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Essays on Macroeconomics with Financial Frictions

Candidate:
Martino Nicola RICCI

Supervisor:
Prof. Patrizio TIRELLI

Ph.D. Coordinator
Prof. Alessandro Missale

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Declaration of Authorship

I, Martino Nicola RICCI, declare that this thesis titled, "Essays on Macroeconomics with Financial Frictions" and the work presented in it are my own. I confirm that:

- This work was done wholly or mainly while in candidature for a research degree at this University.
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- Where I have consulted the published work of others, this is always clearly attributed.
- Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work.
- I have acknowledged all main sources of help.
- Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself.

Statement of Conjoint Work

I confirm that Chapter I was jointly co-authored with Prof. Patrizio Tirelli.
Prof. Patrizio Tirelli and myself conceived the original idea. I formulated and solved the theoretical model based on discussions with my co-author. I run all the simulations and drafted the text.

"Nothing is built on stone; all is built on sand, but we must build as if the sand were stone."

J. L . Borges

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Writing a Ph.D. thesis is a long ride, and often a solitary one. However, I don't think I would have been able to go through almost 4 years of grad school without the help and the support of others. Academically, I am indebted to my supervisor Patrizio Tirelli. His advice and direction have been fundamental for the realization of this work and through his assertive approach to problem solving he taught me how to overcome problems and difficulties. I am also grateful to Chiara Forlati, Giorgio Primiceri, Andrea Colciago, Vincent Sterk and Lorenzo Menna for precious advices and suggestions. I would also like to thank Alessandro Missale for his support in many occasions.

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Introduction

The recent financial crisis that originated in the U.S. sub-prime mortgage sector elicited a redefinition of the macroeconomic research agenda. The crisis marked the end of the "Great Moderation", a period about 20 years long characterized by low volatility in inflation and output. In this environment, economists grew complacent on their theories and models.[1] The crisis however shattered the profession's certainties and paved the way to a new strand of research. In particular, it became clear that in order to make sense of the strong decline in output that compounded with the turmoil in the financial sector, economists were to take into account financial frictions seriously in their models. Specifically, Dynamic Stochastic General Equilibrium (DSGE) models, which are the work-horse models in the analysis of the business cycle, have often been silent on financial aspects before the crisis, and therefore came under attack from many pundits as not being able to cope with the complexity of the real economy.

DSGE models are a class of models that analyses the business cycle by resorting to a general equilibrium approach and relying on the microfoundations of their characterizing equations. One typical assumption of those models, which has been particularly criticized in the aftermath of the crisis, is the reduction of the agents populating the economy to a single representative agent. As noted by Kiyotaki (2011), rather than an abstraction from heterogeneity, this assumption hides the idea that markets work perfectly smoothly. In particular, this framework is well carved in the idea that credit flows without impairments from borrowers to savers.

Critiques towards this class of models and to business cycle theory sometimes lingered too heavily on their shortcoming, and seldomly recognized the great deal of efforts that has been put in practice to distance DSGE from Real Business Cycle (RBC) models. While this latter research program has been characterized by an over-optimistic stance towards the efficiency and speed in the adjusting mechanism of market economies, DSGE models, even prior to the crisis, have

[1] As an illustartive example, see for example the speech held by Bernanke (2002) on the occasion of Milton Friedman's ninetieth birthday.

been modified to consider different sources of frictions.
Indeed, the introduction of nominal and real rigidities as well as the introduction of collateral constraints for households mark a distinctive departure from the RBC program towards a more realistic account of the economy. In particular, those achievements have been reached well before the crisis.[2] However, what mainly those models were missing, and most of them still miss, is a complete integration of a financial sector and the study of the interaction of financial intermediaries and their balance sheet with the global economy.

This thesis is an attempt to contribute to the literature on DSGE models with financial frictions. In doing so, my research strategy consists of building on well renowned models in the literature and to add on them with the dual aim of providing new hindsight and to enhance the understanding of those models by exploring their theoretical underpinnings. The thesis is composed of three chapters. The first one profits from the contribution of my supervisor Prof. Patrizio Tirelli, while the second and third chapters are not co-authored. The three chapters can be read as separated works, with their own rationale and motivations. However, they are part of a research program and therefore they share a common ground. In particular, the elements that make the chapters part of a unitary body are related on the one hand to the necessity of considering some salient facts of the financial crisis and on the other hand follow directly from the modelling strategy adopted. The financial crisis made clear that the housing sector has a distinctive role in the economy, which singles it out from other sectors. Housing is not only a durable good, but also the most important asset in households' balance sheets[3] and understanding how its presence affects the propagation of shocks is crucial. In all the models developed in this thesis, housing[4] is always

[2]See for example the financial accelerator mechanism in Bernanke, Gertler, and Gilchrist (1999).

[3]In the U.S. in the period 1952-2008 housing wealth has been on average 1.5 times the GDP, and housing constitutes more than 50% of households' wealth in the U.S.. Furthermore, residential investment is also very volatile and it leads business investment Iacoviello (2010).

[4]Given its theoretical focus, the third chapter does not refer explicitly to housing but features durable goods that can be thought as representing the housing sector.

modelled explicitly, having the additional role of working as collateral for borrowers. Heterogeneity, and therefore the departure from the representative agent model and from the idea that credit circulation is frictionless is taken into account in all the chapters. The economies considered are indeed characterized by the presence of savers and borrowers that interact in the credit market and given intrinsic characteristics of the model economy this gives the rise to dynamics which are influenced by the balance sheet of agents and feed back to the rest of the economy.

The reminder of the thesis is structured as follows: in the first chapter I introduce a distinction between sub-prime borrowers and ordinary borrowers, investigating the response of the economy to different shocks. In particular, I focus on the transmission channels of an unexpected increase in housing investment risk in the sub-prime sector and of a monetary policy shock. The model features risky mortgages and a non-trivial banking sector, characterized by monopolistic competition and therefore sticky loan rates, which in the context of the model can be seen as a proxy for longer term mortgage contracts. The dynamics of the model are influenced by financial frictions, which are given by endogenous variations in the balance sheet of both constrained agents and banks. As a consequence, the results of our baseline model are given by the interaction and coexistence of different channels. Borrowers face collateral constraints and run up nominal debt. As a result, changes in the asset values, i.e. house prices, and in the inflation rate – Fisher effect – have a direct impact on households' borrowing conditions. Binding collateral constraints are instead affected by changes in the real interest rate. Indeed, an increase in the cost of the mortgage impairs borrowers' ability to get loans. This, combined with the fact that debt is nominal, contributes to a magnification of shocks. Banks' balance sheets are instead important for they influence directly credit conditions and therefore affect the shadow value of borrowing and the loan rate.
In the second chapter I investigate the response of private consumption and output to public consumption shocks and to changes in taxes. It is well known that in frictionless economies it may be difficult to rationalize the empirically observed positive or non-significant

response of private consumption to such shocks. The model focuses on the introduction of a collateral constraint tied to the expected value of the housing stock for a group of households. The presence of this kind of financial friction has important consequences for the transmission of fiscal policy, given that constrained and unconstrained households reaction to the shock is at odds. The model designed in this work also allows to compare the effect of a relatively large menu of taxes on the main macro-aggregates and to study changes in one of the institutional characteristic of the credit market, namely the loan-to-value ratio.

The third chapter focuses on a technical aspect of DSGE models with durable goods. In these models, a co-movement problem between consumption of durable and non-durable goods arises after a monetary policy shock in presence of flexible durable prices, i.e. a monetary contraction causes an expansion in the durable sector. I revisit the debate in the literature on this problem and I try to calrify what are the necessary elements that those models need to take into account to avoid a negative correlation between durable and non-durable goods.

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Chapter 1

Sub-prime Mortgages and Banking in a DSGE Model

Abstract

This paper seeks to contribute to the growing literature on DSGE models with financial frictions by studying the transmission mechanism of a shock to housing investment that is confined to a limited group of constrained households (sub-primers). Financial frictions are not only operating via the borrowers' balance sheet but also through changes in banks' balance sheet. Indeed, on the one hand the initial shock reverberates through a decline in house prices bringing about a contagion effect that reduces consumption of durable and non-durable goods of prime borrowers, who are initially immune to the exogenous shock. On the other hand, the presence of a banking sector alters the dynamics of the shock via changes in the loan rates. We claim the following contributions. A shock to a small group of borrowers, (sub-primers account for less then 4% of total households) triggers a decline in total output because of endogenous propagation channels. We show that the amplification mechanism works mainly via house prices and changes in credit conditions. Second, sticky bank rates, and therefore monopolistic power in the banking sector amplify the shock. Third, monetary policy has a stronger effect on sub-primers since being more leveraged, they are more sensitive to changes in credit conditions. Fourth, if we compare an economy characterized by frictions on the side of the lenders and an economy with a frictionless flow of credit from lenders to borrowers the latter economy is more resilient to a house price shock. Finally, we show how an increase in the share of sub-primers, a salient fact of the pre-crisis years, magnifies the size of the initial shock.

1.1 Introduction

The 2007-2009 financial crisis that hit the U.S. economy and rapidly spread to the rest of the world had its epicentre in the housing residential market and it featured sub-prime borrowers as the main protagonists. The role of the banking sector has also been crucial, for banks on the one hand have been responsible for the widespread availability of sub-prime mortgage contracts, and on the other hand recorded heavy losses on their balance sheet as a consequence of increasing mortgage delinquencies.

The ensuing turmoil in the financial sector led to a tightening in financial conditions which made the downturn even more severe and contributed to the depth of the crisis. Figure 1.1 shows that residential private investment in the U.S. contracted considerably in the period $2006 - 2009$ and that it was followed by a strong and prolonged decline in consumption and GDP.

The U.S. economy underwent some major changes in the years running up to the crisis. A well documented fact, which is likely to be at the root of the crisis, is the sharp increase in mortgage lending, that reverberated into a equally large increase in households' debt (Justiniano, Primiceri, and Tambalotti, 2015). This can be seen in figure 1.2, which shows the steep increase in households' leverage in the 2000s, measured as outstanding mortgages over GDP. Indeed, in 2003, when the industry was at its peak, the mortgage market accounted for around 25% of U.S. economy – about 4 trillion of U.S. dollars. Those dynamics have been in part shaped and in part reinforced by the spike in house prices. Although, relative house prices started to increase already somewhere in the mid-20th century (Knoll, Schularick, and Steger, 2014),[1] their rise accelerated in the 2000s. Figure 1.3 shows that in the period the level of mortgages to GDP piled up, house prices increased by around 60%. Housing is historically one of the most important form of investment in the U.S. (Tracy, Schneider, and Chan, 1999), indeed about $2/3$ of U.S. households own a house and housing is the most important asset in their balance sheets, given that about 50% of their wealth is constituted by their housing stock

[1] The same authors observe that this phenomenon is not an isolated characteristic of the U.S. economy, but concerns many other advanced economies.

(Iacoviello, 2010). It does not surprise then, that the study of the sector has received considerable attention, even prior to the financial crisis.

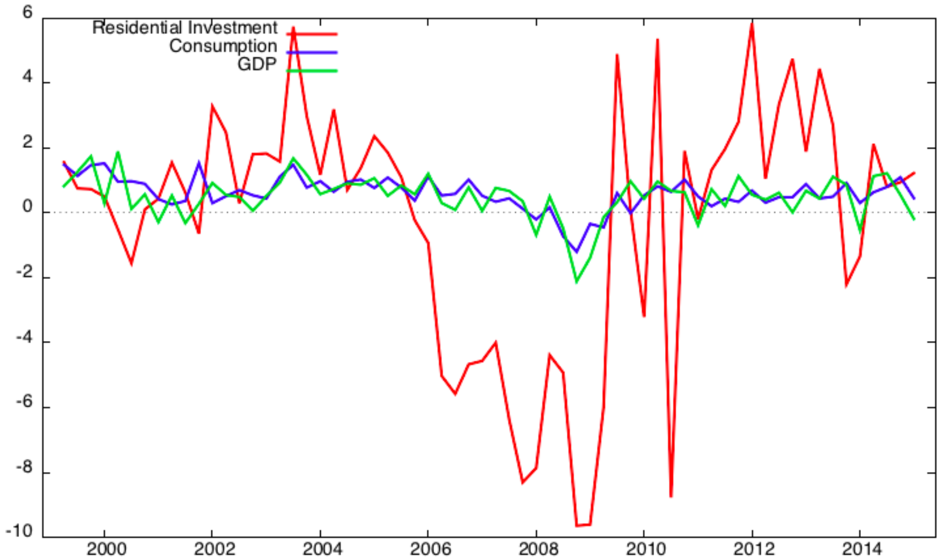

FIGURE 1.1: *The U.S. during the Great Recession – Federal Reserve Economic Data – FRED – St. Louis Fed. – Quarterly data of: Real Private Residential Fixed Investment, Real Personal Consumption Expenditures, and Real Gross Domestic Product*

The growth of the sub-prime market started back in mid $1990s$ (Chomsisengphet and Pennington-Cross, 2006).[2] However, while between 1996 and 2003 the sub-prime mortgage market accounted on average for only 9% of total market, this share more than doubled in 2006, reaching the unprecedented level of 23.5% (see figure 1.4). Before the unfolding of the crisis, sub-primers default rate was close to 6%, compared to a rate of default of primers lower than 1%. In figure 1.5, we present evidence of the increase in the rate of default, which gradually climbs by the end of 2006. At its pick in 2009, the rate of default of sub-primers was about 30%.[3] As shown by Mian and Sufi

[2]The alternative Mortgage Transaction Parity Act in 1982 is the official starting date for the sub-prime sector.

[3]We measure the default rate using the National Delinquency Survey, a publication of the Mortgage Bankers Association. More precisely, the measure we adopt is the percent of loans in foreclosure and among those only the seriously delinquent loans, which are 90 or more days past due.

(2009), the increase in the default rate on mortgages has been exacerbated in areas where the shares of sub-primers was higher, and those were also the areas where the increase in mortgage credit concentrated. It is therefore important to try to understand how a shock that originates in this market segment affects the rest of the economy and its transmission channels.

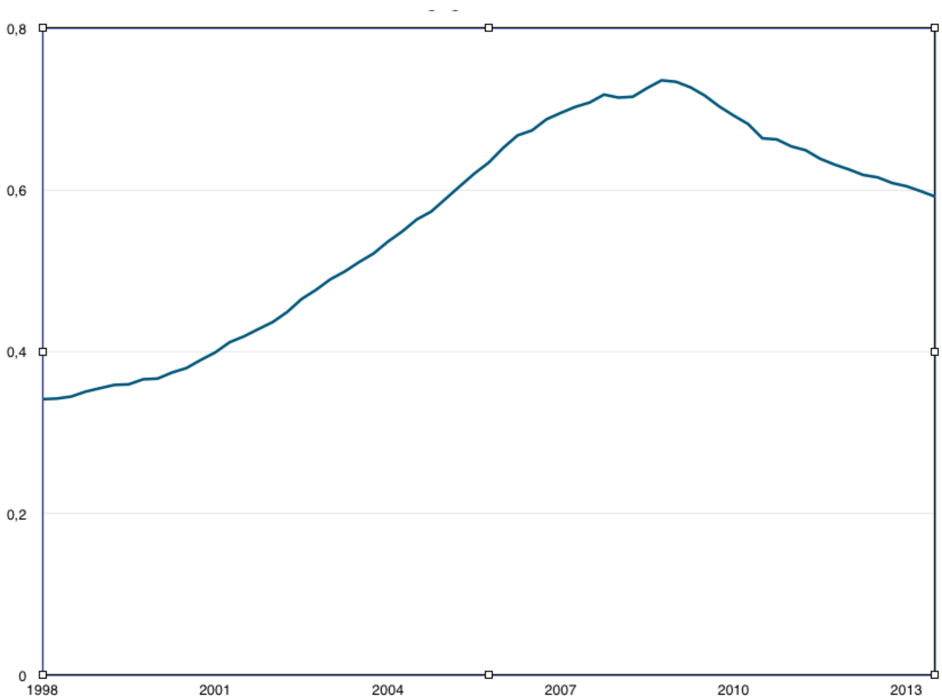

FIGURE 1.2: *Mortgage to GDP in the United States*

There is no agreed definition of what a sub-prime loan really is. According to the Federal Reserve Bank of San Francisco (2007), subprime is a label attached to a loan by the lender in all the cases in which a borrower misses some requirements that would allow him or her to be granted credit without any impairment. Therefore, subprime mortgage contracts are usually characterized by higher rate of defaults, higher loan to value ratios and higher interest rates than prime contracts.

Through sub-prime contracts poorer households – who were before excluded from the market – got their access to credit, despite

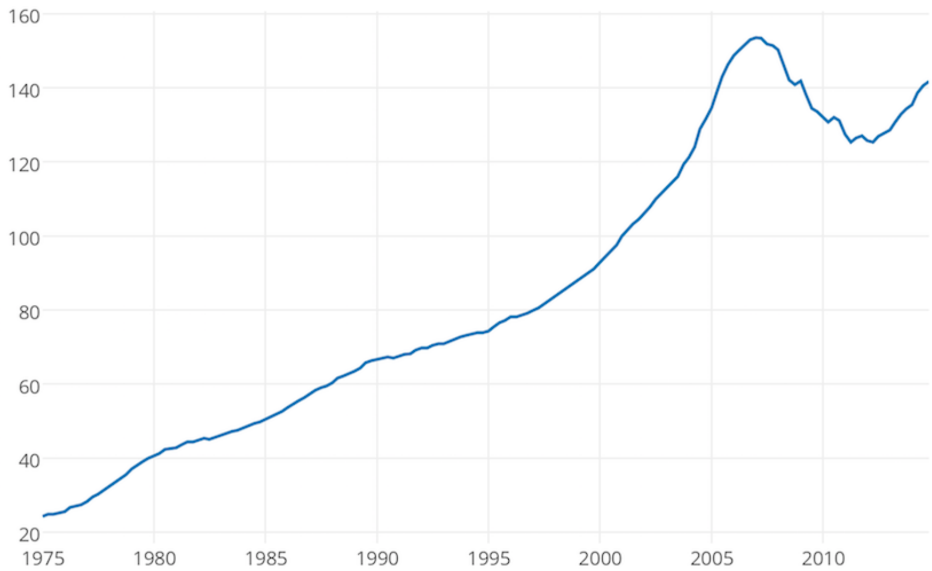

FIGURE 1.3: *All-Transactions House Price Index for the United States, Index 2001:Q1=100, Quarterly, Not Seasonally Adjusted – Federal Reserve Bank of St. Louis.*

they had a bad credit history, low credit scores and/or low down-payments or lack some of the documentation required. However, Demyanyk and Hemert (2011) showed that the idea that sub-prime loans were given only to credit impaired borrowers is only a myth, and that the sub-primer group was composed by borrowers of all types. One of the reason for this is that sub-prime is a label often attached for some intrinsic characteristics of the loan itself rather than for the credit condition of the borrower[4]. As it will become clear in the following section, this consideration is important for our modelling strategy, considering that we try to model explicitly sub-prime borrowers and that our modelling strategy does not rest on income inequality.

In this work we try to build a laboratory that can help us shed some light on two topics that we believe are strongly intertwined: the way the presence of sub-primers affects the response of an economy to shocks and the role played by the financial sector in this process.

[4]For example, the "2/28 hybrid" mortgage loan is a mortgage contract not usually sold as a prime loan and therefore only available in the sub-prime market notwithstanding creditors scores.

We do this by considering a shock to housing investment that only hits sub-primers and by investigating the effects of a monetary policy shock in an economy populated by this category of households.

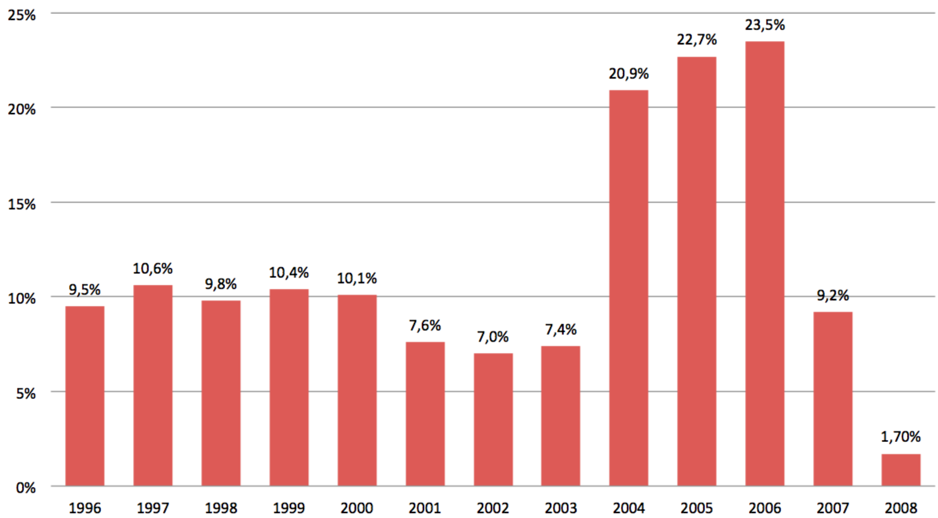

FIGURE 1.4: *Share of sub-prime mortgages over the total mortgage market. Source: The Financial Crisis Inquiry Report 2011.*

Our modelling strategy follows a well established theoretical approach, that of Dynamic Stochastic General Equilibrium (DSGE) models. The defining equations of this class of models are derived from first principles and allow us to study the response of an economic system to a perturbation of its steady state equilibrium. DSGE models include a number of frictions, that distance this modelling strategy from the neo-classical understanding of the economy – characterized by competitive markets that always clear smoothly. Recent literature has underlined the importance of financial frictions if we want to build models that are consistent to empirical facts. In this paper, we present a model where financial frictions are not only operating via the borrowers balance sheets but also through changes in banks balance sheet. Indeed, on the one hand the initial shock that we consider reverberates through a decline in house prices, bringing about a contagion effect that reduces consumption of durable and non-durable of prime borrowers, who are initially immune to the exogenous shock. On the other hand, the presence of a banking sector alters the dynamics of the shock via changes in the loan rates. We claim the following contributions. A shock to a small group of borrowers, (sub-primers account for less than 4% of total households) triggers a decline in total output because of endogenous propagation channels. We show that the amplification mechanism works mainly via house prices and changed credit conditions. Second, sticky bank rates, and therefore monopolistic power in the banking sector amplify the shock. This stickiness may also be viewed as a proxy for fixed-rate mortgage contracts and in case of a monetary policy, however, it plays an attenuating role. Third, monetary policy has a stronger effect on sub-primers since being more leveraged, they are more sensitive to changes in credit conditions. Fourth, if we compare an economy characterized by frictions on the side of the lenders and an economy with a frictionless flow of credit from lenders to borrowers the latter economy is more resilient to a house price shock. Finally, we show how an increase in the share of sub-primers, a salient fact of the pre-crisis years, magnifies the size of the initial shock.

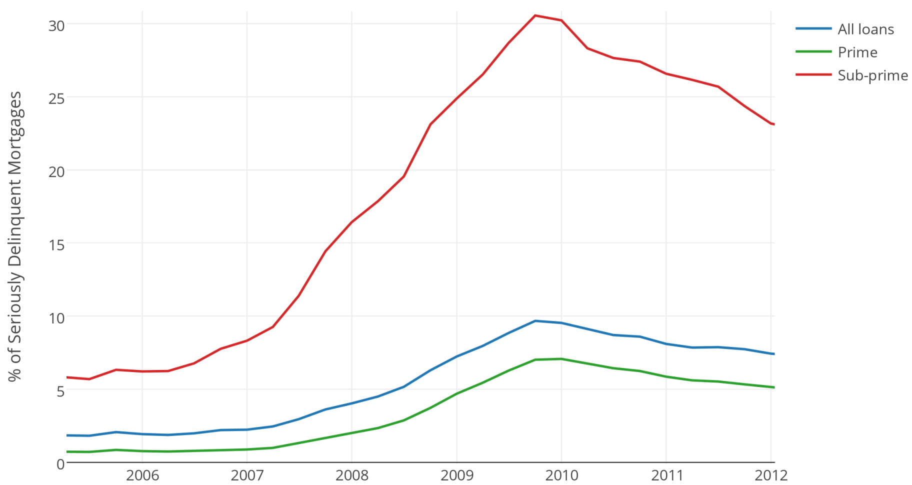

FIGURE 1.5: *Delinquency rates by loan type – Seriously Delinquent Loans, 90+ days past due – National Delinquency Survey Data – Mortgage Bankers Association.*

1.2 Literature Review

The study of the role played by financial frictions over the business cycle has always been a fertile avenue of research in economics, one that has a long stand tradition, stretching back to the contribution of economists who directly experienced the consequences of the Great Depression such as Fisher (1933) and Keynes (1936)[5]. However, Dynamic Stochastic General Equilibrium (DSGE) models, a particular class of models that are now the workhorse for macroeconomic analysis in academia and institutions as well, partly underestimated the importance of the sources of financing for firms and households alike. It is enough to say that many Central Banks around the world prior to the financial crisis relied on models that did not even consider explicitly the financial sector[6] a symptom of overconfidence on the efficiency of the financial sector hiding the implicit acceptance of the Modigliani-Miller theorem. The financial crisis provided new impetus to the analysis of financial frictions and by creating a vivid example of how financial institutions behavior and their balance sheet can affect the real economy, it forced scholars to reconsider the importance of impairments in the circulation of credit. In particular, while demand-side factors such as the borrowers' balance sheet structure were already taken into account before the crisis, economists now switched their focus on supply-side aspects, namely on lenders' balance sheets. It is in the integration of both demand and supply concerns that our model finds its rationale.

The literature on financial frictions is particularly vast but the integration of financial frictions into general equilibrium models of the New-Keynesian types begun only with the seminal contribution by Bernanke, Gertler, and Gilchrist (1999) (hereafter BGG). The authors built on Carlstrom and Fuerst (1997) and Bernanke and Gertler (1986), and quantified the relevance of balance sheet constraints on the firms level in determining the propagation and persistence of

[5]See Brunnermeier, Eisenbach, and Sannikov (2012) for an exhaustive survey on financial frictions.

[6]Examples are: the SIGMA model at the Federal Reserve, the Smets and Wouters model at the ECB and the Bank of England's Quarterly Model (Verona, Martins, and Drumond, 2013).

shocks over the business cycle. This approach, goes under the name of financial accelerator, for it underscores how financial conditions might magnify the effect of even small shocks. A second important strand of literature on financial frictions moves along the lines of Kiyotaki and Moore (1997), and studies the effects on the economy of introducing collateral constraints based on the presence of durable goods. It does so by abandoning the representative agent model and dividing agents into borrowers and savers on the basis of their different discount factor. Nested in this strand of research are DSGE models featuring housing, a particular form of durable goods that on the one hand enter in the utility function and on the other allow a class of agents in the model (relatively high impatient borrowers) to use their value as a collateral against which to borrow. Important contributions in this area are given by Iacoviello (2005) and Iacoviello and Neri (2010) who estimated a New-Keynesian model with housing for the U.S. economy. In the two papers, the authors find that collateral constraints and nominal debt change the dynamics of a DSGE model and that the volatility of housing investment is mainly explained by housing demand and technology shock. Calza, Monacelli, and Stracca (2013) analyzed the way institutional factors affect the response of an economy featuring housing used as a collateral to a monetary shock. According to their findings, economies which are characterized by higher loan to values and flexible mortgage rates are less resilient to a monetary shock. Following the work done by Forlati and Lambertini (2011) (hereafter FL) we are able to take into account both strands of research. FL transfer the agency problem used by BGG to characterize entrepreneurs to the household side. The agency problem is built on the riskiness of housing investment, on households' defaulting possibilities and on the fact that the outcome of the investment is private information of borrowers. As in BGG, FL use the Costly State Verification approach, pioneered by Townsend (1979), which entails the presence of monitoring costs μ if borrowers wish to verify the outcome of the investment. The presence of monitoring costs gives the rise to a debt contract characterized by a risk premium and an endogenous loan to value ratio (LTV). The framework of FL has been used by Pataracchia et al. (2013), who

included the endogenous LTV approach in a large policy model estimated on the Euro Area (QUEST 3) and underlined how the use of this approach improves the fit of the model.
We build on FL but we extend their model on several dimensions: to begin with, we add frictions in the price adjustment mechanism of wages and housing investment, then we move forward and model explicitly sub-primer borrowers. Our model features therefore three types of households: unconstrained savers and constrained primers and sub-primers. We ask then what is the response of the economy to a shock in the standard deviation of the idiosyncratic investment risk and to a monetary policy shock. Furthermore, we study the effect of the introduction of a non trivial banking sector characterized by market power and sticky bank rates. To the best of our knowledge we are among the firsts to include sub-prime borrowers into a DSGE model. In an recent paper, Justiniano, Primiceri, and Tambalotti (2016) introduce sub-primer borrowers and they distinguish them from primers on the basis of their income level, their modelling strategy allows them to theoretically make sense of the evidence that areas characterized by a higher share of sub-prime contracts were also characterized by higher credit growth and higher house prices. Grodecka (2016) considers also sub-prime borrowers in a DSGE model, and does so by distinguishing them from primers for the latter get mortgage contracts with a fixed rate while the former can only get mortgage contracts characterized by flexible interest rates. Her findings are that sub-primers play a disturbing role for they amplify the effect of shocks to the economy. Our modelling strategy is different from both approaches and it rests on the assumption that sub-primeers and primers have a different attitude towards defaults, and therefore sub-primer mortgage contracts are characterized by higher LTV ratios and higher spreads. We explain our approach in details in the next section.

Another main strand of literature we are indebted to is the one that flourished after the financial crisis and started to formally consider supply-side financial frictions by modelling banks explicitly.

This literature is a response to the critiques moved to DSGE models to their inability to warn for the upcoming crisis.[7] In particular, this work builds on Gerali et al. (2010) (hereafter GNSS) for the modelling of the banking sector. In that paper the authors added a mechanism through which the capitalization of the banking sector affects the level of the interest rate in the economy, and further introduced stickiness in banks rates. Those two factors have an effect for the dynamics of the model in the economy. In our approach they become interesting for they interact with the frictions on the borrowers' side and affect households default rates.

Several authors have tried to incorporate financial frictions on the side of financial intermediaries using different approaches. Gertler and Karadi (2011), for example, introduced a standard agency problem between borrowers and lenders, which imposes a constraint on the bank rather than on the final borrower. The constraint creates a wedge between the cost of external finance and the opportunity cost of financing an activity with bank's internal resources. This wedge affects borrowers' final credit conditions. The counter-cyclicality of this wedge derives from the balance sheet of the bank and it is key in unraveling the crisis as it increases the cost of credit when a negative shock hits the economy. A positive evolution of economic conditions, instead, improves the balance sheet of the bank, reducing the external cost of finance and ultimately the cost of credit. Hence, the financial accelerator mechanism in this framework works via the banks' net worth. The authors used this framework, which can be introduced in a standard DSGE model without increasing much its complexity, to study the effect of unconventional monetary responses. Gertler and Kiyotaki (2011) proposed a model along the lines of Gertler and Karadi (2011), however recognizing that a salient aspect of the financial crisis has been the freeze in the inter-bank market and introducing a mechanism to model idiosyncratic shock affecting the liquidity of different banks. In order to do so, they introduce an exogenous shock in banks' capital quality which finds its empirical justification from the losses in mortgage baked securities held by banks after the collapse in house prices. The deterioration in the asset value

[7] For a strong critique to the DSGE approach see Stiglitz (2011)

affects the net worth of the bank in proportion to its leverage. According to (Adrian, Colla, and Shin, 2012) a limitation of this work is in the fact that although the two authors are able to talk about the role of banking sector in business cycle fluctuations they are silent on procyclicality of leverage, which as Adrian and Shin (2014) have shown increases during a boom and decreases in a bust. In a more recent paper, Gertler and Kiyotaki (2013) add the possibility of bank runs to their previous model. Building on the seminal work by Diamond and Dybvig (1983), they allow for an equilibrium in which bank runs are possible. This event is the result of averse macroeconomic conditions that affect two key variables: banks' balance sheet and the liquidation price of assets, which is endogenously determined. In other words, a bank run equilibrium is possible when the liquidation value of bank assets falls below its liabilities. A high leverage and a low liquidation price, which depends on economic activity, are key in determining the bank run scenario. Using this approach the authors are able to build a framework which takes into account both the role of financial frictions in hindering economic activity via an increase in the spread between fundable loans and deposits, and the possibility of bank runs. Boissay, Collard, and Smets (2012) presented another interesting model, accounting for an heterogeneous and non-trivial banking sector. The authors, introduced a moral hazard problem, which might lead to a freeze in the interbank market with repercussions for the real economy. The main contribution of the paper is to allow for the possibility that a financial crisis is the result of small shocks in productivity, and not of a big negative shock.

1.3 The Model Economy

1.3.1 Mortgage Defaults

The starting point to discuss households' defaulting possibilities is to consider the put option component of the mortgage (Bajari, Chu, and Park, 2008). Consider a frictionless economy, absent any defaulting costs, borrowers would default when the present value of their asset (the house) is lower than the outstanding value of their debt (the mortgage). This is the implicit assumption behind many of the models that consider endogenous default possibilities and it is sometimes referred to in the literature as the "ruthless defaulting condition". However, the literature on mortgage defaults points both at the presence of additional costs of defaulting and to motives that might abstract from pure economic reasons. Guiso, Sapienza, and Zingales (2013) show that not only pecuniary motives, but also considerations related to fairness and morality play a role in determining defaulting decision. Furthermore, they argue that being exposed to strategic defaulters increases the chances of behaving similarly. The presence of further components affecting the decisional problem of homeowners justifies the idea of the so-called negative equity condition, which tells that homeowners will default when the level of their equity (housing) is strictly negative and sometimes the difference between the current value of their housing and the value of the mortgage they have to pay back is quite large. It does not surprise then, that a large body of literature tried to estimate how negative the "negative equity" actually is. Indeed, Foote, Gerardi, and Willen (2008) show that in the recession of 1990-1991 in Massachusetts only 6.4% of homeowners decided to default even if they were in a negative equity position. Independently from the particular level of the threshold below which borrowers prefer to default, defaulting is considered strategic when reaching a particular level of negative equity the homeowners would still be able to repay his or her loan but rather prefers to default. According to our approach, all defaults, being them coming from primers or sub-primers, are strategic, the difference being that we design a financial contract that allows sub-primers to exercise the put option as long as their housing value falls below the mortgage repayment, while primers exercise the option at a lower threshold.[8]

In our approach we do not aim at describing with extreme realism this decision. However, by allowing sub-prime borrowers to default

[8]In our approach we do not consider an important aspect highlighted in the literature which affects homeowners decisions to default, that of liquidity constraints, derived from idiosyncratic shocks to homeowners' income – Foote, Gerardi, and Willen (2008) call the joint combination of a negative equity and liquidity shocks the double trigger hypothesis. However, we do allow for the possibility of an idiosyncratic shock to the value of housing investment, which somehow renders the idea of an income shock.

on the basis of a utility-based approach we explicitly refer to the idea of strategic default. Furthermore, following the findings of those studies, we introduce an exogenous component that we call *stigma*, which is added to the defaulting condition. By taking on a positive value for primers, this component ensures that their rate of default in steady state is lower than that of sub-primers. The *stigma* component is a catchall variable, a short cut that we take in order to consider all the motives which attenuate home-owners willingness to default.
Introducing strategic default option in a DSGE framework allows us to have a clear separation between two distinct classes of borrowers with the advantage of rendering some key aspects of the mortgage market, such as the different LTV ratios, different risk premia and default rates.

1.3.2 An overview of the model

The model economy is composed by three categories of households (savers, prime and sub-prime borrowers), by banks and firms, which are owned by savers and by unions.
There is a continuum of households over the [0,1] interval, and each household is composed by a large number of members. Households groups share the same utility function which comprises, a part from consumption, an aggregate non-durable good – housing – and labor services. We follow FL assuming that housing investment, for each single household member, is subject to an idiosyncratic shock ω_t^ι affecting its final value, and allowing borrowers to default, though one first important novelty of our approach is to explicitly model primers and sub-primers separately. The idiosyncratic shock is private information of the investor and it is assumed to be independently and identically distributed (i.i.d.) across members of the same household and across time. In particular, ω_t follows a log normal distribution with p.d.f equal to $f_t(\omega_t)$ and cumulative distribution function equal to $F_t(\omega_t)$[9]. Furthermore, its expected value is $E_t(\omega_t) = 1$ at all time for each households in each group. This means that there is no aggregate risk in housing investment at the household level. This reason,

[9]We follow BGG by imposing a restriction on the hazard rate $h(\omega) = \frac{\dot{F}(\omega)}{1-F(\omega)}$. Namely that: $\frac{\partial \omega h(\omega)}{\partial \omega} > 0$

coupled with the fact that savers do not borrow and therefore never default, suffices to ignore the effect of the shock on savers.
All households members in the prime and sub-prime group are ex-ante identical. When members are required to pay back their loan they can decide to default strategically. We assume that there is perfect insurance among household members so that consumption of non-durable goods and housing services are ex post equal across all members of the household. Hence, borrower household members are also ex post identical.
The riskiness of housing investment changes over time through a change in the standard deviation $\sigma_{\omega,t}$ of the shocks' distribution. The idiosyncratic shock is private information of the household member and to observe it the lender must pay an auditing cost that is a fixed proportion μ of the realized housing stock value. This constitutes an agency problem that introduces a first financial friction in the model since borrowers are endogenously constrained in the amount they can borrow from banks. The presence of an agency problem between borrowers and lenders allows us to endogenize the constraint and to introduce a risk premium in a way similar to the problem developed by BGG. As explained by FL, the shock can be thought as a shock to the investment itself or as a shock to the price of houses, given by geographical differences. Considering the nature of the shock, which displays an unchanged mean productivity of housing investment, we can also think about it as an increase in uncertainty that endogenously triggers a higher number of defaults in the housing sector (Pataracchia et al., 2013). Finally, as noted by Demyanyk and Hemert (2011), the quality of loans considerably deteriorated during the 6 years before the financial crisis, therefore we can also interpret the shock to the standard deviation as a way to reproduce this deterioration of loans in the sub-prime sector.

Banks collect deposits from savers and lend to impatient households. Lending assumes the form of a one period contract, where a state-contingent contractual interest rate r_t^k is paid each period by non defaulting borrowers to ensure that the banks get a safe return (r_t^l), therefore the risk is entirely borne by borrowers. If a household's member decides to default the bank can seize the housing stock of the agent, after having paid the monitoring cost. Banks are subject to an optimal leverage ratio, which can be thought as arising from regulatory requirements as for example the Basel framework on capital adequacy. In deviating from that optimal level, the bank incurs into a cost, that endogenously pushes the bank to get back to the optimal level of leverage. The deviation of the bank from the optimal level reduces banks's margins and exacerbates its capital position, entailing a reduction of the loan rate, which moves sluggishly given monopolistic competition in the bank market.

1.4 Households

Imagine an economy populated by a continuum of infinitely-lived households distributed over the $[0,1]$ interval, each household being composed by a large number of members. Households are identical but for their rate of time preference. A fraction ξ is impatient while the remaining fraction $(1-\xi)$ is composed by patient individuals. That leads patient households to lend to impatient ones, therefore we can also refer to those two groups indistinctly as savers (s) and borrowers (b).

Households enjoy utility from consumption of non-durable goods (C_t) and from housing (H_t), while they receive disutility from labor efforts (N_t). They maximize their life-time utility with respect to housing and consumption while they delegate to unions wage setting decisions and therefore they do not maximize utility also with respect to labor efforts. We use an utility function of this form:

$$E_0 \sum_{t=0}^{\infty} \beta_\imath^t \left(\ln X_t - \zeta_\imath \sum_{m=c,h} \frac{N_{m,t}^{(1+\eta)}}{(1+\eta)} \right), \, with \, \imath = (b,s) \;\; 0 < \beta_\imath < 1 \quad (1.1)$$

where X_t is as an index of housing and non-durable goods:

$$X_t \equiv [(1-\alpha)(C_t - b_h C_{t-1})^{\frac{(\chi-1)}{\chi}} + \alpha H_t^{\frac{(\chi-1)}{\chi}}]^{\frac{\chi}{(\chi-1)}}$$

and $\beta_s^t > \beta_b^t$ – that is, savers discount the future less heavily than borrowers. The parameters $\alpha > 0$ and $\zeta > 0$ represent respectively the share of housing in the composite index and are the weight of housing and labor in the utility function. η is the inverse of the wage elasticity of labor supply and we allow for external habit in consumption, driven by the parameter b_h. Finally, working hours are indexed since we consider two separate sectors: consumption (c) and housing (h).[10] We introduce a further element of heterogeneity in the model by identifying a fraction ϑ of borrowers as what we call prime borrowers, and the remaining $(1-\vartheta)$ as sub-primers. Borrowers $b = (p, s\text{-}p)$ enjoy the same discount factor, and their distinction rests on their different attitude towards defaulting. While sub-primers take defaulting decisions following a ruthless negative equity condition, primers attach a relatively higher value to their housing holdings. Borrowers are constrained in the amount they can borrow by the value of their collateral, which in this model is represented by their housing stock. The constraint is endogenously determined and its size originates from an agency problem between borrowers and lenders. We describe in detail this problem and the financial contract that it generates separately for sub-primers and primers.

