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Three Essays in Monetary Economics: Central Bank Transparency and Macroeconomic Implications of Financial Frictions

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Chapter 1

Introduction

The extraordinarily devastating effects on financial markets and the real economy of the global financial crisis 2007 and 2008 have led economists to question many achievements in monetary economics at the theoretical and policy levels. Before this crisis, many consensual views on monetary economics and policies had developed into models that ignored financial intermediation, particularly frictions in the financial system. The most important issues in central banking (e.g., inflation targeting, central bank accountability, independence and transparency, and monetary policy discretion and commitment) are examined in models that can be reduced to one equation, i.e., the traditional or New-Keynesian Phillips curve. How the financial markets work is completely unimportant for monetary policy analysis, as they are assumed to function without frictions, and market fluctuations are assumed to be independent of private agents economic decisions, even though economists and policymakers know that these markets are important for the economy.

On the other hand, many Dynamic Stochastic General Equilibrium (DGSE) models that are designed to analyze the effects of economic policies or exogenous shocks share the same conceptions with regard to financial intermediation and markets, although some attention is paid to the financial constraints imposed on household and corporate borrowing before the global financial crisis. Little effort has been dedicated to exploring the implications of financial intermediation, particularly financial frictions that affects the flow of credit, for the transmission mechanism of exogenous shocks and the dynamic properties of the business cycles. Furthermore, economists know little about how the central bank should react when such frictions are present and affect the outcomes of conventional monetary policies. Moreover, the effects of unconventional monetary policy measures that are introduced when the conventional ones fail cannot be well evaluated without incorporating these frictions into macroeconomic models.

To address the new challenges that the global financial crisis introduced, the literature is increasingly focusing on the integration of financial intermediaries and the financial frictions that arise in the process of intermediaries funding themselves into monetary macroeconomic analysis. The works presented in this dissertation are situated in this new trend of monetary macroeconomics. This dissertation's contributions have some important implications for monetary policy conduct. First, this dissertation seeks to examine how the analysis of central bank transparency is modified if financial intermediation's role is considered through the introduction of the cost channel. By accounting for firms' needs to borrow funds from banks for the working capital, the cost channel allows the interest rate to affect the Phillips curve. Second, this dissertation seeks to investigate how imperfect financial intermediation affects the business cycle fluctuations when the central bank adopts conventional monetary policies that are formulated in terms of Taylor rule. Finally, my reflection about the consequences of the global financial crisis and its implications for central banking allow me to analyze the transmission mechanisms of unconventional monetary policy measures in a framework with financial frictions.

1.1 Central bank transparency

Since the 1990s, central banks have become increasingly transparent in their communication with the public and financial markets. Several related factors explain the rise of central bank transparency. First, responding to popular pressures, transparency is part of a broader trend to make governments more responsive to the public. Second, transparency is considered a key element in ensuring accountability as central banks gain more independence and are freer to make their decisions. In effect, transparency is a mechanism that enables the public to assess whether central bankers actions are consistent with their mandates.[1] Third, central bank transparency is considered a way of enabling market operators to respond more smoothly to policy decisions, as transparency about the central banks economic outlook and how that outlook relates to its policy stance makes it less likely that monetary policy decisions come as surprises, thus improving private expectations. Given that investors are less likely to be caught unawares by policy actions, policy changes will be less likely to cause extreme movements in asset prices at the origin of financial distress. Fourth, transparency enhances the credibility of the central banks commitments. A commitment to ensure low and stable inflation will be more convincing if the central bank clearly explains why and how its policies could produce the desired inflation. On the other hand, a commitment with greater credibility gives the central bank more liberty to deviate from announced policy paths in particular situations. In other words, the public views such deviation as transitory and still in line with the pursuit of long-run monetary policy targets. As a result, central bank transparency enhances policy credibility and policy flexibility.

[1] Central bank independence is observed as an efficient means of addressing the time consistency problems affecting discretionary policy. For this reason, such independence is widely advocated as a means of insulating monetary policy from short-term political pressures (see Blinder, 1998 [3], Rogoff, 1985 [33], Walsh, 2003 [36], Grilli *et al.*, 1991 [22] and Debelle and Fischer, 1994 [16]).

Chapter 2 addresses the issue of central bank political transparency, i.e., transparency about the relative weight assigned to the output stabilization. The main motivation of our study is that, while it is quite common to see many central banks announcing their inflation target, communicating about their economic outlooks and publishing the minutes of their decisions, a central bank rarely produces a public statement that specifies the weights assigned to its objectives. This type of opacity would be unjustified in the Barro-Gordon framework (1983) [1]. The Barro-Gordon framework does not affect the average inflation and output gap but induces higher inflation and output-gap variability (Beetsma and Jensen, 2003 [2], and Demertzis and Hughes Hallet, 2007 [17]).

According to Dai (2014) [14], given the presence of monopolistic competition in the standard New Keynesian model (Clarida *et al.*, 1999 [11]), partial disclosure about the central banks' preferences could improve social welfare. In such a model, intransparency generally reduces the average response of inflation to inflation shocks and inflation volatility; however, it also increases those of the output gap–more so when inflation shocks are highly persistent–and can therefore improve social welfare if the weight assigned to output-gap stabilization is low. These results echo those obtained in models that introduce distortions and inefficiencies to the economy.[2]

Chapter 2 contributes to the literature on central bank transparency by introducing the cost channel in a standard New-Keynesian model, which is based on Christiano *et al.*, (2005) [8] and Ravenna and Walsh (2006) [32]. The analysis in this chapter complements that of Dai (2014) [14] and its objective is to investigate how the presence of the cost channel modifies the effects of opacity (i.e., intransparency, imperfect transparency) about the central banks' preferences on the cyclical fluctuations of inflation and the output gap.

In this chapter, the financial intermediation process is frictionless, while the following two chapters, which examine the effects of financial frictions in New-Keynesian DSGE models, do not consider central banks' transparency.

1.2 Macroeconomics with Financial Frictions

The importance of imperfect financial markets for business cycle fluctuations has been analyzed for decades in macroeconomics. One reason for explicitly modeling such frictions is that credit flows are highly procyclical (Covas and Den Haan, 2011 [11]). The growth of private liabilities substantially drops during recessions, especially sizeable during the Great Recession of 2008. Financial markets' cyclical properties are not only reflected by the aggregate volatility of credit flows but also by many banks' tightening credit standards

[2]See e.g. Sorensen, 1991 [34], Grüner, 2002 [23] and Spyromitros and Zimmer, 2009 [35] who introduce distortion in wage settings, Hughes Hallett and Viegi, 2003 [25], Ciccarone *et al.*, 2007 [9] and Hefeker and Zimmer, 2011 [24] to tax rates, and Dai and Sidiropoulos, 2011 [15] to the public investment. One reason that central bank opacity could improve welfare in these models with distortions is that it could discipline the private sector or the government in setting wages or tax rates.

during recessions and the increase in credit spreads, i.e., interest rate differentials between securities that are associated with different risk levels (Gilchrist *et al.*, 2009 [21]).

According to Modigliani and Miller (1958) [31], if markets were frictionless, the financial structures of individual agents (households, firms, or financial intermediaries) would be indeterminate. Thus, there would not be reasons for the financial flows to follow a cyclical pattern. However, the fact that credit flows are highly procyclical and the indicator of tightening standards is countercyclical casts doubt on the frictionless financial market paradigm.

There are two features characterize the models with financial frictions. First, the trade of certain assets cannot take place, i.e., markets for some contingencies are missing. Private agents will thus be unable to advance or delay expenditures (consumption or investments) or to smooth consumption or investments by insuring against uncertain events. In an economy with complete markets, private agents can trade any type of contingency. There are two approaches for modeling incomplete markets: "exogenous" market incompleteness and "endogenous" market incompleteness. The first includes models that imposes the assumption that certain assets can not be traded. For example, the total amount of debt cannot exceed a certain exogenously fixed limit (i.e., the borrowing constraint). The second includes models where the set of debt contracts arises from agency problems. The idea is that parties are reluctant to engage in some trades due to the problems of enforceability or incentive compatibility, thus implying that markets are missing. Note that the endogenous market incompleteness generally results from two agency problems: limited enforcement and information asymmetry. Limited enforcement implies that, although the lender can fully observe if the borrower is fulfilling the obligations in his contract, the absence of pertinent tools prevents the lender from enforcing these obligations. Lenders' capabilities to force the borrowers to fulfill their obligations are also limited by information asymmetries, i.e., the lender's inability to observe the borrowers action.

The second feature that characterizes the models with financial frictions is that, private agents in the economy are heterogeneous. It is clear that if all agents are homogeneous, there is no reason to trade claims intertemporally or intratemporally. A common approach of modeling agent heterogeneity is to assume that there are two types of agents with different preferences and/or technologies. In equilibrium, one agent will be the borrower and the other the lender (see e.g., Iacoviello, 2005 [26]). An alternative approach is to assume a continuum of heterogeneous agents with their aggregate behaviors characterized by unique representative agents through linear aggregation (see e.g., Carlstrom and Fuerst, 1997 [7] and Bernanke *et al.*, 1999 [5]).

Financial frictions and amplification

Much of the earlier literature on dynamic monetary economics has focused on the amplification effects of financial market frictions. This literature assumes that, financial frictions can exacerbate a recession even though they are not at its origin. In other words, the amplitude of a recession generated by the nonfinancial shocks (e.g., the technology or monetary policy shock) would be much greater when the financial frictions are present than when they are absent in the model economy. The baseline models with financial frictions are the costly state verification model proposed by Bernanke and Gertler (1989) [4] and the borrowing constraint model of Kiyotaki and Moore (1997) [28].

Costly state verification model

In the costly state verification model of the Bernanke and Gertler (1989) [4], financial frictions derive from information asymmetry about the future payoff of firms' project. The verification cost is induced by an idiosyncratic shock that affects each entrepreneur's technology and is unobservable to outsiders. Consequently, the optimal contract between an entrepreneur and lender must be such that the entrepreneur does not profit from the information asymmetry or minimize the deadweight loss due to the verification cost.

In this model, the authors focus on the fact that a temporary shock can have long-lasting persistent effects via feedback effects of financial frictions. Negative shocks to the entrepreneur's net worth increase financial frictions and force the entrepreneurs to invest less, reducing the entrepreneur's capital stock and hence his net worth. This reduction leads to a vicious downward spiral of lower economic activity and additional declines in the value of capital.

In essence, the cost of state verification acts as investment adjustment costs do by reducing aggregate volatility, making it difficult to generate large amplifications. However, this model has the potential to generate more persistence, but it is limited by the two-period model structure. To generate large amplification effects, Carlstrom and Fuerst (1997) [7] and Bernanke, Gertler and Gilchrist (1999) [5] have embedded the costly state verification in dynamic macroeconomic models with infinitely lived agents.[3]

Model with collateral constraints

An alternative approach of incorporating financial frictions proposed by Kiyotaki and Moore (1997) [28] assumes that entrepreneurs use a production input–land, as borrowing collateral. In this framework, a small shock to the economy can generate large fluctuations by triggering interactions between the land price and firms' borrowing constraint. Higher land price raises firms' net worth, increasing their ability to borrow and thus to invest in land and raise the production of consumption goods.

However, some subsequent research found that the borrowing constraint in Kiyotaki and Moore (1997) [28] cannot generate the observed land price fluctuations. For example, Kocherlakota (2000) [29] suggests that collateral constraints cannot generate large enough effects because some agents hold liquid assets to self-insure in the event of small shocks. Cordoba and Ripoll (2004) [10] develop a NK model with the borrowing constrain tied to

[3]According to Bernanke *et al.*, (1999) [5], the financial accelerator could generate sizeable amplifications of monetary policy shocks and larger fluctuations in capital price if adjustment costs are added in the production of capital goods.

the value of land and they find that a large capital share and a very low intertemporal substitution are needed to produce a significant amplification effect. To address these quantitative concerns, researchers have introduced additional feature into the model with collateral constraints. For example, Iacoviello (2005) [26] ties the collateral constraint to housing values and introduces household heterogeneity; Mendoza (2010) [30] introduces sticky wages; and Jermann and Quadrini (2012) [27] assume that entrepreneurs need external funds to finance working capital.

Financial intermediation

Starting with the *subprime* crisis crisis in the summer of 2007, recent economic and financial events suggest that financial intermediation constitutes an important source of business cycle fluctuations and the key in understanding the financial stability. Indeed, the traditional macroeconomic model used for monetary policy analysis (e.g., the "bank lending channel" model that postulates an essential role for banks while assuming specific constraints) becomes less relevant in describing the modern financial system. In particular, it is assumed that commercial banks mainly depend on deposits for their funding, that a numerous borrowers depend on banking credit, and that banks do not have many investment opportunities to employ their funds other than lending to bank-dependent borrowers. Such an assumption becomes less relevant due to financial innovations and regulatory changes that have been introduced since the 1980s.

With concerns about the relevance of the bank lending channel, other models have instead stressed the balance sheet channel discussed above, such that lenders might be reluctant to extend credit to more risky and less well capitalized nonfinancial borrowers, as in seminal contributions from Bernanke and Gertler (1989) [4], Kiyotaki and Moore (1997) [28] and Bernanke, Gertler, and Gilchrist (1999) [5]. However, these models cannot explain the recent crisis that, at least in its initial stage, was characterized by the intermediaries' reduced ability to supply credit, which results from adverse developments in the financial sector itself rather than reduced credit demand due to ultimate borrowers' problems.

Moreover, in the context of the recent financial crisis, central banks in many industrial countries have adopted various unconventional policy tools that have not been used before (e.g., the large-scale asset purchase programs (LSAPs) initiated by the Federal Reserve). For central banks, these unconventional policies represent a break with the traditional policy measures and their transmission mechanisms have not been well understood.

To evaluate the effectiveness of these measures, there have been ongoing efforts devoted to constructing new generation of macroeconomic models with financial frictions that arise in the financial intermediation sector. These models aim to investigate, frist, the link between the financial disruptions and business cycle fluctuations, and second, the effects of various unconventional monetary policies on the financial market conditions and hence the real economic activity (e.g. Cúrdia and Woodford, 2010 [12] and 2011 [13] and Gertler and Karadi, 2011 [18] and 2013 [19]). In these models, financial intermediaries' lending capacity is primarily determined by the level of intermediaries' equity capital.

Chapter 3 and 4 in this dissertation contribute to this strand of literature. We develop a quantitative general equilibrium model with financial frictions due to an moral hazard problem of Gertler and Karadi (2011) [18] and limited enforcement of heterogeneous secured credit. In Chapter 3, we use this model to examine the role played by the imperfect financial intermediation in the transmission of exogenous shocks to the economy. In Chapter 4, we use this model to analyze the effects of the Fed's large-scale asset purchases in the economies with different degrees of credit market segmentation.

1.3 Outline of the dissertation

This dissertation presents three essays on monetary economics. Chapter 2, *"Central bank transparency with the cost channel,"* focuses on the effects of opacity about the central banks' preferences, i.e., uncertainty about the relative weight that the central bank assigns to output-gap stabilization in a New-Keynesian model. We consider in this model the presence of cost channel which is characterized by distortions due to firms need to prefinance their production. In this framework, we have shown that the cost channel not only significantly affects the central bank intransparency associated with inflation shocks, but it also produces these effects based on demand shocks. Compared with inflation shocks, demand shocks are associated with similar but smaller effects of opacity except when they have a much larger volatility. Intransparency generally reduces inflation's average response to both types of shocks and thus reduces inflation volatility, but it also increases those of the output gap, even more so when these shocks are highly persistent. It could thus improve social welfare if society assigns a low weight to output-gap stabilization and even more so under the cost channel. Chapters 3 and 4 present two essays on monetary business cycle theories. Their common denominator is the macroeconomic implications of financial frictions that arise in the process of credit intermediation.

Chapter 3, *"Imperfection financial intermediation and business cycles fluctuations,"* builds on the New-Keynesian model with financial frictions that was proposed by Gertler and Karadi (2011) [18] to analyze the role of financial frictions in affecting the ability of financial intermediaries to supply credit in the transmission of exogenous shocks and their effects on the macroeconomic fluctuations. As in Gertler and Karadi (2011 [18], 2013 [19]) and Gertler and Kiyotaki (2010) [20] and, the moral hazard problem that bankers face vis-à-vis their branch managers limits on those branches' ability to raise funds and creates a wedge between the interest rate on loans and the interest rate on deposits. I add two main features to this framework: (1) a housing sector and differentiated corporate and mortgage credit markets and (2) partially segmented credit markets.

We find that the exogenous shocks, such the a positive technology shock or a positive borrowing constraint shock that raise asset prices, stimulate investment, demand for housing and output in the presence of financial frictions, generating countercyclical credit spreads and triggering a balance sheet effect that raises the bank's equity capital and ability to supply credit to private sector. However, the model stimulation in addition show a "banking attenuator" effect in the transmission of monetary policy shock. An unexpected decline in the policy rate reduces the external funding cost for banks, but tends to raise interest rate spreads which dampens the response of financial market and real economy variables to the monetary policy shock.

The model simulations for banks' various leverage ratios show that the presence of imperfect financial intermediation can amplify the economy's responses to disturbances (e.g., technology, monetary and borrowing constraint shocks) through the strength of the bank balance sheet effect on credit supply.

Chapter 4, *"Large-scale asset purchases with segmented mortgage and corporate loan markets,"* based on the paper coauthored with Meixing Dai and Frédéric Dufourt, uses the New-Keynesian model developed in Chapter 3 to analyze the transmission mechanisms and macroeconomic effects of large-scale asset purchases that the Federal Reserve implemented in the context of the recent crisis. It considers two additional dimensions that are not considered in the Gertler and Karadi paper or in other related models of the literature. These dimensions are nevertheless crucial for understanding the effects of LSAPs: The first dimension involves the central bank's purchases of mortgage-backed securities (MBS) in addition to (or in place of) corporate bonds. The second is considering two polar assumptions regarding the degree of credit market segmentation when analyzing LSAP effects. Two alternative configurations of credit markets, partially versus totally segmented credit markets, are analyzed. The total segmentation of credit markets reflects a crisis situation in which equity capital reallocation between bank loan branches is impossible.

We have shown that, following a large disruption of financial intermediation, central bank purchases of mortgage-backed securities are uniformly less effective than outright purchases of corporate bonds at easing credit market conditions and stabilizing economic activity.

Moreover, the size of the effects crucially depends on the extent to which credit markets are segmented, i.e. to which a "portfolio balance channel" is at work in the economy. More segmented credit markets imply larger, but more local effects of particular asset purchases. With strongly segmented credit markets, large scale purchases of MBS are useful to stabilize the housing market but do little to mitigate the contractionary effect of the crisis on employment and output.

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Chapter 2

Central bank transparency with the cost channel

2.1 Introduction

In the past two decades, adopting high standards of transparency has become a common practice among a growing number of central banks. Improved transparency, which enhances the accountability and thus the public support for central bank independence, is perceived to reduce political influence over monetary policy. Besides the benefits of making central banks independent from the government, a significant amount of attention has been put on the effects of political, economic, procedural, policy and operational transparency in monetary policy decisions.[1]

On the basis of theoretical and empirical studies, most researchers share the view that central bank transparency is in general desirable because it lowers inflation expectations and inflation by making the central bank more credible and its policy more precisely anticipated by the private sector. Even though empirical evidence shows no obvious influence on output and output variability, one might expect that better economic decisions resulting from higher transparency lead to higher social welfare (Chortareas *et al.*, 2002 [6], Dincer and Eichengreen, 2007 [17] and 2010 [18]).

Since the pioneer work undertaken by Cukierman and Meltzer (1986) [13], issues of central bank transparency have been largely investigated across different types of models. However, existing studies do not account for the cost channel. The latter assigns banks a key role in the transmission of monetary policy, which stems from the idea that firms depend on credit to pre-finance production (Christiano and Eichenbaum, 1992 [7] and Barth and Ramey, 2001 [1]) so that their marginal cost and hence price decisions directly

[1] These five motives for central bank transparency are defined in Geraats (2002) [26]. For some recent surveys of the literature on central bank transparency, see Blinder *et al.* (2008) [4], Crowe and Meade (2008) [12], Geraats (2009) [27], Eijffinger and van der Cruijsen (2010) [22], and Ehrmann *et al.* (2012) [20].

depend on the nominal rate of interest. In the presence of the cost channel, demand shocks will affect the equilibrium level of inflation and the output gap. Therefore, the central bank could not neutralize the effects of demand shocks by adopting an optimal interest rate policy and hence transparency will not only interact with inflation shocks but also with demand shocks.

This chapter contributes to the literature on central bank transparency by examining the effects of opacity[2] about the central bank's preferences, i.e., the uncertainty about the relative weight that the central bank assigns to output-gap stabilization, in a model with the cost channel based on Christiano *et al.* (2005) [8] and Ravenna and Walsh (2006) [36]. A direct consequence of introducing such a channel is that a monetary contraction induces an upward pressure on prices by deteriorating credit conditions through higher interest rates besides the negative effect on inflation operating through the effect of the interest rate on the demand and hence the output (the interest rate channel). The presence of the cost channel implies that all shocks to the economy will generate a trade-off between stabilizing inflation and stabilizing the output gap, and thus could have important implications for central bank transparency. The total effect of the cost channel depends on the importance of the cost channel and the amplitude of demand shocks. While recent empirical studies are divergent about the importance of the cost channel according to the econometric methods adopted,[3] a number of studies show that nominal demand shocks could explain a large part of short-run price and output fluctuations (see, e.g. Blanchard and Quah, 1989 [3] and Dufourt, 2005 [19]). Thus, even the marginal effects of the cost channel are not important, its overall implication for the monetary policy and hence central bank intransparency could still be very important.

Generally, it is quite common to see many central banks announcing their inflation target, communicating about their economic outlooks and publishing their minutes of decision. However, it is rare that a central bank produces a public statement that specifies the weights assigned to its objectives. Imperfect transparency of this kind could not be justified in the Barro-Gordon framework since it has no significant effect on the average inflation and output gap but will increase inflation and output-gap variability (Beetsma and Jensen, 2003 [2] and Demertzis and Hughes Hallet, 2007 [16]).

In contrast, in the standard New Keynesian model (Clarida *et al.*, 1999) [11], imperfect disclosure about the central bank's preferences could be justified. In such a framework, imperfect transparency generally reduces the average response of inflation to inflation shocks and the volatility of inflation, but increases those of the output gap more so when inflation shocks are highly persistent, and could therefore improve social welfare if the weight assigned to output-gap stabilization is low (Dai, 2014) [14]. In a New Keynesian

[2]Throughout, we use the terms "opacity", "intransparency", or "imperfect transparency" interchangeably.
[3]See, among others, Barth and Ramey (2001) [1], Christiano *et al.* (2005) [8], Tillmann (2008) [40], 2009b [42]), Henzel *et al.* (2009), Gabriel and Martins (2010) [25] and Castelnuovo (2012) [5].

framework, knowledge of the relative weight assigned to the output-gap target is essential for private agents to evaluate how quickly the central bank plans to steer the economy back to the equilibrium following an inflation or demand shock. The higher is this weight, the longer time period is allowed by the central bank for the inflation to get back to its target, causing a larger volatility of inflation but a smaller volatility of output. Thus, the contradictory effects of an increase in opacity could improve social welfare or not, crucially depending on the value of model parameters. Moreover, the cost channel could reinforce or weaken the effects of opacity according to the variables and the degree of persistence of inflation and demand shocks.

Focusing on the effects of transparency through the cost channel, we find that imperfect transparency can similarly interact with demand shocks (including fiscal and productivity shocks) as with inflation (or supply) shocks. More precisely, imperfect transparency about central bank preferences could be welfare improving if, in average, the society assigns a low relative weight to output-gap stabilization. The effects of opacity associated with the cost channel could be substantial if the variance of demand shocks is significantly higher than that of inflation shocks. Moreover, the inclusion of the cost channel does modify quantitatively, but not qualitatively, the effects of imperfect transparency associated with inflation shocks.

The fact that opacity could potentially improve social welfare in the New- Keynesian framework with the cost channel does not suggest that the central bank should be intransparent about its preferences since these effects are model sensitive. In studies using the static Barro-Gordon framework (e.g., Nolan and Schaling, 1998 [35], Eijffinger *et al.*, 2000 [21], Faust and Svensson, 2001 [23], Beetsma and Jensen, 2003 [2] and Demertzis and Hughes Hallet, 2007 [16]), it is shown that imperfect transparency about the central bank' preferences is detrimental to social welfare when corrections are made for the effects due to arbitrary specifications of uncertainty about one or the other parameter attached to the central bank's objectives. The conclusions of our paper are to some extent similar to those obtained in models introducing distortions through the wage setting behavior of labor unions (e.g. Sørensen, 1991 [38], Grüner, 2002 [28]), distortionary taxes (Hughes Hallett and Viegi, 2003 [31], Ciccarone *et al.* 2007 [10], Hefeker and Zimmer, 2011 [29] and Dai and Sidiropoulos, 2011 [15]). In these models, central bank opacity could improve global welfare because it could discipline the private sector when setting wage or the government when setting the tax rate and public investment. In the New Keynesian model with the cost channel, characterized by two distortions, i.e., monopolistic competition with price rigidities and the effect of nominal interest rate on firms' marginal cost, imperfect transparency could discipline the price behaviors of firms.

Our results are about a special aspect of central bank transparency, i.e., political transparency. We do not attempt to capture the general effects of different aspects of transparency. Thus, our results are not in contradiction with empirical studies that generally show the positive effect of transparency on macroeconomic performance.[4] Our theoretical study suggests that empirical studies should go further by separating the effects of uncertainty about the relative weight that central banks assign to output-gap stabilization from those of other transparency motives while taking into account the effects of monopolistic competition and the cost channel.

This chapter is closely related to a number of recent studies that have explored various implications of the cost channel for the monetary policy by taking into account the matching technology in the labor market (Ravenna and Walsh, 2008 [37]), the robust approach of monetary policy (Tillmann, 2009a [41]), monopolistic competition in loan markets and fixation of loan rates in a staggered way (Hülsewig, *et al.* 2009 [32]), interest rate smoothing (Kaufmann and Scharler, 2009 [33]), and financial frictions arising from heterogeneity in firms productivity and asymmetric information (Fiore and Tristani, 2013 [24]).

The remainder of this chapter is organized as follows. In Sec tion 2.2, we present the basic model with the cost channel. In Section 2.3, we solve the model under monetary discretion. Section 2.4 analyzes the effects of opacity about the central bank's preferences on the level and volatility of macroeconomic variables and their dynamic properties. The last section 2.5 concludes.

2.2 The model

Our framework is based on Christiano *et al.* (2005), and Ravenna and Walsh (2006) who introduce the cost channel into a standard New Keynesian model. The basic idea that distinguishes this kind of model from a standard New Keynesian model is that firms are assumed to pay their factors of production before receiving revenues from selling their products, and they need to borrow working capital from financial intermediaries. Therefore, a variation in the policy interest rate affects not only the IS equation but also the Phillips curve, implying that the optimal monetary policy will not completely neutralize the effects of demand shock on inflation and the output gap.

A stylized New Keynesian model with the cost channel is given by:

$$\pi_t = \beta E_t \pi_{t+1} + \kappa(\sigma + \eta)x_t + \kappa\phi R_t + e_t, \tag{2.1}$$

$$x_t = E_t x_{t+1} - \frac{1}{\sigma}(R_t - E_t \pi_{t+1}) + u_t, \tag{2.2}$$

where π_t is the inflation rate, x_t the output gap, R_t the risk-free nominal interest rate controlled by the central bank and E_t the expectation operator. All variables are expressed

[4]See e.g. Demertzis and Hughes Hallet, 2007 [16], Geraats, 2009 [27], Dincer and Eichengreen, 2007 [17] and 2010 [18], van der Cruijsen *et al.*, 2010 [43], Spyromitros and Tuysuz, 2012 [39] and Ehrmann *et al.*, 2012 [20].

in percentage log deviations around their respective steady-state values. The parameters β, σ and η denote the discount factor, the coefficient of relative risk aversion, and the inverse Frisch elasticity of labor supply, respectively. The composite coefficient $\kappa = (1 - \omega)(1 - \omega\beta)/\omega$, depends negatively on the degree of price stickiness, ω, which represents the fraction of firms that do not optimally adjust but simply update their previous price by the steady-state inflation rate. The parameter ϕ is a dummy variable. When $\phi = 1$, we are in the presence of the cost channel. Setting, $\phi = 0$, we obtain the standard New Keynesian model.

Cost-push shock e_t and demand shock u_t, which captures productivity, taste and fiscal policy shocks, are serially correlated and follow an AR(1) process:

$$e_t = \rho_e e_{t-1} + \upsilon_{et}, \quad 0 \leq \rho_e \leq 1 \text{ and } E_{t-1}\upsilon_{et} = 0; \tag{2.3}$$

$$u_t = \rho_u u_{t-1} + \upsilon_{ut}, \quad 0 \leq \rho_u \leq 1 \text{ and } E_{t-1}\upsilon_{ut} = 0; \tag{2.4}$$

where ρ_e and ρ_u measure the degree of persistence of inflation and demand shocks, respectively, and υ_{et} and υ_{ut} have zero mean and are serially uncorrelated.

Following Sørensen (1991) [38], we specify that the central bank minimizes the loss function:

$$L \equiv \frac{1}{2} E_t \sum_{t=0}^{\infty} \beta^t \left[(1 + \varepsilon)\pi_t^2 + (\lambda - \varepsilon)x_t^2 \right], \tag{2.5}$$

where λ denotes the expected relative weight assigned by the central bank to the output-gap objective. The parameter $\varepsilon \in [-1, \lambda]$ is a stochastic variable, with zero mean and variance σ_ε^2, implying that the weights associated with inflation and output-gap targets cannot be perfectly predicted by the private sector. Note that the variance σ_ε^2 represents the degree of opacity about the central bank's preferences. If $\sigma_\varepsilon^2 = 0$, the central bank is fully predictable and hence fully transparent. Given that ε takes values in a compact set and is expected to be equal to zero, Ciccarone *et al.* (2007) [10] and Ciccarone and Marchetti (2009) [9] have proved that σ_ε^2 has an upper bound so that $\sigma_\varepsilon^2 \in [0, \lambda]$. According to Beetsma and Jensen (2003) [2], introducing uncertainty in the parameter associated with either inflation or output-gap objective leads to very different results regarding the effects of transparency. The assumption that ε is associated with both objectives, adopted in our analysis, avoids that uncertainty about the central bank's preferences yields arbitrary effects on macroeconomic performance and social welfare.

2.3 Optimal monetary policy

The central bank is assumed to determine the optimal policy under discretion, i.e., it makes no pre-commitment about future policy and re-optimizes its objective function in each period taking inflation expectations as given.[5] Under discretion, the decision problem of the central bank becomes the single period problem of choosing the values of inflation and the output gap that minimize the loss function (2.5) subject to the inflation adjustment equation (2.1) and the IS equation (2.2). The policy instrument is the interest rate which is set to implement the optimal time-consistent discretionary monetary policy.

2.3.1 The equilibrium

Under discretion, the central bank treats expected future inflation as given when setting the optimal monetary policy. The first-order conditions of its optimization problem lead to the inflation targeting rule:

$$(1+\varepsilon)\pi_t = -\frac{(\lambda-\varepsilon)}{\kappa(\sigma+\eta)-\sigma\kappa\phi}x_t \tag{2.6}$$

The system of equations (2.1)-(2.2) and (2.6) has a unique non-explosive rational expectations solution. Known as the "minimal state variable" (MSV) solution, it is obtained by using the method of undetermined coefficients (McCallum, 1983 [34]). Given that cost-push shock and demand shock constitute the only state variables in this model, the equilibrium solutions of main endogenous variables are expressed as follows:[6]

$$E_t\pi_{t+1} = \frac{\rho_u\kappa\phi\sigma E_t(\Theta)u_t}{1+\rho_u\kappa\phi\sigma\zeta E_t(\Omega)-\rho_u E_t(\Theta)(\beta+\kappa\phi)} + \frac{\rho_e E_t(\Theta)e_t}{1+\rho_e\kappa\phi\sigma\zeta E_t(\Omega)-\rho_e E_t(\Theta)(\beta+\kappa\phi)}, \tag{2.7}$$

$$E_t x_{t+1} = \frac{-\rho_u\kappa\phi\sigma\zeta E_t(\Omega)u_t}{1+\rho_u\kappa\phi\sigma\zeta E_t(\Omega)-\rho_u E_t(\Theta)(\beta+\kappa\phi)} + \frac{-\rho_e\zeta E_t(\Omega)e_t}{1+\rho_e\kappa\phi\sigma\zeta E_t(\Omega)-\rho_e E_t(\Theta)(\beta+\kappa\phi)}, \tag{2.8}$$

[5] In this chapter, we abstract from discussing optimal policy under commitment and focus on discretionary policy. Under discretion, the central bank re-optimizes its objective function period by period taking inflation expectations in each period as given. Under commitment, the central bank takes advantage of the forward-looking nature of inflation expectations through the introduction of policy inertia. An extension of the present analysis to the case of commitment could be easily carried out as in Dai (2014) [14], who has shown that, in the absence of the cost channel, commitment would reinforce the welfare-improving effects of opacity and hence render the latter more desirable compared to discretion.

[6] The details of solution is available but not included in this dissertation.

$$\pi_t = \frac{\kappa\phi\sigma\Theta u_t}{1 + \rho_u\kappa\phi\sigma\zeta E_t(\Omega) - \rho_u E_t(\Theta)(\beta + \kappa\phi)} + \frac{\Theta e_t}{1 + \rho_e\kappa\phi\sigma\zeta E_t(\Omega) - \rho_e E_t(\Theta)(\beta + \kappa\phi)}, \tag{2.9}$$

$$x_t = -\frac{\kappa\phi\sigma\zeta\Omega u_t}{1 + \rho_u\kappa\phi\sigma\zeta E_t(\Omega) - \rho_u E_t(\Theta)(\beta + \kappa\phi)} + \frac{\zeta\Omega e_t}{1 + \rho_e\kappa\phi\sigma\zeta E_t(\Omega) - \rho_e E_t(\Theta)(\beta + \kappa\phi)}, \tag{2.10}$$

where $\Omega \equiv \frac{1+\varepsilon}{\lambda-\varepsilon+\zeta^2(1+\varepsilon)}$ and $\Theta \equiv \frac{\lambda-\varepsilon}{\lambda-\varepsilon+\zeta^2(1+\varepsilon)}$ with $\zeta \equiv \kappa(\sigma+\eta) - \sigma\kappa\phi$. Their expected values are approximated using the second-order Taylor development as $E_t(\Theta) \cong \frac{\lambda}{\lambda+\zeta^2} - \frac{\zeta^2(1+\lambda)(1-\zeta^2)}{(\lambda+\zeta^2)^3}\sigma_\varepsilon^2 < 1$ and $E_t(\Omega) \cong \frac{1}{\lambda+\zeta^2} + \frac{(1+\lambda)(1-\zeta^2)}{(\lambda+\zeta^2)^3}\sigma_\varepsilon^2$. To ensure that a positive cost-push or demand shock always induces an increase in the expected inflation, we assume the denominators in (2.7)-(2.10) are positive.[7]

The variances of inflation and the output gap are calculated using (2.9) and (2.10) as:

$$\begin{aligned}\operatorname{var}(\pi_t) =& \frac{\kappa^2\phi^2\sigma^2 E_t(\Theta^2)}{[1 + \rho_u\kappa\phi\sigma\zeta E_t(\Omega) - \rho_u E_t(\Theta)(\beta + \kappa\phi)]^2}\sigma_u^2 \\ &+ \frac{E_t(\Theta^2)}{[1 + \rho_e\kappa\phi\sigma\zeta E_t(\Omega) - \rho_e E_t(\Theta)(\beta + \kappa\phi)]^2}\sigma_e^2,\end{aligned} \tag{2.11}$$

$$\begin{aligned}\operatorname{var}(x_t) =& \frac{\kappa^2\phi^2\sigma^2\zeta^2 E_t(\Omega^2)}{[1 + \rho_u\kappa\phi\sigma\zeta E_t(\Omega) - \rho_u E_t(\Theta)(\beta + \kappa\phi)]^2}\sigma_u^2 \\ &+ \frac{\zeta^2 E_t(\Omega^2)}{[1 + \rho_e\kappa\phi\sigma\zeta E_t(\Omega) - \rho_e E_t(\Theta)(\beta + \kappa\phi)]^2}\sigma_e^2,\end{aligned} \tag{2.12}$$

where $\sigma_e^2 = \operatorname{var}(e_t)$ and $\sigma_u^2 = \operatorname{var}(u_t)$. $E_t(\Omega^2)$ and $E_t(\Theta^2)$ are respectively approximated using the second-order Taylor development as $E(\Omega^2) \cong \frac{1}{(\lambda+\zeta^2)^2} + \frac{(1+\lambda)(1+3-2\zeta^2)}{(\lambda+\zeta^2)^4}\sigma_\varepsilon^2$ and $E_t(\Theta^2) \cong \frac{\lambda^2}{(\lambda+\zeta^2)^2} + \frac{\zeta^2(1+\lambda)[\zeta^2+\lambda(3\zeta^2-2)]}{(\lambda+\zeta^2)^4}\sigma_\varepsilon^2$.

Examining solutions (2.7)-(2.12), we notice that opacity impacts $E_t\pi_{t+1}$, $E_t x_{t+1}$, $\operatorname{var}(\pi_t)$ and $\operatorname{var}(x_t)$ through both the numerator and the denominator while affecting π_t and x_t only via the denominator. The presence of the cost channel ($\phi = 1$) implies that opacity also affects endogenous variables and their volatility through the demand shock. Their effects are not anymore neutralized as in the case of the standard New Keynesian model. Furthermore, the cost channel affects the intensity of the effects of opacity on the levels and volatility of inflation and the output gap through inflation shocks. Given that the

[7]Using parameter values in Ravenna and Walsh (2006) [36], i.e., $\kappa = 0.0858$, $\sigma = 1.5$, $\eta = 1$, $\beta = 0.99$ and $\lambda = 0.25$, we have checked that the denominators in (2.7)-(2.10) are positive for $\phi = 1$, ρ_u, $\rho_e < 0.997$ and $\sigma_\varepsilon^2 = 0$.

effects of opacity through inflation shocks in the standard New Keynesian model have been extensively studied in Dai (2014) [14], we focus in this study on the effects of opacity through the demand shock and how the cost channel modifies the effects of opacity when the economy is hit by inflation shocks.

2.4 The equilibrium effects of central bank opacity

Intransparency indirectly exerts its effects on inflation and the output gap through the inflation expectations (or indirect) channel. Intransparency affects the volatility of inflation and the output gap through both this indirect channel and the policy rule (or direct) channel. The latter corresponds to the fact that uncertainty about the central bank's preferences modifies the average slope of the monetary policy rule (2.6), and hence the response of inflation and the output gap to inflation and demand shocks and their respective volatilities. In addition, the effects of opacity through these two channels are affected by the cost channel affecting the firms decisions.

Distinguishing these channels, we examine the effects of opacity by considering first uncorrelated and then correlated inflation and demand shocks.

2.4.1 Serially uncorrelated inflation and demand shocks

This is the case where $\rho_e = \rho_u = 0$, implying that $E_t e_{t+1} = 0$ and $E_t u_{t+1} = 0$, and hence $E_t \pi_{t+1} = 0$. Given that $E_t \pi_{t+1} = 0$, the effects of opacity on the average level and volatility of inflation and the output gap are transmitted through the policy rule channel.

Studying the response of $\pi_t, x_t, E_t(\frac{\partial \pi_t}{\partial e_t})$, $E_t(\frac{\partial \pi_t}{\partial u_t})$, $E_t(\frac{\partial x_t}{\partial e_t})$, $E_t(\frac{\partial x_t}{\partial u_t})$, $\text{var}(\pi_t)$ and $\text{var}(x_t)$ to a decrease in transparency leads to following propositions.

Proposition 1. *When inflation and demand shocks are serially uncorrelated, the level of inflation and the output gap are not affected by intransparency for a given preference shock. Under the cost channel, a lower degree of transparency reduces (increases) the average response of inflation (the output gap) to inflation and demand shocks if* $\kappa(\sigma+\eta)-\sigma\kappa\phi < 1$.

