INTEREST RATE PASS-THROUGH AND CREDIT SPREAD IN NEW KEYNESIAN MODELS. THEORETICAL AND EMPIRICAL RELEVANCE

By

Dott. Danilo Liberati

A Thesis Submitted to the Doctoral School of Economics

in Partial Fulfillment of the Requirements for the Degree of

DOCTOR OF ECONOMICS

at

Sapienza University of Rome

Major Subject: Economics - Monetary Economics

Approved by the
Examining Committee:

____
Giuseppe Ciccarone, Thesis Adviser

____
Pierpaolo Benigno, Thesis Adviser

____
Efrem Castelnuovo, Member

____
Lilia Cavallari, Member

____
Fabrizio Mattesini, Member

Doctoral School of Economics, Sapienza University
Rome

December 2012

Ph.D. Thesis

Interest Rate Pass-Through and Credit Spread in New Keynesian Models. Theoretical and Empirical Relevance

Author:
Danilo Liberati[a]

Supervisor:
Prof. Giuseppe Ciccarone[b]

Co-supervisor:
Prof. Pierpaolo Benigno[c]

[a]Sapienza University of Rome and Bank of Italy.
[b]Sapienza University of Rome.
[c]LUISS Guido Carli University and EIEF.

To my family and Valentina

"There is no harm in being sometimes wrong,
especially if one is promptly found out"

(John Maynard Keynes, 1883 - 1946)

"It is better to be vaguely right than exactly wrong"

(Carveth Read, 1848 - 1931)

Contents

1 Incomplete Pass Through from Policy to Retail Interest Rates: a Critical Survey **9**

1.1 Introduction . . . 9
1.2 The Empirical Evidence . . . 10
1.3 Macroeconomics, Credit Spread and Interest Rate Pass-Through . . . 15
1.4 The Basic NK Model . . . 17
1.4.1 Households . . . 17
1.4.2 Wholesale firms . . . 18
1.4.3 Retail firms . . . 19
1.4.4 Banks . . . 20
1.4.5 Monetary authorities . . . 25
1.5 Estimation and Model Comparison . . . 25
1.5.1 Sensitivity Analysis: Mapping Stability . . . 26
1.5.2 Data . . . 27
1.5.3 Calibrated Parameters . . . 27
1.5.4 Priors . . . 28
1.5.5 Posteriors Estimates . . . 29
1.6 Simulation . . . 31
1.6.1 Monetary Shock . . . 31
1.6.2 Technology Shock . . . 32
1.6.3 Bayesian Comparison . . . 33
1.7 Conclusions . . . 35

2 An Estimated DSGE Model with Search and Matching Frictions in the Credit Market **43**

2.1 Introduction . . . 43
2.2 The Model Economy . . . 46
2.2.1 Matching . . . 47
2.2.2 Households . . . 47
2.2.3 Wholesale firms . . . 49
2.2.4 Retail firms . . . 49
2.2.5 Banks . . . 50
2.2.6 Loan interest rate bargaining . . . 51
2.2.7 Monetary authorities . . . 55
2.2.8 Market clearing . . . 55

2.3 Estimation . . . 56
2.3.1 Data . . . 56
2.3.2 Calibrated Parameters . . . 56
2.3.3 Priors . . . 57
2.3.4 Sensitivity Analysis: Mapping Stability . . . 58
2.3.5 Posteriors estimates . . . 59
2.4 Dynamic properties of the model . . . 61
2.4.1 The monetary policy shock and the interest rate pass-through . . . 61
2.4.2 The technology shock: credit spread and real wages' dynamics . . . 63
2.4.3 The credit shock . . . 65
2.5 Conclusions . . . 67