1.4.1 Sub-prime Borrowers

Sub-primers follow a simple defaulting rule – namely they exercise the put-option of the mortgage contract following a ruthless defaulting condition. More precisely a sub-primer ι defaults whenever the value of her loan (mortgage) is higher than the present value of her housing stock:

$$\omega_{t+1}^{\iota,s-p} H_t^{\iota,s-p} P_{h,t+1}(1-\delta) \leq L_t^{\iota,s-p}(1+r_{t+1}^{k,s-p}) \tag{1.2}$$

where P_h is house nominal price, δ is the housing depreciation rate and L_t^{s-p} the size of the loan. Note the timing in this equation. The borrower decides H_t^{s-p} and L_t^{s-p} at time t. At the beginning of $t+1$ the shock hits her housing stock. She compares the value of her housing stock with the cost of the mortgage, which is given by $r_{t+1}^{k,s-p}$ and decides consequently whether to default or not. After the idiosyncratic shock hits the housing sector, some households' members will

[10] We kept the utility function as generic as possible, Appendix A contains a detailed description of the form taken by the utility function relative to the parameters chosen.

default, while the rest shall prefer to fulfill their obligations. We can therefore identify a threshold value for ω_{t+1}, which we call $\bar{\omega}_{t+1}$. Households' members whose investment value happens to be below this threshold shall prefer to default:

$$\bar{\omega}_{t+1}^{s-p} H_t^{s-p} P_{h,t+1}(1-\delta) = L_t^{s-p}(1 + r_{t+1}^{k,s-p}) \tag{1.3}$$

Therefore, $\bar{\omega}_{t+1}$ is an endogenous threshold determining the share of households that will default on their obligations.
Banks, collect deposits and agree to pay back a risk free interest rate r_t^d on them, which in this model corresponds to the policy rate. Following GNSS we distinguish banks into a retail and a wholesale branch. The wholesale branch operates in a perfectly competitive market, it collects deposits and issues loans, which are then passed to the retail branch at the interbank rate r_t^{int}. Banks in the retail sector operates in a monopolistic competitive market, this results in a loan rate r_t^l set as a mark-up over the interbank rate. Banks' return is predetermined, namely the rate r_t^l is agreed at time t and paid in the following period, notwithstanding contingencies. Again, let us remind that this assumption entails that the risk is borne by borrowers only. However, this does not rule out the possibility for bank to suffer a reduction in profits therefore reducing their net worth. Taking this into account we can write the participation constraint for the bank as:

$$\begin{aligned}(1 + r_t^l)L_t^{s-p} = &\int_0^{\bar{\omega}_{t+1}^{s-p}} \omega_{t+1}(1-\mu)(1-\delta)P_{h,t+1}H_t^{s-p} f_{t+1}(\omega)\, d\omega \\ &+ \int_{\bar{\omega}_{t+1}^{s-p}}^{\infty} (1 + r_{t+1}^{k,s-p})L_t^{s-p} f_{t+1}(\omega)\, d\omega\end{aligned} \tag{1.4}$$

The participation constraint reads as follow: the value of the housing stock being seized by banks combined with the value of the loans paid back by non-defaulters (right hand side of (1.4)) must be equal to the pre-determined return on loans $(1 + r_t^l)L_t^{s-p}$. Note that this equation does not hold in expectations, but it is always satisfied. This is possible because the rate paid on mortgages $r_{t+1}^{k,s-p}$ adjusts as to satisfy the constraint at any point in time. That means that in this model we are assuming that mortgage contracts last only one period and feature adjustable rates.However, the presence of sticky bank rates might be seen as a modelling shortcut that allows to think to mortgage contracts as featuring fixed rates, at least to some extent. We have all the elements we need to identify the financial contract between borrowers and lenders. The contract is identified by an amount of lending L_t^{s-p} and a mortgage rate $r_{t+1}^{k,s-p}$. Given the distribution of the shock and households housing stock, the choice of those two variables pins down the default threshold and therefore households' defaulting rate. Therefore, it is convenient to identify the financial contract with the couple $(L_t^{s-p}, \bar{\omega}_{t+1}^{s-p})$. Given this specification, we can simplify the borrower problem by using some definitions. Let:

$$G_{t+1}(\bar{\omega}_{t+1}^{s-p}) \equiv \int_0^{\bar{\omega}_{t+1}^{s-p}} \omega_{t+1} f_{t+1}(\omega)\, d\omega \tag{1.5}$$

be the share of defaulters's housing stock that the bank expects to seize, gross of monitoring costs, and:

$$\Gamma_{t+1}(\bar{\omega}_{t+1}^{s-p}) \equiv \bar{\omega}_{t+1}^{s-p} \int_{\bar{\omega}_{t+1}^{s-p}}^{\infty} f_{t+1}(\omega) d\omega + G_{t+1}(\bar{\omega}_{t+1}^{s-p}) \tag{1.6}$$

be the total expected share of the housing value that would go to the bank gross of monitoring costs. Using the above definitions and plugging (1.3) into (1.4) we can rewrite the participation constraints expressing everything in terms of the housing stock, and getting rid of the contractual rate $r_{t+1}^{k,s-p}$:

$$(1 + r_t^l) L_t^{s-p} = [\Gamma_{t+1}(\bar{\omega}_{t+1}^{s-p}) - \mu G_{t+1}(\bar{\omega}_{t+1}^{s-p})](1-\delta) P_{h,t+1} H_t^{s-p} \tag{1.7}$$

where

$$[\Gamma_{t+1}(\bar{\omega}_{t+1}^{s-p}) - \mu G_{t+1}(\bar{\omega}_{t+1}^{s-p})] \tag{1.8}$$

is the loan to value ratio, that measures the size of the loans the sub-primers can get compared to the value of the housing stock. We can also read the loan to value ratio as the share of the housing stock that goes to lenders in return of their lending activity. The loan to value is an increasing function in $\bar{\omega}$ meaning that a higher default rate goes hand in hand with an increase in the contractual rate r^k and therefore in the repayment to the lender. Now, we can rewrite (1.7) in real terms by dividing everything for $P_{c,t}$:

$$(1 + r_t^l) l_t^{s-p} = [\Gamma_{t+1}(\bar{\omega}_{t+1}^{s-p}) - \mu G_{t+1}(\bar{\omega}_{t+1}^{s-p})](1-\delta) p_{h,t+1} H_t^{s-p} \pi_{t+1} \tag{1.9}$$

In order to write down the households' budget constraint we need to determine the housing stock that households are left with at time t:

$$\int_{\bar{\omega}_t^{s-p}}^{\infty} \omega_t(1-\delta)H_{t-1}^{s-p}P_{h,t}f_t(\omega)\,d\omega = [1-G_t(\bar{\omega}_t^{s-p})](1-\delta)H_{t-1}^{s-p}P_{h,t} \tag{1.10}$$

we can write this using the fact that $E_t(\omega) = 1$, namely:

$$E_t(\omega_t) = \int_0^{\infty} \omega_t f_t(\omega) d\omega f_t = 1$$

$$= \int_0^{\bar{\omega}_t^{s-p}} \omega_t f_t(\omega) d\omega f_t + \int_{\bar{\omega}_t^{s-p}}^{\infty} \omega_t f_t(\omega) d\omega f_t = 1$$

and therefore:

$$\int_{\bar{\omega}_t^{s-p}}^{\infty} \omega_t f_t(\omega) d\omega f_t = [1 - G_t(\bar{\omega}_t^{s-p})] \tag{1.11}$$

We can now write the budget constraint in nominal terms:

$$\begin{aligned} &C_t^{s-p}P_{c,t} + P_{h,t}H_t^{s-p} + L_{t-1}^{s-p}(1+r_t^k)[1-F_t(\bar{\omega}_t^{s-p})] \\ &= L_t^{s-p} + (1-\delta)[1-G_t(\bar{\omega}_t^{s-p})]P_{h,t}H_{t-1}^{s-p} + \sum_m W_{m,t}^{s-p}N_{m,t}^{s-p} \end{aligned} \tag{1.12}$$

Now we can use the relationship in (1.3) and in (1.7) as shown in Appendix A to eliminate $r_t^{k,s-p}$, and also rewrite it in real terms:[11]

$$\begin{aligned} C_t^{s-p} + p_{h,t}H_t^{s-p} + \frac{l_{t-1}^{s-p}}{\pi_t}(1+r_{t-1}^l) = l_t^{s-p} + (1-\delta)[1-\mu G_t(\bar{\omega}_t^{s-p})]p_{h,t}H_{t-1}^{s-p} \\ + \sum_m w_{m,t}^{s-p}N_{m,t}^{s-p} \end{aligned} \tag{1.13}$$

The sub-primer maximizes (1.1) with respect to C_t^{s-p}, H_t^{s-p}, l_t^{s-p} and $\bar{\omega}_{t+1}^{s-p}$ subject to the budget constraint (1.13) and the participation constraint (1.9).

The first order condition with respect to C_t^{s-p} equates marginal utility from consumption $MU_{c,t}^{s-p}$ with the Lagrange multiplier from the budget constraint[12]:

$$MU_{c,t}^{s-p} = \lambda_t^{s-p} \tag{1.14}$$

[11] See Appendix A for details.

[12] Details of the problem can be found in the Appendix A

The first order condition with respect to H_t^{s-p} defines the investment decision in the housing sector:

$$\lambda_t^{s-p} p_{h,t} = MU_{h,t}^{s-p} + (1-\delta)\beta_b E_t[(1-\mu G_{t+1}(\bar{\omega}_{t+1}^{s-p}))\lambda_{t+1}^{s-p} p_{h,t+1} + \gamma_{t+1}^{s-p}[\Gamma_{t+1}(\bar{\omega}_{t+1}^{s-p}) - \mu G_{t+1}(\bar{\omega}_{t+1}^{s-p})] p_{h,t+1}\pi_{t+1}] \quad (1.15)$$

where $MU_{h,t}$ is the marginal utility from housing services. Equation (1.15) deserves a closer scrutiny. This condition requires that the marginal gain from consumption equals the marginal gain from housing. That is not only given by the marginal utility of housing but also from the fact that housing can be sold in the next period and used to buy an additional unit of consumption and by the fact that it can be used as a collateral (latter term on the right).

The first order condition with respect to l_t^{s-p} is given by:

$$\lambda_t^{s-p} - (1+r_t^l)E_t\left[\frac{\lambda_{t+1}^{s-p}}{\pi_{t+1}}\beta_b + \gamma_{t+1}^{s-p}\right] = 0 \quad (1.16)$$

where γ_{t+1}^{s-p} is the Lagrange multiplier of the participation constraint. This equation also reads as the Euler equation for savers and it states that the marginal utility from consumption today is higher than the marginal utility from consumption tomorrow when the constraint is binding ($\gamma_{t+1}^{s-p} > 0$).

Finally, we have the first order condition with respect to the defaulting threshold:

$$-\lambda_{t+1}^{s-p}\beta_b\mu G'_{t+1}(\bar{\omega}_{t+1}^{s-p}) + \gamma_{t+1}^{s-p}[\Gamma'_{t+1}(\bar{\omega}_{t+1}^{s-p}) - \mu G'_{t+1}(\bar{\omega}_{t+1}^{s-p})]\pi_{t+1} = 0 \quad (1.17)$$

Note that this condition is not expressed in expectations since $\bar{\omega}_{t+1}$ always adjust to ensure that the participation constraint (1.9) always holds with equality.

This condition equates the marginal gain from a small increment in the defaulting threshold and the additional cost of defaulting. The former is given by the increase in the loan to value ratio, and it is bigger the higher is γ_{t+1}^{s-p}, namely the more the borrower is constrained. The latter is given by the marginal increase in the resources wasted by a higher rate of default. Indeed, $\mu G(\bar{\omega}_{t+1}^{s-p})$ is the amount of monitoring costs, which in this set-up are *de iure* paid by the lender, but *de facto* paid by borrowers.

1.4.2 Prime Borrowers

The maximization problem and the financial contract designed for primer borrowers is similar to the one outlined for sub-primers in the previous section. However, the default for this class of borrowers is less likely to happen. Formally we model this condition by adding a *stigma* component to the defaulting condition of primers which is proportional to the value of the housing stock. The *stigma* component is a catchall variable that summarizes non-economic motives that lie behind borrowers' decision to default. Namely, by adding this further component in the defaulting condition of primers, we are assuming that primers are more attached to their housing stock and that they value it more than sub-primers. This translates, ceteris paribus, into a lower default threshold, and therefore into a lower contractual rate.[13]

For a single primer ι the defaulting condition might be written as:

$$\omega_{t+1}^{\iota,p} H_t^p P_{h,t+1}(1-\delta) + (stigma) H_t^p P_{h,t+1}(1-\delta) \leq L_t^{\iota,p}(1 + r_{t+1}^{k,p}) \quad (1.18)$$

Following the sub-primer problem we can now identify a threshold value for $\omega_{t+1}^{\iota,p}$:

$$(\bar{\omega}_{t+1}^p + stigma) H_t^p P_{h,t+1}(1-\delta) = L_t^p(1 + r_{t+1}^{k,p}) \quad (1.19)$$

Equation (1.19) suggests that ceteris paribus primers' default will be less likely than that of sub-primers since the way we introduced the stigma component works as a positive component that increases the value of primers' housing stock. Indeed, this is exactly the meaning that we want to attach to this variable, given that some households do not consider only economic reasons when they have to decide whether to leave their home or keep on paying their mortgages even though the value of their house fell below that of the mortgage payment.

As we shall show in the next section, the threshold chosen by primers is going to be lower than that of sub-primers for the reasons explained above. This would in turn entail a lower contractual rate on the mortgage $r_{t+1}^{k,p}$ and a lower loan to value ratio, given that the

[13] Note that one can also think of sub-primers as primers with a stigma component equal to zero.

latter one is increasing in $\bar{\omega}_t$ and $r_t^{k,p}$.
The analysis of the primer's problem follows closely the one we already developed for the sub-primer. By plugging (1.19) into the participation constraint:

$$\begin{aligned}(1+r_t^l)L_t^p = &\int_0^{\bar{\omega}_{t+1}^p} \omega_{t+1}(1-\mu)(1-\delta)P_{h,t+1}H_t^p f_{t+1}(\omega)\,d\omega \\ &+ \int_{\bar{\omega}_{t+1}^p}^{\infty} (1+r_{t+1}^{k,p})L_t^p f_{t+1}(\omega)\,d\omega\end{aligned} \tag{1.20}$$

we get the partecipation constraint in real terms:

$$\begin{aligned}(1+r_t^f)l_t^b = \{&\Gamma_{t+1}(\bar{\omega}_{t+1}^b) - \mu G_{t+1}(\bar{\omega}_{t+1}^b) \\ &+ [1-F_{t+1}(\bar{\omega}_{t+1}^b)](\textit{stigma})\}(1-\delta)p_{h,t+1}H_t^b\pi_{t+1}\end{aligned} \tag{1.21}$$

Primers maximize the utility function (1.1) subject to the following budget constraint:

$$\begin{aligned}&C_t^p P_{c,t} + P_{h,t}H_t^p + L_{t-1}^p(1+r_t^k)[1-F_t(\bar{\omega}_t^p)] \\ &= L_t^p + (1-\delta)[1-G_t(\bar{\omega}_t^p)]P_{h,t}H_{t-1}^p + \sum_m W_{m,t}N_{m,t}^p\end{aligned} \tag{1.22}$$

which in real terms is equal to:

$$\begin{aligned}C_t^p + p_{h,t}H_t^p + \frac{l_{t-1}^p}{\pi_t}(1+r_{t-1}^l) = l_t^p + (1-\delta)[1-\mu G_t(\bar{\omega}_t^p)]p_{h,t}H_{t-1}^p \\ + \sum_m w_{m,t}N_{m,t}^p\end{aligned} \tag{1.23}$$

and to the lender participation constraint (1.21). The first order condition with respect to C_t^p is identical to the one obtained for the sub-primer, and it defines the Lagrange multiplier of the budget constraint:

$$MU_{c,t}^p = \lambda_t^p \tag{1.24}$$

Differentiating with respect of H_t^p we obtain the housing investment demand which is also similar to that derived above for the sub-primer:

$$\begin{aligned}MU_{h,t} = &\lambda_t^b p_{h,t} \\ &- (1-\delta)\beta_b E_t\{(1-\mu G_{t+1}(\bar{\omega}_{t+1}^b))\lambda_{t+1}^b p_{h,t+1} + \gamma_{t+1}^b[\Gamma_{t+1}(\bar{\omega}_{t+1}^b) \\ &- \mu G_{t+1}(\bar{\omega}_{t+1}^b) + [1-F_{t+1}](\bar{\omega}_{t+1}^b)(stigma^{\text{b}})]p_{h,t+1}\pi_{t+1}\}\end{aligned} \tag{1.25}$$

By differentiating with respect of l_t^p we obtain:

$$\lambda_t^p - (1 + r_t^l)E_t \left[\frac{\lambda_{t+1}^p}{\pi_{t+1}} \beta_b + \gamma_{t+1}^p \right] = 0 \tag{1.26}$$

where γ_{t+1}^p is the Lagrange multiplier of the participation constraint for the primer group of households. This condition is the Euler equation for primers, and it differs from a standard Euler equation for the presence of γ_{t+1}^p. Finally, the first order condition with respect to $\bar{\omega}_{t+1}^p$ differs significantly form the sub-primer problem as it comprises the stigma component. It is this condition that determines a lower optimal threshold.

$$\begin{aligned} &-\lambda_{t+1}^p \beta_b \mu G'_{t+1}(\bar{\omega}_{t+1}^p) + \gamma_{t+}^p [\Gamma'_{t+1}(\bar{\omega}_{t+1}^p) \\ &- \mu G'_{t+1}(\bar{\omega}_{t+1}^p) - f_{t+1}(\bar{\omega}_{t+1}^p)(\textit{stigma})]\pi_{t+1} = 0 \end{aligned} \tag{1.27}$$

1.4.3 Differences between primers and sub-primers

The defaulting condition for the primer is ceteris paribus lower than that of the sub-primer. This comes from our definition of the problem, namely from the introduction of the *stigma* component, and directly feeds into the loan to value equation, which hints a lower loan to value ratio for primers. Indeed, consider two different households with the same level of housing stock contracting the same nominal debt. If we set the stigma component to zero for one of the two households – the sub-primer – and we allow $stigma > 0$ for primers we get that for the same realization of the idiosyncratic shock the primer will attach a higher value to the housing stock:

$$(\omega_{t+1}^{\iota,p} + \textit{stigma})H_t P_{h,t+1}(1-\delta) \leq L_t^\iota (1 + r_{t+1}^k) \tag{1.28}$$

$$\omega_{t+1}^{\iota,s-p} H_t P_{h,t+1}(1-\delta) \leq L_t^\iota (1 + r_{t+1}^k) \tag{1.29}$$

Therefore the defaulting threshold of the primer will be lower than that of the sub-primer and it will be determined by the size of the *stigma* component, namely we have that: $\bar{\omega}_{t+1}^p < \bar{\omega}_{t+1}^{s-p}$.

The decision of a lower threshold is endogenously determined once we allow primers defaulting condition to be disturbed by the *stigma* component. Consider now that the loan to value is increasing in $\bar{\omega}$[14],

[14] Look at Appendix A in Bernanke, Gertler, and Gilchrist (1999) and to our Appendix A for an in depth explanation.

but as we have shown above $\bar{\omega}$ is decreasing in *stigma*. Therefore, being *stigma* equal to zero for sub-primers and strictly positive for primers, the loan to value ratio is ceteris paribus lower for the latter group of households. Figure 1.6 might help providing an intuition for the role played by the *stigma* component. While the true productivity of housing investment stays unchanged, the presence of *stigma* shifts to the left the threshold for primers, who can be thought as perceiving a higher productivity for their housing investment.

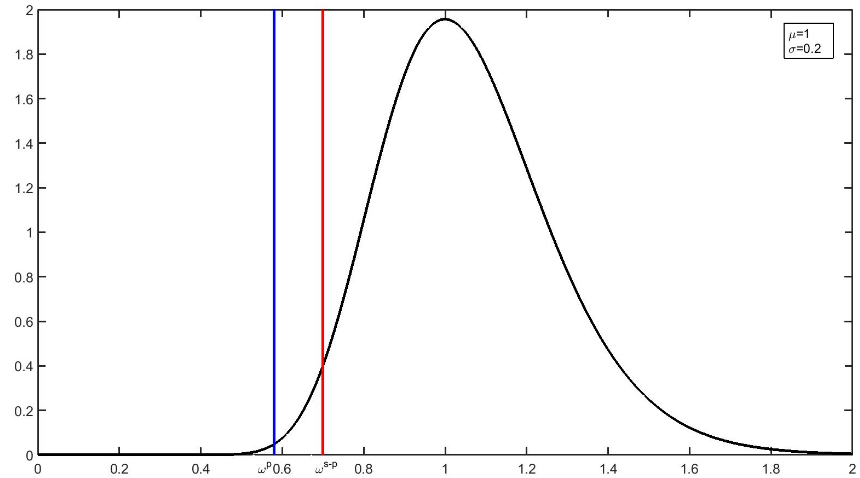

FIGURE 1.6: *The log-normal distribution and an example of two different thresholds . As an illustrative example we plot in blue a hypothetical threshold for prime borrowers while in red one for sub-primers. A higher threshold is associated with a higher share of defaulters.*

It is important to highlight that in this framework borrowers decide the defaulting threshold, which implicitly means that they define the contractual rate on their loans. This also means that a different $\bar{\omega}$ for the two groups also implies a different contactual rate. Namely, a lower threshold for primers entails that in steady state:

$$r_t^{k,s-p} > r_t^{k,p} \tag{1.30}$$

1.4.4 Savers

The problem of savers – that we denote with a $\sim$ is standard. They maximize (1.1) over $\tilde{C}_t$, $\tilde{H}_t$ and $\tilde{d}_t$ subject to the following budget constraint defined in real terms:

$$\tilde{C}_t + p_{h,t}[\tilde{H}_t - \tilde{H}_{t-1}(1-\delta)] + \tilde{d}_t = \frac{\tilde{d}_{t-1}(1 + r^d_{t-1})}{\pi_t} + \tilde{w}_t\tilde{N}_t + \Pi^{fi}_t \tag{1.31}$$

where d_t is real deposits and r_t^d the risk free rate earned on deposits and Π_t^{fi} are profits rebated from firms and the banking sector.

The first order condition with respect to $\tilde{C}_t$ defines the Lagrange multiplier:

$$\tilde{MU}_{c,t} = \tilde{\lambda}_{c,t} \tag{1.32}$$

while that on $\tilde{H}_t$ defines housing investment. Notice that, differently from what we saw above this decision is only constrained by the budget constraint:

$$\tilde{\lambda}_{c,t} p_{h,t} = \tilde{MU}_{h,t} + \beta(1-\delta)E_t[p_{h,t+1}\tilde{\lambda}_{t+1}] \tag{1.33}$$

Finally, the first order condition with respect to $\tilde{d}_t$ is given by a standard Euler Equation:

$$\tilde{\lambda}_t = \tilde{\lambda}_{t+1}\beta\frac{(1+r_t^d)}{\pi_{t+1}} \tag{1.34}$$

1.5 The Supply Side

The supply side of the economy is composed by final goods producers, an intermediate goods sector and labor unions. Furthermore, we can distinguish between two macro-sectors $m = (c, h)$, namely, the durable and non-durable sector of the economy. The two sectors will differ for the calibration and for the different degree of price stickiness. In particular, as highlighted by Carlstrom and Fuerst (2010), it seems implausible that house prices are sticky, for they are usually negotiated between buyer and seller[15].

1.5.1 Final Goods Producers

We assume that a continuum of perfectly competitive firms produces the final good using a CES technology of this form:

$$Y_{m,t} = \left(\int_0^1 Y_{m,t}(i)^{\frac{\varepsilon_m - 1}{\varepsilon_m}} \, di \right)^{\frac{\varepsilon_m}{\varepsilon_m - 1}} \tag{1.35}$$

where $i \in [0, 1]$ is the good produced by the intermediate goods producer firm i. Following the producer maximization problem we can derive the demand for intermediate goods:

$$Y_{m,t}(i) = \left(\frac{P_{m,t}(i)}{P_{m,t}} \right)^{-\varepsilon_m} Y_{m,t} \tag{1.36}$$

and the price index[16]:

$$P_{m,t} = \left(\int_0^1 P_{m,t}(i)^{1-\varepsilon_m} \right)^{\frac{1}{1-\varepsilon_m}} di \tag{1.37}$$

1.5.2 Intermediate Goods Producers

A measure $i \in [0, 1]$ of intermediate goods producers operates under monopolistic competition. Firms readjust their prices following a Rotemberg mechanism.

The production function in the intermediate sector is represented by:

$$Y_{m,t}(i) = A_{m,t} N_{m,t}(i) \tag{1.38}$$

[15] For further comments and analysis on this see Chapter III

[16] See the Appendix A for details.

where $N_t(i)$ is labor hours and A_t is an idiosyncratic productivity parameter.

Monopolistic firms face quadratic costs of adjusting prices:

$$ADJ\_P_t(i) = \frac{\gamma_m}{2}\left(\frac{P_{m,t}(i)}{P_{m,t-1}(i)} - 1\right)^2 Y_{m,t} \tag{1.39}$$

Notice that the costs increase in the scale of final output $Y_{m,t}$.

We can write the maximization problem of the firm under this setting. Firms take the price level $P_{m,t}$, the nominal wage $W_{m,t}$ and the aggregate level of output $Y_{m,t}$ as given. They maximize profits over $N_{m,t}(i)$ and $P_{m,t}(i)$:

$$\begin{aligned}\max_{P_{m,t}(i),N_{m,t}(i)} E_t \sum_{k=0}^{\infty} \Lambda_{t,t+k} \Bigg[& P_{m,t}(i) Y_{m,t+k}(i) - W_{m,t+k} N_{m,t+k}(i) \\ & - \frac{\gamma_{m,t}}{2}\left(\frac{P_{m,t}(i)}{P_{m,t-1}(i)} - 1\right)^2 P_{m,t} Y_{m,t} \Bigg]\end{aligned} \tag{1.40}$$

given the demand and the production function:

$$\begin{aligned} Y_t(i) &= \left(\frac{P_t(i)}{P_t}\right)^{-\epsilon} Y_t; \qquad Y_t(i) \\ &= A_t N_t(i) \end{aligned} \tag{1.41}$$

and where the discount factor $\Lambda_{t,t+k}$ is the one of savers for they own intermediate goods producers.

In a symmetric equilibrium $\frac{P_{m,t}(i)}{P_{m,t}} = 1$, meaning that all the firms set the same price and also employ the same amount of labor $N_{m,t}$.

First order conditions with respect to $N_{m,t}(i)$ yield:

$$\frac{W_{m,t}}{A_{m,t}} = MC^N_{m,t}(i) \tag{1.42}$$

where the superscript N stands for nominal. This condition suggests that nominal marginal costs are given by the ratio of the nominal wage over the marginal product of labor.

The FOC w.r.t. $P_t(i)$, considering gross inflation as usual as:

$$\pi_{m,t} = \frac{P_{m,t}}{P_{m,t-1}} \tag{1.43}$$

is equal to:

$$(1-\varepsilon_m) + \varepsilon_m mc_{m,t} = \gamma_{m,t}(\pi_{m,t}-1)\pi_{m,t} - \gamma_{m,t} E_t \left[\frac{\Lambda_{t+1}}{\Lambda t}\frac{P_{m,t+1}}{P_{m,t}}\frac{Y_{m,t+1}}{Y_{m,t}}(\pi_{m,t+1}-1)\pi_{m,t+1}\right] \tag{1.44}$$

Equation (1.44) is the New-Keynesian Philips Curve.

In order to introduce housing construction adjustment costs we follow Carlstrom and Fuerst (2010). In the paper, the authors argue that adjustment costs in housing investment is a necessary component in the model in order to reconcile the behavior of housing with the evidence suggested by data. In particular, if the model features wage stickiness, housing is very sensitive to a monetary policy shock. Introducing adjustment costs attenuates this sensitivity. Carlstrom and Fuerst (2010) introduce firm-level adjusting cost separating between the cost that a firm faces in adjusting the *level* of production and the cost the firm faces in *changing* the production level. Those are respectively:

$$\textit{Costs adjusting the level} = P_{h,t}\phi_1^h \frac{Y_{h,ss}}{2}\left(\frac{Y_{h,t}-Y_{h,ss}}{Y_{h,ss}}\right)^2 \tag{1.45}$$

$$\textit{Costs changing the production level} = P_{h,t}\phi_2^h \frac{Y_{h,ss}}{2}\left(\frac{Y_{h,t}-Y_{h,t-1}}{Y_{h,ss}}\right)^2 \tag{1.46}$$

Technically, introducing those costs changes the maximization problem of intermediate firms, equation (1.40) becomes:

$$\max_{P_{m,t}(i),N_{m,t}(i)} E_t \sum_{k=0}^{\infty} \Lambda_{t,t+k}\Bigg[P_{m,t}(i)Y_{m,t+k}(i) - W_{m,t+k}N_{m,t+k}(i) - \frac{\gamma_{m,t}}{2}\left(\frac{P_{m,t}(i)}{P_{m,t-1}(i)}-1\right)^2 P_{m,t}Y_{m,t} - P_{m,t}\phi_1^m\frac{Y_{m,ss}}{2}\left(\frac{Y_{m,t}(i)-Y_{h,ss}}{Y_{m,ss}}\right)^2 - P_{m,t}\phi_2^m\frac{Y_{m,ss}}{2}\left(\frac{Y_{m,t}(i)-Y_{h,t-1}(i)}{Y_{m,ss}}\right)^2\Bigg] \tag{1.47}$$

We can therefore rewrite the Lagrangian for the problem (also in this case we drop the m to simplify notation):

$$\begin{aligned}
\mathcal{L} = \Lambda_t \Bigg[& P_t(i) \left(\frac{P_t(i)}{P_t} \right)^{(-\varepsilon_m)} Y_t - W_t N_t - \frac{\gamma_m}{2} \left(\frac{P_t(i)}{P_{t-1}(i)} - 1 \right)^2 P_t Y_t \\
& - MC_t^N \left(\left(\frac{P_t(i)}{P_t} \right)^{(-\varepsilon_m)} Y_t - A_t N_t \right) \\
& - P_t \phi_1^h \frac{Y_{ss}}{2} \left(\left(\frac{P_t(i)}{P_t} \right)^{-\varepsilon_m} \frac{Y_t}{Y_{ss}} - 1 \right)^2 \\
& - P_t \phi_2^h \frac{Y_{ss}}{2} \left(\left(\frac{P_t(i)}{P_t} \right)^{-\varepsilon_m} \frac{Y_t}{Y_{ss}} - \left(\frac{P_{t-1}(i)}{P_{t-1}} \right)^{-\varepsilon_m} \frac{Y_{t-1}}{Y_{ss}} \right)^2 \Bigg] \\
& + \Lambda_{t+1} \Bigg[P_{t+1}(i) \left(\frac{P_{t+1}(i)}{P_{t+1}} \right)^{(-\varepsilon_m)} Y_{t+1} \\
& - W_{t+1} N_{t+1} - \frac{\gamma_m}{2} \left(\frac{P_{t+1}(i)}{P_t(i)} - 1 \right)^2 P_{t+1} Y_{t+1} \\
& - MC_{t+1}^N \left(\left(\frac{P_{t+1}(i)}{P_{t+1}} \right)^{(-\varepsilon_m)} Y_{t+1} - A_{t+1} N_{t+1} \right) \\
& - P_{t+1} \phi_1^h \frac{Y_{ss}}{2} \left(\left(\frac{P_{t+1}(i)}{P_{t+1}} \right)^{-\varepsilon_m} \frac{Y_{t+1}}{Y_{ss}} - 1 \right)^2 \\
& - P_{t+1} \phi_2^h \frac{Y_{ss}}{2} \left(\left(\frac{P_{t+1}(i)}{P_{t+1}} \right)^{-\varepsilon_m} \frac{Y_{t+1}}{Y_{ss}} - \left(\frac{P_t(i)}{P_t} \right)^{-\varepsilon_m} \frac{Y_t}{Y_{ss}} \right)^2 \Bigg]
\end{aligned} \tag{1.48}$$

the first order condition with respect to $P_t(i)$ reads as follows:

$$
\begin{aligned}
\frac{\partial \mathcal{L}}{\partial P_t} = {} & (1-\varepsilon_m)\Lambda_t \left(\frac{P_t(i)}{P_t}\right)^{(-\varepsilon_m)} Y_t - \Lambda_t \gamma_m \frac{P_t}{P_{t-1}(i)} Y_t \left(\frac{P_t(i)}{P_{t-1}(i)} - 1\right) \\
& + \Lambda_t MC_t^N \varepsilon_m \left(\frac{P_t(i)}{P_t}\right)^{(-\varepsilon_m - 1)} \frac{Y_t}{P_t} \\
& + \Lambda_t \varepsilon_m \phi_1^h Y_t \left(\frac{P_t(i)}{P_t}\right)^{(-\varepsilon_m - 1)} \left(\left(\frac{P_t(i)}{P_t}\right)^{-\varepsilon_m} \frac{Y_t}{Y_{ss}} - 1\right) \\
& + \Lambda_t \varepsilon_m \phi_2^h Y_t \left(\frac{P_t(i)}{P_t}\right)^{(-\varepsilon_m - 1)} \left(\left(\frac{P_t(i)}{P_t}\right)^{-\varepsilon_m} \frac{Y_t}{Y_{ss}} \right. \\
& \qquad \left. - \left(\frac{P_{t-1}(i)}{P_{t-1}}\right)^{-\varepsilon_m} \frac{Y_{t-1}}{Y_{ss}}\right) \\
& + \Lambda_{t+1} \gamma_m Y_{t+1} \left(\frac{1}{P_t(i)}\right)^2 P_{t+1} P_{t+1}(i) \left(\frac{P_{t+1}(i)}{P_t(i)} - 1\right) \\
& - \Lambda_{t+1} \varepsilon_m \phi_2^h Y_t \frac{P_{t+1}}{P_t} \left(\frac{P_t(i)}{P_t}\right)^{(-\varepsilon_m - 1)} \left(\left(\frac{P_{t+1}(i)}{P_{t+1}}\right)^{-\varepsilon_m} \frac{Y_{t+1}}{Y_{ss}} \right. \\
& \qquad \left. - \left(\frac{P_t(i)}{P_t}\right)^{-\varepsilon_m} \frac{Y_t}{Y_{ss}}\right) \\
= {} & 0
\end{aligned} \tag{1.49}
$$

Now, divide everything by Λ_t and by Y_t and consider a symmetric equilibrium in which $P_t(i) = P_t$:

$$
\begin{aligned}
(1-\varepsilon_m) + \varepsilon_m mc^{real} = {} & \gamma_m \pi_t (\pi_t - 1) - \frac{\Lambda_{t+1}}{\Lambda_t} \gamma_m \frac{Y_{t+1}}{Y_t} (\pi_{t+1})^2 (\pi_{t+1} - 1) \\
& - \varepsilon_m \phi_1^h \left(\frac{Y_t}{Y_{ss}} - 1\right) - \varepsilon_m \phi_2^h \left(\frac{Y_t}{Y_{ss}} - \frac{Y_{t-1}}{Y_{ss}}\right) \\
& + \frac{\Lambda_{t+1}}{\Lambda_t} \varepsilon_m \phi_2^h \pi_{t+1} \left(\frac{Y_{t+1}}{Y_{ss}} - \frac{Y_t}{Y_{ss}}\right)
\end{aligned} \tag{1.50}
$$

This equation reads as the New-Keynesian Phillips Curve modified to include adjusting cost in housing construction. Indeed, if $\phi_1^h = \phi_2^h = 0$, equation (1.50) boils down to equation (1.44).

1.6 The Labor Market

The labor market is modelled in a way similar to Iacoviello and Neri (2010) since we consider a union operating for each household group and for each sector.[17] However, we assume that unions face quadratic

[17] While wages can differ across sectors, the probability to readjust the wage is the same across household's groups.

costs à la Rotemberg of adjusting the real wage instead of being subject to a Calvo scheme:

$$AC_{w,t} = \frac{\gamma_w}{2} \left(\frac{W_t}{W_{t-1}} - 1 \right)^2 w_t \tag{1.51}$$

Households offer homogeneous labor services to unions that differentiate labor and set their wages as a mark-up over their marginal rate of substitution. Labor services are then reassembled by labor packers that offer labor to goods producers. Solving the unions problem we have six conditions, two for each households'group. As an example we report the conditions for savers.

$$\begin{aligned} \frac{\tilde{w}_{c,t}}{\tilde{w}_{c,t-1}} \tilde{\gamma}_{w,c} \left(\frac{\tilde{w}_{c,t}}{\tilde{w}_{c,t-1}} - 1 \right) = \gamma_{w,c} \frac{\gamma \tilde{\lambda}_{t+1}}{\tilde{\lambda}_t} \frac{\tilde{w}_{c,t+1}}{\tilde{w}_{c,t}} \frac{\tilde{w}_{c,t+1}}{\tilde{w}_{c,t}} \left(\frac{\tilde{w}_{c,t+1}}{\tilde{w}_{c,t}} - 1 \right) \\ + (1 - \varepsilon_{wc}) \tilde{N}_{c,t} + \tilde{N}_{c,t} \frac{\varepsilon_{wc}}{\tilde{w}_{c,t}} \frac{\tilde{v} \tilde{N}_{c,t}^{\tilde{\eta}}}{\tilde{\lambda}_t} \end{aligned} \tag{1.52}$$

$$\begin{aligned} \frac{\tilde{w}_{h,t}}{\tilde{w}_{h,t-1}} \tilde{\gamma}_{w,c} \left(\frac{\tilde{w}_{h,t}}{\tilde{w}_{h,t-1}} - 1 \right) = \gamma_{w,c} \frac{\gamma \tilde{\lambda}_{t+1}}{\tilde{\lambda}_t} \frac{\tilde{w}_{h,t+1}}{\tilde{w}_{h,t}} \frac{\tilde{w}_{h,t+1}}{\tilde{w}_{h,t}} \left(\frac{\tilde{w}_{h,t+1}}{\tilde{w}_{h,t}} - 1 \right) \\ + (1 - \varepsilon_{wd}) \tilde{N}_{h,t} + \tilde{N}_{h,t} \frac{\varepsilon_{wd}}{\tilde{w}_{h,t}} \frac{\tilde{v} \tilde{N}_{h,t}^{\tilde{\eta}}}{\tilde{\lambda}_t} \end{aligned} \tag{1.53}$$

1.7 Financial Intermediaries

The banking sector is modelled along the lines of GNSS. Banks are divided into two distinct branches: a wholesale and a retail one. Those two units perform different tasks and this modelling strategy is chosen in order to introduce rate stickiness in the model. In particular, while the wholesale branch operates under perfect competition, the retail branch operates into a monopolistic competitive market, which allows it to set the loan rate as a markup over the interbank rate. The bank as a whole is subject to a balance sheet identity. Namely the total amount of loans that it can finance, $L_t = L_t^{s-p} + L_t^p$ must be equal to the sum of deposits D_t and equity NW_t. Banks can perfectly discriminate between the types of borrowers, but the realization of the idiosyncratic shock is private information of each single household. Given that we do not assume any sort of constraint that would limit banks to hold sub-prime mortgages in their balance sheet, and that banks require the same risk free interest rate on both types of loans r_t^l, we can consider the aggregate level of loans L_t in banks' balance sheet equation:

$$L_t = D_t + NW_t \tag{1.54}$$

Banks are also indifferent in funding themselves via deposits or equity. However, the introduction of an exogenous capital-to-assets ratio (i.e. leverage ratio) pins down their liabilities. The introduction of a optimal leverage might be seen as a way to model capital requirements imposed to banks by international agreement (e.g. Basel Accords) and it makes banks' balance sheet play a role in the transmission of shocks to the economy.

1.7.1 Wholesale branch

The bank's wholesale branch operates under perfect competition. It funds households' loans L_t, collects deposits and pays back a deposit rate r_t^d, which, is pinned down by the policy rate r_t.[18] By means of deposits and internal capital, which evolves according to:

[18] The implicit assumption behind $r_t^d = r_t$ is that banks can deposit excess funds at the Central bank at the policy rate.

$$NW_t = (1-\delta_{banks})NW_{t-1} + div._{banks}\Pi^{banks}_{t-1} \tag{1.55}$$

The parameter δ_{banks} measures the depreciation of banks capital, which comes from the resources needed to manage capital itself, while $div._{banks}$ measures the banks dividend policy, where Π^{banks}_{t-1} are banks profits at time $t-1$. We assume that banks are subject to an exogenous capital-to-asset ratio $\widehat{\varphi}$. When banks deviate from that value they incur a cost. Therefore, on the one hand, banks would be willing to expand their credit supply because this would increase their profits, on the other hand, in doing so they would pay a cost, therefore in steady state the marginal value of an additional loan must be equal to the marginal cost of funding it. The cost of deviating from the leverage ratio for a generic bank j is given by:

$$Dev.\,cost = -\frac{k_b}{2}\left(\frac{NW_t(j)}{L_t(j)} - \widehat{\varphi}\right)^2 NW_t(j) \tag{1.56}$$

The bank maximizes profits over $NW_t(j)$ and $D_t(j)$, taking as given the wholesale loan rate and the deposit rate, respectively $r^{int.}_t$ and r^d_t:

$$\begin{aligned} max \sum_{t=0}^{\infty} \tilde{\Lambda}_{0,t} \Bigg[&(1+r^{int.}_t)L_t(j) - (1+r^d_t)D_t(j) \\ &- NW_t(j) - \frac{k_b}{2}\left(\frac{NW_t(j)}{L_t(j)} - \widehat{\varphi}\right)^2 NW_t(j) \Bigg] \end{aligned} \tag{1.57}$$

subject to (1.54). Assuming symmetry across banks,[19] the first order condition of the problem reads as follows:

$$r^{int.}_t = r^d_t - k_b\left(\frac{NW_t}{L^{tot}_t} - \widehat{\varphi}\right)\left(\frac{NW_t}{L^{tot}_t}\right)^2 \tag{1.58}$$

rearranging equation (1.58), and considering $r^d_t = r_t$, we can see that the spread in the wholesale banking sector is a positive function of the leverage of the banking sector (and consequently, it is negatively correlated with the capital to asset ratio):

[19] An additional assumption is given by the fact that savers own banks, and therefore the discount factor in the maximization problem refers to this group of households.

$$\begin{aligned} spread_{banks} &= r_t^{int.} - r_t \\ &= -k_b \left(\frac{NW_t}{L_t^{tot}} - \widehat{\varphi} \right) \left(\frac{NW_t}{L_t^{tot}} \right)^2 \end{aligned} \tag{1.59}$$

This equation determines a link between banks balance sheet and banks margin. In particular, in response to a shock to households, this modelling strategy allows to generate a feedback loop that goes from borrowers to banks and back to borrowers, for a change in banks balance sheet affects the spread and therefore households' borrowing condition. Banks capital also plays a role in determining credit conditions, for a reduction in banks profit and net worth is associated with a reduction in lending.

1.7.2 Retail branch

In order to consider sticky bank rates, we assume that retail banks operate under a regime of monopolistic competition. This implies that banks set rates, and do so adding a mark-up over the interbank rate $r_t^{int.}$. Retail banks receive loans from the wholesale branch, for which they have to pay the interbank rate, they differentiate them at no cost and offer them to borrowers at a contractual rate that allows them to earn the risk free loan rate r_t^l. In carrying on their activity, they pay quadratic costs if they want to change rates, this implies inertia in the movements of r_t^l in response to a shock. Given that in our model we consider one period mortgages, the introduction of sticky bank rates might be seen as a way to overcome this initial assumption since it entails some degree of persistence in the mortgage contract rates. In particular, the final mortgage rate r_t^k, can be seen as the combination of two elements. On the one hand there is a risky component, that is group specific and that reacts immediately to a shock, on the other hand the rate is given by a component that is determined in the banking sector and reacts only sluggishly to changes in the economic activity. As it will be clear in the following section, this entails some important consequences in terms of contagion effects.

In order to introduce monopolistic competition in the retail banking sector we need a further assumption. Namely, the loans bought by borrowers are a composite CES basket of differentiated products offered by banks, and the elasticity of substitution, $\varepsilon_{b,t}$[20] among loan types governs the degree of banks' market power. Articulating the problem in this way allows us to consider a demand for loans which is given by:

$$L_t^h(j) = \left(\frac{r_t^l(j)}{r_t^l}\right)^{-\varepsilon_t^b} L_t^I \tag{1.60}$$

where L_t^I represents the aggregate demand for loans and $L_t^h(j)$ the demand of a single household for loans at bank j. Retail banks maximize profits subject to (1.60) by choosing the optimal rate $r_t^l(j)$:

$$max \sum_{t=0}^{\infty} \tilde{\Lambda}_{0,t} \left[r_t^l(j)L_t(j) - r_t^{int} L_t(j) - \frac{k_h}{2}\left(\frac{r_t^l(j)}{r_{t-1}^l(j)} - 1\right)^2 r_t^l(j)L_t(j) \right] \tag{1.61}$$

First order condition of the problem yields the following equation:

$$\begin{aligned} 1 - \varepsilon_{b,t} + \frac{\varepsilon_{b,t}\ (r_t^{int.})}{r_t^l} - k_h \left(\frac{r_t^l}{r_{t-1}^l} - 1\right) \\ + \left(\frac{r_{t+1}^l}{r_t^l} - 1\right)\left(\frac{r_t^l}{r_{t-1}^l} - 1\right)\frac{\gamma\,\tilde{\lambda}_{t+1}}{\tilde{\lambda}_t} kkh \left(\frac{r_{t+1}^l}{r_t^l} - 1\right)\frac{L_{t+1}}{L_t} = 0 \end{aligned} \tag{1.62}$$

which, assuming no costs in changing the loan rate, namely $k_h = 0$, implies that the loan rate is a mark-up over the interbank rate:

$$r_t^l = \frac{\varepsilon_{b,t}}{\varepsilon_{b,t} - 1} r_t^{int.} \tag{1.63}$$

Finally, we can write down the overall profits in the banking sector, which for bank j, can be written as:

$$\begin{aligned} \Pi^{banks} = r_t^l L_t - r_t^d D_t - \frac{k_b}{2}\left(\frac{NW_t(j)}{L_t(j)} - \widehat{\varphi}\right)^2 NW_t(j) \\ - \frac{k_h}{2}\left(\frac{r_t^l(j)}{r_{t-1}^l(j)} - 1\right)^2 r_t^l(j)L_t(j) \end{aligned} \tag{1.64}$$

[20] Notice the t subscript, which implies that we allow for the possibility of shocks to banks mark-up.

1.8 Equilibrium Conditions

Total nominal output in the economy is given by the sum of output in the non-durable and in the housing sector:

$$Y_t P_{c,t} = Y_{c,t} P_{c,t} + Y_{h,t} P_{h,t} \tag{1.65}$$

We define real output as follows:

$$Y_t = Y_{c,t} + p_{h,t} Y_{h,t} \tag{1.66}$$

where the real housing price is defined as $p_{h,t} = \frac{P_{h,t}}{P_{c,t}}$.

Notice that, as common in the literature with durable goods, in our IRFs we consider total output at constant relative prices. Namely we keep $p_{h,t}$ fixed at its steady state level $\bar{p}_{h,t}$. The market clearing condition in the non-durable sector requires total output in c to be equal to aggregate demand:

$$Y_{c,t} = (1-\xi)\tilde{C}_t + \xi(1-\vartheta)C_t^{s-p} + \xi\vartheta C_t^p \tag{1.67}$$

In the housing sector, total output is equal to the total amount of investment carried out by each households' group:

$$\begin{aligned} Y_{h,t} = {} & (1-\xi)[\tilde{H}_t - (1-\delta)\tilde{H}_{t-1}] \\ & + \xi(1+\vartheta)[H_t^{s-p} - (1-\mu G_t(\bar{\omega}_t^{s-p})H_{t-1}^{s-p})(1-\delta)] \\ & + \xi(\vartheta)[H_t^p - (1-\mu G_t(\bar{\omega}_t^p)H_{t-1}^p)(1-\delta)] \end{aligned} \tag{1.68}$$

Notice, the equilibrium condition for housing investment is gross of monitoring costs.

With respect to the labor market the equilibrium condition requires the following equations for savers, sub-primers and primers to be satisfied with equality:

$$\begin{aligned} \int_0^1 & = \tilde{N}_{m,t}(\iota)d\iota \\ & = (1-\xi)\tilde{N}_{m,t} \end{aligned} \tag{1.69}$$

$$\begin{aligned} \int_0^1 & = N_{m,t}^{s-p}(\iota)d\iota \\ & = \xi(1-\vartheta)N_{m,t}^{s-p} \end{aligned} \tag{1.70}$$

$$\begin{aligned}\int_0^1 &= N_{m,t}^p(\iota)d\iota \\ &= \xi\vartheta N_{m,t}^p\end{aligned} \tag{1.71}$$

Finally, the equilibrium condition in the credit market requires total loans to be equal to deposits plus aggregate banks' net worth:

$$\xi(1-\vartheta)L_t^{s-p} + \xi\vartheta L_t^p = (1-\xi)\tilde{D}_t + NW_t \tag{1.72}$$

1.9 Monetary Policy

We consider a Central Bank seeking to control inflation and output through a Taylor Rule operating via changes in the nominal interest rate:

$$\frac{1+r_t^f}{1+\bar{r}^f} = [\pi_{C,t}^{\phi_\pi}]^{1-\phi_r}\left[\frac{1+r_{t-1}^f}{1+\bar{r}^f}\right]^{\phi_r}\left[\left(\frac{Y_t}{Y_{t-1}}\right)^{\phi_y}\right]^{1-\phi_r} A_{M,t} \tag{1.73}$$

where $\bar{r}^f$ is the steady state risk free nominal interest rate, ϕ_r is the coefficient associated to the lagged interest rate, ϕ_π the coefficient associated to the inflation target and ϕ_y the coefficient that measures the response to changes in the output gap. Finally $A_{M,t}$ is a shock to the monetary policy, which evolves according to:

$$\ln A_{M,t} = \rho_M \ln A_{M,t-1} + \varepsilon_{M,t} \tag{1.74}$$

where $\varepsilon_{M,t}$ is an i.i.d. innovation with mean zero and standard deviation equal to σ_M.

