segmentation and the constrain firms face to invest.[31] These ingredients account for unconventional monetary policy in the form of QE and macroprudential regulation in terms of capital requirements that affect the long-term rates of government debt. Given that banks are faced with capital requirements under increased assets, when monetary authorities acquire government

[31] Markets are segmented in the sense that agents don't directly interact with each other, but do so through financial intermediation to access any type of securities.

bonds by implementing LSAP through creating reserves, it eases space in the banking institutions' balance sheets. This increases the supply of credit in the credit markets and pushes up the price of long term bonds, allowing for increase investment. Overall, as the central bank acquires the debt, it frees up space in the balance sheets of the financial system in order to stimulate private credit. Thus, the central bank acts through two channels to provide liquidity: by directly purchasing assets in the bond markets but also by freeing up space in the financial sector to further stimulate lending to private sector (firms). The results highlight how when central bank acts as holder of government debt it allows to stimulate credit provision to the real economy, consistent with the literature (see e.g. Albertazzi et al (2021), Boeckx et al (2020) Gambetti and Musso (2017) Rodnyansky and Darmouni (2017), among others).

4.5.3 How do shocks compare when facing the zero lower bound?

The analysis of monetary policy in the context of the ZLB is complex given the non-linearity in the policy function on nominal interest rate. The non-linearity resulting from Occasionally Binding Constraints implies that linearization techniques and higher-order perturbations wouldn't handle the ZLB as an interest rate peg results in equilibrium indeterminacy. Several approaches in the DSGE literature are used to solve models with Occasionally Binding Constraints. This chapter relies on the OCCBIN toolkit by Guerrieri and Iacoviello (2015), to generate impulse responses to analyse the effects under the lower bound of short term rate.[32] The toolkit uses a piecewise (or two-state) linear approximation driven by a Markov chain and treats the model economy as switching between regimes where one regime would be that of a biding constraint and the other regime would be that of an unconstrained regime. The approximation of the policy functions in each regime relies on perturbation methods (taylor approximation). To drive the economy to the constraint, a sequence of shocks are generated to cause the ZLB of the policy rate to bind for some periods (quarters).[33] Afterwards the same series of shocks is generated and in the 10^{th} quarter an additional shock is added for each independent exercise in this section. The simulation then takes the difference between the simulation with

[32]Models with OBCs can be simulated using global solution methods, which allow to capture model non-linearities, however the ability to capture all model non-linearities is restricted to "small-scale" models given the increasing computation cost as the model gets bigger. Among the other methods used in the literature are dynareOBC by Holden (2016) and OCCBIN by Guerrieri and Iacoviello (2015).

[33]The economy is hit with a sequence of contractionary conventional monetary shocks, where the size of these shocks are large enough to retain the economy at the ZLB for 10 quarters.

the additional exogenous shock and the simulation without it, showing that for the 10 periods that the constraint binds, the short-term rate stays at zero.

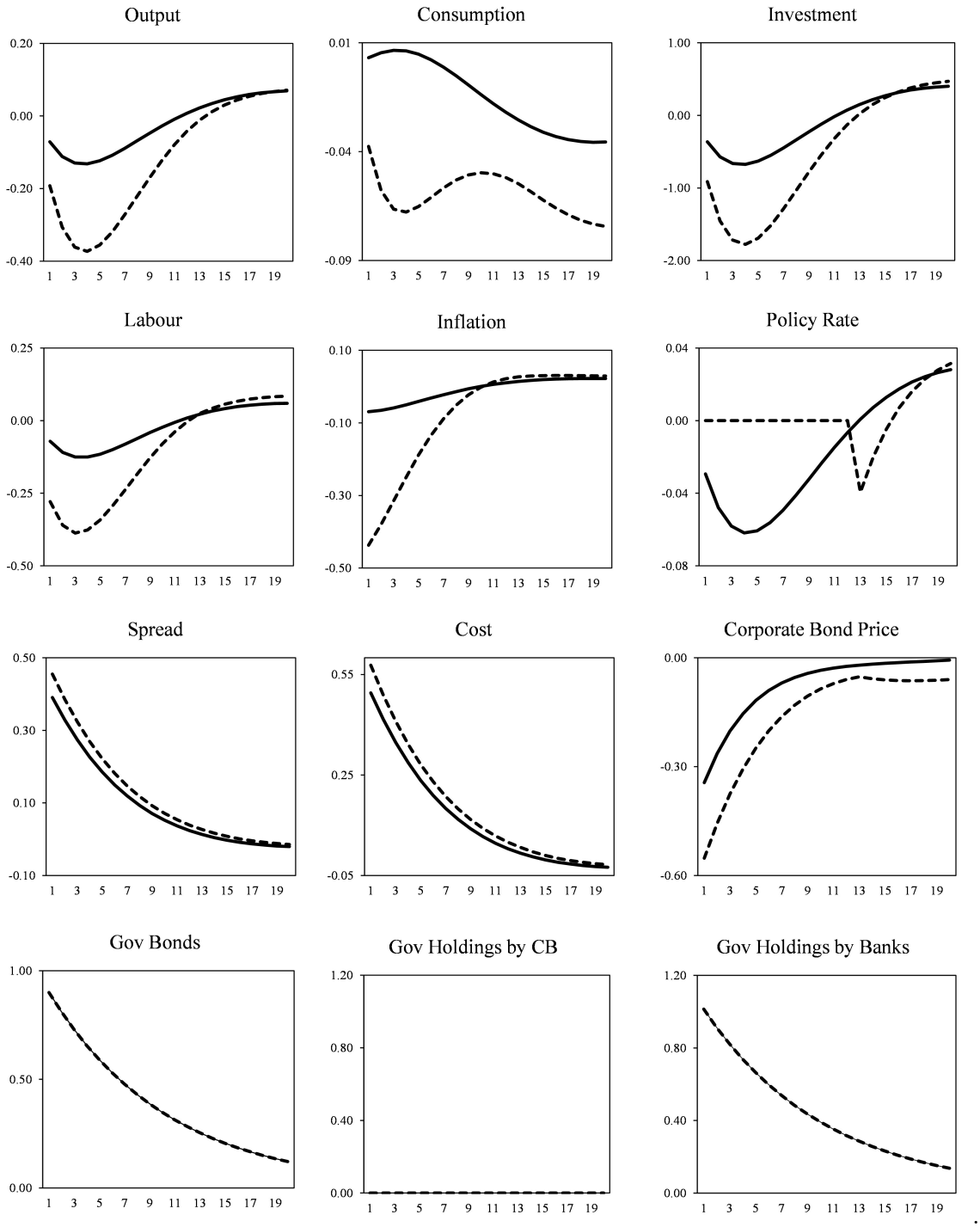
This section discusses two different shocks: a debt shock and a QE/LSAP shock. The reason to focus on these two shocks is to compare how financial frictions in financial intermediation have a consequence on real activity.[34] As discussed in the previous section, the former describes the situation where banks hold the debt whereas the latter describes the situation in which the debt is acquired by the central bank. Figure 4.6 shows a debt shock where the commercial banks acquire public debt, which exerts pressure on their balance sheets, crowding out private lending and showing a reduction in investment. In contrast, Figure 4.7 displays the case where the central bank acts as the holder of sovereign debt (QE shock) the opposite is observed.

Under normal times, the transmission mechanism remains as already explained in the previous sections. This section focuses on the differences in responses under the binding ZLB on short term rates. The effects under the ZLB are shown in the *dashed lines* and can be compared to the responses under normal times (solid lines), which refer to the case where the ZLB is not binding.

As shown in Figures 4.6 and 4.7, output, consumption, investment, labour and inflation are observed to react more in the period where the policy rate is bounded to zero, consistent with the literature on ZLB which anticipates higher multipliers compared to the times where the constraint is not binding. The responses under a debt shock (Fig 4.6) cause that when banks face higher costs for holding additional assets, the credit spread rises. This instigates a contraction in investment which further reduces aggregate demand leading to lower output and inflation in the economy. In normal times, the central bank would react by relying on conventional adjustments to the short-term rate to stimulate economic activity. Yet, under a binding lower bound, the policy rate cannot react in response to changes in output and inflation, leading to amplified responses for the economy. This means that by having the short-term rate restricted to zero, inflation is lower than in normal times, which implies higher real rates for firms (and lower corporate bond prices) contracting investment even more in the lower-bound scenario. The larger fall in investment in turn leads to lower labour input for production and lower output in the economy compared to normal times.