3 Incomplete interest rate pass-through under credit and labor market frictions 75
3.1 Introduction . . . 75
3.2 The Model Economy . . . 77
3.2.1 Matching . . . 78
3.2.2 Households . . . 78
3.2.3 Wholesale firms . . . 80
3.2.4 Wage and hours bargaining . . . 81
3.2.5 Retail firms . . . 82
3.2.6 Banks . . . 82
3.2.7 Loan Rate Bargaining . . . 83
3.2.8 Monetary authorities . . . 85
3.2.9 Market clearing . . . 85
3.3 Benchmark parametrization . . . 86
3.4 Dynamic properties of the model and the interest rate pass-through . . . 87
3.4.1 The dynamic behavior of the benchmark model . . . 87
3.4.2 Comparison with the complete pass-through model . . . 89
3.5 Determinants of the interest rate pass-through . . . 90
3.5.1 Bargaining powers . . . 90
3.5.2 Posting costs . . . 92
3.6 Conclusions . . . 93

Technical Appendices 99

A Appendix to Chapter 1 101

B Appendix to Chapter 2 111

C Appendix to Chapter 3 125

Preface

The behavior of banks and the determination of retail interest rates have taken a prominent role after the recent financial crisis: high levels of the cost of credit and quantity rationing are characterizing the actual economic environment. Monetary policy has sought to address the setting of bank rates by continuous operations on the monetary policy rate. Nevertheless, the adjustment of bank rates has not been complete.

The aim of this dissertation is to show that the incomplete pass-through of policy rate changes on the loan rate may depend also on market frictions, in particular those existing in the credit market. To this aim, we present three self-contained but highly correlated papers in which we discuss the role of these frictions, and their interplay with those existing in the labor market, on the size of the interest rate pass-through and its relevance in shaping business cycle dynamics. The study of interest rate dynamics also allows us to focus on the cyclical behavior of the credit spread, which is often used as a leading indicator of the economic activity. In order to shed light on these issues, we employ a New Keynesian framework (Walsh, 2003) which offers a convenient setting for monetary policy analysis. What is relevant in this model is the so-called "cost channel" that links the current and the expected future real marginal costs of the productive sector of the economy with inflation and then with the business cycle dynamics. If, as in this work, the loan interest rate enters the definition of marginal costs, it can affect the dynamics of the main macroeconomic and financial variables.

Theis dissertation is organized as follows.

In chapter 1, after reporting the empirical and theoretical literature on the interest rate pass-through and the credit spread, we present a critical survey that uses Bayesian techniques to compare models which explain the interest rate on loans on the basis of different theoretical mechanisms. In particular, we propose a model - to be more detailed in chapter 2 - in which credit market frictions are modeled by the search and matching technology. We conclude that the specification which benefits from the most favorable evidence is one in which the banking lending rate depends on its past value, as well as on credit market frictions.

In chapter 2 we describe a New Keynesian model with search and matching frictions in the credit market and we derive a definition of the banking lending rate which depends on the aggregate credit market tightness. We estimate and simulate the model with respect to monetary, technology and credit shocks and we highlight both the incompleteness of the interest rate pass-through and the countercyclical behavior of the credit spread. We also show the importance of the bargaining power of banks to explain the degree of (in)completeness of the interest rate adjustment, as well as the (more or less) countercyclical behavior of the credit spread.

In chapter 3 we study the interplay of search and matching frictions in the labor and in the credit markets, focusing on monetary policy disturbances. We confirm that the incompleteness of the interest rate pass-through depends on some deep parameters, such as the relative bargaining powers and the search costs of agents. By comparing the model outcomes with those which obtain with parameter values generating a complete pass-through, we show that the transmission of monetary policy shocks to output and inflation is more relevant than suggested by the recent literature, even though the presence of credit market frictions has a moderation effect on the main macroeconomic dynamics.

Chapter 1

Incomplete Pass Through from Policy to Retail Interest Rates: a Critical Survey[†]

Empirical evidence highlights an incomplete pass-through from policy to retail interest rates. In particular the phenomena is relevant by comparing the dynamics of the policy and banking lending rates. Further, it is observable a countercyclical behavior of the credit spread. However, some disagreement still exists about the theoretical mechanism by which the interest rate on loans is derived. In this chapter we survey and compare these theoretical devices into a basic New Keynesian DSGE model. Furthermore, we employ a Bayesian VAR analysis that confirms the low adjustment of the banking lending retail rate when a positive policy interest rate shock hits the economy.