1.10 Calibration

Our calibration is based on the U.S. economy, for the focus of our paper is the financial crisis that originated in the U.S. mortgage market. We calibrate the share of constrained borrowers to 36% following a well established literature on the U.S. economy. For the share of sub-primers we refer to the report on the financial crisis issued by the The Financial Crisis Inquiry Commission (2011). According to the report the share of sub-prime mortgages originated in the U.S. over the total amount of mortgages fluctuated considerably in recent years. While it has been around 9% from 1996 to 2003 in 2004 it spiked to 20.9% and it remained close to this figure in the following two years before getting back to 9.2% in 2007. Given this figures we decide to calibrate the share of sub-primers to a value (10%) close to the pre-crisis level. Note that this entails the overall share of sub-primers being equal to only 3.6% of total households. In order to take into account the change in this share and the implied consequences of a higher number of sub-prime borrowers, we consider different values in our simulations.

To calibrate the deep parameters of the model we follow FL and we refer to a largely consolidate literature on the topic. For the part related to financial intermediaries we mainly follow GNSS. The parameter α that measures the weight of housing in the utility function has been chosen as in FL in order to get a share of housing over total GDP of 8% in steady state. This measure reflects the combined share of residential and non residential fixed investment in structures in the U.S. economy for the period 2000-2007[21].

In order to get a yearly risk free rate of 4% we set the discount rate of savers to 0.99. We calibrate the discount factor of borrowers, the standard deviation of the idiosyncratic shock, the monitoring costs and the stigma component to obtain in steady state the rate of default for primers and sub-primers recorded in the National Delinquency Survey. Namely, our target is the default rate in the first trimester of 2006, when, on the verge of the crisis the default for primers equalled 0.77% and that of for sub-primers 6.2%. The resulting loan to value

[21] As noted by FL, this share has been historically lower on average, being equal to 5% over the period 1960-2009.

ratio is equal to 63.5% for sub-primers, which is a result not far to the average loan to value ratio of 75.7% registered in the U.S between 1973 and 2008 as noted by FL.[22] The LTV ratio for primers in our calibration is 55%, a result that we consider sensible, given that the calibrated rate of default is considerably lower than the average rate of default in the mortgage sector.[23] We assign a value of 0.12 to the monitoring costs incurred by banks when they want to assess the outcome of a defaulting investor, while we assign a value of 0.2 to the standard deviation of the idiosyncratic shock. Both values are in line with the calibration used by FL and BGG. Notice that we assume the same standard deviation for both borrower types. This stresses that our distinction of sub-primers does not rest on any parameter different from the *stigma* component. The spread between the thirty year conventional mortgage rate and the interest rate on the U.S. Treasury thirty-year bond has been on average 150 basis point. While FL calibrate this spread to only 50 basis point in our calibration the spread is equal to 115bp for primers and 215bp for sub-primers. This spread is the combination of two distinct features in our model. First, banks set the risk free loan rate r_t^l as a mark up over the interbank rate, which is ultimately pinned down by the policy rate. Assuming an elasticity of substitution of 5, the mark-up is equal to 20%, implying a 100bp spread between the two rates.[24] Second, the presence of the agency problem between borrowers and banks, accounts for the spread between the risk free loan rate and the contractual rate, which is equal to 4.1% for primers and 6.2% for sub-primers.

For the short and long run elasticities in the adjustment costs of housing investment we follow the calibration presented in Carlstrom and Fuerst (2010). By assigning a value of 1 to χ – the parameter measuring the elasticity of substitution between housing and consumption in the consumption bundle – the function becomes a Cobb-Douglas. The value of the inverse of the Frisch elasticity of labor supply η is 1

[22]Notice that in calibrating the parameters related to primers and sub-primer we must make a choice between targeting the LTV ratios and the default rates. We could have increased the LTV ratio for sub-primers by playing around with the above mentioned structural parameters. However, we preferred to limit the differences between the two classes of borrowes to a minimum.

[23]Around 2% in 2006.

[24]This value is also in line with Gertler and Karadi (2011)

and the weight of labor in the utility function is households specific and calibrated such that each individual agent chooses to work $1/3$ of her available time in steady state, while the parameter that measures habits in consumption is equal to 0.6. The elasticity parameters in both sectors and in the wage Phillips curve are chosen in order to have a mark-up of 15%. We calibrate γ_c and $\gamma_{w,m}$ in order to render the same situation that under Calvo pricing mechanism makes firm and unions adjusting respectively their prices and wages on average once every four quarters. House prices are instead left perfectly flexible as in most of the literature on housing, therefore we set $\gamma_h = 0$.[25] In order to pin down the level of banks net worth in steady state, we need to assume a depreciation rate in banks' capital equal to 0.01, while the dividend policy of the banks is exogenously fixed to 0.67. The parameters measuring the adjustment costs in the banking sector are instead based on GNSS's findings, while in our baseline calibration the capital-to-asset ratio is equal to 0.1, implying a banking leverage of 10. Finally, the parameters in the monetary policy rule are based on the estimated results in Iacoviello and Neri (2010).

[25]Under our modellization of the labor market the presence of different discount factors for borrowers and savers implies slightly different values for the parameters related to the cost of adjusting wages.

TABLE 1.1: *Calibrated Parameters*

Parameter Name	Value	Description
η	1	Inverse elasticity of labor supply
β_s	0.99	Discount factor of Savers
δ_d	0.01	Rate of depreciation of housing
β_b	0.96	Discount factor of Borrowers
ε_c	7.5	Elasticity of substitution for C goods
ε_d	7.5	Elasticity of substitution for D goods
ε_{wc}	7.5	Elasticity of substitution labor in C
ε_{wd}	7.5	Elasticity of substitution labor in D
ϕ_π	1.44	Taylor rule sensitivity to inflation
ϕ_y	0,52	Taylor rule sensitivity to output
ϕ_R	0.59	Taylor rule smoothing
ρ_e	0.0	Autoregressive parameter shock TR
ξ	0.36	Share of constrained agents
ϑ	0.1	Share of sub-primers
φ_{D1}	0.33	Adjustment costs. housing (SR)
φ_{D1}	0.66	Adjustment costs. housing (LR)
b_h	0.6	Habits in consumption paramter
μ	0.12	Monitoring costs
σ^p	0.2	Standard deviation id. shock primers
σ^p	0.2	Standard deviation id. shock sub-primers
ρ_s	0.9	Autocorrelation idios. shock
ε_b	5	Elasticity banks loans
$\widehat{\varphi}$	0.1	Optimal capital asset ratio
δ_{banks}	0.01	Depreciation banks capital
$div._{banks}$	0.67	Banks' div. policy
k_b	10.63	Adjusting cost param. banks
k_h	13.58	Adjusting cost param. hous. loan dem

1.11 Experiments

In this section we analyze the dynamics of the model after having linearized it around the steady state. We focus on two different shocks: a shock to the standard deviation of the idiosyncratic shock that hits sub-primers' housing investment and a monetary policy shock. We present the impulse response functions of each shock and we also show the difference entailed by considering the benchmark model, characterized by a non-trivial financial sector, and a model which has no frictions in the circulation of funds from lenders to borrowers. We characterize this second model by switching the costs related to changes in the interbank and in the loan rate to zero, k_b and k_h respectively. The dynamics of the model are influenced by financial frictions, which are given by endogenous variations in the balance sheet of both constrained agents and banks. As a consequence, the results of our baseline model are given by the interaction and coexistence of different channels. One the one hand, we have the frictions that characterize the borrowers' side, on the other hand those related to the banking sector. Borrowers face collateral constraints and run up nominal debt, which, as explained by Iacoviello (2005), is a common characteristic of mortgage contracts in all advanced economies. As a result, changes in the asset values, i.e. house prices, and in the inflation rate – Fisher effect – have a direct impact on households' borrowing conditions. Binding collateral constraints are instead affected by changes in the real interest rate. Indeed, an increase in the cost of the mortgage impairs borrowers' ability to get loans and together with nominal debt contributes to a magnification of shocks. Banking sectors' balance sheet are instead important for they influence directly credit conditions and therefore affect the shadow value of borrowing. The presence of banks is also indirectly connected to credit conditions, for their presence alters the dynamics of the model and therefore has repercussions on households through the other channels mentioned. The idiosyncratic risk in housing investment allows us to single out a peculiar source of shock, which – to our knowledge – has never been analyzed in the presence of a non-trivial banking sector. Furthermore, modelling sub-primers adds an additional degree of heterogeneity to the model which allows to study the effects of a change in the share of borrowers over the total of constrained agents, the pass-through of the shock to the other households' groups and the distributional consequences of monetary policy.

1.11.1 A Shock to the Standard Deviation of Sub-primers' Idiosyncratic Shock

The first shock we consider is an increase in the standard deviation of the idiosyncratic shock on sub-primers' housing investment. The shock evolves according to the following process:

$$\ln \frac{\sigma_{\omega^{sp},t}}{\bar{\sigma}_{\omega^{sp}}} = \rho_{\sigma_{\omega^{sp}}} \ln \frac{\sigma_{\omega^{sp},t-1}}{\bar{\sigma}_{\omega^{sp}}} + \varepsilon_{\sigma_{\omega^{sp}},t} \tag{1.75}$$

where $\bar{\sigma}_{\omega^{sp}}$ is the steady state value of the standard deviation and $\rho_{\sigma_{\omega^{sp}}}$ is the serial correlation coefficient. $\varepsilon_{\sigma_{\omega^{sp}},t}$ is an i.i.d. shock with a standard deviation equal to $\sigma_{\sigma_{\omega^{sp}}}$ and a mean of zero. A mean preserving increase in the standard deviation of the idiosyncratic shock brings about an increase in the rate of default for any given threshold level $\bar{\omega}$. This result is a direct consequence of the properties of the log-normal distribution, in fact an increase in the standard deviation thickens the tails of the distribution meaning that – for the same $\bar{\omega}$ – more households end-up in the left tail of the distribution and therefore the rate of default increases. Figure 1.7 shows two log-normal distributions characterized by the same mean and a different standard deviations as an illustrative example.

An increase in sub-primers' rate of default goes hand in hand with an increase in monitoring costs that coupled with the ensuing rise in risk entails a spike in the contractual rate of mortgages paid by sub-primers. We calibrate the shock in order to get on impact an increase of sub-primers' default rate equal to 16.42%, which corresponds to the percentage of seriously delinquent loans in the first quarter of 2008, when the financial crisis started. The impulse response functions are plotted in figure 1.8. As financing loans becomes more expensive and the risk of default increases, sub-primers loan to value declines, implying lower housing and non-durable consumption for the group. This mechanism is exacerbated by a feedback loop that works through declining house prices, that further

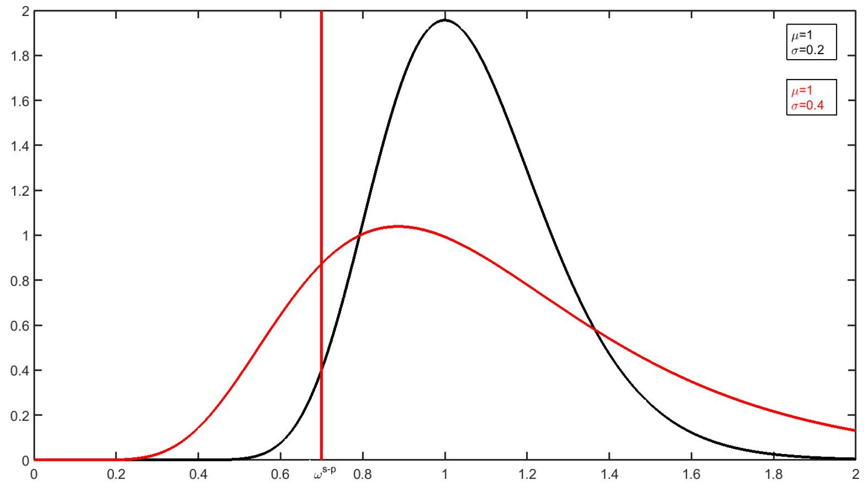

FIGURE 1.7: *The log normal distribution for two different values of the standard deviation.*

reduce the loan to value ratio and are especially important in reducing sub-primers' consumption of housing. The initial shock, despite confined to a very small fraction of the model's population – i.e. only 3.6% of all households are sub-primers –, brings about a reduction in total output of about 0.2%, which is driven by a contraction in both sectors. The magnitude of the recession is affected by the contagion effect that transmits via the banking sector and via the real economy from sub-primers to primers and also partly affects savers. As macroeconomic conditions deteriorate so do banks profits and banks' net worth. Banks have to pay a cost whenever they deviate from the optimal capital to asset (i.e. leverage) ratio. An increase in the banks leverage ratio reduces banks margins, which eventually affect the loan rate, for loan rates are set as a mark-up over the interbank rate. Loans reduction, combined with declining house prices, reduces primers consumption of durable and housing. The decrease in house prices is responsible for the increase in the risk premium and in the default rate of primers. Notice, however that the risk premium spread between the two groups, measured by $r_t^{k,s-p} - r_t^{k,p}$ increases, which means that sub-primers' external finance premium increases relatively more.

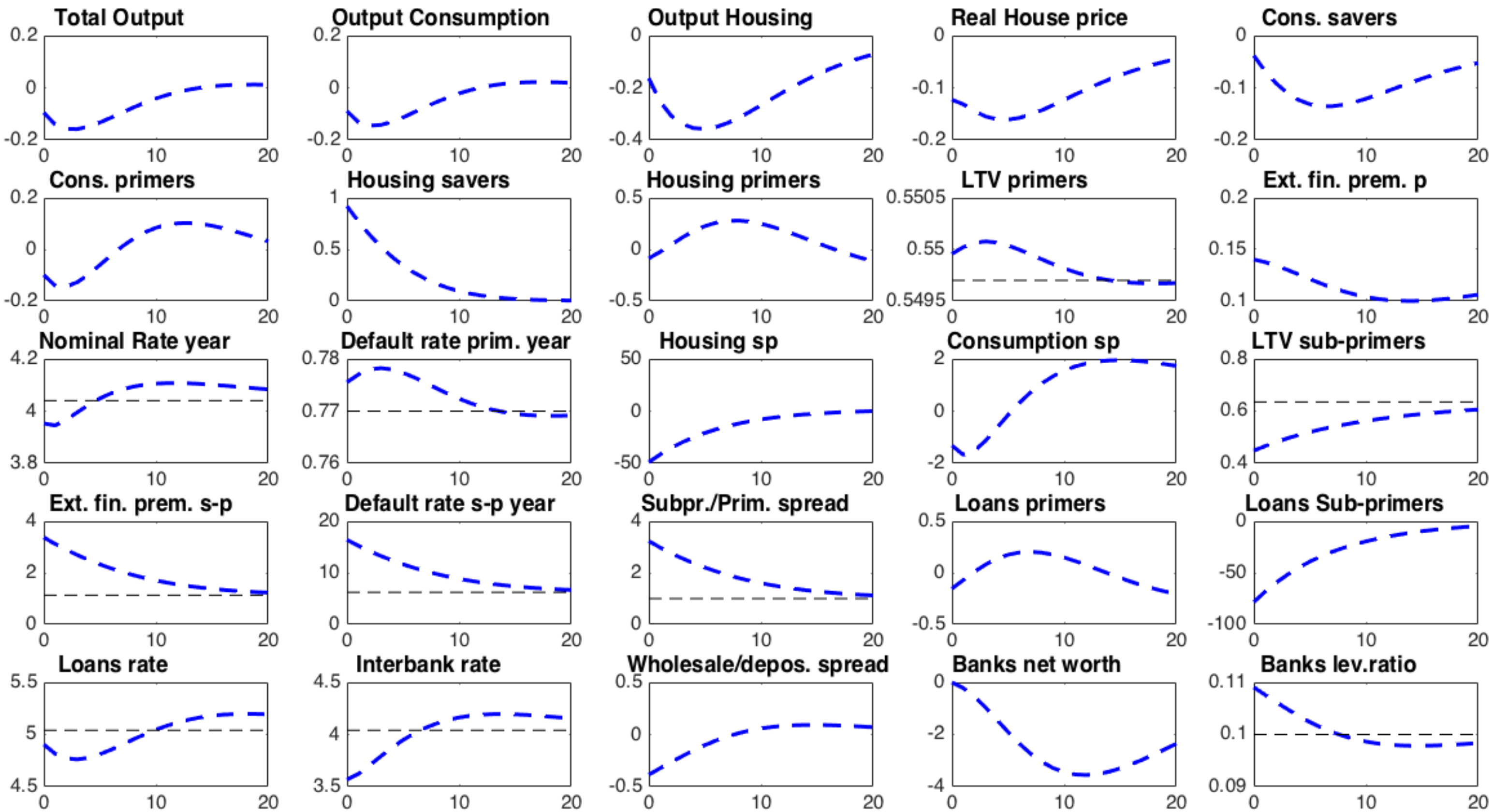

FIGURE 1.8: *A shock to the standard deviation of sub-primers idiosyncratic shock. All variable are expressed as a percentage deviation from steady state. Loan rates, rate of defaults, loan to values and banks' leverage are instead in levels.*

The risk free loan rate only responds sluggishly to changing economic conditions, reflecting on the one hand monopolistic power in the banking sector, while on the other hand it can be thought as a proxy of mortgage contracts with a duration that is longer than one period. More precisely, we can think of the mortgage contract as composed by a component that adjusts quickly to increasing risk in the households' willingness to repay their debts and by a part that adjusts only sluggishly.

As figure 1.9 shows, the transmission of the shock from sub-primers to primers depends on the degree of flexibility of the risk free rate on mortgages. When r_t^l is stickier, and therefore it declines less in response to a change in banks'capitalization, the original shock transmits more powerfully on primers, entailing a lower reduction of loans and of consumption of both durable and non-durable goods. The stickiness of the loan rate partly sheds banks from the shock, indeed their net worth is less affected by the shock. While this has positive effects on the economy, the overall dynamics are dominated by the effect on prices. We can therefore consider the degree of rates stickiness as a measure of the role played by banks' balance sheets in acting as a cushion to the shock. The lower the stickiness, the more the banks absorb the shock and the less it transmits to primers.

Due to the stickiness introduced in the labor market, real wages decline in both sectors for all households categories. However, their labor response is at odds 1.10. Indeed, while sub-primers increase their labor efforts, primers and savers increase leisure. The income effect stemming from a reduction in the real wages, combined with a relative increase of non-durable prices implies a reduction of consumption for savers, while they increase their purchase of durable goods, for they find more convenient to buy durables given lower house prices.

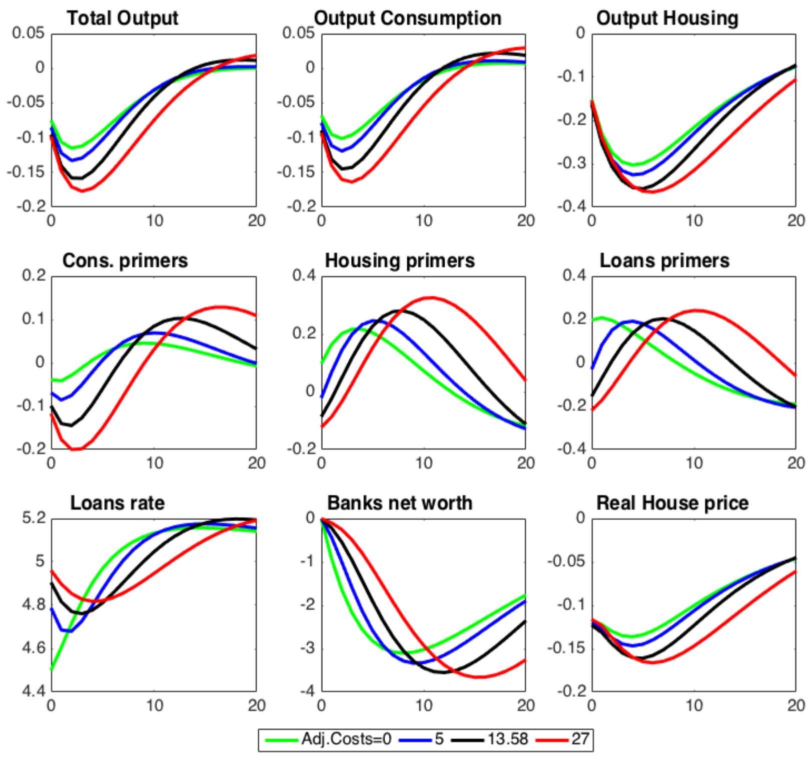

FIGURE 1.9: *A shock to the standard deviation of sub-primers' idiosyncratic shock. All variable are expressed as a percentage deviation from steady state. Loan rates, rate of defaults, loan to values and banks' leverage are instead in levels.*

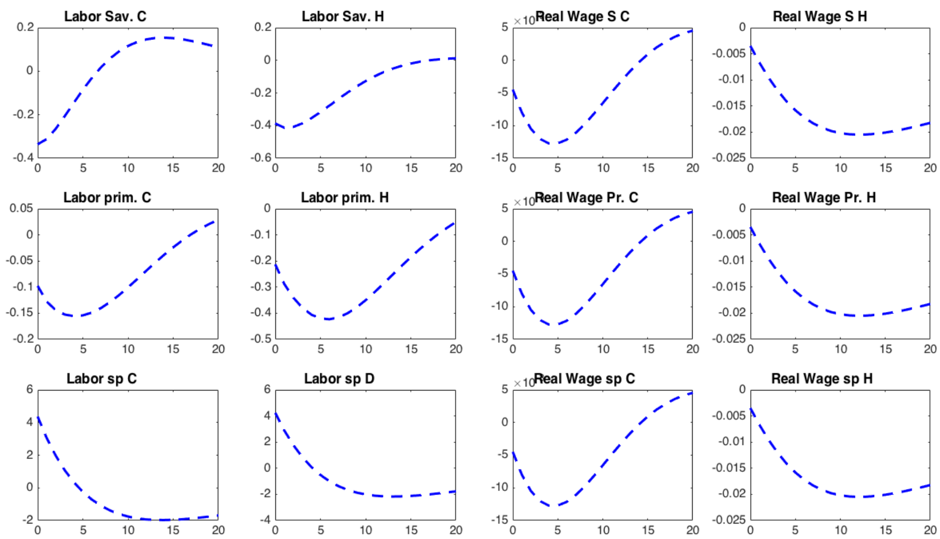

FIGURE 1.10: *A shock to the standard deviation of sub-primers' idiosyncratic shock. All variable are expressed as a percentage deviation from steady state. Loan rates, rate of defaults, loan to values and banks' leverage are instead in levels.*

The exercise carried out so far does not contemplate the possibility of an increase in the share of sub-primers on the total share of constrained agents. However, a salient fact of the build-up of the financial crisis has been the steep increase in that share. Indeed, in 2006 at the verge of the financial crisis, the sub-prime share of the entire mortgage market rose to 23.5%. Our modelling strategy allows us to quantify the effect of an increase in the share of sub-primers. In figure 1.11, we simulate the same shock as above, but allowing for different shares of sub-primers, namely 0%, 5%, 10% –our baseline value– and 23.5%. We see that the effects of the shock becomes quite significant as we increase the share of sub-primers to the pre-crisis levels. Output contracts by about 0.4% within four quarters, while the decline in housing is much larger and close to 1%. This is due to the stronger and more persistent decrease in house prices.

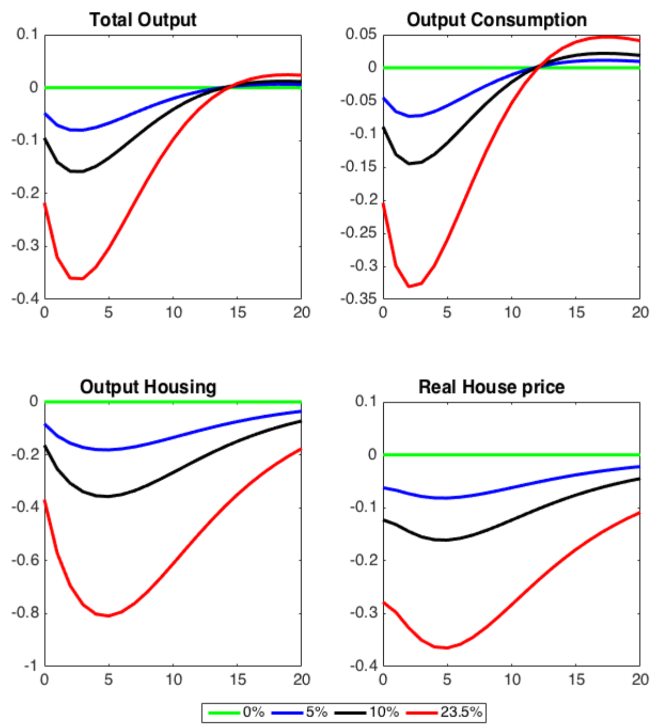

FIGURE 1.11: *A shock to the standard deviation of sub-primers' idiosyncratic shock. All variable are expressed as a percentage deviation from steady state. Loan rates, rate of defaults, loan to values and banks' leverage are instead in levels.*

Also, the contagion effects from sub-primers to the other households' groups in the model gets magnified by the increasing size of high leveraged borrowers. Figure 1.12, shows that the amplification of the shock starts in the banking sector, with a reduction of banks net worth and continues through the same channels analyzed above, implying an increase in the rate of default of primers and a decrease in the consumption of both durables and non-durables for this group of borrowers. Savers consumption also declines more, while the substitution effects from non-durable to durable goods gets magnified.

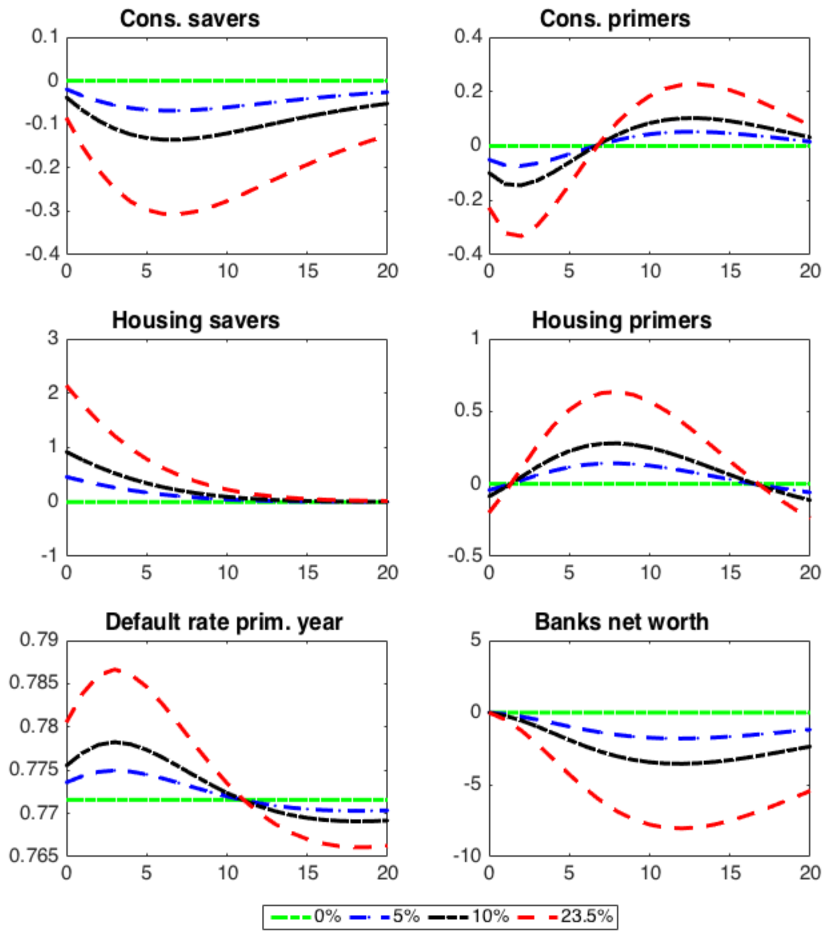

FIGURE 1.12: *A shock to the standard deviation of sub-primers' idiosyncratic shock. All variable are expressed as a percentage deviation from steady state. Loan rates, rate of defaults, loan to values and banks' leverage are instead in levels.*

1.11.2 Monetary policy shock

In this section, we analyze the impulse response functions of the model to a 25 basis point increase in the policy rate. The literature on models featuring non-durable goods highlights the difficulties of theoretical models in matching the empirical evidence, notably with respect to the co-movement between consumption and residential investment. As documented in in Carlstrom and Fuerst (2010), New-Keynesian models featuring nominal wage rigidities, habit in consumption and adjusting cost in housing investment deliver theoretical impulse responses that are consistent with the VAR evidence. Our model features all those ingredients and as figure A.3 shows it renders well all the qualitative effect of a monetary policy tightening on the economy.
The increase in the nominal interest rate is contractionary, and, in particular, the response of the model confirms the empirical evidence on monetary policy with housing, which highlights not only the co-movement of output in the durable and non-durable sector but also that housing contracts more than consumption.

The main finding, is in line with what already highlighted by GNSS, namely that the presence of sticky bank rates attenuates the impact of a monetary policy shock. Indeed, the overall contraction is quite small if compared to the empirical evidence of a monetary policy shock in the U.S.. This highlights the absence in this model of a risk channel related to the financial sector, which could actually magnify the effects of a monetary policy shock. An interesting result that can be analyzed given our modelling strategy is the re-distributional consequence of monetary policy. Indeed, the transmission of monetary policy in our model is somewhat different from a standard New-Keynesian model. The reason is due to the contemporary presence of financial frictions in the form of an endogenous loan to value ratio and in the form of frictions tied to the banking sector's balance sheet.

Differently from previous models that studied the response of the economy to a monetary policy shock, our model includes two different classes of borrowers and is therefore interesting to see the concomitant response of primers and sub-primers to the shock. Calza, Monacelli, and Stracca (2013) showed that economies characterized

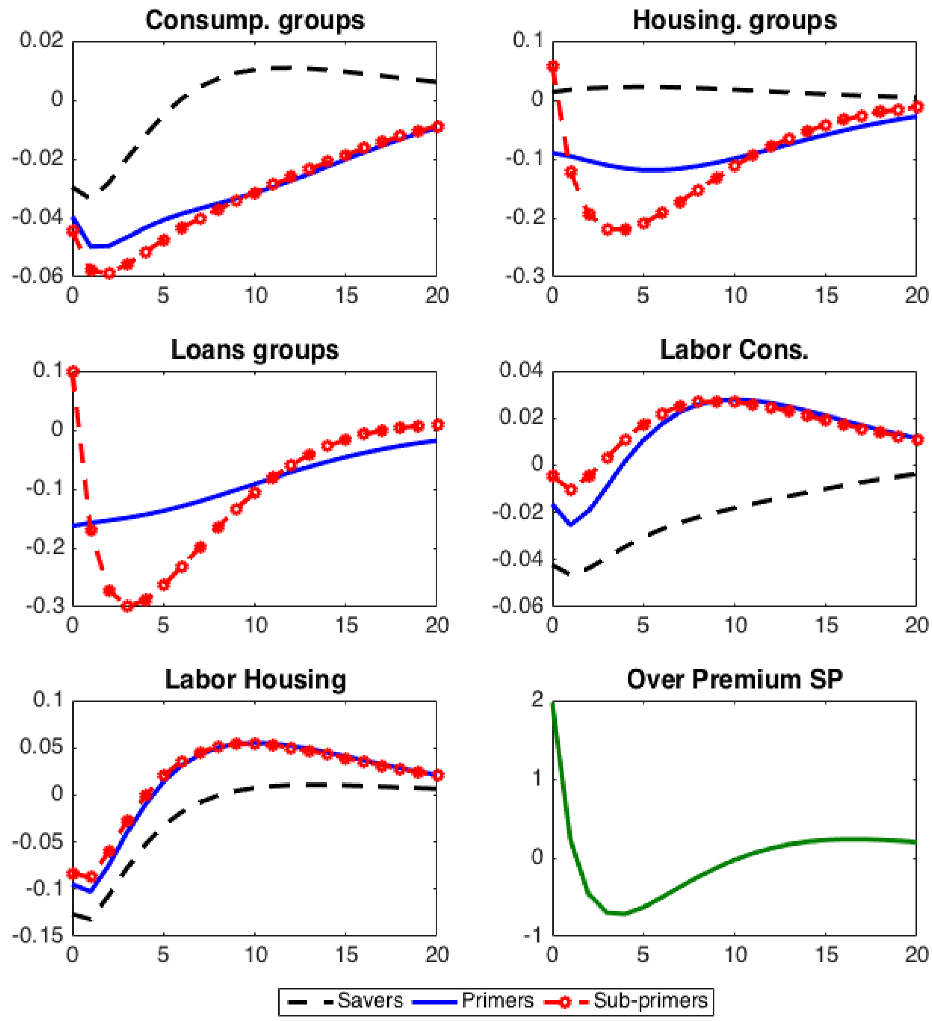

FIGURE 1.13: *25 basis point increase in the policy rate. All variable are expressed as a percentage deviation from steady state. Loan rates, rate of defaults, loan to values and banks' leverage are instead in levels.*

by higher loan to value ratios are less resilient to a monetary policy shock. Our results confirm and strengthen that finding for the response of sub-primers to the monetary tightening is stronger than that of primers. Both the default rate and contractual rates increase, bringing about an increase in the loan to value ratio of both classes of borrowers. However the increase is stronger for sub-primers and as a result the sub-primers/primers spread increases. This latter factor explains why the reduction in the amount of loans is higher for sub-primers. The reasons behind those results are manifold. First of all, the increase in the nominal interest rate – which in turns pushes up the return that banks ask on the loans granted to borrowers – increases the shadow value of borrowing, for it is now more expensive for borrowers to tilt preferences towards current consumption. Secondly, borrowers' equity declines,[26] and given that sub-primers have a higher loan to value ratio they are more sensitive to the decrease in the present value of equity. Furthermore, following a monetary shock, relative house prices decline, in line with the assumption that house prices are more flexible than non-durable prices. Therefore, the Fisher effect kicks in and it further reduces household's equity through an increase of real debt.

Finally, it is interesting to notice that the shock has a negative effect also on banks net worth. This effect is given by two different factors. First, a reduction in the intermediation of banks entails a reduction in the net worth, as well as the decline in house prices reduces its value. Second, the increase in the banking rate is lower than the monetary policy increase. This further compresses banks spread and reduces their net worth. The response of savers – who are consumption smoother – is standard. The Euler equation suggests that savers respond to an increase in the risk free interest rate by substituting current with future consumption. At the same time the decline in house prices implies a substitution effect from consumption to housing. Finally, notice that in response to the shock, savers increase leisure much more than the other households groups.

1.11.3 Frictionless vs friction economy

What are the responses of the benchmark model when compared to a model that does not consider frictions in the banking sector? This is question is important, for one innovation of our paper to the literature that analyses endogenous LTV ratios for households is the introduction of a non-trivial banking sector. Figure 1.14, shows the impulse responses for the shocks analyzed in the previous sections. We disentangle the effect of sticky rates and of banks' balance sheet. The first row compares the results in the case of a shock in the standard deviation of sub-primers idiosyncratic shock for the benchmark

[26] This can be seen from the budget constraint

model (in blue) and a model where we switch off both costs considered in the banking sector (in red) and therefore representing an economy where funds flow freely from banks to borrowers. In the latter case, banks' balance sheet has no effect overall on the circulation of credit, while loan rates are flexible. The presence of both

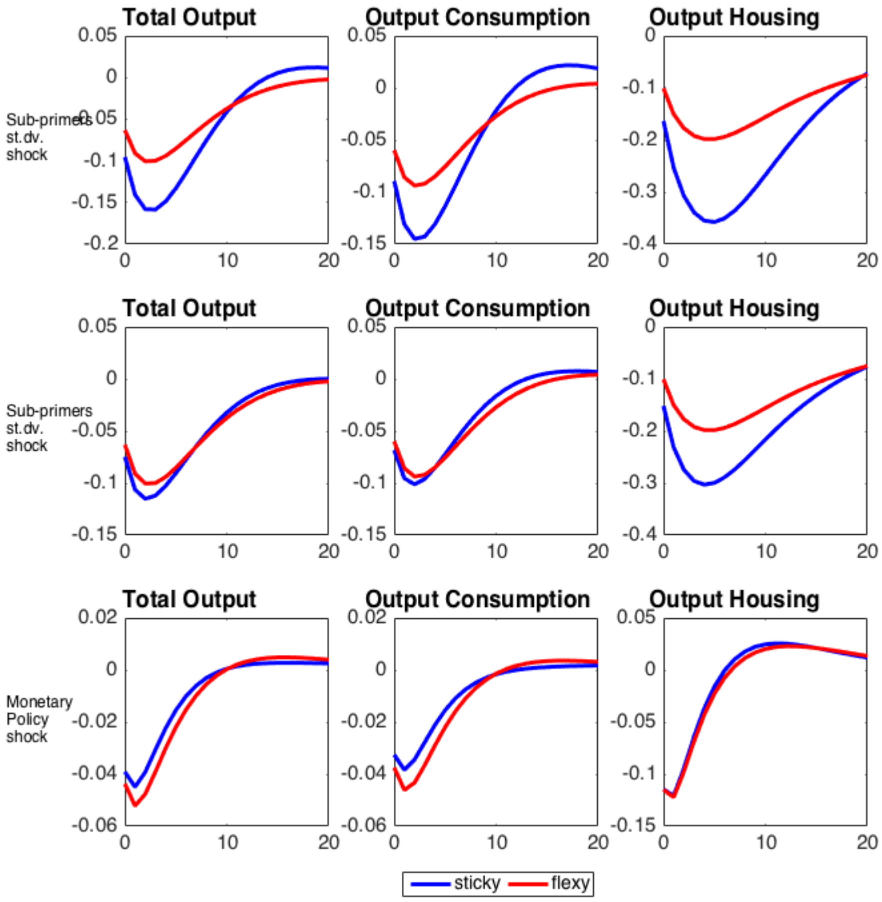

FIGURE 1.14: *All variable are expressed as a percentage deviation from steady state. First row represents an economy where both adjustment costs in the bank sector are switched off. Second row, instead, only costs of adjusting the loan rate are off.*

frictions in the banking sector magnifies the response of total output, consumption and housing investment in response to an increase in the standard deviation of sub-primer's shock. When we allow rates to move freely, but we still keep positive the elasticity of the banking spread to changes in the leverage, the outcome is still contractionary if compared to the flexible economy case. This underlines the role played by banks balance sheet in the circulation of credit. By disentangling the two sources of frictions we note that sticky rates have a quantitatively more important role in determining the magnitude of the contraction. Indeed, when loan rates are flexible the shock is partly absorbed by banks, which shed borrowers and limit the contagion to primers. In the case of a monetary policy shock, the transmission of the shock is magnified in the absence of frictions in the banking sector. This result is driven by the fact that the loan rate can increase freely, therefore implying a stronger effect on constrained agents.

1.12 Conclusion

The recent crisis that originated in the U.S. residential market underscored the importance of frictions in the circulation of credit. The depth of the recession, and the inability of a large part of the economic profession to foresee the crisis are at the basis of the revision of the research agenda related to the development of quantitative economic models. In particular, DSGE models, which are the workhorse models in the analysis of the business cycle, have been since then amended in order to take into account relevant frictions.

In this paper we tried to contribute to the growing literature on financial frictions by introducing frictions on both sides of the credit relationship and by studying a shock to a riskier class of borrowers. On the one hand, borrowers are constrained by the value of their collateral in the amount of debt that they can run up. On the other hand, loan rates are sticky, while changes in banks' balance sheet affect the margin that banks get on loans. In the model, we add a further degree of heterogeneity with respect to the canonical model that takes into account constrained households. We do this by modelling subprime borrowers, which differ from primers for their higher rate of default, loan to value ratio and for the rate they have to pay on their mortgages. Given that housing investment is risky, we can study the effect of a shock that affects only this riskier class of borrowers. The propagation of the shock to the real economy are influenced by the frictions introduced in the model. In particular, when banks deviate from the optimal capital-to-asset ratio, they see their margins decline, this has an effect on the economy which depends on the degree of price stickiness. Stickier bank rates exacerbate the contagion effect that goes from sub-primers to primers. We also study how a monetary policy shock transmits to the economy in the presence of this further degree of heterogeneity on the borrowers side. We find that sub-primers – who are more leveraged – are more sensitive to movements in the policy rate and that the presence of frictions in the banking sector attenuates the magnitude of the shock.

Chapter 2

Fiscal Policy, Housing and Financial Frictions

Abstract

This work studies the effect of financial frictions on fiscal policy. More precisely, it focuses on the introduction of a collateral constraint tied to the expected value of the housing stock for a group of households. The presence of this kind of financial friction has important consequences for the transmission of fiscal policy, given that constrained and unconstrained households reaction to the shock is at odds. The model designed in this work also allows to compare the effect of a relatively large menu of taxes on the main macro-aggregates and to study changes in one of the institutional characteristic of the credit market, namely the loan-to-value ratio. Financial frictions affect the transmission of fiscal policy through compositional effects, and public expenditure seems to be the most effective fiscal shock to expand output in the short-run.

2.1 Introduction

The greater consideration conceded by macroeconomists during the last few decades placed monetary policy in a position of preeminence with respect to fiscal policy. This is especially true if we consider the theoretical literature that stretches back to the Real Business Cycle (RBC) models and that subsequently, by incorporating Keynesian elements, continued with DSGE models[1] and resulted eventually in what has been defined the new-neoclassical synthesis. Recent developments connected to the financial crisis and the Great Recession renewed the interest towards the effectiveness of fiscal policy. Central banks around the world reacted firmly to declining GDPs by decreasing interest rates and often resorted to unconventional monetary policy measures to get over the limitation of zero lower bounds. However, according to some economists, lagging growth rates and the spectre of deflation in Europe make an argument for resorting more on fiscal policy as a tool for business cycle stabilization.

Both from a theoretical and an empirical point of view, the effects of an increase in government expenditure on output, consumption and investment are not clear. In particular, while most of the evidence at our disposal recognizes the expansionary effects of fiscal policy, in the form of an increase in government expenditure or as tax reductions, there is not the same sort of agreement on some other important issues. Namely, there is still uncertainty surrounding the size of the fiscal multipliers[2] and there is still not wide agreement on the qualitative response of consumption and investment and some other main macroeconomic variables. In a recent paper aimed at gauging the relative contribution of tax cuts and government expenditure on growth, Alesina and Ardagna (2010) argue that "It is fair to say that we know relatively little about the effect of fiscal policy on growth and in particular about the so called fiscal multipliers, namely how much one dollar of tax cuts or spending increases translates in terms

[1] As an illustrative example, one might consider that one of the leading graduate textbooks on DSGE models , Galí (2008), explicitly refers to monetary policy in the title while does not mention fiscal policy throughout the rest of the book.

[2] On this topic, an interesting reading is Blanchard and Leigh (2013). The authors find that fiscal multipliers have probably been higher than what assumed by forecasters during the consolidation episodes triggered by the financial crisis.

of GDP". Those considerations suggest that more research is needed on the topic to clarify the effects of fiscal policy.
In the theoretical literature, as put by Gali, López-Salido, and Vallés (2007), the part of the academic profession closer to the neoclassical tenets, underlines the importance of the Ricardian equivalence, through which households' consumption decisions suffer from the expected future increase in taxes resulting from expansionary fiscal policies. At the opposite side of the spectrum, a strand of economists closer to the Keynesian tradition, refutes those conclusions and insists on a positive correlation between expansionary fiscal policy and consumption. When it comes to investment, the debate is even more blurred and less polarized, for there is not complete agreement on the crowding effect of government spending.

DSGE models are used by central banks and major institutions around the world for policy analysis and have been used in the academia to offer analytical support to a broad range of economic ideas. Those models have the advantage of being micro-founded, their structural nature allows an easy identification of shocks and they can be used as laboratory to analyse the effect of policies, therefore providing fertile ground to test the effectiveness of fiscal policy. However, to do so it becomes crucial to introduce in those models the right elements. The financial crisis exposed some limitations of DSGE models, and paved the way for an increase in the contribution of works on financial frictions. An interesting way of introducing financial frictions in DSGE models is strictly connected to the presence of housing. The introduction of housing in DSGE models stretches back to Barsky, House, and Kimball (2007) and acquired attention in the literature by performing the additional role of collateral for constrained agents with Iacoviello (2005). However, most of the papers that followed this strand of literature have been interested in assessing the effect of monetary policy rather than that of fiscal policy, whose effects are still somewhat unexplored.