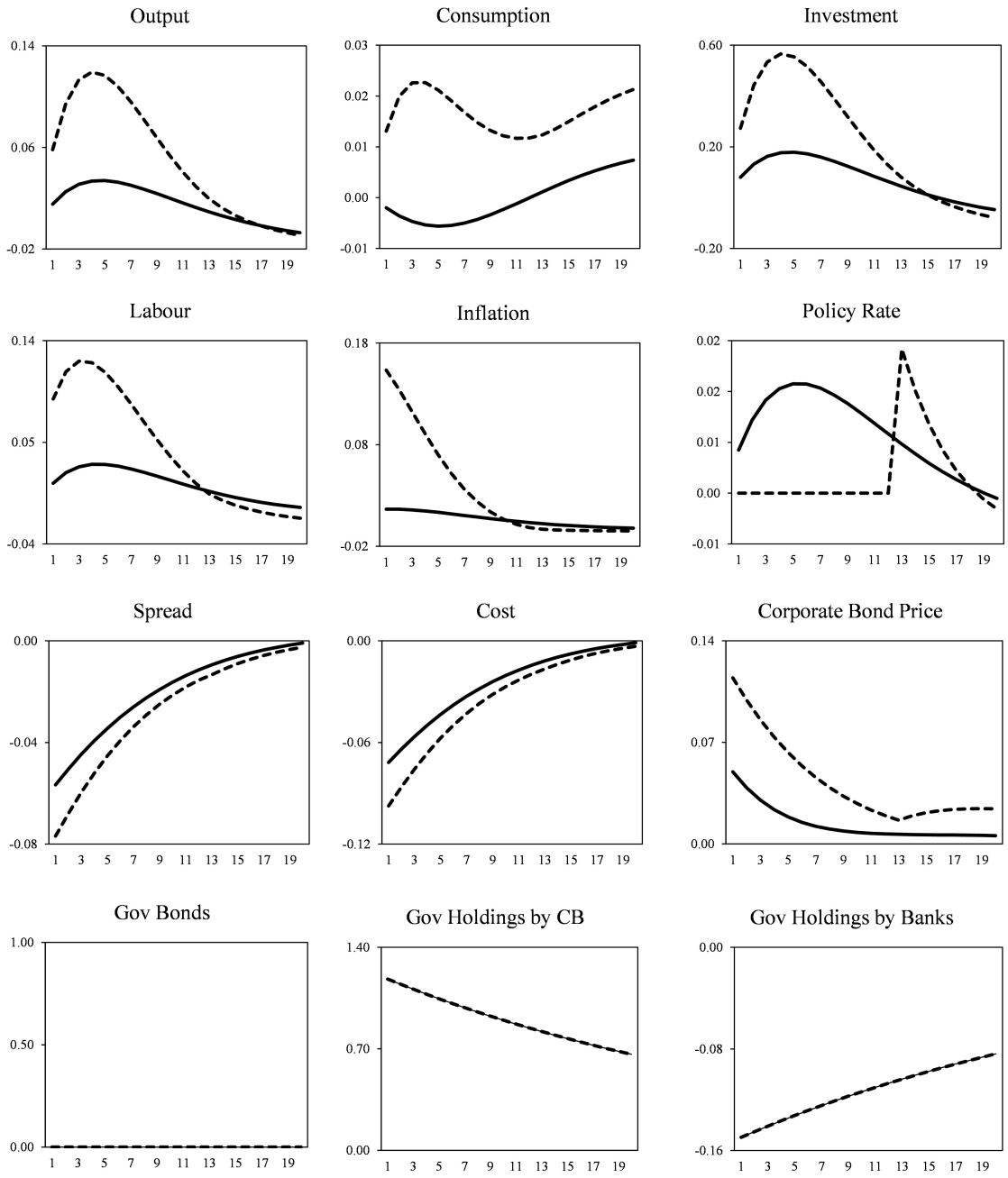
[34] As discussed before, the government spending shock has no effect in the financial sector and thus the mechanism of transmission is not observed. However, for the curious reader, Figure C.1 presents the exercise of a Government spending shock comparison with ZLB binding and not binding.

Figure 4.6 Government Debt Shock under ZLB



Responses to a 1 percent debt exogenous shock in percentage deviations from steady state. Horizontal axis is measured in quarters. Solid lines display the dynamics where short-term rate is not constrained to the ZLB and dashed lines display the dynamics where the ZLB binds (set to bind for 10 quarters).

Figure 4.7 Public LSAP / Quantitative Easing under ZLB



Responses to a 1 percent public QE exogenous shock in percentage deviations from steady state. QE is defined as an exogenous increase in central bank government debt holdings in its balance sheet. Solid lines display the dynamics where short-term rate is not constrained to the ZLB and dashed lines display the dynamics where the ZLB binds (set to bind for 10 quarters). Horizontal axis is measured in quarters.

In a similar vein, under a LSAP shock (Fig 4.7), the acquisition of debt by central bank eases balance sheets for commercial banks which further allows them to facilitate credit, stimulating investment and output. When conventional monetary policy can be used to affect short term rates, as the economy faces higher inflation, the central bank responds by rising the nominal rate, which in turn eases the positive effects on aggregate demand. However, when the ZLB prevents the central bank to react and adjust the nominal rate, aggregate demand expansion is higher than under active conventional monetary policy. Note that by not making changes to the short-term rate, the response in consumption are positive during the time the ZLB binds, as a consequence of greater economic activity and the fall observed in "normal times" (non binding ZLB constraint) does not occur, which responds to an increase in saving given higher short-term rates when they are not bound to zero.

These results show how the LSAP program stimulated economic activity, lower unemployment and boosted inflation, considering the context after the financial crisis of low growth and low inflation, in accordance to the mandate objectives by the central bank. These results highlight the mechanisms that allow the monetary authority to meet its mandate objectives of price and financial stability through the LSAP program. Regarding the price stability objective, the effects of asset purchases help boost inflation and stimulate spending in the economy. It also shows the effectiveness of the LSAP program at achieving its financial stability objective by allowing to ease the tight credit conditions for borrowers seeking to invest. Furthermore, the model evaluates the role of LSAP when conventional policy faces the ZLB and suggest state contingency upon the state of the economy. This means that the effects on spending and inflation are amplified when short term rates are constrained to the lower bound, suggesting that the policy is even more effective at boosting inflation and output at times where conventional tools are constrained to the lower bound.

As here discussed, the main conclusion arising from this section is that the effects on macroeconomic activity are amplified when the policy rates for conventional monetary policy are constrained to zero. The mechanism yields similar results to those in the original model by Sims and Wu (2021), although the driving mechanism that impacts the balance sheets of commercial banks is now consistent with capital regulation for financial institutions.

4.6 Concluding Remarks

In response to the financial crisis, the European Central Bank and other central banks led short-term monetary policy rates to zero in an attempt to stimulate economic activity. With the impossibility of using conventional monetary policy to provide liquidity to the real economy, central banks launched long-term asset purchase packages as an unconventional policy measure.[35]

This chapter studies how unconventional monetary policy in the form of LSAP of government securities allows for financial stability by improving credit conditions in the economy. By relying on a DSGE framework we model the impact of of LSAP on financial and real variables using the European Union as the case of study. This chapter contributes to the literature by proposing a model accounting for interactions among fiscal, macroprudential and unconventional monetary policy, while also compares the responses to the scenario when short-term rates are constrained to the ZLB. Results from the calibrated model show how asset purchases by the Central Bank boost the economy by providing liquidity through purchases of government debt and allowing banks to further increase credit, achieving financial stability. The mechanism of transmission through which LSAP influence real activity comes from how the wholesale firms face investment constraints and financial institutions face capital requirements which create a credit spread. [36] The asset purchases by the central bank ease the balance sheet of financial intermediaries allowing them to expand credit to firms seeking to invest. This means that as the central bank buys assets that consist of long-term government bonds issued by fiscal authorities, it eases balance sheets of banks subject to capital requirements that in turn can provide liquidity to the private sector to increase investment and further stimulate real activity. Also, results indicate that the effects of an unconventional monetary policy in the form of LSAP show to be larger when short term rates are constrained to zero.

[35] Other unconventional policies include Forward guidance and Negative rates, no addressed in this work.

[36] This can be thought of being analogous to the way firms (entrepreneurs) faced collateral constraints in Chapter 2 which limited their ability to invest and increase output. In both cases the fact that agents face constraints that affect their investment decisions allows for the mechanisms to have real economic impact.

In terms of policy implications, the current context has shifted central bank's focus from the acquisition of long-term assets and instead on the unwinding/reversal of the LSAP programs. The ECB decided in June 2022 to reverse the LSAP program at a predictable pace to avoid disruption of market functioning. The unwinding of LSAP is set to be more gradual than the expansion of balance sheets by purchasing long term assets. Also, the unwinding of the LSAP program happens in a setting where conventional policy will be relied on to tackle the persistence in inflation. In the current high inflation context, the short-term policy rate has left the ZLB, leaving room for it to operate normally. In this regard, although the LSAP program is unwinding, the ECB has clarified that their policy rate is the primary tool used for restoring price stability and has increased its policy rate since mid 2022. When thinking about unconventional measures, the model shows that its impact is highly state contingent. This means that in normal times (where both conventional and unconventional monetary policies can be implemented and the ZLB is not binding), LSAP programs tend to have lower effects relative to the times where the economy is constrained by the lower bound. As such, the impact of unwinding unconventional measures depends on the size of the LSAP reversal relative to conventional monetary tightening, but also that under "normal" times the program shows lower effects compared to a binding lower bound scenario.