1.1 Introduction

The study of the business cycle has always been one of the main focus in the economic literature. The labor market analysis, through the introduction of different kinds of imperfections and rigidities into New Keynesian (NK) Dynamic Stochastic General Equilibrium (DSGE) models with sticky prices and monopolistic competitive markets, is now a standard in this framework. Further, in the recent years, the introduction of the banking sector in the basic model was growing. This extension is receiving an increased attention since it helps to describe in a better way the dynamics of the main financial variables and their relationships with the real economy. In particular, the study of the (in)completeness of the banking (lending and deposit) interest rate pass-through to change of the policy rate and the behavior of the credit spread over the cycle are two features on which the literature is still facing.

Several empirical contributions which appeared before the recent financial crises provided convincing evidence that shifts in policy rates were not completely passed through to retail (market) banking lending rates.[1] However, despite the large empirical evidence on the interest rate pass-

[†]We wish to thank P. Benigno, G. Ciccarone, F. Giuli, S. Neri, F. M. Signoretti and M. Tancioni. The views expressed herein are solely those of the author and do not necessarily reflect the views of the Bank of Italy.

[1]See the next section.

through some disagreement still exists about the theoretical mechanism by which the interest rate on loans is derived. Several explanations for the stickiness of the retail rates are been provided by the literature on subject. One of the most common explanations refers to the bank's collusive behavior and the concentration in the financial market (Sander and Kleimer, 2004). In particular Van Leuvensteijn et al. (2008) show that the competitive pressure is greater in the loan market than in the deposits market such that banks under competition compensate the reduction of the revenues in the loan market by lowering the deposit rates. Explanations of the incompleteness of the interest rate pass-through also rely to the presence in the credit market of agency costs à la Stiglitz and Weiss (1981) and customer switching costs à la Klemperer (1987). The former which derive from the imperfect information which characterizes the financial market can provide credit rationing effects; the latter include learning and transactions costs or any type of cost imposed by firms. Further, fixed adjustment costs or menù costs can explain the sluggishness of the retail rates (Hannan and Berger, 1991; Hofmann and Mizen, 2004). Close customer relationships developed over time (Berger and Udell, 1992; Gambacorta and Mistrulli, 2011) can be relevant: banks with close relationships to their customers may hold interest rates relatively constant despite variations of the policy rate. Hannan and Berger (1991) also propose the so-called customer reaction hypothesis linked to different clients' reaction with respect to an upward or downward price change and to the degree of the bargaining power of borrowers. The previous arguments are often used to justify, from the theoretical point of view, the countercyclical behavior of the credit spread.

The aim of this study is contributing to this literature by proposing a theoretical assessment of the main devices allowing to determine the banking lending rate. In particular, after the study of a simple economy in which banking lending and policy (deposit) rates coincide, we analyze a NK DSGE model where the policy rate and interest rate on loans can be different for the presence of an interest rate mark-up, for the adding of a smoothness factor, for monopolistic competition in the banking sector and a Calvo's adjustment for the interest rates, or for a credit market characterized by search and matching frictions. Furthermore, we estimate and select the previous models by using the Bayesian procedures. Hence, the main goal of the chapter is selecting the model with more evidence consistent with the data.

The chapter is structured as follows. In the next section we report the empirical evidence highlighting the existence of an incomplete interest rate pass-through and a countercyclical behavior of the credit spread; we employ a Bayesian VAR analysis (BVAR) which confirms the limited adjustment of the banking lending rate to variations of the policy rate. In section 1.3 we report the main macroeconomic implications related to an incomplete interest rate pass-through and to the countercyclical behavior of the credit spread. In section 1.4 we describe the model economy. In section 1.5 we discuss our estimation and model selection strategy. In section 1.6 we present the dynamic properties of the model and our results on interest rate pass-though and credit spread. Section 1.7 concludes.