Most of the models that discuss the response of a DSGE model to fiscal policy share some limitations: they either consider only non-distortionary taxation or focus only on government expenditure, and/or they rely on a Walrasian labor market. On top of that there are very few studies that take the distance from the representative agent problem which is illustrative of smooth credit markets. The aim of this paper is to fill this gap in the literature by considering financial frictions in a DSGE model that includes also all the ingredients that the literature considers fundamental in order to replicate qualitatively and quantitatively the response to a monetary policy shock. As made clear by the theoretical research on housing and monetary policy, it is necessary to add wage stickiness, and adjustment costs of housing investment, in addition to other more used frictions such as habits in consumption and price stickiness,[3] to render the empirical effects of a monetary policy shock. Taking this approach allows me to have a baseline model over which to test the importance of those frictions in the context of a fiscal expansion. However, some caveats are in order. The first one is that the presence of several frictions at the same time makes it difficult to disentangle the role played by each single friction in delivering the final results. The second one, is that I am aware that this study cannot be conclusive on the quantitative side, for other important ingredients might be missing in the model.[4] Therefore, particularly the quantitative suggestions of this work, such as the size of the multiplier, have to be taken with caution.

An interesting work that tries to tackle the effect of fiscal policy and financial frictions is the paper by Fernández-Villaverde (2010). By resorting to the classical financial accelerator model of Bernanke, Gertler, and Gilchrist (1999), the author tries to assess which is the most effective fiscal policy shock in order to boost output in the short run. In this paper I follow a similar approach, however the differences with this work are substantial. First of all, I model heterogeneity and financial frictions in a different way. Following Iacoviello (2005), and Iacoviello and Neri (2010), households are divided in two separate groups, borrowers and savers. Borrowers, although still intertemporal optimizing agents, are constrained in the amount that they can borrow to the value of their collateral, which is given by the expected value of their housing stock. Second, the presence of housing allows me to study the effect o a larger menu of taxes

[3] See on this Carlstrom and Fuerst (2006), Sterk (2010) and the third chapter.

[4] I think, just as an illustrative example, at the presence of rule of thumb consumers.

and to consider the effect of fiscal policy on residential investment. Third, I can study what happens to a change in an institutional characteristic of the credit market. Namely, I investigate the response of the model when there is a change in the loan-to-value (LTV) ratio. This experiment replicates what Calza, Monacelli, and Stracca (2013) have already done with respect to monetary policy, and it is interesting for its effects on the two distinct classes of borrowers. This exercise is also useful not only because economies are characterized by heterogeneous LTV ratios, but also to think about macroprudential policies. Whit this paper I try to add on the debate on the effects of fiscal policy, and I seek to shed some lights on its transmission to the economy. Indeed, the distinction of households in two separate groups has normative implications, for constrained households response is very distant from that of Ricardian households.

2.2 Literature Review

As already mentioned in the previous section, there are only a few studies that focus on fiscal policy if compared to the large body of literature, especially from a theoretical point of view, that focuses on monetary policy. An important issue, extensively analysed in theoretical papers, has been to reconcile empirical and theoretical evidence with respect to the positive correlation between output and consumption after a shock in government spending – the so called *Government-Spending-Puzzle*. The ancestors of New-Keynesian DSGE models, RBC models, underlined how according to the Ricardian equivalence an increase in government expenditure is internalized by agents, therefore entailing a reduction in consumption through wealth effects which make households to work more and cut consumption. A possible solution to this puzzle has been presented by Gali, López-Salido, and Vallés (2007). In this paper, the authors use an idea put forward by Mankiw (2000), that of the presence of rule-of-thumb (RoT) consumers, so called because they are not intertemporal optimizer but they rather spend all their income at any given period. The presence of this particular category of households curbs the negative effect of Ricardian agents, and it allows – for some parameterizations – to revert the initial conclusions of RBC models[5]. Bilbiie and Straub (2004) build on Gali and analyse a richer framework characterized by distortionary taxation and a Walrasian labor market. They conclude that it is more complicated to reproduce the effect seen in data with respect to consumption in this larger set-up. In particular, what helps to render empirical consistent results is a low degree of persistence in the fiscal shocks, a weak response of monetary policy to inflation and a high degree of price stickiness. They also underscore the important role played in the model by the real wage, that needs to fluctuate considerably for consumption to increase after an increase in government expenditure. The procyclicality of the real wage is however a feature that is not confirmed in the data. Colciago (2011) adds on the literature by introducing wage stickiness in a model that considers RoT consumers. He finds that in this context the real wage does not move as much as without wage rigidities and therefore the effect of fiscal policy is attenuated. Alpanda and Zubairy (2013) investigate in a model with constrained households what are the effects of tax policies related to housing on macro variables. The paper is interesting for it singles out the effect of a large menu of house related taxes[6] and concludes that in order to reduce household debt and raise more revenues from taxation the most effective instrument is to eliminate the mortgage interest deduction. Albonico, Paccagnini, and Tirelli (2016) design and estimate a DSGE model to study the fiscal stance of the Euro Area. Their estimated share of non-ricardian agents (53%) is somewhat larger than what has been estimated in previous research, therefore implying larger fiscal multipliers. One of the few papers that deals with the introduction of financial frictions on the households side is Roeger and Veld (2009). In the paper the authors use a version of the European Commission model, the Quest III, to investigate the effect of the

[5]The mechanism works through the following lines: RoT agents are not influenced by the wealth effect that stems from fiscal policy, but they are strongly affected by labor income. Therefore, the presence of nominal price rigidities allows real wages to rise, allowing them to increase current consumption.

[6]They consider the following taxes: increasing property tax rates, eliminating the mortgage interest deduction, eliminating the depreciation allowance for rental income, instituting taxation of imputed rental income from owner-occupied housing and eliminating the property tax deduction.

presence of constrained borrowers on fiscal policy, which is assumed to be passive. In this paper, the government is not explicitly modelled and fiscal shocks are assumed to follow simple autoregressive processes that do not pose any strain on government budgets, being the latter excluded by the analysis. The authors find that adding constrained households in this medium-scale DSGE model makes fiscal policy more effective, especially when monetary policy is accomodative. My work shares some methodological aspects with it, namely the way borrowers are modelled, but differs from that analysis in many directions. First, in this work I study a larger menu of taxes, and focus on their effect at impact on the economy, with the idea of identifying the best policy option to revive output in the short run. In order to do so, following Fernández-Villaverde (2010), I calibrate the shocks in a way that makes them comparable. More precisely, the magnitude of the shocks is such that it generates the same drag on governments' budget. To carry out this task, it becomes then crucial to model the fiscal authorities in details. Second, I analyse the result of varying institutional characteristics of the credit market, which are identified in changes in the loan-to-value ratio. Finally, following most of the literature that analyses fiscal policy, I introduce and provide results for two different specifications of fiscal rules, and model the government sector explicitly. Considering a fiscal rule is important, for a large majority of advanced countries, but also some developing ones, follow one or more national or supernational rules.[7]

From an empirical point of view, several studies agree on the fact that an increase in government expenditure has a positive effect on output, consumption and hours worked. Blanchard and Perotti (2002) use vector autoregressive (VAR) analysis and find evidence of the positive effect of government spending on output, while investment is crowded out and the multiplier is relatively small (close to one). Fatás and Mihov (2001) find that the fiscal multiplier is larger than one and that the increase in output after an expansionary fiscal shock is mainly driven by the response of consumption, while the response of investment is mute. Mountford and Uhlig (2009) using VAR with

[7] See the following link for a detailed overview of fiscal rules used around the world: http://www.imf.org/external/datamapper/FiscalRules/map/map.htm

sign restriction find that deficit-financed tax cuts are the best instrument to boost output. In particular, they find that for the government spending scenario the multiplier is smaller than the one estimated by Blanchard and Perotti (2002). They find that consumption is positive only on impact and investment is crowded out by the increase in government expenditure. Interestingly enough, real wages do not increase in response to the shock.[8] Gali, López-Salido, and Vallés (2007) also provide an empirical analysis based on VAR and find that a positive shock in government expenditure is associated with a persistent rise in consumption, income, real wages and output. The response of investment is slightly negative but not significant.

2.3 The Model

The model draws partly from Iacoviello and Neri (2010) and partly from Fernández-Villaverde (2010). More precisely, I model heterogeneity on the households side and therefore financial frictions as in the former paper, while I follow the latter for the characterization of the government sector, the monetary policy rule and the design of shocks. Furthermore, beside the fiscal rule in Fernández-Villaverde (2010), for some scenarios I consider that in Gali, López-Salido, and Vallés (2007). Models with housing and financial frictions have been subject to a large scrutiny by the literature with respect to a monetary policy shock. This allows me to confidently introduce adjustment costs in capital accumulation, wage rigidities and habit in consumption, for they are key in replicating some empirical facts.[9] The model economy is composed by three main blocks: households, firms and monetary and fiscal authorities.

2.3.1 Households

Households are divided in two groups according to their impatience. In steady state, the impatient group borrows from the patient one,

[8]This is of theoretical interest, since some DSGE models require an increase in the real wage to drive consumption up.

[9]In particular, an issue in the literature has been represented by the comovement problem between the consumption of durable and non-durable goods. This problem is analysed in the third chapter of the thesis.

which is composed by so-called savers or lenders. Households can be represented as a continuum over the (0,1) interval. Borrowers are a fraction ω of total households while the remaining part is composed by savers. The discount factor of borrowers is given by β while savers discount utility by $\gamma > \beta$. This is a parsimonious way to introduce heterogeneity within households, since higher impatience in turn affects the first order conditions of households and makes it more convenient for savers to lend and for borrowers to borrow in steady state. In the following equations I solve the maximization problem of the two groups, notice that the variables related to savers are identified with a tilde. Both groups of households maximize a similar utility function. Utility is a function of consumption C_t – where h identifies the degree of habits in consumption – housing (D_t) and labor efforts (N_t), which are separated for the two sectors c (non-durable) and d (housing). The parameter η represents the elasticity of substitution between housing and consumption, which I assume to be equal to one in the baseline calibration, thus implying separability between the two goods. For the specification of the disutility of labor I follow Iacoviello and Neri (2010) and implicitly Horvath (2000). Allowing the parameters ξ and φ to be positive reduces mobility across sectors. In particular in the polar case in which $\xi = 0$, hours worked in the two sector are perfectly substitutes.

$$E_0 \sum_{t=0}^{\infty} \gamma^t \left(ln \left[(1-\alpha)(\tilde{C}_t - h\tilde{C}_{t-1})^{\frac{(\eta-1)}{\eta}} + \alpha \tilde{D}_t^{\frac{(\eta-1)}{\eta}} \right]^{\frac{\eta}{(\eta-1)}} - \frac{\tilde{v}}{1+\varphi} \left(\tilde{N}_{c,t}^{(1+\xi)} + \tilde{N}_{d,t}^{(1+\xi)} \right)^{\frac{(1+\varphi)}{(1+\xi)}} \right), \tag{2.1}$$

$$E_0 \sum_{t=0}^{\infty} \beta^t \left(ln \left[(1-\alpha)(C_t - hC_{t-1})^{\frac{(\eta-1)}{\eta}} + \alpha D_t^{\frac{(\eta-1)}{\eta}} \right]^{\frac{\eta}{(\eta-1)}} - \frac{v}{1+\varphi} \left(N_{c,t}^{(1+\xi)} + N_{d,t}^{(1+\xi)} \right)^{\frac{(1+\varphi)}{(1+\xi)}} \right), \tag{2.2}$$

The budget constraint of savers in real terms is somewhat richer than that of borrowers, for savers can accumulate capital in both sectors besides housing, they can lend to the governments by buying bonds, identified by b^g_t, and to borrowers, where I define loans with b_t. Savers earn a state contingent return R_t and R^b_t on the two assets. With a τ I indicate taxation on the variables of interest and with δ the depreciation rates. Finally, q_t is the relative price of housing, ϕ_t represents convex adjustment costs for capital[10] and Div_t is a catch-all variables which considers profits from monopolistic firms and unions and transfers from government, if positive, or a lump-sum tax if negative.

$$
\begin{aligned}
&(1+\tau_{c,t})\,\tilde{C}_t + k_{c,t} + k_{d,t} + q_{h,t}\left(\tilde{D}_t - (1-\delta_d)(1-\tau_{d,t})\tilde{D}_{t-1}\right) + \tilde{b}_t + b^g_t \\
&= \frac{(1+(1-\tau_{b,t})R^b_{t-1}\tilde{b}_{t-1})}{\pi_t} + \frac{(1+(1-\tau_{g,t})R_{t-1}b^g_{t-1})}{\pi_t} \\
&+ \left((1-\tau_{k,t})R^k_t + 1 - \delta_{kc}\right) K_{c,(t-1)} + \left(1-\tau_{kd,t})R^{kd}_t + 1 - \delta_{kd}\right) K_{d,(t-1)} \\
&+ (1-\tau_{l,t})\tilde{w}_{c,t}\tilde{N}_{c,t} + (1-\tau_{l,t})\tilde{w}_{d,t}\tilde{N}_{d,t} - \phi_t + Div_t
\end{aligned}
\tag{2.3}
$$

The budget constraint of borrowers differs from that of savers for borrowers do not accumulate capital and they do not invest in bonds. This results in the variable b_t representing credit obtained by savers rather than loans. Finally, the variable T_t is transfers to borrowers from the government.

$$
\begin{aligned}
&(1+\tau_{c,t})\;C_t + q_t\;(D_t - (1-\delta)\;D_{t-1}\;(1-\tau_{d,t})) + \frac{R^b_{t-1}\,b_{t-1}}{\pi_{c,t}} \\
&= b_t + (1-\tau_{l,t})\;w_{c,t}\,N_{c,t} + (1-\tau_{l,t})\;w_{d,t}N_{d,t}\;+ T_t
\end{aligned}
\tag{2.4}
$$

The differences between savers and borrowers are also given by an additional constraint. Namely, borrowers can only get an amount of loans that is tied to the value of their housing stock:

$$
b_t = \frac{(1-\delta)\;(1-\chi)\;D_t\,E_t\{\pi_{c,t+1}\,q_{t+1}\;(1-\tau_{d,t+1})\,\}}{R^b_t} \tag{2.5}
$$

Notice that the parameter χ represents the downpayment and therefore $(1-\chi)$ is the loan-to-value (LTV) ratio.

[10] See Appendix B for its specification.

Solving the maximization problem for savers, yields the following first order conditions:

$$\tilde{\lambda}_t = \frac{\frac{1-\alpha}{1+\tau_{c,t}}}{\tilde{C}_t - h\,\tilde{C}_{t-1}} - \frac{\frac{(1-\alpha)\,h\,\gamma}{1+\tau_{c,t+1}}}{\tilde{C}_{t+1} - \tilde{C}_t\,h} \tag{2.6}$$

$$\begin{aligned}\tilde{\lambda}_t \left(1 + \phi_{kc}\left(\frac{K_t}{K_{t-1}} - 1\right)\right) = \gamma\,\tilde{\lambda}_{t+1} \Bigg((1-\tau_{k,t})\; R_t^k + 1 - \delta_k \\ + \left(\frac{K_{t+1}}{K_t} - 1\right)\,\phi_{kc}\left(\frac{K_{t+1}}{K_t} - 1\right)\Bigg)\end{aligned} \tag{2.7}$$

$$\begin{aligned}\tilde{\lambda}_t \left(1 + \phi_{kh}\left(\frac{K_t^d}{K_{t-1}^d} - 1\right)\right) = \gamma\,\tilde{\lambda}_{t+1} \Bigg(1 - \delta + (1-\tau_{kd,t})\; R_t^{kh} \\ + \left(\frac{K_{d,t+1}}{K_{d,t}} - 1\right)\,\phi_{kh}\left(\frac{K_{d,t+1}}{K_{d,t}} - 1\right)\Bigg)\end{aligned} \tag{2.8}$$

$$\tilde{\lambda}_t = \frac{\gamma\,\tilde{\lambda}_{t+1}\,\left(1 + (1-\tau_{g,t+1})\,(R_t - 1)\right)}{\pi_{c,t+1}} \tag{2.9}$$

$$\tilde{\lambda}_t = \frac{\gamma\,\tilde{\lambda}_{t+1}\,\left(1 + (1-\tau_{b,t+1})\,(R_t^b - 1)\right)}{\pi_{c,t+1}} \tag{2.10}$$

$$\tilde{\lambda}_t\,q_t = \frac{\alpha}{\tilde{D}_t} + \tilde{\lambda}_{t+1}\,\gamma\,(1-\delta)\,(1-\tau_{d,t+1})\,q_{t+1} \tag{2.11}$$

The optimal conditions for the borrower are instead the following:

$$\lambda_t = \frac{\frac{1-\alpha}{1+\tau_{c,t}}}{C_t - h\,C_{t-1}} - \frac{\frac{(1-\alpha)\,h\,\beta}{1+\tau_{c,t+1}}}{C_{t+1} - h\,C_t} \tag{2.12}$$

$$R_t^b\,\psi_t = 1 - \beta\,\frac{\lambda_{t+1}}{\lambda_t}\,\frac{R_t^b}{\pi_{c,t+1}} \tag{2.13}$$

$$q_t\,\lambda_t = \frac{\alpha}{D_t} + q_{t+1}\,\lambda_{t+1}\,(1-\tau_{d,t+1})\,(1-\delta)\,\beta + q_t\,\psi_t\,\lambda_t\,(1-\delta)\,(1-\chi)\,\pi_{d,t+1} \tag{2.14}$$

Two comments are in order. The first one is the presence of ψ_t in equation (2.13), which is the Lagrange multiplier of the borrowing

constraint. In equilibrium $\psi_t > 0$, thus signalling the willingness of borrowers to tilt their consumption choice towards the present but the impossibility to do so due to the constraint. The borrowing constraint also affects equation (2.14), the first order condition with respect to housing. Indeed, the third element on the right hand side stems from the role that housing plays in borrowers' optimization problem, which is the additional use as collateral.
Households do not maximize utility also with respect to labor efforts, rather they let unions contract their wage and then offer the amount of labor requested by firms. Unions set the optimal wage as a mark-up over the marginal rate of substitutions of each group of households. As in Iacoviello and Neri (2010), I assume that there are four different unions that serve the interests of the two groups of households in the two different productive sectors of the economy. Appendix B provides a detailed characterization of the problem.

2.3.2 Firms

In order to introduce price rigidity I assume that there is a distinction between perfectly competitive final goods producers and the intermediate sector, where firms enjoy a certain degree of monopolistic power. Furthermore, the consumption good and housing sector are modeled symmetrically. The technology employed in the intermediate sector is:

$$Y_{c,t} = (N_{c,t} + \tilde{N}_{c,t})^{(1-\mu_c)} k_{c,t-1}^{\mu_c} \tag{2.15}$$

$$Y_{d,t} = (N_{d,t} + \tilde{N}_{d,t})^{(1-\mu_d)} k_{d,t-1}^{\mu_d} \tag{2.16}$$

while the final goods producers'technology is represented by a Dixit-Stiglitz aggregator[11]. Intermediate producers face quadratic costs of adjusting prices $\acute{a}$ la Rotemberg[12]. The two following Phillips Curves represent the result of the maximization problem in both sectors:

$$1 - \varepsilon_c + \varepsilon_c\, mc_{c,t} = \pi_{c,t}\,\theta_c\,(\pi_{c,t} - 1) - \theta_c\,\pi_{c,t+1}\,\frac{\tilde{\Lambda}_{t+1}}{\tilde{\Lambda}_t}\,\frac{Y_{c,t+1}}{Y_{c,t}}\,(\pi_{c,t+1} - 1) \tag{2.17}$$

[11] The specification of the problem follows what has been outlined in the first chapter, but for the introduction of capital

[12] Rotemberg (1982).

$$1 - \varepsilon_d + \varepsilon_d\, mc_{d,t} = \pi_{d,t}\, \theta_d\, \left(\pi_t^d - 1\right) - \theta_d\, \pi_{t+1}^d\, \frac{\tilde{\Lambda}_{t+1}}{\tilde{\Lambda}_t}\, \frac{q_{t+1}}{q_t}\, \frac{Y_{d,t+1}}{Y_{d,t}}\, \left(\pi_{d,t+1} - 1\right) \tag{2.18}$$

Appendix B also provides detailed first order conditions for the problem. The introduction of capital, besides making the model more realistic, finds its justification in dampening the importance of real wage fluctuations. Indeed, as discussed at length by Bilbiie and Straub (2004), a strong positive response of the real wage its crucial in making consumption positively correlated to government spending. When labor is the only factor of production the importance of movements in the real wage might be exaggerated, thus the introduction of capital as a complementary factor of production helps in obtaining more robust results.

2.3.3 Monetary Policy Rule

For the specification of the monetary policy rule and the calibration of γ_R and γ_π, the parameters associated respectively to the lag-response of the interest rate and to the response to inflation, I follow Fernández-Villaverde (2010). The response of the interest rate to changes in inflation is crucial in determining the dynamics of the model and therefore some robustness checks are conducted and shown in Appendix B.[13] The Central Banks reacts only to inflation and the Taylor rule features a certain degree in the persistence of the interest rate, measured by the parameter γ_R.

$$\frac{R_t}{\bar{R}} = \left(\frac{R_{t-1}}{\bar{R}}\right)^{\gamma_R} \left(\frac{\pi_{c,t}}{\bar{\pi}}\right)^{\gamma_\pi (1-\gamma_R)} e_t \tag{2.19}$$

The variable e_t represents a monetary policy shock, which, as common in this literature follows an autoregressive process of order one.[14]

[13] Fernández-Villaverde (2010) does not discuss the reason why he chose a relatively low value for the elasticity of the policy rate to inflation. Perhaps, the author imagine a crisis scenario with a monetary authority following a very accomodative stance. Given that in his baseline calibration is $\gamma_R = 0.95$ and $\gamma_\pi = 0.95$, the parameter associated to inflation is 0.0475. Robustness checks show that increasing the response to inflation reduces significantly the size of the multiplier.

[14] $log\,(e_t) = \rho_\pi\, log\,(e_{t-1}) + u_t$.

2.3.4 Government Sector

Fiscal authorities have to abide to the following budget constraint:

$$b_t^g = T_t + g_t + \frac{R_{t-1}\, b_{t-1}^g}{\pi_{c,t-1}} - tax_t \tag{2.20}$$

where, b_t^g is government debt, g_t is public expenditure in terms of the consumption good and R_{t-1} is the contingent rate paid on its debt. The government finances public expenditure and transfers through the collection of taxes. Taxes are distortionary and given by the following equation:

$$\begin{aligned} tax_t = \tau_{c,t}\, \left(C_t\, \omega + \tilde{C}_t\, (1-\omega)\right) + \tilde{N}_{c,t}\, \tilde{w}_{c,t}\, \tau_{l,t} + \tilde{N}_{d,t}\, \tau_{l,t}\, \tilde{w}_{d,t} + N_{c,t}\, \tau_{l,t}\, w_{c,t} \\ + N_{d,t}\, \tau_{l,t}\, w_{d,t} + \tau_{g,t}\, (R_{t-1} - 1)\, b_t^g + b_t\, \tau_{b,t} b_t\, \left(R_{t-1}^b - 1\right) \\ + \tau_{d,t}\, D_t^{tot} + K_{t-1}\, \tau_{k,t}\, \left(R_{t-1}^k - \delta_k\right) + K_{t-1}^d\, \tau_{kh,t}\, \left(R^k h_{t-1} - \delta_d\right) \end{aligned} \tag{2.21}$$

Government expenditure fluctuates according to:

$$\hat{g}_t = \rho_{gg}\, \hat{g}_{t-1} + d_g\, \frac{b_{t-1}^g}{\pi_t^c Y_t} + \varepsilon_{g,t} \tag{2.22}$$

where $\hat{g} = log\left(\frac{g_t}{\bar{g}}\right)$ is the log deviation of inflation with respect to its steady state value, while the parameter d_g is the one measuring the sensitivity of public expenditure to deviations of the ratio of the public debt. Finally, $\varepsilon_{gg,t}$ represents a shock to public expenditure. The laws of motion for the tax rates defined in the model are all modelled as autoregressive processes of order one, where $\varepsilon_j \sim \mathcal{N}(0, \sigma_{\tau,j})$

$$log\left(\frac{1+\tau_{c,t}}{1+\bar{\tau}_c}\right) = \rho_c\, log\left(\frac{1+\tau_{c,t-1}}{1+\bar{\tau}_c}\right) - \varepsilon_{\tau c,t} \tag{2.23}$$

$$log\left(\frac{1-\tau_{l,t}}{1-\bar{\tau}_l}\right) = \rho_l\, log\left(\frac{1-\tau_{l,t-1}}{1-\bar{\tau}_l}\right) + \varepsilon_{\tau l,t} \tag{2.24}$$

$$log\left(\frac{1-\tau_{d,t}}{1-\bar{\tau}_d}\right) = \rho_d\, log\left(\frac{1-\tau_{d,t-1}}{1-\bar{\tau}_d}\right) + \varepsilon_{\tau d,t} \tag{2.25}$$

$$log\left(\frac{1-\tau_{g,t}}{1-\bar{\tau}_g}\right) = \rho_g\, log\left(\frac{1-\tau_{g,t-1}}{1-\bar{\tau}_g}\right) + \varepsilon_{\tau g,t} \tag{2.26}$$

$$log\left(\frac{1-\tau_{b,t}}{1-\bar{\tau}_b}\right) = \rho_b\, log\left(\frac{1-\tau_{b,t-1}}{1-\bar{\tau}_b}\right) + \varepsilon_{\tau b,t} \tag{2.27}$$

$$log\left(\frac{1-\tau_{k,t}}{1-\bar{\tau}_k}\right) = \rho_k\, log\left(\frac{1-\tau_{k,t-1}}{1-\bar{\tau}_k}\right) + \varepsilon_{\tau k,t} \tag{2.28}$$

$$log\left(\frac{1-\tau_{kh,t}}{1-\bar{\tau}_k h}\right) = \rho_k h\, log\left(\frac{1-\tau_{kh,t-1}}{1-\bar{\tau}_k h}\right) + \varepsilon_{\tau kh,t} \tag{2.29}$$

$$log\left(\frac{T_t}{\bar{T}}\right) = \rho_T\, log\left(\frac{T_{t-1}}{\bar{T}}\right) + \varepsilon_{T,t} \tag{2.30}$$

I use the above specification in section 2.5.2 in order to replicate Fernández-Villaverde (2010)'s experiment aimed at assessing the type of fiscal shock that has a stronger effect on impact on output. In the remaining sections of the simulations I rely to an alternative specification of the *fiscal policy rule*, and I follow a more consolidated tradition in the literature. Namely, as in Gali, López-Salido, and Vallés (2007) and Bilbiie and Straub (2004) I specify government deficit as:

$$def. = g + T - tax \tag{2.31}$$

and the linear fiscal rule as:

$$def. = g_t\phi_g + b_t^g\phi_b \tag{2.32}$$

and therefore I do not consider equation (2.30) and replace the law of motion of public expenditure with an autoregressive process of order one:

$$log\left(\frac{g_t}{\bar{g}}\right) = \rho_{gg}\, log\left(\frac{g_{t-1}}{\bar{g}}\right) + ugg_t \tag{2.33}$$

I do this in order to follow as closely as possible the literature on the topic, and provide the results that arise following the alternative rule as robustness checks.

2.3.5 Market Clearing Conditions

Equilibrium in the consumption and in the housing sector requires:

$$Y_{c,t} = g_t + C_t\,\omega + \tilde{C}_t\,(1-\omega) + Y_{c,t}\,\frac{\theta_c}{2}\,(\pi_t^c - 1)^2 \tag{2.34}$$

$$Y_{d,t} = \left(D_t - (1-\delta)\ D_{t-1}\ \left(1-\tau_t^d\right)\right)\ \omega + (1-\omega)\ \left(\tilde{D}_t - \left(1-\tau_t^d\right)\ (1-\delta)\ \tilde{D}_{t-1}\right) + Y_{d,t}\ \frac{\theta_d}{2}\ \left(\pi_t^d - 1\right)^2 \tag{2.35}$$

where the last element in both the above equations is the fraction of output wasted in the process of adjusting prices. The equilibrium in the labor market requires:

$$N_{c,t} = N_{c,t}\,\omega + \tilde{N}_{c,t}\ (1-\omega) \tag{2.36}$$

$$N_{d,t} = N_{d,t}\,\omega + \tilde{N}_{d,t}\ (1-\omega) \tag{2.37}$$

$$N_t^{tot} = \omega\ (N_{c,t} + N_{d,t}) + (1-\omega)\ \left(\tilde{N}_{c,t} + \tilde{N}_{d,t}\right) \tag{2.38}$$

where $N_{i,t} = \int N_{i,t}(j)\, dj$, and j represents a continuum of firms over the (0,1) interval. Total output is given by the sum of output in the non-durable and in the durable sector[15] plus business investment.

$$Y_t = Y_{c,t} + q_t\, Y_{d,t} + I_{c,t} + I_{d,t} \tag{2.39}$$

where:

$$I_{c,t} + I_{d,t} = K_t - (1-\delta_k)K_{t-1} + K_{d,t} - (1-\delta_{kd})K_{d,t-1} - \phi_t \tag{2.40}$$

Finally, the equilibrium in the credit market requires:

$$b_t\omega = b_t(1-\omega) \tag{2.41}$$

2.4 Calibration

For the model has been built drawing mainly on two different papers, namely Iacoviello and Neri (2010) and Fernández-Villaverde (2010), also the calibration follows these two models as closely as possible. In particular, the latter model has been used as the benchmark for the calibration of parameters related to the fiscal sector and the monetary policy rule, while the former model has been used for the remaining part. Most of the parameters are standard in the literature therefore I will mainly discuss those that are more specific to

[15] As standard in this literature, output in the durable sector is measured at constant prices.

this model. The calibration is based on the US economy, for I mainly follow works that focus on the U.S. The parameter α, the share of housing in the utility function, and the depreciation rate of housing which has been set to 1% on a quarterly base, have been calibrated to match a level of residential investment in steady state equal to 6%, while the weight of the disutility of labor $\tilde{v}$ and v are group specific and have been calibrated in order to pin down steady state level of hours worked to $1/3$ of households' total time. The depreciation rate of capital in the non-durable sector is set to 0.025, while the depreciation rate of capital in the durable sector is slightly higher and equal to 0.03.[16] Those two parameters and the share of capital in the production function, μ_c and μ_d have been used to pin down the total share of investment over GDP to roughly 20%. Government debt as a share of GDP, differently from Fernández-Villaverde (2010),[17] is equal to 60% in steady state, a value that is consistent with the average of US government debt as a share of GDP from 1990 to 2007. The model features nominal rigidities both on the firms level and with respect to wage setting. Prices are sticky only in the non-durable sector, and they can be reset on average once every four quarters. House prices are flexible, this assumption is not without consequences,[18] but the largest part of the literature on the topic agrees on considering it quite sensible. Wages are instead sticky in both sectors and they are reset on average once a year. The downpayment χ is set to 0.24, thus implying a LTV ratio of 76%, in line with the estimates for the U.S..[19] The share of borrowers is equal to 0.5 while habits in consumption parameter is equal to 0.6, a value found in many estimated models. I follow Gali, López-Salido, and Vallés (2007) in setting the share of government expenditure to GDP to 20% , which was roughly the post-war years average in the U.S.. As in Fernández-Villaverde (2010) the steady state values are equal to 0.05 for the consumption tax, 0.2 for the labor tax and 0.32 for the tax on savings. For

[16] The reason behind this difference has to be found in the lower service life of construction machineries, see Iacoviello and Neri (2010) for more details.

[17] In his model debt is zero in steady state.

[18] See Barsky, House, and Kimball (2007) on the topic, especially with respect to the importance of modelling prices as sticky in the durable sector for the conduct of monetary policy. See also the third chapter for an in depth analysis of the problem.

[19] See Calza, Monacelli, and Stracca (2013) for an empirical account of different LTV ratios in advanced economies.

the calibration of the property tax on housing I follow Alpanda and Zubairy (2013) and set it to 0.0035, which corresponds to an annual rate of 1.4%[20]. An important parameter is d_g, the response of government expenditure to changes in the level of public debt. Following Fernández-Villaverde (2010), this parameter has been set to -0.001. Its relatively small value makes variation of government expenditure in the short run not strongly affected by variations in government debt, while its sign makes the model stable. Finally the autoregressive processes have all a persistence of 0.95, which is standard given the quarterly frequency of the model. When I use the alternative specification of the fiscal rule, I use as baseline values of 0.1 for the sensitivity of deficit to government expenditure and a value of 0.3 for the sensitivity of deficit to changes in the level of debt.

[20]The authors calibrate this figure using the 50-State Property Tax Comparison Study conducted by the Minnesota Taxpayers Association (2011).

TABLE 2.1: *Parameters*

Parameter Name	Value	Description
γ	0.99	Discount factor of Savers
β	0.98	Discount factor of Borrowers
δ_d	0.01	Rate of depreciation of housing
δ_{kc}	0.025	Rate of depreciation of Capital in C
δ_{kd}	0.03	Rate of depreciation of Capital in D
ε_c	7.5	Elasticity of substitution for C goods
ε_d	7.5	Elasticity of substitution for D goods
ε_{wc}	7.5	Elasticity of substitution labor in C
ε_{wd}	7.5	Elasticity of substitution labor in D
χ	0.24	Downpayment
γ_R	0.95	Taylor rule smoothing
γ_π	0.95	Taylor rule sensitivity to inflation
ω	0.5	Share of Borrowers
h	0.6	Habits in consumption paramter
ξ	0.871	Elasticity of substitution across labor types
ϕ	0.5	Inverse elasticity of labor supply
ρ_τ	0.95	Autoregressive coefficient in tax shocks
d_g	-0.001	Sensitivity of expenditure to debt
ϕ_b	0.3	Sensitivity of deficit to debt
ϕ_g	0.1	Sensitivity of deficit to gov. exp.
$\bar{\tau}_c$	0.05	Steady state value of cons. tax
$\bar{\tau}_l$	0.2	Steady state value of labor tax
$\bar{\tau}_d$	0.0035	Steady state value of house tax
$\bar{\tau}_b$	0.32	Steady state value of tax on savings
$\bar{g}$	20%	Share of gov.expenditure
$\bar{b}^g$	60%	Steady state level of public debt
ϕ_{kc}	14.25	Adjusting cost parameter, capital C
ϕ_{kd}	14.25	Adjusting cost parameter, capital D
μ_c	0.39	Capital share C
μ_d	0.39	Capital share D

2.5 Experiments and Simulations

In the following sections I run several simulations related to the implementation of fiscal policy. I use the model as a laboratory to get intuitions on the transmission of fiscal policy to the economy in presence of financial frictions and housing. Section 2.5.1 shows how the model responds to a one percent increase in government expenditure and it argues that the presence of constrained borrowers alters the dynamics of the model and that fiscal policy has short-term redistributional consequences, this is clear when the responses of the two groups of households are compared. Section 2.5.2 shows what is the effect on impact of five different fiscal shocks. More in details, it compares what is the response of the model on impact given that they all impose the same increase in the budget deficit. Finally, section 2.5.3, illustrates what are the effects of varying the LTV ratio, therefore showing the implications of different values of one of the institutional characteristic of the credit market. This exercise is interesting not only because economies around the world have different LTV ratios but also for two additional reasons. The first one is that LTV ratios are not exogenous, but rather change across the business cycle, therefore implying potentially stronger or weaker effects of fiscal policy on the economy and on the different households' groups. The second one is that an analysis of the effect of LTV ratios adds to the debate on its adoption as an instrument in the context of macroprudential policies.

2.5.1 Government Expenditure

In this section I simulate a positive shock to government expenditure. Remember that in this model government expenditure is modelled as being simply directed towards consumption of non-durable goods.[21] The shock is debt financed, and repaid in the medium term by an increase in taxes. The overall effect of the shock is expansionary: output increases on aggregate given the increase in both sectors, inflation raises and the Central Bank reacts following the Taylor rule

[21] Therefore, I abstract from the possibility of the government to invest in housing or in productive capital.

by raising the policy rate. Residential investment is not crowded out by government sector expenditure, it actually increases more than consumption, bringing about an increase in the relative price of housing. Overall the fiscal multiplier is equal to 1.64.[22] The value of the multiplier is affected in particular by the value of ϕ_g in the fiscal rule.[23] Furthermore, given the relative small scale of the model, my primary goal is not to suggest a precise measure for the multiplier.

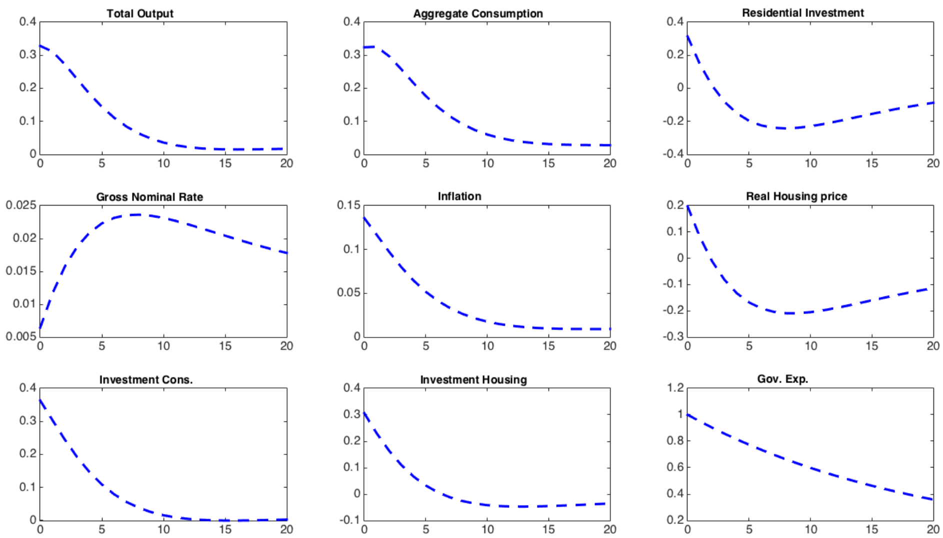

FIGURE 2.1: *Response to a* 1% *increase in government expenditure*

It is interesting to go behind the aggregate results and dig deeper as the model can give us useful information with respect to the transmission of fiscal policy.

As figure 2.2 makes clear, the reaction to the initial shock of savers and borrowers is quite different. Differently from models that rely on rule of thumbers, here both agents in the model are consumption smoother, however their reaction is at odds. Let me first examine the reaction of savers. The increase in government expenditure corresponds to a negative wealth effect for them, because given Ricardian equivalence agents know that they will have to face an increase

[22]The IRFs in the figures show the increase of output to a one percent increase of government expenditure from its steady state value. Since the model is linear and government expenditure in steady state is 20% of total output the multiplier is higher than one and equal to 1.64.

[23]Therefore Appendix B provides some robustness checks and some additional considerations with respect to this value.

in taxes in the future that compensates the initial shock in government expenditure. Savers react by increasing labor efforts and reducing housing consumption, while they also decrease consumption of non-durable goods, which at its through declines by 0.2%. Note however, that consumption increases marginally in the first period after the shock, a result that is probably given by the initial increase in real house prices which entails a substitution effect from housing to consumption. The response of borrowers is completely different. Borrowers exploit the fact that the increase in government expenditure brings about an increase in inflation therefore reducing their real value of debt, this corresponds to a relaxation of their borrowing constraint and they react by increasing both the consumption of non-durable goods and that of housing. The increase in housing consumption is so strong that compensates the reduction of housing consumption by savers. This increases house prices, but differently from savers house prices dynamics have a positive effect for borrowers since their spike increases the value of their collateral and therefore works as an additional channel that allows them to further increase consumption.

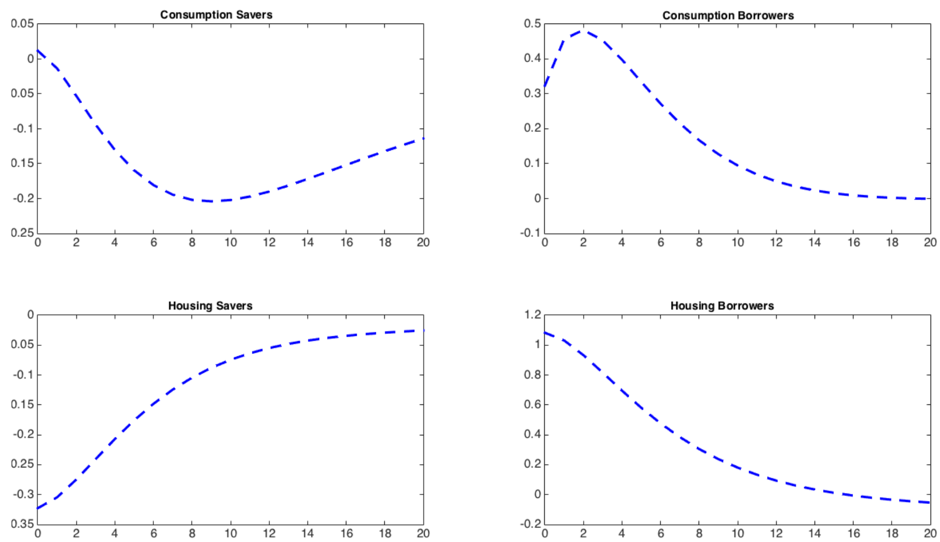

FIGURE 2.2: *Response to a 1% increase in government expenditure*

As shown in Appendix B, the IRFs of the model if we consider a shock in one of the distortionary tax rate are different in terms of magnitude but do not differ much qualitatively. The main difference is given by savers consumption of non-durable and the way they rearrange consumption in the durable and non-durable sector. For example, the increase in consumption is higher when there is a reduction of taxes on consumption and the reduction of housing consumption is lower when the expansionary measure is given by a reduction in τ_d. In the next section I show and confront the effect of shocking different tax rates and compare them with public expenditure.

2.5.2 Fiscal Shocks

In order to study what kind of fiscal shock has the strongest effect on total output, I conduct an experiment following closely the one presented by Fernández-Villaverde (2010) and in order to do so I considering the same modellization of the fiscal side proposed in that paper. I study then the response at impact of total output, consumption and residential investment after a shock to government expenditure and to other 4 shocks to taxes, namely a tax on consumption, a tax on labor, a tax on debt and a tax on housing.[24] It is not straightforward to decide how to confront those different shocks. Indeed two kinds of problems emerge, the first one is if we should consider the effect on impact of the shock, or rather its medium term effect or its welfare related implications, that in this model, differently from Fernández-Villaverde (2010) are even more complicated because of the presence of two distinct classes of households. The second one is related to the problems in calibrating the shocks in a way that would allow one to compare them in the most informative way. These problems have been solved in the above mentioned paper by confronting the effect of the different shocks on impact and by calibrating the shocks in order to consider the same effect on the public balance as the one caused by an increase of one percent of public expenditure. That is also the approach I take in this study. More formally, this calibration is performed considering the following:

[24]Note that the original experiment by Fernández-Villaverde (2010) is limited to output and as specified earlier it uses the financial accelerator related to firms net worth.

$$0.01 \times \bar{g} = -\Delta\tau_{l,t} \times (\tilde{N}_{c,t}\,\tilde{w}_{c,t} + \tilde{N}_{d,t}\,\tilde{w}_{d,t} + N_{c,t}\,w_{c,t} + N_{d,t}\,w_{d,t}) \quad (2.42)$$

$$\Delta\tau_{l,t} = -0.01\frac{\bar{g}}{\times(\tilde{N}_{c,t}\,\tilde{w}_{c,t} + \tilde{N}_{d,t}\,\tilde{w}_{d,t} + N_{c,t}\,w_{c,t} + N_{d,t}\,w_{d,t})}$$

where I use as an explicative example the way I calibrated the size of the shock on labor efforts. Namely, I impose that the variation in public expenditure, which puts a strain on government deficit equal to a one percent of the steady state value of g is equal to an equivalent temporary increase in the budget given in this case by a reduction in labor taxes.[25]

Now, considering that the percent deviation of labor tax on impact is given by $\hat{\tau}_l$:

$$\hat{\tau}_l = log\left(\frac{1-\tau_l}{1-\bar{\tau}_l}\right) \quad (2.43)$$

and that I want it to decrease it by the amount specified above, then:

$$\begin{aligned}\hat{\tau}_l &= log\left(\frac{1-\tau_l-\Delta\tau_{l.t}}{1-\bar{\tau}_l}\right)\\ &= log\left(1-\frac{\Delta\tau_{l,t}}{1-\bar{\tau}_l}\right)\\ &= log\left(1+0.01\frac{1}{1-\tau_{l,t}}\frac{\bar{g}}{\times(\tilde{N}_{c,t}\,\tilde{w}_{c,t} + \tilde{N}_{d,t}\,\tilde{w}_{d,t} + N_{c,t}\,w_{c,t} + N_{d,t}\,w_{d,t})}\right)\end{aligned}$$

I follow the same procedure to calibrate all other shocks and then examine the impulse response functions. The main result, which confirms the one of Fernández-Villaverde (2010) and that can be red from figure 2.3, is that the fiscal shock that works better in increasing output on impact is an increase in government expenditure. Indeed, the multiplier of all other shocks is somewhat smaller than that implied by a positive increase in g_t. While the overall effect is similar for all kinds of shocks, there is a different response in residential investment and aggregate consumption. What however emerges clearly

[25] Note that all the values considered in those computations are the steady state values.

from this analysis is that fiscal policy in presence of constrained agents, despite the source of the shock, crowds in residential investment and consumption and ultimately increases total output. The overall effect is stronger for the government expenditure shock, with a multiplier that is about 0.5% larger with respect to all other shocks.