Appendix C

C.1 Equations of the model

The equilibrium is comprised of the following endogenous variables: $\{Y_t,\, C_t,\, I_t,\, G_t,\, L_t,\, L_{d,t},\, \hat{I}_t,\, Y_t^w,\, K_t,\, u_t,\, w_t,\, w_t^{\#},\, mrs_t,\, \Pi_t\ ,\, \Pi_t^{\#},\, p_t^k,\, p_{wt},\, f_{1t},\, f_{2t},\, x_{1t},\, x_{2t},\, v_t^p,\, v_t^w,\, Q_t,\, Q_t^B,\, R_t^F,\, R_t^B,\, R_t^d,\, R_t^{re},\, R_t^{tr},\, M_{1t},\, M_{2t},\, mu_t,\, \Lambda_t,\, f_{tw},\, f_t,\, b_t,\, re_t,\, d_t,\, n_t,\, f_t^{cb},\, b_t^{cb},\, b_t^G,\, A_t,\, A_t^T\}$ and the corresponding 47 equations:

HOUSEHOLDS:

$$\Lambda_{t,t-1} = \frac{\beta_t \mu_t}{\mu_{t-1}} \tag{C.1.1}$$

$$\mu_t = (C_t - b_t C_{t-1})^{-1} - \beta b(\mathbf{E}_t\, C_{t+1} - bC_t)^{-1} \tag{C.1.2}$$

$$\chi L_t^{\eta} = mrs_t \mu_t \tag{C.1.3}$$

$$1 = Rd_t\, \mathbf{E}_t\, \Lambda_{t+1} \Pi_{t+1}^{-1} \tag{C.1.4}$$

LABOUR UNIONS:

$$w_t^{\#} = \frac{\epsilon_w}{\epsilon_w - 1} \frac{f_{1t}}{f_{2t}} \tag{C.1.5}$$

$$f_{1t} = mrs_t w^{\epsilon_w} L_{d,t} + \phi_w\, \mathbf{E}_t\, \Lambda_{t+1} \Pi_{t+1}^{\epsilon_w} f_{1,t+1} \tag{C.1.6}$$

$$f_{2t} = w^{\epsilon_w} L_{d,t} + \phi_w\, \mathbf{E}_t\, \Lambda_{t+1} Pi_{t+1}^{\epsilon_w - 1} f_{2,t+1} \tag{C.1.7}$$

CAPITAL PRODUCING FIRMS:

$$\hat{I}_t = \left[1 - \frac{\psi_k}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2\right] I_t \tag{C.1.8}$$

$$1 = p_t^k\left[1-\left(\frac{\psi_k}{2}\frac{I_t}{I_{t-1}} - 1\right)^2 - \psi_k(\frac{I_t}{I_{t-1}} - 1)\left(\frac{I_t}{I_{t-1}}\right)\right] + \mathbf{E}_t\,\Lambda_{t+1} p_{t+1}^k \psi_k\left(\frac{I_{t+1}}{I_t} - 1\right)\left(\frac{I_{t+1}}{I_t}\right)^2 \tag{C.1.9}$$

RETAIL FIRMS:

$$\Pi_t^{\#} = \frac{\epsilon_p}{(\epsilon_p - 1)}\frac{x_{1t}}{x_{2t}} \tag{C.1.10}$$

$$x_{1t} = p_{wt} Y_t + \phi_p\,\mathbf{E}_t\,\Lambda_{t+1}\Pi_{t+1}^{\epsilon_p} x_{1t+1} \tag{C.1.11}$$

$$x_{2t} = Y_t + \phi_p \Lambda_{t+1}\Pi_{t+1}^{\epsilon_p - 1} x_{2t+1} \tag{C.1.12}$$

WHOLESALE FIRMS:

$$w_t = (1-\alpha) p_{wt} A_t (u_t K_{t-1})^{\alpha} L_{d,t}^{-\alpha} \tag{C.1.13}$$

$$P_t^k M_{2t}(\delta_1 + \delta_2(u_{t-1})) = \alpha p_{wt} A_t (u_t K_{t-1})^{\alpha-1} L_{d,t}^{1-\alpha} \tag{C.1.14}$$

$$p_t^k M2_t = \mathbf{E}_t\,\Lambda_{t+1}\left[(\alpha p_{wt+1} A_{t+1}(u_{t+1}K_t)^{\alpha-1} u_{t+1} L_{d,t+1}^{1-\alpha} + p_{t+1}^k M2_{t+1}\left(1-\delta_0-\delta_1(u_{t+1}-1)-\frac{\delta_2}{2}(u_{t+1}-1)^2\right)\right. \tag{C.1.15}$$

$$Q_t M1_t = \mathbf{E}_t\,\Lambda_{t+1}\Pi_{t+1}^{-1}(1 + \kappa Q_{t+1} M1_{t+1}) \tag{C.1.16}$$

$$\frac{M1_t - 1}{M2_t - 1} = \frac{1}{\psi} \tag{C.1.17}$$

$$Y_t^w = A_t (u_t K_{t-1})^{\alpha} L_{d,t}^{1-\alpha} \tag{C.1.18}$$

$$K_t = \hat{I}_t + \left[1 - \delta_0 - \delta_1(u_t - 1) - \frac{\delta_2}{2}(u_t - 1)^2\right] K_{t-1} \tag{C.1.19}$$

$$\psi p_t^k \hat{I}_t = Q_t(f_{wt} - \kappa \Pi_t^{-1} f_{wt-1}) \tag{C.1.20}$$

FINANCIAL SECTOR:

$$\mathbf{E}_t\,\Lambda_{t+1}\Pi_{t+1}^{-1}(R_{t+1}^F - R_t^d) = \mathbf{E}_t\,\Lambda_{t+1}\Pi_{t+1}^{-1}\Big[\kappa_1^b + \kappa_2^b[\phi_t^b - \phi^b]\Big] \tag{C.1.21}$$

$$\mathbf{E}_t\,\Lambda_{t+1}\Pi_{t+1}^{-1}(R_{t+1}^B - R_t^d) = \Delta\,\mathbf{E}_t\,\Lambda_{t+1}\Pi_{t+1}^{-1}\Big[\kappa_1^b + \kappa_2^b[\phi_t^b - \phi^b]\Big] \tag{C.1.22}$$

$$\mathbf{E}_t\,\Lambda_{t+1}(R_t^{re} - R_t^d)\Pi_{t+1}^{-1} = 0 \tag{C.1.23}$$

$$Q_t f_t + Q_t^B b_t + re_t = d_t + n_t \tag{C.1.24}$$

$$\phi_t^b = \frac{Q_t f_t + \Delta Q_t^B b_t}{n_t} \tag{C.1.25}$$

$$\begin{aligned} div_t^B = \Pi_t^{-1}\Big[&(R_t^F - R_{t-1}^d)Q_{t-1}f_{t-1} + (R_t^B - R_{t-1}^d)Q_{t-1}^B b_{t-1} \\ &+(R_{t-1}^{re} - R_{t-1}^d)re_{t-1} + R_{t-1}^d n_{t-1} - C^b(.)n_{t-1}\Big] - n_t \end{aligned} \tag{C.1.26}$$

$$C^b(.) = \kappa_1^b[\phi_t^b - \phi^b] + \frac{\kappa_2^b}{2}[\phi_t^b - \phi^b]^2 \tag{C.1.27}$$

$$n_t = \Pi_t^{-1}\Big[(1-\delta^b)n_{t-1}\Big] + div_t^B \tag{C.1.28}$$

CENTRAL BANK:

$$ln(R_t^{tr}) = (1-\rho_r)ln(R^d) + \rho_r ln(R_{t-1}^{tr}) + (1-\rho_r)\Big[\phi_\Pi[ln(\Pi_t) - ln(\Pi)] + \phi_y[ln(Y_t) - ln(Y_{t-1}]\Big] + s_r\epsilon_{r,t} \tag{C.1.29}$$

$$ln(R_t^{re}) = max(0, ln(R_t^{tr}); \tag{C.1.30}$$

$$f_t^{cb} = (1-\rho_f)f^{cb} + \rho_f f_{t-1}^{cb} + s_f\epsilon_{f,t} \tag{C.1.31}$$

$$b_t^{cb} = (1-\rho_b)b^{cb} + \rho_b b_{t-1}^{cb} + s_b\epsilon_{b,t} \tag{C.1.32}$$

$$Q_t f_t^{cb} + Q_t^B b_t^{cb} = re_t \tag{C.1.33}$$

AGGREGATE CONDITIONS:

$$1 = (1-\phi_p)\Big(\Pi_t^{\#}\Big)^{1-\epsilon_p} + \phi_p \Pi_t^{\epsilon_p - 1} \tag{C.1.34}$$

$$w_t^{1-\epsilon_w} = (1-\phi_w) w_t^{\#\,1-\epsilon_w} + \phi_w \Pi_t^{\epsilon_w - 1} w_{t-1}^{1-\epsilon_w} \tag{C.1.35}$$

$$Y_t^w = Y_t v_{pt} \tag{C.1.36}$$

$$v_{pt} = (1-\phi_p)\Big(\Pi^{\#}\Big)^{-\epsilon_p} + \phi_p \Pi_t^{\epsilon_p} v_{pt-1} \tag{C.1.37}$$

$$L_t = L_{d,t} v_t^w \tag{C.1.38}$$

$$v_t^w = (1-\phi_w)\left(\frac{w_t^{\#}}{w_t}\right)^{-\epsilon_w} + \phi_w \left(\frac{w_t}{w_{t-1}}\right)^{\epsilon_w} \Pi_t^{\epsilon_w} v_{t-1}^w \tag{C.1.39}$$

$$f_t^w = f_t + f_t^{cb} \tag{C.1.40}$$

$$b_t^G = b_t + b_t^{cb} \tag{C.1.41}$$

$$Y_t = C_t + I_t + G_t \tag{C.1.42}$$

$$R_t^F = \frac{1 + \kappa Q_t}{Q_{t-1}} \tag{C.1.43}$$

$$R_t^B = \frac{1 + \kappa Q_t^B}{Q_{t-1}^B} \tag{C.1.44}$$

$$ln(A_t) = \rho_A ln(A_{t-1}) + s_A \epsilon_{At} \tag{C.1.45}$$

$$ln(G_t) = (1-\rho_G) ln(G) + \rho_G ln(G_{t-1}) + s_G \epsilon_{Gt} \tag{C.1.46}$$

$$ln(b_t^G) = (1-\rho_B) ln(b^G) + \rho_B ln(b_{t-1}^G) + s_B \epsilon_{Bt} \tag{C.1.47}$$