1.2 The Empirical Evidence

Figure 1.1 shows the dynamics of the quarterly policy rate and some quarterly retail rates of the U.S. economy. In the top panel it is possible to observe that the bank prime loan rate (green line) is shifted above the federal funds rate (blue line) over the whole sample. Further the spread between the previous rates is increasing in recent years Conversely, the short (6 months' duration) dynamics of the deposit rates (certificate of deposit rate, treasury bill rate and Eurodollar deposit rate, respectively red, sky-blue and violet lines) are very close to the policy rate. Hence, a low adjustment is mainly highlighted by the banking lending rates. The bottom panel of figure 1.1 provide for a more short sample period (1997:Q2 - 2011-Q4) the dynamics of the federal funds rate (solid line), the bank prime loan rate (dashed line) and the weighted average effective loan rate (dotted lines). We show that dynamics of the latter rate follows (and it is shifted) that of (over) the federal funds rate but it is more volatile than the prime loan rate. In the following of the chapter we will use the weighted average effective loan rate as the banking lending rate used to estimate the model.[2]

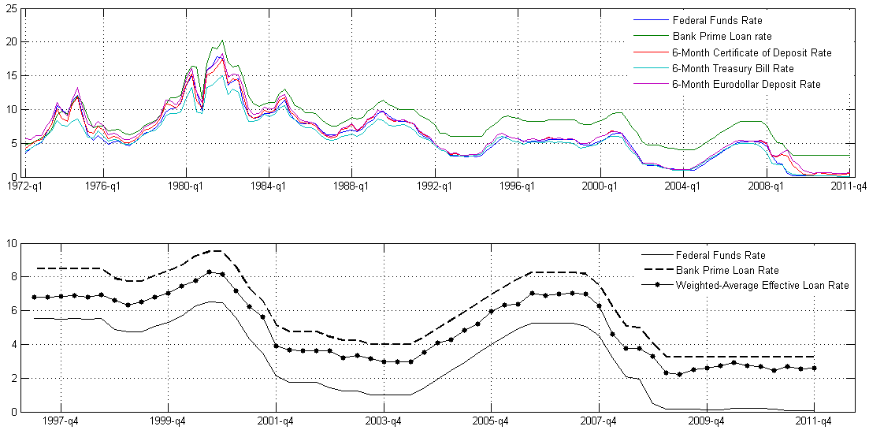

Figure 1.1: Interest rates dynamics.

Empirical evidence also show as significant differences existed in the degree of incompleteness which was experienced across countries. The phenomenon was particularly sharp in the Euro Area.[3] During the financial crisis, the transmission of policy rate changes to retail rates has become less efficient in this Area (Čihák, Harjes and Stavrev, 2009) where, however, the short-term rates has been less affected than in the United States whereas the long-term rates has been heavily impaired in both economies (IMF, 2008). The existence of an incomplete pass-through of policy rate changes to the loan rates in the Euro Area and in the United States is confirmed by a recent study by Karagiannis, Panagopoulos and Vlamis (2010).

The presence of several episodes of financial crisis may alter the speed and the degree of the response of the banking lending rates to changes of the policy rate. Hence, nonlinearity in the adjustment of the bank retail rates is tested by nonlinear VAR/VECM models that allow for Markow switching regime. Fuertes, Hoffernan and Kalotychou (2010) focus on the speed, the asymmetry and sign of the adjustment by employing a nonlinear ECM model for the U.K. by using a broad disaggregated sample of credit and deposit products: they find that large changes in the policy rate trigger faster bank retail rates responses than small variations and that for deposits (banking lending) rates the adjustment is faster (slower) when the policy rate decreases (increases).

[2] The shape of the dynamics of the bank and intebank rates follow that of monetary policy whereas the behavior of the corporate bonds rate is tied to the balance sheets and to the financial statements of the firms.

[3] See, e.g., De Bondt (2005); Angeloni, Kashyap and Mojon (2003); Gambacorta (2008); de Bondt, Mojon and Valla (2005); Hofmann (2006).