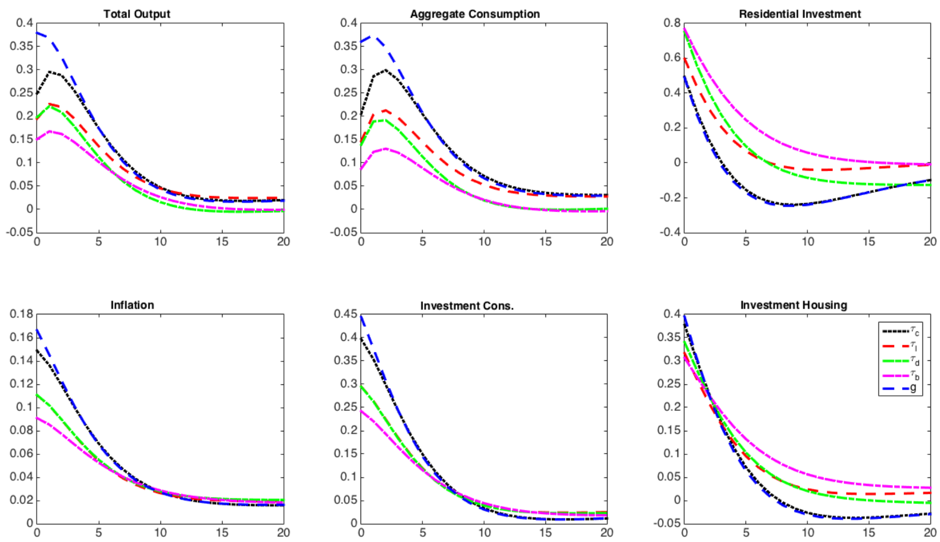

FIGURE 2.3: *Response to a* 1% *increase in government expenditure*

As highlighted in the fourth panel of figure 2.3, an important channel through which the model works is through the increase in inflation, this effect is stronger after a shock to government expenditure which directly increases aggregate demand. The mechanism I refer to is debt-deflation, which comes from Fisher's account of the Great Depression and in the context of monetary policy has been already highlighted in different set-ups by (Bernanke, Gertler, and Gilchrist, 1999) and in a model similar to the one here presented by (Iacoviello, 2005). Indeed, debt in this model is nominal and an increase of inflation decreases its value.[26] This works through the relaxation of borrowers budget constraint that goes in the same direction of an increase in house prices. Therefore, it boosts their consumption of non-durable goods and of housing.

Figure 2.4 shows the way the two distinct groups react to the shocks and helps shading some lights on the aggregate results. The

[26]The original analysis of Fisher was more focused on the effect of deflation on the magnification of debt.

figure highlights once again that households react differently to the shocks. A reduction in the tax rate on consumption has the second strongest effect on aggregate output and it works mainly through an increase in consumption. However, the incentive to consumption lowers investment with respect to a shock to government expenditure and is furthermore hindered by the presence of habits in consumption. The reduction of housing taxes has also expansionary effects, which differently from the previous shock rely more on the higher increase in housing consumption by borrowers. Interestingly enough, savers still reduce their housing consumption, due to the increase in real house prices, however their consumption of durable goods gets back to steady state far more quicker than in other shock exercises, and it overshoots dramatically after that. A reduction of taxes on savings increases savings by patient households. Indeed, that is reflected in figure 2.4 by the strong decline in housing consumption by them and by the opposite movement in the consumption of housing by borrowers. The two effects tend to compensate each other, while the effect on non-durable consumption is more limited therefore the reduction of this tax rate is the least effective between the ones analysed. Lastly, a reduction in the tax on labor does not manage to have effects on total output that are as stronger as in the case of government expenditure shock. One reason might be related to the fact that this tax shock shifts households labor supply, therefore has limited effects on inflation.

This section highlights how different the reactions of the two groups of households are. However, the focus of the model is not on the welfare effect of fiscal shocks, for the analysis would also require to take a stance on the effect of government expenditure on the utility of households. This issue has not been tackled in this paper and since the empirical evidence on this topic is still mixed I omit any further discussion on the topic and leave it to future research.

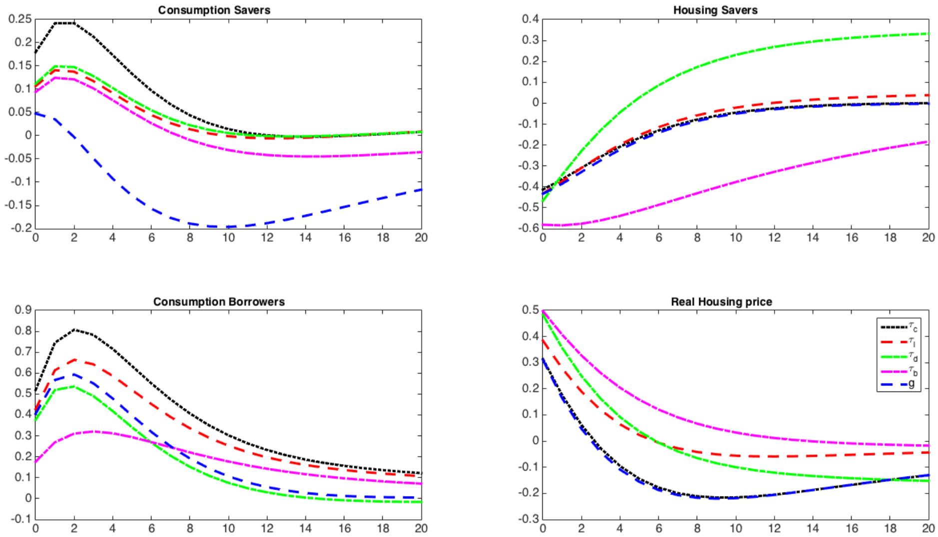

FIGURE 2.4: *Response to a 1% increase in government expenditure*

2.5.3 Institutional Characteristics

The last part of the results, focuses on the effect of fiscal policy in light of different institutional characteristics.[27] In particular, in this section I explore the effects of changing the LTV ratio, which level usually differs across countries and across time, reflecting characteristic of the credit market that are distinctive of the economy under analysis. This topic has been studied with reference to monetary policy by Calza, Monacelli, and Stracca (2013) among others. In that paper, the authors first provide empirical evidence of the different characteristic of the mortgage market in advanced economies, focusing on the LTV ratio and on the flexibility of the interest rate in the contract, and then use a DSGE model similar to the one described here to confirm their empirical results. Both their empirical and theoretical analysis reaches the conclusion that in presence of a higher LTV ratio, and therefore when financial markets are more developed, monetary policy has stronger effects on output and investment. Discussions related to the LTV are not just confined to a broad analysis of the degree of development of financial markets. Indeed, the LTV ratio has been already adopted by several countries

[27]Note that in this section the specification of the fiscal side is similar to Gali, López-Salido, and Vallés (2007). I provide as usual the results for the alternative specification in the Appendix B.

as a macro-prudential tool. The reason for that is straightforward, LTV ratios are pro-cyclical, for mainly two reasons. The first one comes directly from the appreciation of assets during expansions, and the second is due to the apparent receding risk and increase in competition that usually goes hand in hand with a boom (Borio and Shim, 2007). It follows, that authorities could use the LTV ratio in order to steer the business cycle. On aggregate, LTV ratios tend to be higher in booms rather than in a contraction. However, if we consider the case of households that run up consistent amount of debt in face of the increasing value of their properties, a sudden drop in house prices, leaves them strongly leveraged, and therefore with higher LTV ratios. The aim of this section is to check whether different level of households indebtedness impinge on the transmission of fiscal policy. To do so, I consider a shock to government expenditure as in section 2.5.1 and three different levels for the LTV, namely 60, 75 (which is a figure almost identical to the baseline used in the model) and 90. All the values are plausible since they span the range of LTV identified by the literature. Figure 2.5 shows how the model dynamics are affected by different levels of the LTV ratio. In particular, notice that both the responses of borrowers and savers to the shock, despite qualitatively unchanged, are magnified by an increase in its value. The reasons for this result is straightforward and works mainly through borrowers, while the reaction of savers is, to some extent, a reaction to changes in the behaviour of borrowers. A higher LTV increases the amount of resources that borrowers can actually borrow out of their housing stock value. The higher borrowing capacity reflects itself in higher consumption of both durable and non-durable goods. Interestingly, as it can be seen in figure 2.6, this change does not affect households labor supplies and wages, if not marginally and after some periods, these dynamics are key to understand what happens on aggregate. An increase in government expenditure, as already shown in the previous sections, has an expansionary effect. The increase in output brings also inflation up. The increase in inflation relaxes the borrowing constraint of borrowers through the Fisher effect and this pushes up their consumption of durable and non durable goods. The increase in residential investment pushes house prices up and this feeds back into the borrowing constraint once again, further increasing the consumption possibilities of borrowers through an increase of their housing value. Those effects are magnified by a higher LTV ratio. However, the overall effect on total output, consumption and residential investment is very little affected by the mechanism so far highlighted. This is somehow surprising, and the explanation is in the highlighted dynamics in the labor market and in the consequent reaction by savers. Indeed, savers reduce the consumption of housing, given the relative increase in house prices but increase the consumption of non-durable goods. Savers' response mirrors the one of borrowers, but in the opposite direction. This reduces the overall effect of the shock on the aggregates, indeed total output is only marginally affected, while is slightly more evident the increase in total consumption and the corresponding reduction in housing investment when the LTV ratio is higher.

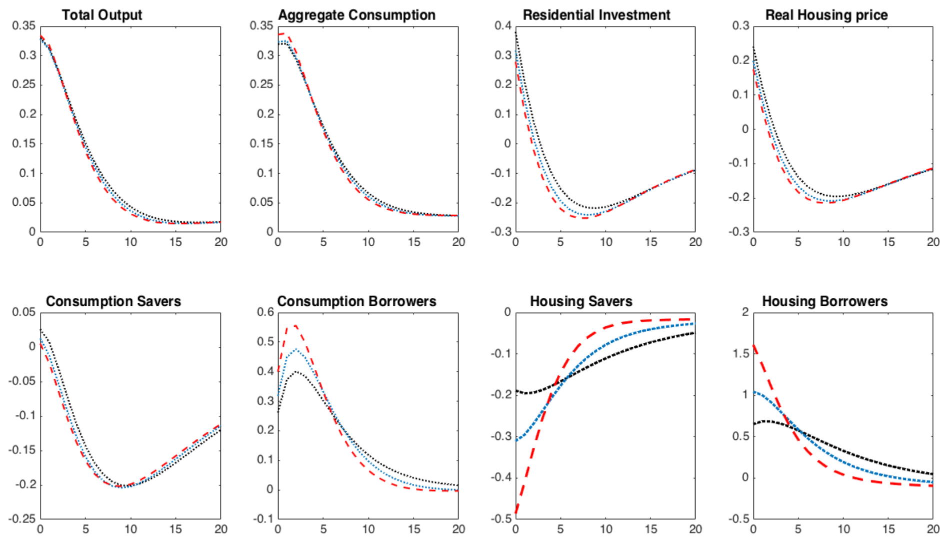

FIGURE 2.5: *Response to a* 1% *increase in government expenditure*

This result is interesting for it suggests that fiscal policy is more redistributive the higher is the level of debt that borrowers hold with respect to their housing stock value. However, despite the high sensitivity of borrowers to fiscal policy, and the increasing sensitivity they show with respect to the LTV ratio, it cannot be concluded that higher LTV ratios imply a larger responsiveness of the economy to fiscal policy. This result might underline also some limitations of the model, and in particular the presence of a more detailed modellization of firms might revert or amplify some of the conclusions reached here.

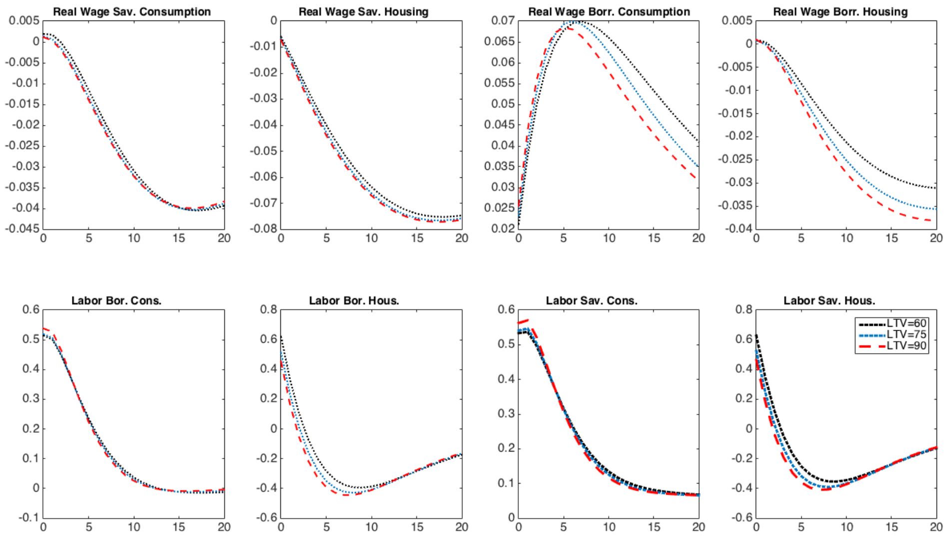

FIGURE 2.6: *Response to a* 1% *increase in government expenditure*

2.6 Further extension, limitation

An interesting extension of the model would be to consider a more detailed modellization of the public sector. This would allow the exploration of further shocks and it would facilitate the application of the model to contexts that are different from the ones analysed in this work. In particular, it could be taken into account the possibility for the government to invest in housing and in capital. Creating an alternative channel through which the government can intervene on the economy would most likely alter the effect of fiscal policy on the business cycle. Another interesting application of the model might be that of assessing the effects of fiscal consolidation. During the recent sovereign debt crisis in the Euro Area, in particular the Greek government has been forced to reduce the size of the public sector by laying-off part of the employees in the public administration or by reducing their wages. There are not may papers that rely to DSGE models to analyse the issue of fiscal consolidation. Carvalho and Martins (2011) investigate the topic trying to understand if the composition of fiscal consolidation is important. They do so without considering financial frictions, and therefore it might be interesting to study their effect in that kind of framework. Another possible further extension of the model might be to study optimal policy. In this work I did not take any stance on the redistributional effects of fiscal policy, and studying optimal fiscal policy might shed some lights on this topic. Furthermore, it would be interesting to compare different taxations in that context.

2.7 Conclusion

The Great Recession and the sovereign debt crisis in Europe, both underscored although for different reasons, the importance of fiscal policy. Indeed, on the one hand some governments used fiscal policy as an additional tool to revitalize their economies, on the other hand, the higher level of public debt, especially in Europe forced some governments to slash expenditure and increase taxes. Both episodes highlight the need to understand in full how fiscal policy affects macroeconomic variables and the magnitude of its effect, namely the size of the fiscal multiplier. This work has tried to contribute to the literature interested in assessing the role and the scope of fiscal policy by resorting to a DSGE model with financial frictions. While the role of financial frictions, especially in the form of a collateral constraint tied to the value of households' housing stock, has been extensively explored in the literature with respect to a monetary policy shock, this is not the case with respect to fiscal policy. In this paper I simulated some fiscal shocks and tried to shed some lights on the transmission of fiscal policy and its short run implications. My main findings are that constrained households react very differently from unconstrained ones. In particular, constrained households increase their consumption of durable and non-durable goods in light of an increase in government expenditure while the negative wealth effect arising from the expansionary shock brings about a reduction in savers' consumption. Furthermore, following Fernández-Villaverde (2010), I compare four different tax shocks to the government expenditure shock, finding that on impact an increase in public expenditure has the strongest effect on output. Finally, I consider changes in the LTV ratio and analyse the resulting IRFs. I find that borrowers that can enjoy higher LTV ratios respond more strongly to a fiscal shock. The opposite is true for savers and this, coupled with a very small response in labor and wage setting decisions, brings about only modest changes to the total level of output.

Chapter 3

Durable Goods, Collateral Constraints and the Co-movement Problem in DSGE Models

Abstract

This paper investigates the behavior of DSGE models with durable goods. In particular, it seeks to replicate some of the results that have been documented in the literature to amend a baseline model with durable goods and nominal price rigidity. In this model, when durable goods prices are flexible, a co-movement problem between consumption of durable and non durable goods arises following a monetary policy shock. I will show how, contrary to what argued by Monacelli (2009), financial frictions, in the form of a collateral constraint tied to the value of durables, do not solve this problem, while wage stickiness is much more effective in reconciling theoretical with empirical evidence. Furthermore, I will add on the literature by arguing that a simple model that includes durables as collateral, like the one presented in Calza, Monacelli, and Stracca (2013), is not able to overcome the co-movement problem, contrary to what reported in that paper. This reverts an important conclusion of that study, that increasing the loan to value ratio magnifies the impact of a monetary policy shock. I will finally show that for those results to hold it suffices to introduce wage stickiness in the model.

3.1 Introduction

In this paper I will focus on the behavior of DSGE models with durable goods. In particular, I will try to replicate some of the results that have been documented in the literature, and in doing so I will to revisit the debate triggered by Barsky, House, and Kimball (2007). In this AER paper, the authors showed that in the presence of durable goods, different combinations of relative price stickiness in the two sectors have strong effects on the final behavior of the model in response to a monetary policy shock. In particular, they stress how under flexible prices in the durable sector a co-movement problem, arises. Namely, after a monetary policy tightening the non-durable sector contracts while the durable sector expands. A consequence of this is that monetary policy becomes neutral in the short run. These results, which are at odds with empirical evidence, can be accounted for from a theoretical point of view, but they also underline the necessity to amend the baseline DSGE model with durable goods in order to reconcile theoretical and empirical results.

Different solutions have been proposed to this puzzle. In this work I replicate a simple DSGE model with durable goods and analyse some of them. In particular, I focus on the introduction of financial frictions, wage stickiness and adjustment costs of investment. These features are all of particular interest with respect to models featuring durable goods. This exploration led me to revisit some results that were taken for granted in the literature.

In particular, Monacelli (2009) argued that introducing financial frictions, in the form of a borrowing constraint, goes in the direction of solving the co-movement problem, despite the degree of flexibility in the durable sector. However, by using the same model, Sterk (2010) proves that the introduction of this particular source of friction actually makes it even more difficult to solve the co-movement problem. The reason for this is strictly related to the simplistic way the labor market is modeled and calls for the presence of further ingredients to reconcile theoretical and empirical evidence. As documented by Carlstrom and Fuerst (2010), three elements seem to make a good job in order to have DSGE models with durable goods replicate the empirical observations. Those elements are adjustment costs in housing

investment, to mitigate the strong effect of a monetary policy shock on investment, habit in consumption to replicate the hump shaped response of aggregate consumption, and wage stickiness. The latter feature is crucial to break down the co-movement problem.
In their analysis Carlstrom and Fuerst (2010) do not tackle the issue of financial frictions. This leaves open a question related to the importance of this source of credit impairment in a DSGE model. Kim and Oh (2014) try to answer this question by introducing wage stickiness in the set-up sketched by Monacelli (2009). They conclude that the presence of this further nominal rigidity suffices to argue that borrowing constraints magnify the effect of a monetary policy shock.

The introduction of durable goods in DSGE models most frequently goes hand in hand with the departure from perfect financial markets – well captured by the representative agent framework – and the move towards the analysis of economies characterized by frictions in the credit debit relationships between heterogeneous agents. This literature stretches back to Kiyotaki and Moore (1997), who pioneered an approach based on the introduction of durable goods used as collateral by borrowers in order to obtain loans from less impatient savers.
Thinking about durable goods and their use as collateral, means to a first approximation to think about the residential sector, given that housing is by far the most important durable good in national accounting. The importance of considering the housing sector in theoretical models is magnified on the one hand by the empirical consideration that this sector is very sensitive to interest rate movements, and on the other by the fact that housing accounts for a large share not only of GDP but also of households' wealth.[1] Furthermore, the recent financial crisis gave new impetus to an already lively literature. In light of those considerations, models with a stronger empirical flavour explicitly refer to housing rather than adopting the broader label of durable goods.

Aoki, Proudman, and Vlieghe (2004) propose a model along the lines of Bernanke, Gertler, and Gilchrist (1999) in which households

[1]Housing constitutes about 50% of households' wealth and housing wealth has been on average 1.5 the size of GDP in the period 1952 − 2008 (Iacoviello, 2010).

can lower the cost of credit by using their housing stock as collateral. They find that this form of financial friction increases the sensitivity of the economy to a monetary policy shock[2]. Iacoviello (2005) estimates a DSGE model with borrowers and savers and an housing sector. In this model entrepreneurs, as well as borrowers, can run up debt up to the value of their housing stock value. Debt is nominal and a change in asset prices following a shock has strong repercussions on the real economy. Using a similar model, Iacoviello and Neri (2010) analyse the spillovers from the housing sector to the US economy over a 40 years period, concluding that they are significant, especially on consumption. Evidence on the degree of price stickiness in the durable sector is mixed but it tends to indicate that prices are more flexible in the housing sector. Indeed, house prices are usually negotiated among the parties, therefore it is difficult to justify any degree of stickiness in this sector. As a result, most of the models that deal theoretically with the presence of housing consider flexible prices in the housing (durable) sector and sticky prices in the non durable one.
The second main feature considered in this paper is nominal wage stickiness, which is introduced in several DSGE models to account for the variation of macroeconomic variables in response to shocks. In particular, as highlighted by Christiano, Eichenbaum, and Evans (2005) wage stickiness might be even more important that price stickiness to replicate the observed persistence in output and sluggish response in inflation following a monetary policy shock.

The remainder of this paper is as follows, in the first section I present the results of a standard DSGE model with durable goods. Then, I compare those results with a standard model that includes financial frictions. In order to do so I follow closely Monacelli (2009), who presents a simple model with durable goods and financial frictions. In the following sections I discuss if the presence of financial frictions suffices to solve the co-movement problem. In doing so, I rely on the analysis provided by Sterk (2010). In the other sections I add wage stickiness, adjusting costs of investment in the durable sector and habits in consumption separately, in order to see if it is

[2] Their model does not feature borrowers and savers, in fact heterogeneity in households is given by the presence of rule of thumb consumers.

possible to reconcile models with durable goods with conventional wisdom and to gauge the importance of each single friction. In order to do so I follow the work by Carlstrom and Fuerst (2010), who add those features in a standard model with durable goods and Kim and Oh (2014) who consider wage stickiness in the framework proposed by Monacelli (2009). I then reconsider the difference between a model with financial frictions and the representative agent model in light of the presence of wage stickiness.
In the final section, I revisit the results of a paper that is strictly related to Monacelli (2009). Indeed, in a very influential paper, Calza, Monacelli, and Stracca (2013) provide empirical evidence of how institutional characteristics affect the response of the economy to a monetary policy shock. By institutional characteristics the authors mean some characteristics related to the mortgage contract and in particular the size of the loan to value (LTV) ratio and the duration of the mortgage contract. They consider more developed financial markets those where contractual rates are flexible and the LTV ratio is higher, and find that financial development goes hand in hand with stronger effects of monetary policy shocks to the economy. The authors also rationalize their empirical findings through a DSGE model which is in spirit very close to the one presented in Monacelli (2009). They show that an increase in the LTV ratio magnifies the response of monetary policy shock also in their theoretical set-up. However, I show that, on the contrary, increasing the size of the loan to value does not seem to magnify further the effect of a tightening in monetary policy in their very model. The reason has to be found in the co-movement problem and in the discussion laid out in the rest of this work. For their result to hold I finally show that one solution is the introduction of wage stickiness.

3.2 A DSGE Model with Durable Goods

In order to build a DGSE model with durable goods I follow Monacelli (2009), who presents a simple DSGE model that is well suited for our analysis, for it departs from the standard New-Keynesian model only for the presence of durable goods.

There is a continuum of households over the (0,1) interval divided in two distinct groups. The separation of households is driven by their impatience. A fraction ω of households are considered borrowers and have a discount factor β which is lower than the discount factor γ of the remaining fraction of households $(1-\omega)$.

Borrowers: The less patient agents in the model, maximize the following utility function over consumption of non-durable goods C_t, durable goods D_t and labor efforts N_t:

$$E_0 \sum_{t=0}^{\infty} \beta^t \left(log[(1-\alpha)(C_t)^{\frac{(\eta-1)}{\eta}} + \alpha D_t^{\frac{(\eta-1)}{\eta}}]^{\frac{\eta}{(\eta-1)}} - v \frac{N_t^{(1+\varphi)}}{(1+\varphi)} \right), \quad (3.1)$$

with $0 < \beta < 1$ and where α represents the share of durable goods in the utility function, φ is the inverse of the wage elasticity of labor supply, η the elasticity of substitution between durable and non-durable goods and v the weight of labor in the utility function.

Borrowers' budget constraint in real term is given by:

$$C_t + q_{h,t}(D_t - (1-\delta)D_{t-1}) + \frac{R_{t-1}b_{t-1}}{\pi_t} = b_t + w_t N_t + T_t \quad (3.2)$$

furthermore, the amount that they can borrow is tied to the expected value of their durable stock:

$$b_t = \frac{(1-\chi)(1-\delta)E_t\{D_t q_{t+1} \pi_{t+1}\}}{R_t} \quad (3.3)$$

In the equations above w_t is real wage, T_t are transfers, b_t is real debt, χ is the downpayment and therefore $(1-\chi)$ reads as the loan to value ratio, q_t is the relative price of durable goods π_t is inflation in the non durable sector and R_t the gross nominal rate.

First order conditions with respect to N_t, D_t and C_t reads:

$$\frac{-U_{n,t}}{U_{c,t}} = w_t \quad (3.4)$$

$$q_t U_{c,t} = U_{d,t} + \beta(1-\delta)E_t\{U_{c,t+1}q_{t+1}\} + (1-\chi)(1-\delta)U_{c,t}q_t\psi_t E_t\{\pi_{d,t+1}\} \quad (3.5)$$

$$R_t\psi_t = 1 - \beta E_t\Big\{\frac{U_{c,t+1}}{U_{c,t}}\frac{R_t}{\pi_{t+1}}\Big\} \tag{3.6}$$

where $U_{n,t}$, $U_{c,t}$ and $U_{d,t}$ are marginal utilities, while ψ is the ratio of the Lagrange multiplier of the borrowing to the budget constraint.

Savers: Patient households face a very similar problem, with the only difference given by the absence of a borrowing constraint. They maximize:

$$E_0\sum_{t=0}^{\infty}\gamma^t\left(log[(1-\alpha)(\tilde{C}_t)^{\frac{(\eta-1)}{\eta}} + \alpha\tilde{D}_t^{\frac{(\eta-1)}{\eta}}]^{\frac{\eta}{(\eta-1)}} - \tilde{v}\frac{\tilde{N}_t^{(1+\varphi)}}{(1+\varphi)}\right) \tag{3.7}$$

with $0 < \beta < 1$ subject to:

$$\tilde{C}_t + q_{h,t}(\tilde{D}_t - (1-\delta)\tilde{D}_{t-1} + \frac{R_{t-1}\tilde{b}_{t-1}}{\pi_t} = \tilde{b}_t + w_t\tilde{N}_t + \frac{\Pi_t}{(1-\omega)} \tag{3.8}$$

where Π_t are profits coming from monopolistically competitive firms, which are owned by savers. First order conditions are:

$$\frac{-\tilde{U}_{n,t}}{\tilde{U}_{c,t}} = w_t \tag{3.9}$$

$$q_t\tilde{U}_{c,t} = \tilde{U}_{d,t} + \beta(1-\delta)E_t\{\tilde{U}_{c,t+1}q_{t+1}\} \tag{3.10}$$

$$R_t = 1 - \beta E_t\Big\{\frac{\tilde{U}_{c,t+1}}{\tilde{U}_{c,t}}\frac{R_t}{\pi_{t+1}}\Big\} \tag{3.11}$$

While I assume a competitive frictionless labor market, and therefore the labor supply looks similar for both households groups, this is not true for the other two first order conditions. Consider the Euler equations first (3.6 and 3.11). The presence of ψ_t in the borrower's equation ensures that the consumption profile of borrowers is tilted towards the present. Namely, marginal utility of current consumption is higher than the expected marginal utility at time $t + 1$.

Therefore, if they could, borrowers would expand current consumption.[3] The other difference is in the first order condition with respect to D_t. Also in this case, borrower's equation features an additional term: $(1-\chi)(1-\delta)U_{c,t}q_t\psi_t E_t\{\pi_{d,t+1}\}$, which stems from the fact that durable goods do not only provide utility for their fruition but also from the fact that can be used as collateral. Interestingly, notice that the right-hand-side of equation 3.5 can be also read as the *shadow value of durables*.

Firms : the firms sector is composed by competitive goods producers and intermediate firms that enjoy a certain degree of monopolistic power. The level of market power is measured by the elasticity of substitution $(\varepsilon_i, \ \ i=(c,d))$ in the Dixit-Stiglitz aggregator, which is the technology used by final goods producers. The problem is standard and it is symmetric in both sectors. Intermediate goods producer face quadratic costs of adjusting prices following Rotemberg (1982). Optimality conditions in the two sectors boil down to the two following Phillip's Curves:

$$(1-\varepsilon_c)+\varepsilon_c mc_{c,t}=\vartheta_c(\pi_t-1)-\vartheta_c\Big[\frac{\tilde{\Lambda}_{t+1}}{\tilde{\Lambda}_t}\frac{Y_{c,t+1}}{Y_{c,t}}(\pi_{t+1}-1)\pi_{t+1}\Big] \tag{3.12}$$

$$(1-\varepsilon_d)+\varepsilon_d mc_{d,t}=\vartheta_d(\pi_t-1)-\vartheta_c\Big[\frac{\tilde{\Lambda}_{t+1}}{\tilde{\Lambda}_t}\frac{q_{t+1}}{q_t}\frac{Y_{d,t+1}}{Y_{d,t}}(\pi_{d,t+1}-1)\pi_{d,t+1}\Big] \tag{3.13}$$

where mc_i are real marginal costs in the two sectors, and given that labor is the only input of production (e.g. $Y_{i,t}=N_{i,t}$) they equal the real wage[4]. Λ_t is the stochastic discount factor of savers, given that they own firms, and ϑ_i is the price adjustment cost parameter. Notice that since the model is solved taking a log-linear approximation of the equilibrium conditions around the non-stochastic steady state the Calvo-Yun model and the Rotemberg model are equivalent.

[3]Notice that, differently from rule-of-thumb consumers (as in Gali, López-Salido, and Vallés (2007)), constrained borrowers are still rational-forward looking agents.

[4]More precisely, w_t in the non-durable sector and w_t/q_t in the durable one.

Equilibrium Conditions: Market clearings are given by the following equations:

$$Y_{c,t} = \omega C_t + (1-\omega)\tilde{C}_t + \frac{\vartheta_c}{2}(\pi - 1)^2 Y_{c,t} \tag{3.14}$$

$$Y_{d,t} = \omega(D_t - (1-\delta)D_{t-1}) + (1-\omega)(\tilde{D}_t - (1-\delta)\tilde{D}_{t-1}) + \frac{\vartheta_d}{2}(\pi - 1)^2 Y_{d,t} \tag{3.15}$$

$$Y_{c,t} + Y_{d,t} = \omega N_t + (1-\omega)\tilde{N}_t \tag{3.16}$$

$$\omega B_t = (1-\omega)\tilde{B}_t \tag{3.17}$$

where B_t is nominal debt.

Monetary Policy : The central bank follows a simple Taylor Rule of this form: $R/\bar{R} = (\pi/\bar{\pi})^{\phi_\pi} e_t$;, where e_t is a shock that evolves according to a simple AR(1) process.

3.2.1 Calibration

The model is parameterized following the baseline calibration in Monacelli (2009). Table 3.2.1 provides the value for the parameters used, which are all somewhat standard in this literature. The parameter α in the utility function is calibrated in order to have a share of durable goods of 20% over GDP in steady state, while v and $\tilde{v}$ are calibrated in order to have workers in steady-state working $1/3$ of their time.[5] Finally, parameters ϑ_c and ϑ_d are set in order to replicate different scenarios of price stickiness. Notice also that a value of $\eta = 1$ entails that consumption choices take the form of a Cobb-Douglas, and therefore the presence of the log operator in equation 3.1 ensures that housing and consumption are separable in the utility function.

[5] This means that the two parameters are different for borrowers and savers given the difference marginal utility in steady state. As noted by Monacelli (2009), this means that effective hours worked between the two agents will differ to make sure that they work for the chosen share of their total available time.

TABLE 3.1: *Calibrated Parameters - Chapter III model 1*

Param. name	**Value**	**Description**
φ	1	Inverse elasticity of labor supply
γ	0.99	Discount factor saver
β	0.98	Discount factor borrower
δ	0.01	Depreciation rate durables
ε_c	6	Elas. subst. between non-durables
ε_d	6	Elas. subst. between durables
χ	0.25	Down-payment
ϕ_π	1.5	Response to inflation in Taylor Rule
ρ_π	0.5	Shock persistence
ω	0.5	Share of borrowers
η	1	El. sub. between durables and non-durables

3.2.2 Simulations

In this section I analyse through numerical simulations what are the effects of a monetary policy shock in a standard DSGE model with durable goods. Namely, I consider the model sketched in the previous section without a borrowing constraint, which collapses to a simple representative agent model with durable goods. The shock analysed consists in an increase in the policy rate.[6]

[6] In order to better compare our results to Sterk (2010), I calibrated the standard deviation of the shock to 0.001.

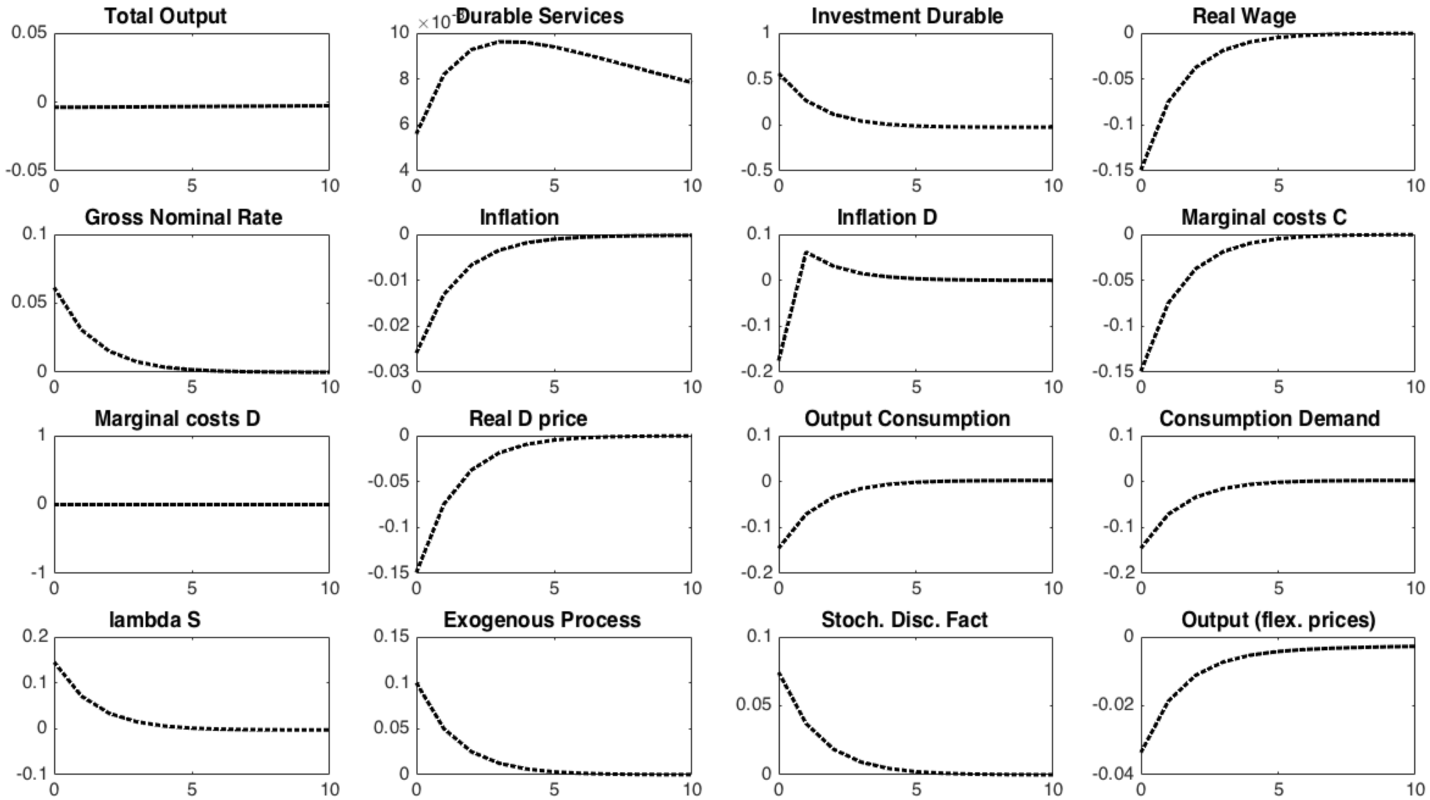

FIGURE 3.1: *Baseline calibration, response to a monetary policy tightening. Average frequency of price adjustment 1 year for the non durable sector. Durable goods prices are flexible.*

The empirical evidence[7] suggests that after a monetary policy tightening the short term interest rate increases and this brings about a reduction in overall output. At the same time both consumption of non durable and of durable goods decline, with investment in the durable sector experiencing the strongest decline. Figure 3.1 shows that when prices are flexible in the durable sector but sticky in the non durable one some anomalies emerge.[8]

First of all, both durable services and investment in durable goods move counter-ciclically and therefore co-move negatively with aggregate consumption. Second, total output is barely affected by the shock. This result is in line with what already highlighted by Barsky, House, and Kimball (2007). In fact, the authors showed that under some conditions if prices in the durable sector are flexible monetary policy is neutral in the short run.

In figure 3.2, I vary the degree of price stickiness in the durable sector. The average frequency of price adjustment in this sector is crucial in determining the response of the model to the shock. In particular, notice that the introduction of price stickiness in the durable sector makes the model behave as if all prices were sticky (another result documented in Barsky, House, and Kimball (2007)). Namely, the co-movement problem is solved and durable consumption as well as investment declines. Furthermore, notice that within the range of price stickiness analysed, only in the case in which durable prices are reset on average once every two quarters the policy rate increases on impact as we would expect.

[7]There are several studies documenting through VAR analysis the response of durable goods and consumption to monetary policy, see for example Bernanke and Gertler (1995).

[8]Note that in line with both the empirical and theoretical literature on durable goods and housing our measure of total output considers constant prices in the durable sector. I also provide the alternative measure with flexible prices (var. name Output (flex. prices)).

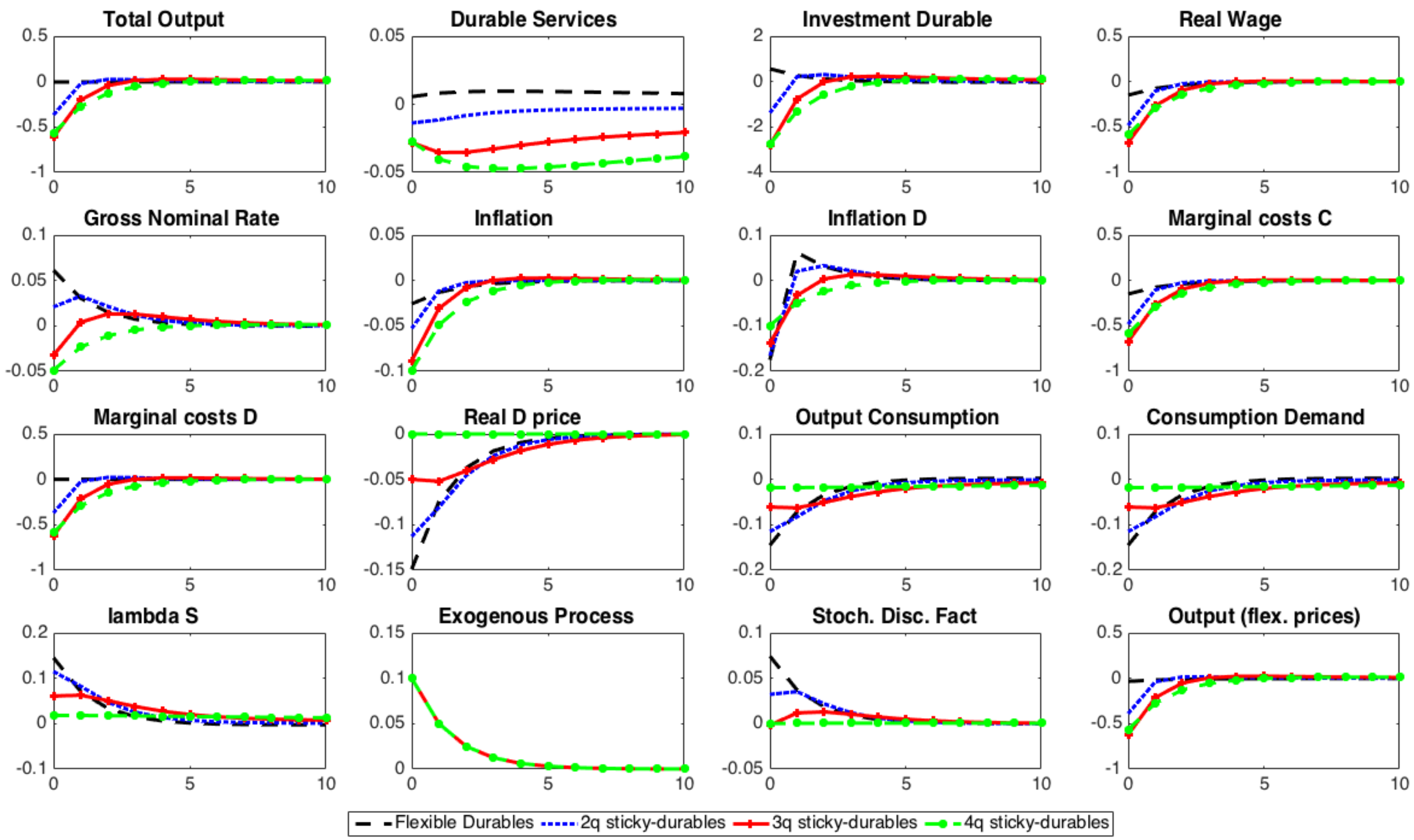

FIGURE 3.2: *Baseline calibration, response to a monetary policy tightening.*

Those preliminary simulations show that the representative agent model with durable goods and sticky prices is strongly reliant on the combination of price stickiness in the two sectors, hinting that some amendments to this set up are needed if we want to take the presence of durable goods seriously.

From an analytical point of view, the reason for the co-movement problem is given, as explained by Barsky, House, and Kimball (2007), by the quasi-constancy of the shadow value of durables. As already mentioned, the shadow value of durables is:

$$V_t = q_t \tilde{U}_{c,t} = \tilde{U}_{d,t} + \gamma(1-\delta)E_t\{\tilde{U}_{c,t+1}q_{t+1}\} \tag{3.18}$$

Iterating forward the right hand side of this equation, V_t can be rewritten as:

$$V_t = q_t \tilde{U}_{c,t} = E_t\{\sum_{j=0}^{\infty}[\beta(1-\delta)]^j \tilde{U}_{d,t+j}\} \tag{3.19}$$

The shadow value of durable goods is almost constant because temporary shocks have a small effect on the utility derived from durables, which is given by the stock of durables and not by its flow. Equation (3.19) entails therefore that if V_t is almost constant, any variation in the relative price of durables must be matched by an opposite variation in the marginal utility of consumption. Therefore, when prices are more sticky in the non-durable sector and q_t declines C_t must decrease (given that the marginal utility of consumption must increase), while at the same time households have an incentive to buy more housing given the drop in relative prices.
It is also interesting to notice what happens to the labor supply, which can be rewritten as:

$$-\tilde{U}_{n,t} = \frac{w_t}{q_t} q_t \tilde{U}_{c,t} \tag{3.20}$$

Consider the case with fully flexible durable prices. First, the real wage in units of durables does not move, second, as showed above, the shadow value of durables $q_t \tilde{U}_{c,t}$ is almost constant, and therefore total employment does not move and since labor is the only factor of production this feeds directly into total output.

3.2.3 The Model with Financial Frictions

In this section are reported the results of the full model, which nests the representative agent one. In this model, credit markets are not perfect since a fraction of households cannot consume as much as it would. Indeed, credit is bound to the value of the stock of durables in their possession. According to Monacelli (2009) the presence of financial frictions goes in the direction of making DSGE models with durable goods closer to empirical evidence on two grounds. First, constrained borrowers are more sensitive to a monetary policy shock.[9] Second, the model with financial frictions makes this class of models less dependent on the price stickiness assumption. While the former statement is correct, Sterk (2010) shows that the latter is not, and that the presence of credit frictions make it even more complicated for a model with durable goods to break the co-movement problem. The simulation presented in this paper confirm Sterk's findings.

Figure 3.3 shows how the model with financial frictions responds after a monetary policy shock when durable goods prices are flexible but sticky in the non durable sector[10].

[9] Monacelli (2009) shows analytically that this is due to the change in the user cost of borrowers.

[10] The figure mirrors the one in the previous section.