Proof. Deriving (2.9) and (2.10) with respect to e_t (or u_t) and σ_ε^2 for $\rho_e = 0$ (or $\rho_u = 0$) leads to the results reported in the first part of Proposition 1. Calculating $E_t(\frac{\partial \pi_t}{\partial e_t})$, $E_t(\frac{\partial \pi_t}{\partial u_t})$, $E_t(\frac{\partial x_t}{\partial e_t})$ and $E_t(\frac{\partial x_t}{\partial u_t})$ using (2.9) and (2.10), and deriving the results with respect to σ_ε^2 for $\rho_e = 0$, $\rho_u = 0$ and $\zeta \equiv \kappa(\sigma+\eta) - \sigma\kappa\phi < 1$ lead to the results reported in the second part of Proposition 1. ■

Proposition 2. *Intransparency reduces the volatility of inflation if* $\kappa(\sigma+\eta) - \sigma\kappa\phi < \sqrt{\frac{2\lambda}{1+3\lambda}}$ *and vice versa. It increases the volatility of the output gap if* $\kappa(\sigma+\eta)-\sigma\kappa\phi < \sqrt{\frac{\lambda+3}{2}}$ *and vice versa. Without the cost channel, the effect of intransparency is only associated* *with inflation shocks and the previous conditions become* $\kappa(\sigma+\eta) < \sqrt{\frac{2\lambda}{1+3\lambda}}$ *and* $\kappa(\sigma+\eta) < \sqrt{\frac{\lambda+3}{2}}$.

Proof. Deriving $\text{var}(\pi_t)$ and $\text{var}(x_t)$ given by (2.11)-(2.12) with respect to σ_e^2 and σ_ε^2 for $\rho_e = 0$ leads to

$$\frac{\partial^2 \text{var}(\pi_t)}{\partial\sigma_e^2 \partial\sigma_\varepsilon^2} = \frac{\partial E_t(\Theta^2)}{\partial\sigma_\varepsilon^2} = \frac{\zeta^2(1+\lambda)\left[\zeta^2 + \lambda(3\zeta^2 - 2)\right]}{(\lambda+\zeta^2)^4} < 0, \quad \text{if } \zeta < \sqrt{\frac{2\lambda}{1+3\lambda}}, \tag{2.13}$$

$$\frac{\partial^2 \text{var}(x_t)}{\partial\sigma_e^2 \partial\sigma_\varepsilon^2} = \frac{\partial E_t(\Omega^2)}{\partial\sigma_\varepsilon^2} = \frac{\zeta^2(1+\lambda)(\lambda+3-2\zeta^2)}{(\lambda+\zeta^2)^4} > 0, \quad \text{if } \zeta < \sqrt{\frac{\lambda+3}{2}}. \tag{2.14}$$

Similar results could be obtained for $\frac{\partial^2 \text{var}(\pi_t)}{\partial\sigma_u^2 \partial\sigma_\varepsilon^2}$ and $\frac{\partial^2 \text{var}(x_t)}{\partial\sigma_u^2 \partial\sigma_\varepsilon^2}$ for $\rho_u = 0$. ■

The results presented in Propositions 1 and 2 reflect the absence of the inflation expectations channel in the transmission of the effects of opacity on inflation and the output gap. In effect, when inflation and demand shocks are serially uncorrelated, the expected inflation rate is always equal to zero. Thus, it is through the policy rule channel that the average response and the volatility of inflation and the output gap are affected by opacity.

For $\phi = 0$, the cost channel is removed from the model. Thus, we fall back to the canonical New Keynesian framework where the effects of imperfect transparency are only related to inflation shocks, given that demand shocks are fully neutralized by the optimal monetary policy and do not affect inflation and the output gap. In the absence of the cost channel, the conditions in Propositions 1 and 2 become more restrictive.

Under the cost channel ($\phi = 1$), changes in the short-term interest rate shift the Phillips curve, implying that the optimal monetary policy will no longer be able to neutralize the effects of demand shocks on inflation and the output gap. Thus, intransparency affects the level and volatility of these variables in their response to both inflation and demand shocks. Using the standard parameter values ($\kappa = 0.0858$, $\eta = 1$ and $\sigma = 1.5$) into (2.9)-(2.10) and (2.11)-(2.12), we find that the effects of imperfect transparency in the case of demand shocks represents a fraction of those in the case of inflation shocks if these two types of shocks have the same variance. If demand shocks have a variance significantly higher than inflation shocks, the effects of opacity associated with demand shocks could still be substantial.

The results in Propositions 1 and 2 crucially depend on the value of the term $\kappa(\sigma + \eta) - \sigma\kappa\phi$. For the standard parameter values in Ravenna and Walsh (2006) [36], we have $\kappa(\sigma + \eta) - \sigma\kappa\phi = 0.0858 \times (2.5 - \phi) < 1$ for both $\phi = 0$ and $\phi = 1$. Thus, for these parameter values, the conditions $\zeta \equiv \kappa(\sigma+\eta) - \sigma\kappa\phi > \sqrt{\frac{\lambda+3}{2}}$ and $\kappa(\sigma+\eta) > \sqrt{\frac{\lambda+3}{2}}$ are not verified, meaning that the case where imperfect transparency decreases the volatility of the output gap is eliminated.

2.4.2 Serially correlated inflation shocks

Consider now that inflation and demand shocks are persistent, i.e., $0 < \rho_e < 1$ and $0 < \rho_u < 1$. As we have observed in the above, the numerical values set for parameters are such that $\zeta \equiv \kappa(\sigma+\eta) - \sigma\kappa\phi$ is generally quite small. Thus, we consider in the following only the case $\zeta \equiv \kappa(\sigma+\eta) - \sigma\kappa\phi < 1$ when examining the effect of imperfect transparency on the level and volatility of inflation and the output gap.

Under persistent inflation shocks, expected future inflation rates will be different from zero independently of the presence or not of the cost channel. However, the latter is crucial for the expected future inflation to depend on persistent demand shocks. This is explained by both the repercussions of current inflation (or demand) shocks on future inflations and the response of the central bank to these shocks. Equation (2.7) implies that

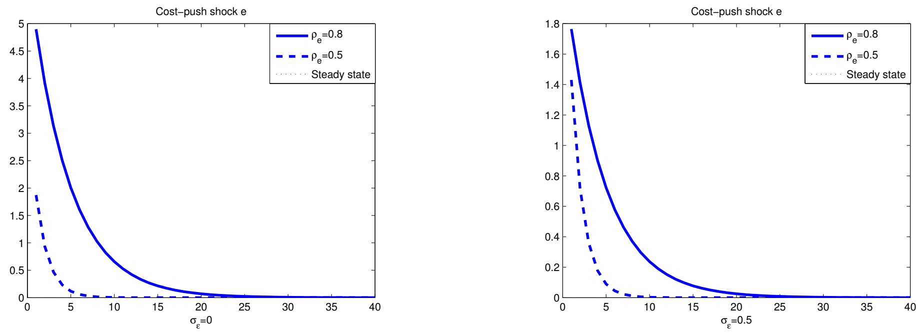
$$\frac{\partial^2 E_t \pi_{t+1}}{\partial u_t \partial \sigma_\varepsilon^2} = \frac{-\rho_u \kappa\phi\sigma\zeta(1+\lambda)(1-\zeta^2)(\zeta+\rho_u\kappa\phi\sigma)}{(\lambda+\zeta^2)^3\left[1+\rho_u\kappa\phi\sigma\zeta E_t(\Omega) - \rho_u E_t(\Theta)(\beta+\kappa\phi)\right]^2} < 0, \quad \text{if } \zeta < 1, \tag{2.15}$$

$$\frac{\partial^2 E_t \pi_{t+1}}{\partial e_t \partial \sigma_\varepsilon^2} = \frac{-\rho_e \zeta(1+\lambda)(1-\zeta^2)(\zeta+\rho_e\kappa\phi\sigma)}{(\lambda+\zeta^2)^3\left[1+\rho_e\kappa\phi\sigma\zeta E_t(\Omega) - \rho_e E_t(\Theta)(\beta+\kappa\phi)\right]^2} < 0, \quad \text{if } \zeta < 1. \tag{2.16}$$

Provided that $\frac{\partial^2 E_t \pi_{t+1}}{\partial e_t} > 0$ and $\frac{\partial^2 E_t \pi_{t+1}}{\partial u_t} > 0$, these second-order partial derivatives suggest that intransparency will induce the private sector to moderate the adjustment of inflation expectations in response to current inflation and demand shocks. Thus, the central bank could reduce the response of inflation (and hence the output gap) to inflation and demand shocks by being opaque. Without the cost channel, $\phi = 0$, we have $\frac{\partial^2 E_t \pi_{t+1}}{\partial e_t \partial \sigma_\varepsilon^2} = \frac{-\rho_e \zeta(1+\lambda)(1-\zeta^2)\zeta}{(\lambda+\zeta^2)^3[1-\rho_e E_t(\Theta)\beta]^2} < 0$, if $\zeta < 1$ and $\frac{\partial^2 E_t \pi_{t+1}}{\partial u_t \partial \sigma_\varepsilon^2} = 0$.

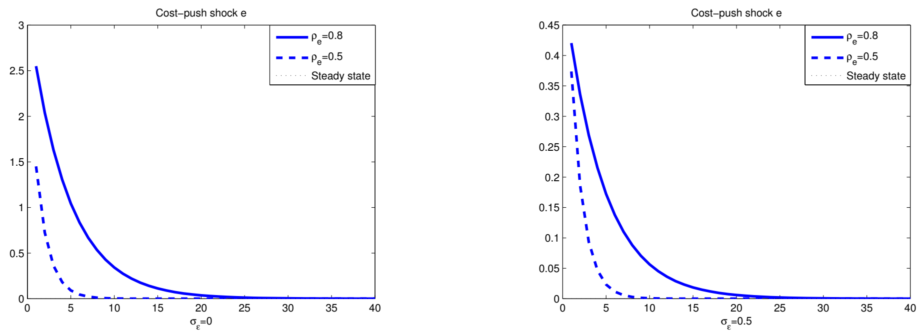
Proposition 3. *With the cost channel, opacity attenuates the response of inflation, inflation expectations and the output gap to a serially correlated inflation or demand shock, for $\kappa(\sigma+\eta) - \sigma\kappa\phi < 1$. Without the cost channel, the effect of opacity is only associated with inflation shocks and the previous condition becomes $\kappa(\sigma+\eta) < 1$.*

Proof. We derive (2.9) and (2.10) with respect to e_t (or u_t) and σ_ε^2. By inserting the approximated value of $E_t(\Theta)$ and $E_t(\Omega)$ into the resulting derivatives, it is straightforward to obtain the effects of opacity on inflation and the output gap reported in Proposition 3. The effect of opacity on inflation expectations follows from (2.15) and (2.16). ■



(a) $\sigma_\varepsilon = 0$ **(b)** $\sigma_\varepsilon = 0.5$

Figure 2.1: *The effects of opacity on the response of the expected inflation to cost-push shocks with* $\phi = 1$



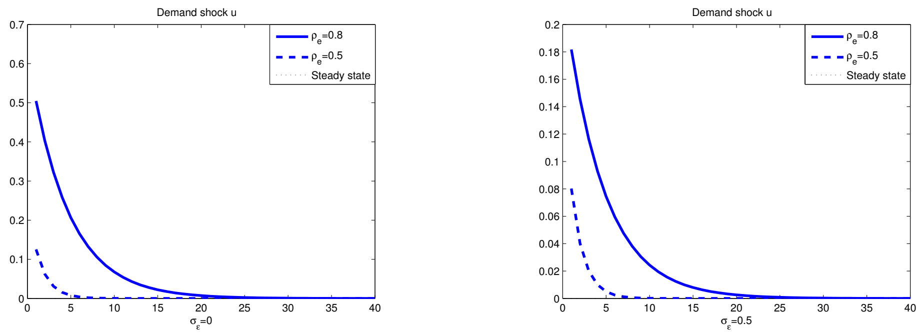
(a) $\sigma_\varepsilon = 0$ **(b)** $\sigma_\varepsilon = 0.5$

Figure 2.2: *The effects of opacity on the response of the expected inflation to cost-push shocks with* $\phi = 0$

To grasp the relative importance of the effects of imperfect transparency on the expected inflation with and without the cost channel during the dynamic adjustment, we resort to numerical simulation by calibrating $\kappa = 0.0858$, $\sigma = 1.5$, $\beta = 0.99$, $\lambda = 0, 25$ and $\eta = 1$. We consider one percent cost-push or demand shock with two degrees of persistence, i.e., ρ_e,$\rho_u = 0.5$ and ρ_e, $\rho_u = 0.8$, and two values for initial degrees of opacity $\sigma_\varepsilon = 0$ and $\sigma_\varepsilon = 5$. Given these parameter values, we simulate the response of the expected inflation to inflation shocks with the cost channel (Figure 2.1) and without the cost channel (Figure 2.2).

Figure 2.1 and Figure 2.2 show that the cost channel significantly reinforces the response of inflation expectations to cost-push shocks. Therefore, as shown by the comparison of Figure 2.1 and Figure 2.2, the cost channel clearly reinforces the moderating effect of opacity on inflation expectations in absolute terms but not necessarily in relative terms. In all cases, an increase in the persistence of shocks reinforces the effect of opacity.

Figure 2.3 illustrates the dynamic response of the expected inflation to demand shocks and shows that an increase in the initial degree of opacity σ_ε from 0 to 0.5 reduces more than half the effect of demand shocks on the expected inflation when $\rho_u = 0.8$. This attenuation effect of opacity is significantly smaller in relative terms when $\rho_u = 0.5$ than when $\rho_u = 0.8$.



(a) $\sigma_\varepsilon = 0$ **(b)** $\sigma_\varepsilon = 0.5$

Figure 2.3: *The effects of opacity on the response of the expected inflation to demand shocks with* $\phi = 1$

In the absence of the cost channel, the Phillips curve is independent of the interest rate and thus, opacity affects inflation and the output gap through the inflation expectations channel only when the inflation shock is persistent. In contrast, with the presence of the cost channel, an inflation shock affects the inflation dynamics through policy rule and inflation expectations channels, as well as the funding cost channel. Thus, under the cost channel, the effects of intransparency could play a greater role in stabilizing the economy. However, since other factors (notably, the persistence of shocks) could also influence the equilibrium, the final impact of the cost channel on the effects of opacity associated with inflation shocks cannot be determined with clear-cut conditions.

The above results show that inflation expectations are less responsive to current monetary policy actions characterized by imperfect transparency. This is consistent with the consensus in the literature on central bank transparency, which suggests that imperfect transparency deteriorates the private sectors understanding of the central bank's objectives and decisions. On the other hand, only unanticipated changes in monetary policy could affect the real economy, implying that imperfect transparency may increase the effectiveness of monetary policy by permitting the latter to surprise the public. By reducing (but increasing) the welfare costs of achieving a higher level of output gap (inflation), intransparency enhances the central bank's ability to mitigate the effect of an inflation shock (and a demand shock under the cost channel) on the economy. This explains that it helps to smooth the response of inflation to shocks but amplify those of the output gap. Moreover, if the central bank has a greater preference for the inflation stabilization, these effects could be reinforced due to an increased possibility of trade-off between stabilizing the output gap and stabilizing inflation.

The role of intransparency in the monetary policy transmission mechanism depends on the persistence of inflation and demand shocks. A higher degree of persistence of these shocks, by inducing higher inflation expectations, reinforces the role of intransparency and therefore amplifies its attenuation effect on the expected inflation rate (Figure 2.1, 2.2 and 2.3).

Denote $\Gamma = \frac{(\lambda+\zeta^2)^3+\rho_u(\lambda+\zeta^2)^2[(\beta+\kappa\phi)\lambda-\kappa\phi\sigma\zeta]}{\rho_u(1+\lambda)(1-\zeta^2)[\kappa\phi\sigma\zeta+(\beta+\kappa\phi)\zeta^2]}$. Examining the interactions between the effects of persistence and opacity on inflation and the output gap leads to the following proposition.

Proposition 4. *For $\kappa(\sigma+\eta)-\sigma\kappa\phi<1$, an increase in the persistence of inflation or demand shocks strengthens the effects of intransparency on inflation expectations. It could reinforce the effects of intransparency on inflation and the output gap if: a) $\lambda > \frac{\kappa\sigma\zeta}{\beta+\kappa}$ and $\sigma_\varepsilon^2 < \Gamma$ are simultaneously verified; b) $\lambda < \frac{\kappa\sigma\zeta}{\beta+\kappa}$, ρ_u,$\rho_e < \frac{\lambda+\zeta^2}{\kappa\sigma\zeta-\lambda(\beta+\kappa)}$ and $\sigma_\varepsilon^2 < \Gamma$ are simultaneously verified.*

Proof. See Appendix A1. ■

Our previous propositions show that the serial correlation of inflation and demand shocks leads to, under opacity, a larger response of inflation expectations to both types of shocks if the output-gap elasticity of the inflation ($\zeta \equiv \kappa(\sigma+\eta)-\sigma\kappa\phi$ or $\zeta \equiv \kappa(\sigma+\eta)$ respectively in the presence or the absence of the cost channel) is lower than unity. In the absence of the cost channel, an increase in the persistence of inflation shocks amplifies the effect of opacity on inflation and the output gap through the channel of inflation expectations. However, under the cost channel, an increase in the persistence of both types of shocks could affect, through the interactions between the cost channel and opacity, the equilibrium solutions of inflation and the output gap in the opposite direction of the inflation expectation channel. Therefore, it could either amplify or attenuate the effect of opacity. The effect of imperfect transparency on inflation and the output gap through the policy rule channel manifests itself in the average response of these variables.

Proposition 5. *For $\kappa(\sigma+\eta)-\sigma\kappa\phi<1$, opacity attenuates the average response of inflation to serially correlated inflation and demand shocks. It strengthens the average response of the output gap to these shocks if $\rho_u < \frac{1}{\beta+\kappa\phi}$.*

Proof. See Appendix A2. ■

Without the cost channel, given that serially correlated demand shocks do not affect inflation and the output gap, opacity has no impact on the average response of inflation and the output gap to these shocks. Furthermore, the condition $\rho_u < \frac{1}{\beta+\kappa\phi}$ is redundant since $\phi = 0$ leads to $\frac{1}{\beta+\kappa\phi} > 1$.

Due to the presence of the cost channel, the effect of serially correlated demand shocks is not anymore neutralized by the optimal monetary policy. The average response of inflation and the output gap to serially correlated inflation shocks are thus also modified by imperfect transparency according to its initial degree. Moreover, the sign of its effect on the output gap depends on the degree of persistence of shocks.

The denominator in (2.9) and (2.10), i.e. $1 + \rho_j \kappa\phi\sigma\zeta E_t(\Omega) - \rho_j E_t(\Theta)(\beta + \kappa\phi)$, with $j = u, e$, is increasing in σ_ε^2 given that $E_t(\Omega)$ and $E_t(\Theta)$ are respectively increasing and decreasing in σ_ε^2. Consequently, the effects of opacity reported in Proposition 5 become less important following an increase in the initial degree of opacity.

However, with the cost channel, the relationship between the persistence of shocks and the effects of opacity on the average response of endogenous variables becomes ambiguous. In effect, an increase in the degree of persistence induces a higher expected future inflation according to Proposition 3, implying that opacity generally has a stronger negative effect on inflation expectations and hence makes a larger impact on inflation and the output gap on average. On the other hand, a higher degree of persistence reinforces the effects of shocks on endogenous variables through the policy rule channel. Deriving $E\left[\frac{\partial \pi_t}{\partial u_t}\right]$ and $E\left[\frac{\partial x_t}{\partial u_t}\right]$ with respect to ρ_u, and $E\left[\frac{\partial \pi_t}{\partial e_t}\right]$ and $E\left[\frac{\partial x_t}{\partial e_t}\right]$ respect to ρ_e, and comparing the resulting second derivatives with these first-order derivatives lead to the following proposition.

Proposition 6. *An increase in the degree of persistence of inflation and demand shocks increases the attenuation effect of opacity on the average inflation if* $\frac{\kappa\phi}{\beta+\kappa\phi} < \frac{E_t(\Theta)}{\sigma\zeta E_t(\Omega)}$ *but reduces its effect if* $\frac{\kappa\phi}{\beta+\kappa\phi} > \frac{E_t(\Theta)}{\sigma\zeta E_t(\Omega)}$ *and* $\rho_u, \rho_e > \frac{1}{\kappa\phi\sigma\zeta E_t(\Omega) - E_t(\Theta)(\beta+\kappa\phi)} - 2\zeta$ *for* $\zeta \equiv \kappa(\sigma + \eta) - \sigma\kappa\phi < 1$. *When the initial degree of persistence is relatively low, i.e.,* ρ_u, $\rho_e < \frac{1}{\beta+\kappa\phi}$, *an increase in the persistence will reduce the amplification effect of opacity on the average output gap if* $\frac{\kappa\phi}{\beta+\kappa\phi} < \frac{E_t(\Theta)}{\sigma\zeta E_t(\Omega)}$, *and vice versa.*

Proof. See Appendix A3. ■

When $\phi = 0$, the condition $\frac{\kappa\phi}{\beta+\kappa\phi} < \frac{E_t(\Theta)}{\sigma\zeta E_t(\Omega)}$ is always verified and the case where $\frac{\kappa\phi}{\beta+\kappa\phi} > \frac{E_t(\Theta)}{\sigma\zeta E_t(\Omega)}$ is excluded. Thus, without the cost channel, an increase in the persistence of inflation shocks generally reinforces (weakens) the attenuation (amplification) effects of opacity on the average response of inflation (the output gap) to inflation shocks.

Under the cost channel, we could have either $\frac{\kappa}{\beta+\kappa} < \frac{E_t(\Theta)}{\sigma\zeta E_t(\Omega)}$ or $\frac{\kappa}{\beta+\kappa} > \frac{E_t(\Theta)}{\sigma\zeta E_t(\Omega)}$, where $\frac{\kappa}{\beta+\kappa}$ represents the relative importance of the effect of inflation expectations through the cost channel κ (i.e., the interest rate in the Phillips curve) compared to the total effect of inflation expectations $\beta + \kappa$. An increase in the persistence of shocks could affect positively or negatively the effect of opacity on the average inflation and output gap through above-mentioned three channels. The importance of the effects through these channels crucially depend on the threshold conditions imposed on the degree of persistence as well as $\frac{\kappa}{\beta+\kappa} < \frac{E_t(\Theta)}{\sigma\zeta E_t(\Omega)}$ or $\frac{\kappa}{\beta+\kappa} > \frac{E_t(\Theta)}{\sigma\zeta E_t(\Omega)}$. The latter could be expressed in terms of threshold conditions imposed on the preference parameter for output-gap stabilization. Using $\zeta \equiv \kappa(\sigma + \eta) - \sigma\kappa = \kappa\eta$ and the approximated values of $E_t(\Omega)$ and $E_t(\Theta)$, we can show that $\frac{\kappa}{\beta+\kappa} < \frac{E_t(\Theta)}{\sigma\zeta E_t(\Omega)}$ is equivalent to $\lambda > \frac{\sigma\eta\kappa^2}{\beta+\kappa} + \frac{(1+\lambda)(\lambda+\zeta^2)(1-\zeta^2)\sigma_\varepsilon^2}{(\lambda+\zeta^2)^2+(1+\lambda)(1-\zeta^2)\sigma_\varepsilon^2}$ and vice versa. When $\sigma_\varepsilon^2 = 0$, the last condition becomes $\lambda > \frac{\sigma\eta\kappa^2}{\beta+\kappa}$. Using the standard parameter values, we obtain $\lambda > \frac{\sigma\eta\kappa^2}{\beta+\kappa} = 0.01026$. Except when the central banker is an inflation nutter and practices strict inflation targeting, the previous condition is generally verified. However, given that the term $\frac{(1+\lambda)(\lambda+\zeta^2)(1-\zeta^2)\sigma_\varepsilon^2}{(\lambda+\zeta^2)^2+(1+\lambda)(1-\zeta^2)\sigma_\varepsilon^2}$ is increasing in σ_ε^2, the threshold condition on λ could be significantly relaxed when σ_ε^2 is large, making more likely the case where we have $\frac{\kappa}{\beta+\kappa} > \frac{E_t(\Theta)}{\sigma\zeta E_t(\Omega)}$ and hence an increase in the persistence of shocks weakens (reinforces) the attenuation (amplification) effect of opacity on the average inflation (output gap).

As the interactions between monetary policy intransparency and persistence of shocks depend on the initial degrees of opacity and persistence, in the following, we only consider the case where the initial equilibrium is characterized by full transparency, i.e. $\sigma_\varepsilon^2 = 0$, to obtain some results with clear-cut conditions when examining the effects of opacity on macroeconomic volatility. These results show under what conditions the central bank has incentive to deviate from a situation characterized by full transparency.

Proposition 7. *Without the cost channel, departing from an initial equilibrium with full transparency, an increase in opacity decreases the volatility of inflation induced by inflation shocks if* $\kappa(\sigma+\eta) < \sqrt{\frac{2\lambda}{1+3\lambda}}$, $\forall\rho \in [0,1]$ *or* $\sqrt{\frac{2\lambda}{1+3\lambda}} < \kappa(\sigma+\eta) < 1$ *and* $\rho_e > \frac{(\lambda+\zeta^2)\left\{\kappa^2(\sigma+\eta)^2+\lambda\left[3\kappa^2(\sigma+\eta)^2-2\right]\right\}}{(1+\lambda)\lambda\beta\kappa^2(\sigma+\eta)^2}$; *it increases the volatility of the output gap induced by inflation shocks if* $\kappa(\sigma+\eta) < 1$, $\forall\rho \in [0,1]$.

Proof. See Appendix A4. ■

Given that the degrees of persistence and opacity interact, the effect of an increase in opacity depends on the initial levels of ρ_u and ρ_e. The effects of opacity via the inflation expectations channel (indirect effect) on the volatility of inflation and the output gap are negative. Through the policy rule channel (direct effect), opacity has either negative or positive effect on the volatility of inflation but only positive effect on the volatility of the output gap. Therefore, the sign of the total effect of opacity through these two channels is ambiguous.

Without the cost channel ($\phi = 0$), demand shocks have no effect on the macroeconomic volatility and hence do not interact with opacity. Applying $\phi = 0$ to (2.11) and (2.12), it is straightforward to check that if $\zeta = \kappa(\sigma+\eta) < 1$, the effects of opacity on the volatility of inflation and the output gap through the inflation expectations channel are both negative. The effect of opacity on the volatility of inflation via the policy rule channel could be negative if $\kappa(\sigma+\eta) < \sqrt{\frac{2\lambda}{1+3\lambda}}$ and vice versa. Therefore, the total effect of opacity on the variance of inflation is negative either when both direct and indirect effects of opacity are negative, i.e. if $\kappa(\sigma+\eta) < \sqrt{\frac{2\lambda}{1+3\lambda}}$, or when the indirect negative effect dominates the positive direct effect, i.e., if $\sqrt{\frac{2\lambda}{1+3\lambda}} < \kappa(\sigma+\eta) < 1$ and $\rho_e > \frac{(\lambda+\zeta^2)\left\{\kappa^2(\sigma+\eta)^2+\lambda\left[3\kappa^2(\sigma+\eta)^2-2\right]\right\}}{(1+\lambda)\lambda\beta\kappa^2(\sigma+\eta)^2}$.

For $\kappa(\sigma+\eta) < 1$, the total effect of intransparency on the volatility of the output gap is positive given that the negative indirect effect is dominated by the positive direct effect whatever the degree of persistence of inflation shocks.

Proposition 8. *Under the cost channel, departing from an initial equilibrium with full transparency, an increase in opacity will reduce the volatility of inflation induced by inflation and demand shocks if* $\zeta > \sqrt{\frac{2\lambda}{1+3\lambda}}$, $\forall \rho_u, \rho_e \in [0,1]$ *or if* $\sqrt{\frac{2\lambda(1-\lambda)+\lambda\sqrt{4(1-\lambda)^2+8(1+3\lambda)}}{2(1+3\lambda)}} < \zeta < 1$, *and* $\rho_u, \rho_e > \frac{\zeta(\lambda+\zeta^2)\left[\zeta^2+\lambda(3\zeta^2-2)\right]}{\lambda(\beta+\kappa)\zeta^3(1+\lambda)-\kappa\sigma\{\zeta^2[\zeta^2+\lambda(3\zeta^2-2)]-2\lambda^2(1-\zeta^2)\}} > 0$*; it increases the volatility of the output gap induced by inflation and demand shocks if* $\frac{\kappa}{\beta+\kappa} > \frac{\lambda(\lambda+3-2\zeta^2)+2\zeta^2(1-\zeta^2)}{\sigma\zeta(1+\lambda)}$, $\forall \rho_u, \rho_e \in [0,1]$ *or if* $\frac{\kappa}{\beta+\kappa} < \frac{\lambda(\lambda+3-2\zeta^2)+2\zeta^2(1-\zeta^2)}{\sigma\zeta(1+\lambda)}$ *and* $\rho_u, \rho_e < \frac{(\lambda+\zeta^2)(\lambda+3-2\zeta^2)}{(\beta+\kappa)[\lambda(\lambda+3-2\zeta^2)+2\zeta^2(1-\zeta^2)]-\kappa\sigma\zeta(1+\lambda)}$ *for* $\zeta < 1$.

Proof. See Appendix A4. ■

Notice that the condition $\frac{\zeta(\lambda+\zeta^2)\left[\zeta^2+\lambda(3\zeta^2-2\right]}{\lambda(\beta+\kappa)\zeta^3(1+\lambda)-\kappa\sigma\{\zeta^2[\zeta^2+\lambda(3\zeta^2-2)]-2\lambda^2(1-\zeta^2)\}} > 0$ in Proposition 8 implies $\frac{\kappa}{\beta+\kappa} < \frac{\lambda\zeta^3(1+\lambda)}{\sigma\{\zeta^2[\zeta^2+\lambda(3\zeta^2-2)]-2\lambda^2(1-\zeta^2)\}}$. This means that the lower bound for the degree of persistence ρ_u, ρ_e is positive only when the effect of inflation expectations through the cost channel relative to their total effect is relatively small. Otherwise, this threshold constraint will no longer be useful. Similar comments could be made with $\frac{(\lambda+\zeta^2)(\lambda+3-2\zeta^2)}{(\beta+\kappa)[\lambda(\lambda+3-2\zeta^2)+2\zeta^2(1-\zeta^2)]-\kappa\sigma\zeta(1+\lambda)} > 0$.

Under the cost channel ($\phi = 0$), demand shocks affect macroeconomic volatility and hence interact with intransparency. Furthermore, the cost channel modifies the interactions between the effects of opacity and the effects of inflation shocks on macroeconomic volatility. These impacts are reflected in Proposition 8 by the fact that the equilibrium is similarly affected by intransparency when there are demand and inflation shocks, and that the conditions presented in Proposition 8 are significantly different from those reported in Proposition 7.

Using (2.5), we define the social welfare function as follows:

$$W^s \equiv -\frac{1}{2}E_t\sum_{i=0}^{\infty}\beta^t(\pi_t^2+\lambda x_t^2). \tag{2.17}$$

The effects of imperfect transparency on social welfare could be appreciated by examining its effects on the economy through two channels. In the present model, greater opacity makes the expected inflation, and hence the level and volatility of inflation and the output gap less responsive to current monetary policy actions, with the size of moderation effect significantly increased by the presence of the cost channel. This is because imperfect transparency deteriorates the private sector's understanding of the central bank's objectives and decisions. The second channel corresponds to the effect of opacity on the consequences of unanticipated changes in monetary policy. In effect, imperfect transparency could increase the effectiveness of monetary policy by permitting the latter to surprise the public. Thus, imperfect disclosure about central bank preferences makes easier for monetary policy to mitigate the effect of inflation and demand shocks on inflation and the output gap, and more so under the cost channel. This explains that imperfect transparency may have contradictory effects on the volatility of inflation and the output gap.

In other words, intransparent monetary policy could help smooth the variations of inflation but amplify those of the output gap because it reduces (increases) the welfare costs of achieving a higher level of output-gap (inflation). These effects are stronger when the trade-off between inflation and the output gap is larger, due to higher persistence of inflation shocks and/or lower relative weight assigned to output-gap stabilization. Therefore, the effect of imperfect transparency on social welfare will crucially depend on the relative weight that the society puts on the stabilization of the output gap. Generally, if this weight is low, imperfect transparency could improve social welfare, and much more significantly so under the cost channel.

The marginal effects of an increase in opacity on the volatility of inflation and the output gap are simulated with $\lambda = 0.50$, $\phi = 1$, $\kappa = 0.0858$, $\sigma = 1.5$, $\eta = 1$, and $\beta = 0.99$. Taking account of the constraint $\sigma_{\varepsilon}^2 \in [0, \lambda]$, we vary then the initial degree of opacity (σ_{ε}^2) d the persistence of inflation and demand shocks (ρ_e and ρ_u) to show how their effects on the volatility of inflation and the output gap interact under the cost channel and when it is absent.

The numerical results reported in Table 2.1 show that the effects of opacity on the macroeconomic volatility are more sensitive to a variation in the persistence of inflation and demand shocks than to a change in the initial degree of opacity. More precisely, the marginal effects of opacity associated with demand shocks are present only under the cost channel and they are generally small for one percent demand shocks. However, the fact that demand shocks could explain 40 to over 95 percent of short-run economic fluctuations (Blanchard and Quah, 1989 [3] and Dufourt, 2005 [19]) implies that the total effect of opacity associated with such shocks could be quite important. Furthermore, their significance is reinforced when the degree of persistence of demand shocks is high and the initial degree of opacity is low. As regard to the effects of an increase in opacity associated with inflation shocks, they are very sensitive to the latters persistence for a given initial degree of opacity but not too sensitive to a change in the initial degree of opacity except when the degree of persistence of inflation shocks is high. At low degrees of persistence, an increase in opacity has weaker effects on the volatility of inflation than on the output gap and would actually decrease social welfare measured by (2.17) if the weight assigned by the society to the stabilization of the output gap is not too low. For $\rho \leq 0.70$, opacity would likely to have smaller negative effect on social welfare under the cost channel because it, while attenuating less the volatility of inflation, amplifies much less the volatility of the output gap in absolute terms. At high degrees of persistence, opacity clearly improves

$\sigma_\varepsilon^2 = 0.05$						
		$\rho = 0.1$	$\rho = 0.3$	$\rho = 0.5$	$\rho = 0.7$	$\rho = 0.9$
$\partial^2 var(\pi_t)/\partial\sigma_e^2\partial\sigma_\varepsilon^2$	$\phi = 1$	-0.23	-0.53	-1.60	-8.67	-470.54
	$\phi = 0$	-0.87	-1.52	-3.15	-8.90	-51.93
$\partial^2 var(\pi_t)/\partial\sigma_u^2\partial\sigma_\varepsilon^2$	$\phi = 1$	0.0	-0.01	-0.03	-0.14	-7.79
	$\phi = 0$	0	0	0	0	0
$\partial^2 var(x_t)/\partial\sigma_e^2\partial\sigma_\varepsilon^2$	$\phi = 1$	0.72	1.20	2.40	6.98	76.43
	$\phi = 0$	3.17	4.82	8.21	16.91	52.28
$\partial^2 var(x_t)/\partial\sigma_u^2\partial\sigma_\varepsilon^2$	$\phi = 1$	0.01	0.02	0.04	0.12	1.27
	$\phi = 0$	0	0	0	0	0
$\sigma_\varepsilon^2 = 0.25$						
		$\rho = 0.1$	$\rho = 0.3$	$\rho = 0.5$	$\rho = 0.7$	$\rho = 0.9$
$\partial^2 var(\pi_t)/\partial\sigma_e^2\partial\sigma_\varepsilon^2$	$\phi = 1$	-0.23	-0.50	-1.40	-6.38	-134.56
	$\phi = 0$	-0.85	-1.38	-2.56	-5.87	-20.80
$\partial^2 var(\pi_t)/\partial\sigma_u^2\partial\sigma_\varepsilon^2$	$\phi = 1$	-0.00	-0.01	-0.02	-0.11	-2.23
	$\phi = 0$	0	0	0	0	0
$\partial^2 var(x_t)/\partial\sigma_e^2\partial\sigma_\varepsilon^2$	$\phi = 1$	0.71	1.14	2.11	5.13	21.86
	$\phi = 0$	3.09	4.38	6.66	11.19	20.94
$\partial^2 var(x_t)/\partial\sigma_u^2\partial\sigma_\varepsilon^2$	$\phi = 1$	0.01	0.02	0.03	0.09	0.36
	$\phi = 0$	0	0	0	0	0
$\sigma_\varepsilon^2 = 0.45$						
		$\rho = 0.1$	$\rho = 0.3$	$\rho = 0.5$	$\rho = 0.7$	$\rho = 0.9$
$\partial^2 var(\pi_t)/\partial\sigma_e^2\partial\sigma_\varepsilon^2$	$\phi = 1$	-0.23	-0.48	-1.24	-4.82	-55.78
	$\phi = 0$	-0.83	-1.26	-2.11	-4.09	-10.33
$\partial^2 var(\pi_t)/\partial\sigma_u^2\partial\sigma_\varepsilon^2$	$\phi = 1$	-0.00	-0.01	-0.02	-0.08	-0.92
	$\phi = 0$	0	0	0	0	0
$\partial^2 var(x_t)/\partial\sigma_e^2\partial\sigma_\varepsilon^2$	$\phi = 1$	0.70	1.08	1.86	3.88	9.06
	$\phi = 0$	3.01	3.99	5.48	7.78	10.39
$\partial^2 var(x_t)/\partial\sigma_u^2\partial\sigma_\varepsilon^2$	$\phi = 1$	0.01	0.02	0.03	0.06	0.15
	$\phi = 0$	0	0	0	0	0

Table 2.1: *The marginal effects of opacity on macroeconomic volatility*

social welfare even if the weight put on the output gap stabilization is relatively high and much more so under the cost channel, particularly when the initial degree of opacity is low.

2.5 Conclusions

This chapter has examined the effects of political transparency under optimal monetary discretion in a forward-looking New Keynesian model with a role for the cost channel in the transmission of monetary policy. The direct dependence of firms marginal cost and hence price decisions on the nominal rate of interest implies that both inflation and demand shocks to the economy can generate a trade-off between stabilizing inflation and stabilizing the output gap, and thus central bank transparency could interact not only with inflation shocks but also with demand shocks.

We find that imperfect transparency about the relative weight assigned by the central bank to output-gap stabilization modifies the impacts of inflation and demand shocks on the economy in the same direction but with different amplitudes. The effects of imperfect transparency also vary according to the degree of persistence of these shocks.

If inflation and demand shocks are serially uncorrelated, imperfect transparency does not modify inflation expectations and hence has no effect on the level of inflation and the output gap through this channel. Given that the equilibrium value of these variables are affected by shocks to central bank preferences, an increase in opacity reduces (increases) the average response of inflation (the output gap) to inflation and demand shocks for standard parameter values, implying a reduction (an increase) in the volatility of inflation (the output gap). The effects of opacity associated with demand shocks could be substantial since empirical evidence shows that the latter have a significantly higher volatility than supply shocks.

Serial correlation of inflation and demand shocks attenuates the response of inflation and the output gap to inflation or demand shocks in the New Keynesian model with the cost channel through the inflation expectations channel. However, through the policy rule channel, higher persistence of inflation shocks reinforces (reduces) the attenuation (amplification) effect of opacity on the average response of inflation (the output gap) to inflation and demand shocks. In terms of macroeconomic performance, the volatility of inflation decreases with opacity while the volatility of the output gap increases with it, and both of them increase with shock persistence. The cost channel clearly amplifies the size of effects of opacity due to inflation shocks on endogenous variables and social welfare and it reinforces the effects of opacity associated with persistence. Generally, intransparency could improve social welfare if the society is quite conservative in the sense of assigning a low weight to output-gap stabilization and more significantly so when the cost channel is present.

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Chapter 3

Imperfect financial intermediation and business cycle fluctuations

3.1 Introduction

Over the past two decades, there has been an increasing emphasis in macroeconomic research that the financial market frictions play an important role in business cycles. Starting with the well known theoretical studies of Bernanke and Gertler (1989) [1] and Kiyotaki and Moore (1997) [27], a large body of literature has shown that the presence of financial market frictions can transform relative small exogenous shocks into large business cycle fluctuations. Most of these models that incorporate financial market frictions focus mainly on the demand side of the credit market. It models the financial accelerator working via consumers or producing firms' balance sheets but based on the assumption that the credit intermediation process is frictionless and as a result have not addressed the nontrivial role of banks in cyclical fluctuations.[1] More recently, the dramatic events unfolding in the Great Recession during the last few years have shown that the financial intermediation sector's activities can be an important source of business cycle fluctuations and have made it clear that a framework for macroeconomic analysis needs to allocate a nontrivial role for banks and takes account of the frictions that can impede an efficient supply of credit.