C.2 Steady state

The model is a linear approximation around the non-stochastic steady state.[1] In this steady state reserve and deposit rates are equal and the ZLB doesn't bind. The steady state is defined as follows:

$$R^d = \frac{1}{\beta} = \Lambda^{-1} \tag{C.2.1}$$

$$R^F = R^d + \kappa_1^b \tag{C.2.2}$$

$$R^B = \Delta(R^F - R^d) + R^d \tag{C.2.3}$$

$$Q = \frac{1}{R^F - \kappa} \tag{C.2.4}$$

$$Q^B = \frac{1}{R^B - \kappa} \tag{C.2.5}$$

$$M_1 = \frac{\beta}{Q(1 - \beta\kappa)} \tag{C.2.6}$$

$$M_2 = 1 + \psi(M_1 - 1) \tag{C.2.7}$$

$$p_w = \frac{(\epsilon_p - 1)}{\epsilon_p} \tag{C.2.8}$$

$$K = \left[\frac{\alpha p_w}{M_2(\frac{1}{\beta} - (1 - \delta_0))}\right]^{1/(1-\alpha)} \tag{C.2.9}$$

$$Y = K^\alpha \tag{C.2.10}$$

$$G = g * Y \tag{C.2.11}$$

$$I = \delta_0 K \tag{C.2.12}$$

$$w = (1 - \alpha) p_w K^\alpha \tag{C.2.13}$$

$$\delta_1 = \frac{\alpha p_w K^{\alpha-1}}{M_2} \tag{C.2.14}$$

$$C = Y(1 - g) - I \tag{C.2.15}$$

$$\mu = \frac{1}{C}\frac{(1 - \beta b)}{(1 - b)} \tag{C.2.16}$$

$$mrs = \frac{(\epsilon_w - 1)}{\epsilon_w} w \tag{C.2.17}$$

$$\chi = \mu * mrs \tag{C.2.18}$$

[1] The model follows that of a zero-inflation steady state such that $\Pi = 1$ (zero in logs).

$$f^w = \frac{\psi I}{Q(1-\kappa)} \tag{C.2.19}$$

$$re = bcsY \tag{C.2.20}$$

$$b^{cb} = \frac{bcbG * re}{Q^B} \tag{C.2.21}$$

$$f^{cb} = \frac{(re - Q^B * b^{cb})}{Q} \tag{C.2.22}$$

$$f = f^w - f^{cb} \tag{C.2.23}$$

$$b^G = \frac{by * Y}{Q^B} \tag{C.2.24}$$

$$b = b^G - b^{cb} \tag{C.2.25}$$

$$n = \frac{Qf + \Delta Q^B b}{\phi^b} \tag{C.2.26}$$

$$d = Qf + Q^B b + re - n \tag{C.2.27}$$

$$\Delta = \frac{(R^B - R^d)}{(R^F - R^d)} \tag{C.2.28}$$

$$div^B = \delta^b n \tag{C.2.29}$$

C.3 Sensitivity Analysis

This section presents a sensitivity analysis of some parameters relevant for the transmission mechanism, to see the sensitivity of the model to different values of these. The results are presented only for the case of LSAP of public bonds (QE) because the main question that this document seeks to answer is the effect of LSAP.[2] For comparability, the solid lines in each graph correspond to the baseline effects presented in the main text. Likewise, it is limited to only presenting the sensitivity analysis for "normal times", which implies the scenario where the ZLB is not binding. Hoping that the reader can extrapolate that the results presented here may be comparable to those in the main text and that what would change in the case of ZLB binding is a change in the magnitude of the baseline scenario presented in the Results section of the main text in this chapter. This section presents the following cases:

1) Figure C.1 analyses the effects of a government spending shock in the scenario where it is subject to ZLB and when it is not. Unlike normal times, with policy rate at zero, the effects on consumption and investment are less negative and inflation increases to a greater extent as there is no reaction of monetary policy to fight inflation following the Taylor rule on short term rates when the ZLB is binding.

2) Figure C.2 presents a comparison between the LSAP of government bonds vs. LSAP of corporate bonds. Given the main objective of the paper is analysing purchases of government debt, this is not included in the main text but is left as part of the appendix for comparability. For this work, LSAP of government bonds can be considered as the equivalent to the PSPP program described in the introduction, which consists of the acquisition of bonds issued by Euro-area governments, agencies and European institutions. Moreover, purchase of corporate bonds on the primary and secondary markets can be viewed as (CSPP) which corresponds to bonds issued by non-banks resided in the euro area, and the additional share of (ABSPP) which correspond to the purchases of asset backed securities issued by the private sector.

3) Subsequently, Figure C.3 presents the sensitivity analysis for the debt-financed investment parameter. Since this is one of the frictions that allows unconventional monetary policy to spill over to the real economy through its effect on investment, having a sensitivity analysis of this parameter is relevant. It starts from the baseline of 81 percent following the parameter used in Sims and Wu (2021). However, ac-

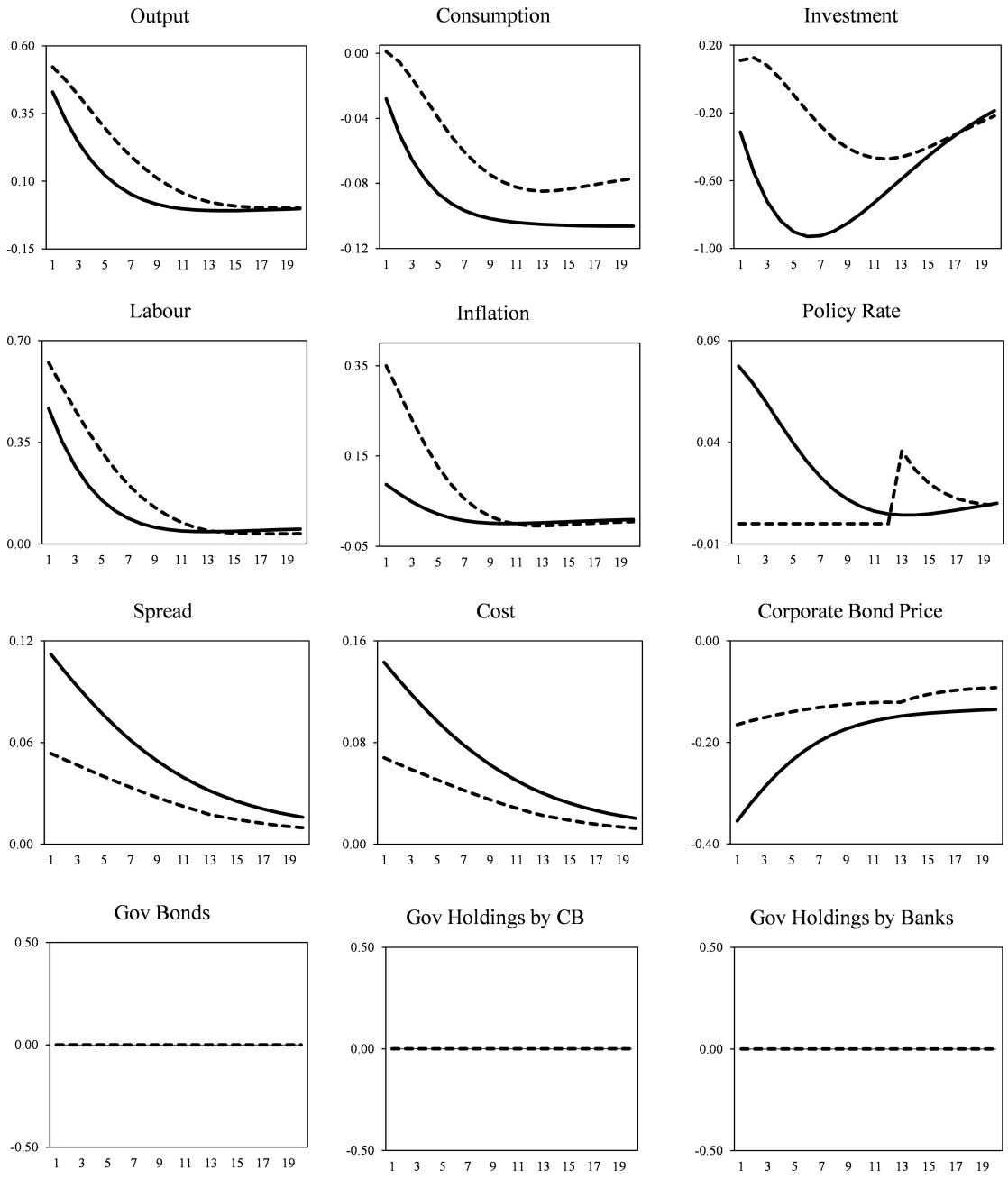
[2]Although different shocks are presented in the main text, they are associated with reference to other chapters of the thesis for comparison purposes.

cording to Kochen (2022), this parameter may be lower.[3] As shown in the impulse responses, to the extent that the parameter is smaller, the effects on the real economy are amplified. This can be understood as a relaxation in the investment in advance constraint, that is, for the same value of corporate debt, firms can incur in larger investment.