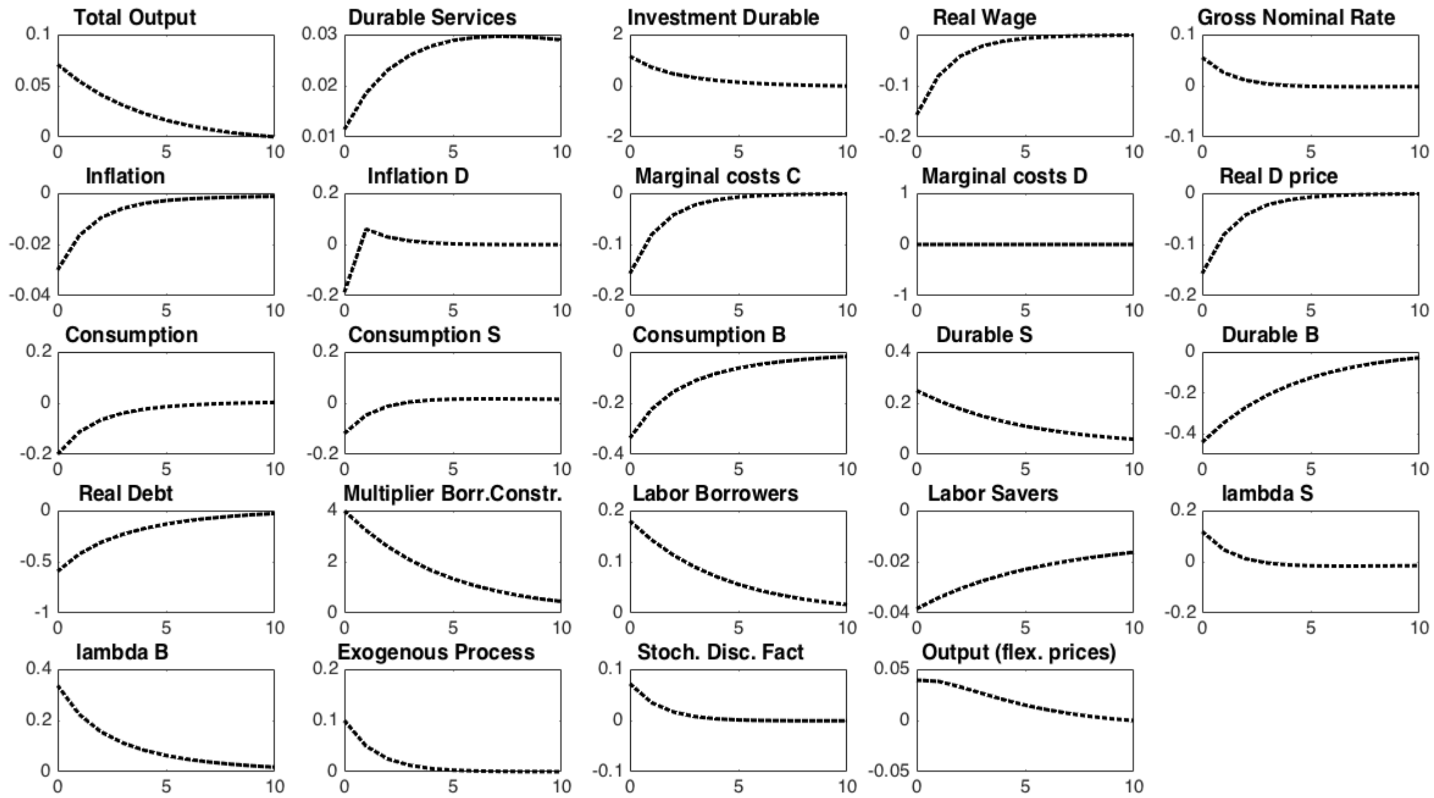

FIGURE 3.3: *Baseline calibration, response to a monetary policy tightening. Average frequency of price adjustment 1 year for the non durable sector. Durable goods prices are flexible. The plotted multiplier of the constraint is ψ, namely the ratio of the Lagrange multiplier of the borrowing to the budget constraint.*

It is very interesting to notice that the co-movement problem is broken down for borrowers for the same combination of price stickiness used in the representative agent model. The shock brings about a decline in the relative price of durables and this entails a tightening in borrowers' budget constraint since its value decreases. As a result, both consumption and durable services fall for borrowers. Durables fall by more on impact, because the user cost of durable goods increases, entailing a substitution effect. However, for the savers there is a positive income effect – which works in the opposite direction of that experienced by borrowers– but considering that savers are consumption smoother the increase in the real rate makes them willing to substitute consumption intertemporally. Given the reduction in the relative price of durables, savers increase their consumption of durable services. On aggregate the co-movement problem is not solved, e.g. aggregate investment and consumption of durable goods increase after a monetary policy shock. What is striking, is that financial frictions not only do not seem to solve the co-movement problem on aggregate, but they also bring about a slight increase in total output. As noted by Sterk (2010) a simple durable model with financial frictions makes it even more complicated to solve the co-movement problem. Figure 3.4, shows the impulse responses for different degrees of price stickiness.

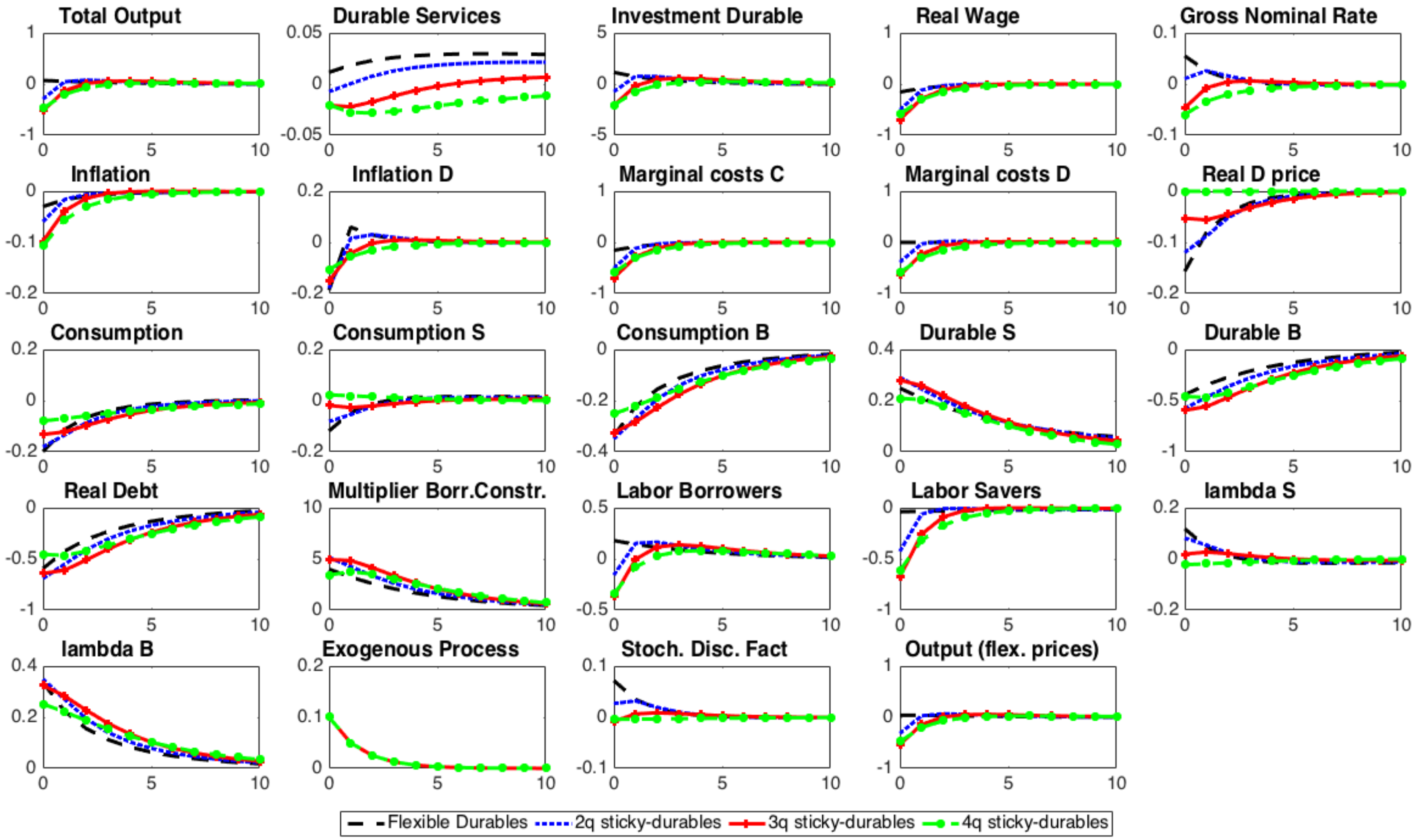

FIGURE 3.4: *Baseline calibration, response to a monetary policy tightening. Plotted multiplier of the constraint is ψ, the ratio of the Lagrange multiplier of the borrowing to the budget constraint.*

Differently from what argued by Monacelli (2009) the model seems to be still very dependent on the degree of price stickiness in the two sectors. In order to break down on aggregate the co-movement problem durable prices must be sticky. To say if the model with financial frictions scores better than the representative agent model we need to compare directly the IRFs of the two model. This is what I do in the next subsection.

3.2.4 Comparing The Two Models

According to Monacelli (2009), the presence of financial frictions in the form of a collateral constraint that binds borrowers helps the model being less dependent on the combination of price stickiness to deliver results that are consistent with the empirical literature featuring durable goods. In this section I investigate if this is true by comparing the IRFs of the two models more closely. I take the stance that in order for the model with financial frictions to be considered better than the representative agent model in accounting for the empirical facts, it should break down the co-movement problem for more combinations of price stickiness between the two sectors. I also investigate more in detail what is the effect of introducing financial frictions both on consumption and on durable investment, for the literature on the topic points at a magnification of monetary policy shocks given by the presence of financial frictions.

Figure 3.5 compares the model with financial frictions and the representative agent model for different combinations of price stickiness and it replicates Sterk (2010) findings. The first row shows the case for an average frequency of price adjustment in the non-durable sector of a year, while prices in the durable sector are flexible. Then, in each row the degree of price stickiness in the non-durable sector is kept constant while it increases in the durable one.

As it can be easily noticed, while aggregate consumption in the model with financial frictions declines more on impact in all cases, the decline of durable consumption and the stronger contraction in investment in the representative agent model compensate for this decline, bringing about a similar change in aggregate output in the two models. One striking difference is the case with full price flexibility in the durable sector. Indeed, it cannot be concluded that the model with financial frictions performs better than the representative agent on, for total output in the frictions model actually goes up. This contradicts Monacelli (2009)'s results by showing that financial frictions do not amplify the effects of a monetary policy shock and make it even more difficult to solve the co-movement problem. This point was first noticed by Sterk (2010), who observed that the reduction in borrowing by savers entitles them with more resources today, and this in turn tends to offset the decline in consumption by borrowers.

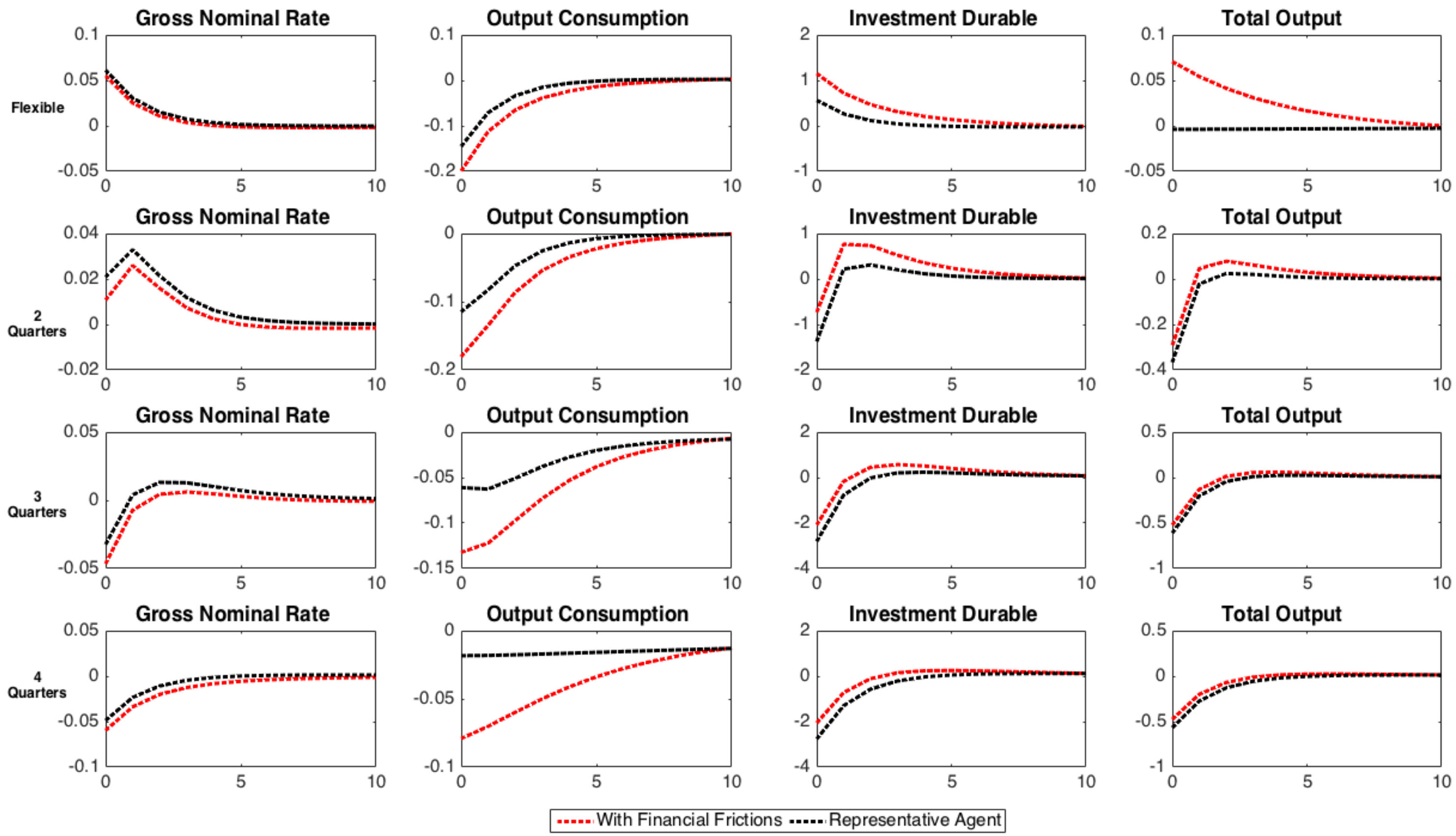

FIGURE 3.5: *Baseline calibration, response to a 25 basis points increase in the policy rate. Average frequency of price adjustment 1 year for the non durable sector, while price stickiness in the durable sector varies from the full flexible case to 1 year average frequency.*

Sterk (2010) provides an intuition on why the model with frictions fails in breaking down the co-movement problem. As already noticed, the shadow value of durable goods is not the same for borrowers and savers. In particular, the one for constrained agents reads as follows:

$$V_t = q_t U_{c,t} = \frac{U_{d,t} + \beta(1-\delta)E_t V_{t+1}}{1-(1-\chi)(1-\delta)\psi_t \pi_{d,t+1}} \tag{3.21}$$

Equation (3.21) is positively correlated to ψ_t, the shadow value of the borrowing constraint. According to Monacelli (2009) a tightening of the constraint, brings about an increase of V_t and therefore a substitution effect from durables to non-durables. [11] What is important in this analysis is that this smooths the tendency of households to buy durables when their relative price declines. However, the numerical simulations presented here showed that on aggregate output increases under flexible durable goods prices. To see the reason for this, consider the case of flexible durable prices and rewrite the total labor supply condition as:

$$N_t = \omega N_t + (1-\omega)\tilde{N}_t = \frac{w_t}{q_t}\left[\frac{\omega}{v}V_t + \frac{(1-\omega)}{\tilde{v}}\tilde{V}_t\right] \tag{3.22}$$

it has already been pointed out how, under flexible durable prices, the real wage in terms of durable goods is constant. Given that also $\tilde{V}_t$ is almost constant, the increase in V_t brings about an increase in total output.

This discussion suggests that more ingredients are needed in this simple model. Particularly, altering the conditions of perfect competition in the labor market seems to be key to amend the inconsistency of the model. The introduction of additional features is the aim of the next sections.

3.2.5 Adding Habit Persistence in Consumption

Carlstrom and Fuerst (2010) note that one of the ingredients that helps delivering plausible results in a DSGE model with durable

[11] In all our numerical simulations V_t always increase, irrespective of the degree of price stickiness considered in the durable sector. This holds true also when the nominal rate is negative and ψ_t declines instead of increasing.

goods is the introduction of habit persistence in consumption. In particular, this feature helps in rendering the hump in consumption observed in the data. The aim of this section is to lay-out the basis for a model able to break the co-movement problem even when durable good prices are flexible.

In order to introduce habit in consumption we need to consider the following modification to the maximization problem solved in the previous sections. The utility function now becomes:

$$E_0 \sum_{t=0}^{\infty} \beta^t \left(log[(1-\alpha)(C_t - hC_{t-1})^{\frac{(\eta-1)}{\eta}} + \alpha D_t^{\frac{(\eta-1)}{\eta}}]^{\frac{\eta}{(\eta-1)}} - v\frac{N_t^{(1+\varphi)}}{(1+\varphi)} \right), \tag{3.23}$$

with $0 < \beta < 1$ and where h is the parameter governing the degree of habits in consumption. Consequently, first order conditions read as follows[12]:

$$\frac{-U_{n,t}}{\lambda_t} = w_c \tag{3.24}$$

$$\lambda_t = U_{c,t} - h\beta E_t\{U_{c,t+1}\} \tag{3.25}$$

$$q_t\lambda_t = U_{d,t} + \beta(1-\delta)E_t\{\lambda_{t+1}q_{t+1}\} + (1-\chi)(1-\delta)\lambda_t q_t \psi_t E_t\{\pi_{d,t+1}\} \tag{3.26}$$

$$R_t\psi_t = 1 - \beta E_t\left\{\frac{\lambda_{t+1}}{\lambda_t}\frac{R_t}{\pi_{t+1}}\right\} \tag{3.27}$$

Figure 3.6 shows the IRFs for some selected variables to a change in the nominal policy rate for the model with financial frictions. As in previous cases, the figure shows an average frequency of price adjustment of one year for the non-durable sector, while prices are flexible in the durable sector. Two results are worth noticing beside the presence of a hump in total consumption. The first one is that the introduction of habits in consumption, as we would expect, does not solve the co-movement problem. The second one is that the stronger

[12] I only rewrite the first order conditions for the borrower. The change, of course, applies also for savers.

is the decline in consumption, the stronger is the positive response of durable investment, which suggests a substitution effects between the two forms of consumption.

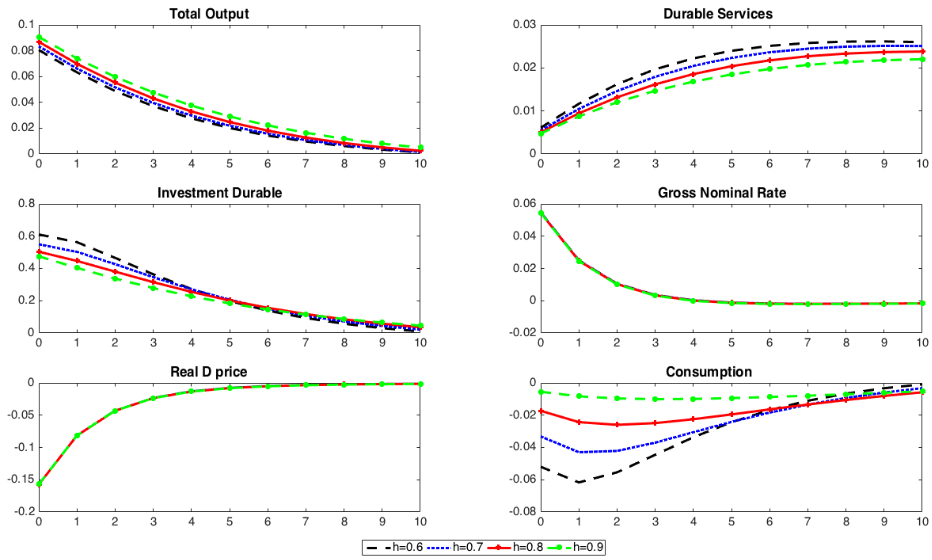

FIGURE 3.6: *Baseline calibration, model with financial frictions, response to a monetary policy tightening. Average frequency of price adjustment 1 year for the non durable sector, while prices are flexible in the durable sector.*

3.2.6 Adding Wage Stickiness

Adding wage stickiness in a model with durable goods fixes the co-movement problem. This has been noted by Erceg and Levin (2006) and by Carlstrom and Fuerst (2010) among the others. In this section it is shown the effect of introducing wage stickiness in a model with durable goods, with and without financial frictions.

Wage stickiness is introduced and modeled in a way similar to Kim and Oh (2014). The problem of the households in the presence of wage stickiness resembles also that for firms briefly outlined in the previous section. Households offer homogeneous labor services and rely on unions to set their wages as a mark-up over their marginal rate of substitution. Unions differentiate labor and set wages facing adjustment costs à la Rotemberg:

$$AC_{w,t} = \frac{\theta_w}{2}\left(\frac{W_t}{W_{t-1}} - 1\right)^2 w_t \tag{3.28}$$

where θ_w is the wage adjustment cost parameter[13] and the wage refers to a single household. Labor services are then reassembled by labor packers that offer labor to goods producers. I assume that there is a union for each households group and calibrate the two elasticity of substitution between labor types, ε_w and $\tilde{\varepsilon}_w$, in order to have a mark-up of 20% in steady state. Solving the unions problem we get the following first order conditions:

$$\begin{aligned}\vartheta_w(\pi_t^w - 1)\pi_w = \vartheta_w \beta E_t \frac{\lambda_{t+1}}{\lambda_t}\left[(\pi_{t+1}^w - 1)\pi_{t+1}^w \frac{w_{t+1}}{w_t}\right] \\ + (1-\varepsilon_w)N_t + \varepsilon_w MRS_t \frac{N_t}{w_t}\end{aligned} \tag{3.29}$$

$$\begin{aligned}\tilde{\vartheta}_w(\tilde{\pi}_t^w - 1)\tilde{\pi}_w = \tilde{\vartheta}_w \gamma E_t \frac{\tilde{\lambda}_{t+1}}{\tilde{\lambda}_t}\left[(\tilde{\pi}_{t+1}^w - 1)\tilde{\pi}_{t+1}^w \frac{\tilde{w}_{t+1}}{\tilde{w}_t}\right] \\ + (1-\tilde{\varepsilon}_w)\tilde{N}_t + \tilde{\varepsilon}_w M\tilde{R}S_t \frac{\tilde{N}_t}{\tilde{w}_t}\end{aligned} \tag{3.30}$$

Notice that I assume borrowers and savers to be identical but for their impatience, this also entails that they supply the same labor types to unions and earn the same wage: $w_t = \tilde{w}_t$, which implies that $\pi_t^w = \tilde{\pi}_t^w$. Notice also, that when $\vartheta_w = \tilde{\vartheta}_w = 0$, there are no adjustment costs in setting the wage and therefore the condition states that the wage is set as a positive mark-up over the marginal rate of substitutions of the two groups.

Several simulations considering different degrees of wage rigidities are considered. In the following figure, ϑ_w is set in order to obtain an average frequency of wage adjustment of half a year for both groups. In order to calibrate the two parameters I map ϑ_w and $\tilde{\vartheta}_w$ to get the same elasticity used in the Calvo model.[14]

[13]This specification of the problem implies that the adjustment cost parameter for borrowers and savers is going to be different if we want to have the same frequency of wage adjustment for the two households groups.

[14]In order to do so I compute ϑ_w as follows: $\vartheta_w = (\varepsilon_w - 1)\theta_w(1+\varepsilon\phi))/((1-\theta_w)(1-\beta\theta_w))$

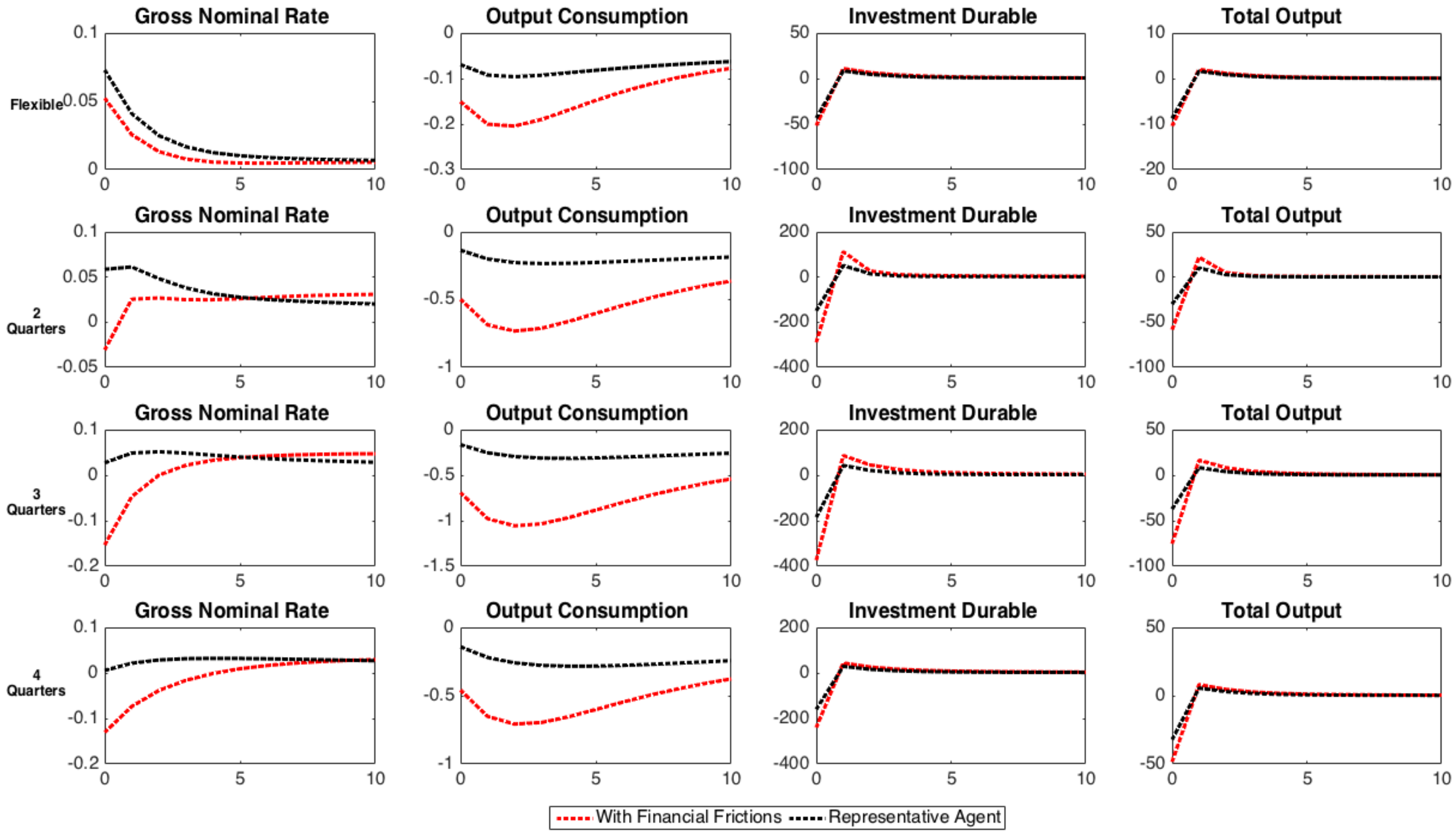

FIGURE 3.7: *Baseline calibration, response to a monetary policy tightening. Average frequency of price adjustment 1 year for the non durable sector, while price stickiness in the durable sector varies from the full flexible case to 1 year average frequency. Habit in consumption parameter is:* $h = 0.6$*. Wages are sticky on average for half a year.*

Interestingly, as already noted by Kim and Oh (2014), the introduction of wage stickiness seems to solve the co-movement problem for both specifications, irrespective of the combination of price stickiness in the two sectors. This holds true even if we consider a relatively small degree of stickiness in the wage adjustment problem.[15]

The presence of financial frictions now has a strong effect on total output, durable goods investment dynamics and aggregate consumption. Indeed, those variables reacts more strongly than in the representative agent model, for any combination of price rigidities considered. Therefore, financial frictions seem to play a role, but the presence of wage rigidity is crucial. From an intuitive point of view, the reason why durable investment collapses – bringing about an overall strong contraction in output – is given by the fact that the introduction of wage stickiness in the durable sector makes durable prices sticky even if they are flexible, for labor is the only factor of production for durables.

The introduction of wage stickiness seems not only to solve the co-movement problem, but also to restore the importance of financial frictions. However, an issues seem to emerge, that is the strong response in durable investment following a monetary policy shock. The reaction of investment is the object of the following section, and is a well known effect of wage stickiness, already highlighted among the others by Carlstrom and Fuerst (2010).

3.2.7 Adding Adjusting Costs of Durable Investment

As highlighted in the previous section, introducing wage rigidity makes durable goods investment very sensitive to changes in the policy rate. In order to overcome the problem, one solution is to consider adjustment costs in durable investment.

Carlstrom and Fuerst (2010) introduce this friction by operating a separation between the costs that firms face in adjusting the *level* of

[15] In sensitivity analysis different degrees of wage stickiness and non-durable price stickiness are also considered. This result is in line with what already noticed by Iacoviello and Neri (2010).

production and the costs firms face in *changing* the production level. Those are given by the following expressions:

$$\textit{Costs adjusting the level} = P_{h,t}\phi_1 \frac{Y_{h,ss}}{2}\left(\frac{Y_{h,t}-Y_{h,ss}}{Y_{h,ss}}\right)^2 \tag{3.31}$$

$$\textit{Costs changing the production level} = P_{h,t}\phi_2 \frac{Y_{h,ss}}{2}\left(\frac{Y_{h,t}-Y_{h,t-1}}{Y_{h,ss}}\right)^2 \tag{3.32}$$

where the parameter ϕ_1 and ϕ_2 refer respectively to the cost of changing the level of production, and to that of changing the production level. Calibrating those parameters corresponds to finding the short and long run elasticity of durable investment.[16] Several simulations using different values for those two parameters are performed. For this exercise I consider the full model with an average duration of price stickiness of one year for the non durable sector, the same average duration for wages, whereas durable goods prices are sticky. Erceg and Levin (2006) estimate that the response of durable investment following a 100 basis point change in the nominal interest rate on an annual base, is 10 times larger then that of consumption. Figure 3.8 presents the results considering the main combinations of long and short run elasticity proposed by Carlstrom and Fuerst (2010)[17]. In all cases presented, durable investment is now not as responsive as in the cases analysed in the previous section.

This section completes our exploration of the ingredients that can be added to DSGE models with durable goods in order to amend the co-movement problem and other documented implausible results. In line with Carlstrom and Fuerst (2010) and Kim and Oh (2014) I find that wage stickiness, and on a lower extent habit in consumption and adjusting costs of investment, are important ingredients for these models. The importance of those additional features however,

[16] See Appendix C for further details.

[17] Notice that the model presented here is different from the one proposed by Carlstrom and Fuerst (2010) and it considers the broad category of durables rather than housing, entailing further differences also in calibration.

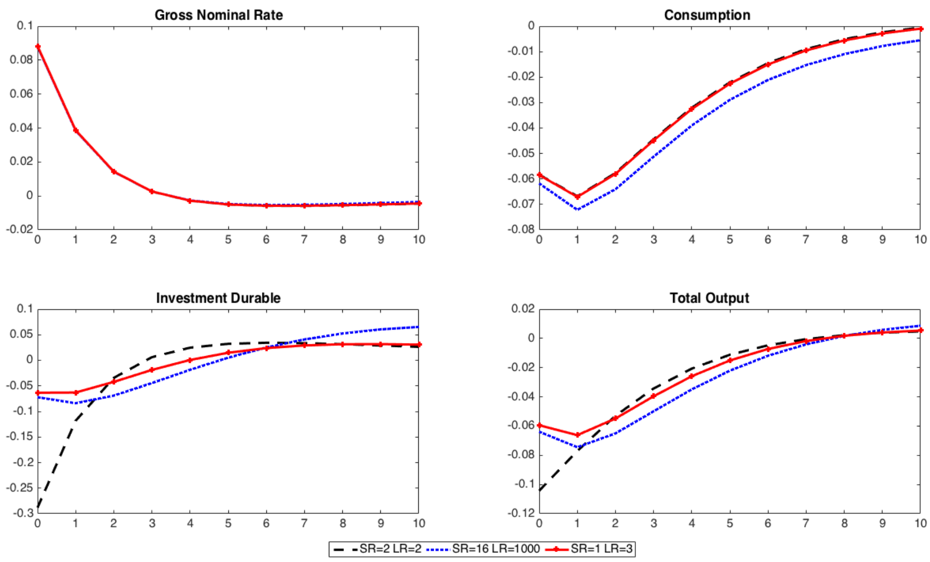

FIGURE 3.8: *Baseline calibration, response to a monetary policy tightening. Average frequency of price adjustment 1 year for the non durable sector, while prices are flexible in the durable sector. Wages are reset on average once a year and the habits in consumption parameter is* $h = 0.6$.

is not limited to the co-movement problem, but it is also instrumental for financial frictions in the form of collateral to play a role. In the next section I report the results obtained using a variation of the model proposed above and discuss another result related to the presence of financial frictions documented by the literature.

3.3 The Role of Financial Frictions

Calza, Monacelli, and Stracca (2013) documented both empirically and by resorting to a DSGE model similar in spirit to the one used in the previous sections, that economies characterized by higher loan to value ratios and by flexible mortgage contract rates[18] are more sensitive to a monetary policy shock. In order to complete the analysis undertaken with this work, the remainder of the paper is dedicated to the study of the effect of a monetary policy shock by resorting to the exact same model used in Calza, Monacelli, and Stracca (2013).

[18] As in many other models discussed here, they explicitly refer to housing and not to durable goods.

This model is a variation of the one laid out in Monacelli (2009). The difference is only given by the calibration, by the consideration of habit persistence in consumption, and by the the labor market, which is still perfectly competitive but more plausible, for it now allows for four different labor supplies and wages. The maximization problem of the borrower looks now as follows:

$$E_0 \sum_{t=0}^{\infty} \beta^t \left(log[(1-\alpha)(C_t - hC_{t-1})^{\frac{(\eta-1)}{\eta}} + \alpha D_t^{\frac{(\eta-1)}{\eta}}]^{\frac{\eta}{(\eta-1)}} - v\frac{N_{c,t}^{(1+\varphi)}}{(1+\varphi)} - v\frac{N_{d,t}^{(1+\varphi)}}{(1+\varphi)} \right), \tag{3.33}$$

$$with \quad 0 < \beta < 1$$

$$C_t + q_{h,t}(D_t - (1-\delta)D_{t-1}) + \frac{R_{t-1}b_{t-1}}{\pi_t} = b_t + w_{c,t}N_{c,t} + w_{d,t}N_{d,t} + T_t \tag{3.34}$$

and the only first order condition that changes with respect to the previous version of the model is, of course, the one related to labor[19]:

$$\frac{-U_{n,t}}{\lambda_{c,t}} = \frac{W_{i,t}}{P_{c,t}} \qquad \textit{for(i=c,d)} \tag{3.35}$$

Notice also that monetary policy is linear in the logs of inflation and the nominal interest rate:

$$\log\left(\frac{R_t}{\bar{R}}\right) = \phi_\pi \log\left(\frac{\pi_{i,t}}{\bar{\pi}}\right) + \xi_t \tag{3.36}$$

and the shock evolves according to:

$$\xi_t = \rho_\pi \xi_{t-1} + u_t \tag{3.37}$$

This specification of the policy rule allows to respond either to π_c, to π_d or to a linear combination of the two. In Calza, Monacelli, and Stracca (2013) as well as in the simulations presented here $\pi_{i,t} = \pi_{c,t}$.

[19]Same applies to savers.

TABLE 3.2: *Calibrated Parameters*

Param. Name	Value	Description
φ	1	Inverse elasticity of labor supply
γ	0.99	Discount factor saver
β	0.98	Discount factor borrower
δ	0.01/4	Depreciation rate durables
ε_c	7.5	Elas. subs. between non-durables
ε_d	7.5	Elas. subs. between durables
χ	0.4	Down-payment
ϕ_π	1.5	Response to inflation in the Taylor Rule
ρ_π	0.15	Shock persistence
ω	0.5	Share of borrowers
η	1	Elas. subs. durables and non-durables
α	0.16	Share of durables in the utility function
h	0.9	Habit parameter

In this section, the results for this model are presented by following the same calibration (see Table 3.3) used in Calza, Monacelli, and Stracca (2013) and focusing only on differences in institutional factors which relate to the loan to value ratio. Namely, different time structures in the mortgage contract are not taken into account.[20]

The results to a 25 basis points increase in the nominal policy rate are presented in figure C.1 and 3.9. In the calibration considered, the housing sector is characterized by price stickiness – one year average duration of price – while prices are flexible in the durable sector.[21] Beside simulating the model for the baseline calibration, the down-payment rate is allowed to vary from a baseline of 0.4 to 0.25 and to 0.15. This corresponds to an increase in the loan to value ratio, which is equal to 1 minus the down-payment, and therefore the second and third scenario can be interpreted as reproducing economies with more developed capital markets and therefore more leveraged

[20]I do not consider the possibility for fixed-rate type mortgage contracts for it is not instrumental to this analysis and its discussion is separated from the conclusions related to the change in the down-payment.

[21]This is the exact same combination of price stickiness analysed by Calza, Monacelli, and Stracca (2013).

borrowers. The original model, proposed by Calza, Monacelli, and Stracca (2013) gets to the following results. The presence of a collateral constraint makes borrowers more sensitive to a monetary policy shock, along the lines to what has been shown in previous sections. However, what is striking is that the authors not only show a decline in consumption, but also a drop in housing investment and therefore in total output. This results is at odds with the results presented here, for it can be obtained by simply considering habit in consumption and a different specification for labor. In fact, many studies[22] and this work so far, have shown that a simple model with durable goods and flexible prices in that sector is subject to the co-movement problem. Furthermore, this paper has also proven that, contrary to what stated in Monacelli (2009), the introduction of financial frictions in the form of a collateral constraint is not enough to overcome this problem, while Calza, Monacelli, and Stracca (2013) argue that habits in consumption and financial frictions are key to deliver their results.

A second important result documented by Calza, Monacelli, and Stracca (2013) empirically and validated by their model, is that increasing the loan to value ratio magnifies the decline in both consumption and housing investment, and therefor in total output. Figure 3.9 shows that this is actually not the case. Indeed, housing investment not only increases but it also increases more when the loan to value ratio is larger. This, in turn, has an effect on the relative price of housing and on total output, the former declining less as the loan to value gets larger, while the latter increasing more. Those results are not in line to what presented in Calza, Monacelli, and Stracca (2013) and revert the conclusion of the authors. However, several studies that resorted in richer models than the one presented in this section,[23] confirmed that financial frictions, in the form here presented make the economy more sensitive to a monetary policy shock. Therefore, this work does not argue against the use of financial frictions in DSGE models, but against the fact that the results obtained in Calza, Monacelli, and Stracca (2013) can be obtained with the model therein used.

[22]See also Iacoviello and Neri (2010) who confirm that wage rigidity (even just sectoral) is needed to make residential investment sensitive to monetary policy.

[23]See for example the already cited Iacoviello and Neri (2010) or Iacoviello (2005)

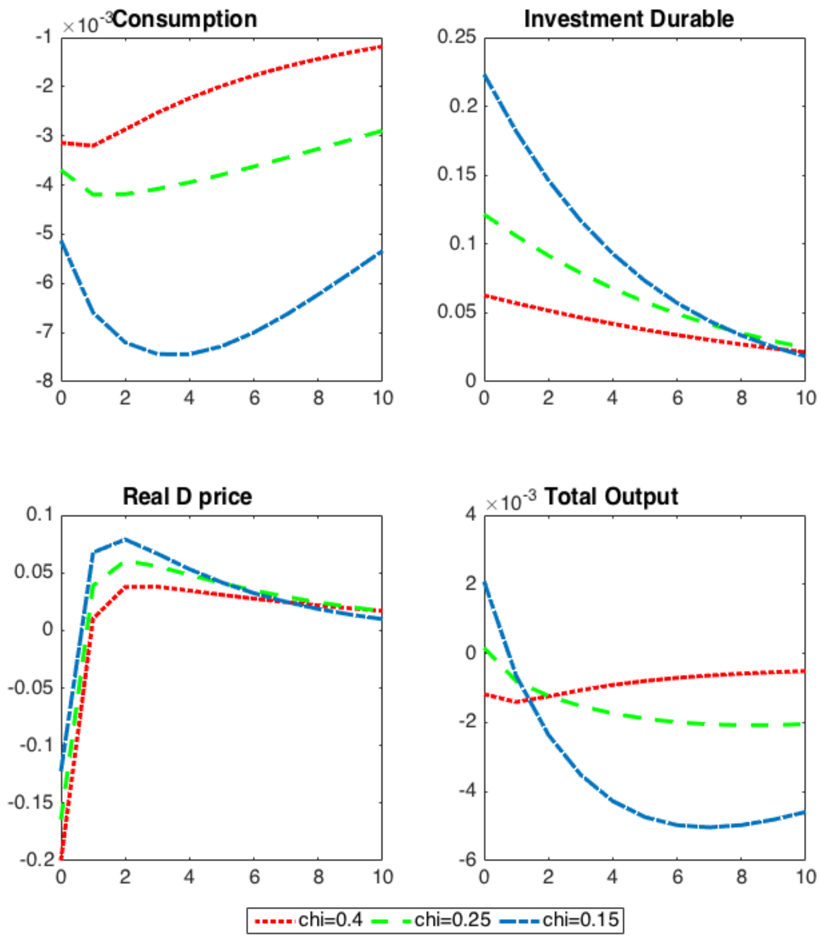

FIGURE 3.9: *Baseline calibration, response to a monetary policy tightening. Average frequency of price adjustment 1 year for the non durable sector, while prices are flexible in the durable sector.*

In order to account for the differences between the results hereby presented and what maintained in Calza, Monacelli, and Stracca (2013) I show what influences the behavior of residential investment in this model, following an argument similar to the one proposed in section 3.2.4.

Considering the specification of the production function, aggregate investment is given by:

$$N_{d,t}^{agg} = (1 - \omega)(\tilde{N}_{d,t}) + \omega N_{d,t} \tag{3.38}$$

The labor supply in the sector, respectively for borrowers and savers, can be expressed as:

$$\upsilon N_{d,t}^{\phi} = \frac{w_{d,t}}{q_t} q_t \lambda_t \tag{3.39}$$

$$\tilde{\upsilon} \tilde{N}_{d,t}^{\phi} = \frac{\tilde{w}_{d,t}}{q_t} q_t \tilde{\lambda}_t \tag{3.40}$$

In this model the shadow value of housing is given by $V_t = q_t \lambda_t$ and $\tilde{V}_t = q_t \tilde{\lambda}_t$, therefore equation (3.38) can be rewritten as:

$$N_{d,t}^{agg} = (1-\omega)\left(\frac{\tilde{w}_{d,t}}{q_t}\frac{\tilde{V}_t}{\tilde{\upsilon}}\right) + \omega\left(\frac{w_{d,t}}{q_t}\frac{V_t}{\upsilon}\right) \tag{3.41}$$

Given the assumption of perfectly competitive labor markets, $\frac{\tilde{w}_{d,t}}{q_t} = \frac{w_{d,t}}{q_t}$, therefore (3.42) simplifies to:

$$N_{d,t}^{agg} = \frac{w_{d,t}}{q_t}\left[\frac{(1-\omega)}{\tilde{\upsilon}}\tilde{V}_t + \frac{\omega}{\upsilon}V_t\right] \tag{3.42}$$

As also discussed in section 3.2.4, $\tilde{V}_t$, savers' shadow value of housing, is quasi-constant, while $\frac{w_{d,t}}{q_t}$ is constant since I am considering perfectly flexible prices in the durable sector. A consequence of this is that any increase in the shadow value of housing for borrowers V_t is mirrored by an increase in housing investment. Remember then, that the shadow value of borrowers differs from that of savers for the presence of this component: $1-(1-\chi)(1-\delta)\psi_t\pi_{d,t+1}$ at the denominator. A lower value of χ entails a higher loan to value ratio and therefore a stronger increase in V_t in response to a shock that tightens the borrowing constraint and therefore increases ψ. This explains the behavior of residential investment in figure 3.9.

It is interesting then to check whether the introduction of wage stickiness, as well as adjustment costs in housing investment, in this model is enough to restore the validity of the theoretical results in Calza, Monacelli, and Stracca (2013). To do so this section considers wage stickiness as presented in section 3.2.6 but as in Iacoviello and Neri (2010) I allow for the presence of four different unions, one for each group of household/sector. Figure 3.10 shows that the introduction of wage stickiness solves the co-movement problem, as we would expect. Under nominal wage rigidity housing investment declines while consumption and therefore total output, responds more strongly in the case in which the loan to value ratio is higher. Notice that even adding wage rigidities it is difficult to argue that housing investment are more sensitive to a monetary policy shock when the LTV ratio is higher.