The objective of this chapter is to analyze the effect of frictions in the financial intermediation sector on financial conditions and hence the real economy. We propose a framework for study with a view to addressing the following questions. Do financial frictions that arise in the process of financial intermediaries raising funds affect the transmission of the exoge-

[1] See for example, the real model of Carlstrom and Fuerst (1997) [7], the sticky-price model of Bernanke *et al.*, (1999), the housing collateral constraint model of Iacoviello (2005) [23], and the working capital model of Jermann and Quadrini (2012) [25]. Quadrini (2011) [35] and Brunnermeier *et al.* (2012) [5] give recent surveys of this field.

nous shocks to the economy? In other words, do the presence of bank's equity capital and the leverage ratio make lending and the macroeconomic fluctuations significantly different relative to an economy with perfect financial intermediation? What are the implications of the procyclical or countercyclical variations in credit spreads? Do the dynamic properties of these variations are associated with particular shocks that arises in the economy? And do the credit spread differentials have important impact on assets pricing and hence on the economic activity? Moreover, we ask what are the effects of bank leverage ratio on the transmission of shocks?

To anwser these questions, we extend a dynamic general equilibrium model with imperfect financial interemdiation developed by Gertler and Karadi (2011) [21] and Gertler and Kiyotaki (2011) [20] by introducing limited enforcement of heterogeneous secured credit. In this framework, the presence of a moral hazard problem of Gertler and Karadi (2011) [21] faced by bankers vis-à-vis their loan branch managers determines an endogenous equity capital of bank, together with a limit on the ability of banks to raise funds. The presence of this financial friction creates a wedge between the interest rate on loans and the interest rate on deposits. We incorporate a housing sector and differentiated corporate and mortgage credit markets into this framework. Constraints on secured credit depend on the future expected value of households' housing stocks and firms' capital. The reason for incorporating housing and mortgage credit in the analytical framework is that over the last decade, we observe that house prices fluctuate considerably over time.[2] Although the previous theoretical and empirical literature has highlighted the important impact of changes in housing prices on macroeconomic fluctuations, they have not addressed this issue in a framework with imperfect financial intermediation.[3]

In the model, we assume that impatient households must obtain loans to increase their housing stock, and entrepreneurs must borrow funds to finance their capital acquisition. Corporate and mortgage loans are provided by banks, each of which is divided into two branches specialized in mortgage and corporate lending, respectively. Given this, the credit markets are segmented in the sense that impatient workers and firms could not arbitrage away the spread between interest rate on corporate and mortgage loans. However, at the same time, we allow for an important feature in the model: the possibility of limits to arbitrage of security returns, through an optimal reallocation of equity capital between loan branches. In this way, the market is partially segmented. Changes in economic conditions following exogenous shocks can trigger arbitrage by bankers in the private bond markets,

[2]Muellbauer and Murphy (1990) [31], for example, argued that house price increases stimulated a consumption boom in the UK in the late 1980's. Case, Quigley and Shiller (2003) [9] find a strong correlation between aggregate house prices and aggregate consumption in a panel of developed countries from the late 1970's through the late 1990's.

[3]A strand of recent DSGE literature on house prices assumes that a subset of households are credit constrained and these households use the real estate as collateral to finance consumption expenditures and found joint dynamics between housing prices and aggregate economic activity, including Iacoviello (2005) [23], Iacoviello and Neri (2010) [24], Favilukis, Ludvigson, and van Nieuwerburgh (2011) [16] and Kiyotaki and Michaelides (2011) [28] and Liu *et al.*, (2013) [30].

which could in turn have important impact on the macroeconomy.[4]

We first use the model to investigate how the transmission mechanisms of technology and monetary policy shocks are affected by the presence of imperfect financial intermediation by comparing with the case of perfect financial intermediation, which is equivalent to the absence of banks. Second, I analyze in the model, how shocks that affect the housing and mortgage markets are transmitted to the real economy. Moreover, I ask whether the shock's effects on the wider economy are amplified or attenuated in an economy with highly leveraged financial intermediation.

The main findings of this chapter are as follows. First, impulse response functions of the model show that the presence of imperfect financial intermediation amplifies the effects of the technology and mortgage borrowing constraint shocks on credit intermediation through varying bank balance-sheet strengths, i.e., the bank balance sheet effect and generates countercyclical variations in interest rate spreads. For example, a positive technology shock raises the price of capital and the amount of credit demanded by firms. This in turn increases expected earnings of corporate loan branches, raising their equity capital. The increased equity capital loosens the borrowing constraint set on corporate lending, leading to a rise in credit granting, which further raises loan branches' equity capital and hence their lending capacity. In the case of a positive mortgage borrowing constraint shock, an unexpected reduction in the Loan-to-Value (LTV) ratio triggers a rise in housing prices and an expansion of mortgage lending, which increase mortgage sector's equity capital, therefore further raising the supply of mortgage loans. In our numerical experiment of a positive monetary policy shock, the presence of the banking sector serves as an endogenous attenuation mechanism which leads to an procyclical variation in interest rate spreads, the equity capital of loan branches and a strengthened lending capacity, but a modest response of loan granting, investment and output due to the imperfect loan interest rate pass-through.

The second main finding is that, in the case of technology shock and shock to the LTV ratio, we also find that arbitrage between corporate and mortgage bonds which are exploited by bankers plays an important role in transmitting the shock effect from one credit market to another credit market. For example, when an unexpected borrowing constraint shock leads to a relative change in returns on loan assets that bankers hold on their balance sheets, equity capital transfers from mortgage to corporate loan branches improve the latter's balance sheet condition, leading to increases in supply of corporate loan, a decline in cost of borrowing and higher price of capital. Given this arbitrage in the private credit markets, the model produces a positive co-movement between housing prices and investment, which is consistent with much of the evidence suggesting that shocks that affect housing prices lead to increases not just in real estate prices, but also in investment

[4] The model also incorporates insights from Shleifer and Vishny (1997) [36], who demonstrate that financial constraints can lead to fluctuations of risk premia.

and the real activity.[5]

The third finding in this chapter is that exogenous shocks produce enhanced responses of macroeconomic variables in an economy with highly leveraged banks. This enhanced amplification is due to the fact that everything else equal, the high leverage ratio amplifies the effect of changes in equity capital on bank's lending capacity.

The content of this chapter can be organized as follows. Section 3.2 presents a short review of the related literature. Section 3.3 introduces the model. Section 3.4 describes the calibration. Section 3.5 presents the main findings from numerical experiments. Finally, Section 3.6 provides concluding comments.

3.2 Related literature

Much of the earlier macroeconomics literature with financial frictions emphasized credit market constraints on nonfinancial borrowers and treated intermediaries largely as a veil. The seminal contributions from Bernanke and Gertler (1989) [1] who introduce agency costs and Kiyotaki and Moore (1997) [27] who consider the credit constraints show how financial frictions can amplify and propagate disturbances to macroeconomic fundamentals, such as shocks to factor productivity or to monetary policy in a general equilibrium model.

The work in this chapter belongs to a strand of literature that is devoted to incorporate the financial frictions stems from the banking sector into the quantitative general equilibrium models for understanding the effects of imperfect financial intermediation on macroeconomic fluctuations or the effects of monetary policies that have been used by the central banks to correct credit market dysfunctions. A quantitative exploration of Goodfriend and McCallum (2007) [21] made a first attempt to quantify the role of banking in business cycle fluctuations. In this model, loans and deposits are costly to produce, thus there are differentials between the loan interest rates and the interest rate on deposits. The authors argue that a central bank that fails to recognize the interest rate spreads could miss its appropriate settings. Cúrdia and Woodford (2010a) [12] incorporate the imperfection of Goodfriend and McCallum (2007) [21] into a basic NK model and give particular attention to the problems about the central bank's choice of using its balance sheet as unconventional monetary policy tool when it is contrained by the zero lower bound. Cúrdia and Woodford (2010b) [13] modify a standard Taylor rule to incorporate either an adjustment for changes in interest rate spreads or a response to changes in the aggregate amount of credit. Using a DSGE model with financial market firctions, they find that either types of adjustment, can help stabilize the disturbances originating in

[5] See for example, the credit market frictionless model of Iacoviello (2005) [24], Iacoviello and Neri (2010), and Kiyotaki and Michaelides (2011) [28], Liu *et al.*(2013) [30] and the dynamic model with imperfect financial intermedaiton of Gerali *et al.*, (2010) [17].

the financial sector. Gerali *et al.*, (2010) [17] who introduce an imperfectly competitive banking sector into a DSGE model for analyzing the effects of imperfect financial intermediation on business cyclical fluctuations. In this model, they assume that loan interest rates depend on the bank's capital-to-assets ratios and the degree of interest rate stickiness and find that financial shocks explain the largest share of the fall of output in 2008 in the euro area.[6] Gertler and Karadi (2011) [21] develop a quantitative monetary DSGE model with financial intermediaries that face endogenously determined balance sheet constraints due to a moral hazard problem. They find that shocks to the asset quality of financial intermediaries plays an important role in business cycle fluctuations. Using the same analytical framework, Gertler and Kiyotaki (2010) [20] address the issues of how disruptions in financial intermediation can induce a crisis that affects real activity and how various credit market interventions by the central bank and the treasury mitigated the recent financial crisis.

The study in this chapter is also closely related the literature on the role of bank capital in the transmission of macroeconomic shocks. To measure the welfare effects of bank capital requirements, Van den Heuvel (2008) [39] presents a DSGE framework with a moral hazard problem on the part of banks that arises due to deposit insurance. Meh and Moran (2008) [32] construct a DSGE model in which the presence of bank capital due to banks lacking the ability to adequately monitor entrepreneurs' projects can affect the propagation of exogenous shocks to the economy and exogenous declines in bank equity capital can lead to sizeable declines in output and investment. Finally, Jiménez *et al.*, (2012) [26] analyzed the impact of monetary policy on the supply of bank credit and found that tighter monetary and worse economic conditions substantially reduce banks' lending, especially from banks with lower capital or liquidity ratios.

3.3 The model

The model is based on the canonical New-Keynesian model of Christiano *et al.* (2005) [37] and Smets and Wouters (2007) [37], extended to incorporate imperfect financial intermediation activities in line with Gertler and Karadi (2011) [18] and Gertler and Kiyotaki (2010) [20]. We introduce in this benchmark setup a housing sector à la Iacoviello (2005) [23], and two types of credit activities: mortgage and corporate loans. The economy is composed of three types of consumers: patient and impatient workers, who derive utility from consumption of the non-durable final good and from housing services, and

[6]The model also feature a differentiated corporate and mortgage credit markets; however, unlike the model presented in this chapter, which allows for arbitrage in private intermediation, asset prices in Gerali *et al.*, (2010) [17] are determined in totally segmented financial markets. Moreover, Gerali *et al.*, (2010) [17] model imperfect financial intermedaiton which is based on an endogenously determined adjustment cost of bank equity, whereas this chapter follows Gertler and Karadi (2011) [21] by focusing on the a moral hazard problem which gives rise to endogenous bank leverage ratio.

entrepreneurs, who produce intermediate goods using capital and labor and derive utility only from non-durable consumption. Patient workers are net savers and save in the form of interest-bearing deposits. Impatient workers and entrepreneurs are net borrowers, and must borrow part of the funds they need using their housing stock and their capital stock, respectively, as collateral.

Banks act as intermediaries between savers and borrowers. They collect deposits from patient workers and distribute loans to impatient workers and entrepreneurs. Since loans are distributed on a collateral basis, which requires some expertise, banks are divided into two branches specialized in corporate and mortgage loan activities. As in Gertler and Karadi (2011) [18], a moral hazard problem between bankers and loan branch managers will create a wedge between the interest rate on loans and the interest rate on deposits.

The model also includes three types of firms: capital producing firms, which repair the depreciated capital and build new one, retailers, which produce retail goods using intermediate goods as inputs (acting in a monopolistically competitive market with sticky prices), and final good producers. Firms are held by patient workers who receive any profit in the form of dividends.

Finally, there is a government, which collects taxes and makes public spending, and a central bank. The central bank conducts the monetary policy following a simply Taylor rule.

3.3.1 Patient workers

There is a continuum of identical patient workers of unit mass. Patient workers are owners of banks and non-financial firms (capital producing firms and retail firms). They consume, work, save and adjust their housing stock in order to maximize their lifetime utility function. Saving is done in the form of interest-bearing deposits at the bank. Let C_t^s be the representative patient workers consumption, h_t^s its housing stock and L_t^s the number of hours supplied. The program solved by the representative patient worker is:[7]

$$\max E_t \sum_{i=0}^{\infty} (\beta^s)^i \left[\ln(C_{t+i}^s - gC_{t+i-1}^s) + j^s \frac{(h_{t+i}^s)^{1-\sigma}}{1-\sigma} - \frac{\left(L_{t+i}^s\right)^{1+\varphi}}{1+\varphi} \right], \tag{3.1}$$

subject to the budget constraint for any date t (expressed in real terms):

$$C_t^s + D_t + q_t^h(h_t^s - h_{t-1}^s) + T_t^s = W_t^s L_t^s + \frac{R_{t-1}}{\pi_t} D_{t-1} + \Pi_t^{nf} + \Pi_t^l, \tag{3.2}$$

where $0 < \beta^s < 1$, is the subjective discount factor, $0 < g < 1$ is a consumption habit parameter, and $j^s, \sigma, \varphi > 0$ are other preferences parameters. In (3.2), D_t denotes the

[7] Without loss of generality, we follow Woodford (2003) [47] and consider the limit case in which the transaction services provided by money are negligible, so that the economy becomes cashless.

period t bank deposits and bond holdings, W_t^s is the real wage for labor supplied by savers, q_t^h is the real housing price, $\pi_t = P_t/P_{t-1}$ the gross rate of inflation, Π_t^{nf} are nonfinancial firms' redistributed profits, Π_t^l are the payouts received from ownership of banks, and T_t^s are lump-sum taxes paid by savers. We assume that bank deposits and the government debt are perfect substitutes, both paying the same gross nominal return R_t from t to $t+1$. Solving savers' maximization problem yields the following first-order conditions:

$$\lambda_t^s = \frac{1}{C_t^s - gC_{t-1}^s} - \beta^s g E_t \left(\frac{1}{C_{t+1}^s - gC_t^s} \right), \tag{3.3}$$

$$q_t^h = \frac{j^s}{\lambda_t^s}(h_t^s)^{-\sigma} + \beta^s E_t \Lambda_{t,t+1}^s q_{t+1}^h, \tag{3.4}$$

$$\lambda_t^s W_t^s = (L_t^s)^{\varphi}, \tag{3.5}$$

$$1 = \beta^s E_t \Lambda_{t,t+1}^s \frac{R_t}{\pi_{t+1}}, \tag{3.6}$$

where λ_t^s is the Lagrange multiplier associated with patient workers' budget constraint, and $\Lambda_{t,t+1}^s \equiv \lambda_{t+1}^s/\lambda_t^s$.

3.3.2 Impatient workers

There is also a continuum of identical "impatient" workers of unit mass, characterized by a discount factor β^b which is smaller than that of patient workers: $\beta^b < \beta^s < 1$. They consume, work and adjust their housing stock in order to maximize lifetime utility. Denoting by C_t^b the representative impatient worker's consumption, h_t^b its housing stock and L_t^b the number of hours worked, the program solved by the representative impatient worker is:

$$\max E_t \sum_{i=0}^{\infty} (\beta^b)^i \left[\ln(C_{t+i}^b - gC_{t+i-1}^b) + j^b \frac{(h_{t+i}^b)^{1-\sigma}}{1-\sigma} - \frac{\left(L_{t+i}^b\right)^{1+\varphi}}{1+\varphi} \right], \tag{3.7}$$

with $j^b > 0$. Impatient workers' choices must obey the intertemporal budget constraint

$$C_t^b + q_t^h(h_t^b - h_{t-1}^b) + \frac{R_{t-1}^h S_{t-1}^h}{\pi_t} + T_t^b = W_t^b L_t^b + S_t^h, \tag{3.8}$$

where W_t^b is impatient workers' real wage and T_t^b are lump-sum taxes. In addition, impatient workers have access to mortgage loan contracts offered by banks.[8] These contracts

[8] Of course, mortgage loan contracts offered to workers can be viewed as mortgage-related securities from the viewpoint of bankers. In particular, to each loan amount S_t^h granted to impatient workers is associated a quantity Q_t^h of *claims,* backed by the housing stock of impatient workers, whose unit price is equal to the price of a unit of housing stock (so that $S_t^h = q_t^h Q_t^h$). In the remaining of the paper, we thus use the two terms of "mortgage loans" and "mortgage securities" interchangeably. Although modelling the complex process of securitization–pooling individual loans so as to convert them into liquid MBS – is beyond the scope of this paper, Hancock and Passmore (2011) [27] show that the Fed's purchase of MBS

stipulate that the loan amount S_t^h granted to borrowers at the gross nominal interest rate R_t^h is constrained by the value of their collateral, defined as the expected value of their housing stock at $t+1$. The borrowing constraint is

$$R_t^h S_t^h \leq \mu_t^b E_t q_{t+1}^h h_t^b \pi_{t+1}, \tag{3.9}$$

where $0 < \mu_t^b < 1$ is the LTV ratio. As shown in Kiyotaki and Moore (1997), such type of borrowing constraint can be endogenously derived from a costly enforcement problem between bankers and borrowers. Impatient workers thus maximize (B.7) subject to (B.8) and (B.9). The first-order conditions are:

$$\lambda_t^b = \frac{1}{C_t^b - gC_{t-1}^b} - \beta^b g E_t \left(\frac{1}{C_{t+1}^b - gC_t^b} \right), \tag{3.10}$$

$$q_t^h = \frac{j^b}{\lambda_t^b} \left(h_t^b \right)^{-\sigma} + \beta^b E_t \Lambda_{t,t+1}^b q_{t+1}^h + \left[1 - \beta^b E_t \left(\frac{\Lambda_{t,t+1}^b R_t^h}{\pi_{t+1}} \right) \right] \frac{S_t^h}{h_t^b}, \tag{3.11}$$

$$\lambda_t^b W_t^b = (L_t^b)^{\varphi}, \tag{3.12}$$

where λ_t^b is the Lagrange multiplier associated with impatient workers' budget constraints, and $\Lambda_{t,t+1}^b = \lambda_{1t+1}^b / \lambda_{1t}^b$. In addition, it is easy to verify that the restriction $\beta^b < \beta^s$ implies that inequality (B.9) binds at optimum.

3.3.3 Entrepreneurs

There is a continuum of identical entrepreneurs of unit mass. Entrepreneurs produce and sell intermediate goods and use collected earnings to consume, aiming to maximize their intertemporal utility function:

$$\max E_t \sum_{i=0}^{\infty} (\beta^e)^i \ln(C_{t+i}^e - gC_{t+i-1}^e), \tag{3.13}$$

where β^e, the subjective discount factor of entrepreneurs, satisfies $\beta^e < \beta^s < 1$.

In any period t, entrepreneurs start with an amount K_{t-1} of capital inherited from the preceding period. They then combine capital and labor from patient (L_t^s) and impatient (L_t^b) workers – adjusting the capital utilization rate U_t – to produce a quantity $Y_{m,t}$ of intermediate goods according to the production function

$$Y_{m,t} = A_t (U_t K_{t-1})^{\alpha} (L_t^s)^{(1-\alpha)\vartheta} (L_t^b)^{(1-\alpha)(1-\vartheta)}, \tag{3.14}$$

with $0 < \alpha, \vartheta < 1$, where A is a total factor productivity level.

during QE1 significantly lowered MBS yields and mortgage loan rates altogether.

At the end of period t, entrepreneurs sell their output to retailers at the competitive market price $P_{m,t}$ (relatively to output price) and buy a quantity I_t of new units of capital from capital producers at unit price q_t^c. The capital stock evolves according to

$$K_t = I_t + [1 - \delta(U_t)]\, K_{t-1}. \tag{3.15}$$

Entrepreneurs must finance part of their capital acquisition by obtaining funds from intermediaries. To do so, they issue one-period bonds in order to borrow an amount S_t^c just sufficient to cover their funding needs. Denoting by R_t^c the nominal gross interest rate on these bonds, entrepreneurs are subject to the following flow-of-funds constraint:

$$P_{m,t}Y_{m,t} + S_t^c = C_t^e + T_t^e + W_t^b L_t^b + W_t^s L_t^s + q_t^c I_t + \frac{S_{t-1}^c R_{t-1}^c}{\pi_t}, \tag{3.16}$$

where T_t^e are lump-sum taxes raised by the government. In addition, due to a costly enforcement problem, the loan amount entrepreneurs can obtain (or, equivalently, the amount of funds they can obtain by issuing corporate bonds)[9] is limited by the following credit constraint:

$$R_t^c S_t^c \leq \mu^e E_t \left[1 - \delta(U_{t+1})\right] q_{t+1}^c K_t \pi_{t+1}, \tag{3.17}$$

where $0 < \mu^e < 1$ is the LTV ratio for entrepreneurs. The borrowing constraint (3.17) implies that the expected value of the capital stock, used as collateral to secure loans, must be enough to ensure repayment of debt and interests.

Entrepreneurs thus solve (B.14) subject to (3.14)–(3.17). Denoting by λ_t^e the Lagrange multiplier on the budget constraint (3.16), we obtain the following first-order conditions:

$$\lambda_t^e = \frac{1}{C_t^e - gC_{t-1}^e} - \beta^e g E_t \left(\frac{1}{C_{t+1}^e - gC_t^e} \right), \tag{3.18}$$

$$q_t^c = \beta^e E_t \left\{ \Lambda_{t,t+1}^e \left(\alpha \frac{P_{m,t+1}Y_{m,t+1}}{K_t} + q_{t+1}^c (1 - \delta(U_{t+1}) \right) \right\} + \left(1 - \beta^e E_t \left\{ \frac{\Lambda_{t,t+1}^e R_t^c}{\pi_{t+1}} \right\} \right) \frac{S_t^c}{K_t}, \tag{3.19}$$

$$W_t^s = \vartheta (1 - \alpha) \frac{P_{m,t}Y_{m,t}}{L_t^s}, \tag{3.20}$$

$$W_t^b = (1 - \vartheta)(1 - \alpha) \frac{P_{m,t}Y_{m,t}}{L_t^b}, \tag{3.21}$$

$$\alpha \frac{P_{m,t}Y_{m,t}}{U_t} = \delta'(U_t) q_t^c K_{t-1}, \tag{3.22}$$

where $\Lambda_{t,t+1}^e = \lambda_{t+1}^e / \lambda_t^e$.

It can also be verified that the condition $\beta^e < \beta^s < 1$ is sufficient to ensure that

[9] As with mortgage loans, we assume that to each loan amount S_t^c is associated a quantity Q_t^c of *corporate bonds,* backed by entrepreneurs' capital stock, whose unit price is equal to the price of a unit of capital (so that $S_t^c = q_t^c Q_t^c$).

inequality (3.17) binds at optimum.

3.3.4 Banking sector

There is a continuum of competitive banks of measure unity, indexed by $j \in (0,1)$, each of which is managed by a banker. Each bank j is composed of one corporate and one mortgage loan branch which specialize in corporate and mortgage lending, respectively, and finance themselves by collecting deposits from savers. While bankers aim to maximize the expected discounted flows of dividends distributed to savers, each loan branch is managed by a manager whose aim is to maximize the terminal wealth of its own branch. Credit markets are thus segmented, in the sense that entrepreneurs and borrowers can only borrow from their respective loan branch, justifying that interest rates on loans (and credit spreads) may be different between branches. Yet, the banker can reallocate the equity capital between its corporate and mortgage loan branches, giving rise to the possibility of arbitrage between corporate and mortgage assets when disproportional changes in excess return on those two assets occur in the markets.

Loan branches. Let $l \in \{c,h\}$ be an index representing corporate and mortgage loan branches respectively. At period t, the loan-branch manager l of bank j has a net worth $n^l_{j,t}$ accumulated from the past. He then collects deposits $d^l_{j,t}$ from savers and provides one-period loans $s^l_{j,t}$. The balance sheet of the branch is:

$$s^l_{j,t} = d^l_{j,t} + n^l_{j,t}. \tag{3.23}$$

Let $\xi^l_{j,t}$ (which could be positive or negative) denote net-worth transfer between loan branches. A positive (negative) $\xi^c_{j,t}$ represents an amount of equity capital that the corporate loan branch receives from (transfers to) the mortgage branch, implying that $\xi^c_{j,t} = -\xi^h_{j,t}$. Thus, the net worth $n^l_{j,t}$ is the sum of retained earnings that a loan branch accumulates from intermediating credits, $m^l_{j,t}$, and net worth transfers $\xi^l_{j,t}$:

$$n^l_{j,t} = m^l_{j,t} + \xi^l_{j,t}. \tag{3.24}$$

At $t+1$, each loan branch receives the stochastic return R^l_t on loans granted at t and pays to savers the non-contingent nominal gross interest rate R_t on deposits. The loan-branch net worth (prior to net worth transfers) is thus, in real terms :

$$\begin{aligned} m^l_{j,t+1} &= \frac{R^l_t}{\pi_{t+1}} s^l_{j,t} - \frac{R_t}{\pi_{t+1}} d^l_{j,t} \\ &= \frac{R^l_t - R_t}{\pi_{t+1}} s^l_{j,t} + \frac{R_t}{\pi_{t+1}} n^l_{j,t}. \end{aligned} \tag{3.25}$$

Accordingly, the end–of-period net worth of each loan branch is:

$$n^l_{j,t+1} = \frac{R^l_t - R_t}{\pi_{t+1}} s^l_{j,t} + \frac{R_t}{\pi_{t+1}} n^l_{j,t} + \xi^l_{j,t+1}. \tag{3.26}$$

Agency problems in credit intermediation. Following Gertler and Kiyotaki (2010) and Gertler and Karadi (2011), we assume that the relationship between bankers and branch managers is subject to a moral hazard/costly enforcement problem owing to the fact that, at the beginning of any period t, managers can choose to divert a (possibly stochastic) fraction λ^l of the assets they have under their management and transfer the collected funds $\lambda^l s^l_{j,t}$ to the household of which they are a member. If this occurs, bankers can force the loan branch into bankruptcy and recover the remaining fraction of assets.

As seen below, this agency problem generates in each period a positive gap between the loan interest rate R^l_t and the interest rate on deposit R_t, implying that loan branches make profits on each dollar of loan intermediated. To ensure that the net worth of loan branches does not grow to infinity, it is assumed that at the end of any period t, a constant fraction θ of branches close for an exogenous reason and their net worth is transferred back to savers in the form of dividends. Denoting by $V^l_{j,t}$ the expected terminal wealth of branch l in bank j, we have:

$$V^l_{j,t} = \max E_t \sum_{k=0}^{n} (\beta^s)^{k+1} (1-\theta)(\theta)^k \Lambda^s_{t,t+1+k} m^l_{j,t+1+k}.$$

The prevention of misbehavior from branch managers requires that the following incentive constraint must hold:

$$V^l_{j,t} \geq \lambda^l s^l_{j,t}. \tag{3.27}$$

Using (3.25) and after a few manipulations, $V^l_{j,t}$ can be expressed as follows:

$$V^l_{j,t} = \nu^l_t \cdot s^l_{j,t} + \eta^l_t \cdot n^l_{j,t}$$

with

$$\nu^l_t = E_t \left\{ \beta^s \Lambda^s_{t,t+1} (1-\theta) \left(\frac{R^l_t - R_t}{\pi_{t+1}} \right) + \beta^s \Lambda^s_{t,t+1} \theta x^l_{t,t+1} \nu^l_{t+1} \right\},$$

$$\eta^l_t = E_t \left\{ (1-\theta) + \beta^s \Lambda^s_{t,t+1} \theta z^l_{t,t+1} \eta^l_{t+1} \right\},$$

where $x^l_{t,t+1} \equiv s^l_{t+1}/s^l_t$ and $z^l_{t+1} \equiv n^l_{t+1}/n^l_t$ are, respectively, the gross growth rate of asset holdings and the gross growth rate of net worth between t and $t+1$ in each loan branch.[10]

[10] As explained below, the ratio $\xi^l_{j,t+1}/n^l_t$ of transfers relatively to net worth can be assumed to be the same for any bank j, implying that ν^l_t and η^l_t do not depend on bank-specific factors.

The variable ν_t^l represents the expected discounted marginal gain for loan branches from an additional unit of assets $s_{j,t}^l$, holding $n_{j,t}^l$ constant. Likewise, η_t^l is the expected discounted marginal gain from adding a unit of equity capital $n_{j,t}^l$, holding $s_{j,t}^l$ constant.

Clearly, the incentive constraint (3.27) places a restriction on the amount of loans $s_{j,t}^l$ a branch can distribute relatively to its net worth. This limit to arbitrage possibilities creates a wedge $R_t^l - R_t > 0$ between the policy rate and the interest rates on loans. Indeed, when constraint (3.27) binds, which occurs when $0 < \nu_t^l < \lambda^l$, we obtain:

$$\begin{aligned} s_{j,t}^l &= \frac{\eta_t^l}{\lambda^l - \nu_t^l} n_{j,t}^l \\ &= \phi_t^l n_{j,t}^l, \end{aligned} \tag{3.28}$$

where $\phi_t^l \equiv \eta_t^l/(\lambda^l - \nu_t^l)$, is an endogenously determined *leverage ratio* for loan branches. As (3.28) shows, the branch ability to expand loans is constrained by its net worth, as any loan amount greater than $s_{j,t}^l = \phi_t^l n_{j,t}^l$ would imply that the net gain from defaulting was larger than the cost, thus violating the incentive constraint.

Using (3.26), we can also express $x_{t,t+1}^l$ and z_{t+1}^l as

$$x_{t+1}^l = \frac{\phi_{t+1}^l}{\phi_t^l} z_{t+1}^l,$$

$$z_{t+1}^l = \frac{1 + \varrho_{t+1}^l}{\pi_{t+1}} \left[(R_t^l - R_t)\phi_t^l + R_t \right],$$

where $\varrho_t^l = \xi_t^l/(n_t^l - \xi_t^l)$ is the ratio of transfer relative to net worth.

In Appendix B, we show that equity capital transfers are possible and are optimally determined by bankers. We now turn to this optimal capital transfer decision.

Banker's equity capital transfer. Bankers aim to maximize the total expected discounted flow of dividends distributed to shareholders. In Appendix B, we show that as long as $\phi_t^c(R_t^c - R_t) > \phi_t^h(R_t^h - R_t)$, it is optimal for bankers to transfer equity capital from their mortgage loan branch to their corporate loan branch. Yet, at the aggregate level, these capital inflows generate an increase in the supply of corporate loans and a decrease in the supply of mortgage loans, leading in turn to a decrease in R_t^c and an increase in R_t^h.[11] Thus, equity capital transfers occur until the following non-arbitrage condition

$$\phi_t^c(R_t^c - R_t) = \phi_t^h(R_t^h - R_t) \tag{3.29}$$

is satisfied at any period in time. Since this condition only depends on the *aggregate* amount of equity capital transfer and not on individual amounts, we assume that each

[11] Of course, the argument goes in reverse way if $\phi_t^c(R_t^c - R_t) < \phi_t^h(R_t^h - R_t)$.

bank j makes the same transfer amount in proportion to its net worth, so that the ratio $\xi^l_{j,t+1}/n^l_t$ does not depend on j, conformably with our above analysis.

Condition (3.29) underlines how the arbitrage between assets affects the economy. When capital inflows are possible between branches, bankers make continuous arbitrage between profit opportunities offered by the two loans branches. For bankers, each dollar invested in loan branch l allows it to increase loans by ϕ^l_t dollars, and to receive $\phi^l_t(R^l_t - R_t)$ dollars of excess return. The condition then simply states that, at the optimum, equity capital transfers between branches are made until there is equality between marginal returns in the two branches. As analyzed below, we will show that through this mechanism, changes in excess return and price of one asset should affect those of another asset and hence the marcoeconomy.

Banking sector aggregation. Let S^l_t be the aggregate loan amount granted by loan branches l and N^l_t be their total equity capital. Given that the leverage ratio ϕ^l_t does not depend on bank-specific factors, summing (3.28) across individual loan branches yields:

$$S^l_t = \phi^l_t N^l_t. \tag{3.30}$$

As mentioned above, a constant fraction θ of branches close at the end of any period t. To keep the total number of loan branches fixed in each loan sector we also assume that, for each exiting branch, a new branch is established and receives from savers a start-up funds equal to a fraction ω^l of loans intermediated in the preceding period as initial net worth. Summing (3.26) and (3.28) across banks, we obtain the equation describing how the aggregate net worth N^l_t in loan branch $l \in \{c, h\}$ evolves through time:

$$N^l_t = \theta N^l_{t-1}\left[\phi^l_{t-1}\left(\frac{R^l_{t-1} - R_{t-1}}{\pi_t}\right) + \frac{R_{t-1}}{\pi_t}\right] + \omega^l S^l_{t-1} + \Theta^l_t, \tag{3.31}$$

where $\omega^l S^l_{t-1}$ are total start-up funds received by new loan branches and Θ^l_t is the aggregate level of equity capital transfers between loan branches decided by bankers.

3.3.5 Non-borrowing firms

Besides entrepreneurs who need to raise funds on financial markets, the economy features three types of non-borrowing firms: capital producing firms, final good producing firms, and retailers. For simplicity, we assume that all firms are held by patient workers, who are the recipients of any profit.

Capital producing firms. In any period t, capital producing firms build new capital using the final good as input and sell it to entrepreneurs at the relative price q^c_t per unit. Denoting by I_t the amount of capital created at t, we assume that investment is subject to adjustment costs materialized by a quadratic function $f\left(I_t/I_{t-1}\right)$ satisfying $f\left(1\right) = f'\left(1\right) = 0$ and $f''\left(1\right) > 0$. The problem of capital producers is thus to maximize profits:

$$\max E_t \sum_{\tau=t}^{\infty} \left(\beta^s\right)^{\tau-t} \Lambda^s_{t,\tau} \left\{ q^c_t - \left[1 - f\left(\frac{I_\tau}{I_{\tau-1}}\right)\right]\right\} I_\tau.$$

Solving this problem delivers as first-order condition a dynamic equation for the real price of capital

$$q^c_t = 1 + f\left(\frac{I_\tau}{I_{\tau-1}}\right) + f'\left(\frac{I_\tau}{I_{\tau-1}}\right)\frac{I_\tau}{I_{\tau-1}} - \beta^s E_t \Lambda^s_{t,\tau+1} f'\left(\frac{I_{\tau+1}}{I_\tau}\right)\left(\frac{I_{\tau+1}}{I_\tau}\right)^2, \tag{3.32}$$

which is the usual Tobin's q, implying that the price of capital is related to the adjustment cost of investment.

Final good producing firms. There is a perfectly competitive final good market. Final output Y_t is produced through a CES composite made of a continuum of mass unity of retail goods, indexed by $f \in (0, 1)$:

$$Y_t = \left(\int_0^1 Y_{f,t}^{(\varepsilon-1)/\varepsilon} df\right)^{\varepsilon/(\varepsilon-1)},$$

where $Y_{f,t}$ is the output of retailer f and $\varepsilon > 1$ is the elasticity of substitution between retail goods. Profit maximization by final good producers leads to the standard demand function:

$$Y_{f,t} = \left(\frac{P_{f,t}}{P_t}\right)^{-\varepsilon} Y_t, \tag{3.33}$$

where P_t, the aggregate price index, is defined by:

$$P_t = \left[\int_0^1 P_{f,t}^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}}. \tag{3.34}$$

Retail firms. Retailers simply repackage intermediate goods. In period t, they buy intermediate goods from entrepreneurs at the relative price $P_{m,t}$ (determined in a perfectly competitive market), repackage it and sells the obtained retail good at price $P_{f,t}$ to final good producers (so that one unit of intermediate good produces one unit of retail output). Following Calvo (1983) [6], we assume that in each period t, the probability of a retail firm being able to reset its price is $1 - \gamma$. During periods for which they are unable to reset prices, they simply index them to the lagged inflation rate using an indexation coefficient $\gamma_p \in (0, 1)$. The retailers' pricing problem is then to choose the optimal reset price P^*_t to solve

$$\max E_t \sum_{i=0}^{\infty} (\gamma\beta^s)^i \Lambda^s_{t,t+i} \left[\frac{P^*_t}{P_{t+i}} \prod_{k=1}^{i} (\pi_{t+k-1})^{\gamma_p} - P_{m,t+i} \right] Y_{f,t+i},$$

subject to (3.33). The first-order condition is:

$$E_t \sum_{i=0}^{\infty} (\gamma\beta^s)^i \Lambda^s_{t,t+i} \left[\frac{P^*_t}{P_{t+i}} \prod_{k=1}^{i} (\pi_{t+k-1})^{\gamma_p} - \mu P_{m,t+i} \right] = 0,$$

where $\mu = \varepsilon/(\varepsilon - 1) > 1$ is the steady-state markup factor.

Given (3.34) and the probability γ of having the price unchanged, we can deduce by the law of large numbers the evolution of the aggregate price level:

$$P_t = \left[(1-\gamma)(P^*_t)^{1-\varepsilon} + \gamma(\Pi^{\gamma_p}_{t-1} P_{t-1})^{1-\varepsilon} \right]^{\frac{1}{1-\varepsilon}}. \tag{3.35}$$

3.3.6 Government and central bank policy

Conventional monetary policy. The central bank sets its policy rate R_t according to the following Taylor rule:

$$\log R_t = (1-\rho^R) \left[\log R + \kappa_\pi \log(\pi_t/\pi) + \kappa_y \log(Y_t/Y) \right] + \rho^R \log R_{t-1} + \varepsilon^R_t, \tag{3.36}$$

where R, π and Y are the steady state values of the short-term interest rate, inflation rate, and output level, respectively, ρ^R is the parameter capturing the degree of interest rate smoothing, the coefficients κ_π and κ_y are the relative weights assigned to the inflation rate and the output gap, respectively, and ε^R_t is an exogenous monetary policy shock.

Fiscal policy. Government expenditures G are exogenously fixed and are financed by fiscal revenues (lump-sum taxes raised on consumers). We also assume that the government runs a balanced budget, implying that

$$G = T^s_t + T^b_t + T^e_t.$$

3.3.7 Market clearing conditions

In equilibrium, final output is equal to the sum of aggregate consumption $C_t = C^s_t + C^b_t + C^e_t$, investment I_t, government expenditures G, and the cost associated with the production of new capital $f(I_t/I_{t-1})I_t$. The market clearing condition in the final goods market is:

$$Y_t = C^s_t + C^b_t + C^e_t + \left[1 + f\left(\frac{I_t}{I_{t-1}} \right) \right] I_t + G. \tag{3.37}$$

The housing market equilibrium, assuming a fixed housing stock normalized to unity, is:

$$h_t^s + h_t^b = 1. \tag{3.38}$$

The corporate and mortgage loan market equilibrium conditions are respectively

$$\frac{\mu^e E_t \left[1 - \delta(U_{t+1})\right] q_{t+1}^c K_t \pi_{t+1}}{R_t^c} = S_t^c, \tag{3.39}$$

$$\frac{\mu_t^b E_t q_{t+1}^h h_t^b \pi_{t+1}}{R_t^h} = S_t^h. \tag{3.40}$$

Finally, real wages W_t^s and W_t^b adjust to ensure the equality between supply and demand on each type of labor market.

3.3.8 Calibration

To facilitate comparisons, most parameter values are set as in Gertler and Karadi (2011) [21]. The discount factor of savers is set to $\beta^s = 0.99$, implying an annual steady state real interest rate of 4%. The inverse of the Frisch labor supply elasticity is set to $\varphi = 0.276$. The habit parameter g is set to $g = 0.815$. The share of capital in the production function is set to $\alpha = 0.33$, the steady state value of the utilization rate to $U = 1$, and the steady-state depreciation rate to $\delta = 0.0025$. The elasticity of the marginal depreciation rate of capital with respect to the utilization rate is set to $\zeta = 7.2$. For the inverse elasticity of net investment to the price of capital, we find that setting $\eta_c = 0.5$ (a value somewhat smaller than the value of 1.72 considered by Gertler and Karadi, 2011 [21]) enables to obtain a larger decline in investment and output during the crisis without altering the other predictions of the model. The probability of keeping prices fixed is $\gamma = 0.779$, and the indexation parameter is $\gamma_p = 0.241$. The steady-state inflation factor is set to unity. The monetary policy rule parameters are calibrated as follows: the coefficient on inflation is $\kappa_\pi = 1.5$, the coefficient on the output gap is $\kappa_y = 0.125$, and the interest rate smoothing parameter is $\rho^R = 0.8$. The steady-state ratio of government spending to GDP is set to 20%. The survival probability of banks, $\theta = 0.972$, implies an expected horizon of eight years for loan branches.