4) Finally, Figure C.4 presents sensitivity on the inverse Frisch elasticity parameter. The Frisch elasticity of labour supply controls intertemporal substitution responses to fluctuations of wage. As seen in the figure, the change to this parameter has no effect on the financial sector, but affects consumption, investment and output through responses to labour. Thus, responses to lower (higher) inverse elasticity positively (negatively) displace the responses of non-financial variables. In particular, when the parameter decreases, it implies more willingness of people to work if the wage increases, amplifying the effects on the non financial variables.

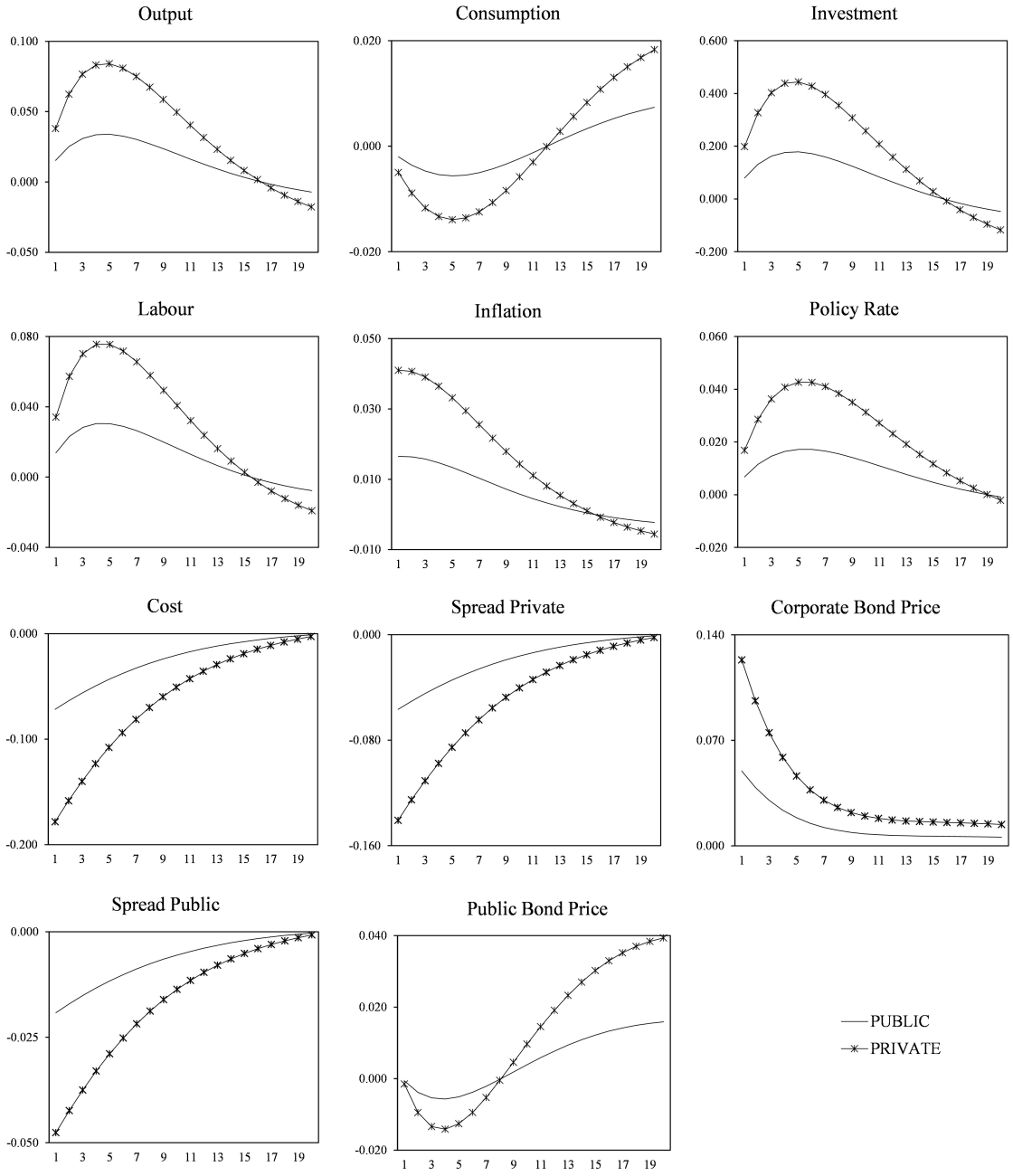
[3]Although financing with equity is not modelled here, it could be assumed that for the purposes of the model the parameter would represent the share that is not financed by own resources, hence a value of around 0.50

Figure C.1 Government Spending under ZLB



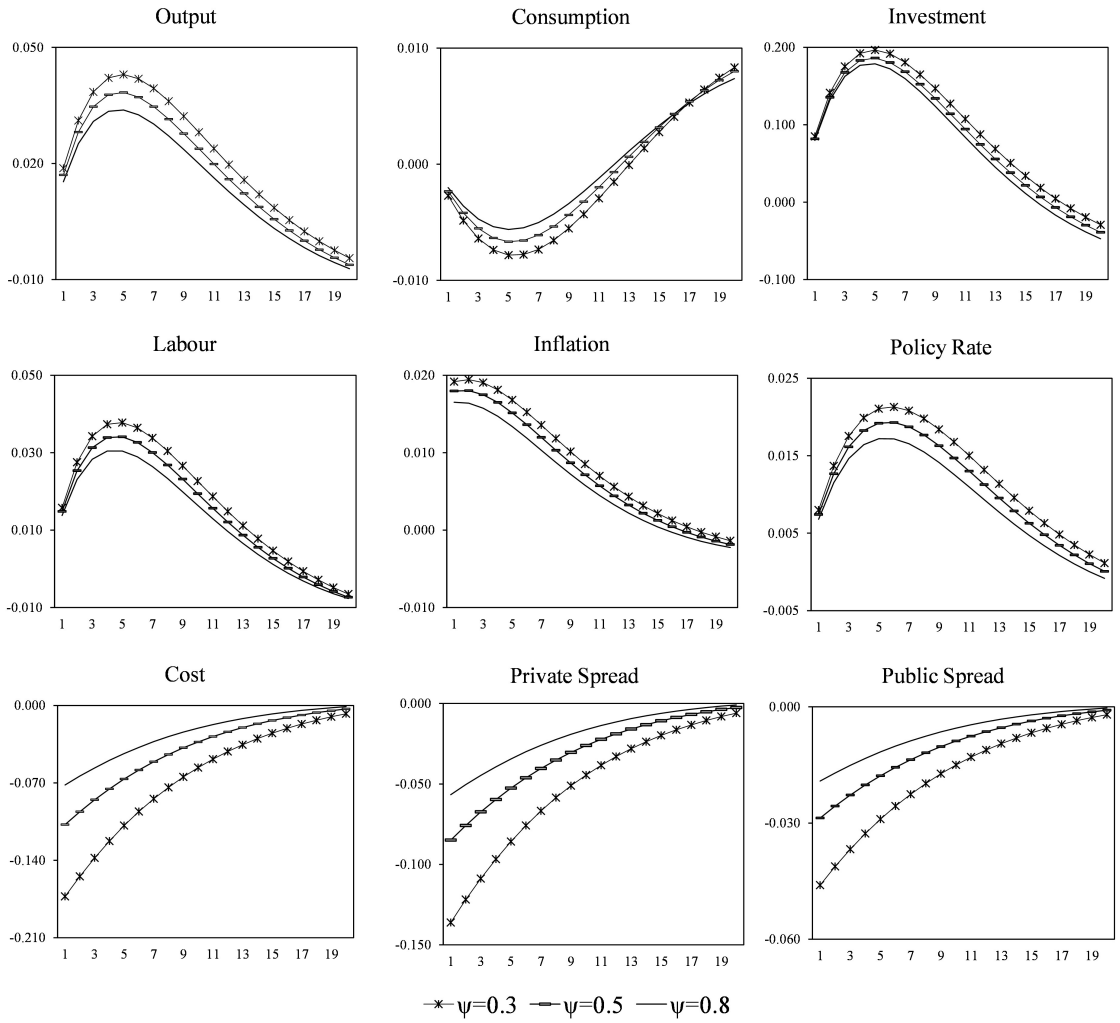
Responses to a 1 percent government spending exogenous shock in percentage deviations from steady state. Horizontal axis is measured in quarters. Solid lines display the dynamics where short-term rate is not constrained to the ZLB and dashed lines display the dynamics when the ZLB binds.