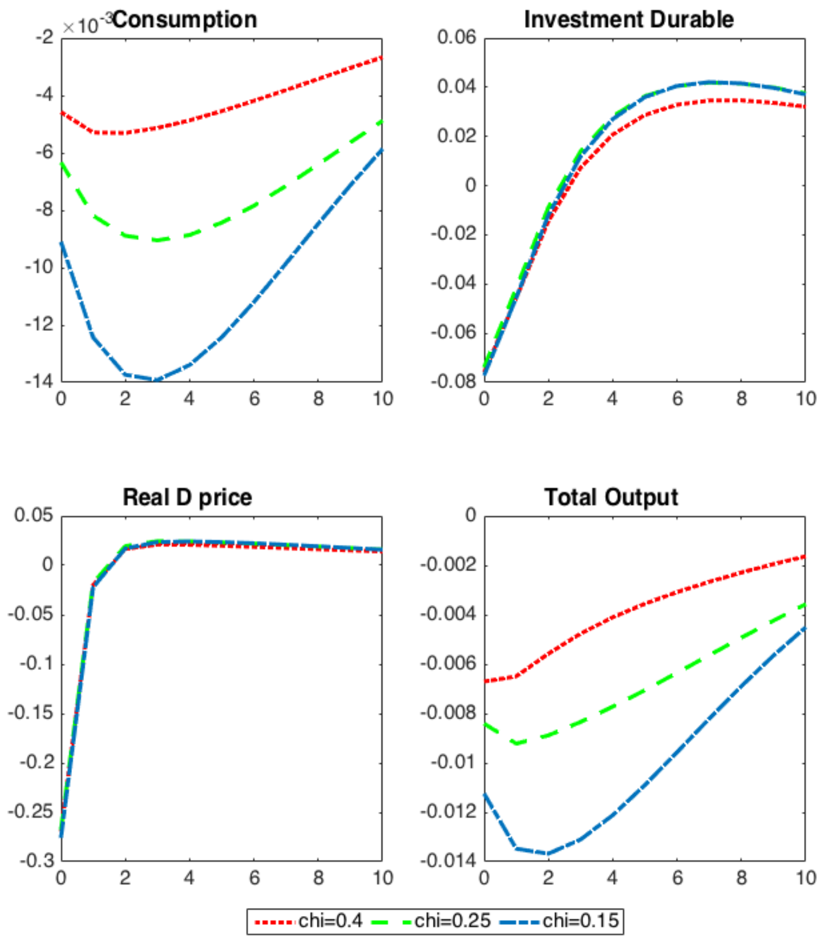

FIGURE 3.10: *Baseline calibration, response to a monetary policy tightening. Average frequency of price adjustment 1 year for the non durable sector, while prices are flexible in the durable sector. Average frequency of wage adjustment equal to 1 year in both housing and consumption. Adjustment costs of housing investment calibrated in order to have a short and long run elasticity:* $SR = 1$ *and* $LR = 3$.

3.4 Conclusion

This paper has briefly revisited the co-movement problem that arises in DSGE models with durable goods. In doing so, it focused on the role played by financial frictions in the form of a collateral constraint tied to the value of borrowers' stock of durable goods. Comparing the models with and without financial frictions in the versions presented in Monacelli (2009) and in Calza, Monacelli, and Stracca (2013), it is possible to conclude that the departure from the representative agent model does not seem to be a fruitful exercise if we do not consider additional features. Indeed, the presence of financial frictions in those set-ups makes it even more complicated to break down the co-movement between durable and non-durable consumption (at least when durable goods prices are flexible). Specifically, in some combinations of price stickiness considered, the presence of financial frictions goes in the opposite direction with respect to the one pointed out by most of the literature. Furthermore, it has been shown that increasing the loan to value ratio, and therefore the leverage of borrowers, is not detrimental for the economy when hit by a monetary policy shock. In the simple models presented above, financial frictions do not play the role highlighted by some literature of amplifying the effect of a monetary policy shock to the economy. Adding wage stickiness restores an active role for financial frictions and helps reconciling theoretical with empirical evidence. Those results have two main implications. The first one is that nominal wage stickiness seems to be more important than financial frictions, in the form hereby presented, in breaking the co-movement problem and bringing theoretical IRFs closer to what can be observed in the data. The second implication is that conditional to the presence of wage stickiness – or other features not explored here – financial frictions play an important role in business cycle analysis.

Appendix A

Appendix for Chapter I

A.0.1 The log-normal distribution

We assume that ω is log-normally distributed. Under the assumption that $\ln(\bar{\omega}) \sim (-\frac{1}{2}\sigma^2, \sigma^2)$, its expected value is: $E(\omega) = 1$.

We define $F(\bar{\omega})$ and $f(\bar{\omega})$ respectively as the cumulative distribution function and the probability density function of the log-normal variable $\bar{\omega}$. In particular, the economic meaning of $F(\bar{\omega})$ is that it represents the share of defaulters and therefore we can alternatively refer to it as the rate of default (RoD).

Instead of working with F and f, we work with Φ and ϕ, which are the cumulative distribution function and the probability density function of the standard normal. This is possible because the log-normal distribution can be related to the normal distribution by defining the following variable:

$$z = \frac{\ln(\bar{\omega}) + .5\sigma^2}{\sigma} \tag{A.1}$$

and therefore:

$$\begin{aligned} \Phi(z) &\equiv F(\bar{\omega}) \\ &\equiv \Phi\left(\frac{\ln \bar{\omega} - \mu}{\sigma}\right) \\ &\equiv \textit{Rate of default} \end{aligned} \tag{A.2}$$

Now, we can defined the variable $G(\omega)$ and $\Gamma(\omega)$ by making use of our definition in (A.1):

$$\begin{aligned} G(\bar{\omega}) &\equiv \int_0^{\bar{\omega}} \omega \;\; f(\omega) d\omega \\ &\equiv \Phi\left(\frac{\ln \bar{\omega} - \mu}{\sigma} - \sigma\right) \\ &\equiv \Phi\left(z - \sigma\right) \end{aligned} \tag{A.3}$$

$$\begin{aligned} \Gamma(\bar{\omega}) &\equiv \bar{\omega} \int_{\bar{\omega}}^{\infty} \;\; f(\omega) d\omega + G(\bar{\omega}) \\ &\equiv \bar{\omega}[1 - \Phi(z)] + G(\bar{\omega}) \end{aligned} \tag{A.4}$$

Now we are ready to compute the first derivative with respect to $\bar{\omega}$:

$$G'(\bar{\omega}) = \frac{\phi(z - \sigma)}{\sigma \bar{\omega}} \tag{A.5}$$

while the derivative of Γ is:

$$\Gamma'(\bar{\omega}) = 1 - \Phi(z) - \frac{\phi(z)}{\sigma \bar{\omega}} + \frac{\phi(z - \sigma)}{\sigma \bar{\omega}} \tag{A.6}$$

Finally, consider that as shown in Bernanke, Gertler, and Gilchrist (1999) the first and second derivative of the function:

$$\Gamma(\bar{\omega}) \equiv \bar{\omega} \int_{\bar{\omega}}^{\infty} \;\; f(\omega) d\omega^* + \int_0^{\bar{\omega}} \omega \;\; f(\omega) d\omega \tag{A.7}$$

are:

$$\Gamma'(\bar{\omega}) = 1 - F(\bar{\omega}) \tag{A.8}$$

and

$$\Gamma''(\bar{\omega}) = -f(\bar{\omega}) \tag{A.9}$$

Implying that the gross return of the lender is increasing at a decreasing rate in the threshold level. This implies a higher loan to value for a higher cutoff value and therefore a higher contractual rate r^k.

A.0.2 Robustness checks - further IRFs

In this section we present further results and robustness checks.
The monetary policy shock is affected by the calibration of the parameters in the Taylor Rule, while the response after the shock of the borrowers change with changes in the flexibility of the loan rates. While qualitatively we confirm the results presented in the main section, the following IRFs show that when the loan rate is flexible, the relative stronger decline in loans and in housing consumption by sub-primers becomes more evident.

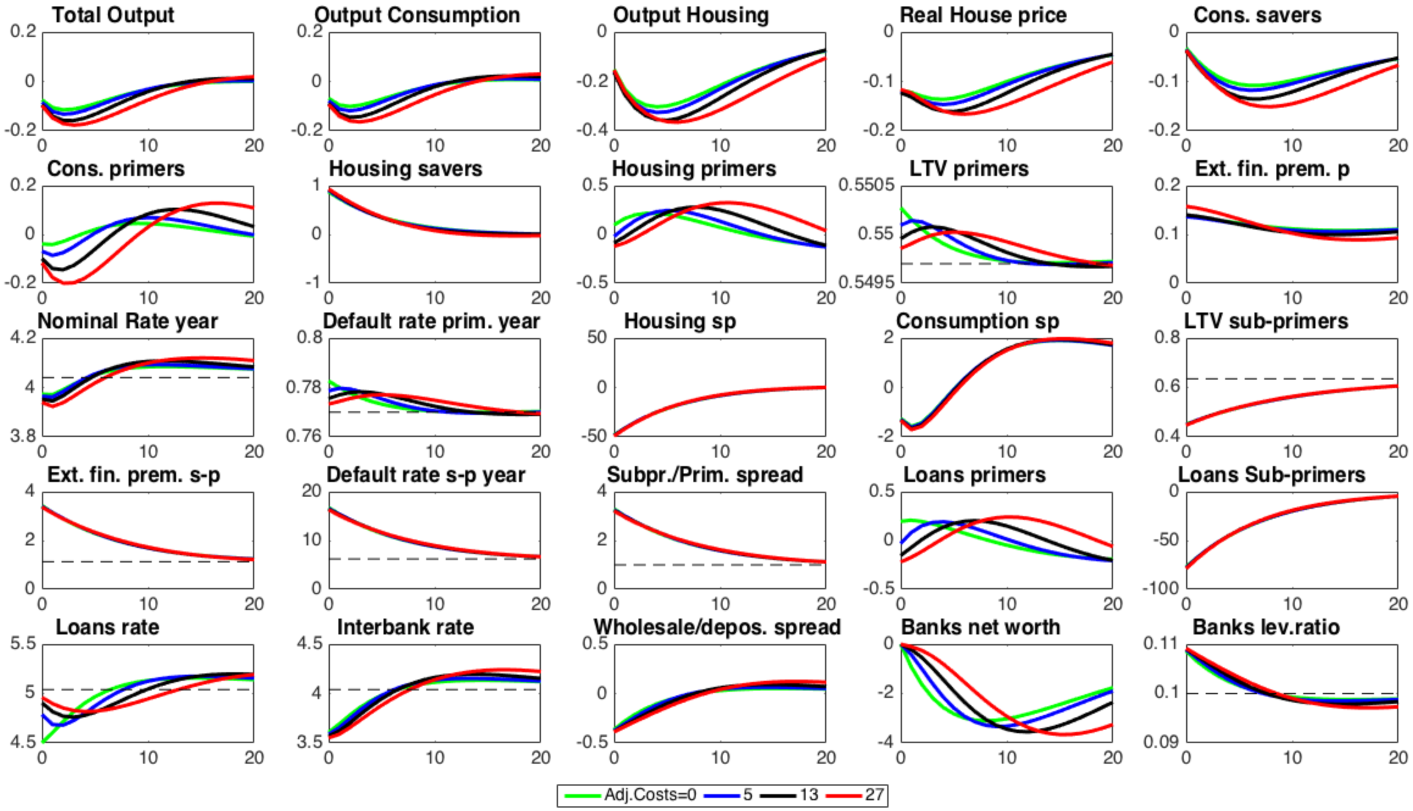

FIGURE A.1: *A shock to the standard deviation of sub-primers' idiosyncratic shock. All variable are expressed as a percentage deviation from steady state. Loan rates, rate of defaults, loan to values and banks' leverage are instead in levels.*

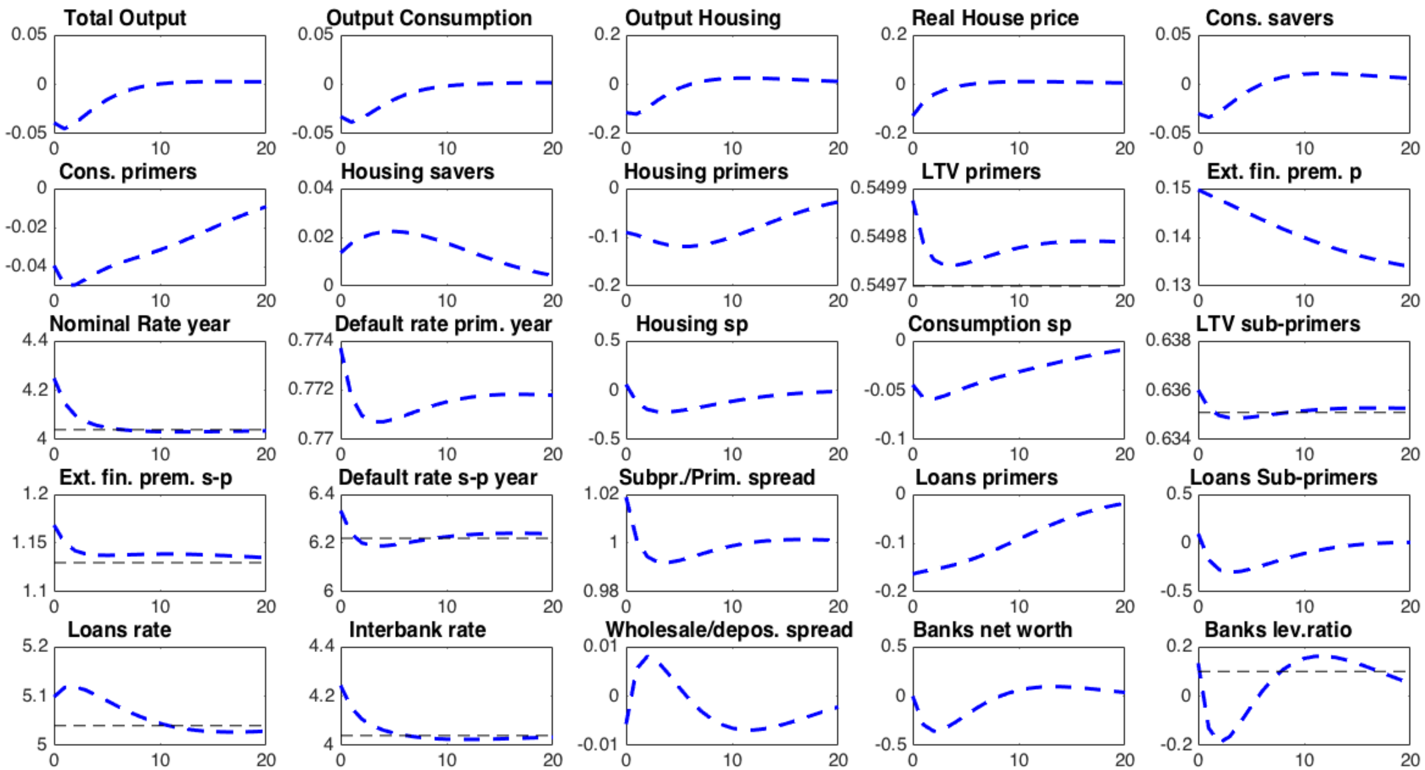

FIGURE A.2: *25 basis point increase in the policy rate. All variable are expressed as a percentage deviation from steady state. Loan rates, rate of defaults, loan to values and banks' leverage are instead in levels.*

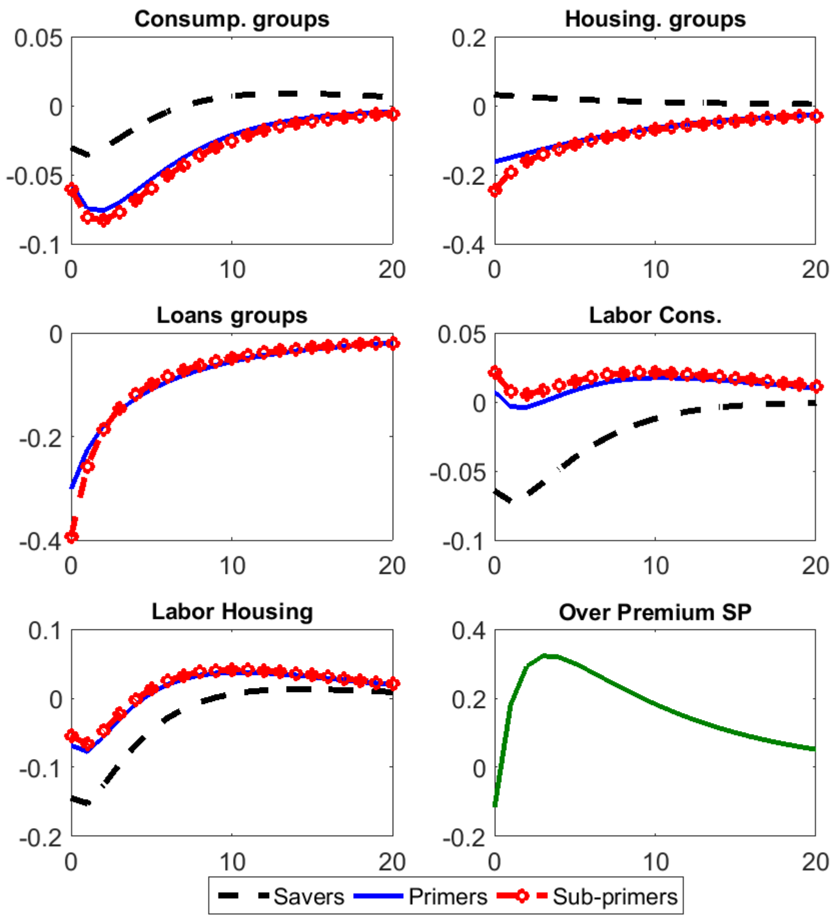

FIGURE A.3: ***Flexible loan rate*** *25 basis point increase in the policy rate. All variable are expressed as a percentage deviation from steady state. Loan rates, rate of defaults, loan to values and banks' leverage are instead in levels.*

A.0.3 Derivations

In the following sections we report some derivations and the maximization problem for savers and borrowers.

A.0.4 Savers

Savers' budget constraint in nominal terms is:

$$\begin{aligned} &\tilde{C}_t P_{c,t} + P_{h,t}[\tilde{H}_t - \tilde{H}_{t-1}(1-\delta)] + \tilde{D}_t \\ &= \tilde{D}_{t-1}(1 + r^f_{t-1}) + \sum_m \tilde{W}_{m,t}\tilde{N}_{m,t} + \Pi^{fi}_t \end{aligned} \tag{A.10}$$

The real budget constraint ((1.31)) is written as follows for we divide the nominal budget constraint by $P_{c,t}$. In particular, notice that real deposits are given by $d_{t-1} = D_{t-1}/P_{c,t-1}$ and the gross inflation rate at time t is $\pi_t = \frac{P_{c,t}}{P_{c,t-1}}$:

$$\tilde{C}_t + p_{h,t}[\tilde{H}_t - \tilde{H}_{t-1}(1-\delta)] + \tilde{d}_t = \frac{\tilde{d}_{t-1}(1 + r^d_{t-1})}{\pi_t} + \tilde{w}_t\tilde{N}_t + \Pi^{fi}_t \tag{A.11}$$

Consider a generic utility function, the agent derives utility from consumption and housing and disutility from hours worked in the two sectors $m = (c, h)$:

$$E_t\left[\sum_{t=0}^{\infty} \beta^t_s U(\tilde{C}_t, \tilde{H}_t, \tilde{N}_{c,t}, \tilde{N}_{h,t})\right] \tag{A.12}$$

Savers maximize utility subject to the budget constraint (1.31) The Lagrangian for the savers maximization problem is:

$$\begin{aligned} \mathcal{L} = U(\tilde{C}_t, \tilde{H}_t, \tilde{N}_{c,t}, \tilde{N}_{h,t}) - \tilde{\lambda}_t \Bigg(&\tilde{C}_t + p_{h,t}[\tilde{H}_t - \tilde{H}_{t-1}(1-\delta)] + \tilde{d}_t \\ &- \frac{\tilde{d}_{t-1}(1 + r^f_{t-1})}{\pi_t} - \sum_m \tilde{W}_{m,t}\tilde{N}_{m,t} - \Pi^{fi}_t \Bigg) \end{aligned} \tag{A.13}$$

The first order conditions of the problem are: with respect to C_t

$$\widetilde{MU}_{c,t} = \tilde{\lambda}_{c,t} \tag{A.14}$$

with respect to H_t

$$\tilde{\lambda}_{c,t} p_{h,t} = \widetilde{MU}_{h,t} + \beta(1-\delta)E_t[p_{h,t+1}\tilde{\lambda}_{t+1}] \tag{A.15}$$

Finally, the first order condition with respect to $\tilde{d}_t$ is given by:

$$\tilde{\lambda}_t = \beta_s(1 + r_t^f)E_t\left(\frac{\tilde{\lambda}_{t+1}}{\pi_{t+1}}\right) \tag{A.16}$$

Note: assuming that unions set the wage on behalf of savers implies that they do not maximize also with respect to the hours worked in the two sectors.

A.0.5 Borrowers Loan to Value

In this section we show how to derive borrowers loan to value. We refer to a sub-primer but nothing differs for the primer.

Plug:

$$\bar{\omega}_{t+1}^{s-p} H_t^{s-p} P_{h,t+1}(1-\delta) = L_t^{s-p}(1 + r_{t+1}^{k,s-p}) \tag{A.17}$$

into the participation constraint to get rid of r_t^k:

$$\begin{aligned}(1 + r_t^l)L_t^{s-p} = &\int_0^{\bar{\omega}_{t+1}^{s-p}} \omega_{t+1}^{s-p}(1-\mu)(1-\delta)P_{h,t+1}H_t^{s-p} f_{t+1}(\omega)\, d\omega \\ &+ \int_{\bar{\omega}_{t+1}^{s-p}}^{\infty} \bar{\omega}_{t+1}^{s-p} H_t^{s-p} P_{h,t+1}(1-\delta) f_{t+1}(\omega)\, d\omega\end{aligned} \tag{A.18}$$

from the definitions of $G_t(\bar{\omega}_{t+1}^{s-p})$ and $\Gamma_t(\bar{\omega}_{t+1}^{s-p})$ we know that:

$$\int_0^{\bar{\omega}_{t+1}^{s-p}} \omega_{t+1}^{s-p} f_t(\omega) = G_{t+1}(\bar{\omega}_{t+1}^{s-p}) \tag{A.19}$$

and that:

$$+\int_{\bar{\omega}_{t+1}^{s-p}}^{\infty} \bar{\omega}_{t+1}^{s-p} f_t(\omega)\, d\omega = \Gamma_{t+1}(\bar{\omega}_{t+1}^{s-p}) - G_t(\bar{\omega}_{t+1}^{s-p}) \tag{A.20}$$

we get that:

$$\begin{aligned}(1+r_t^l)L_t^{s-p} = G_{t+1}(\bar{\omega}_{t+1}^{s-p})(1-\delta)P_{h,t+1}H_t^{s-p} - \mu G_{t+1}(\bar{\omega}_{t+1}^{s-p})(1-\delta)P_{h,t+1}H_t^{s-p} \\ + \Gamma_{t+1}(\bar{\omega}_{t+1}^{s-p})H_t^{s-p}P_{h,t+1}(1-\delta) - G_{t+1}(\bar{\omega}_{t+1}^{s-p})H_t^{s-p}P_{h,t+1}(1-\delta)\end{aligned} \tag{A.21}$$

which eventually leads to:

$$(1 + r_t^l)L_t^{s-p} = [\Gamma_{t+1}(\bar{\omega}_{t+1}^{s-p}) - \mu G_{t+1}(\bar{\omega}_{t+1}^{s-p})](1-\delta)P_{h,t+1}H_t^{s-p} \tag{A.22}$$

A.0.6 Borrowers Budget Constraint

Also in this section we consider the problem of a sub-primer but the solution method can be extended also to primers. From the budget constraint with r^k to the one expressed with the predetermined interest rate r^l in the borrower's problem: In order to simplify the exposition we write the parts of the budget constraint which deserve a closer scrutiny, for the agency problem of borrowers has an impact on the,. The elements of the nominal budget constraint we are interested in are:

$$L_{t-1}(1+r_t^k)[1-F_t(\bar{\omega}_t)] = (1-\delta)[1-G_t(\bar{\omega}_t)]P_{h,t}H_{t-1} \quad \text{(A.23)}$$

In the following passages we show how we get from the nominal budget constraint to the final result:

$$L_{t-1}(1+r_{t-1}^f) = [1-\mu G(\bar{\omega}_t)](1-\delta)P_{h,t}H_{t-1}] \quad \text{(A.24)}$$

Note that in the budget constraint used in the computation the contractual rate r_t^k does not appear anymore, while we can define the problem in terms of the risk free loan rate: r_{t-1}^l.

Using equation (1.3) defined at time t and pluggin it into (A.23) we get:

$$\bar{\omega}_t H_{t-1}P_{h,t}(1-\delta) = L_{t-1}(1+r_t^k) \quad \text{(A.25)}$$

(A.23) then becomes:

$$\bar{\omega}_t H_{t-1}P_{h,t}(1-\delta)[1-F_t(\bar{\omega}_t)] = (1-\delta)[1-G_t(\bar{\omega}_t)]P_{h,t}H_{t-1} \quad \text{(A.26)}$$

which is

$$(1-\delta)P_{h,t}H_{t-1}[\bar{\omega}_t[1-F_t(\bar{\omega}_t)] + G_t(\bar{\omega}_t) - 1] = 0 \quad \text{(A.27)}$$

we know that:

$$\Gamma_t(\bar{\omega}_t) \equiv \bar{\omega}_t \int_{\bar{\omega}_t}^{\infty} f_t(\omega)d\omega + G_t(\bar{\omega}_t) \quad \text{(A.28)}$$

and that:

$$[1-F_t(\bar{\omega}_t)] \equiv \int_{\bar{\omega}_t}^{\infty} f_t(\omega)d\omega \quad \text{(A.29)}$$

therefore (A.27) becomes:

$$(1-\delta)P_{h,t}H_{t-1}[\Gamma_t(\bar{\omega}_t) - 1] = 0 \quad \text{(A.30)}$$

Now, we know that the loan to value can be rewritten in terms of Γ:

$$\Gamma_t(\bar{\omega}_t)P_{h,t}H_{t-1}(1-\delta) = (1+r^l_{t-1})L_{t-1} + \mu G_t(\bar{\omega}_t)(1-\delta)P_{h,t}H_{t-1} \quad \text{(A.31)}$$

and therefore we can substitute this into (A.30):

$$(1+r^l_{t-1})L_{t-1} + \mu G_t(\bar{\omega}_t)(1-\delta)P_{h,t}H_{t-1} - (1-\delta)P_{h,t}H_{t-1} = 0 \quad \text{(A.32)}$$

rearranging we get:

$$(1+r^l_{t-1})L_{t-1} = (1-\mu G_t(\bar{\omega}_t))[(1-\delta)P_{h,t}H_{t-1}] \quad \text{(A.33)}$$

which is exactly the way those elements enter into the budget constraint.

A.0.7 Borrowers maximization problem

This section shows how to derive the first order conditions for any given borrower $b = (\text{s}-\text{p}, p)$. To be more general we derive the problem by making explicit the presence of the stigma component, namely we show the maximization problem by making explicit the right hand side of the following equation: $\bar{\omega}^{b,p}_{t+1} = \bar{\omega}^p_{t+1} + stigma^b$:

Borrowers maximize utility:

$$E_t\left[\sum_{t=0}^{\infty} \beta_b^t U(C^b_t, H^b_t, N^b_{c,t}, N^b_{h,t})\right] \quad \text{(A.34)}$$

subject to the budget constraint and the participation constraint:

$$\begin{aligned} C^b_t + p_{h,t}H^b_t + l^b_{t-1}(1+r^l_{t-1}) = l^b_t + (1-\delta)[1-\mu G_t(\bar{\omega}^b_t)]p_{h,t}H^b_{t-1} \\ + \sum_m w^b_{m,t}N^b_{m,t} \end{aligned} \quad \text{(A.35)}$$

$$\begin{aligned} (1+r^f_t)l^b_t = [\Gamma_{t+1}(\bar{\omega}^b_{t+1}) - \mu G_{t+1}(\bar{\omega}^b_{t+1}) \\ + [1-F_{t+1}(\bar{\omega}^b_{t+1})](stigma^b)](1-\delta)p_{h,t+1}H^b_t\pi_{t+1} \end{aligned} \quad \text{(A.36)}$$

Now, consider that $\Gamma(\bar{\omega}^b)$ is given by:

$$\Gamma_t(\bar{\omega}^b_t) \equiv \bar{\omega}_t \int_{\bar{\omega}^b_t}^{\infty} f_t(\omega^b)d\omega^b + G_t(\bar{\omega}^b_t) \quad \text{(A.37)}$$

we can write down the Lagrangian for the problem[1]:

[1] We only report the part of the Lagrangian which is of interest for the maximization problem.

$$\mathcal{L} = U(C_t^b, H_t^b, N_{c,t}^b, N_{h,t}^b) - \lambda_t^b \left(C_t^b + p_{h,t}H_t^b + \frac{l_{t-1}^b}{\pi_t}(1 + r_{t-1}^f) \right. \tag{A.38}$$
$$\left. - l_t^b - (1-\delta)[1 - \mu G_t(\bar{\omega}_t^b)]p_{h,t}H_{t-1}^b - \sum_m w_{m,t}^b N_{m,t}^b \right)$$
$$- E_t\lambda_{t+1}^b \beta_b \left(C_{t+1}^b + p_{h,t+1}H_{t+1}^b + \frac{l_t^b}{\pi_{t+1}}(1 + r_t^f) - l_{t+1}^b \right.$$
$$\left. - (1-\delta)[1 - \mu G_{t+1}(\bar{\omega}_{t+1}^b)]p_{h,t+1}H_t^b - \sum_m w_{m,t+1}^b N_{m,t+1}^b \right)$$
$$- \gamma_{t+1}^b \Big([(1 + r_t^f)l_t^b$$
$$- [\Gamma_{t+1}(\bar{\omega}_{t+1}^b) - \mu G_{t+1}(\bar{\omega}_{t+1}^b) + [1 - F_{t+1}(\bar{\omega}_{t+1}^b)](\textit{stigma}^b)](1-\delta)p_{h,t+1}H_t^b\pi_{t+1} \Big)$$

The first order conditions with respect to C_t^b, H_t^b, l_t and $\bar{\omega}_{t+1}^b$ are:

$$MU_{c,t}^b - \lambda_t^b = 0 \tag{A.39}$$

$$\begin{aligned} MU_{h,t} = {} & \lambda_t^b p_{h,t} \\ & - (1-\delta)\beta_b E_t\{(1 - \mu G_{t+1}(\bar{\omega}_{t+1}^b))\lambda_{t+1}^b p_{h,t+1} + \gamma_{t+1}^b[\Gamma_{t+1}(\bar{\omega}_{t+1}^b) \\ & - \mu G_{t+1}(\bar{\omega}_{t+1}^b) + [1 - F_{t+1}](\bar{\omega}_{t+1}^b)(stigma^{\mathrm{b}})]p_{h,t+1}\pi_{t+1}\} \end{aligned} \tag{A.40}$$

$$\lambda_t^b - (1 + r_t^l)E_t\left[\frac{\lambda_{t+1}^b}{\pi_{t+1}}\beta_b + \gamma_{t+1}^b\right] = 0 \tag{A.41}$$

$$\begin{aligned} & -\lambda_{t+1}^b\beta_b(1-\delta)p_{h,t+1}H_t^b\mu G'_{t+1}(\bar{\omega}_{t+1}^b) \\ & + (1-\delta)p_{h,t+1}H_t^b\pi_{t+1}\gamma_{t+1}^b[\Gamma'_{t+1}(\bar{\omega}_{t+1}^b) \\ & - \mu G'_{t+1}(\bar{\omega}_{t+1}^b) - f_{t+1}(\bar{\omega}_{t+1}^b)(\textit{stigma}^b)] = 0 \end{aligned} \tag{A.42}$$

which, dividing by $(1-\delta)p_{h,t+1}H_t^b$ can be rewritten as:

$$\begin{aligned} & -\lambda_{t+1}^b\beta_b\mu G'_{t+1}(\bar{\omega}_{t+1}^b) + \gamma_{t+1}^b[\Gamma'_{t+1}(\bar{\omega}_{t+1}^b) \\ & - \mu G'_{t+1}(\bar{\omega}_{t+1}^b) - f_{t+1}(\bar{\omega}_{t+1}^b)(\textit{stigma}^b)]\pi_{t+1} = 0 \end{aligned} \tag{A.43}$$

Notice that in the .mod file the problem looks slightly different. Borrowers find the optimal threshold $\bar{\omega}$, that already takes into account the presence of the *stigma* component, therefore in the loan to value we do not consider the *stigma* again because it would duplicate its effect, for it is already included in the threshold identified by the borrowers. In a few words, one can consider the participation constraint for the borrowers as including the *stigma*, but the true loan to value ratio does not take the *stigma* into account, therefore the part related to it in equation (A.36) drops out.

A.0.8 Parametrization - Utility Functions

We follow the majority of the literature on DSGE with housing in considering the following utility function:

$$E_0 \sum_{t=0}^{\infty} \beta_{\imath}^{t} \left(\ln X_t - \zeta_{\iota} \sum_{m=c,h} \frac{N_{m,t}^{(1+\eta)}}{(1+\eta)} \right), \; with\, \imath = (b,s) \;\; 0 < \beta_{\imath} < 1 \tag{A.44}$$

where we consider X_t as an index of housing and non-durable goods:

$$X_t = \left[[(1-\alpha)(C_t - b_h C_{t-1})^{\frac{(\chi-1)}{\chi}} + \alpha H_t^{\frac{(\chi-1)}{\chi}}]^{\frac{\chi}{(\chi-1)}} \right] \tag{A.45}$$

The parameter η is the inverse of the Frisch elasticity of labor supply and ζ_{ι} a parameter measuring the weight of labor in the utility function.

The parameter α represents the share of housing in the consumption index and χ is the elasticity of substitution between consumption and housing, the parameter b_h allows us to introduce external habit in consumption and C_{t-1} represents aggregate consumption in period $t-1$. As $\chi \to 1$ the index takes the form of a Cobb-Douglas:

$$X_t = \left[[(C_t - b_h C_{t-1})^{(1-\alpha)} H_t^{\alpha} \right] \tag{A.46}$$

Given the presence of the logarithmic function, the utility function becomes separable in housing and consumption.

$$E_0 \sum_{t\,=0}^{\infty} \beta_{\varsigma}^{t} \left((1-\alpha)\ln(C_t - b_h C_{t-1}) + \alpha \ln H_t - \zeta \sum_{m=c,h} \frac{N_{m,t}^{(1+\eta)}}{(1+\eta)} \right), \tag{A.47}$$

Considering (A.47) the marginal utility of consumption is given by:

$$MU_{c,t} = \frac{(1-\alpha)}{(C_t - b_h C_{t-1})} \tag{A.48}$$

$$MU_{h,t} = \frac{\alpha}{H_t} \tag{A.49}$$

Appendix B

Appendix for Chapter II

B.0.1 Robustness Checks

In this section I show how the model dynamics change when I allow changes in the parameter measuring the response of monetary authorities to inflation, γ_π, and the sensitivity of taxes to public expenditure ϕ_g. Figure B.1 clearly shows how the multiplier is affected by the stance of monetary policy. Indeed, the lower is the reaction of the policy rate to an increase in inflation the higher is the level of the multiplier. Another parameter that influences the magnitudes quite strongly is the sensitivity of taxes to public expenditure ϕ_g. The quantitative results of the model are affected by how strongly the shock is deficit financed (figure B.2).

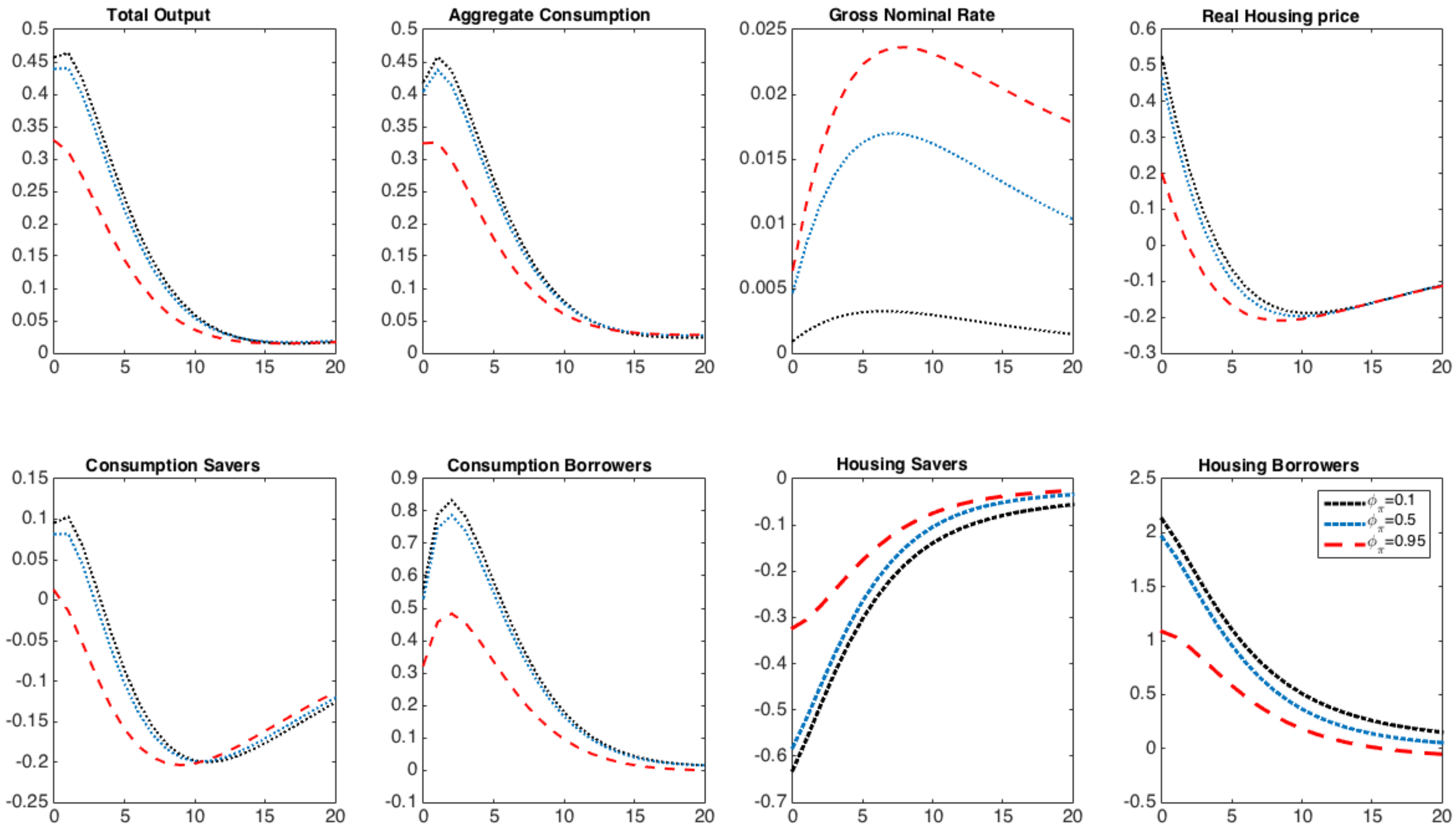

FIGURE B.1: *Response to a 1% increase in government expenditure*

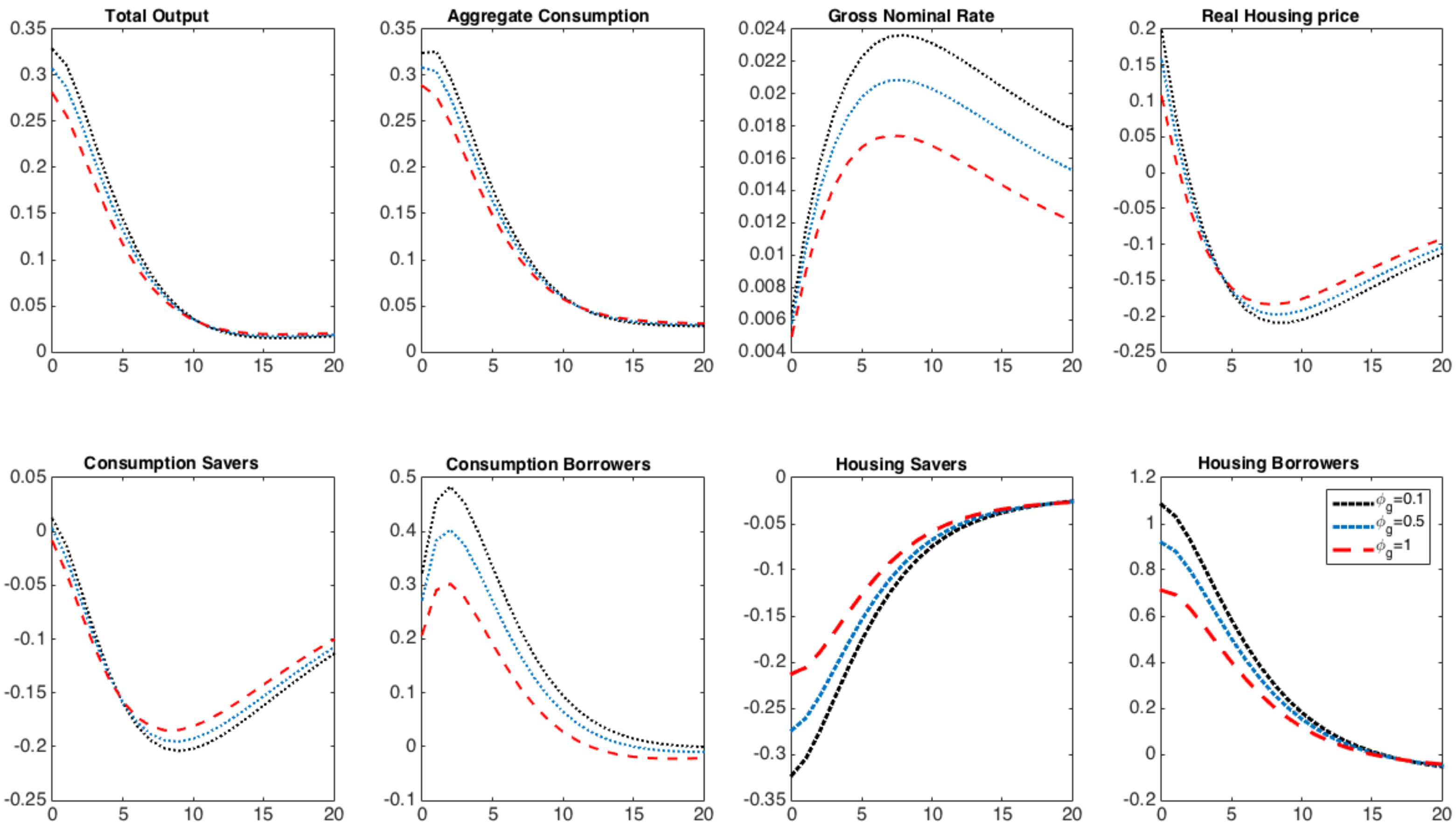

FIGURE B.2: *Response to a 1% increase in government expenditure*

B.0.2 Wage Rigidities

I model wage rigidities in a way that is similar to the canonical way price rigidities are introduced on the firms side. In particular, wage rigidities is due to unions' monopolistic power and to adjustment costs à la Rotemberg:

$$AC_{w,t} = \frac{\theta_w}{2}\left(\frac{W_t}{W_{t-1}} - 1\right)^2 w_t \tag{B.1}$$

the modellization is similar to the one used in Iacoviello and Neri (2010), but the use of Rotemberg costs of adjustment makes it closer to Kim and Oh (2014).