Concerning the parameters specific to our model, we set the discount factor of borrowers and entrepreneurs to $\beta^b = \beta^e = 0.975$. We set the technology parameter ϑ to $\vartheta = 0.64$, implying a borrowers' income share in total wage income of around 36 percent, which is in line with evidence in Campbell and Mankiw (1989) [8]. The curvature parameter on housing in the utility function, σ, influences the response of the housing price and relative housing stocks to changes in the economic environment. We find that setting $\sigma = 3$ allows to imply a declining housing price after a negative shock affecting the financial system, while still generating substantial reallocation of housing units between savers and borrowers. We calibrate the LTV ratio for impatient workers at $\mu^b = 0.55$, as estimated by Iacoviello (2005) [23]. The value of the LTV ratio for entrepreneurs, μ^e, and the weights on housing in the households' utility function, j^b and j^s, are set so that the steady state corporate debt to output ratio S^c/Y equals to 0.72, the steady state mortgage debt to output ratio S^h/Y equals to 0.73 and the fraction of housing stock held by savers at the steady states is $h^s = 1/3$. The values of S^c/Y and S^h/Y are calibrated to match the ratio of total debt owed by the domestic nonfinancial corporate and non-corporate business sector to GDP and the ratio of outstanding mortgage debt to GDP in the U.S., respectively, at the onset of the crisis (first two quarters of 2007), as reported by the Board of Governors of the Federal Reserve System. For the savers' housing stock, we use data from the 2007 American Housing Survey which indicates that among the 75.6 millions of total occupied units, 24,9 millions were clear of mortgages (see Table 3.15 p. 162).

Concerning the banking sector, our strategy is to calibrate the spread between the interest rate on corporate loans and the policy rate, $R^c - R$, the spread between the interest rate on mortgage loans and the policy rate, $R^h - R$, the leverage ratio in the corporate loan sector ϕ^c and the size of transfers from the corporate loan to the mortgage loan branches Θ^c/N^c, and let the values for λ^c, λ^h, ω^c and ω^h be determined endogenously.[12] The spread $R^c - R$ is set to 169 basis points (annualized) at the steady-state, based on the pre-crisis level of excess return on Moody's Seasoned Baa corporate bond yield over the 10-year Treasury constant maturity rate (averaged over 2006). The spread $R^h - R$ is set to 127 basis points (annualized), based on the pre-crisis spreads between the 15-year fixed rate mortgage average and the 10-year Treasury constant maturity rate (averaged over 2006). We calibrate the leverage ratio for corporate lending to $\phi^c = 4$ and the steady-state net worth transfers to $\Theta^c/N^c = 0.001$.[13] The implied steady state leverage ratio of mortgage credit intermediation ϕ^c is around 5.26, reflecting the fact that large and complex commercial and investment banks which intensively invested in mortgage related securities were thinly capitalized and did not have a sufficient cushion to absorb the losses as they were hit by the subprime crisis.

3.4 Model analysis

This section presents the impulse response functions of the model to three disturbances: a technology shock, a monetary shock and shock to mortgage borrowing constraint. I then analyze the role played by the leverage ratio in these responses. In Figure 3.1, 3.2 and 3.3, the solid lines represent the responses in the benchmark economy with the presence of moral hazard problems between loan branch managers and bankers, i.e., imperfect financial intermediation, while dashed lines represent an economy with perfect financial

[12] Details on how these relationship are derived at the steady-state are given in Appendix B.
[13] Quantitatively, our results are not sensitive to the assumed value for Θ^c/N^c.

intermediation which is equivalent to the absence of banks.

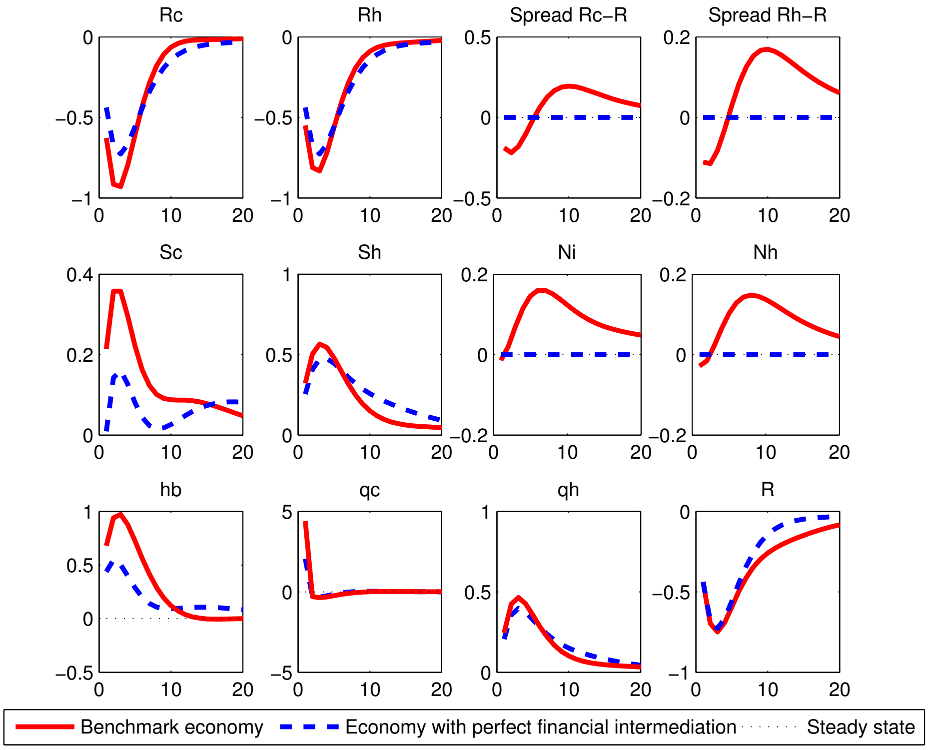
3.4.1 Technology shock

Figure 3.1 displays impulse responses of key "financial market" variables (see Panel a) and "real economy" variables (see Panel b) to a one-standard deviation positive technology shock, with an autoregressive coefficient 0.9. In both economies with and without banks, the positive shock increases the productivity of the intermediate good producing firms, a rise that is expected to persist for several periods. This in turn raises the expected return on capital in future periods and thus an increase in investment, raising the price of capital q_t^c. The increased price of capital boosts the collateral value of capital held by entrepreneurs, thus positively affecting entrepreneurs' borrowing capacity. This triggers the accelerator effect, allowing entrepreneur to borrow more funds from corporate loan branches and raise their investment even more and hence the stock of capital in production. Consequently, with high investment and consumption, aggregate demand rises, generating a rise in output.

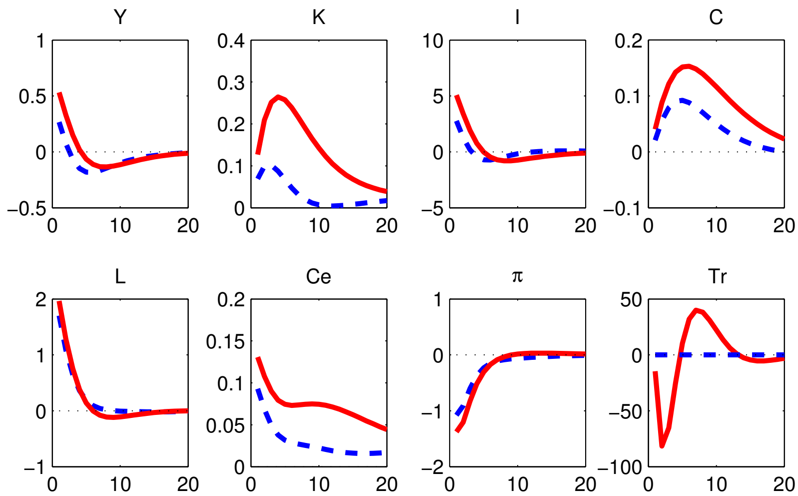
In the economy with imperfect financial intermediation, the rise in capital price strengthens the corporate loan branch's balance sheet, because capital price q_t^c is also the price at which loan branches purchase the firms' debts. The resulting higher level of loan branches' equity capital N_t^c leads to a rise in the supply of credit to entrepreneurs. As shown in the figure, capital accumulation continues to increase for an extended period, reaching its maximum four quarters after the onset of the shock, at a maximum increase of about 0.2%.

As the figure shows, the positive technology shock induces downward pressure on inflation. The monetary policy responses taken by the central bank in response to the fall in inflation is to lower the policy rate, which declines by as much as 78 basis points. Note that the decreased short-term interest rate represents an additional source of enforcement in the economy via reducing the funding costs for loan branches. As a result, the increase in net interest margins and the rise in asset prices raise the value of both corporate and mortgage loan branches, increasing their ability to make loans and, as a consequence, generating a decline in loan interest rates R_t^c and R_t^h, which stimulate the demand for credit by firms and impatient workers.

The effects of the positive technology shock is also transmitted to the housing and mortgage markets, inducing a rise in housing price q_t^h and reallocation of housing stock from patient to impatient workers. In addition to the positive effect of reducing the short-term interest rate on mortgage loan branches' balance sheets, the figure (in Panel b) shows that as a result of the fall in interest rate spread $R_t^c - R_t$, to arbitrage away the leverage-adjusted interest rate spread differential, a fraction of equity capital is transferred by bankers from their corporate loan branches to mortgage loan branches (i.e., $\hat{\xi}_{j,t}^c<0$). Such



(a)



(b)

Figure 3.1: *Impulse responses to a positive 1% technology shock*

arbitrage increases the ability of the latter to grant loans to impatient workers, leading to a decline in both the mortgage rate R_t^h and interest rate spread $R_t^h - R_t$.

Comparing the case with and without imperfect financial intermediation, we see that the responses of these two economies to the shocks are markedly different. When the moral hazard problem between the loan branch managers and bankers is not present, banks lend exactly the amount they borrow from patient savers and they do not need to accumulate and invest their own funds in private sector projects. Thus, the amplification effect operating through the banks' balance sheet is absent and the equity capital stop impacting the economy's responses to the shock. As the figure shows, the increase in real economic activity is both less pronounced and less persistent in the economy in which banks are absent. The rise in investment in the economy with perfect financial intermediation is only 2.8% at its maximum, i.e., two thirds of the rise in the economy with imperfect financial intermediation. The response of output is also dampened, with a peak rise of only 0.26%, significantly smaller than the one observed in the case of imperfect financial intermediation.

Note that the different responses of the two economies also influence the dynamics of the policy rate R_t: in the economy with perfect financial intermediation, the smaller rise in the supply of credit by banks and the modest rise in real activity reduce deflationary pressure. The fall in inflation is modest, leading to a smaller drop in the policy rate relative to the case with imperfect financial intermediation.

This shock experiment shows that the presence of financial frictions amplifies the expansionary effects of the technology shock, which results in a sizeable expansion of credit to the private sector (either mortgage borrowers and firms) and investment. By contrast, in the model without frictions in the intermediation process, the shock's impact on the economy is dampened. The rises in investment and output, and the decline in inflation are more modest. These results are consistent with the evidence that the evolution of bank capital significantly affects bank lending and real economic activity (Peek and Rosengren, 1997 [33] and 2000 [34]).

3.4.2 Monetary policy shock

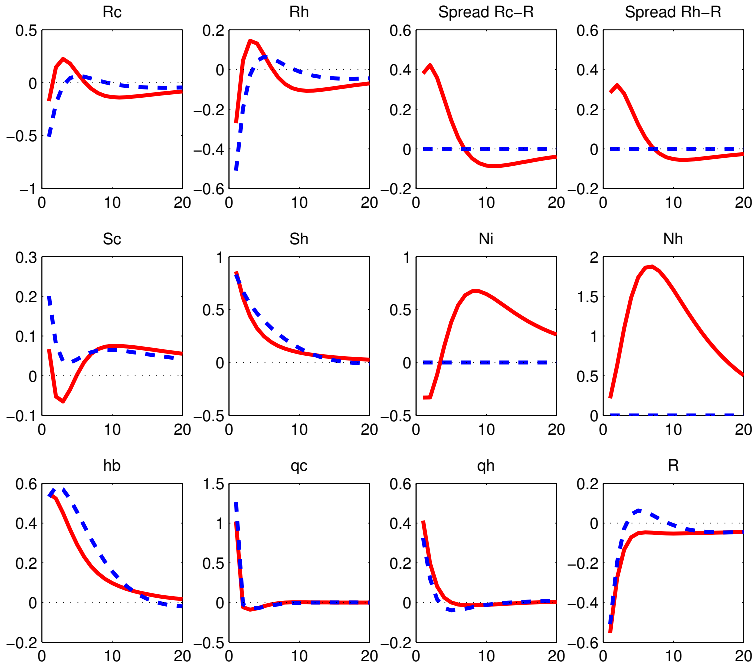
Figure 3.2 displays the impulse response functions to a monetary policy shock, for the economy with imperfect or perfect financial intermediation. The monetary shock is an unanticipated 100 basis points decline in the policy rate R_t.

As shown in the figure, the decline in the policy rate induces a fall loan interest rates R_t^c and R_t^h. However, R_t^c and R_t^h fall by less than R_t does, generating an increases in interest rate spreads $R_t^c - R_t$ and $R_t^h - R_t$. These increased interest rate spreads imply that the presence of banks and financial frictions significantly affects the transmission of the central bank's short-term interest rate policy, i.e., the long-term interest rates do not move perfectly with the short-term interest rate. In the model, interest rate spreads increase following the positive monetary policy shock can be explained as follows: the decline in R_t reduces the costs for banks to fund themselves, thus raising the expected future earnings and hence the equity capital through the increased marginal earning of granting loans. It also means that with the presence of financial frictions, leveraged loan branches have to increase their equity capital so as to be able to increase loan granting after the policy rate cuts. As shown in the figure, the monetary policy shock and the resulting declines in costs of borrowing stimulates the demand for mortgage loans and housing by impatient workers and the demand for corporate loans and capital by firms. More credit granting then raises asset prices q_t^c and q_t^h, which has a positive effect on loan branches' balance sheets and triggers the financial accelerator effect on demand side of credit, sustaining the demand for credit by firms and impatient workers.

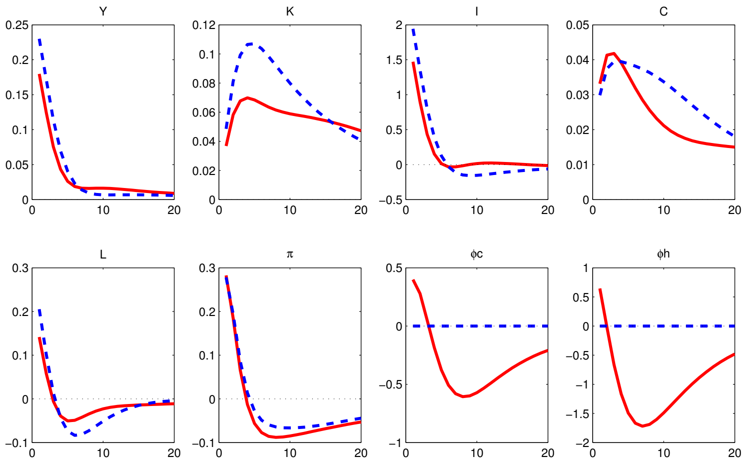
Since loan branches partially translate the changes in the policy rate to loan interest rates due to the presence of financial frictions. This attenuation effect on the monetary policy reduces the response of both the financial-market and real economy variables (compared to the economy with perfection financial intermediation). The imperfect interest rate pass-through dampens the response of loan interest rates R_t^c and R_t^h relative to R_t and hence the responses of the amount of loans granted to firms S_t^c and to impatient workers S_t^h. Since the increase in lending is modest in the economy with imperfect financial intermediation, the impact of the positive monetary policy shock on investment, housing demand, aggregate consumption and output is limited. These findings on the presence of an banking "attenuator" effect that tends to blunt the impact of monetary policy actions are in line with the results obtained by Goodfriend and McCallum (2007) [21] and Gerali *et al.*, (2010) [17]. In Goodfriend and McCallum (2007) [21], the attenuation effect stems from the presence of a procyclical external finance premium, which indicates that an expansionary monetary policy shock increases the real marginal cost of granting loans. The attenuation effect in Gerali *et al.*, (2010) [17] is mainly due to the sluggish loan interest rate adjustments by assuming that the banking sector is monopolistically competitive. Although we share the same result with these two works, banks in their models are rather different compared to ours. The bank attenuator in our model is more general, as changes in interest rates spreads do not depend on the exogenously imposed assumptions that the interest rate spread is increasing in the amount of financial intermedaiton service (Goodfriend and McCallum, 2007 [21]) or loan interest rates are sluggish (Gerali *et al.*, 2010 [17]).

3.4.3 Mortgage borrowing constraint shock

Figure 3.3 displays the impulse responses of the financial and real economy variables following a 1% increase in the LTV ratio μ_t^b. This relaxation in mortgage borrowing constraint can be interpreted as banks loosening the underwriting standards of their mortgage



(a)



(b)

Figure 3.2: *Impulse responses to a 100-basis-points decline in the policy rate* R_t

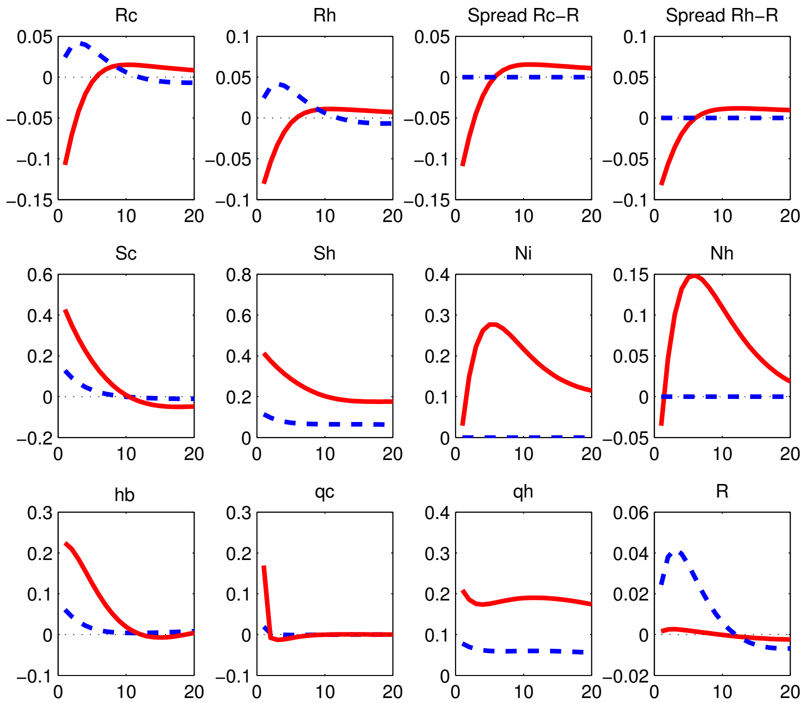
lending as we observed during the period leading up to the credit crisis of 2007.

In both economies, the reduction in borrowing constraint positively affects impatient workers' borrowing capacity. It allows impatient workers to acquire more loanable funds from mortgage loan branches for given value of housing used as collateral, causing a rise in housing price q_t^h. The increased housing prices in turn raise impatient workers' net worth, further loosening their borrowing constraints. This results in a further expansion of credit and a further rise in the housing price. As shown in the figure, higher amount of mortgage loans increases impatient workers' demand for both consumption and housing services. Given that impatient workers are collateral-constraint and have a higher propensity to spend than patient workers, the net effect of the rise in borrowing on aggregate consumption is positive.

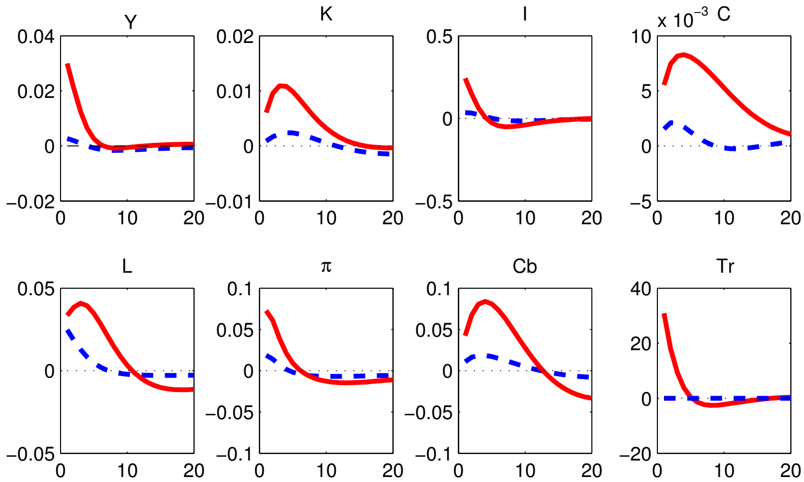
In the supply side of mortgage loans, in the economy with imperfect financial intermediation, the increase in the value of mortgage loans S_t^h fwllowing the shock raises mortgage loan branches' earnings from lending, which leads to a higher level of net worth thereby enabling mortgage loan branches to obtain more loanable funds from patient workers, strengthening their lending capacity. As shown in the figure, following the shock, the housing price q_t^h and supply of mortgage loans S_t^h reach a maximum rise of almost 0.22% and 0.41%, respectively.

As Figure 3.3 shows, the shock generates positive co-movements between housing prices and investment. These results are consistent with some evidence that a rise in housing prices in tandem with a rise in bank lending and real economic activity (see e.g. Case *et al.*, 2003 [9], Iacoviello, 2005 [23], Iacoviello and Neri, 2010 [24] and Liu *et al.*, 2013 [30]). Indeed, in the economy with imperfect financial intermediation, bankers' arbitrage between mortgage and corporate loan assets is key for the effects of the borrowing constraint shock spill over to corporate loan market and hence the real activity. When the leverage-adjusted return $\phi_t^h(R_t^h - R_t)$ declines and becomes smaller relative to $\phi_t^c(R_t^c - R_t)$ as a result of the rise in equity capital for the mortgage sector, to take advantage of the higher excess return on corporate loans, bankers would like to purchase more debts issued by firms. Since corporate lending is constraint by the value of loan branches' equity capital, as the figure illustrates, a fraction of equity capital is then transferred from mortgage to corporate loan branches (i.e., $\hat{\xi}_{j,t}^c$>0). These transfers loosen the borrowing constraint set on corporate lending. As a result, the supply of corporate loans S_t^c rises and both the loan interest rate R_t^c and the interest rate spread $R_t^c - R_t$ decline, stimulating the demand for corporate loans by firms and hence raising investment. However, this reallocation of equity capital tightens the borrowing constraint set on mortgage loan branches, thus inducing an attenuating effect on the rise in supply of mortgage credit to impatient workers.[14]

[14]According to the simulation, this attenuation effect on mortgage lending seems to be dominated by the bank balance sheet effect that leads to improved mortgage loan branches' balance sheets, thus the increase in mortgage lending is significant.



(a)



(b)

Figure 3.3: *Impulse responses to a 1% increase in the LTV ratio* μ_t^b

In the economy with perfect financial intermediation, the relaxation of mortgage borrowing constraint raises the aggregate demand, putting upward pressure on inflation. In reaction, the central bank follows a tight policy after the onset of the shock, increasing the policy rate R_t. Such a policy stance limits the rise in inflation but attenuates the rise in demand for credit by private sector. Thus, comparing to the case with imperfect financial intermediation in which loan interest rates R_t^c and R_t^h decline, we see that the increase in both the housing price and the volume of mortgage loans is modest.

As Figure 3.3 shows, the relaxation of mortgage borrowing constraint also generates a rise in business investment and output in the economy with perfect financial intermediation. Unlike in the case with imperfect financial intermediation in which the spillovers from mortgage and housing markets to the real activity through the arbitrage of asset returns, when the bank balance sheet is removed, entrepreneurs' consumption decisions have important implication for the investment dynamics. Since the relaxation of borrowing constraint triggers a persistent increase in aggregate consumption, entrepreneurs receives a higher level of dividend payout from firms. Due to the habit formation in consumption and concave intertemporal utility, entrepreneurs respond to the increase in dividend payout by smoothing their consumption and raising investment. More investment by firms leads to increases in price of capital q_t^c, generating a financial accelerator effect which enhances firms demand for credit, even if this increases the cost of financing R_t.

As Figure 3.3 shows, in the economy with imperfect financial intermedaiton, loan interest rates decline and the increase in lending from banks is larger, highlighting the fact that the bank balance sheet plays an important role in business cycle fluctuations. However, when the bank balance sheet is absent, the costs of borrowing and hence the demand for credit are directly affected by the policy rate R_t which rises as there are increases in inflation and aggregate output following the shock to the borrowing constraint. Thus, the increase in investment in the economy with perfect financial intermediation is modest, with only about 10% of the increases experienced by the economy with imperfect financial intermediations. The response of output is also dampened and significantly smaller than the one observed in the economy with imperfect financial intermediation.

3.4.4 Impact of leverage ratio

In this subsection, we analyze the impact of the bank leverage ratio on the dynamic effects of the shocks. We address this issue by conducting a numerical experiment. We consider several levels of steady state leverage ratio for loan branches. In the first case, we set a high level of steady state value for the leverage ratio of corporate loan branches, i.e., ϕ^c equals 5.2. At this value, ϕ^c is 30% higher than its level in the benchmark economy and the corresponding leverage ratio for mortgage loan branches (given by Equation (B.74) in Appendix B), ϕ^h, rises to 6.92, as compared to 5.26 in the benchmark economy. In Figure

3.4, the dashed lines portray this case. In the second case, the steady state leverage ratio ϕ^c is decreaseand to 2.8, which is 30% lower than its value in the benchmark economy. Accordingly, the leverage ratio for mortgage loan branches ϕ^h is decreased to 3.72. The dotted lines portray this case in the figure. For comparison, the solid lines portray the benchmark economy.

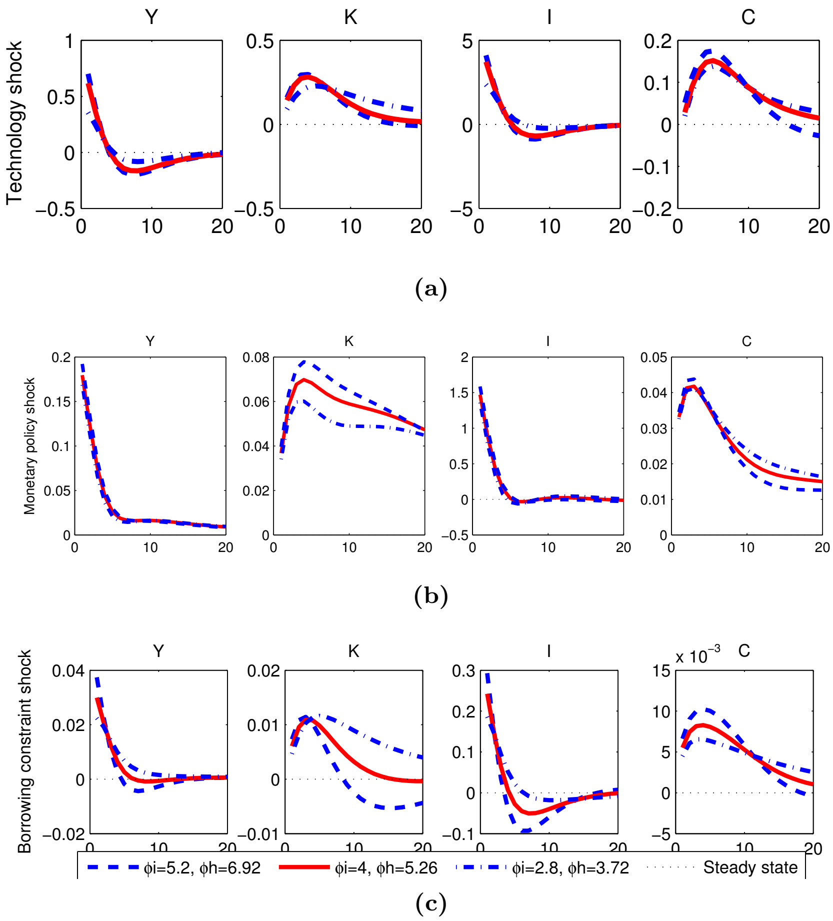


Figure 3.4: *Impact of leverage ratio on impulse response functions*

Figure 3.4 then compares the impulse responses of four key economic variables, including output, capital accumulation, investment and aggregate consumption in the economy with imperfect financial intermediation to the three types of shocks that we have analyzed in the previous subsections. In the case with highly leveraged loan branches (i.e., $\phi^c = 5.2$ and $\phi^c = 6.92$), the effects of these shocks are markedly amplified. Investment, output and bank lending all increase more than they do in the benchmark economy. This is because the higher leverage enhances the bank balance sheet effect on the macroeconomy. Indeed, each of these three shocks considered in the experiment represents an important driver of asset prices fluctuation. An improvement in the expected payoff should be seen as an increase in the value of bank assets, which flows through entirely to an increase in loan branches equity capital. The increase in equity capital in turn relaxes the borrowing constraint that limits the ability of loan branches to fund themselves, therefore enabling loan branches to increase their supply of credit to the private sector. This balance sheet effect has strengthened when the steady state leverage is high in that loan branches lending capacity has increased with the same value of rise in equity capital. By contrast, in the second case in which the leverage ratio is low for loan branches (i.e., $\phi^c = 2.8$ and $\phi^c = 3.72$), the balance sheet effect on bank lending is relatively weak and thus the business cycle fluctuations are modest.

3.5 Conclusion

This chapter has studied the impact of financial frictions arising in the process of credit intermediation on macroeconomic dynamics. An important contribution of the chapter is to introduce a housing sector and differentiated mortgage and corporate loan markets into a New-Keynesian model with financial frictions à la Karadi (2011) [18] and Gertler and Kiyotaki (2010) [20] and Gertler. The agency problem is important in the model because it introduces an important channel through which exogenous shocks can affect the supply of credit intermediation, by affecting the capital of banks, which determines the degree to which banks are able to leverage their position.

We have shown that financial frictions which arise in the process of credit intermediation amplifies the effects of the shocks (i.e., the techonology shock and shock to mortgage borrowing constraint) which directly affect asset prices, through the strengthen of the bank balance sheet effect and act as a banking attenuator in the transmission of a monetary policy shock due to the imperfect interest rate pass-through induced by the banks' balance sheet adjustments. The model generates a procyclical movement of banks' leverage ratios and the aggregate economic activity. We found that the cyclical properties of interest rate spreads depend on where the shock comes from: the model features countercyclical interest rate spreads of technology and borrowing constraint shocks and procyclical interest rate spreads of monetary policy shocks. The model with borrowing-constrained banks is capable of explaining the positive co-movements between housing prices and business investment. Since our model features differentiated corporate and mortgage loan markets, we found that when capital inflows are possible between loan branches, bankers engage in continuous arbitrage between profit opportunities offered by the intermediation of corporate and mortgage loans, providing an important channel through which the effect of a shock (the technology or mortgage borrowing constraint shocks) that affects the price of particular asset to be transmitted to other assets. Finally, we also show that high leverage ratio of banks can enhance the effect of an increase in bank equity capital on bank's lending capacity, i.e., the bank balance effect, leading to sizeable expansion of credit and increase in the real economic activity.

The study in this chapter represents one step in establishing a framework to study the link between imperfect financial intermediation and macroeconomic fluctuations. In the fourth chapter, based on a paper coauthored with Meixing Dai and Frédéric Dufourt, we use this framework to analyze the large-scale asset purchase programs that the Federal Reserve pursued over the course of the recent financial crisis.

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Chapter 4

Large-scale asset purchases with segmented mortgage and corporate loan markets

4.1 Introduction

The recent financial crisis started with the burst of the housing bubble and the collapse in the value of mortgage-related securities. Large financial institutions, which were holding significant amounts of those securities, experienced a severe deterioration of their balance sheets, leading them to fire-sell assets and drastically reduce the amounts of loans distributed to households and firms. Both this deleveraging process and the erosion of confidence in the solidity of the banking system led to sharp increases in long-term interest rates and credit spreads. Central banks in many countries quickly faced the unprecedented situation of having their main policy instrument—the overnight interest rate—stuck at the zero lower bound while credit spreads were still rising and the economic activity was contracting. As a result, major central banks around the world implemented a series of unconventional monetary policy measures designed to reduce longer-term interest rates and ease overall financial conditions. Large-scale asset purchases programs (LSAP), which consists of purchasing longer-term securities by the Federal Reserve, have probably been the most spectacular and most widely discussed of those policies, raising lengthy discussions among the general public and stimulating a vigorous debate among academic researchers.[1]

Much discussion of LSAPs treats the "portfolio balance channel" as the key channel for policy transmission. For example, Chairman Ben S. Bernanke told an audience of

[1]The Fed was not the only central bank that purchases longer-term assets to combat the crisis. For example, since 2007, the Bank of England has purchased commercial papers and corporate bonds; the European Central Bank, covered bonds; and the Bank of Japan, Asset Backed CPs (ABCPs) and ABSs outright.

central bankers assembled at the Federal Reserve's 2010 Jackson Hole annual meeting [3] the following:

"I see the evidence as most favorable to the view that such purchases work primarily through the so-called portfolio balance channel, which holds that once short-term interest rates have reached zero, the Federal Reserve's purchases of longer-term securities affect financial conditions by changing the quantity and mix of financial assets held by the public."

As emphasized by Woodford (2012) [48], for LSAP programs to work, it must either be the case that (i) securities with identical risk and return characteristics have additional features that make them imperfectly substitutable from the viewpoint of investors (such as liquidity providing services), or (ii) there are limits to the quantities of assets that some investors can buy at prevailing market prices, i.e. some investors are submitted to binding constraints.

Building on these considerations, a growing recent literature has developed suitable frameworks to analyze the qualitative and quantitative effects of LSAPs within dynamic macroeconomic models with financial frictions (see in particular Chen *et al.*, (2012) [10], Cúrdia and Woodford, (2010) [14] and (2011) [15], Del Negro *et al.*, (2011) [17], Gertler and Karadi, (2011) [21] and (2013) [22], He and Krishnamurthy, (2012) [28] and Williamson, (2012) [45]).[2] In these papers, LSAPs consist either in central bank purchases of corporate bonds[3], of long term Treasury bonds[4], or of both.[5]

Although the assumption of central bank purchases of corporate bonds is a good starting point–enabling to emphasize crucial aspects of LSAP programs–it also has some potential limitations. In the US, the status of the Fed prevents it from buying risky private securities unless they are implicitly backed by the government. Consequently, the primary focus of the first round of LSAPs (often referred to as "QE1")–by far the most important of all LSAP programs in terms of volume–has been the acquisition of Agency Mortgage-Backed Securities (AMBS): among the 1.75 trillion of Fed's purchase of long-term assets conducted in QE1, 1.25 trillion involved MBS. Besides, the most recent Fedâs operation (announced in September 2012 and implemented since then) also includes additional purchases of MBS at a pace of 40 billion per month. Thus, from a theoretical perspective, understanding whether, and under which circumstances, targeted purchases of MBS should be expected to have similar or different effects as equivalent purchases of corporate bonds is of crucial importance. Actually, a recent controversy has emerged in academic debates as to whether and why large scale purchases of MBS should be expected

[2]Other relevant frameworks includes Brunnermeier and Sannikov (forthcoming) [9] and Christiano *et al.* (2013) [13], even if these papers do not examine LSAPs.
[3]See e.g. Curdia and Woodford (2011) [15], Del Negro *et al.*, (2011) [17], Gerter and Karadi (2011) [21] and Williamson (2012) [45].
[4]See Chen *et al.*, (2012) [10].
[5]See Gertler and Karadi (2013) [22].

to have a significant impact on the economy beyond their mere impact on the mortgage loan market.[6]

As far as we know, no existing theoretical studies have considered the possibility of the central bank buying mortgage-related securities. The aim of this chapter, coauthored with Meixing Dai and Frédéric Dufourt, is to address this issue. We use the framework developed in Chapter 3 for our analysis.

We think this framework is rich enough to assess the impact of LSAPs on corporate bonds and mortgage backed securities, as the model explicitly incorporates a housing sector and differentiated corporate and mortgage credit markets. In addition, the credit markets are segmented in this model, as each bank is divided into two branch categories that specialize in mortgage and corporate lending. Thus, the extent to which bankers can reallocate equity capital between branches along the business cycle to attenuate differences in interest rate spreads reflects the degree to which credit markets are segmented, thus influencing the extent to which a "portfolio balance channel" is at work in the economy.

In this chapter, the calibrated model of Chapter 3 is first used to simulate a financial crisis by introducing a large exogenous "confidence shock" into the banking system. This shock materializes as an abrupt, unexpected increase in the intensity of agency problems which affect the relationship between bankers and managers. The shock means to capture the distress in credit intermediation activities after the housing bubble burst and major financial institutions (e.g., Lehman Brothers) collapsed. We show that this large defiance shock stemming from the banking system triggers an abrupt decline in housing and capital asset prices, a decline in loans granted to consumers and firms (as branches start to deleverage), a significant increase in credit spreads (despite the central bank cutting its target interest rate), and a sharp economic contraction (with output, consumption, investment and hours worked all dropping down).

We analyze in this context the effects of LSAPs provided by the central bank. As in Gertler and Karadi (2011 [21] and 2013 [22]), LSAPs can be seen as central bank intermediation that aim to supplement private intermediation. In the model, purchasing longer-term securities (MBS or corporate bonds) is equivalent to providing additional loans to households and entrepreneurs at current market conditions (although the central bank is not balance-sheet constrained). We compare the effectiveness of two LSAP programs of identical size: the first one consists of purchasing MBS, and the second one consists of purchasing corporate bonds. Moreover, we conduct these experiments under two configurations in terms of the degree of credit market segmentation. In the first configuration, credit markets are partially segmented (e.g., the benchmark model in Chapter

[6]For example, while Bernanke repeatedly argued the purchases of MBS should be expected to have a significant impact on all long-term interest rates (see e.g. Bernanke, 2012 [5]), Woodford (2012) [48] offers convincing arguments why this might not necessarily be the case. Woodford (2012) [48] also challenges the view that LSAPs work through a channel different than a mere "signaling effect" about the future path of the central bank's target rate.

3). Impatient borrowers and entrepreneurs are thus forced to borrow from their respective bank's branch (so that there are two distinct borrowing rates in the corporate and mortgage loans markets), but bankers can freely reallocate equity capital between branches. In contrast, in the second configuration, credit markets are totally segmented (equity capital reallocation between branches is no longer possible). As will be discussed later, the second configuration means to capture the situation of complete disarray in financial market functioning that, according to many authors, was prevalent during the 2007 to 2009 financial crisis when QE1 was implemented (see in particular Krishnamurthy and Vissing-Jorgensen, (2011) [33]). Considering these two polar cases enables us to shed light on the importance of the "portfolio balance channel" for LSAP program effectiveness.

Our results show that LSAPs targeting the mortgage loan market are, in both configurations, less effective at mitigating the economic contraction triggered by the financial crisis than LSAPs targeting the market for corporate bonds. Thus, according to our results, studies in which central bank purchases of private assets involve corporate bonds somewhat overestimate the impact of LSAP programs that target instead MBS. Moreover, we also show that the differences in the stabilizing effects of the two programs crucially depend on the extent to which credit markets are segmented.

When credit market are partially segmented, the effects of large scale purchases of MBS are actually very similar – albeit slightly attenuated – to those of an equivalent size purchase of corporate bonds. The moderate difference between these two programs comes from the fact that corporate loan branches are, on average, less leveraged than mortgage loan branches (i.e., corporate loan branches are submitted to a greater moral hazard problem than mortgage loan branches at the steady state). Thus, compared to a situation without intervention, the central bank's purchases of corporate bonds free up slightly more bank capital than equivalent purchases of mortgage securities. The portfolio balance channel then implies that part of this freed equity capital can be profitably reinjected into the mortgage credit branch since, for each dollar of equity capital, the higher leverage ratio implies that banks can expand loans by a greater amount in the mortgage loan branch.

In the complete segmentation case, however, effects are significantly different. The absence of equity capital transfers implies that the portfolio balance channel is no longer at work. Consequently, LSAPs targeting a particular credit market have much more "local" effects: central-bank purchases of MBS have a stronger effect on the mortgage loan market but a weaker effect on the corporate loan market, and vice versa. In this configuration, large scale MBS purchases are useful to stabilize the housing market (decreasing the reallocation of houses units between mortgage borrowers and lenders following the crisis) but are now much less effective at stabilizing aggregate employment and output than equivalent purchases of corporate bonds. The reason is that, in the US, residential investment accounts for a significantly smaller share of GDP than non-residential investment (2.5% and 10.7%, respectively), and the absence of any pass-through effect of the central bank's

MBS purchases to other credit markets implies that the overall effect on economic activity is limited.[7]

The content of this chapter can be summarized as follows. Section 4.2 gives a brief description of the practice and theory of the Fed's large-scale asset purchase programs. Section 4.3 presents a short review of empirical and theoretical studies of LSAPs that have been written in recent years. In Section 4.4, we first simulate the effects of a financial crisis by introducing a large confidence shock into the banking system. We then introduce mortgage and corporate bonds purchases by the central bank to analyze the transmission mechanisms of the LSAP programs, assuming either partial or total credit markets segmentation. Finally, Section 4.5 provides concluding comments.