Further responses of the bank rates to a monetary policy change depends on the disequilibrium gap of the models' variables prevailing at the time of the policy action. Humala (2005) run a Markov switching VAR model in order to analyze the Argentinian banking system. He shows that under normal financial conditions the stickiness of the bank retail rates is larger for rates on loans with higher credit risk whereas in a financial distress scenario characterized by high volatility the transmission of impulses on money market rate to the retail rates increases. Banerjee, Bystrov and Mizen (2010) examine the role of the forecasts of rates in determining the short and the long run pass-through. After using a principal components method to extract the main factors explaining market interest rate setting for European countries, they test different forecasting models. They conclude that models which do not include forecasts of future rates are unspecified. Burgstaller and Sharler (2010) examine the reaction of the banking lending rates to shifts in credit demand by employing a Three Stage Least Squares estimation in the period 1999-2007 for the U.K. They conclude that U.K. banks adjust their banking lending rates partially and accommodate variations in credit demand by providing insurance to firms against liquidity shocks but potentially increasing their overall riskiness as well as the business cycle volatility.

The literature on the credit spread is also relevant in order to explain business cycle dynamics and volatility. Gilchrist, Yankov and Zakrajšek (2009) construct a credit spread portfolio by collect information on senior unsecured corporate bonds treated in the secondary market issued by more than 900 non financial firms in the sample 1990-2008: by employing a factor-augmented VAR model they find that shocks to medium risk long maturity corporate credit spreads account for a significant fraction of the variance in economic activity of the last 20 years. Similar evidence is provided by Gilchrist, Ortiz and Zakrajšek (2009) by a Bayesian maximum likelihood estimation of a DSGE model with the financial accelerator mechanism for the sample 1973-2008. Conversely, Lee and Otsu (2011) estimate by the maximum likelihood method a DSGE model in which they show that shocks to corporate credit spread are not too important in accounting for the U.S. business cycle in the period 1990-2008. Chen (1991) and Fama and French (1989) show as the difference between the average yields on BAA rated and AAA-rated corporate bonds rises during recessions and fall during business cycle booms. Then, several authors argue that credit spread can be used as leading indicator of the business cycle both in the short term (Stock and Watson, 1989) and for long maturity (Guha and Hiris, 2002).

Furthermore, it is useful to note as movements in interest rate spreads can also be associated to the literature concerning the banking markups. Hence, Dueker and Thornton (1997), by employing a model with switching costs by which baking industry has some kind of market power, show for the period 1973-1993 in U.S. a countercyclical behavior of the loan spread defined as the difference between the commercial paper rate (prime lending rate) and the Treasury bill rate (180-day certificates of deposit rate). Corvoisier and Gropp (2002), by using yearly data from 1995 and 1999 for 11 euro area countries finds a countercyclical movement of the difference between the contractual loan and deposit rates. A recent contribution by Olivero (2010) proposes a two country, two good RBC model with complete asset market and noncompetitive financial intermediation to study the transmission of the productivity shock in an open economy. She finds a main role of the countercyclical behavior of the loan margin in explaining the cross-country dynamics of the principal macroeconomic variables. Moreover she confirms the countercyclical behavior of the banking interest rate spread in U.S. by employing different methods. In particular after computing raw correlations between the difference between the banking lending and deposit rate and the GDP based on IFS data (for the period 1970-2008), she checks the result by employing a (bivariate and multivariate) VAR analysis to study the cyclical behavior between banking margins and GDP at different business cycle frequencies. Finally she uses the VAR forecast errors to provide the evidence on countercyclical credit spread.