Figure C.2 LSAP- Quantitative vs. Credit Easing shock



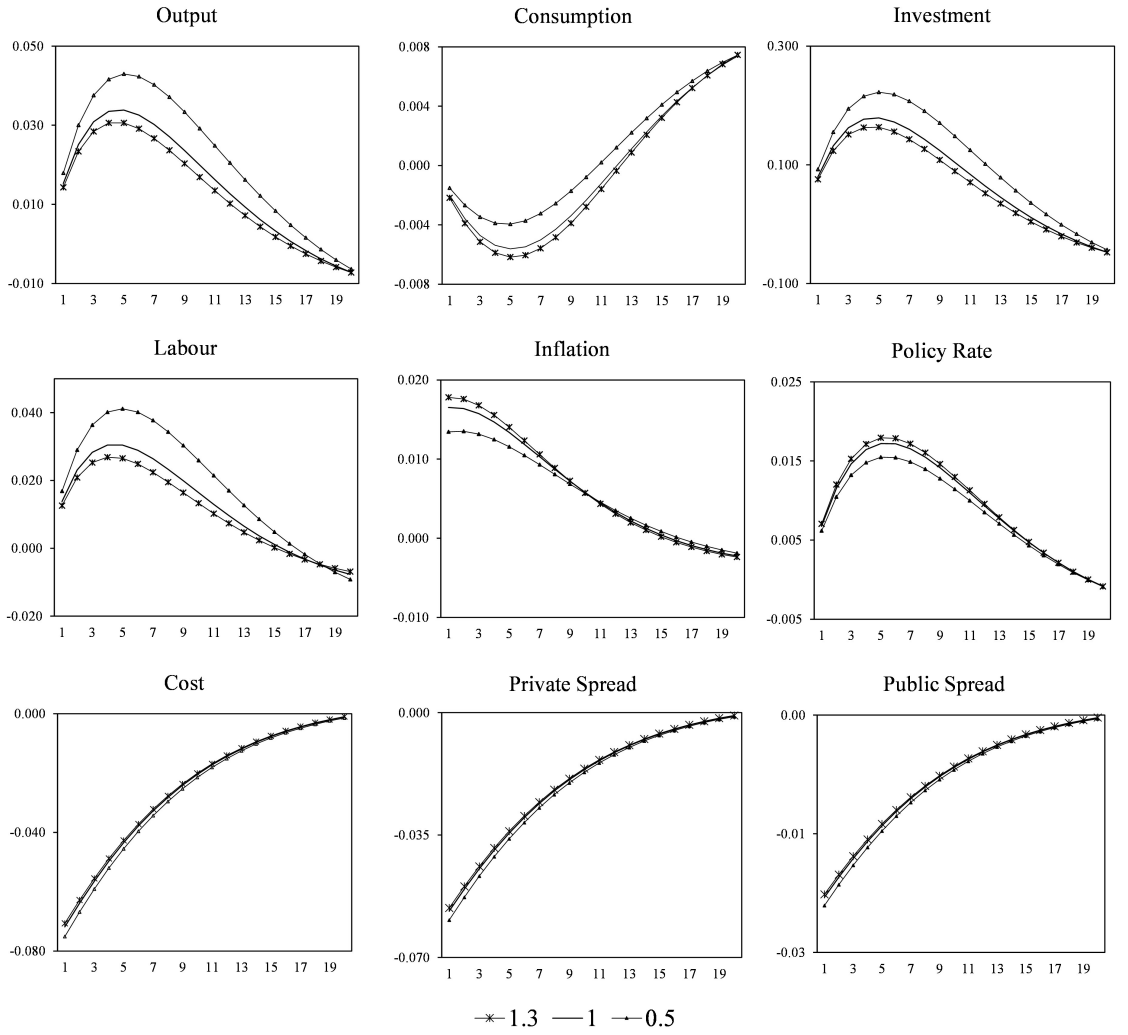
Responses to a 1 percent Private CE exogenous shock (gray crossed line) and Public QE shock (black solid line) in percentage deviations from steady state. QE is defined as an exogenous increase in central bank sovereign debt holding whereas CE is defined as corporate debt holdings by the monetary authority. Horizontal axis is measured in quarters.

Figure C.3 Sensitivity: Debt Financed Investment



Responses to a 1 percent QE shock in percentage deviations from steady state. QE is defined as an exogenous increase in central bank sovereign debt holding. Solid line (0.8) corresponds to the baseline presented in the main section of the chapter. Horizontal axis is measured in quarters. The parameter in the loan in advance constraint of firms is the main driver of investment decisions and mechanism through which the effects are transmitted to the real economy. The parameter is allowed to take on lower values to relax the constraint, indicating that for same bond issuance firms enjoy higher investment levels.

Figure C.4 Sensitivity: Frisch elasticity



Responses to a 1 percent QE shock in percentage deviations from steady state. The Frisch elasticity is interpreted as willingness to work when wage changes. Lower values of the inverse frisch elasticity imply more willingness of people to work if the wage increases. Solid line (with elasticity set to 1) is baseline presented in the main section of the chapter. Horizontal axis is measured in quarters.

C.4 Supporting Figures

Figure C.5 Spread BAA to MRO

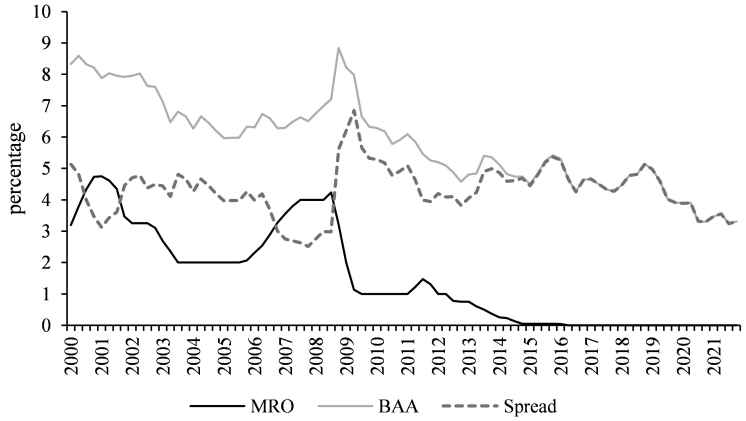
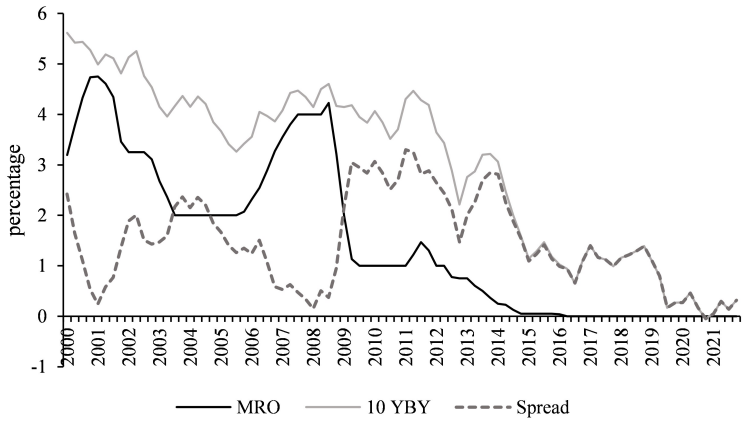


Figure C.6 Spread Long Term Gov Bonds to MRO



The MRO rate is the ECB Main Refinancing Operations Rate. For the period 2000-2008 where the MRO fixed is not reported, the series are derived from the average between ECB Deposit Facility Rate and ECB Marginal Lending Facility Rate for Euro Area, which are the other two rates used by ECB as policy rates. Corporate Bonds captured by Moody's Seasoned Baa Corporate Bond Yield and Long-Term Government Bond Yields captured by the 10-year bond yields for the Euro-Area. The spread is defined as the difference between the BAA corporate bond yield and Gov bond yields to the MRO rate. Sources: Federal Reserve Bank of St. Louis.

Chapter 5

Conclusion

Following the financial crisis of 2008, national governments of advanced economies applied expansionary fiscal policies by increased indebtedness, having repercussions in their domestic financial sector who acted as the main holder of sovereign debt. Motivated by the high levels of debt that have occurred after the financial crisis, this thesis explores the dynamics of debt holdings in the financial institutions (both commercial and central banks) in economic activity but in particular in credit and investment.

Chapters 2 and 3 focus on the dynamics of the purchase of government bonds by the commercial banking sector where the second chapter focuses on explaining the *theoretical model* and estimates the parameters for the aggregate European periphery while the third focuses on the *empirical analysis* of this public debt transmission channel by exploiting country heterogeneity responses across European countries. Chapter 4 proposes a theoretical model for understanding how the central bank's acquisition of public debt frees up the banking sector to make loans to the productive sector. Furthermore, the Chapter allows to examine the effects when the economy is also subject to a zero lower bound with the use of occasionally binding constraints on the short-term rate. The contribution on the theoretical models employed in chapters 2 and 4 is that it incorporates macroprudential policies that allow bond holdings in the banking sector to generate frictions on the supply side of the credit market, allowing debt to have a direct effect on the balance sheets of financial institutions to model the effects of debt policy on economic activity and on investment levels. For its part, the contribution of Chapter 3 lies in the use of panel data to analyse the effects of the proposed channel in the DSGE model in Chapter 2 but allows to capture country heterogeneity that is not exploited in the theoretical framework.

The objective of this thesis is to answer 3 main questions:Firstly, What are the effects of government spending financed with debt on credit supply and capital formation, when the banking sector act as the primary sovereign debt holder? Secondly, How does credit and investment react to debt shocks in the European Monetary Union and are there asymmetric effects on credit to enterprises and investment across European MU countries? and finally, How do Large Scale Asset Purchase Programs (LSAP) of Public Debt play a role in Business cycles to achieve financial stability? The following section presents the main findings and policy implications that arise from each essay to answer these questions.

5.1 Findings and Policy Implications

Chapter 2 presented a two-region general equilibrium model estimated with Bayesian techniques for an aggregate of peripheral European countries. The chapter contributes with a theoretical framework to examine the hypothesis that the banks that were most exposed to domestic public debt did so at the expense of corporate lending and investment. To address the evidence of the financial sector being exposed to sovereign debt, this chapter builds upon the work of Kamber and Thoenissen (2013) to account for minimum capital requirements but extends the model to incorporate a fiscal authority and the holdings of government securities in the balance sheets of financial institutions. The model incorporates frictions in both sides of the credit marker: (i) Borrowing constrained agents who pledge collateral to access credit, (ii) Banks subject to minimum capital requirements and (iii) heterogeneous agents that differ in their degree of impatience giving a role for financial intermediation in the steady state.