4.2 Large-scale purchases of long-term securities: practice and theory

4.2.1 The Federal Reserve's policy responses to the financial crisis

The Federal Reserve's conventional monetary policy tool consists of using its target for the federal funds rate–the short-term interest rate at which banks lend to each other on an overnight basis–to affect some key market interest rates and thus influence real economic activity. For instance, when the economy is weak, the Fed lowers its federal funds rate target to stimulate growth. To ensure that the effective federal funds rate decreases along with the target rate, the Fed performs whatever open market purchases of short-term Treasury securities that might be necessary. These actions increase the aggregate quantity of reserve balances that banks hold at the Fed, putting direct downward pressure on other short-term interest rates. Declines in short-term interest rates in turn influence long-term interest rates—such as corporate bond rates and residential mortgage rates—because those rates reflect, among other factors, the current and expected future values of short-term rates. In the presence of nominal price rigidities, these declines in nominal interest rates lead to declines in real interest rates, which encourage purchases of consumption goods, houses and capital goods. According to historical evidence, changes in the policy interest rate have sizeable impacts on the output and prices.[8]

However, since the onset of the global financial crisis of 2007 and 2008, the traditional monetary policy became ineffective in stabilizing the financial conditions and supporting

[7]A by-product of this conclusion is that, from a theoretical perspective, analyzing the effects of LSAPs by abstracting from the mortgage market and assuming that the central bank purchases corporate bonds instead of MBS (as done in the previous literature) is a correct approximation when financial markets work normally. However, such modeling assumption may lead to substantially biased results if financial markets are in complete disarray, as many argue was the case in the 2007-2009 crisis.

[8]Estimates for the US suggest that a 100-basis point reduction in the federal funds rate should usually lead to a peak incerase in real GDP of $0.5 - 0.7\%$ and a $0.1 - 0.4\%$ increase in the price level. See for example, Leeper *et al.* (1996) [34], Bernanke and Mihov, (1998) [7] and Christiano *et al.*, (1999) [12].

the economic growth. From September 2007 to the end of April 2008, the Fed responded to the emergent financial stresses by lowering its target for the federal funds rate by a cumulative 325 basis points, from 5.25% to 2%, which held constant over the summer of 2008. As the crisis intensified significantly in September 2008 after the collapse of Lehman Brothers, the Fed further cut its target rate by 100 basis points in October. In December 2008, as evidence of the recession's severity and ongoing financial market strains, the Fed decided to set its target to a range of 0 to 25 basis points, i.e., its effective lower bound (ZLB). That target range remains in place today.[9] Despite these sharp reductions in the policy rate, long-term market interest rates did not move perfectly with the short-term interest rates and interest rate spreads sharply increased. The US economy was still struggling with high unemployment rate and was facing deflation risk, which increased pressure on the real interest rates.[10]

The reason that the Fed's traditional open market operations–buying short-term securities to increase monetary base became ineffective is that when the quantity of liquidity supply pushes the nominal short-term interest rates near zero, the interest rate at which banks are willing to hold short-term Treasury securities is no longer greater than the interest rate paid on reserves, and thus the opportunity costs for banks to hold excess reserves on their balance sheets disappear. Therefore, in Fed's traditional open market operations, short-term Treasuries and bank reserves become perfect substitutes. Under such conditions, banks' demand for reserves becomes infinitely elastic. Any increase in the quantity of central bank money leads to an equivalent increase in the demand for reserves, which becomes unbounded. This absolute liquidity preference was further exacerbated by an inefficient interbank market freeze that resulted from a sharp rise in the banking system's counterparty risk due to the banks' subprime mortgage losses. In such circumstances, any expansion in reserve supply through open market operations in short-term treasuries would affect the structure of yields and returns and thereby stimulating aggregate demand.

To provide additional monetary accommodation at ZLB, the Fed has used two types of unconventional policy tools. The first is forward guidance on federal funds rates, e.g., the central bank's communication strategy. By providing assurance to the market that the short-term interest rates will be maintained at a low level for a longer period (even after the zero lower bound ceases to bind) than is currently expected, the Fed can influence private sector's expectations about the future trajectory of short-term interest rates and inflation, thereby affecting long-term interest rates and leading to more accommodative financial conditions. The rationale for such policy stance has been clearly stated by Woodford (1999) [46] who argues that "it is unlikely that monetary policy can do much to loosen

[9]In the aftermath of the failure of Lehman Brothers in September 2008, the Fed also took in emergency lending programs to provide short-term liquidity in markets and stabilize key institutions (see Appendix C1).

[10]The unemployment rate in the U.S. was approximately 7% in December of 2008 when the federal funds rate reached its effective lower bound, and it continued to rise, eventually peaking at 10% in October 2009.

the constraint imposed by the zero bound, except by changing what people expect policy to be like after the constraint ceases to bind." Note that the way that forward guidance works to affect the financial market conditions is similar to the conventional monetary policy actions, which also typically affect not only current short-term rates, but longt-term interest rates.

The second new policy is a series of large-scale asset purchases. In conducting LSAPs, the Fed expands its balance sheet to purchase long-term Treasuries and long-term securities issued or guaranteed by government-sponsored agencies such as Fannie Mae or Freddie Mac. LSAPs differ from the conventional monetary policy in important way; as stated by many Federal Open Market Committee (FOMC) members, LSAPs are designed to affect risk/liquidity premiums in the markets that were dysfunctional[11], while the federal funds rate policy works to affect long-term interest rates mainly through its impact on the expectations component of these rates.

To date, the Fed has implemented three rounds outright long-term asset purchases. The first round (known as LSAP1 or QE1) was announced in November 2008. Through opened market operations, the Fed purchased $1.75 trillion in high grade long-term securities, among which $1.25 trillion in MBS.[12] Others assets purchased under QE1 include agency debts and long-term Treasuries.[13] In the second round (known as LSAP2 or QE2), from November 2010 through June 2011, the Fed purchased $600 billion in long-term Treasuries. The most recent Fed operation, QE3, was announced in September 2012 and is still in force; it includes additional MBS purchases (at a pace of $40 billion per month) and long-term Treasuries (at a pace of $45 billion per month). Moreover, starting in September 2011 to the year-end 2012, under a sterilized version of LSAP, the Maturity Extension Program (the MEP, commonly called "Operations Twist"), the Fed sold a total of $667 billion in short-term Treasuries in exchange for long-term Treasuries. These asset purchases have not only significantly increased the size of the Fed's balance sheet, but they also changed the composition of Fed's portfolio of securities holdings, which were primarily short-term Treasuries before large-scale asset purchases were implemented.

4.2.2 The basic theoretical mechanisms of LSAPs

Most recent studies consider three primary channels as the principal channels through which LSAPs work to affect long-term interest rates. The first is the *signaling* channel. LSAPs can assure investors that the central bank intends to pursue a more accommodative policy stance for a prolonged period, thereby impacting market expectations about the future path of federal funds rate and lowering interest rate risks that are associated with

[11] See for example, Bernanke, (2011) [4], Kohn, (2009) [32], Williams, (2011) [44], and Yellen, (2011) [49].

[12] Agency MBS were purchased between January 2009 and March 2010.

[13] Agency debt purchases were announced in November 25, 2008 and completed in August 2010. Long-term Treasuries purchases were announced on Mars 18, 2009 and completed on October 2009.

holding longer-term securities. Such signaling can also diminish household and corporate uncertainty about "tail" risks (e.g., deflation).

The second channel that has played a role in the effect of large long-term asset purchases is the *scarcity* channel. The basic idea is that the Fed's specifically targeted asset purchases can reduce the supply of long-term Treasuries or MBS in the markets. The increasing scarcity of those assets would make them to be traded at a higher price and thus reduce the premia in yields of those assets. This channel is likely to be important for times when the degree of market segmentation is high, so the beneficial effects of asset purchases tend to concentrate on purchased assets and their close substitutes (see Woodford, 2012 [48], Krishnamurthy and Vissing-Jorgensen, 2011 [33] and Joyce *et al.*, 2010 [30]).

The third is the *duration* channel. When the central bank purchases long-term securities, no matter the type, it reduces the duration or interest rate risks in investors' portfolio, thus reducing not only the yields on purchased assets, but also yields of all long-term securities of the similar duration as well (see Greenwood and Vayanos, 2010 [25], Gagnon *et al.*, 2011 [20], D'Amico and King, 2012 [16], and Hamilton and Wu, 2012 [26]).

The theory underpinning scarcity and duration channels is the portfolio balance effect, which is based on the views of several earlier leading economists—including James Tobin, Milton Friedman, Franco Modigliani, Karl Brunner, and Allan Meltze—on monetary policy. This theory argues that increasing the central bank's holdings of long-term assets can reduce yields on those assets relative to the path of the expected short-term interest rate if different classes of assets are not perfect substitutes in investors' portfolios.[14] In particular, when the central bank purchases riskier long-term assets, such as Baa corporate bonds or MBS, it replaces that quantity of private investor assets with safe assets, such as high powered money or short-term Treasury securities. Investors react by replacing the securities sold to the central bank with other assets to rebalance their portfolios, which induces the prices of the assets they buy to rise and their yields to decline. Thus, given this portfolio balance effect, central-bank purchases of long-term Treasuries or MBS, should be expected to raise the prices and lower the yields of these securities but also should affect other long-term assets. Therefore, given this portfolio balance effect, central bank purchases of long-term Treasuries or MBS, should be expected to raise these securities' prices and lower their yields but they also should affect other long-term assets.

However, such findings are hard to square with the standard efficient market hypothesis model.[15] In this framework, the strong assumption of complete and frictionless financial markets stipulates that the price of any asset is the discounted value of future flow of consumption and the stochastic discount factor is derived from the representative household's marginal utility of income in the future states of the world. As a consequence,

[14]See Tobin (1965 [39], 1969 [40]), Modigliani and Sutch (1966a) [35], Brunner and Meltzer (1973) [8], and Friedman and Schwartz (1982) [19]. Nelson (2011)[?] discusses the relevance of Friedmanâs views on recent Federal Reserve policy.

[15]See e.g. Wallace, (1981) [42], Eggertsson and Woodford, (2003) [18] and Walsh, (2009) [43].

the Modigliani-Miller theorem applies to the central bank's asset purchases which do not change the current real quantity of available household consumption or their future flows of consumption. Thus, the representative household's marginal value of consumption in different states of nature should not change, as do the risky returns and the market price of an asset.

In reality, there are many reasons for this neutrality not to hold. First, one can imagine that the markets could have additional features for different assets with identical risk and return characteristics that would make them imperfectly substitutable from investors' perspectives. For example, the Treasury securities provide a sort of liquidity service. They are the risk-free assets guaranteed by the U.S. government, and they are usually used by banks as collateral for short-term financing (e.g., *repo* transactions). The Treasury purchases by the central bank should increase a "safe premium" that is specifically associated with the holding of those assets and thereby lower their yields and increase their prices, even if the expected path of the short interest rates is unaffected.

However, this effect should be expected to vanish once there are sufficient purchases of long-term Treasuries, which drive the special convenient yield to a maximum. This expectation is equivalent that of the pure quantitative easing policy drives the interest rate on short-term Treasuries to the interest rate on reserves.

Another reason that the irrelevance result may not to hold in practice might be the existence of asset market segmentation due to constraints on participation in particular markets or on the positions that particular traders can take in those markets. One can imagine that a group of investors that have a preference for investing at given maturities. For instance, these investors, might be pension funds, which, based on the structure of their liabilities, commonly purchase long-term assets. When the supply of long-term Treasuries declines relative to the supply of short-term Treasuries, these investors would be willing to accept a lower expected return from long-term Treasuries.[16] Moreover, the market segmentation might be the case that there are leveraged arbitrageurs (e.g., broker-dealers or hedge funds), which attempt to enforce the expectations hypothesis[17], but given limited capital and a balance sheet constraint, all return differentials cannot be totally arbitraged away, thus making changes in composition of arbitrageurs' portfolio an effective way of affecting the assets' yields and prices.

[16] This idea goes back to Modigliani and Sutch (1966a) [35] and (1966b) [36].

[17] The expectations hypothesis states that the long-term interest rate is determined by the market's expectation for the short-term interest rate over the holding period of the long-term asset, plus a constant risk premium.

4.3 Related literature

4.3.1 Evidence on the effectiveness of LSAPs

Many recent empirical studies of the Fed's large-scale asset purchases have found that this unconventional monetary policy tool has been effective in lowering various long-term interest rates and consequently supporting the economic recovery while mitigating the deflation risk. In general, the estimated effects of QE1 on 10-year Treasuries lie in the neighbor from 40 to 110 cumulative basis points and the Treasury purchases under QE2 appear to induce additional reductions in yield on such asset by 15 to 45 basis points. The decline in yield on MBS appears to be significant during the implementation of QE1 and 3, which involve MBS purchases. A balanced reading of the evidence supports the prevalence of the signaling channel (see Bauer and Rudebusch , 2011 [2] and Christensen and Rudebusch, 2012 [11] and Krishnamurthy and Vissing-Jorgensen, 2011 [33]), the portfolio balance effect, which works through scarcity (see Krishnamurthy and Vissing-Jorgensen, 2011), and duration channels (see Gagnon *et al.*, 2011 [20], Diana Hancock and Wayne Passmore, 2011 [27] and D'Amico and King, 2013 [16]).[18] In general, the literature finds evidence for the signaling channel to be important in QE1, QE2 and QE3, while the portfolio balance effect was crucial in the period during QE1 and QE3, when the Fed purchased MBS. Appendix C summarizes the effects of the Federal Reserve's LSAPs on the financial conditions, as gleaned from the empirical literature.

In an influential paper, Gagnon *et al.*, (2011) [20] consider the market movements in response to eight specific official FOMC announcements about large-scale asset purchase programs, and examine one-day changes in the long-term interest rates and term premiums following each LSAP purchase announcement.[19] They find that QE1 was associated with significant portfolio effects on asset prices, and much of the decline in long-term interest rates on LSAP announcement days was due to declines in the term premium on those days, rather than to changes in the expectations component of long-term interest rates. They document that the eight LSAP announcements led to a 91-basis-point decline in 10-year Treasury yields (the term premium fells by 71 bps), a 113-basis-point decline in agency MBS yields, and a 67-basis-point decline in Baa-rated corporate bond yields.

Bauer and Rudebusch (2011) [2] focus on the same eight LSAPs announcement dates,

[18]These studies seek to obtain precise estimates of the effects of the various channels through which LSAPs cause declines in long-term interest rates. One approach used by some researchers is to decompose the yields of long-term assets into two components, i.e., the term premium and the expectations of future policy rates, and assume that the signaling channel mostly affects the average expectations of future short-term rates over the bond's maturity, and the portfolio balance channels play an important role in affecting the term premium. Another approach uses a model-free evaluation of LSAPs. Several channels are supposed to affect particular assets differently, and the effects of LSAPs are based on a comparison of price changes across assets.

[19]Other event studies include Joyce *et al.*, (2011) [30], Krishnamurthy and Vissing-Jorgensen (2011) [33] and Swanson (2011) [38].

but use term premium estimates that are based on an arbitrage-free dynamic term structure model (DTSM) with reduced bias. They found important signaling effects for the QE1 announcements, i.e., long-term interest rates decline mainly due to changes in market expectations of the future path of monetary policy. However, their analysis of QE2 and Operation Twist shows little evident that the signaling effects were also significant in these purchase programs. The authors argue that market participants already had excessive expectations for the overall effects of LSAPs on financial markets over a substantial time horizon, which explains this insignificant effect.

Krishnamurthy and Vissing-Jorgensen (2011) [33] exploit both daily and intra-day effects of the QE1 and QE2 announcements on a range of risk premiums. They find evidence that the QE1 announcements helped reduce the yields on MBS and long-term Treasuries that the Fed had purchased under LSAPs, while other securities, such as corporate bonds, were not significantly affected by these announcements. According to their study, the Fed's MBS purchases reduced the risk associated with holding of such assets, resulting in a reduction of MBS-specific risk premiums, while long-term Treasury purchases increased the scarcity of such assets in the market, which raised a specific safety premium associated with holding such assets and thus reduced the yield on long-term Treasuries relative to private securities, such as MBS and corporate bonds. For the QE2 which involves only safe long-term Treasuries, the authors find that the announcement substantially impacted those assets, but there was little to no evidence suggesting that purchases of long-term Treasuries also affect the yields and price of MBS.

As found in Krishnamurthy and Vissing-Jorgensen (2011) [33], the narrow beneficial effects of the Federal Reserve's LSAPs indicate that LSAPs principally affect the price and yield of the Fed's purchased assets and they could be expected to have large impact on assets whose risk premiums are high due to a severe financial disruption, while their effects could be felt when financial markets function more normally. As Woodford (2012) [48] argues, if the mortgage related asset markets are significantly disrupted and the central bank's goal is to lower the interest rates on mortgage or support the housing market, MBS purchases are more likely to be effective, though even purchases of that type would not necessarily be as effective under current conditions as they were under the unusual circumstances.

4.3.2 Theoretical literature on LSAPs

This chapter belongs to the growing theoretical literature that attempt to analyze the transmission mechanisms of the Fed's large-scale asset purchases, which were implemented in response to the Great Recession. Some recent papers consider the purchases of long-term Treasury securities and highlight the importance of market segmentation for the transmission mechanism of this unconventional monetary policy. For example, Vayanos and Vila

(2009) [41] analyze the effects of long-term Treasury purchases on the risk premium of particular asset in a model in which investors have heterogeneous preferences for assets of different maturities. The model predicts that the purchase of long-term Treasuries of a given maturity can lower the term premium of those assets, as a set of preferred habitat investors who have a special demand for those assets are willing to pay a convenience yield. Similar to Vayanos and Vila (2009) [41], in the preferred-habitat framework, Chen *et al.*, (2011) [10] finds that QE2 and the Maturity Extension Program, which involve only long-term Treasuries, are principally effective in supporting the economic recovery because of limits to arbitrage and market segmentation between short-term and long-term Treasuries.

Others consider asset purchase programs that involve open market operations in riskier private assets (i.e., corporate bonds). Del Negro *et al.*, (2011) [17] develop a DSGE model in which they distinguish illiquid private assets (that the central bank purchases in its open market operations) and short-term government bonds (that the central bank sells in its open market operations) by introducing a resaleablity constraint to the private assets. They find that without the Fed's LSAPs, output and inflation would have dropped by an additional 50%. Cúrdia and Woodford (2010) [14] introduce the credit spread into a standard NK model to investigate the role for the central bankâs balance sheet used as tool to stabilize the financial markets.[20] In this framework, the credit spread is assumed to be increasing in the volume of bank-issued "bad loans" and the costs of originating and servicing loans, and decreasing in the amount of reserves that the bank holds at the central bank. This model allows for real effect of asset purchases at ZLB if the condition that the increase in reserves allows the central bank to increase its holdings of private assets rather than Treasury securities. Moreover, they argue that at the ZLB, the private asset purchases, which are financed by either the increase in reserves or selling short-term Treasuries should be expected to have identical effect. Gertler and Karadi (2011) [21] develop a DSGE model with financial intermediaries that are subjected to an endogenously determined balance sheet constraint due to a moral hazard problem. By assuming that the central bank is not constraint as private banks, they show that the Fed's purchases of corporate bonds by issuing short-term Treasuries can significantly reduce excess returns. Williamson (2012) [45] suggests that the central bank's private asset purchases can only affect the bond yields if the central bank lends on better terms than does the private bank.

Gertler and Karadi (2013) [22] analyze the impact of LSAPs of both long-term Treasuries and corporate bonds in a single framework, which is based on the model of Gertler and Karadi (2011) [21]. They argue that LSAPs stimulate the economy by reducing a range of credit costs, because there are limits to arbitrage in private intermediation. Given that financial friction is greater for holding corporate bonds than for holding government bonds,

[20] The NK model, which distinguishes between loan interest rates and the policy rate, was first developed by Goodfriend and McCallum (2007) [24].

the authors argue that LSAPs of private assets lead to larger reductions in long-term yields than an equivalent size purchase of government bonds.

4.4 Large-scale asset purchases with segmented mortgage and corporate loan markets

The discussion has thus far provided a brief description of the existing theoretical literature on the transmission mechanisms of unconventional asset purchases of corporate bonds and long-term Treasuries. However, to date, no existing studies have considered the Federal Reserve's purchases of mortgage-related securities. In this section, we aim to fill this gap in the literature and provide a theoretical formulation for analyzing the relationship between the effectiveness of private asset purchases and the credit market structure.

Our analysis is based on the model developed in Chapter 3. It is a standard NK model that has been modified to allow banks to obtain intermediate funds from households to nonfinancial firms and mortgage borrowers. Proposed by Gertler and Karadi (2011) [21], a particular form of financial frictions limits the ability of banks' specialized loan branches to obtain funds from households and thus generates a spread between loan interest rates and the policy rate. In response to business cycle fluctuations, the equity capital transfers between loan branches give rise to arbitrage in private asset markets, which is crucial for a "portfolio balance channel" at work in the economy. In this chapter, we consider the possibility of the central bank directly providing liquidity to private markets by purchasing corporate bonds and MBS in this framework. As in Gertler and Karadi (2011 [21] and 2013 [22]), these long-term asset purchases can be observed as central bank intermediation that aims to supplement private intermediation when the markets for certain assets are severely disrupted.

In this chapter's model economy, the problems of patient and impatient workers, entrepreneurs, financial and nonfinancial firms are unchanged compared with those in Chapter 3. In this section, we will first describe the central bank's problem with unconventional asset purchases. We then show the subsequent slightly modified credit market clearing conditions by considering the central bank's credit intermediation before going on to the LSAP experiments.

4.4.1 The model

4.4.1.1 The central bank's purchase of long-term assets

We assume that to lower excess returns on assets and the costs of borrowing in private credit markets, the central bank can decide to purchase corporate bonds or MBS at existing market conditions. In contrast with private financial intermedaition, the central-bank intermediation does not suffer from agency problems, i.e., the central bank can elastically provide funds to private borrowers. However, the central bank does not have as much expertise as private banks in monitoring loans, so that central bank intermediation is subject to an efficiency cost assumed to be equal to ι percent of units of loans intermediated. The fact that the central bank is less efficient than the private banks in providing intermediation services implies that it cannot entirely substitute private banks in this activity. LSAPs can thus only improve financial conditions when private credit markets are severely disrupted and the excess returns are large.[21]

We assume that the central bank funds its securities purchases by issuing short term (one period) debt D_t^g at the gross nominal interest rate R_t. The raised funds allow it to purchase a total value $S_t^{c,g}$ of corporate bonds and $S_t^{h,g}$ of mortgage loans in the hands of private banks, and it is assumed that any profits or losses made by the central bank through LSAPs, $\Phi_t = (R_{t-1}^c - R_{t-1})S_{t-1}^{c,g} + (R_{t-1}^h - R_{t-1})S_{t-1}^{h,g}$ are transferred to the Treasury. Let S_t^l be the total value of corporate and mortgage loans, $l \in \{c, h\}$. Given the leverage ratio ϕ_t^l and the total equity capital N_t^l across the individual loan branches, the amount of credit intermediated by loan branches is $S_t^{l,p} = \phi_t^l N_t^l$. Thus, we have

$$S_t^l = S_t^{l,p} + S_t^{l,g}. \tag{4.1}$$

The central bank decides on the amount of public credit intermediation $S_t^{l,g}$ it undertakes in any period t. We assume that $S_t^{l,g}$ follows a first-order stochastic process:

$$\log S_t^{l,p} = \rho^g \log S_{t-1}^{l,p} + (1 - \rho^g) \log S^{l,g} + \Upsilon \epsilon_t, \tag{4.2}$$

where the autoregressive coefficient ρ^g is between 0 and 1, $\Upsilon > 0$ is a scale parameter, and ϵ_t is an exogenous shock described below.

4.4.1.2 Fiscal policy

Government expenditures G are exogenously fixed and are financed by fiscal revenues (lump-sum taxes raised on consumers) and by income transfers related to the central bank holdings of private securities. We also assume that the government runs a balanced budget, implying that

$$G = T_t^s + T_t^b + T_t^e + \Phi_t. \tag{4.3}$$

[21] For example, ι can be calibrated so as to imply that no central bank intervention is desirable at the steady-state. In this case, the "Bills only" doctrine applies in normal times, and LSAPs are only justified to the extent that unusually large shocks generate an abrupt increase in credit spreads. See Cúrdia and Woodford (2010) [14] for more discussion on this point.

Thus, profits or losses made by the central bank are compensated by equivalent variations in taxes raised on consumers so as to keep the budget balanced.

4.4.1.3 Credit market clearing conditions

Given that the total amount of loans granted to the private sector are the sum of credit intermediated by both private banks and the central bank, the corporate and mortgage loan market equilibrium conditions are respectively

$$\frac{\mu^e E_t \left[1 - \delta(U_{t+1})\right] q^c_{t+1} K_t \pi_{t+1}}{R^c_t} = S^c_t = S^{c,p}_t + S^{c,g}_t, \tag{4.4}$$

$$\frac{\mu^b E_t q^h_{t+1} h^b_t \pi_{t+1}}{R^h_t} = S^h_t = S^{h,p}_t + S^{h,g}_t. \tag{4.5}$$

4.4.2 Model analysis

We now turn to the quantitative analysis of the model. The calibration of the model is the same as in the model developed in Chapter 3. We show that our model can reproduce reasonably well the characteristic features of the US economy following the trigger of the crisis, materialized here as a sudden increase in agency problems in financial markets. We then analyze the transmission channels involved in the purchases of corporate bonds and MBS, and compare their relative efficacy in easing credit conditions and in stimulating the real economy.

4.4.2.1 Simulating the financial crisis: the moral hazard shock

As emphasized earlier, we interpret the financial crisis as stemming out from a major loss of confidence in the financial system, due to an exacerbation of agency problems in credit intermediation activities. Since, in our model, the degree of financial market imperfections is materialized by the fraction $\lambda_{l,t}$ of assets that loan branch managers can divert in any period t, we introduce a shock to this parameter. Specifically, we assume that $\lambda_{l,t}$ is a first-order autoregressive process with autoregressive coefficient 0.8 as follows,

$$\log \lambda_{l,t} = \rho^\lambda \log \lambda_{l,t-1} + (1 - \rho^\lambda) \log \lambda_l + \varepsilon^\lambda_t, \tag{4.6}$$

where $l \in \{c, h\}$. We favor this negative "confidence shock" affecting financial markets to a more traditional "capital quality" shock considered in Gertler and Karadi (2011 [21] and 2013 [22]) for pragmatic reasons, as in our model this shock does qualitatively a better job at accounting for the main features of the current crisis than the capital quality shock does.

Figure 4.1 displays the impulse response functions of the model following a positive 5% shock to $\lambda_{l,t}$ in both the corporate and mortgage loan sectors, assuming at this stage that there is no central bank intervention in the credit markets. In the figure, solid lines are used to depict the responses in an economy with partially segmented credit markets, while dashed lines are used for an economy with total credit market segmentation.

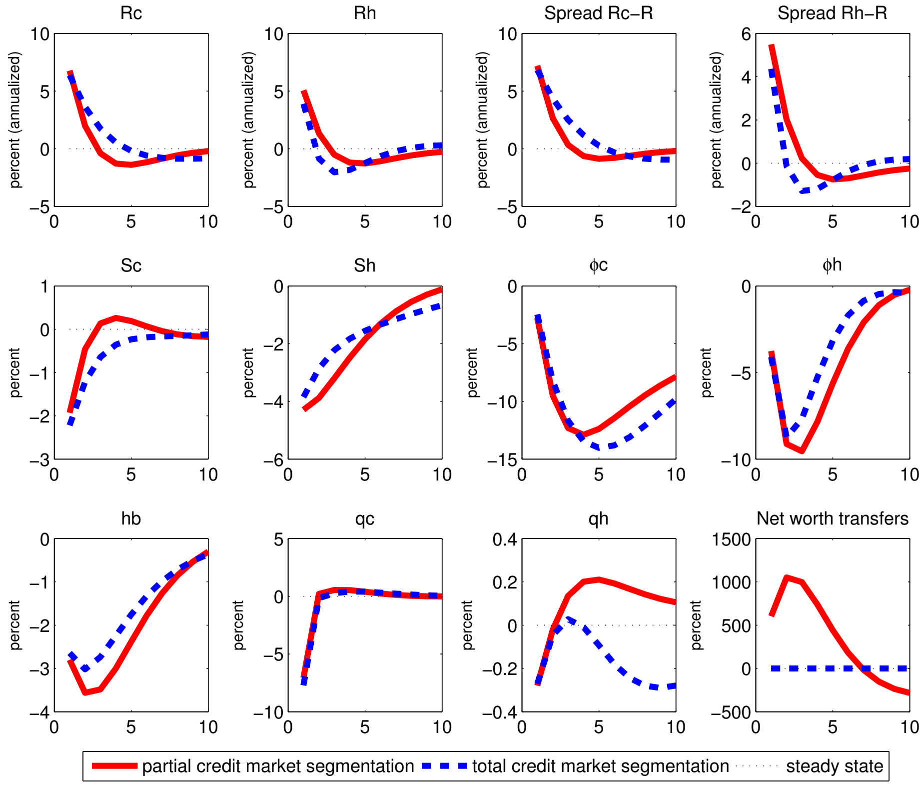
In both economies, the exacerbation of agency problem in financial intermediation generates an instantaneous increase in borrowing rates, R_t^c and R_t^h (with a larger increase in corporate loan rates) and induces loan branches to deleverage (see Panel a – Financial and credit market-related variables). This induces a significant decrease in the amounts of loans S_t^c and S_t^h granted to entrepreneurs and mortgage borrowers, respectively. With loans becoming scarce and more expensive, the demand for capital and the demand for housing from impatient borrowers decrease. As a result, asset prices drop: in the partially segmented economy, the capital price q_t^c collapses by -7% and the housing price q_t^h decreases by -0.3%. In the totally segmented economy, the corresponding declines are -7.7% and -0.3%, respectively.

The fact that the capital price declines less in an economy with partial credit market segmentation underlines the role of equity capital inflows in the propagation of the crisis. When credit market are partially segmented, Figure 4.1 (Panel a) shows that, in order to compensate from the disproportional increase in the corporate loan rate compared to the mortgage loan rate, bankers choose to reallocate equity capital by transferring equaity capital from the mortgage loan branch to the corporate loan branch. At the aggregate level, these transfers occur until the "leverage-adjusted excess returns", $\phi_t^l(R_t^l - R_t)$, are the same in each branch $l \in \{c, h\}$.[22] Thus, compared to an economy in which credit markets are totally segmented, equity capital transfers tend to mitigate the reduction in loans granted to entrepreneurs.

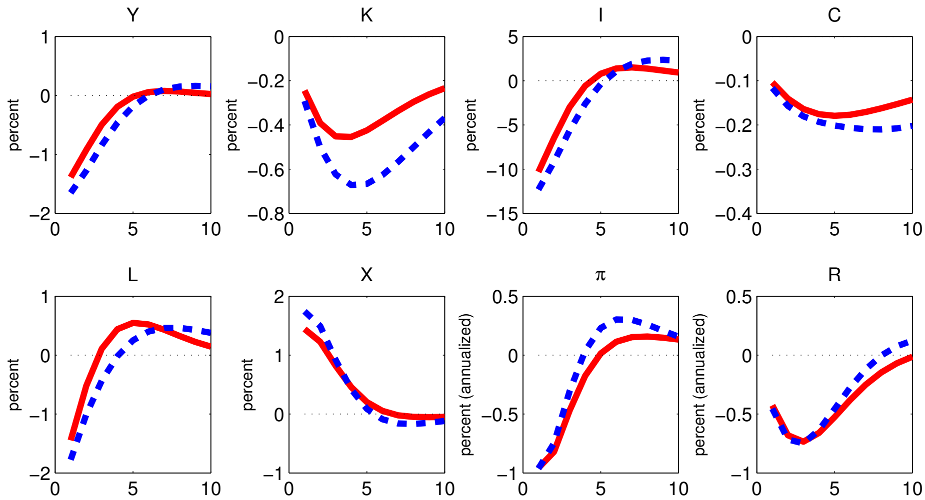
Figure 4.1 (Panel b – Real economy variables) shows how the "real side" of the economy is in turn affected by the disruption in financial markets. The decline in corporate loans generates a collapse in aggregate investment, which drops by -10% in the partial segmentation case, and by -12% in the economy with total segmentation. As capital accumulation slows down, the marginal productivity of labor also falls for several quarters, and so do real wages. Labor supply decreases as a result of this decline in real wages, and aggregate consumption decreases as a joint result of the lower wage income and of the negative impact on households' wealth implied by sharply falling asset prices. With low investment and low consumption, aggregate demand falls, generating a decrease in output and a decrease in the price level.

Facing a simultaneous contraction in output and in the inflation rate, the central

[22] The non-arbitrage condition is given by equation (29) $\phi_t^c(R_t^c - R_t) = \phi_t^h(R_t^h - R_t)$ in Chapter 3. It underlines how the "portfolio rebalance channel" is at work in this economy. When capital inflows are possible between branches, bankers make continuous arbitrage between profit opportunities offered by the two loans branches.



(a) *Financial and credit market related variables*



(b) *"Real economy" variables*

Figure 4.1: *Impulse responses to a 5% moral hazard shock*

bank reacts by cutting its policy rate R_t.[23] Yet, as Figure 4.1 (Panel b) reveals, this reduction in the policy rate is not sufficient to counteract the negative effects of distressed financial markets conditions on long-term interest rates. With a decreasing R_t and strongly increasing R_t^c and R_t^h, credit spreads jump by a significant amount. In accordance with the data, the credit spread increase in the corporate loan sector is larger than the one in the mortgage loan sector: in the economy with partial credit market segmentation, $R_t^c - R_t$ increases by 720 basis points, and $R_t^h - R_t$ increases by 550 bps. In the economy with total credit market segmentation, the corresponding increases are 680 bps and 440 bps, respectively.

Overall, although the model is too simple to match quantitatively all observed features following the crisis, we find that the inclusion of a mortgage sector and of segmented corporate and mortgage credit markets allows to account for a broader set of empirical facts associated with the burst of the financial crisis (declining housing prices, housing reallocation between lenders and mortgage borrowers, differentiated credit spread evolutions on credit markets, etc.), without altering the accurate predictions of the Gertler and Karadi (2011) [21] model on the behavior of other variables. Thus, we believe that the model is a useful benchmark to analyze the differentiated effects of LSAPs targeting different assets (MBS versus corporate loans).

4.4.2.2 Large-scale asset purchases with partial credit market segmentation

We now analyze the effects of LSAPs in the crisis experiment undertaken above, assuming for the moment that credit markets are partially segmented. To do so, we assume that in response to the large confidence shock on the financial system, the central bank directly purchases private securities at current market conditions. As explained in Gertler and Karadi (2011) [21], LSAPs can thus be viewed as central bank intermediation, with the difference that this intermediation is not subject to agency problems.[24] To facilitate comparisons, we distinguish between two kinds of LSAPs: the first one involves only the purchase of corporate bonds and the second one involves only the purchase of mortgage loans (MBS). In each case, we assume that the amount of credit intermediation $S_t^{l,g}$ provided by the central bank follows the same first-order autoregressive process (4.2) with autoregressive factor $\rho^g = 0.9$ where ϵ_t is the 5% confidence shock introduced above. The scale parameter Υ is set so that the total amount of assets purchased by the central bank represents 2% of steady-state GDP at impact. Our policy simulation is only meant to be

[23] For technical reasons–in particular, to avoid handling the computational difficulties associated with solving a large scale DSGE model with occasionally binding constraints–the size of the confidence shock has been limited so as to avoid that the central bank's policy rate hits the zero lower bound. Papers in the literature that have explicitly handled this constraint (e.g. Del Negro *et al.*, 2011, Chen *et al.*, 2012 and Gertler and Karadi, 2011, 2013) have typically found that the effects of large shocks on financial markets are qualitatively the same, but are substantially amplified when the ZLB constraint is hit.

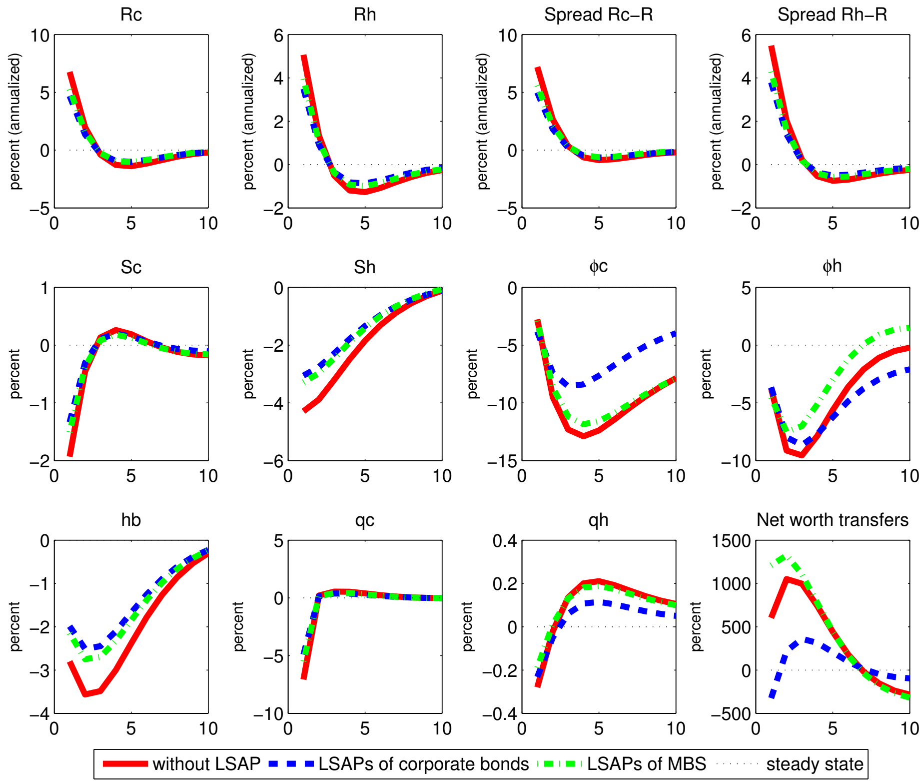
[24] This transmission channel of LSAPs, where central bank purchases of securities help to mitigate credit market imperfections, is sometimes referred to as the "credit easing" channel of LSAPs.

suggestive, as we do not attempt to perfectly reproduce the timing of shocks and policy interventions involved in the recent crisis. Results from these experiments are displayed in Figure 4.2 (Panels a and b).

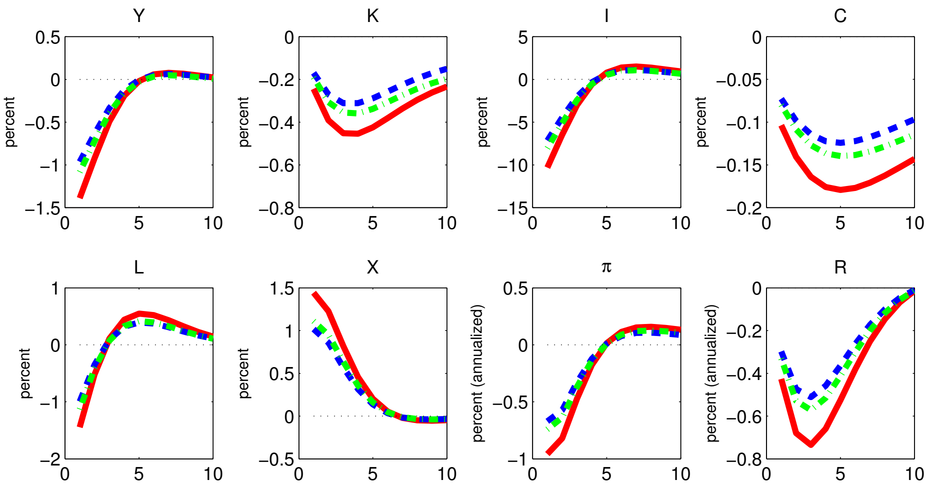
Consider first the responses of the economy following the purchase of corporate bonds only (long dashed line). As in Gertler and Karadi (2011 [21], 2013 [22]), this unconventional asset purchases allows to mitigate the increase in the corporate loan rate and excess return. As a result, the total loan amount distributed to firms decreases less compared to baseline (and so do the price of capital), which tends to attenuate the contractionary effects of the crisis on investment and on entrepreneurs' consumption (and, ultimately, on aggregate output). Yet, the additional interesting feature of our model is that it enables to analyze how such policy affects credit markets other than those targeted by the program (in particular, the mortgage loan market) and, more generally, to analyze how such policy influences macroeconomic variables less directly related to firms' environment. As Figure 4.2 shows, when credit markets are partially segmented, large scale purchases of corporate bonds also generate a significant decrease in the mortgage rate, and thus attenuate the fall in mortgage loans granted to borrowing households. This contributes to stabilize the housing market, with housing prices and borrowersâ housing stock (and consumption) decreasing less compared to baseline.