In order to confirm the presence of incompleteness of the response of the banking lending rate when a policy rate shock hits the economy we employ a BVAR model. For this scope we use 6 observables for the U.S.: federal funds rate, weighted-average effective loan rate for all commercial and industrial loans, real GDP, employment, real wage and inflation. We take raw data: the implementation of the Bayesian techniques allow us to handle the over-fitting problem and the nonstationarity due to possible unit roots of the macroeconomic series. We only consider a seasonally adjustment. The optimal number of lags is chosen by the Bayesian information criteria: we find $p = 8$. The sample period is 1997:Q2 - 2011:Q4.[4]

Consider the following matrix form of the VAR(p) model:

$$Y = XB + U$$

where

$$Y = \begin{bmatrix} y_1 \\ \vdots \\ y_T \end{bmatrix} \quad X = \begin{bmatrix} y_0 & \cdots & y_{1-p} & 1 \\ \vdots & \ddots & \vdots & \vdots \\ y_{T-1} & \cdots & y_{T-p} & 1 \end{bmatrix} \quad B = \begin{bmatrix} \beta_1 \\ \vdots \\ \beta_p \\ \alpha \end{bmatrix} \quad U = \begin{bmatrix} u_1 \\ \vdots \\ u_T \end{bmatrix}$$

where $t = 1 \ldots T$ is the time index, y_t is a column vector of n endogenous variables, $u_t \overset{i.i.d.}{\sim} \mathcal{N}(0, \Sigma_u)$ is a column vector of the residuals, $\beta_1, \beta_2, \ldots, \beta_p$ are $n \times n$ autoregressive matrices and α is a $1 \times n$ matrix. Hence, Y and U have dimension $T \times n$, X is a $T \times k$ matrix whereas B has dimension $k \times n$ where $k = np + 1$. Finally we can write $U \overset{i.i.d.}{\sim} \mathcal{N}(\mathbf{0}, \Sigma)$.

The implementation of the Bayesian procedures implies the use of prior distributions over the parameters B and Σ.[5] In the following description we use the symbols $\mathbf{p}$ and $\mathcal{P}$ to indicate the notations related to the priors and the posteriors respectively. We estimate the BVAR model by using a prior which is a combination of a diffuse and dummy observation (Minnesota) priors:

$$\begin{aligned} p(B, \Sigma) \quad \propto \quad & |\Sigma|^{-\frac{(df^{\mathbf{p}}+n+1)}{2}} \exp\left\{-\frac{1}{2}Tr(\Sigma^{-1}S^{\mathbf{p}})\right\} \times \\ & |\Sigma|^{-\frac{k}{2}} \exp\left\{-\frac{1}{2}Tr(\Sigma^{-1}(B - \hat{B}^{\mathbf{p}})' X^{\mathbf{p}'} X^{\mathbf{p}} (B - \hat{B}^{\mathbf{p}}))\right\} \end{aligned} \tag{1.1}$$

where $df^{\mathbf{p}}$, $S^{\mathbf{p}}$, $\hat{B}^{\mathbf{p}}$ and $X^{\mathbf{p}}$ depend on the dummy observations.[6] From the prior (1.1) it is possible to observe that (i) Σ is distributed according to an inverse-Wishart distribution, with $df^{\mathbf{p}}$ degrees of freedom[7] and parameter $S^{\mathbf{p}}$ and (ii) conditionally to Σ, matrix B is distributed according to a matrix-normal distribution, with mean $\hat{B}^{\mathbf{p}}$ and variance-covariance parameters Σ and $(X^{\mathbf{p}\prime}X^{\mathbf{p}})^{-1}$.

The likelihood of the VAR model and the marginal density are respectively:

---

[4]In order to obtain the optimal number of lags we employ the Schwartz Criterion. The same result is provided by using the Akaike Information Criterion. The Bayesian VAR model is also simulated using the bank prime loan rate for a longer period (1960:Q1-2011:Q4) with results qualitatively similar to those described in the text. In this case the Bayesian information criteria provide $p = 2$.

[5]See Lubik and Schorfheide (2005).

[6]For a complete description of the BVAR construction see the technical appendix.