The chapter shows how when the fiscal authority issues government debt to finance expenditure, the expansion in the assets side of the bank balance sheet coupled with banks facing capital requirement costs of intermediation, contracts the credit supply and increases credit spreads. From the demand side of the credit market, the entrepreneur's decision to borrow is affected by higher borrowing costs and the need to pledge more collateral to access credit, negatively affecting investment and capital formation decisions. The chapter highlights that bank's exposure to sovereign debt propagates the transmission through changes in their credit supply and amplifies the effects on capital formation in the real economy. Moreover, it shows how capital requirements can explain the costs faced by financial institutions that affect credit provision and contraction in investment. Additionally, the chapter demonstrates that during a sub-sample period covering the financial and debt crisis in Europe, the effects of higher debt led to more credit tightening and more pronounced investment

contractions.

In terms of policy implications, it becomes crucial to seek to implement policy measures that help mitigate the frictions present in the financial sector. In an economy like the European one with a high dependence of companies on bank credit as a source of liquidity, any shock that affects the ability of the financial sector to grant credit can affect investment levels and lead to adverse consequences for the economy. This chapter argued the relevance of the banking sector to propagate macroeconomic policy shocks. These shocks may be in the form of greater regulations for the banking sector in terms of capital requirements or may simply be associated with macroeconomic policy that has direct repercussions on the banking sector's balance sheets. To the extent that banks cannot adjust immediately to shocks hitting the economy, it could lead to them having to adjust their credit provision further affecting investment in the economy.

The financial crisis brought with it a tightening of credit conditions and investment in the Euro area. However, the effects of the different policies implemented had differentiated effects not only because the economies within the EMU have different fiscal policies to mitigate the effects of the recession, but also because of the high degree of heterogeneity that exists in the financial sector of each country. Chapter 3 estimates a Bayesian Panel Vector Autoregressor model to analyse the importance of debt financed fiscal policy on real and financial variables. The use of the Panel VARs allows to model the common effects present across European Monetary countries while allowing for individual behaviours of countries or groups of countries. The chapter contributes to the literature by expanding with empirical evidence the mechanism suggested in the theoretical framework explored in a DSGE model in Chapter 2 by considering the heterogeneity that exists across six of the largest countries in the money union (EMU-6). The main difference of this work compared with the existing literature lies in that it analyzes the effects debt shocks on bank's balance sheet composition, through its impact on credit and investment for European economies to quantify a balance sheet channel of fiscal policy.

Results suggests that the evolution of the bank's balance sheets influences the bank lending channel of fiscal policy for European economies. The chapter shows that under a debt shock, the re-composition in the balance sheets of financial institutions negatively impacted the credit provision and investment and that the highest credit crunches and fall in investment were observed in those economies with more exposure to sovereign debt exposure. Moreover, despite a prevailing channel of

debt-financed fiscal policy, the differences in responses within the EMU could also be associated with the regulatory framework and institutional characteristics that are idiosyncratic to each country. This chapter reviews the macroeconomic implications of public debt for the European countries in the presence of macro-financial linkages by first showing the mechanism holds for the pool of EMU countries, but also emphasising heterogeneity at different levels: by splitting the sample in blocks of stressed (periphery)/non stressed(core) countries as has been suggested in the literature; and by analysing the mechanism allowing for heterogeneity at the country level.

The results have important implications for policy design to understand the effects of debt-financed fiscal policy when it leads to increased bond holdings by financial institutions. Given the European economies have a primarily bank-based financial system, the changes in the composition of bank's balance sheets can have important repercussions in the transmission of macroeconomic policy. Thus, to the extent that banks remain the main suppliers of credit in the European economy, shocks that affect their liquidity provision may pose a source of systemic risk as impact to the private sector may disrupt the economic recovery. Moreover, despite the commonalities within the EMU countries, a degree of heterogeneity in macro-financial linkages remain in their response to debt financed fiscal policy on credit and investment. Plausible reasons for this lie in the idiosyncratic components like country specific legal frameworks and fragilities present in the credit markets (in terms of size of banks and firms). Countries with a credit market represented by small firms which tend to be bank dependent might face higher problems when the financial fragility in the banking sector is compromised. Thus, the relevance of understanding the financial fragilities in each member country is of utmost importance for the fiscal policy decision in the presence of macro-financial linkages.

Finally, in response to the financial crisis, monetary policy was also used to compliment fiscal and prudencial policies in trying to stimulate activity while at the same time allow for financial stability. The European Central Bank and other central banks applied expansionary policies which led short-term policy rates to zero. With the impossibility of using conventional monetary policy to provide liquidity to the real economy, central banks launched long-term asset purchase packages as an unconventional policy measure to handle the provision of liquidity in the financial markets.

In the current context in which the central banks own a big portion of domestic public debt in their balance sheets, understanding the role played by fiscal indebt-

edness and central bank's balance sheet in achieving financial stability is crucial. Chapter 4 employs a DSGE model that incorporates central bank intermediation in the form of LSAP as a tool for unconventional monetary policy. Moreover, the inclusion of nominal rigidities to allow for conventional monetary policy to have real effects is extended to account for a scenario where the policy rate faces a Zero Lower Bound (ZLB) using occasionally binding constraints of the short-term policy rate. The innovation of the model lies in the inclusion of macroprudencial policy in the framework, to account for financial frictions present in financial intermediation. One of the most used frictions in the DSGE modelling literature is the use of agency problems (moral hazard) to simulate frictions in the financial market, although this friction does not seem to capture the main reason why in reality, banks choose to hold (or are forced to hold) capital. In this chapter, the decision to maintain capital is based on the macroprudential regulations imposed by Basel Committee to mitigate systemic risk. By allowing segmentation and intermediation, the financial sector plays a key role in the model. In this model, segmentation occurs because economic agents do not interact with each other, and all financial interactions happen through the financial sector. Thus, allowing for segmentation and intermediation is what gives the financial sector a role for transmission of shocks to the real economy. The chapter proposes a mechanism of transmission through which LSAP influence real activity by easing wholesale firms' investment constraints and lowering the cost faced by financial institutions subject to capital requirements. This means that as the central bank acquires government bonds, it eases the balance sheets of financial intermediaries. This increases the supply of credit to firms seeking to borrow and pushes up the price of long term bonds, allowing for increased investment under lower long term real rates used as reference for real investments. Moreover, results show that in the presence of the ZLB for short term rates, the effects on the economy are amplified.

A series of general policy implications arise from this chapter especially with a public debt build-up in the European economies in the past decade. Economies with high levels of indebtedness and with a banking sector highly exposed to local sovereign debt have faced larger declines in private credit and capital accumulation. Therefore, to the extent that LSAP can mitigate the exposure of the national banks in those countries to allow the flow of credit to the productive sector, it can lead to reactivation of credit levels and recovery of investment levels. However, the implementation of monetary policy oriented to the aggregate of European countries can imply asymmetries in responses of credit provision as the easing of financial sector's balance sheet would not be homogeneous across member states. Furthermore, studying the reverse effect of *quantitative tightening* to analyze the repercussions

of the central bank seeking to loosen their balance sheets while trying to mitigate possible distress to the economy pose an interesting policy implication in terms of financial vulnerability and how quantitative tightening could affect the fiscal stance of European governments. Thus, the LSAP unwinding should aim to be implemented in a predictable pace to avoid disruption of market functioning. Also, in a period where inflation is trending upward, it leaves room for conventional monetary tools to operate normally. As such, the impact of unwinding unconventional measures depends not only on the size and speed of the LSAP reversal relative to conventional monetary tightening, but also that at times where the ZLB is not binding, the unconventional measures shows lower effects compared to a binding lower bound scenario.

5.2 Final Comments

The causes of the crisis are not discussed in this work; however, they are of crucial relevance to understand why it is important to analyze the different policies applied after the crisis and the role of the banking sector in the propagation of shocks. Prior to the financial crisis, most of the literature (DSGE and empitical) found that banks didn't play a greater role in the propagation of shocks to the economy and models didn't give a mayor role to the financial sector frictions in the amplification of macroeconomic shocks(see e.g. Claessens and Kose (2018) and Albertazzi et al (2020)). However, the deregulation of the banking sector and the excessive facilitation of credit in the run-up of the financial crisis, turned the banking sector into not only a large agent in the economy, but also an important actor in the propagation of shocks.[1]

This thesis seeks to provide an insight on the macroeconomic policies that played a significant role in the post crisis period: fiscal stimulus, unconventional monetary policies, and regulatory supervision in terms of macroprudential regulation on capital requirements. Given the nature of the financial crisis and that it was propagated through the financial sector, this thesis shows how debt dynamics play a role in credit markets and the implications of the financial sector in understanding macro-financial linkages. The acknowledgment of the importance of Macro-financial linkages has led to the study of the relationship between the financial and the real economy. In

[1] In the two decades prior to the financial crisis, both the United States and Europe went through a period of high financial deregulation to keep the banking sector more competitive, under the argument that the greater competition led to more available credit as a consequence of better credit rates and better conditions for borrowers (Albertazzi et al (2020)).

that line, this thesis highlights: 1) that the sovereign debt holdings in the banking sector can lead to readjustments in the balance sheets of commercial banks that can impact liquidity to the economy. 2) that the tightening of capital regulatory requirements post-crisis implied capitalization costs for banks which affected credit. 3) that unconventional monetary measures relaxed pressures from the European banking system highly exposed to domestic public debt to help facilitate credit in the economy (see e.g. Albertazzi et al (2018)).