The reasons for these favorable effects of LSAPs—going beyond the mere stabilization of the corporate loan market—are obviously to be found in the portfolio balance channel emphasized by Bernanke (2012) [5] and the preferred-habitat literature (see Andrés *et al.* (2004) [1] and Vayanos and Vila (2009) [41] for modern formulations of this theory). Others things equal, large scale purchases of corporate bonds reduce the aggregate supply to the private sector of such bonds. This tends to increase their price and to decrease their return compared to mortgage-related securities. Yet, when equity capital transfers between loan branches are possible, bankers arbitrage away this difference in marginal returns by transferring equity capital from the corporate to the mortgage loan branch until the "leverage-adjusted" excess returns are the same in both sectors. This explains why LSAPs of corporate bonds spread out to other credit markets and have a broader economic effect than a mere easing of credit market conditions for entrepreneurs.

Consider now the responses of the economy following the purchases of MBS by an equivalent amount (dotted lines). As Figure 4.2 shows, this alternative policy has, qualitatively, very similar effects on aggregate variables. This results again from the portfolio balance channel, which generates pass-through effects from one credit market to another. Yet, Figure 4.2 also shows that these effects are quantitatively slightly weaker than those obtained from an equivalent size purchase of corporate bonds. The reason for this difference is that mortgage loan branches are, on average, more leveraged than corporate loan branches (i.e., corporate loan branches are submitted to a greater moral hazard problem than mortgage loan branches at the steady state). Thus, compared to a situation without



(a) *Financial and credit market related variables*



(b) *"Real economy" variables*

Figure 4.2: *LSAPs – partial credit market segmentation*

intervention, the central bank purchases of MBS relax banksâ balance sheet constraint proportionately less than equivalent purchases of corporate bonds. This effect is similar to the one obtained by Gertler and Karadi (2013) when comparing the relative efficacy of asset purchases targeting private securities versus Treasury bonds. However, our results show that to the extent that frictions in the mortgage and the corporate loan markets are not too different from each other (as reflected by the small difference in steady-state credit spreads in each sector), this quantitative difference should remain small. The implication of such finding is straightforward: to the extent that excess returns on two classes of similar-maturity assets are roughly the same and that portfolio adjustments by investors can be done at small cost, it does not matter much which asset the central bank purchases since the portfolio balance channel implies that both policies will have quantitatively similar effects on credit markets. The corollary of this proposition of course also holds: if two similar-maturity assets have large differential returns (reflecting significantly different degrees of financial frictions), the efficacy of asset purchases is greater if these purchases involve the asset with the largest return.

4.4.2.3 Large-scale asset purchases with totally segmented credit markets

The extent to which the portfolio balance channel has been at work in recent experiences of unconventional monetary policies is the subject of considerable debate in the recent literature. Empirical studies usually tend to confirm that LSAPs of particular assets (whether MBS or long-term Treasury bonds) helped to ease other credit market conditions by reducing yields on other assets (see Table C.1 in Appendix C). Yet, Woodford (2012) [48] stresses that the period over which QE1 took place (December 2008 - March 2010) was a period of significant disruption of the markets involved in mortgage securitization, leading to a much stronger degree of credit market segmentation than usual. According to Woodford (2012) [48], credit market segmentation is a credible reason for why targeted central bank purchases of a particular asset (here, MBS) should affect its yield and price. Yet, it also reduces the extent to which such effects are expected to be passed on to other credit markets. In other words, LSAPs are expected to have much more “local” effects when the functioning of financial markets is so disrupted that credit market segmentation is strong.[25]

To explore the implications of this line of arguments within our model, we now analyze the effects of the two types of LSAPs considered above within an environment in which equity capital transfers between loan branches are no longer possible (which can be seen as an extreme form of credit market segmentation). Results from these experiments are displayed in Figure 4.3. Again, dashed lines are used for a LSAP program involving corporate bonds, and dotted lines are used for LSAPs targeting MBS.

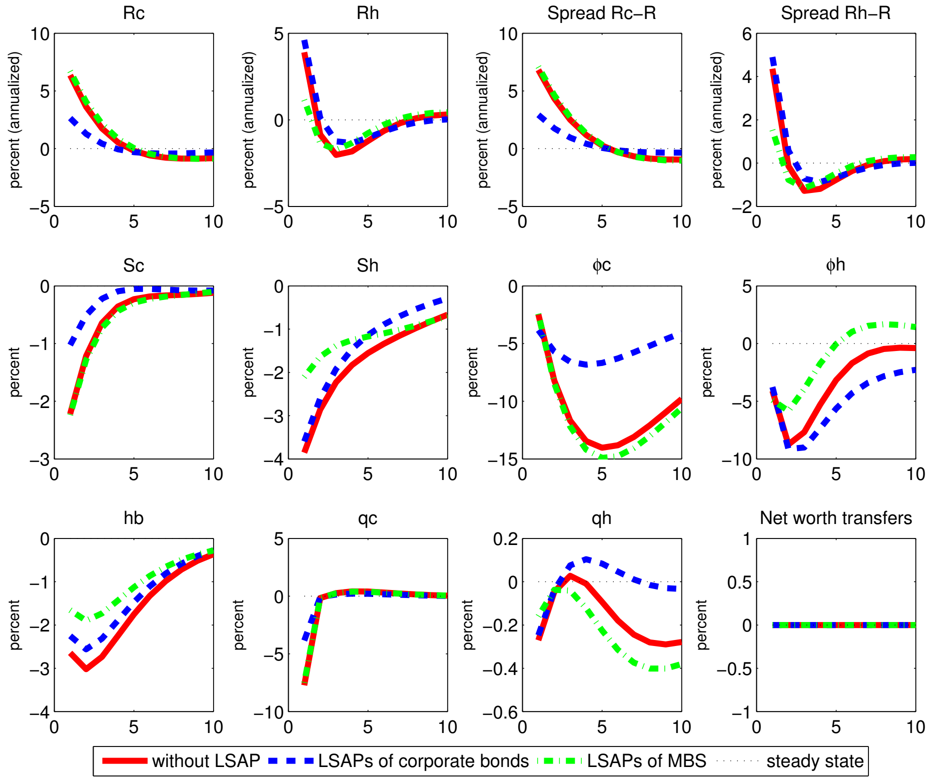
[25] Del Negro *et al.* (2011) [17] also interpret the 2008-2009 financial crisis as a major freezing of secondary markets for private securities, materialized as a decrease in the âresaleabilityâ of these assets.

Overall, the results clearly confirm Woodford's assertions. As shown in Figure 4.3, central bank purchases of corporate bonds reduce the borrowing rate of entrepreneurs by a much larger extent than in the former case of partial market segmentation. Yet, they also leave the mortgage loan rate almost unaffected. The opposite result of course holds when considering large scale purchases of MBS: they lower the mortgage loan rate by a greater amount than in the partial segmentation case, but have no visible effect on the yield on corporate bonds. Thus, different LSAP programs clearly have much more "local" effects when credit markets are totally segmented. This set of theoretical results is well supported by empirical evidence in Gagnon *et al.*, (2011) [20] and Krishnamurthy and Vissing-Jorgensen (2011) [33], who find that the impact of LSAP programs on MBS rates is large when such programs involve MBS purchases, but not when they involve other asset purchases (in particular, Treasury bonds).[26]

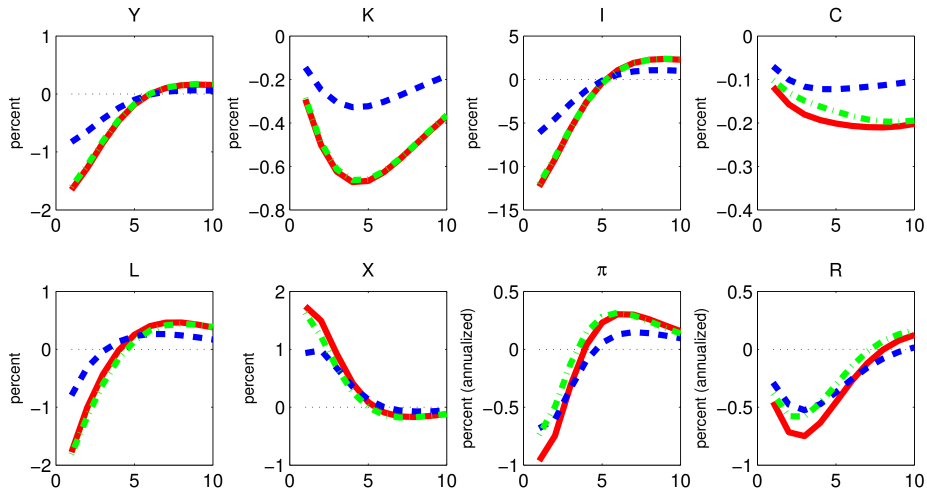
The model then also makes predictions concerning the macroeconomic effects of LSAPs that are not often discussed in the academic literature (whether theoretical or empirical). Figure 4.3 shows that while central bank purchases of corporate bonds significantly moderate the negative effects of the financial crisis on economic activity as a whole (as measured, e.g., by aggregate output and employment), equivalent-size purchases of MBS have very little effects on macroeconomic variables other than those related to the housing market. For example, in the model, the decline in output following the large negative confidence shock is -1.66 percent when there is no central bank intervention, -0.82 percent in the case of central bank purchases of corporate bonds, and -1.61 percent in the case of central bank purchases of MBS. Clearly, under this extreme form of credit market segmentation, large scale purchases of MBS do very little to attenuate the recession. Again, this sharply contrasts with the case of partial credit market segmentation in which both types of programs were quite effective at mitigating the effects of the crisis on macroeconomy.

How can such differential effects be explained? When credit markets are strongly segmented, central bank purchases of corporate bonds could increase the amount of credit granted to entrepreneurs, therefore stimulating investment spending. As a result, aggregate investment decreases considerably less compared to the economy without central bank intervention. Because non-residential investment is a significant component of GDP (10.7% in the US economy), this policy stimulates aggregate demand and mitigates the

[26] Both Gagnon *et al.* (2011) [20] and Krishnamurthy and Vissing-Jorgensen (2011) [33] find stronger effects of QE1 on MBS rates than on Baa corporate bond yields. Note that our model predicts that corporate bond yields decrease more than mortgage rates following central bank purchases of MBS when credit market segmentation is partial, while it predicts the opposite when credit market segmentation is total (in this latter case, the corporate loan rate is virtually unaffected while the mortgage loan rate strongly decreases). Combining these two sources of evidence suggests that credit market segmentation was indeed strong during the period over which QE1 took place, even though not as strong as to imply, as in the extreme case of our model, the absence of any pass-through effect on other credit rates. An alternative explanation for the decline in corporate bond yields is that LSAPs also influenced the economy through a signaling channel, changing agents' expectations about the future path of the policy rate (Eggertson and Woodford, 2003 [18]).



(a) *Financial and credit market related variables*



(b) *"Real economy" variables*

Figure 4.3: *LSAPs – total credit market segmentation*

crisis effects on aggregate output and employment. By contrast, when the central bank purchases MBS, the reduction in mortgage loan rates attenuates the fall in mortgage loans to impatient workers, thereby contributing to stabilizing the housing market. However, since the aggregate stock of houses is fixed in our model, this has no significant effect on employment and output (the policy mostly mitigates the redistributive effects of the crisis on housing holdings between patient and impatient workers).[27] Although the assumption of a fixed housing stock was made for simplicity and does not exactly match the situation of the US economy, residential investment is actually a very small fraction of GDP in the US (2.5%). Explicitly incorporating a construction sector in the model is thus unlikely to change significantly this conclusion.

4.5 Concluding remarks

This chapter first reviews the Federal Reserve's policy responses to the financial crisis 2007-2009, notably the Fed's experience with the large-scale asset purchase programs that this chapter interrelates. A survey of the related literature gives a overview of both the empirical estimates of the effect and theoretical analysis of LSAPs. Then, using the New-Keynesian model developed in Chapter 3, we have analyzed the effect of LSAPs with segmented corporate and mortgage loan markets.

Our results show that the effects of central bank's long-term asset purchases depend crucially on the degree of credit market segmentation, as materialized by the possibility to make equity capital transfers between loan branches in the face of differing marginal returns. When credit markets are partially segmented, central bank purchases of a particular asset reduce the borrowing rate and expand loans on the corresponding credit market, but the portfolio balance channel implies that this effect spreads out to the other credit markets. In this case, the effectiveness of asset purchases is the strongest when the central bank targets the credit market with the largest degree of financial frictions at the steady-state (i.e., the corporate loan market in our model). Nonetheless, to the extent that excess returns do not differ too much between the two sectors at the steady state, the quantitative differences in terms of policy responses between the two purchase programs are small. A corollary of this proposition, from a theoretical perspective, is that formal models which analyze LSAP effects by abstracting from modeling the housing market and assuming that the central bank purchases corporate bonds instead of MBS can still describe quite accurately the economy's response to LSAPs if financial markets work normally (so that the portfolio balance channel is at work) and the degrees of markets frictions in the two credit markets are roughly the same.

[27]Note however that this redistributive effect is not completely neutral, as it generates an aggregate "housing wealth effect" owing to the fact that impatient households have a larger propensity to consume wealth than patient households. Our simulation results show that this wealth effect is quantitatively small.

When credit markets are totally segmented, however, results are significantly different. In this case, the central bank's long-term asset purchases have much more local effects: corporate bond purchases help to stabilize the corporate loan market (decreasing firmsâ borrowing rate and increasing loans to entrepreneurs) but do little on the mortgage loan market, and vice versa. Thus, which type of asset the central bank purchases now matters a lot, and the choice crucially depends on which credit market the central bank aims to stabilize (as well as which overall effect it expects from implementing its purchase policy). For example, stabilizing the housing market may have been desirable during the 2007-2009 financial crisis when the burst of the housing bubble was generating a significant increase in adjustable mortgage rates, which was forcing many borrowing households into foreclosure. Our model shows that central bank purchases of MBS indeed attenuate the sharp redistribution of housing units from impatient to patient workers. At the same time, it suggests that such policy should not be expected to have very strong effects on aggregate output and employment, if credit market segmentation is strong, since residential investment accounts for only a small share of GDP in the US economy. If the aim of the central bank's asset purchases is to sustain economic activity as a whole, economic policies aiming more directly at expanding loans to businesses should rather be implemented. In this respect, it is interesting to observe that the Bank of England, through its recently implemented Funding for Lending Scheme (FLS), and the ECB in its recent discussions– two economic areas for which credit market segmentation remains strong due to sovereign debt concerns â are seeking more direct ways to stimulate loans to Small and Medium-sized Enterprises than current LSAP programs do.

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Chapter 5

Conclusions and Perspectives

5.1 Conclusions

This dissertation has presented three essays in monetary economics. They share the common denominator of accenting financial intermediation and its implications for some important issues in modern central banking. We consider perfect and imperfect financial intermediation to put into evidence how financial frictions affect the effects of monetary policy and the effects of exogenous shocks on business cycles. The conclusions obtained in this dissertation are theoretical but they also provide some useful insights for the practical conduct of monetary policy.

In Chapter 2, focusing on the effects of central bank intransparency in a New-Keynesian model with a cost channel, we have shown that opacity about the relative weight that the central bank assigns to output stabilization modifies the economic effects of inflation and demand shocks in the same direction but at different amplitudes. The effects of intransparency also depend on these shocks' degrees of persistence. If these shocks are serially uncorrelated, intransparency has no effect on inflation expectations and thus no effect on inflation and the output gap via this channel. At the equilibrium, endogenous variables are affected by shocks to central bank preferences. More opacity decreases (increases) the average response of inflation (the output gap) to inflation and demand shocks for standard parameter values, implying a decrease (an increase) in the inflation (output-gap) volatility. The effects of intransparency that are associated with demand shocks would be quite important if their volatility is significantly higher than that of inflation shocks.

If inflation and demand shocks are serially correlated, the inflation and output-gap responses are attenuated through the inflation expectations channel. Nevertheless, via the policy rule channel, higher persistence of inflation shocks strengthens (weakens) the attenuation (amplification) effect of intransparency on the average inflation (the output gap) response to inflation and demand shocks. The volatility of inflation (the output gap) decreases (increases) with intransparency, and both increases with shock persistence. The cost channel clearly increases the extent of intransparency effects due to inflation shocks on endogenous variables and social welfare, and it strengthens the persistence-linked effects of intransparency. In general, intransparency would improve social welfare if the society is quite conservative in assigning a low weight to output-gap stabilization and , more significantly, if the cost channel is present.

While Chapter 3 and 4 of this dissertation share the same basic model structure, they address different macroeconomic issues.

In Chapter 3, building a model with multiple asset markets, we analyze the effects of an imperfect financial intermediation due to a moral hazard problem, which impedes the efficient supply of credit for business cycle fluctuations. By systematically comparing the effects of various shocks in an economy with financial frictions and those in an economy with frictionless financial intermediation, we found that the imperfect financial intermediation amplifies the response of key economic variables to technology and mortgage borrowing constraint shocks, and it attenuates the effects of monetary policy shocks. Specifically, in the case of a positive technology shock, the capital price rises, triggering the financial accelerator of the type described by Bernanke and Gertler (1999) and Bernanke, Gertler and Gilchrist (1999) and hence loosening firms' borrowing constraints and raising frims' demand for credit. The increase in asset prices also strengthens the bank's balance sheet. Given that debt values remain unchanged, by utilizing the slump in balance sheet capacity, the bank could raise more funds to increase their credit supply in the equilibrium. In the transmission of these two shocks, the partially segmented credit plays an important role in transmitting the shock effect from one bond market to the others through banks' arbitrage which aims to equalize marginal bond returns. Given banks' arbitrage, the model is capable of accounting for co-movements of housing prices and macroeconomic variables across business cycles, as highlighted by the recent financial crisis.

In the case of a lower interest rate, an expansionary monetary policy shock reduces banks' financing costs and increase their equity capital but generates increases in interest rate spreads. As loan interest rates do not co-move perfectly with the changes in the policy rate with the presence of the financial friction, the effects of policy actions is partially transferred to the credit markets and hence the real economy, leading to modest repose of supply of credit, investment and the output relative to the case in which the financial intermediation is frictionless.

Finally, by varying banks' leverage ratios, we have found that the effects of technology, monetary and borrowing constraint shocks are amplified by leverage ratio increases.

In Chapter 4, we use the New-Keynesian model developed in Chapter 3 to study the effects of the Federal Reserve's large-scale asset purchases in the context of the recent crisis. We have considered two dimensions that are not considered in the related literature but are nonetheless crucial for our understanding of LSAPs.

The first dimension involves the central bank's purchases of mortgage backed securities in addition to (or in place of) corporate bonds. This consideration better accounts for the Federal Reserve's QE1, which have thus far been the most important LSAP programs and primarily involved mortgage-backed security. The second dimension analyzes LSAP effects by considering two polar assumptions about the degree of credit market segmentation, which aim to study the extent to which the credit market segmentation affect these policy measures' outcomes. In the first configuration, we assume that credit markets are partially segmented, which allows us to make a unique contribution in the analysis of LSAPs by distinguishing the effects of corporate bond and MBS purchases. In the second configuration, credit markets are however totally segmented, meaning equity capital reallocations between branches are no longer possible. This contribution is important, as evidence strongly suggests that financial markets were severely disrupted during the period in which QE1 took place.

In this context, we analyzed the effects of two LSAP programs of identical sizeâone involving corporate bonds and the other involving MBSâand have reached several conclusions. First, in both configurations, LSAPs targeting the mortgage loan market are less effective than LSAPs targeting the market for corporate bonds at mitigating the economic contraction generated by the financial crisis. However, the magnitude of the stabilizing effects crucially depends on the extent to which credit markets are segmented. Second, when credit markets are partially segmented, large-scale MBS purchases have slightly smaller but almost identical effects as equivalent size purchases of corporate bonds, owning to the portfolio rebalancing behaviors that result from yield and price changes of one particular security to another. Third, when credit markets are totally segmented, LSAPs targeting a particular credit market have much more "local" effects: large-scale MBS purchases are useful in stabilizing mortgage and housing markets (lowering mortgage rates and decreasing the reallocation of housing units between mortgage borrowers and lenders after the crisis) but are much less effective than equivalent corporate bond purchases at stabilizing aggregate employment and output, as residential investment accounts for a much smaller GDP share than non-residential investment.

5.2 Perspectives

The research presented in this dissertation can be extended in various directions. Chapter 2 states that the cost channel assigns a role to firms' borrowing in monetary policy in the transmission of monetary policy. However, in this modelï$\frac{1}{4}$ perfect financial intermediation could limit the cost channel' role and hence its impact on monetary policy and central bank transparency outcomes.

One interesting extension would be to extend our analysis of optimal monetary policies in a New-Keynesian model with a cost channel, with or without central bank opacity, to a framework that accounts for financial frictions in the intermediary sector (work in progress). As shown in Chapters 3 and 4, with the presence of endogenously balance-sheet constrained banks, the marginal cost depends on the loan rate rather than the policy interest rate at which financial intermediaries are able to fund themselves. Since the loan rate and policy rate do not move perfectly together, changes in spread between these two interest rates that reflect changes in credit market conditions might affect monetary policy outcomes via the cost channel. Thus, it would be interesting to see to what extent the results obtained in Chapter 2 and, more generally, the central bank's optimal policy decisions would be affected.

Seeking to reduce the tightening of credit market conditions and thus supporting the economic recovery since the onset of the financial crisis, the Federal Reserve has kept its policy rate near the zero lower bound for more than 4 years and has promised to keep it at this level for even longer. Moreover, longer-term interest rates have also fallen through the large-asset purchase programs. These low interest rates seem harmful for savers or investors who live off the income from bonds. By considering this issue, one possible avenue for future research may ask whether the central bank should raise its policy rate and withdraw from long-term asset purchases. However, we also need to recognize that higher interest rates should induce more tightening of borrowers' borrowing constraints. Therefore, it is thus far unclear whether, on average, the gains from raising interest rates and therefore raising incomes for savers and investors are greater than the borrowers' losses from increased interest rates. To answer this question, we need to construct an appropriate model to evaluate the relative welfare gains between different classes of agents. The model in Chapters 3 and 4 could be used for conducting such an analysis by allowing a fraction of savers who do not exploit arbitrage opportunities to maximize their banks' dividend payments and only make bank deposits to smooth consumption.

Another avenue of research could consider the ZLB in the model developed in Chapters 3 and 4. ZLB modeling could allow us to gain more useful insights into the effectiveness of conventional and unconventional monetary policy measures in a framework in which credit markets could be partially or totally segmented. Our research is also limited by the assumption that housing supply is fixed. One interesting extension would be to introduce the production of housing, which would allow unconventional monetary policy targeting the mortgage sector to have more significant effects on production even when the credit markets are totally segmented.

Conclusion

This thesis was proposed by the ImaBio group in IPHC and is based on the development of a multi-modality imaging system for small animal (AMISSA). AMISSA consists of a micro PET, a micro CT, and a micro SPECT. The last two tomographies have already been realized. Now the group focuses on the integration of the PET system based on the MCP photodetector which has been chosen for its high gain and small size. In this PET system, the parallax error is minimized by orienting the crystals in the axial direction and collecting the optical photons on their both sides. A detector module consists of a matrix of 32 $\times$ 24 LYSO (Ce) crystal with a size of 1.5 mm $\times$ 1.5 mm $\times$ 25 mm for each. The PET system is comprised of 4 detector modules and provides a detection efficiency of about 15% and a spatial resolution of about 1 mm^3. A 64-channel readout chain IMOTEPAD, dedicated to this MCP-based PET imaging, has been realized. IMOTEPAD can measure the input charges from few femtocoulombs to 104 pC with an integral nonlinearity (INL) less than 3%. By integrating a DLL-based TDC, IMOTEPAD can also provide a timing measurement with a bin size of 625 ps.

However the Field-Of-View (FOV) of this PET system is limited to 25 mm. In order to extend the FOV, we can either lengthen the crystal under the condition of combining high-quantum-efficiency photodetectors to avoid degrading the energy resolution, or combine several detector modules together under the condition of using compact photodetectors to minimize the gap between photodetectors. Unfortunately, the above methods can not be implemented into the MCP-based PET imaging due to the low quantum efficiency of about 15% and the high thickness of about 10 mm of the MCP. APD is a potential candidate to extend the FOV due to its high quantum efficiency of about 70% and its fine thickness which minimizes the interaction of gamma rays with the photodetector. However, compared with the gain order of 10^6 for the MCP or PMT, the gain of the APD is very small. For example, the typical value of APD S8550 from HAMAMATSU is about 50. Due to its low gain, we can not achieve the arrival time measurement of an event by triggering a comparator with the weak output signals of the photodetectors. Thus the readout chain IMOTEPAD can not be implemented in the APD-based PET imaging due to its relative high noise and the limitation of the structure. Accordingly, a low noise readout chain has to be designed to well distinguish the output signals and it is also necessary to find a new method to recover the timing information of the event. The design of this kind of readout chain, for APD-based PET imaging to achieve a larger FOV without degrading the spatial resolution, composes the main subject of this thesis.

The proposed method PD2T (Peak Detect and 2 Time) to recover the arrival time of the event is a trade-off between the timing resolution and the complexity of the circuit. By triggering the rising edge and the falling edge, and detecting the peak value of the output signal of a low noise front-end, it is possible to reconstruct the arrival time of the event. Thanks to the low complexity of the circuit and low quantity of the generated data, this method is well suitable for a multi-channel readout chain.

According to this method, a multi-channel readout chain dedicated to APD-based PET imaging has been proposed. In every channel of the readout chain, there are a low noise front-end, a comparator, a peak detect circuit, and a TDC. Two prototypes have been developed, with the technology CMOS AMS (Austriamicrosystems AG) 0.35 μm, in order to realize this readout chain.

The first prototype (APD_Chip) is a 10-channel low noise front-end circuit. Every channel of the prototype is composed by a CSA, a shaper, and an analog buffer. This circuit allows us to maximize the signal-to-noise ratio (SNR), and thus to increase both the energy resolution and the timing resolution. By optimizing the component parameters, for example the input transistor of the preamplifier, the order of the integrator, the shaping time, etc, we achieved a SNR of about 10 (corresponding to an equivalent noise charge (ENC) of about 375 e^-) from test for an input load capacitance of 10 pF. The designed high gain preamplifier allows us to decrease the input impedance and thus to minimize the crosstalk between the channels. This high gain also increases the charge-integration efficiency. The chosen integration time of 1 μs assures the readout frequency of 100 kHz and meanwhile maximizes the energy resolution. The feedback resistance of 10 MΩ in the CSA was designed with a linearized degenerated differential pair to save the circuit area and to assure a good linearity. However, this circuit is more noisy than polysilicon resistances. With the shaping time of 136 ns, the circuit contributes almost 25% of the total noise. Accordingly, if a higher SNR is required in the future, the polysilicon resistances can be used by sacrificing the circuit area.

According to the fast shaping time chosen in the first prototype and the high dynamic range of the output of the photodetectors, an automatic-peak-detecting method should be developed. The proposed current-mirror-based PDH circuit realized this automatic peak detection. Several techniques have been implemented in the PDH to increase the accuracy, such as a two-phase method and a variable-gain amplifier. Two PDHs per channel allows us to avoid the readout dead time. The sparse readout maximize the readout efficiency. The PDHs and the circuits of APD_Chip, such as the CSA, the shaper, and the analog buffer, have been integrated in the second prototype PETROC. The connection between the PDHs and the circuits of APD_Chip allows us to measure the accuracy of the PDH with the shaper's signals. The PDH can also be tested with an external signal.

A 5-channel TDC has also been integrated in the second prototype. This TDC is based on a DLL to obtain stable delays against the variations of the process, the temperature, and the power supply. The implementation of the vernier method decreases the bin size to about 20 ps. Several techniques have been implemented in the DLL to minimize the jitter and the mismatch between the delay cells, such as a short VCDL (voltage-controlled-delay line) and TSPC (True Single-Phase-Clock) phase detector. Two 10-bit Gray counters are used to extend the measurement dynamic range to 10 μs. With the vernier method, the bin size is determined by the delay difference of the gates instead of the gate delay to exceed the limit of the technology. The proposed structure of the TDC provides a potential to achieve a bin size less than 10 ps. As a result, this TDC can not only increase the timing resolution of the MCP-based or APD-based PET imaging but also provide a possibility to design a TOF (Time-of-Flight) PET imaging in the future.

The test board of PETROC has been designed and fabricated. On the test board, a Complex Programmable Logic Device (CPLD, EPM3128ATC100-5 from ALTERA) is used to provide the control signals and test data for PETROC. The CPLD also receives the data from the ASIC. A FT2232H Mini Module (Future Technology Devices International Ltd.) provides a converter interface between the USB (Universal Serial Bus) and the other protocols, such as JTAG or a customized protocol. It is used to program the CPLD and PETROC and also to send the data in the CPLD to the personnel computer. PETROC is on the measurement phase at present.

Based on these two submitted prototypes, a third prototype which comprises complete channels (combination of APD_Chip, PDH, and TDC), can be developed in order to test the PD2T method. The third prototype should also be tested under a real application environment by connecting it with APD photodetectors to verify the performances of the ASIC, such as the ENC, the INL, the timing resolution, etc. Then the validation of this complete prototype allows us to realize a readout chain dedicated to APD-based PET imaging for small animal with a spatial resolution of about 1 mm^3.

These two prototypes provide also the possibility to upgrade the readout chain for MCP-based PET imaging. For example, by replacing the current preamplifier and the integrator in IMOTEPAD by the CSA (Charge Sensible Amplifier) integrated in APD_Chip, we can maximize the SNR and thus the energy resolution. The PDH circuit, instead of the sampling method used in IMOTEPAD, can be used to maximize the measurement accuracy of the amplitude of signals and thus to improve the energy resolution. The timing resolution can also be improved by using the TDC with a bin size of 20 ps instead of the TDC with a bin size of 625 ps.

The theoretical analyses in Chapter **??** show that the ENC of the readout chain is proportional to its input capacitance. Moreover, the ENC should be minimized to improve the energy resolution and the timing resolution, as being indicated by the monte-carlo simulation results presented in Chapter **??**. Accordingly, the connection between the photodetector and the ASIC should be shortened to minimize the input capacitance of the ASIC. The best solution is to integrate the APD photodetector and its readout chain into one ASIC. However, due to the different fabrication process and the different bias voltage for the APD and the readout circuit, the traditional fabrication process is not suitable to this integration. Nowadays, 3D integration technology is emerging. 3D technology allows the integration of several tiers interconnected by through-silicon via (TSV) to realize a high density integration. Each tier can even been fabricated with different fabrication process in the future. As a result, the APD and the readout circuit can be fabricated with different process and then integrated in one ASIC with interconnections of only several tens micrometers. Consequently, the parasitic capacitance of the interconnection is minimized. Moreover, this integration minimizes the thickness of the detector and thus the gap between the detector modules combined to increase the FOV. Furthermore, with 3D integration technology, we can also separate the TDC and the energy measurement part in different tiers in order to maximize the circuit performance and to avoid the influence between each other. For example, for the energy measurement tier, we can use a technology adapted to analog design such as 0.35 μm or 0.13 μm to obtain a high dynamic range, a stable threshold voltage (V_{th}), a less channel-length modulation, etc. On the other side, an advanced technology can be used for TDC tier to minimize its bin size and thus to improve the timing resolution of the PET imaging.

Appendix A

Appendix to Chapter 2

A.1 Proof of Proposition 4

Deriving (2.15) and (2.16) with respect to ρ_u and ρ_e, respectively leads

$$\frac{\partial^3 E_t \pi_{t+1}}{\partial e_t \partial \sigma_\varepsilon^2 \partial \rho_e} = \frac{\zeta(1+\lambda)(1-2\zeta^2)\left[\zeta + \rho_e \kappa\phi\sigma\zeta^2 E_t(\Omega) - \rho_e \zeta(\beta+\kappa\phi)E_t(\Theta) - 2(\zeta+\rho_e\kappa\phi\sigma)\right]}{(\lambda+\zeta^2)^3\left[1+\rho_e\kappa\phi\sigma\zeta E_t(\Omega) - \rho_e(\beta+\kappa\phi)E_t(\Theta)\right]^3}, \tag{A.1}$$

with $\zeta + \rho_e \kappa\phi\sigma\zeta^2 E_t(\Omega) - \rho_e \zeta(\beta+\kappa\phi)E_t(\Theta) - 2(\zeta+\rho_e\kappa\phi\sigma) = \Psi_e$

$$\frac{\partial^3 E_t \pi_{t+1}}{\partial u_t \partial \sigma_\varepsilon^2 \partial \rho_e} = \frac{\kappa\phi\sigma\zeta(1+\lambda)(1-\zeta^2)\left[\zeta + \rho_u \kappa\phi\sigma\zeta^2 E_t(\Omega) - \rho_u \zeta(\beta+\kappa\phi)E_t(\Theta) - 2(\zeta+\rho_u\kappa\phi\sigma)\right]}{(\lambda+\zeta^2)^3\left[1+\rho_u\kappa\phi\sigma\zeta E_t(\Omega) - \rho_u(\beta+\kappa\phi)E_t(\Theta)\right]^3}. \tag{A.2}$$

with $\zeta + \rho_u \kappa\phi\sigma\zeta^2 E_t(\Omega) - \rho_u \zeta(\beta+\kappa\phi)E_t(\Theta) - 2(\zeta+\rho_u\kappa\phi\sigma) = \Psi_u$.

According to the definition of Ω, we have $\zeta^2\Omega \equiv \frac{\zeta^2(1+\varepsilon)}{\lambda-\varepsilon+\zeta^2(1+\varepsilon)} < 1$, implying that $\zeta^2 E_t(\Omega) < 1$. Therefore the numerator of the above derivatives is negative since $\Psi_j = -\rho_j\zeta(\beta+\kappa\phi)E_t(\Theta) - (\zeta+\rho_j\kappa\phi\sigma) - \rho_j\kappa\phi\sigma\left[1-\zeta^2 E_t(\Omega)\right] < 0$, $\forall j = u, e$. This leads to $\frac{\partial^3 E_t\pi_{t+1}}{\partial e_t \partial\sigma_\varepsilon^2\partial\rho_e} < 0$ and $\frac{\partial^3 E_t\pi_{t+1}}{\partial u_t \partial\sigma_\varepsilon^2\partial\rho_e} < 0$ if $\zeta < 1$. Given that $\frac{\partial^2 E_t\pi_{t+1}}{\partial u_t \partial\sigma_\varepsilon^2} < 0$ and $\frac{\partial^2 E_t\pi_{t+1}}{\partial e_t \partial\sigma_\varepsilon^2} < 0$ according to (2.15) and (2.16), an increase in the persistence of inflation shocks reinforces the effect of opacity on inflation expectations. Deriving (2.9) with respect to u_t, σ_ε^2 and

ρ_u yields:

$$\frac{\partial^2 E_t \pi_{t+1}}{\partial u_t \partial \sigma_\varepsilon^2 \partial \rho_u} = - \kappa\phi\sigma\Theta \left[\kappa\phi\sigma\zeta \frac{\partial E_t(\Omega)}{\partial \sigma_\varepsilon^2} - (\beta+\kappa\phi)\frac{\partial E_t(\Theta)}{\partial \sigma_\varepsilon^2} - \right] \frac{1-\rho_u\kappa\phi\sigma\zeta E_t(\Omega)+\rho_u E_t(\Theta)(\beta+\kappa\phi)}{[1+\rho_u\kappa\phi\sigma\zeta E_t(\Omega)-\rho_u E_t(\Theta)(\beta+\kappa\phi)]^3}. \tag{A.3}$$

with $\Xi = \frac{1-\rho_u\kappa\phi\sigma\zeta E_t(\Omega)+\rho_u E_t(\Theta)(\beta+\kappa\phi)}{[1+\rho_u\kappa\phi\sigma\zeta E_t(\Omega)-\rho_u E_t(\Theta)(\beta+\kappa\phi)]^3}$.

Substituting the approximated values of $E_t(\Theta)$ and $E_t(\Omega)$ into Ξ, we obtain

$$\Xi = 1 - \rho_u \frac{\kappa\phi\sigma\zeta - (\beta+\kappa\phi)\lambda}{\lambda+\zeta^2} - \frac{\kappa\phi\sigma\zeta+(\beta+\kappa\phi)\zeta^2}{(\lambda+\zeta^2)^3}\rho_u(1+\lambda)(1-\zeta^2)\sigma_\varepsilon^2. \tag{A.4}$$

For $\sigma_\varepsilon^2 > 0$, $\phi = 1$ and $\zeta < 1$, there are two cases where $\Xi > 0$. In the first case where $\lambda > \frac{\kappa\phi\zeta}{\beta+\kappa}$, we have $\Xi > 0$ and hence $\frac{\partial^2 \pi_t}{\partial u_t \partial \sigma_\varepsilon^2 \partial \rho_u} < 0$ if $\sigma_\varepsilon^2 < \Gamma$. In the second case where $\lambda < \frac{\kappa\phi\zeta}{\beta+\kappa}$, we have $\Xi > 0$ and $\frac{\partial^2 \pi_t}{\partial u_t \partial \sigma_\varepsilon^2 \partial \rho_u} < 0$, if $\rho_u < \frac{\lambda+\zeta^2}{\kappa\sigma\zeta-\lambda(\beta+\kappa)}$ and $\sigma_\varepsilon^2 < \Gamma$. Under these conditions, given that $\frac{\partial^2 \pi_t}{\partial u_t \partial \sigma_\varepsilon^2} < 0$, $\Xi > 0$ implies that under the cost channel an increase in persistence reinforces the effect of opacity on inflation when the economy is hit by demand shocks. If the above condition regarding the value of σ_ε^2 is not verified, i.e., $\sigma_\varepsilon^2 > \Gamma$, we have $\Xi < 0$ and $\frac{\partial^3 \pi_t}{\partial u_t \partial \sigma_\varepsilon^2 \partial \rho_u} > 0$.