All households groups offer homogeneous labor services to unions that differentiate labor and set their wages as a mark-up over their marginal rate of substitution. Labor services are then reassembled by labor packers that offer labor to goods producers. Solving the unions problem we get the following four conditions, two for each households'group:

$$\begin{aligned}\frac{\tilde{w}_{c,t}}{\tilde{w}_{c,t-1}}\,\tilde{\theta}_{wc}\left(\frac{\tilde{w}_{c,t}}{\tilde{w}_{c,t-1}} - 1\right) &= \theta_{wc}\,\frac{\gamma\,\tilde{\lambda}_{t+1}}{\tilde{\lambda}_t}\,\frac{\tilde{w}_{c,t+1}}{\tilde{w}_{c,t}}\,\frac{\tilde{w}_{c,t+1}}{\tilde{w}_{c,t}}\left(\frac{\tilde{w}_{c,t+1}}{\tilde{w}_{c,t}} - 1\right) \\ &+ (1-\varepsilon_{wc})\,\tilde{N}_{c,t} \\ &+ \tilde{N}_{c,t}\,\frac{\varepsilon_{wc}}{\tilde{w}_{c,t}}\,\frac{\tilde{v}\,\tilde{N}_{c,t}^{\tilde{\phi}}\left(\tilde{N}_{c,t}^{(1+\tilde{\phi})} + \tilde{N}_{d,t}^{(1+\tilde{\phi})}\right)^{\frac{\tilde{\xi}-\tilde{\phi}}{1+\tilde{\phi}}}}{\tilde{\lambda}_t\,\left(1-\tau_t^l\right)}\end{aligned} \tag{B.2}$$

$$\begin{aligned}\frac{\tilde{w}_{d,t}}{\tilde{w}_{d,t-1}}\,\tilde{\theta}_{wc}\left(\frac{\tilde{w}_{d,t}}{\tilde{w}_{d,t-1}} - 1\right) &= \theta_{wc}\,\frac{\gamma\,\tilde{\lambda}_{t+1}}{\tilde{\lambda}_t}\,\frac{\tilde{w}_{d,t+1}}{\tilde{w}_{d,t}}\,\frac{\tilde{w}_{d,t+1}}{\tilde{w}_{d,t}}\left(\frac{\tilde{w}_{d,t+1}}{\tilde{w}_{d,t}} - 1\right) \\ &+ (1-\varepsilon_{wd})\,\tilde{N}_{d,t} \\ &+ \tilde{N}_{d,t}\,\frac{\varepsilon_{wd}}{\tilde{w}_{d,t}}\,\frac{\left(\tilde{N}_{c,t}^{(1+\tilde{\phi})} + \tilde{N}_{d,t}^{(1+\tilde{\phi})}\right)^{\frac{\tilde{\xi}-\tilde{\phi}}{1+\tilde{\phi}}}\,\tilde{v}\,\tilde{N}_{d,t}^{\tilde{\phi}}}{\tilde{\lambda}_t\,\left(1-\tau_t^l\right)}\end{aligned} \tag{B.3}$$

$$\frac{w_{c,t}}{w_{c,t-1}}\,\theta_{wd}\,\left(\frac{w_{c,t}}{w_{c,t-1}}-1\right)=\theta_{wd}\,\frac{\beta\,\lambda_{t+1}}{\lambda_t}\,\frac{w_{c,t+1}}{w_{c,t}}\,\frac{w_{c,t+1}}{w_{c,t}}\,\left(\frac{w_{c,t+1}}{w_{c,t}}-1\right) + (1-\varepsilon_{wc})\,N_{c,t} + N_{c,t}\,\frac{\varepsilon_{wc}}{w_{c,t}}\,\frac{\upsilon\,N_{c,t}^{\phi}\,\left(N_{c,t}^{(1+\phi)}+N_{d,t}^{(1+\phi)}\right)^{\frac{\xi-\phi}{1+\phi}}}{\left(1-\tau_t^l\right)\,\lambda_t} \tag{B.4}$$

$$\frac{w_{d,t}}{w_{d,t-1}}\,\theta_{wd}\,\left(\frac{w_{d,t}}{w_{d,t-1}}-1\right)=\theta_{wd}\,\frac{\beta\,\lambda_{t+1}}{\lambda_t}\,\frac{w_{d,t+1}}{w_{d,t}}\,\frac{w_{d,t+1}}{w_{d,t}}\,\left(\frac{w_{d,t+1}}{w_{d,t}}-1\right) + (1-\varepsilon_{wd})\,N_{d,t} + N_{d,t}\,\frac{\varepsilon_{wd}}{w_{d,t}}\,\frac{\left(N_{c,t}^{(1+\phi)}+N_{d,t}^{(1+\phi)}\right)^{\frac{\xi-\phi}{1+\phi}}\,\upsilon\,N_{d,t}^{\phi}}{\left(1-\tau_t^l\right)\,\lambda_t} \tag{B.5}$$

The parameters θ_{wc}, θ_{wd}, $\tilde{\theta}_{wc}$ and $\tilde{\theta}_{wd}$ are set in order to obtain an average frequency of wage adjustment of half a year for both groups. This specification of the problem implies that the adjustment cost parameter for borrowers and savers is going to be different if we want to have the same frequency of wage adjustment for the two households groups because households are characterized by different discount factors. This modellization of the labor sector makes our work easier for it entails that households work the same amount of hours in steady states and earn the same real wage.

B.0.3 First order conditions and other definitions

The optimization problem of firms results also in the following first order conditions:

$$mc_t^c=\frac{\tilde{w}_t^c\,\tilde{N}_t^c}{Y_t^c\,(1-\mu_c)} \tag{B.6}$$

$$mc_t^c=\frac{w_t^c\,N_t^c}{Y_t^c\,(1-\mu_c)} \tag{B.7}$$

$$mc_t^d=\frac{\frac{\tilde{N}_t^d\,\tilde{w}_t^d}{Y_t^d\,(1-\mu_h)}}{q_t} \tag{B.8}$$

$$mc_t^d=\frac{\frac{N_t^d\,w_t^d}{Y_t^d\,(1-\mu_h)}}{q_t} \tag{B.9}$$

$$mc_t^c = \frac{K_{t-1}\, R_t^k}{Y_t^c\, \mu_c} \tag{B.10}$$

$$mc_t^d = \frac{\frac{K_{t-1}^d\, R^k d_t}{Y_t^d\, \mu_h}}{q_t} \tag{B.11}$$

$$\frac{q_t}{q_{t-1}} = \frac{\pi_t^d}{\pi_t^c} \tag{B.12}$$

The adjustment cost of capital is given by:

$$\phi_t = \frac{\phi_{kc}}{2}\left(\frac{K_t}{K_{t-1}} - 1\right)^2 K_{t-1} \frac{\phi_{kd}}{2}\left(\frac{K_{d,t}}{K_{d,t-1}} - 1\right)^2 K_{d,t-1} \tag{B.13}$$

B.0.4 Additional IRFs

Figures B.3 and B.4 replicate the IRFs in figure 1 and 2 and 5 by using the same fiscal rule as in Fernández-Villaverde (2010).

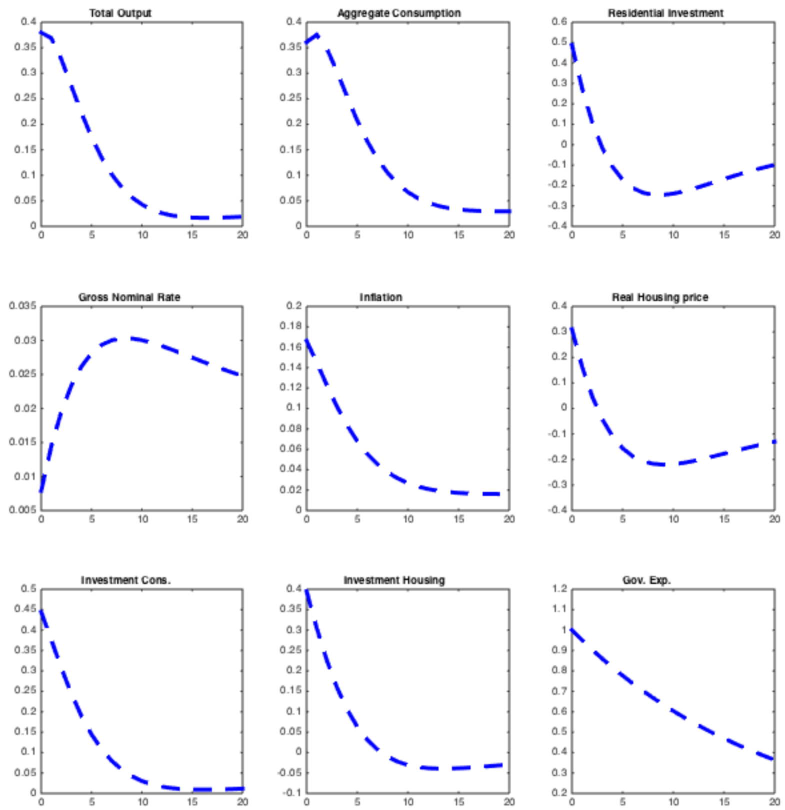

FIGURE B.3: *Response to a* 1% *increase in government expenditure.*

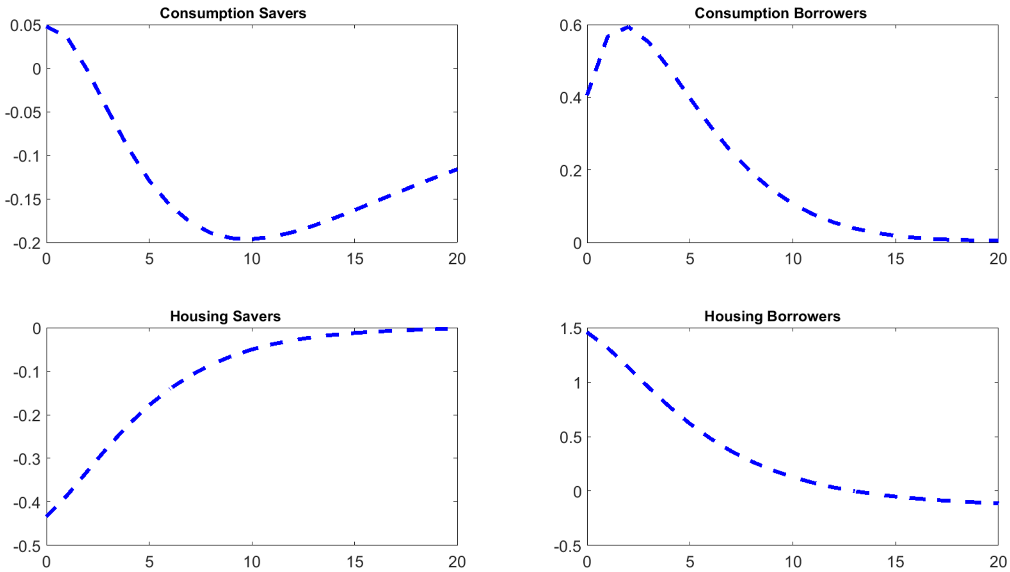

FIGURE B.4: *Response to a 1% increase in government expenditure.*

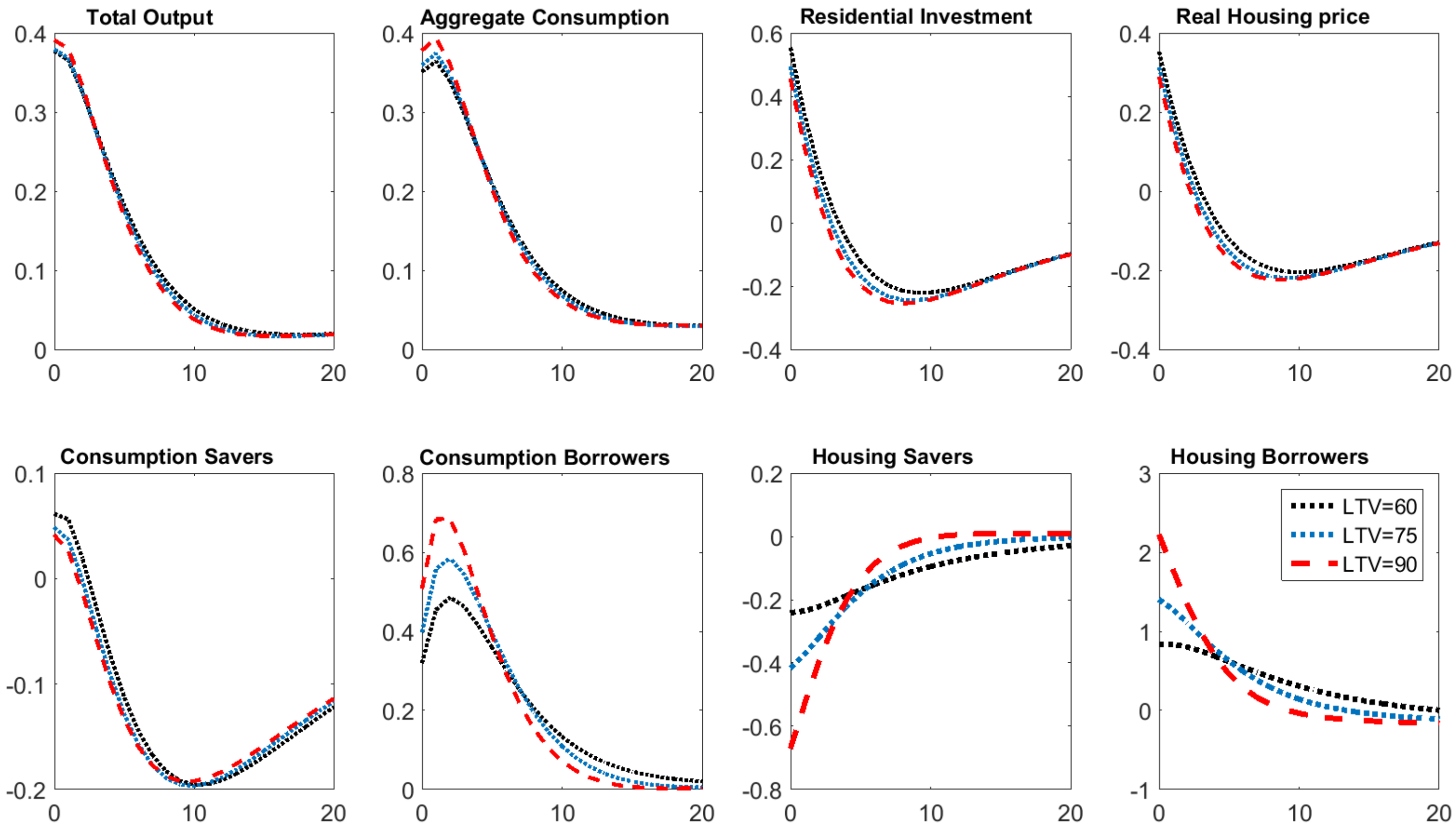

FIGURE B.5: *Response to a 1% increase in government expenditure for different LTV ratios, the fiscal rule used in this figure is the one used in Fernández-Villaverde (2010).*

The following figures show the IRFs for a reduction in the consumption tax, in the tax on bonds, and in the tax on housing.

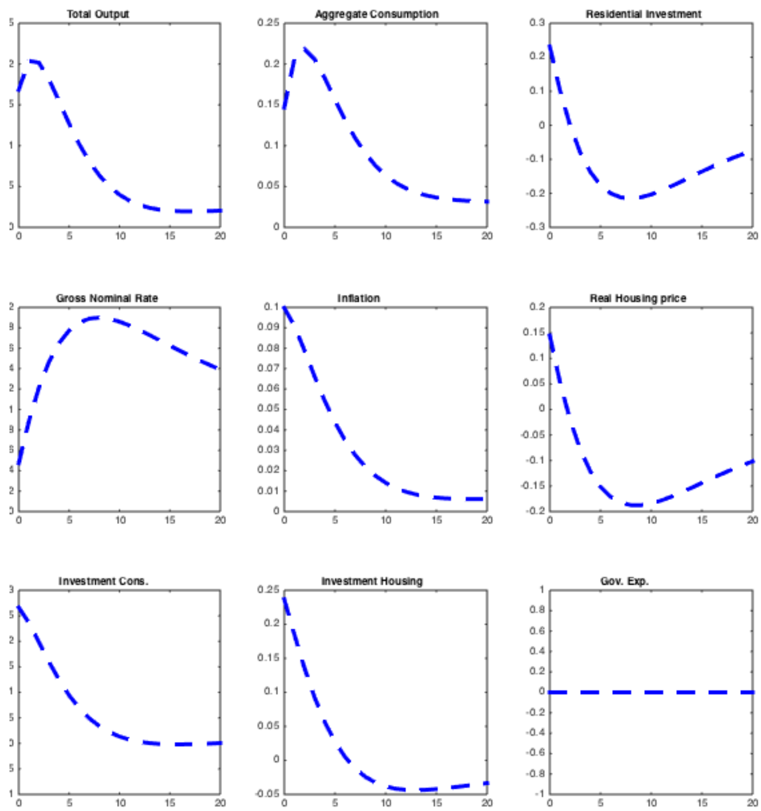

FIGURE B.6: *Response to a 1% decrease in the consumption tax.*

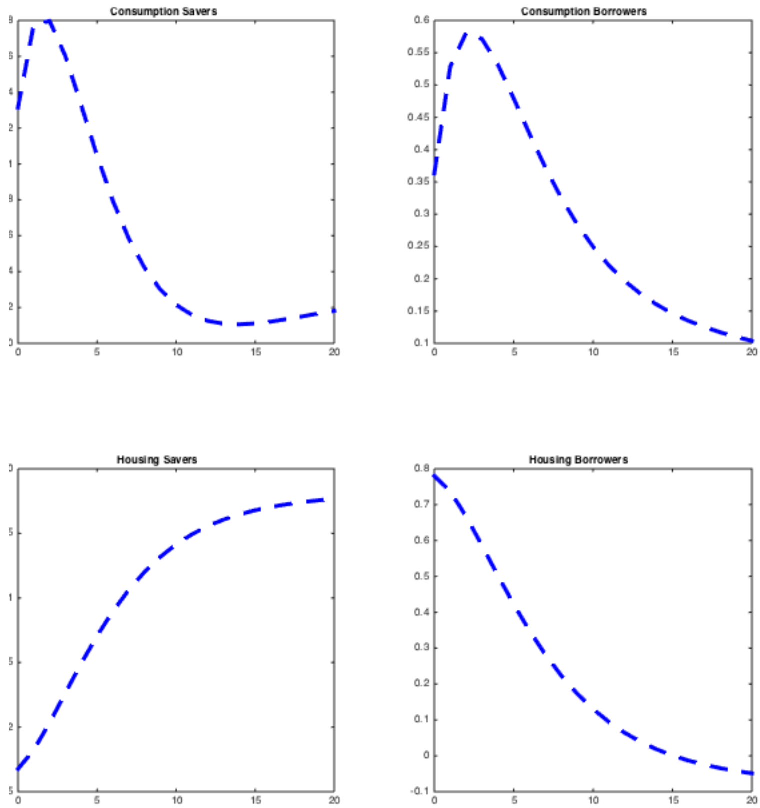

FIGURE B.7: *Response to a* 1% *decrease in the consumption tax.*

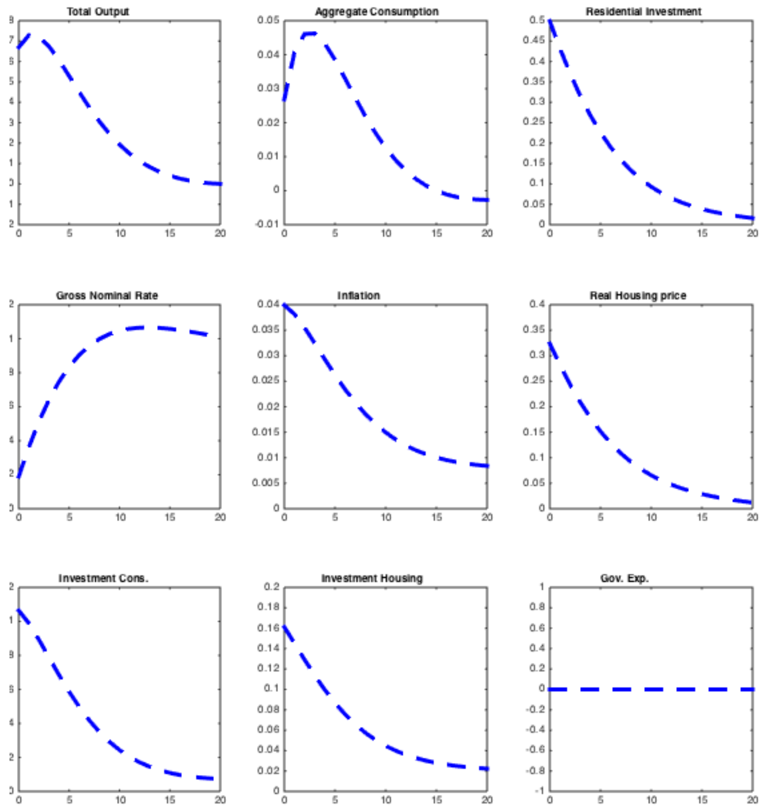

FIGURE B.8: *Response to a* 1% *decrease in the bond tax.*

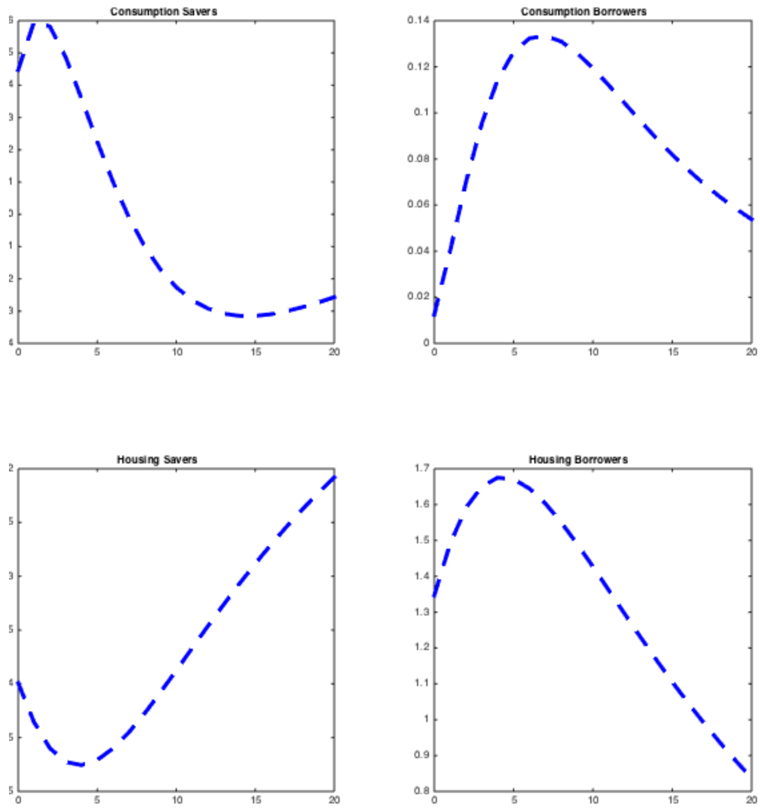

FIGURE B.9: *Response to a 1% decrease in the bond tax.*

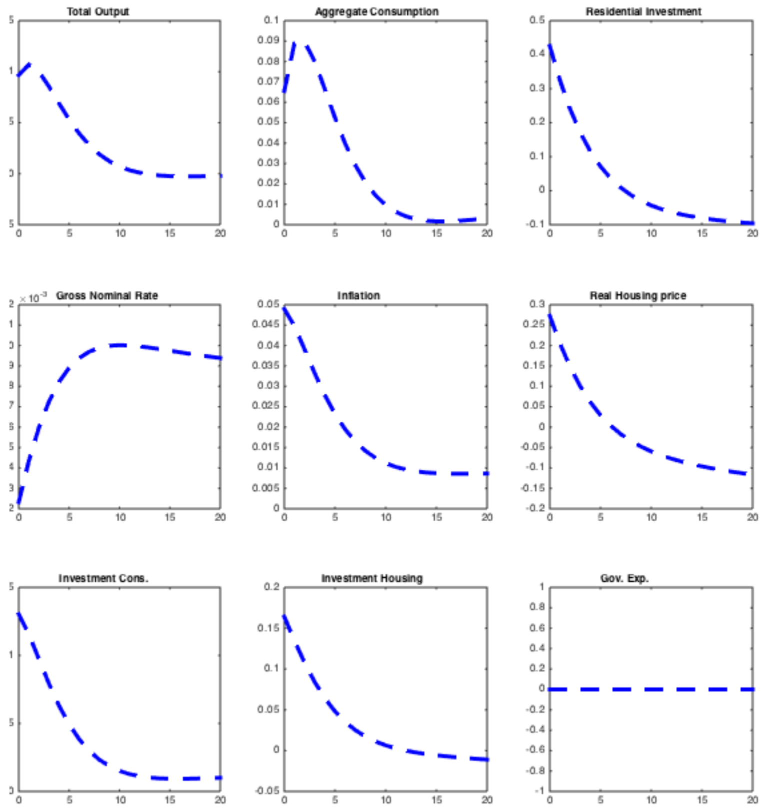

FIGURE B.10: *Response to a 1% decrease in the tax on housing.*

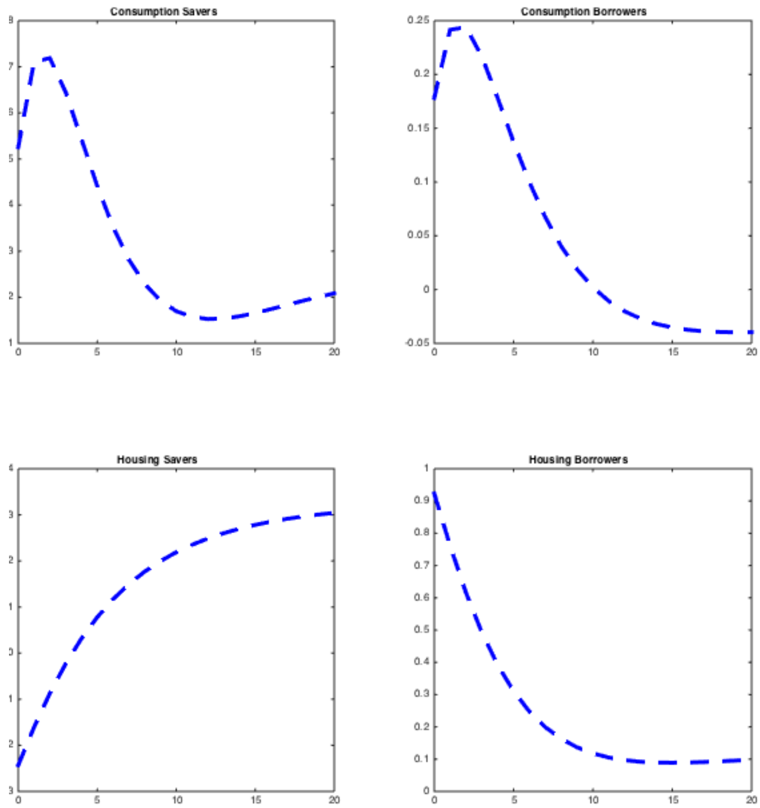

FIGURE B.11: *Response to a 1% decrease in the tax on housing.*

Appendix C

Appendix for Chapter III

C.0.1 Further IRFs

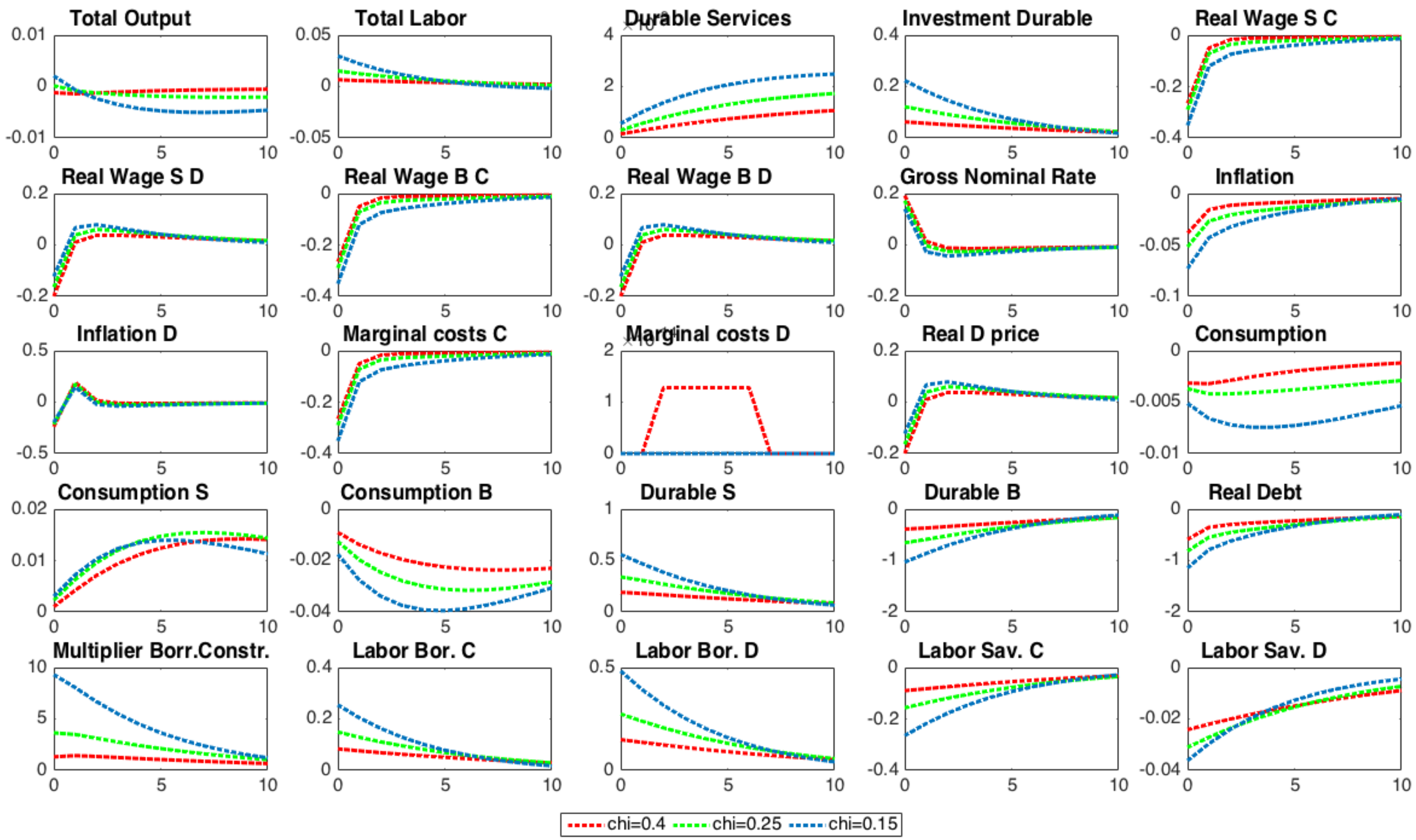

FIGURE C.1: *Baseline calibration, response to a 25 basis points increase in the policy rate. Average frequency of price adjustment 1 year for the non durable sector, while prices are flexible in the durable sector.*

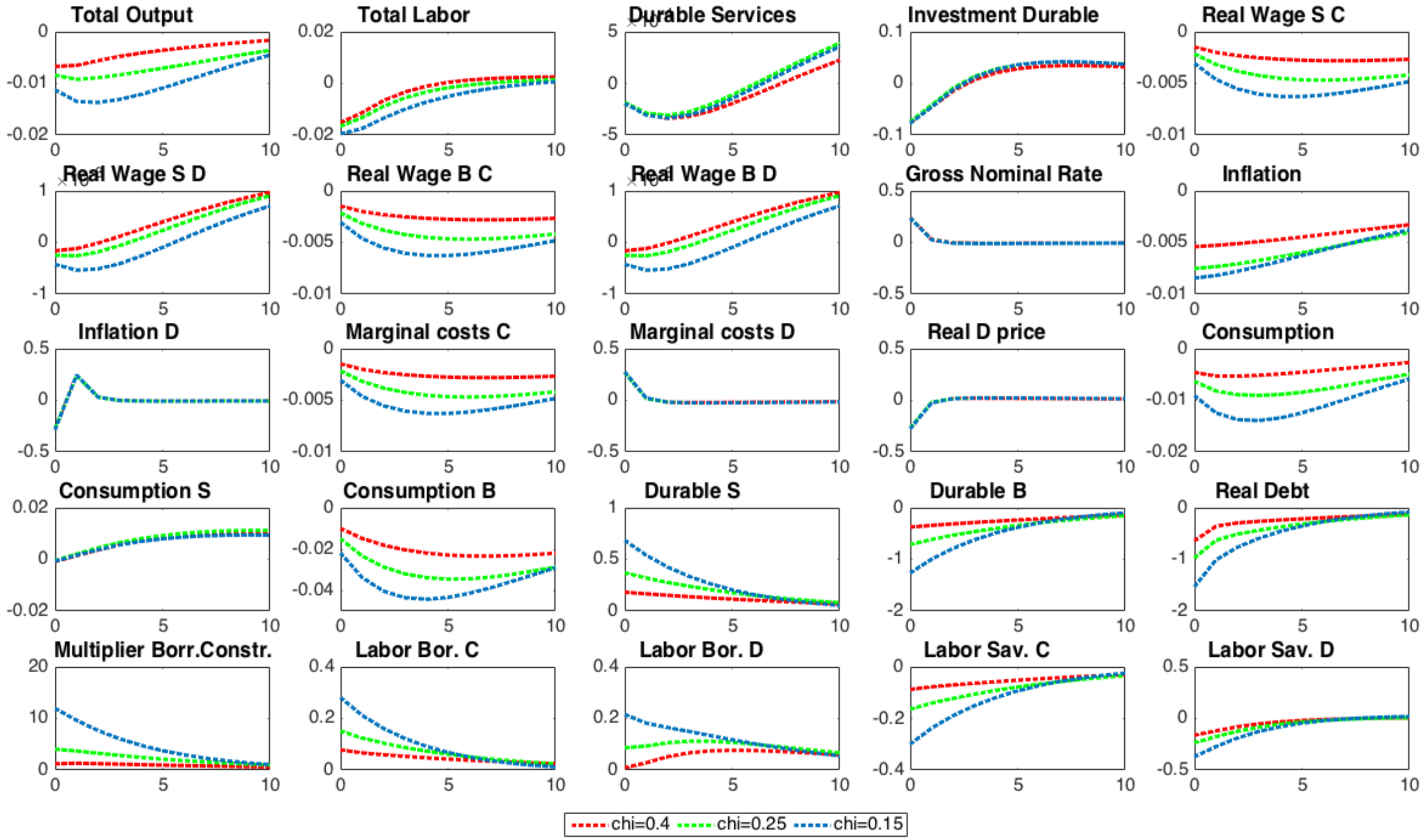

FIGURE C.2: *Baseline calibration, response to a 25 basis points increase in the policy rate. Average frequency of price adjustment 1 year for the non durable sector, while prices are flexible in the durable sector. Average frequency of wage adjustment equal to 1 year in both housing and consumption. Adjustment costs of housing investment calibrated in order to have a short and long run elasticity:* $SR = 1$ *and* $LR = 3$.

C.0.2 Adjusting Costs of Investment

The first order condition to the profit maximization problem of firms is:

$$\gamma\phi_2(y_{t+1} - y_t) - \phi_2(y_t - y_{t-1}) - \phi_1 y_t + \left(\frac{P_{d,t} - W_t}{P_{d,t}}\right) = 0 \qquad \text{(C.1)}$$

where the last expression in round brackets is the mark-up m. Following Carlstrom and Fuerst (2010), it can be argued that if m is exogenous to the firm, the solution of the difference equation above is:

$$y_t = \alpha_1 y_{t-1} + \alpha_2 m_t \qquad \text{(C.2)}$$

In this expression, α_2 represents the *short-run* elasticity, while the *long-run* elasticity is given by:

$$LR = \frac{\alpha_2}{(1 - \alpha_1)} = \frac{1}{\phi_1} \qquad \text{(C.3)}$$

$$SR = \alpha_2 \qquad \text{(C.4)}$$

Having targeted a given value for the short and long-run elasticity, it is possible to back out the values for ϕ_1 and ϕ_2.

Bibliography

Adrian, Tobias, Paolo Colla, and Hyun Song Shin (2012). "Which Financial Frictions? Parsing the Evidence from the Financial Crisis of 2007 to 2009". In: *NBER Macroeconomics Annual 2012* 27, pp. 159–214.

Adrian, Tobias and Hyun Song Shin (2014). "Procyclical Leverage and Value-at-Risk". In: *Review of Financial Studies* 27.2, pp. 373–403.

Albonico, Alice, Alessia Paccagnini, and Patrizio Tirelli (2016). "In Search of the Euro Area Fiscal Stance". In: DEMS Working Paper Series 324.

Alesina, Alberto and Silvia Ardagna (2010). "Large Changes in Fiscal Policy: Taxes versus Spending". In: *NBER Chapters*. National Bureau of Economic Research, Inc, pp. 35–68.

Alpanda, Sami and Sarah Zubairy (2013). "Housing and Tax Policy". In: *Staff Working Papers*.

Aoki, Kosuke, James Proudman, and Gertjan Vlieghe (2004). "House prices, consumption, and monetary policy: A financial accelerator approach". In: *Journal of Financial Intermediation* 13.4, pp. 414–435.

Bajari, Patrick, Chenghuan Sean Chu, and Minjung Park (2008). "An Empirical Model of Subprime Mortgage Default From 2000 to 2007". In: *National Bureau of Economic Research Working Paper Series* 14625.

Barsky, Robert B., Christopher L. House, and Miles S. Kimball (2007). "Sticky-price models and durable goods". In: *American Economic Review* 97.3, pp. 984–998.

Bernanke, Ben S. (2002). *On Milton Friedman's Ninetieth Birthday*. Remarks by Governor Ben S. Bernanke At the Conference to Honor

Milton Friedman, University of Chicago, Chicago, Illinois November 8, 2002.

Bernanke, Ben S. and Mark Gertler (1986). "Agency costs, collateral, and business fluctuations". In: *Proceedings*.

— (1995). "Inside the Black Box: The Credit Channel of Monetary Policy Transmission". In: *Journal of Economic Perspectives* 9.4, pp. 27–48.

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

Bilbiie, F. O. and Roland Straub (2004). "Fiscal policy, business cycles and labor-market fluctuations". In: *MNB Working Papers*.

Blanchard, Olivier and Roberto Perotti (2002). "An Empirical Characterization of the Dynamic Effects of Changes in Government Spending and Taxes on Output". In: *The Quarterly Journal of Economics* 117.4, pp. 1329–1368.

Blanchard, Olivier J. and Daniel Leigh (2013). "Growth Forecast Errors and Fiscal Multipliers". In: *American Economic Review* 103.3, pp. 117–20.

Boissay, Frederic, Fabrice Collard, and Frank Smets (2012). "Booms and systemic banking crises". In: *Working Paper Series*.

Borio, Claudio and Ilhyock Shim (2007). "What can (macro-) prudential policy do to support monetary policy ?" In: *Papersssrncom* April.

Brunnermeier, Markus K., Thomas M. Eisenbach, and Yuliy Sannikov (2012). "Macroeconomics with Financial Frictions: A Survey". In: *NBER Working Papers*.

Calza, Alessandro, Tommaso Monacelli, and Livio Stracca (2013). "Housing finance and monetary policy". In: *Journal of the European Economic Association* 11.SUPPL. 1, pp. 101–122.

Carlstrom, Charles T. and Timothy S. Fuerst (1997). *Agency Costs, Net Worth, and Business Fluctuations: A Computable General Equilibrium Analysis*.

— (2006). "Co-movement in sticky price models with durable goods". In: *Working Paper*.

— (2010). "Nominal Rigidities, Residential Investment, and Adjustment Costs". In: *Macroeconomic Dynamics* 14.01, p. 136.

Carvalho, Vitor M. and Manuel M. F. Martins (2011). "Macroeconomic effects of fiscal consolidations in a DSGE model for the Euro Area: does composition matter?" In: *FEP Working Papers*.

Chomsisengphet, Souphala and Anthony Pennington-Cross (2006). "The evolution of the subprime mortgage market". In: *FRB of St. Louis Review* Jan, pp. 31–56.

Christiano, Lawrence J., Martin Eichenbaum, and Charles L. Evans (2005). "Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy". In: *Journal of Political Economy* 113.1, pp. 1–45.

Colciago, Andrea (2011). "Rule-of-Thumb Consumers Meet Sticky Wages". In: *Journal of Money, Credit and Banking* 43.2-3, pp. 325–353.

Demyanyk, Yuliya and Otto Van Hemert (2011). "Understanding the Subprime Mortgage Crisis". In: *Review of Financial Studies* 24.6, pp. 1848–1880.

Diamond, Douglas W and Philip H Dybvig (1983). "Bank Runs, Deposit Insurance, and Liquidity". In: *Journal of Political Economy* 91.3, pp. 401–19.

Erceg, Christopher J and Andrew Levin (2006). "Optimal monetary policy with durable consumption goods". In: *Journal of Monetary Economics* 53.7, pp. 1341–1359.

Fatás, Antonio and Ilian Mihov (2001). "The Effects of Fiscal Policy on Consumption and Employment: Theory and Evidence". In: *CEPR Discussion Papers*.

Federal Reserve Bank of San Francisco (2007). *The Subprime Mortgage Market 2007 Annual Report*. Tech. rep. Federal Reserve Bank of San Francisco.

Fernández-Villaverde, Jesús (2010). "Fiscal policy in a model with financial frictions". In: *American Economic Review*. Vol. 100. 2, pp. 35–40.

Fisher, Irving (1933). "The Debt-Deflation Theory of Great Depressions". In: *Econometrica* 1.4, pp. 337–357.

Foote, Christopher L., Kristopher Gerardi, and Paul S. Willen (2008). "Negative equity and foreclosure: Theory and evidence". In: *Journal of Urban Economics* 64.2, pp. 234–245.

Forlati, Chiara and Luisa Lambertini (2011). "Risky mortgages in a DSGE model". In: *International Journal of Central Banking* 7.1, pp. 285–335.

Galí, Jordi (2008). *Introduction to Monetary Policy, Inflation, and the Business Cycle: An Introduction to the New Keynesian Framework*. Princeton University Press.

Gali, Jordi, J.D. López-Salido, and J. Vallés (2007). "Understanding the effects of government spending on consumption". In: *Journal of the European Economic Association* 5.1, pp. 227–270.

Gerali, Andrea et al. (2010). "Credit and Banking in a DSGE Model of the Euro Area". In: *Journal of Money, Credit and Banking* 42.s1, pp. 107–141.

Gertler, Mark and Peter Karadi (2011). "A model of unconventional monetary policy". In: *Journal of Monetary Economics* 58.1, pp. 17–34.

Gertler, Mark and Nobuhiro Kiyotaki (2011). "Financial Intermediation and Credit Policy in Business Cycle Analysis". In: *Handbook of Monetary Economics* 3A.11, pp. 547–599.

— (2013). "Banking, Liquidity and Bank Runs in an Infinite-Horizon Economy". In: *NBER Working Paper No. 19129* 1.

Grodecka, Anna (2016). “Subprime Borrowers, Securitization and the Transmission of Business Cycles”. In: *Working Paper Series*.

Guiso, Luigi, Paola Sapienza, and Luigi Zingales (2013). “The determinants of attitudes toward strategic default on mortgages”. In: *Journal of Finance* 68.4, pp. 1473–1515.

Horvath, Michael (2000). “Sectoral shocks and aggregate fluctuations”. In: *Journal of Monetary Economics* 45.1, pp. 69–106.

Iacoviello, Matteo (2005). “House Prices, Borrowing Constraints, and Monetary Policy in the Business Cycle”. In: *The American Economic Review* 95.3, pp. 739–764.

— (2010). “Housing in DSGE Models: Findings and New Directions”. In: *The Macroeconomics of Housing Markets* December 2009, pp. 3–16.

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

Justiniano, Alejandro, Giorgio E. Primiceri, and Andrea Tambalotti (2015). “Credit supply and the housing boom”. In: *Working Paper* March 2014, pp. 1–41.

— (2016). “A simple model of subprime borrowers and credit growth”. In: *Staff Reports*.

Keynes, John Maynard (1936). *The General Theory Of Employment , Interest And Money*. Palgrave Macmillan, p. 400.

Kim, Kwang Hwan and Joonseok Oh (2014). “Collateral Constraints , Sticky Wages , and Monetary Policy”.

Kiyotaki, Nobuhiro (2011). “A perspective on modern business cycle theory”. In: *Economic Quarterly* 97.3, pp. 195–208.

Kiyotaki, Nobuhiro and John Moore (1997). “Credit Cycles”. In: *Journal of Political Economy* 105.2, pp. 211–48.

Knoll, Katharina, Moritz Schularick, and Thomas Steger (2014). “No price like home: global house prices, 1870-2012”. In: *Globalization and Monetary Policy Institute Working Paper*.

Mankiw, N. Gregory (2000). "The Savers-Spenders Theory of Fiscal Policy". In: *American Economic Review* 90.2, pp. 120–125.

Mian, Atif and Amir Sufi (2009). "The Consequences of Mortgage Credit Expansion: Evidence from the 2007 Mortgage Default Crisis". In: *NBER Working Papers*.

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

Mountford, Andrew and Harald Uhlig (2009). "What are the effects of fiscal policy shocks?" In: *Journal of Applied Econometrics* 24.6, pp. 960–992.

Pataracchia, Beatrice et al. (2013). "Endogenous housing risk in an estimated DSGE model of the Euro Area". In: *European Economy - Economic Papers*.

Roeger, Werner and Jan in 't Veld (2009). "Fiscal policy with credit constrained households". Brussels.

Rotemberg, Julio J (1982). "Sticky Prices in the United States". In: *Journal of Political Economy* 90.6, pp. 1187–1211.

Sterk, Vincent (2010). "Credit frictions and the comovement between durable and non-durable consumption". In: *Journal of Monetary Economics* 57.2, pp. 217–225.

Stiglitz, Joseph E. (2011). "Rethinking Macroeconomics: What Failed, And How To Repair It". In: *Journal of the European Economic Association* 9.4, pp. 591–645.

The Financial Crisis Inquiry Commission (2011). *The Financial Crisis Inquiry Report*. Tech. rep. The Financial Crisis Inquiry Commission.

Townsend, Robert M. (1979). "Optimal contracts and competitive markets with costly state verification". In: *Journal of Economic Theory* 21.2, pp. 265–293.

Tracy, Joseph, Henry Schneider, and Sewin Chan (1999). "Are stocks overtaking real estate in household portfolios?" In: *Current Issues in Economics and Finance* 5.Apr.

Verona, Fabio, Manuel Martins, and Ines Drumond (2013). "(Un)anticipated monetary policy in a DSGE model with a shadow banking system". In: *International Journal of Central Banking* 9.3, pp. 73–117.