It should however be noted that the thesis at no time says that debt policy is bad. It is necessary to emphasize that there are trade-offs that emerge from having an exposure of the banking sector to debt. Facilitating liquidity to the public sector also helps stimulate economic activity, particularly when spending is directed towards productive sectors. In general, the argument is that the debt helps to stimulate economic activity, but at the same time an attempt should be made to mitigate the impact on the real sector. Likewise, going forward, it is important to consider the fiscal position of governments' indebtedness on financial stability to the extent that expansionary policies begin to relax to lead to lower levels of debt and monetary authorities implement quantitative tightening. In particular, future research should be focused on understanding the asymmetry that exists in the proposed transmission mechanism when talking about contractions of unconventional monetary or fiscal policies, as a sign asymmetry of the shock is something that seems to be a growing concern in the policy spheres.

Likewise, the thesis doesn't suggest that prudential regulation is harmful to credit, but just represents a cost to financial institutions that should be accounted for. International laws on capital requirements and guidelines on capital and liquidity requirements were formulated and adjusted to build a more resilient financial system since the crisis (see e.g. table 2 in Meier et al (2021) for a summary of regulatory measures in the EU). It should be noted that regulatory requirements imposed in macroprudential regulation activated in the aftermath of the financial crisis have strengthened the capital positions of commercial banks and provided a better health for financial institutions if hit by future shocks.

Finally I would like to conclude by discussing some aspects regarding this work. Each of the chapters here presented have made their own contribution in understanding the implications of debt holdings in the financial sector (both commercial banks and central banks) on the real economy. However, it should be considered that this analysis also has its limitations. In particular, I want to highlight four that I consider relevant to clarify:

Firstly, it is necessary to highlight the fact the results of the theoretical DSGE chapters (2 and 4) depend on the series of assumptions and any robustness at the same time is limited to the stylized nature of the models described in each chapter. The DSGE models in chapters 2 and 4 are first order approximations, which limits the analysis to small deviations from the steady state. However, studying full equilibrium dynamics in global non-linear models not just near the steady state as Brunnermeier and Sannikov (2010) implies high non-linearity and for that the models must be simplified to avoid computational problems. In addition, being a first order approximation, we set aside risk measures captured by higher order approximations. In defence of this work, results suggested in the chaptes go in line with what literature has found. Moreover it can be argued that the Bayesian PVAR in chapter 3 relaxes the assumptions required in the theoretical model of chapter 2, and it still supports the mechanism proposed. However, this chapter also has its limitations in particular given the data limitations that is subject to certain restrictions. The PVAR models allow to capture different interdependencies in the state-space form and several submodels are nested in their general specification. While these elements add more channels of contagion to the specified model, they come at a cost in terms of the dimensionality of parameters to be estimated. Accounting for all sources of heterogeneities, although can provide estimated dynamic responses, may produce inaccurate estimates as the many parameters to be estimated consume many degrees of freedom. As such, better estimates may be produced by relaxing some of the assumptions as suggested in Canova and Ciccarelli (2013).[2]

Secondly, sovereign exposure is understood as financial institutions providing funding to the government and exposing their balance sheets to sovereign debt. To the extent that the various political and regulatory incentives lead banks to hold public debt, they can lead to a distorted allocation of resources in the real economy. Although different mechanisms explain the reason for the domestic sovereign debt bias, this thesis addresses not the *cause* but rather the *implications* of having a high exposure to domestic debt as observed in European countries in the years following the crisis. However, existing literature supports the fact that this is observed and some provide reasons for debt holding bias. See eg. Becker and Ivashina (2017); Battistini et al (2014); De Marco and Macchiavelli (2016); Bonner (2016). This presents opportunity to refine the results presented in the theoretical models. For

[2]They say not all panel VARs features are needed in all applications and suggest that when analyzing countries in a monetary union, allowing for slope heterogeneities such that each country responds differently to the debt shock plays a more important role than allowing for variance heterogeneities.

instance, Chapter 2 has focused on explaining the European peripheral economies that were faced with large domestic bond holdings and the credit crunch in the local economy. Future extensions of this work could be to allow for cross-border holding of government debt such that banks in foreign economy are exposed to periphery debt and allow for sovereign debt diversification. Moreover, for Chapter 4 perhaps the most obvious extension given the closed economy nature of the model, is to allow for an open economy. In the same lines, not having a global dimension does not allow to account for spillover effects to the rest of the world through interbank lending. Although it is worth mentioning that the eligibility criteria to be subject to the Asset purchase program (APP) by the ECB, indicates securities must be euro-denominated debt and the issuer must be resided in the European Union. In this regard, opting for a closed economy model, although simplistic, could be justified by the eligibility criteria of the APP program, which goes in line with the research question this work seeks to answer. In fact Altavilla et al (2019) indicates that globally diversified banks (G-SIBs) reported the lowest increase in loans following the APP program implementation and indicate this pattern can be explained by those banks holding lower shares of assets eligible for purchase under the APP program which needed to be denominated in Euros. Another consideration in Chapter 4 may be the fact that the response by central banks may not necessarily be exogenous. One way to address this could be to include a Taylor-type rule into the central bank bond holdings' law of motion as in Sims and Wu (2021), where it responds to deviations to inflation and output gap, consistent with conventional monetary policy. An alternative approach to endogenizing the response of LSAP programs could involve a response to financial instability through which central banks address market distress, while preserving the response to the inflation gap, given that maintaining price stability is a primary objective of central banks. This however is intended as a future extension of this work.

Thirdly, this thesis analyzes the macroeconomic implications and explains aggregate mechanisms but does not identify patterns on the micro-channels of transmission. The DSGE models in Chapters 2 and 4 make no distinction in terms of firm or bank size, making it silent on the micro-level characteristics of agents participating in the credit markets. Additionally, although the results of Chapter 3 confirm debt effects on the re-composition of the balance sheets for financial insitutions, they also highlight cross-country divergence which might be reflecting difference in banks products, bank's capitalization at country level and the predominant structure of the banks that dominate within each country. For example, Altavilla et al (2019) show how credit to the private sector varies depending on the type of model that banks have. They highlight that retail lenders are the ones that present the highest share of

credit to the private sector and are more concentrated in the domestic market, while the large banks specially those with international orientation are usually those with the largest participation in the foreign market. This means that the heterogeneity that occurs in the response of banks to macroeconomic shocks will affect business credit depending on the business model that dominates in each country within the zone. Also, the structure of smaller and less capitalized banks which tend to be the ones more reactive under shocks affecting their balance sheets. This also makes them restrict credit more aggressively than banks with better capitalization or alternative funding capacity. This however does not affect the aim of this thesis which consists of analyzing the fragility of the financial sector *as a whole*. Thus, although the financial sector in the DSGE models depict a stylized way to model the banking sector as an *aggregate*, it is also realistic enough to account for the fact that overall credit by European banks fell after the financial crisis. And in the empirical work, although there are studies that address the channels of transmission at micro level using granular data, they tend to be constrained to being partial equilibrium in nature. The complementarity of micro insight with macro analysis, however, allows this thesis to reconcile both.

Finally, this thesis seeks to explain the frictions in the bank credit market and consequently the effects on the bank-dependent borrower. The fact that other financial actors in the credit market is not modelled means that these results would only explain bank-dependent borrowers. The reason lies in that banking institutions were faced with capital regulatory requirements that act as the friction on the supply side of credit that this thesis models. Another relevant point to keep in mind is that this thesis does not intend to study the effects on credit to households and focuses solely on credit to enterprises in every chapter. Therefore, households are assumed to be saving agents in the economy that through bank intermediation allow firms to borrow for investment. Other literature can be interested in analyzing the implications of Ricardian and non-Ricardian households although they are outside the scope of this thesis.

Going forward much can be done to exploit these models to accommodate new variants emerging in the literature. In general, it is necessary that as the financial sector continues to change, the models can incorporate the most relevant features to explain the dynamics in the credit markets. In this regard, although a new strand of literature has developed rapidly to address the modelling of the financial sector, macroprudential policy has often been taken for granted in the DSGE literature when deciding why banks hold capital. Likewise, companies faced with the contraction of

bank credit in the aftermath of the crisis, sought financing through the substitution of bank credit for debt issuance through alternative sources. As the financial sector keeps growing and as the non-banking institutions keep attracting relevance in the credit provision to economic agents, is crucial to understand how the growth of the non-bank intermediaries interact with prudential regulation in the transmission of debt-financed fiscal policy and monetary policy. The regulatory gap may cause credit allocation to be carried out differently. As such, the transmission of the non-banking financial system may differ from the mechanisms that operate under the traditional banking sector. Although the main source of external financing in Europe continues to be predominantly the banking sector, the rapidly mutating financial setting implies that the transmission of macroeconomic policy may become more complex. Lastly, models in the future could consider the fact that banks have begun to depend on other sources of financing in addition to deposits, which implies that if they begin to depend on other market sources, banks could become highly sensitive on the liability side to the market conditions in the future.

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