Using the similarity between the expression of $\frac{\partial^3 \pi_t}{\partial u_t \partial \sigma_\varepsilon^2 \partial \rho_\varepsilon}$ and those of $\frac{\partial^3 \pi_t}{\partial u_t \partial \sigma_\varepsilon^2 \rho_\varepsilon}$, $\frac{\partial^3 x_t}{\partial u_t \partial \sigma_\varepsilon^2 \rho_u}$ and $\frac{\partial^3 x_t}{\partial u_t \partial \sigma_\varepsilon^2 \partial \rho_\varepsilon}$, we obtain similar conditions under which higher degrees of persistence of inflation and demand shocks reinforce or weaken the effects of opacity on inflation and the output gap. ■

A.2 Proof of Proposition 5

To evaluate the effects of imperfect transparency on the average response of inflation and the output gap to both shocks, we derive (2.9) and (2.10) first with respect to u_t and e_t, and then the expected values of resulting derivatives with respect to σ_ε^2 as follows:

$$\frac{\partial E\left[\frac{\partial \pi_t}{\partial u_t}\right]}{\partial \sigma_\varepsilon^2} = \frac{-\kappa\phi\sigma\zeta(1+\lambda)(1-\zeta^2)(\zeta+\rho_u\kappa\phi\sigma)}{(\lambda+\zeta^2)^3\left[1+\rho_u\kappa\phi\sigma\zeta E_t(\Omega)-\rho_u E_t(\Theta)(\beta+\kappa\phi)\right]^2} < 0, \quad if\ \zeta < 1 \tag{A.5}$$

$$\frac{\partial E\left[\dfrac{\partial \pi_t}{\partial e_t}\right]}{\partial \sigma_\varepsilon^2} = \frac{-\zeta(1+\lambda)(1-\zeta^2)(\zeta+\rho_e\kappa\phi\sigma)}{(\lambda+\zeta^2)^3\left[1+\rho_e\kappa\phi\sigma\zeta E_t(\Omega)-\rho_e E_t(\Theta)(\beta+\kappa\phi)\right]^2} < 0, \quad if\ \zeta < 1 \quad \text{(A.6)}$$

$$\frac{\partial E\left[\dfrac{\partial x_t}{\partial u_t}\right]}{\partial \sigma_\varepsilon^2} = \frac{-\kappa\phi\sigma\zeta(1+\lambda)(1-\zeta^2)\left[1-\rho_u(\beta+\kappa\phi)\right]}{(\lambda+\zeta^2)^3\left[1+\rho_u\kappa\phi\sigma\zeta E_t(\Omega)-\rho_u E_t(\Theta)(\beta+\kappa\phi)\right]^2} < 0, \quad if\ \rho_u < \tfrac{1}{\beta+\kappa\phi}\ and\ \zeta < 1 \quad \text{(A.7)}$$

$$\frac{\partial E\left[\dfrac{\partial x_t}{\partial e_t}\right]}{\partial \sigma_\varepsilon^2} = \frac{-\zeta(1+\lambda)(1-\zeta^2)\left[1-\rho_u(\beta+\kappa\phi)\right]}{(\lambda+\zeta^2)^3\left[1+\rho_e\kappa\phi\sigma\zeta E_t(\Omega)-\rho_e E_t(\Theta)(\beta+\kappa\phi)\right]^2} < 0, \quad if\ \rho_u < \tfrac{1}{\beta+\kappa\phi}\ and\ \zeta < 1. \quad \text{(A.8)}$$

Comparing the results given by (A.5)-(A.8) with the average response of inflation and the output gap to serially correlated inflation and demand shocks ($E\left[\frac{\partial \pi_t}{\partial u_t}\right] > 0$, $E\left[\frac{\partial \pi_t}{\partial e_t}\right] > 0$, $E\left[\frac{\partial x_t}{\partial u_t}\right] < 0$ and $E\left[\frac{\partial x_t}{\partial e_t}\right] < 0$), we obtain the results reported in Proposition 5. ■

A.3 Proof of Proposition 6

Deriving (A.5) and (A.7) with respect to ρ_u, and (A.6) and (A.8) with respect to ρ_e, we obtain

$$\frac{\partial E\left[\dfrac{\partial \pi_t}{\partial u_t}\right]}{\partial \sigma_\varepsilon^2 \rho_u} = -\frac{\kappa\phi\sigma\zeta(1+\lambda)(1-\zeta^2)\left\{\kappa\phi\sigma-(\rho_u\kappa\phi\sigma+2\zeta)\left[\kappa\phi\sigma\zeta E_t(\Omega)-E_t(\Theta)(\beta+\kappa\phi)\right]\right\}}{(\lambda+\zeta^2)^3\left[1+\rho_u\kappa\phi\sigma\zeta E_t(\Omega)-\rho_u E_t(\Theta)(\beta+\kappa\phi)\right]^3}, \quad \text{(A.9)}$$

$$\frac{\partial E\left[\dfrac{\partial \pi_t}{\partial e_t}\right]}{\partial \sigma_\varepsilon^2 \rho_e} = -\frac{\zeta(1+\lambda)(1-\zeta^2)\left\{\kappa\phi\sigma-(\rho_e\kappa\phi\sigma+2\zeta)\left[\kappa\phi\sigma\zeta E_t(\Omega)-E_t(\Theta)(\beta+\kappa\phi)\right]\right\}}{(\lambda+\zeta^2)^3\left[1+\rho_e\kappa\phi\sigma\zeta E_t(\Omega)-\rho_e E_t(\Theta)(\beta+\kappa\phi)\right]^3}, \quad \text{(A.10)}$$

$$\frac{\partial E\left[\dfrac{\partial x_t}{\partial u_t}\right]}{\partial\sigma_\varepsilon^2\rho_u} = \frac{\kappa\phi\sigma\zeta(1+\lambda)(1-\zeta^2)\left\{\beta+\kappa\phi+[2-(\beta+\kappa\phi)\rho_u]\left[\kappa\phi\sigma\zeta E_t(\Omega)-E_t(\Theta)(\beta+\kappa\phi)\right]\right\}}{(\lambda+\zeta^2)^3\left[1+\rho_u\kappa\phi\sigma\zeta E_t(\Omega)-\rho_u E_t(\Theta)(\beta+\kappa\phi)\right]^3}, \tag{A.11}$$

$$\frac{\partial E\left[\dfrac{\partial x_t}{\partial e_t}\right]}{\partial\sigma_\varepsilon^2\rho_e} = \frac{\zeta(1+\lambda)(1-\zeta^2)\left\{\beta+\kappa\phi+[2-(\beta+\kappa\phi)\rho_e]\left[\kappa\phi\sigma\zeta E_t(\Omega)-E_t(\Theta)(\beta+\kappa\phi)\right]\right\}}{(\lambda+\zeta^2)^3\left[1+\rho_e\kappa\phi\sigma\zeta E_t(\Omega)-\rho_e E_t(\Theta)(\beta+\kappa\phi)\right]^3}. \tag{A.12}$$

Determining the signs of (A.9)-(A.12) according to parameter values and comparing them with those of (A.5)-(A.8) respectively leads to the results reported in Proposition 4b. ■

A.4 Proof of Propositions 7 and 8

Deriving the variances of inflation and the output gap with respect to σ_u^2 (and σ_e^2) and σ_ε^2 using (2.11) and (2.12) yields

$$\begin{aligned}\frac{\partial^2\text{var}(\pi_t)}{\partial\sigma_u^2\partial\sigma_\varepsilon^2} =& \frac{-2\kappa^2\phi^2\sigma^2E_t(\Theta^2)\left[\rho_u\kappa\phi\sigma\zeta\frac{\partial E_t(\Omega)}{\partial\sigma_\varepsilon^2}-\rho_u(\beta+\kappa\phi)\frac{\partial E_t(\Theta)}{\partial\sigma_\varepsilon^2}\right]}{\left[1+\rho_u\kappa\phi\sigma\zeta E_t(\Omega)-\rho_u E_t(\Theta)(\beta+\kappa\phi)\right]^3}\\ &+\frac{\kappa^2\phi^2\sigma^2\frac{\partial E_t(\Theta^2)}{\partial\sigma_\varepsilon^2}}{\left[1+\rho_u\kappa\phi\sigma\zeta E_t(\Omega)-\rho_u E_t(\Theta)(\beta+\kappa\phi)\right]^2}\end{aligned} \tag{A.13}$$

$$\begin{aligned}\frac{\partial^2\text{var}(x_t)}{\partial\sigma_u^2\partial\sigma_\varepsilon^2} =& \frac{-2\kappa^2\phi^2\sigma^2E_t(\Omega^2)\left[\rho_u\kappa\phi\sigma\zeta\frac{\partial E_t(\Omega)}{\partial\sigma_\varepsilon^2}-\rho_u(\beta+\kappa\phi)\frac{\partial E_t(\Theta)}{\partial\sigma_\varepsilon^2}\right]}{\left[1+\rho_u\kappa\phi\sigma\zeta E_t(\Omega)-\rho_u E_t(\Theta)(\beta+\kappa\phi)\right]^3}\\ &+\frac{\kappa^2\phi^2\sigma^2\zeta^2\frac{\partial E_t(\Omega^2)}{\partial\sigma_\varepsilon^2}}{\left[1+\rho_u\kappa\phi\sigma\zeta E_t(\Omega)-\rho_u E_t(\Theta)(\beta+\kappa\phi)\right]^2}\end{aligned} \tag{A.14}$$

$$\begin{aligned}\frac{\partial^2\text{var}(\pi_t)}{\partial\sigma_e^2\partial\sigma_\varepsilon^2} =& \frac{E_t(\Theta^2)\left[\rho_e\kappa\phi\sigma\zeta\frac{\partial E_t(\Omega)}{\partial\sigma_\varepsilon^2}-\rho_e(\beta+\kappa\phi)\frac{\partial E_t(\Theta)}{\partial\sigma_\varepsilon^2}\right]}{\left[1+\rho_e\kappa\phi\sigma\zeta E_t(\Omega)-\rho_e E_t(\Theta)(\beta+\kappa\phi)\right]^3}\\ &+\frac{\frac{\partial E_t(\Theta^2)}{\partial\sigma_\varepsilon^2}}{\left[1+\rho_e\kappa\phi\sigma\zeta E_t(\Omega)-\rho_e E_t(\Theta)(\beta+\kappa\phi)\right]^2}\end{aligned} \tag{A.15}$$

$$\frac{\partial^2 \text{var}(x_t)}{\partial \sigma_e^2 \partial \sigma_\varepsilon^2} = \frac{-2\zeta^2 E_t(\Omega^2)\left[\rho_e \kappa\phi\sigma\zeta \frac{\partial E_t(\Omega)}{\partial \sigma_\varepsilon^2} - \rho_e(\beta+\kappa\phi)\frac{\partial E_t(\Theta)}{\partial \sigma_\varepsilon^2}\right]}{\left[1+\rho_e\kappa\phi\sigma\zeta E_t(\Omega) - \rho_e E_t(\Theta)(\beta+\kappa\phi)\right]^3} + \frac{\zeta^2 \frac{\partial E_t(\Omega^2)}{\partial \sigma_\varepsilon^2}}{\left[1+\rho_e\kappa\phi\sigma\zeta E_t(\Omega) - \rho_e E_t(\Theta)(\beta+\kappa\phi)\right]^2} \quad \text{(A.16)}$$

The first and second terms on the right hand side of (A.13)-(A.16) represent the effect of imperfect transparency through the inflation expectations channel and the policy rule channel, respectively. Using the approximated values of $E_t(\Omega)$, $E_t(\Omega^2)$, $E_t(\Theta)$ and $E_t(\Theta^2)$, substituting $\zeta \equiv \kappa(\sigma+\eta) - \sigma\kappa\phi$ and $\phi = 0$ and $\sigma_\varepsilon^2 = 0$ in equations (A.13)-(A.16), and examining the resulting equations lead to the results reported in Proposition 5a. Setting $\phi = 1$ and $\sigma_\varepsilon^2 = 0$ in equations (A.13)-(A.16) and examining the resulting equations lead to the results reported in Proposition 8. ■

Appendix B

Appendix to Chapter 3

B.1 The model

B.1.1 Patient workers

Patient workers choose consumption C_t^s, housing stock h_t^s, supply of labor L_t^s and bank deposits D_t to maximize:

$$\max E_t \sum_{i=0}^{\infty} (\beta^s)^i \left[\ln(C_{t+i}^s - gC_{t+i-1}^s) + j^s \frac{(h_{t+i}^s)^{1-\sigma}}{1-\sigma} - \frac{\left(L_{t+i}^s\right)^{1+\varphi}}{1+\varphi} \right], \tag{B.1}$$

subject to the following budget constraint:

$$C_t^s + D_t + q_t^h (h_t^s - h_{t-1}^s) + T_t^s = W_t^s L_t^s + \frac{R_{t-1}}{\pi_t} D_{t-1} + \Pi_t^{nf} + \Pi_t^l, \tag{B.2}$$

Solving the problem gives:

$$\lambda_t^s = \frac{1}{C_t^s - gC_{t-1}^s} - \beta^s g E_t \left(\frac{1}{C_{t+1}^s - gC_t^s} \right), \tag{B.3}$$

$$q_t^h = \frac{j^s}{\lambda_t^s} (h_t^s)^{-\sigma} + \beta^s E_t \Lambda_{t,t+1}^s q_{t+1}^h, \tag{B.4}$$

$$\lambda_t^s W_t^s = (L_t^s)^{\varphi}, \tag{B.5}$$

$$1 = \beta^s E_t \Lambda_{t,t+1}^s \frac{R_t}{\pi_{t+1}}, \tag{B.6}$$

where λ_t^s is the Lagrange multiplier associated with patient workers' budget constraint, and $\Lambda_{t,t+1}^s \equiv \lambda_{t+1}^s / \lambda_t^s$.

B.1.2 Impatient workers

The problem solved by impatient workers can be written as

$$\max E_t \sum_{i=0}^{\infty} (\beta^b)^i \left[\ln(C^b_{t+i} - gC^b_{t+i-1}) + j^b \frac{(h^b_{t+i})^{1-\sigma}}{1-\sigma} - \frac{\left(L^b_{t+i}\right)^{1+\varphi}}{1+\varphi} \right], \tag{B.7}$$

subject to

$$C^b_t + q^h_t (h^b_t - h^b_{t-1}) + \frac{R^h_{t-1} S^h_{t-1}}{\pi_t} + T^b_t = W^b_t L^b_t + S^h_t, \tag{B.8}$$

$$R^h_t S^h_t \leq \mu^b_t E_t q^h_{t+1} h^b_t \pi_{t+1}, \tag{B.9}$$

When $\beta^s < \beta^b < 1$, the credit constraint (B.9) is binding, and we obtain the following first-order conditions:

$$\lambda^b_t = \frac{1}{C^b_t - gC^b_{t-1}} - \beta^b g E_t \left(\frac{1}{C^b_{t+1} - gC^b_t} \right), \tag{B.10}$$

$$q^h_t = \frac{j^b}{\lambda^b_t} \left(h^b_t \right)^{-\sigma} + \beta^b E_t \Lambda^b_{t,t+1} q^h_{t+1} + \left[1 - \beta^b E_t \left(\frac{\Lambda^b_{t,t+1} R^h_t}{\pi_{t+1}} \right) \right] \frac{S^h_t}{h^b_t}, \tag{B.11}$$

$$\lambda^b_t W^b_t = (L^b_t)^{\varphi}, \tag{B.12}$$

$$R^h_t S^h_t = \mu^b_t E_t q^h_{t+1} h^b_t \pi_{t+1} \tag{B.13}$$

with $\Lambda^b_{t,t+1} = \dfrac{\lambda^b_{t+1}}{\lambda^b_t}$.

B.1.3 Entrepreneurs

We assume that entrepreneurs discount the future more heavily than patient workers. They maximize

$$\max E_t \sum_{i=0}^{\infty} (\beta^e)^i \ln(C^e_{t+i} - gC^e_{t+i-1}), \tag{B.14}$$

subject to the following constraints,

$$Y_{m,t} = A_t (U_t K_{t-1})^{\alpha} (L^s_t)^{(1-\alpha)\vartheta} (L^b_t)^{(1-\alpha)(1-\vartheta)}, \tag{B.15}$$

$$P_{m,t} Y_{m,t} + S^c_t = W^b_t L^b_t + W^s_t L^s_t + q^c_t I_t + \frac{S^c_{t-1} R^c_{t-1}}{\pi_t} + C^e_t, \tag{B.16}$$

$$K_t = (1 - \delta(U_t))\, K_{t-1} + I_t, \tag{B.17}$$

$$S_t^c \leq \mu^e E_t \left\{ \frac{[1 - \delta(U_{t+1})]\, q_{t+1}^c K_t \pi_{t+1}}{R_t^c} \right\}. \tag{B.18}$$

When $\beta^s < \beta^e < 1$, the borrowing constraint (B.18) is binding, and we obtain the following first-order conditions:

$$\alpha \frac{P_{m,t} Y_{m,t}}{U_t q_t^c K_{t-1}} = \delta' (U_t) \tag{B.19}$$

$$\vartheta(1 - \alpha) \frac{P_{m,t} Y_{m,t}}{L_t^s} = W_t^s \tag{B.20}$$

$$(1 - \vartheta)(1 - \alpha) \frac{P_{m,t} Y_{m,t}}{L_t^b} = W_t^b \tag{B.21}$$

$$\lambda_t^e = \frac{1}{C_t^e - g C_{t-1}^e} - \beta^e g E_t \left(\frac{1}{C_{t+1}^e - g C_t^e} \right) \tag{B.22}$$

$$q_t^c = \beta^e E_t \left\{ \Lambda_{t,t+1}^e \left(\alpha \frac{P_{m,t+1} Y_{t+1}}{K_t} + [1 - \delta(U_{t+1})]\, q_{t+1}^c \right) \right\} + \left(1 - \beta^e E_t \left\{ \frac{\Lambda_{t,t+1}^e R_t^c}{\pi_{t+1}} \right\} \right) \frac{S_t^c}{K_t} \tag{B.23}$$

$$S_t^c = \mu^e K_t E_t \left\{ \frac{[1 - \delta(U_{t+1})]\, q_{t+1}^c \pi_{t+1}}{R_t^c} \right\} \tag{B.24}$$

with $\Lambda_{t,t+1}^e = \dfrac{\lambda_{t+1}^e}{\lambda_t^e}$.

B.1.4 Financial intermediaries

B.1.4.1 Corporate loan market

The time varying parameters are

$$\nu_t^c = E_t \left\{ \beta^s \Lambda_{t,t+1}^s (1 - \theta) \left(\frac{R_t^c - R_t}{\pi_{t+1}} \right) + \beta^s \Lambda_{t,t+1}^s \theta x_{t,t+1}^c \nu_{t+1}^c \right\} \tag{B.25}$$

$$\eta_t^c = E_t \left\{ (1 - \theta) + \beta^s \Lambda_{t,t+1}^s \theta z_{t,t+1}^c \eta_{t+1}^c \right\} \tag{B.26}$$

$$x^c_{t,t+1} = \frac{\phi^c_{t+1}}{\phi^c_t} z^c_{t,t+1} \tag{B.27}$$

$$z^c_{t,t+1} = \frac{N^c_t}{N^c_t - \Theta^c_t}\left[\left(\frac{R^c_t}{R_t} - 1\right)\phi^c_t + 1\right]\frac{R_t}{\pi_{t+1}} \tag{B.28}$$

Corporate loan branch leverage ratio

$$\phi^c_t = \frac{\eta^c_t}{\lambda^c - \nu^c_t} \tag{B.29}$$

Aggregation

$$S^c_t = \phi^c_t N^c_t \tag{B.30}$$

Evolution of aggregate net worth

$$N^c_t = \theta N^c_{t-1}\left(\frac{\left(R^c_{t-1} - R_{t-1}\right)\phi^c_{t-1} + R_{t-1}}{\pi_t}\right) + \omega^c S^c_{t-1} + \Theta^c_t \tag{B.31}$$

B.1.4.2 Mortgage loan market

The time varying parameters are

$$\nu^h_t = E_t\left\{\beta^s \Lambda^s_{t,t+1}(1-\theta)(\frac{R^h_t - R_t}{\pi_{t+1}}) + \beta^s \Lambda^s_{t,t+1}\theta x^h_{t,t+1}\nu^h_{t+1}\right\} \tag{B.32}$$

$$\eta^h_t = E_t\left\{(1-\theta) + \beta^s \Lambda^s_{t,t+1}\theta z^h_{t,t+1}\eta^h_{t+1}\right\} \tag{B.33}$$

$$x^h_{t,t+1} = \frac{\phi^h_{t+1}}{\phi^h_t} z^h_{t,t+1} \tag{B.34}$$

$$z^h_{t,t+1} = \frac{N^h_t}{N^h_t - \Theta^h_t}\left(\left(\frac{R^h_t}{R_t} - 1\right)\phi^h_t + 1\right)\frac{R_t}{\pi_{t+1}} \tag{B.35}$$

Mortgage loan branch leverage ratio

$$\phi^h_t = \frac{\eta^h_t}{\lambda^h - \nu^h_t} \tag{B.36}$$

Aggregation

$$S_t^h = \phi_t^h N_t^h \tag{B.37}$$

Evolution of aggregate net worth

$$N_t^h = \theta^h N_{t-1}^h \left(\frac{\left(R_{t-1}^h - R_{t-1}\right) \phi_{t-1}^h + R_{t-1}}{\pi_t} \right) + \omega^h S_{t-1}^h + \Theta_t^h. \tag{B.38}$$

B.1.4.3 Credit market segmentation

In period t, the loan branch l of bank j starts with a predetermined amount $m_{j,t}^l$ of retained earnings. The after-transfer net worth is:

$$n_{j,t}^l = m_{j,t}^l + \xi_{j,t}^l \tag{B.39}$$

Remind that retain earnings evolve according to

$$m_{j,t+1}^l = \frac{R_t^l - R_t}{\pi_{t+1}} s_{j,t}^l + \frac{R_t}{\pi_{t+1}} n_{j,t}^l \tag{B.40}$$

and that

$$s_{j,t}^l = \phi_t^l n_{j,t}^l \tag{B.41}$$

when the incentive constraint, $V_{j,t}^l \geq \lambda_t^l s_{j,t}^l$ is binding.

Any banker j seeks to maximize the sum of expected terminal net wealth of its two loan branches, i.e., $V_{j,t}^c + V_{j,t}^h$, where

$$V_{j,t}^l = E_t \sum_{k=0}^{n} (\beta^s)^{k+1} (1-\theta)(\theta)^k \Lambda_{t,t+1+k}^s m_{j,t+1+k}^l, \quad \text{for } l \in (c,h). \tag{B.42}$$

Since equity capital transfers can be done in any period, maximizing $V_{j,t}^c + V_{j,t}^h$ in period t only requires to determine the current-period optimal transfer $\xi_{j,t}^c = -\xi_{j,t}^h$ which maximizes the sum of next period retained earnings $m_{j,t+1}^c + m_{j,t+1}^h$ obtained from the two loan branches. Using (B.39), (B.40) and (B.41), the latter sum can be expressed as:

$$\begin{aligned} m_{j,t+1}^c + m_{j,t+1}^h = & ((R_t^c - R_t)\phi_t^c + R_t)(m_{j,t}^c + \xi_{j,t}^c) \\ & + ((R_t^h - R_t)\phi_t^h + R_t)(m_{j,t}^h - \xi_{j,t}^c) \end{aligned} \tag{B.43}$$

Clearly, as long as $(R_t^c - R_t)\phi_t^c > (R_t^h - R_t)\phi_t^h$, it is profitable for any banker j to make equity capital transfers from the mortgage loan branch to the corporate loan branch (and conversely if $(R_t^c - R_t)\phi_t^c < (R_t^h - R_t)\phi_t^h$. Yet at the aggregate level, these transfers occur until the "leverage adjusted" excess returns are the same in the two sectors, so that the non-arbitrage condition (3.29) holds at equilibrium.

B.1.5 Other nonfinancial firms

Capital producing firms

$$\max E_t \sum_{\tau=t}^{\infty} (\beta^s)^{\tau-t} \Lambda_{t,\tau}^s \left\{ q_t^c - \left[1 - f\left(\frac{I_\tau}{I_{\tau-1}} \right) \right] \right\} I_\tau, \tag{B.44}$$

First-order conditions:

$$q_t^c = 1 + f(\cdot) + f^{'}(\cdot)\frac{I_t}{I_{t-1}} - \beta^s E_t \Lambda_{t,t+1}^s f^{'}(\cdot)\left(\frac{I_{t+1}}{I_t}\right)^2 \tag{B.45}$$

Current receipts $\Pi_t^p = (q_t^c - 1)K_t$ are redistributed in each period t to savers.

Retailers

$$\max E_t \sum_{i=0}^{\infty} (\gamma\beta^s)^i \Lambda_{t,t+i}^s \left[\frac{P_t^*}{P_{t+i}} \prod_{k=1}^{i} (\pi_{t+k-1})^{\gamma_P} - P_{m,t+i} \right] Y_{f,t+i}, \tag{B.46}$$

subject to

$$Y_{f,t+i} = \left(\frac{P_t^* \prod_{k=1}^{i} (\pi_{t+k-1})^{\gamma_P}}{P_{t+i}} \right)^{-\varepsilon} Y_{t+i}. \tag{B.47}$$

First order condition:

$$E_t \sum_{i=0}^{\infty} (\beta^s\gamma)^i \Lambda_{t,t+i}^s \left[\frac{P_t^*}{P_{t+i}} \prod_{k=1}^{i} (\pi_{t+k-1})^{\gamma_P} - \mu P_{m,t+i} \right] = 0, \tag{B.48}$$

where $\mu = \varepsilon/(\varepsilon - 1) > 1$ is the steady-state markup factor.
Evolution of the aggregate price level:

$$P_t = \left[(1-\gamma)(P_t^*)^{1-\varepsilon} + \gamma(\Pi_{t-1}^{\gamma_P} P_{t-1})^{1-\varepsilon} \right]^{\frac{1}{1-\varepsilon}}. \tag{B.49}$$

B.1.6 Monetary policy

$$\log R_t = (1-\rho^R)\left[\log R + \kappa_\pi \log \pi_t + \kappa_y \log Y_t\right] + \rho^R \log R_{t-1} \tag{B.50}$$

B.1.7 Exogenous processes

$$\log A_t = \rho^A \log A^c_{t-1} + (1-\rho^A)\log A^c + \varepsilon^A_t \tag{B.51}$$

$$\log R_t = (1-\rho^R)\left[\log R + \kappa_\pi \log\left(\pi_t/\pi\right) + \kappa_y \log\left(Y_t/Y\right)\right] + \rho^R \log R_{t-1} + \varepsilon^R_t, \tag{B.52}$$

$$\log \mu^b_t = \rho^\mu \log \mu^b_{t-1} + (1-\rho^\mu)\log \mu^b + \varepsilon^\mu_t \tag{B.53}$$

B.1.8 Market clearing conditions

Government expenditures:

$$G = T^s_t + T^b_t \tag{B.54}$$

Equilibrium in the corporate loan market:

$$\frac{\mu^e E_t\left[1-\delta(U_{t+1})\right] q^c_{t+1} K_t \pi_{t+1}}{R^c_t} = S^c_t, \tag{B.55}$$

Equilibrium is the mortgage loan market:

$$\frac{\mu^b_t E_t q^h_{t+1} h^b_t \pi_{t+1}}{R^h_t} = S^h_t. \tag{B.56}$$

Equilibrium in the good market implies:

$$Y_t = C^s_t + C^b_t + C^e_t + \left[1 + f\left(\frac{I_t}{I_{t-1}}\right)\right] I_t + G. \tag{B.57}$$

Housing market equilibrium

$$h^s_t + h^b_t = 1 \tag{B.58}$$

B.2 Steady state

The following parameters are calibrated: β^s, β^b, β^e, σ, g, χ, φ, α, ϑ, U, $\delta(U)$, $\zeta \equiv \delta''(U)U/\delta'(U)$, $\eta \equiv f''(1)$, ϵ, γ, γ_p, μ^b, G/Y, θ, ι, ρ^R, π, κ_π, κ_y and the parameters of the exogenous processes (ρ^A and ρ^μ). We calibrate S/Y, S/Y and h^s, and let the corresponding values for j^s, j^b and μ^e be determined endogenously. We also calibrate R^c/R, R^h/R, ϕ^c and Θ^c/N^c and let the values for λ^c, λ^h, ω_c and ω_h be determined endogenously.

$$X = \frac{\epsilon}{\epsilon - 1} \equiv \frac{1}{P_m} \tag{B.59}$$

$$R = \pi/\beta^s \tag{B.60}$$

$$\frac{Y}{K} = \frac{1 - \beta^e(1-\delta)}{\frac{\beta^e \alpha}{X} + \left(1 - d\frac{\beta^e}{\beta^s}\frac{R^c}{R}\right)\frac{S^c}{Y}} \tag{B.61}$$

$$\mu_e = \frac{(S^c/Y)(Y/K)(R^c/R)}{\beta^s\,(1-\delta)} \tag{B.62}$$

$$\frac{I}{Y} = \frac{\delta}{(Y/K)} \tag{B.63}$$

$$\frac{C^e}{Y} = \frac{\alpha}{X} - \frac{I}{Y} - \left(\frac{1}{\beta^s}\frac{R^c}{R} - 1\right)\frac{S^c}{Y} \tag{B.64}$$

$$\frac{C^b}{Y} = \frac{(1-\alpha)(1-\vartheta)}{X} - \left(\frac{1}{\beta^s}\frac{R^h}{R} - 1\right)\frac{S^h}{Y} \tag{B.65}$$

$$\frac{C^s}{Y} = 1 - \frac{C^e}{Y} - \frac{C^b}{Y} - \frac{I}{Y} - \frac{G}{Y} \tag{B.66}$$

$$\left(\frac{W^b L^b}{Y}\right) = \frac{(1-\alpha)(1-\vartheta)}{X} \tag{B.67}$$

$$\left(\frac{W^s L^s}{Y}\right) = \frac{(1-\alpha)\vartheta}{X} \tag{B.68}$$

$$\left(\frac{q^h h^b}{Y}\right) = \frac{1}{\mu^b}\frac{1}{\beta^s}\frac{R^h}{R}\frac{S^h}{Y} \tag{B.69}$$

$$L^b = \left[\frac{1}{\chi} \frac{1-\beta^b g}{(1-g)\dfrac{C^b}{Y}} \left(\frac{W^b L^b}{Y} \right) \right]^{\dfrac{1}{1+\varphi}} \tag{B.70}$$

$$L^s = \left[\frac{1}{\chi} \frac{1-\beta^s g}{(1-g)\dfrac{C^s}{Y}} \left(\frac{W^s L^s}{Y} \right) \right]^{\dfrac{1}{1+\varphi}} \tag{B.71}$$

$$L = L^b + L^s \tag{B.72}$$

$$h^b = 1 - h^s \tag{B.73}$$

Besides, we have (remember that R^c/R, R^h/R, ϕ^c and Θ^c/N^c are calibrated, and we derive the implied values for λ^c, λ^h, ω^c and ω^h):

$$\phi^h = \frac{\dfrac{R^c}{R} - 1}{\dfrac{R^h}{R} - 1} \phi^c \tag{B.74}$$

$$\frac{N^c}{Y} = \frac{1}{\phi^c} \frac{S^c}{Y} \tag{B.75}$$

$$\frac{N^h}{Y} = \frac{1}{\phi^h} \frac{S^h}{Y} \tag{B.76}$$

$$\Theta^h = -\Theta^c \tag{B.77}$$

$$\frac{\Theta^h}{N^h} = -\frac{\Theta^c}{N^c} \frac{(N^c/Y)}{(N^h/Y)} \tag{B.78}$$

$$\eta^c = \frac{1-\theta}{1 - \dfrac{\theta}{1-\Theta^c/N^c} \left[\phi^c \left(\dfrac{R^c}{R} - 1 \right) + 1 \right]} \tag{B.79}$$

$$\eta^h = \frac{1-\theta}{1 - \dfrac{\theta}{1-\Theta^h/N^h} \left[\phi^h \left(\dfrac{R^h}{R} - 1 \right) + 1 \right]} \tag{B.80}$$

$$\upsilon^c = \left(\frac{R^c}{R} - 1\right)\eta^c \tag{B.81}$$

$$\upsilon^h = \left(\frac{R^h}{R} - 1\right)\eta^h \tag{B.82}$$

$$\lambda^c = \frac{\eta^c + \phi^c \upsilon^c}{\phi^c} \tag{B.83}$$

$$\lambda^h = \frac{\eta^h + \phi^h \upsilon^h}{\phi^h} \tag{B.84}$$

$$\omega^c = \frac{1 - \theta\left[\left(\frac{R^c}{R} - 1\right)\phi^c + 1\right]\frac{R}{\pi} - \frac{\Theta^c}{N^c}}{\phi^c} \tag{B.85}$$

$$\omega^h = \frac{1 - \theta\left[\left(\frac{R^h}{R} - 1\right)\phi^h + 1\right]\frac{R}{\pi} - \frac{\Theta^h}{N^h}}{\phi^h} \tag{B.86}$$

B.3 Log-linearization

B.3.1 Impatient workers

$$\frac{1 + \beta^s g^2}{1 - g}\widehat{C}_t^s + (1 - \beta^s g)\widehat{\lambda}_t^s - \frac{\beta^s g}{1 - g}E_t\widehat{C}_{t+1}^s = \frac{g}{1 - g}\widehat{C}_{t-1}^s \tag{B.87}$$

$$-\widehat{q}_t^h - (1 - \beta^s)\widehat{\lambda}_t^s - (1 - \beta^s)\sigma^s\widehat{h}_t^s + \beta^s\left(E_t\widehat{\Lambda}_{t,t+1}^s + E_t\widehat{q}_{t+1}^h\right) = 0 \tag{B.88}$$

$$\widehat{\lambda}_t^s + \widehat{W}_t^s - \varphi\widehat{L}_t^s = 0 \tag{B.89}$$

$$\widehat{\lambda}_t^s - \widehat{\Lambda}_{t-1,t}^s = \widehat{\lambda}_{t-1}^s \tag{B.90}$$

$$\hat{R}_t + E_t\widehat{\Lambda}_{t,t+1}^s - E_t\widehat{\pi}_{t+1} = \tag{B.91}$$

B.3.2 Impatient workers

$$\frac{1+\beta^b g^2}{1-g}\widehat{C}_t^b + (1-\beta^b g)\widehat{\lambda}_t^b - \frac{\beta^b g}{1-g}E_t\widehat{C}_{t+1}^b = \frac{g}{1-g}\widehat{C}_{t-1}^b \tag{B.92}$$

$$\hat{R}_t^h + \widehat{S}_t^h - \widehat{h}_t^b - E_t\widehat{q}_{t+1}^h - E_t\widehat{\pi}_{t+1} - \widehat{\mu}_t^b = 0 \tag{B.93}$$

$$\begin{aligned} &-\widehat{q}_t^h - \left[\left(1-(1-\mu^b)\beta^b - \mu^b\pi/R^h\right)\sigma^b + \mu^b\pi/R^h\right]\widehat{h}_t^b \\ &-\left(1-(1-\mu^b)\beta^b - \mu^b\pi/R^h\right)\widehat{\lambda}_t^b + \mu^b\pi/R^h\widehat{S}_t^h \\ &+(1-\mu^b)\beta^b\left[E_t\widehat{\Lambda}_{t,t+1}^b + E_t\widehat{q}_{t+1}^h\right] = 0 \end{aligned} \tag{B.94}$$

$$\widehat{\lambda}_t^b - \widehat{\Lambda}_{t-1,t}^b = \widehat{\lambda}_{t-1}^b \tag{B.95}$$

$$\widehat{\lambda}_t^b + \hat{W}_t^b - \varphi\hat{L}_t^b = 0 \tag{B.96}$$

$$\begin{aligned} &\left(\frac{C^b}{Y}\right)\widehat{C}_t^b + \left(\frac{q^h h^b}{Y}\right)\widehat{h}_t^b - \frac{1}{\beta^s}\frac{R^h}{R}\left(\frac{S^h}{Y}\right)\widehat{\pi}_t - \frac{W^b L^b}{Y}\left(\widehat{W}_t^b + \widehat{L}_t^b\right) - \left(\frac{S^h}{Y}\right)\widehat{S}_t^h \\ &\qquad = \left(\frac{q^h h^b}{Y}\right)\widehat{h}_{t-1}^b - \frac{1}{\beta^s}\frac{R^h}{R}\left(\frac{S^h}{Y}\right)\left(\widehat{R}_{t-1}^h + \widehat{S}_{t-1}^h\right) \end{aligned} \tag{B.97}$$

B.3.3 Entrepreneurs

$$\hat{Y}_t - \alpha\hat{U}_t - (1-\alpha)\vartheta\hat{L}_t^s - (1-\alpha)(1-\vartheta)\hat{L}_t^b = \alpha\hat{K}_{t-1} \tag{B.98}$$

$$\hat{Y}_t - (1+\zeta)\hat{U}_t + \widehat{P}_{m,t} - \widehat{q}_t^c = \hat{K}_{t-1} \tag{B.99}$$

$$\frac{K}{Y}\widehat{K}_t - \frac{I}{Y}\widehat{I}_t + (R^c - (1-\delta))\frac{K}{Y}\hat{U}_t = (1-\delta)\frac{K}{Y}\widehat{K}_{t-1} \tag{B.100}$$

$$
\begin{aligned}
&-\widehat{q}^c_t-\left(\beta^e\alpha\frac{P_mY}{K}+\left(1-\frac{\beta^e}{\beta^s}\frac{R^c}{R}\right)\frac{S^c}{Y}\frac{Y}{K}\right)\widehat{K}_t+\left(1-\frac{\beta^e}{\beta^s}\frac{R^c}{R}\right)\frac{S^c}{Y}\frac{Y}{K}\widehat{S}^c_t\\
&-\frac{\beta^e}{\beta^s}\frac{R^c}{R}\left(\frac{S^c}{Y}\right)\left(\frac{Y}{K}\right)\widehat{R}^c_t+\beta^e(\mathbf{1}-\delta)E_t\widehat{q}^c_{t+1}\\
&+\beta^e\alpha\frac{P_mY}{K}\left[E_t\widehat{Y}_{t+1}+E_t\widehat{P}_{m,t+1}-E_t\widehat{U}_{t+1}\right]\\
&+\left(\beta^e\alpha\frac{P_mY}{K}+\beta^e(1-\delta)-\frac{\beta^e}{\beta^s}\frac{R^c}{R}\frac{S^c}{Y}\frac{Y}{K}\right)E_t\widehat{\Lambda}^e_{t,t+1}\\
&+\frac{\beta^e}{\beta^s}\frac{R^c}{R}\left(\frac{S^c}{Y}\right)\left(\frac{Y}{K}\right)E_t\widehat{\pi}_{t+1}=0
\end{aligned}
\tag{B.101}
$$

$$\hat{Y}_t-\hat{L}^b_t+\widehat{P}_{m,t}-\hat{W}^b_t=0 \tag{B.102}$$

$$\hat{Y}_t-\hat{L}^s_t+\widehat{P}_{m,t}-\hat{W}^s_t=0 \tag{B.103}$$

$$\frac{1+\beta^eg^2}{1-g}\widehat{C}^e_t+(1-\beta^eg)\widehat{\lambda}^e_t-\frac{\beta^eg}{1-g}E_t\widehat{C}^e_{t+1}=\frac{g}{1-g}\widehat{C}^e_{t-1} \tag{B.104}$$

$$\widehat{\lambda}^e_t-\widehat{\Lambda}^e_{t-1,t}=\widehat{\lambda}^e_{t-1} \tag{B.105}$$

$$
\begin{aligned}
&-\widehat{S}^c_t+\widehat{K}_t-\widehat{R}^c_t+E_t\widehat{\pi}_{t+1}+E_t\hat{q}^c_{t+1}\\
&-\frac{\beta^s\mu^e}{(Y/K)(S^c/Y)(R^c/R)}\alpha\frac{P_mY}{K}E_t\widehat{U}_{t+1}=0
\end{aligned}
\tag{B.106}
$$

$$
\begin{aligned}
&-\frac{1}{(Y/K)}\widehat{K}_t+\frac{\alpha}{X}(\widehat{Y}_t+\widehat{P}_{m,t}-\widehat{U}_t)-\frac{\delta}{Y/K}\widehat{q}^c_t\\
&+\left(\frac{S^c}{Y}\right)\widehat{S}^c_t+\frac{1}{\beta^s}\left(\frac{R^c}{R}\right)\left(\frac{S^c}{Y}\right)\widehat{\pi}_t-\left(\frac{C^e}{Y}\right)\widehat{C}^e_t\\
&=-\frac{1-\delta}{(Y/K)}\widehat{K}_{t-1}+\frac{1}{\beta^s}\left(\frac{R^c}{R}\right)\left(\frac{S^c}{Y}\right)\left(\widehat{R}^c_{t-1}+\widehat{S}^c_{t-1}\right)
\end{aligned}
\tag{B.107}
$$

B.3.4 Capital producing firms

$$\widehat{q}^c_t-(1+\beta^s)\eta\hat{I}_t+\beta^s\eta E_t\hat{I}_{t+1}=-\eta\hat{I}_{t-1} \tag{B.108}$$