[7]The inverse-Wishart distribution requires the number of degrees of freedom to be greater or equal than the number of variables, i.e. $df^{\mathbf{p}} \geq n$. See the technical appendix for more details.

$$p(Y|B,\Sigma,X) = (2\pi)^{-\frac{T\cdot n}{2}}|\Sigma|^{\frac{T}{2}} \exp\left\{-\frac{1}{2}Tr(\Sigma^{-1}(Y-XB)'(Y-XB))\right\} \tag{1.2}$$

$$p(Y|X) = \int p(Y|B,\Sigma,X)p(B,\Sigma)dBd\Sigma \tag{1.3}$$

By using (1.1), (1.2) and (1.3) in the Bayes theorem it is possible to derive the posterior distribution:

$$\begin{aligned} p(B,\Sigma|Y,X) \quad &\propto \quad |\Sigma|^{-\frac{(df^{\mathcal{P}}+n+1)}{2}} \exp\left\{-\frac{1}{2}Tr(\Sigma^{-1}S^{\mathcal{P}})\right\} \times \\ &\quad |\Sigma|^{-\frac{k}{2}} \exp\left\{-\frac{1}{2}Tr(\Sigma^{-1}(B-\hat{B}^{\mathcal{P}})'X^{\mathcal{P}'}X^{\mathcal{P}}(B-\hat{B}^{\mathcal{P}}))\right\} \end{aligned} \tag{1.4}$$

where $df^{\mathcal{P}}$, $S^{\mathcal{P}}$, $X^{\mathcal{P}}$ and $\hat{B}^{\mathcal{P}}$ depend on prior observations. Similarly to the prior case, we can observe that the posterior density (1.4) is such that (i) Σ is distributed according to an inverse-Wishart distribution, with $df^{\mathcal{P}}$ degrees of freedom and (ii) conditionally to Σ, matrix B is distributed according to a matrix-normal distribution, with mean $\hat{B}^{\mathcal{P}}$ and variance-covariance parameters Σ and $(X^{\mathcal{P}'}X^{\mathcal{P}})^{-1}$.

Figure 1.2 plots the Bayesian posterior impulse response functions of BVAR model for the policy and retail rates with respect to a shock to the policy rate.[8] We adopt the Cholesky's identification scheme: the order of the variables is that listed at beginning of this section. We ran 10,000 replications.

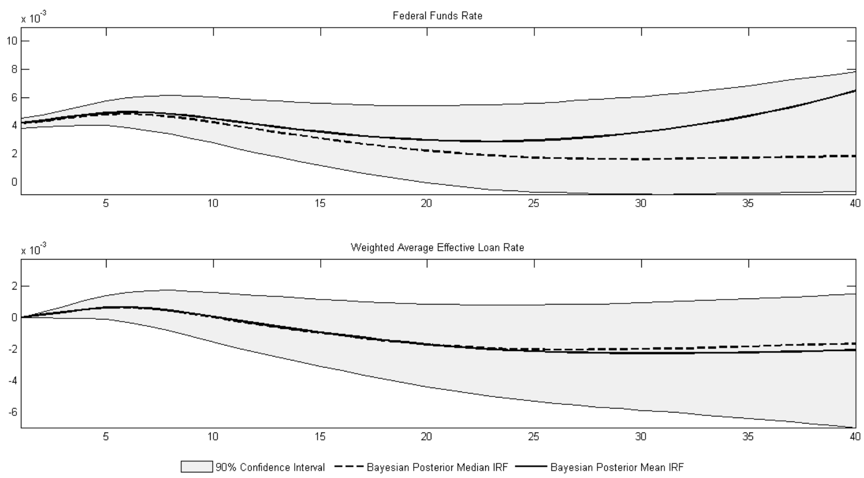

Figure 1.2: Bayesian VAR impulse response functions.

Figure 1.2 confirms the low adjustment of the loan retail interest rates when a positive policy interest rate shock hits the economy: for both median and mean posterior IRFs at the impact the weighted average effective loan rate increases less than the federal funds rate. Moreover the

[8]The result holds for different orders of the variables. A complete description of the Bayesian IRFs is available upon request from the author.

response function of the loan rate is persistently lower than that of the policy rate over the whole simulation's period.