B.3.5 Financial Intermediation

$$
\begin{aligned}
&-\widehat{\nu}_t^c-\theta\left(\frac{1}{1-\Theta^c/N^c}\right)\hat{\phi}_t^c+\left(\frac{1-\theta}{\nu^c}+\theta\phi^c\left(\frac{1}{1-\Theta^c/N^c}\right)\right)\frac{R^c}{R}\hat{R}_t^c \\
&-\left(\frac{1-\theta}{\nu^c}+\theta\left(\frac{1}{1-\Theta^c/N^c}\right)(\phi^c-1)\right)\hat{R}_t+E_t\widehat{\Lambda}_{t,t+1}^s-E_t\widehat{\pi}_{t+1} \\
&+\theta\left(\frac{1}{1-\Theta^c/N^c}\right)\left[\left(\frac{R^c}{R}-1\right)\phi^c+1\right]\left[E_t\hat{\phi}_{t+1}^c+E_t\nu_{t+1}^c\right] \\
&+\theta\left(\frac{\Theta^c/N^c}{(1-\Theta^c/N^c)^2}\right)\left[\left(\frac{R^c}{R}-1\right)\phi^c+1\right]\left[\widehat{\Theta}_t^c-\hat{N}_t^c\right]=0
\end{aligned}
\tag{B.109}
$$

$$
\begin{aligned}
&-\hat{\eta}_t^c+\theta\phi^c\left(\frac{1}{1-\Theta^c/N^c}\right)\left(\frac{R^c}{R}-1\right)\hat{\phi}_t^c-\theta\left(\frac{1}{1-\Theta^c/N^c}\right)(\phi^c-1)\hat{R}_t \\
&+\theta\phi^c\left(\frac{1}{1-\Theta^c/N^c}\right)\frac{R^c}{R}\hat{R}_t^c \\
&+\theta\left(\frac{1}{1-\Theta^c/N^c}\right)\left[\left(\frac{R^c}{R}-1\right)\phi^c+1\right]\left[E_t\widehat{\Lambda}_{t,t+1}^s+E_t\hat{\eta}_{t+1}^c-E_t\widehat{\pi}_{t+1}\right] \\
&+\theta\left(\frac{\Theta^c/N^c}{(1-\Theta^c/N^c)^2}\right)\left[\left(\frac{R^c}{R}-1\right)\phi^c+1\right]\left[\widehat{\Theta}_t^c-\hat{N}_t^c\right]=0
\end{aligned}
\tag{B.110}
$$

$$
\begin{aligned}
&-\widehat{\nu}_t^h-\theta\left(\frac{1}{1-\Theta^h/N^h}\right)\hat{\phi}_t^h+\left(\frac{1-\theta}{\nu^h}+\theta\phi^h\left(\frac{1}{1-\Theta^h/N^h}\right)\right)\frac{R^h}{R}\hat{R}_t^h \\
&-\left(\frac{1-\theta}{\nu^h}+\theta\left(\frac{1}{1-\Theta^h/N^h}\right)\left(\phi^h-1\right)\right)\hat{R}_t+E_t\widehat{\Lambda}_{t,t+1}^s-E_t\widehat{\pi}_{t+1} \\
&+\theta\left(\frac{1}{1-\Theta^h/N^h}\right)\left[\left(\frac{R^h}{R}-1\right)\phi^h+1\right]\left[E_t\hat{\phi}_{t+1}^h+E_t\nu_{t+1}^h\right] \\
&+\theta\left(\frac{\Theta^h/N^h}{(1-\Theta^h/N^h)^2}\right)\left[\left(\frac{R^h}{R}-1\right)\phi^h+1\right]\left[\widehat{\Theta}_t^h-\hat{N}_t^h\right]=0
\end{aligned}
\tag{B.111}
$$

$$
\begin{aligned}
&-\hat{\eta}_t^h+\theta\phi^h\left(\frac{1}{1-\Theta^h/N^h}\right)\left(\frac{R^h}{R}-1\right)\hat{\phi}_t^h-\theta\left(\frac{1}{1-\Theta^h/N^h}\right)\left(\phi^h-1\right)\hat{R}_t \\
&+\theta\phi^h\left(\frac{1}{1-\Theta^h/N^h}\right)\frac{R^h}{R}\hat{R}_t^h \\
&+\theta\left(\frac{1}{1-\Theta^h/N^h}\right)\left[\left(\frac{R^h}{R}-1\right)\phi^h+1\right]\left[E_t\widehat{\Lambda}_{t,t+1}^s+E_t\hat{\eta}_{t+1}^h-E_t\widehat{\pi}_{t+1}\right] \\
&+\theta\left(\frac{\Theta^h/N^h}{(1-\Theta^h/N^h)^2}\right)\left[\left(\frac{R^h}{R}-1\right)\phi^h+1\right]\left[\widehat{\Theta}_t^h-\hat{N}_t^h\right]=0
\end{aligned}
\tag{B.112}
$$

$$\hat{\eta}_t^c + \frac{\nu^c}{\lambda^c - \nu^c}\hat{\nu}_t^c - \hat{\phi}_t^c = 0 \tag{B.113}$$

$$\hat{\eta}_t^h + \frac{\nu^h}{\lambda^h - \nu^h}\hat{\nu}_t^h - \hat{\phi}_t^h = 0 \tag{B.114}$$

$$S_t^c - \widehat{\phi}_t^c - \widehat{N}_t^c = 0 \tag{B.115}$$

$$\widehat{S}_t^h - \widehat{\phi}_t^h - \widehat{N}_t^h = 0 \tag{B.116}$$

$$\begin{aligned} &\hat{N}_t^c + \theta\left[(R^c - R)\phi^c + R\right]\widehat{\pi}_t = -\theta\left(\phi^c - 1\right)R\hat{R}_{t-1} + \theta\phi^c R^c \hat{R}_{t-1}^c + \\ &\theta\left[(R^c - R)\phi^c + R\right]\hat{N}_{t-1}^c + \theta(R^c - R)\phi^c\hat{\phi}_{t-1}^c + \omega^c\phi^c\widehat{S}_{t-1}^c + \frac{\Theta^c}{N^c}\widehat{\Theta}_t^c \end{aligned} \tag{B.117}$$

$$\begin{aligned} &\hat{N}_t^h + \theta\Big[(R^h - R)\phi^h + R\Big]\widehat{\pi}_t = -\theta\Big(\phi^h - 1\Big)R\hat{R}_{t-1} + \theta\phi^h R^h \hat{R}_{t-1}^h + \\ &\theta\Big[(R^h - R)\phi^h + R\Big]\hat{N}_{t-1}^h + \theta(R^h - R)\phi^h\hat{\phi}_{t-1}^h + \omega^h\phi^h\widehat{S}_{t-1}^h + \frac{\Theta^h}{N^h}\widehat{\Theta}_t^h \end{aligned} \tag{B.118}$$

B.3.6 The non-arbitrage condition

$$\phi^c\left(\frac{R^c}{R} - 1\right)\hat{\phi}_t^c + \phi^c\frac{R^c}{R}\hat{R}_t^c - \phi^h\left(\frac{R^h}{R} - 1\right)\hat{\phi}_t^h - \phi^h\frac{R^h}{R}\hat{R}_t^h + \Big(\phi^h - \phi^c\Big)\hat{R}_t = 0 \tag{B.119}$$

$$\widehat{\Theta}_t^c = -\widehat{\Theta}_t^h \tag{B.120}$$

B.3.7 Final good retailers

$$\hat{\pi}_t - \frac{(1-\gamma)(1-\beta^s\gamma)}{\gamma(1+\beta^s\gamma_p)}\widehat{P}_{m,t} - \frac{\beta^s}{1+\beta^s\gamma_p}E_t\hat{\pi}_{t+1} = \frac{\gamma_p}{1+\beta\gamma_p}\hat{\pi}_{t-1} \tag{B.121}$$

B.3.8 Monetary policy

$$\widehat{R}_t = \rho_R\widehat{R}_{t-1} + (1-\rho_R)\Big(\kappa_\pi\widehat{\pi}_t + \kappa_y\widehat{Y}_t\Big) \tag{B.122}$$

B.3.9 Driving process

$$\widehat{A}_t = \rho^A \widehat{A}_{t-1} + \epsilon_t^A \tag{B.123}$$

$$\widehat{\mu_t^b} = \rho^\mu \widehat{\mu_{t-1}^b} + \epsilon_t^\mu \tag{B.124}$$

B.3.10 Market clearing conditions

$$\hat{Y}_t - \frac{C^s}{Y}\hat{C}_t^s - \frac{C^b}{Y}\hat{C}_t^b - \frac{C^e}{Y}\hat{C}_t^e - \frac{I}{Y}\hat{I}_t = 0 \tag{B.125}$$

$$\widehat{h}_t^s + \frac{h^b}{h^s}\widehat{h}_t^b = 0 \tag{B.126}$$

B.3.11 Additional definition equations

$$\widehat{R}_t^{ann} = 4 * \widehat{R}_t \tag{B.127}$$

$$\widehat{\pi}_t^{ann} = 4 * \widehat{\pi}_t \tag{B.128}$$

$$\widehat{R}_t^{c,ann} = 4 * \widehat{R}_t^c \tag{B.129}$$

$$\widehat{R}_t^{h,ann} = 4 * \widehat{R}_t^h \tag{B.130}$$

$$\widehat{SP}_t^{c,ann} = \widehat{R}_t^{c,ann} - \widehat{R}_t^{ann} \tag{B.131}$$

$$\widehat{SP}_t^{h,ann} = \widehat{R}_t^{h,ann} - \widehat{R}_t^{ann} \tag{B.132}$$

$$\widehat{C}_t = \frac{C^b/Y}{C/Y}\widehat{C}_t^b - \frac{C^s/Y}{C/Y}\widehat{C}_t^s - \frac{C^e/Y}{C/Y}\widehat{C}_t^e \tag{B.133}$$

$$\widehat{L}_t = \frac{L^b}{L}\widehat{L}_t^b + \frac{L^s}{L}\widehat{L}_t^s \tag{B.134}$$

The linear RE model is solved using Christopher Sims' gensys code.

Appendix C

Appendix to Chapter 4

C.1 Federal Reserve's crisis-related programs during the financial crisis

- The **lender-of -last-resort tools**: the Fed provided short-term liquidity to banks, other depository institutions, and other financial institutions.

  - **Traditional Discount Window**: lengthened maturity to 90 days of loans to depository institutions at the primary credit rate.[1]
  - **Primary Dealer Credit Facility (PDCF)**: overnight fully secured loan to primary dealers at the primary credit rate.
  - **Term Auction Facility (TAF)**: auctions off short-term credit to depository institutions that are eligible to borrow under the primary credit program.
  - **Term Securities Lending Facility (TSLF)**: Treasury securities lending to primary dealers against program-eligible collateral.
  - **Dollar Liquidity Swap Lines**: provision of liquidity in U.S. dollars to overseas markets.
  - **Foreign-Currency Liquidity Swap Lines**: provision of liquidity to U.S. institutions in currencies of the counterparty central banks.

- **Targeted Credit Facilities**: the Fed directly provided liquidity to borrowers and investors in key credit markets.

  - **Term Asset-Backed Securities Loan Facility (TALF)**: loans to holders of eligible asset-backed securities (ABS) collateralized by a variety of consumer and business loans.
  - **Commercial Paper Funding Facility (CPFF)**: liquidity backstop to U.S. issuers of commercial paper through a specially created limited liability company (LLC) that uses the financing provided by the Fed to purchase three-month unsecured and asset-backed commercial paper from eligible issuers.

[1] The "Primary Credit" is a lending program available to depository institutions that are in generally sound financial condition. The primary credit is priced at a rate 100 basis points above the federal funds rate.

  - **Asset-Backed Commercial Paper Money Market Mutual Fund Liquidity Facility(AMLF)**: financing U.S. depository institutions and bank holding companies to facilitate their purchases of high-quality asset-backed commercial paper (ABCP) from money market mutual funds.
  - **Money Market Investor Funding Facility (MMIFF)**: to complement the CPFF and AMLF by purchasing certain money market instruments (e.g., CD, bank notes and CP) from money market mutual funds and certain other money market investors.

- **Programs to support specific institutions**
  - **Maiden Lane I**: credit to Maiden Lane LLC, a limited liability company created to facilitate the acquisition certainof Bear Stearns assets (March 16, 2008).
  - **Line of Credit to AIG** (September 16, 2008).
  - **Maiden Lane II**: residential mortgage-backed securities (RMBS) of AIG subsidiaries (December 12, 2008).
  - **Maiden Lane III**: multi-sector collateralized debt obligations (CDOs) backed by AIG (November 25, 2008).

When the federal funds rate is stuck at its zero lower bound, the Fed increases the size of its balance sheet to purchase quantities of longer-term securities–Large-Scale Asset Purchase Programs (LSAPs).

- **QE1**:
  - $175 billion of agency debt of Fannie Mae, Freddie Mac, and the Federal Home Loan Banks (from December 2008 to August 2010).
  - $1.25 trillion of agency MBS guaranteed by Fannie Mae, Freddie Mac, and Ginnie Mae (from January 2009 to August 2010).
  - $300 billion of longer-term Treasury securities (from March 2009 to October 2009).
- **QE2**:
  - An additional $600 billion of longer-term Treasury securities (from March 2009 to October 2009)
- **QE3: Open-Ended Asset Purchase Program**
  - Purchase additional agency MBS at a pace of $40 billion per month (starting in September 2012).
  - Purchase longer-term Treasuries at a pace of $45 billion per month (starting in January 2013).
- **Maturity Extension Program (MEP)**: "**Operation Twist**"
  - Extend the average maturity of Fed balance sheet assets by buying $400 billion of Treasuries with maturities of 6 to 30 years and sell an equal amount with maturities of 3 years or less (announced September 21, 2011, to the end of June 2012).
  - additional $267 billion of longer-term Treasury securities purchases against an equal amount of short-term Treasury securities (announced June 20, 2012, to the end of 2012).

C.2 Summary of empirical studies on the financial market impact of LSAPs

Paper	Transmission channels	Method	Reductions in bond yields	Results
QE1				
Gagnon *et al.* (2011)	Portfolio rebalance	Dynamic OLS	30-100 bps (10-yr term premium); 113 bps (yield on agency MBS); 67 bps (yields on Baa-rated corporate bonds)	The authors find that LSAPs change the available quantity of long-term assets held in private sector relative to short-term assets, inducing reductions in long-term interest rates on a variety of securities through the "portfolio balance channel" primarily reflected by lower risk premiums, rather than lower expectations of future short-term interest rates.
Krishnamurthy and Vissing-Jorgensen (2011)	Prepayment risk channel	Event study and OLS	20 bps (10-yr) and 42-200 bps (yield no MBS or agency debt)	The results suggest that the purchases of long-term Treasuries and agency debt increase the scarcity of such assets, reducing the yields on them relative to less safe assets, such as Baa corporate rates. The impact on MBS rates is large only when LSAP involves purchases of MBS.
Bauer and Rudebusch (2011)	Signaling and portfolio rebalance	Event study and OLS	Signaling: 37 bps (10-yr) and 94 bps cumulative; Portfolio rebalance: 56 bps (10-yr)	They find important signaling effects that allows QE1 operates to lower Treasury yields by affecting the expected future short-term interest rates.
Hamilton and Wu (2011)		Affine arbitrage-free model	32 bps (10-yr)	Considering $400 billion purchase of long-term securities financed by interest-rate bearing reserves, they estimate that the 10-year Treasury yield would decline without raising short-term yields.
Christensen and Rudebusch (2012)	Signaling and portfolio rebalance	Event study	Signaling: 53 bps (10-yr) and 89 bps cumulative, portfolio rebalance: 29 bps (10-yr)	Results suggest the important role of signaling channel through which Fed's LSAP program help to lower the expectations component of long-term interest rates.
D'Amico and King (2010)	Portfolio rebalance	OLS	20-50 bps (long-term Treasuries)	Each purchase operation ("flow effect") caused a decline in yields of 3.5 basis points. The program as a whole resulted in a persistent downward shift in the yield curve ("stock effect").
Hancock and Passmore (2011)		Two-stage least squares	50-85 bps	The authors find importance for both the announcement and purchase of MBS in reducing mortgage rates.
QE2				
Krishnamurthy and Vissing-Jorgensen (2012)	Signaling and safety channels	Event study	48 pbs cumulative (10-yr)	The authors find a substantial impact on Treasury and agency bond rates but smaller effects on MBS and corporate rates.
Operation Twist				
Swanson (2011)		Event study	15 bps (10-yr)	

Table C.1: *Summary of empirical studies on the financial market impact of LSAPs*

Résumé de thèse

Trois essais en économie monétaire : Transparence de la banque centrale et implications macroéconomiques des frictions financières

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Présentation

Les effets extrêmement dévastateurs de la crise financière de 2007 et 2008 sur les marchés financiers et l'économie réelle ont amené les économistes à remettre en question de nombreuses réalisations liées à l'économie monétaire sur les plans théorique et politique. Avant cette crise, de nombreuses opinions consensuelles sur l'économie monétaire et sa politique ont engendré des modèles faisant fi de l'intermédiation financière, et plus particulièrement des frictions dans le système financier. Les questions les plus importantes relatives aux banques centrales (notamment le ciblage de l'inflation, la responsabilité, l'indépendance et la transparence de la Banque Centrale, l'engagement et le pouvoir discrétionnaire de la politique monétaire) sont examinées sous forme de modèles pouvant être réduits à une équation, à savoir la courbe de Phillips traditionnelle ou celle des nouveaux économistes keynésiens. La façon dont fonctionnent les marchés financiers s'avère sans importance pour l'analyse de la politique monétaire, puisqu'ils sont censés fonctionner sans frictions, tout comme les fluctuations du marché sont censées rester indépendantes des décisions économiques des agents privés, même si les économistes et décideurs politiques ont conscience que ces marchés demeurent importants pour l'économie.

En revanche, de nombreux modèles d'équilibre général stochastiques dynamiques (EGSD) visant à analyser les effets des politiques économiques ou des chocs exogènes partagent les mêmes conceptions en matière d'intermédiation financière et de marchés, bien qu'une certaine attention soit accordée aux contraintes financières imposées sur l'endettement des ménages et des sociétés avant la crise financière mondiale. Peu d'efforts ont été consacrés à l'étude des conséquences de l'intermédiation financière, et notamment des frictions financières qui affectent le flux de crédit, pour le mécanisme de transmission des chocs exogènes et les propriétés dynamiques des cycles économiques. Par ailleurs, les économistes méconnaissent la manière dont devrait réagir la Banque Centrale lorsque de telles frictions apparaissent et influent sur les résultats des politiques monétaires conventionnelles. En outre, les effets de mesures de politique monétaire non conventionnelle adoptées lors de l'échec de mesures conventionnelles ne peuvent être bien évalués sans intégrer ces frictions dans des modèles macroéconomiques.

Pour relever les nouveaux défis provoqués par la crise financière mondiale, les études se focalisent toujours davantage sur l'intégration d'intermédiaires financiers et les frictions financières qui apparaissent lors du processus d'auto-financement des intermédiaires dans l'analyse macroéconomique monétaire. Les travaux présentés dans cette thèse correspondent à cette nouvelle tendance de macroéconomie monétaire. L'apport de cette thèse suscite des répercussions importantes pour la conduite de la politique monétaire. Tout d'abord, cette thèse vise à étudier la façon dont l'analyse de la transparence de la Banque Centrale est modifiée si le rôle de l'intermédiation financière est considéré en incluant le canal du crédit. En tenant compte des besoins des entreprises à emprunter des fonds auprès des banques pour leurs fonds de roulement, le canal du crédit permet au taux d'intérêt d'influer sur la courbe de Phillips. Deuxièmement, cette thèse vise à analyser en quoi une intermédiation financière imparfaite peut affecter les fluctuations du cycle économique, lorsque la Banque Centrale adopte des politiques monétaires conventionnelles formulées selon la règle de Taylor. Enfin, ma réflexion sur les conséquences de la crise financière mondiale et ses conséquences pour les banques centrales me permet d'analyser les mécanismes de transmission de mesures de politique monétaire non conventionnelle dans un cadre pourvu de frictions financières.

La transparence de la Banque Centrale

Depuis les années 1990, les banques centrales sont devenues de plus en plus transparentes dans leur communication avec les marchés publics et financiers. Plusieurs facteurs connexes expliquent l'amélioration de la transparence de la Banque Centrale. Tout d'abord, en réponse aux pressions populaires, la transparence s'inscrit dans une tendance plus large d'amener les autorités plus près du peuple. Deuxièmement, la transparence est considérée comme un élément clé pour assurer le principe de responsabilité tandis que les banques centrales acquièrent plus d'indépendance et prennent plus librement leurs décisions. En effet, la transparence est un mécanisme permettant au public d'évaluer si les banques centrales agissent conformément à leurs mandats[1]. En troisième lieu, la transparence de la Banque Centrale est considérée comme un moyen de permettre aux opérateurs du marché de répondre plus facilement aux décisions politiques, puisque la transparence sur les perspectives économiques de la Banque Centrale et en quoi ces perspectives sont liées à sa politique diminue le risque que les décisions de politique monétaire arrivent par surprise, améliorant ainsi les anticipations du secteur privé. Étant donné que les investisseurs sont moins susceptibles d'être pris au dépourvu par des actions politiques, tout changement politique sera moins susceptible de provoquer des mouvements extrêmes dans le prix des actifs à l'origine de difficultés financières. Quatrièmement, la transparence renforce la crédibilité des engagements de la Banque Centrale. Un engagement d'assurer une inflation faible et stable sera plus convaincant si la Banque Centrale explique clairement pourquoi et comment ses choix politiques peuvent produire l'inflation désirée. D'un autre côté, un engagement avec une plus grande crédibilité donne à la Banque Centrale plus de liberté de s'écarter des chemins politiques annoncés dans des circonstances particulières. En d'autres termes, le public voit une telle déviation comme transitoire et toujours en ligne avec la poursuite des objectifs de la politique monétaire à long terme. En conséquence, la transparence de la Banque Centrale améliore tant la crédibilité que la flexibilité de la politique.

Le chapitre 2 aborde la question de la transparence politique de la Banque Centrale, c'est-à-dire la transparence sur le poids relatif incombant à la stabilisation de la production. La motivation principale de notre étude s'avère que, tandis qu'il est relativement fréquent de voir de nombreuses banques centrales annoncer leur cible d'inflation, communiquer au sujet de leurs perspectives économiques et publier des compte-rendus de leurs décisions, une Banque Centrale établit rarement une déclaration publique spécifiant les pondérations attribuées à ses objectifs. Ce type d'opacité serait injustifié dans un cadre à la Barro-Gordon (1983). Le cadre Barro-Gordon n'affecte pas

[1] L'indépendance des banques centrales est observée comme un moyen efficace de résoudre les problèmes de cohérence de temps affectant la politique discrétionnaire. Pour cette raison, cette indépendance est largement préconisée comme moyen d'isoler la politique monétaire des pressions politiques à court terme (voir Blinder, 1998 , Rogoff, 1985, Walsh, 2003, Grilli et al., 1991 and Debelle and Fischer, 1994).

l'inflation moyenne ni l'écart de production, mais induit une variabilité plus élevée de l'inflation et de l'écart de production.

Selon Dai (2014), compte tenu de la présence de concurrence monopolistique dans le nouveau modèle keynésien standard (Clarida., 1999), une divulgation partielle sur les préférences des banques centrales pourrait améliorer le bien-être social. Selon un tel modèle, la non-transparence réduit généralement la réaction moyenne de l'inflation vis-à-vis des chocs d'inflation et de la volatilité de l'inflation ; Toutefois, elle augmente également ceux de l'écart de production - plus encore lorsque les chocs d'inflation sont fortement persistants - et peut donc améliorer le bien-être social si le poids attribué à la stabilisation de l'écart de production est faible. Ces résultats sont en ligne avec ceux obtenus dans des modèles introduisant des distorsions et des inefficacités économiques[2] :

Le chapitre 2 contribue à la littérature sur la transparence de la Banque Centrale en introduisant le canal du crédit dans un modèle néo-keynésien standard, basé sur Christiano (2005) et Ravenna & Walsh (2006). L'analyse dans le présent chapitre est complémentaire de celle de Dai (2014) et son objectif est d'étudier comment la présence du canal du crédit modifie les effets de l'opacité (à savoir la transparence, la transparence imparfaite) sur les préférences des banques centrales concernant les fluctuations cycliques de l'inflation et l'écart de production.

Dans ce chapitre, le processus d'intermédiation financière est sans friction, tandis que les deux chapitres suivants, qui examinent les effets des frictions financières dans les modèles néo-keynésien EGSD, ne tiennent pas compte de la transparence des banques centrales.

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[2] Voir par exemple Sorensen, 1991, Grüner, 2002 et Spyromitros et Zimmer, 2009, introduisant une distorsion dans la fixation des salaires, Hughes Hallett et Viegi, 2003, Ciccarone et al., 2007 et Hefeker et Zimmer, 2011 au taux d'imposition, ainsi que Dai et Sidiropoulos, 2011 à l'investissement public. L'une des raisons pour laquelle l'opacité de la Banque Centrale pourrait améliorer le bien-être dans ces modèles avec distorsions est qu'elle pourrait discipliner le secteur privé ou l'État dans la fixation des salaires ou des taux d'imposition.

Macroéconomie et frictions financières

L'importance des marchés financiers imparfaits pour les fluctuations de cycle économique est analysée depuis des décennies en macroéconomie. Une des raisons de modéliser explicitement ces frictions, c'est que les flux de crédit sont fortement procycliques (Covas et Den Haan, 2011). La croissance des dettes privées diminue considérablement durant les récessions, d'une importance particulière au cours de la grande récession de 2008. Les propriétés cycliques des marchés financiers ne renvoient pas seulement à l'instabilité globale des flux de crédit mais également au resserrement des normes de crédit de la plupart des banques lors de récessions et l'augmentation des écarts de taux, c'est-à-dire les écarts de taux d'intérêt entre les titres associés à différents niveaux de risque (Gilchrist et al., 2009).

Selon Modigliani et Miller (1958), avec des marchés sans friction, les structures financières des agents individuels (ménages, entreprises ou intermédiaires financiers) seraient indéterminées. Ainsi, il n'existerait aucune raison pour que les flux financiers suivent un modèle cyclique. Toutefois, le fait que les flux de crédit soient fortement procycliques et que l'indicateur du resserrement des normes soit anticyclique remet en question le paradigme du marché financier sans friction.

On retrouve deux traits caractérisant les modèles avec frictions financières. Tout d'abord, l'achat et la vente de certains actifs ne peut avoir lieu, c'est-à-dire que les marchés pour certains impondérables sont manquants. Les agents privés seront ainsi incapables de faire avancer ou retarder les dépenses (consommation ou investissements) ou encore de lisser la consommation ou les investissements en se protégeant contre tout événement incertain. Dans une économie de marchés complets, les agents privés peuvent échanger n'importe quel type de risque. Il existe deux approches de modélisation des marchés incomplets : le marché "exogène" incomplet et le marché "endogène" incomplet. Le premier comprend des modèles imposant l'hypothèse que certain actifs ne peuvent pas être échangés. Par exemple, le montant total de la dette ne peut pas dépasser une certaine limite exogène fixe (c.-à-d., la contrainte d'endettement). Le second comprend des modèles où l'ensemble des contrats de dette proviennent du problème principal-agent. L'idée s'avère que les parties sont réticentes à s'engager dans certains échanges en raison de problèmes de compatibilité des mesures d'encouragement et d'applicabilité, ce qui implique que des marchés soient manquants. À noter que le marché endogène incomplet résulte généralement de deux problèmes principal-agent: une application limitée et une asymétrie d'information. L'application limitée implique que, bien que le prêteur puisse observer pleinement si l'emprunteur s'acquitte des obligations de son contrat, l'absence d'outils adaptés empêche le prêteur de faire respecter ces obligations. Les capacités des prêteurs à obliger les emprunteurs à s'acquitter de leurs obligations sont également limitées par les asymétries d'information, c'est-à-dire par l'incapacité du prêteur à observer l'action de l'emprunteur.

Le second trait caractérisant les modèles avec frictions financières, c'est que les agents privés au sein de l'économie sont hétérogènes. Il est évident que si tous les agents sont homogènes, il n'y a aucune raison d'échanger des créances intertemporellement ou intratemporellement. Une approche commune de modélisation de l'hétérogénéité des agents suppose qu'il existe deux types d'agents avec des préférences et/ou technologies différentes. En équilibre, un agent sera l'emprunteur et l'autre le prêteur (voir par exemple, Iacoviello, 2005). Une autre approche consiste à assumer qu'un continuum d'agents hétérogènes avec leurs comportements globaux caractérisés par des agents représentatifs uniques par agrégat linéaire (voir par exemple, Carlstrom et Fuerst, 1997 et Bernanke et al., 1999).

Frictions financières et amplification

Une grande partie de la littérature antérieure sur l'économie monétaire dynamique a mis l'accent sur les effets d'amplification des frictions du marché financier. Cette littérature suppose que les frictions financières peuvent aggraver une récession, même si elles n'en sont pas à l'origine. En d'autres termes, l'amplitude d'une récession générée par les chocs non financiers (p. ex., la technologie ou des chocs de politique monétaire) serait beaucoup plus grande lorsque les frictions financières sont présentes que lorsqu'elles sont absentes de l'économie modélisée. Les modèles de base pourvus de frictions financières représentent le modèle des coûts de vérification (Costly state verification model) proposé par Bernanke et Gertler (1989) et le modèle de lacontrainte de l'endettement de Kiyotaki et Moore (1997).

Le modèle des coûts de vérification

Dans le modèle des coûts de vérification de Bernanke et Gertler (1989), les frictions financières dérivent d'asymétrie de l'information sur les bénéfices futurs de projets d'entreprises. Le coût de la vérification est induit par un choc idiosyncrasique qui influe sur la technologie de chaque entrepreneur et est inobservable depuis l'extérieur. En conséquence, le contrat optimal entre un entrepreneur et un prêteur doit être tel que l'entrepreneur ne profite pas de l'asymétrie de l'information et ne minimise pas la perte sèche due au coût de la vérification.

Dans ce modèle, les auteurs se concentrent sur le fait qu'un choc temporaire puisse avoir des effets persistants à long terme par le biais des effets de rétroaction des frictions financières. Les chocs négatifs sur les fonds propres de l'entrepreneur accroissent les frictions financières et contraignent les entrepreneurs à investir moins, réduisant le stock de capital de l'entrepreneur et donc ses fonds propres. Cette réduction aboutit dans une spirale descendante d'activité économique moindre et de fléchissements supplémentaires de la valeur du capital.

En substance, le coût de la vérification agit de la même façon que les coûts de rectification du placement, en réduisant la volatilité globale, rendant difficile la formation de grandes amplifications. Toutefois, ce modèle détient le potentiel pour générer plus de persistance, mais il est limité par la structure du modèle à deux périodes. Pour générer d'importants effets d'amplification, Carlstrom et Fuerst (1997) et Bernanke, Gertler et Gilchrist (1999) ont incorporé les coûts de vérification dans des modèles macroéconomiques dynamiques avec des agents à durée de vie infinie[3].

[3] Selon Bernanke et al., (1999), l'accélérateur financier pourrait générer des amplifications non négligeables des chocs de politique monétaire et de plus grandes fluctuations des capitaux si les coûts d'ajustement sont ajoutés à la production de biens d'équipement.

Le modèle avec contraintes collatérales

Une autre approche de l'intégration des frictions financières proposée par Kiyotaki et Moore (1997) suppose que les entrepreneurs utilisent un facteur de production--foncier, comme garantie d'emprunt. Dans ce cadre, un faible choc à l'économie peut générer d'importantes fluctuations en déclenchant des interactions entre le prix de la terre et la contrainte d'endettement des entreprises. Un prix de la terre plus élevé valorise les fonds propres des entreprises, en augmentant leur capacité d'emprunt et donc à investir dans la terre et à augmenter la production de biens de consommation.

Néanmoins, des recherches ultérieures ont montré que la contrainte d'endettement selon Kiyotaki et Moore (1997) ne peut pas générer les fluctuations de prix de la terre observées. Par exemple, Kocherlakota (2000) suggère que les contraintes collatérales ne peuvent pas générer d'effets suffisants car certains agents détiennent des actifs liquides visant à s'auto-assurer en cas de faibles chocs. Cordoba et Ripoll (2004) proposent un modèle NK avec la contrainte d'endettement liée à la valeur de la terre et ils trouvent qu'une part importante du capital et une très faible substitution intertemporelle sont nécessaires pour produire un effet d'amplification significatif. Pour régler ces problèmes quantitatifs, les chercheurs ont admis une fonction supplémentaire dans le modèle avec contraintes collatérales. Par exemple, Iacoviello (2005) lie la contrainte collatérale aux valeurs immobilières et introduit l'hétérogénéité des ménages ; Mendoza (2010) intègre des salaires rigides ; et Jermann et Quadrini (2012) supposent que les entrepreneurs ont besoin de fonds externes pour financer leurs fonds de roulement.

Intermédiation financière

Depuis la crise des subprimes à l'été 2007, des événements économiques et financiers récents montrent que l'intermédiation financière constitue une importante source de fluctuations du cycle économique et le point clé dans la compréhension de la stabilité financière. En effet, le modèle macroéconomique traditionnel utilisé pour l'analyse de la politique monétaire (par exemple, le modèle de ''canal du prêt bancaire'' qui endosse un rôle essentiel pour les banques, tout en assumant des contraintes spécifiques) devient moins pertinent pour décrire le système financier moderne. En particulier, on suppose que des banques commerciales dépendent principalement des dépôts pour leur financement, que de nombreux emprunteurs dépendent du crédit bancaire et que les banques ne disposent pas de nombreuses opportunités d'investissement pour utiliser leurs fonds autres que les prêts aux emprunteurs rattachés à la banque. Une telle hypothèse devient moins pertinente en raison d'innovations financières et de modifications réglementaires adoptées depuis les années 1980.

Préoccupés par la pertinence du canal du prêt bancaire, d'autres modèles ont plutôt souligné le canal des bilans évoqué précédemment, tel que les prêteurs pourraient être réticents à octroyer du crédit à des emprunteurs non financiers moins bien capitalisés et plus à risque, comme dans les contributions majeures de Bernanke et Gertler (1989), Kiyotaki et Moore (1997) et Bernanke, Gertler et Gilchrist (1999). Toutefois, ces modèles ne peuvent pas expliquer la récente crise qui, au moins dans sa phase initiale, a été caractérisée par la capacité amoindrie des intermédiaires à fournir du crédit, résultant d'évolutions négatives dans le secteur financier lui-même, plutôt que dans la baisse de la demande de crédit due aux problèmes essentiels des emprunteurs.

En outre, dans le contexte de la récente crise financière, les banques centrales dans de nombreux pays industrialisés ont adopté divers outils de politique non conventionnelle n'ayant jamais été utilisés auparavant (par exemple, le programme d'achat d'actifs à grande échelle (LSAP) initié par la Réserve fédérale). Pour les banques centrales, ces politiques non conventionnelles représentent une rupture avec les mesures de politique traditionnelle et leurs mécanismes de transmission n'ont pas été bien compris.

Pour évaluer l'efficacité de ces mesures, des efforts permanents ont été consacrés à la construction d'une nouvelle génération de modèles macroéconomiques avec frictions financières apparaissant dans le secteur de l'intermédiation financière. Ces modèles visent à étudier, tout d'abord, le lien entre les perturbations financières et les fluctuations de cycle économique et, deuxièmement, les effets de diverses politiques monétaires non conventionnelles sur les conditions du marché financier et, par conséquent, sur l'activité économique réelle (p. ex. Curdia et Woodford, 2010 et 2011 et Gertler et Karadi, 2011 et 2013). Dans ces modèles, la capacité de prêt des intermédiaires financiers est principalement déterminée par l'ampleur de fonds propres des intermédiaires.

Les chapitres 3 et 4 de cette thèse contribuent à ce courant de littérature. Nous développons un modèle d'équilibre général quantitatif avec frictions financières en raison d'un problème d'aléa moral de Gertler et Karadi (2011) et de l'application limitée du crédit garanti hétérogène. Dans le chapitre 3, nous utilisons ce modèle pour examiner le rôle joué par l'intermédiation financière imparfaite dans la transmission des chocs exogènes à l'économie. Au chapitre 4, nous utilisons ce modèle pour analyser les effets des achats d'actifs à grande échelle de la Fed sur les économies avec différents niveaux de segmentation du marché du crédit.

Plan de la thèse

Cette thèse présente trois essais sur l'économie monétaire. Le chapitre 2, « La transparence de la Banque Centrale avec le canal du crédit », met l'accent sur les effets de l'opacité sur les préférences des banques centrales, c'est-à-dire sur l'incertitude quant à l'importance relative que la Banque centrale accorde à la stabilisation de l'écart de production dans un modèle néo-keynésien. Dans ce modèle, nous considérons la présence du canal du crédit qui se caractérise par des distorsions en raison du besoin des entreprises de préfinancer leur production. Dans ce cadre, nous avons démontré que le canal du crédit non seulement altérait la non-transparence de la Banque Centrale associée à des chocs d'inflation, mais elle produit également ces effets en fonction des chocs de demande. Par rapport aux chocs d'inflation, les chocs de demande sont associés à des effets similaires mais moindres d'opacité, excepté lorsqu'ils comportent une volatilité beaucoup plus importante. La non-transparence réduit généralement la réaction moyenne de l'inflation pour les deux types de chocs et diminue ainsi la volatilité de l'inflation, mais elle augmente également ceux de l'écart de production, plus encore lorsque ces chocs sont fortement persistants. Elle pourrait ainsi améliorer le bien-être social si la société affectait un faible poids à la stabilisation de l'écart de production et particulièrement plus encore avec le canal du crédit. Les chapitres 3 et 4 présentent deux essais sur des théories monétaires du cycle économique. Leur dénominateur commun s'avère les implications macroéconomiques des frictions financières qui apparaissent dans le processus d'intermédiation du crédit.

Le chapitre 3, « L'intermédiation financière imparfaite et les fluctuations de cycles économiques » repose sur le modèle néo-keynésien avec frictions financières proposé par Gertler et Karadi (2011)pour analyser le rôle des frictions financières affectant la capacité des intermédiaires financiers à fournir du crédit dans la transmission de chocs exogènes et leurs effets sur les fluctuations macroéconomiques. Comme pour Gertler et Karadi (2011, 2013) et Gertler et Kiyotaki (2010), le problème de l'aléa moral auquel sont confrontés les banquiers face à leurs directeurs d'agence limite la capacité de ces agences à amasser des fonds et crée un écart entre le taux d'intérêt sur les prêts et le taux d'intérêt sur les dépôts. J'ai ajouté deux principales caractéristiques à ce cadre: (1) un secteur immobilier et corporatif différentié et des marchés de crédit hypothécaire et (2) des marchés du crédit partiellement segmentés.

Nous constatons que les chocs exogènes, tels qu'un choc technologique positif ou un choc de contrainte d'endettement positif valorisant les prix des actifs, stimulent l'investissement, la demande immobilière et la production en présence de frictions financières, générant des écarts de taux anticycliques et déclenchant un effet de bilan qui augmente les capitaux propres de la banque et la capacité à fournir du crédit au secteur privé. Néanmoins, la simulation du modèle montre en outre un effet d'« atténuateur bancaire » dans la transmission de choc de politique monétaire. Une baisse inattendue du taux directeur réduit le coût de financement externe pour les banques, mais a tendance à augmenter les écarts de taux d'intérêt, ce qui atténue la réaction du marché financier et les variables de l'économie réelle au choc de politique monétaire.

Les simulations du modèle pour différents ratios de levier des banques montrent que la présence d'intermédiation financière imparfaite peut amplifier les réactions de l'économie vis-à-vis des perturbations (p. ex., les chocs de contrainte d'endettement, monétaire et technologique), par le biais de la force de l'effet de bilan de la banque sur l'offre de crédit.

Le chapitre 4, « Les achats d'actifs à grande échelle avec hypothèque segmentée et le marché des prêts aux entreprises », basé sur le livre coécrit par Meixing Dai et Frédéric Dufourt, utilise le modèle néo-keynésien développé au chapitre 3 pour analyser les mécanismes de transmission et les effets macroéconomiques des achats d'actifs à grande échelle mis en place par la Réserve fédérale dans le cadre de la récente crise. Il considère deux dimensions supplémentaires non prises en compte dans l'étude de Gertler et Karadi ni dans aucun autre modèle connexe de documentation. Ces dimensions sont néanmoins cruciales pour comprendre les effets des programmes LSAP : la première dimension concerne les achats par la Banque Centrale de titreshypothécaires (MBS) en plus (ou à la place) d'obligations defirme. La seconde envisage deux cas polaires concernant le degré de segmentation du marché du crédit lors de l'analyse des effets LSAP. Deux configurations alternatives des marchés du crédit - les marchés du crédit totalement segmentés contre partiellement segmentés - sont analysées. La segmentation totale des marchés du crédit traduit une situation de crise dans laquelle la réaffectation des capitaux propres entre agences de prêt bancaire est impossible.

Nous avons montré que, suite à une perturbation importante de l'intermédiation financière, les achats de créances hypothécaires immobilières par la Banque Centrale sont identiquement moins efficaces que les achats fermes d'obligations des firmespour faciliter les conditions du marché du crédit et stabiliser l'activité économique.

En outre, l'ampleur des effets dépend avant tout de l'envergure de la segmentation des marchés, c'est-à-dire du fonctionnement d'un « canal d'équilibre des portefeuilles » dans l'économie. Des marchés du crédit davantage segmentés impliquent des effets plus larges, mais plus localisés, d'achats d'actifs précis. Avec des marchés du crédit fortement segmentés, les achats à grande échelle de MBS sont utiles pour stabiliser le marché immobilier, mais leur action est limitée quant à limiter l'effet d’attenuation de la crise sur l'emploi et la production.