1.3 Macroeconomics, Credit Spread and Interest Rate Pass-Through

Several works show the existence of frictions in financial markets but disagreement exists about their significance in the transmission of exogenous shocks to the economy. Traditional channels by which credit frictions work and affect the real economy are the banking lending and the balance sheet channels.[9] Both mechanisms rely to the presence of asymmetric information in the credit market: the former focuses on the different information between borrowers and lenders about the characteristics of individual projects and the substitutability of the banks' sources of funds; the latter arises by the presence of financial frictions on the liability side of the bank's balance sheet. Furthermore, if the financial intermediaries hold capital, capital requirements may affect the banks' assets and hence the transmission of the monetary policy.[10] Moreover, by focusing on the borrowers' balance sheet, we refer to the financial accelerator literature,[11] where in presence of asymmetric information, the amplification of the main macroeconomic variables depends on firms' ability to borrow linked to the market value of their net worth which is inversely related to the external finance premium. It is useful to note that the definition of external finance premium is different from that of corporate credit spread. The former is the wedge between the rate of return on capital and the risk-free rate; the other one is the difference between the contractual loan interest rate and the risk-free rate.[12]

Many authors analyze the role of the credit spread. Curdia and Woodford (2009, 2010) introduce financial frictions into a standard NK DSGE model. They consider different shocks in an economy in which spreads - defined as the difference between the logarithmic deviations of banking lending and policy rates from their steady states - exist. In line with Lown and Morgan (2002) they find that the credit spread is compressed during monetary policy tightenings. So, differently from the works cited in the previous section, this means that the loan spread has a procyclical behavior even though the interest rate pass-through is incomplete. Furthermore, they find that a modified interest rate rule that reacts to the contemporaneous variation of the credit spread can improve upon the standard Taylor rule by reducing distortions caused by some kind of disturbances as variations of the risk of bad loans. However, the optimal degree of adjustment is not the same for all shocks. Further, it is smaller than that proposed by McCulley and Toloui (2008) (100% of the spread's change) and depends on the degree of persistence of the disturbances.[13] Agénor, Bratsiotis and Pfajfar (2011) examine the impact of a monetary policy shock on the loan spread. Under asymmetric information, they endogenously derive a default probability of the borrowers that drives the loan spread. Since in their model the interest rate on loans is a direct function of the probability of the default and since an increase of the banking lending rate rises the default probability, then a policy rate increase determines further and continuing increases of the previous variables such that the loan spread is amplified and a countercyclical risk premium is highlighted. In the present work we do not consider a bond market and we do not model a default risk. Hence,

[9] Surveys on the credit channel literature can be found in Bernanke and Gertler (1995) and Hubbard (1995).
[10] See Meh and Moran (2004) and Gerali et al. (2010).
[11] See Bernanke, Gertler and Gilchrist (1996, 1999), Calstrom and Fuerst (1997, 1998) for more details on quantitative analysis in partial and general equilibrium frameworks.
[12] See Levin, Natalucci and Zakrajšek (2004) for more details.
[13] See also Goodfriend and McCallum (2007).

the interest rate spread we study is the simple difference between a banking lending interest rate and a policy rate.[14]

The cost channel may be affected by the degree of incompleteness of the interest rate pass-through. The relevance of this issue for New Keynesian DSGE models is testified by the literature on the cost channel of monetary policy (e.g., Christiano, Eichenbaum and Evans, 2005; Ravenna and Walsh, 2006): if the cost channel exists any exogenous shock to the economy generates the stabilization trade-off for the monetary policy. Hence a limited pass-through also has macroeconomic implications: the dynamics of the retail rates by affecting the cost channel may amplify or moderate of output and inflation fluctuations. Sharler (2008) investigates on the previous point by using a New Keynesian DSGE model; she finds that a more incomplete pass-through in the long run reduces the output volatility at the cost of higher inflation volatility with respect to a cost push shock. Hence, the incompleteness exacerbates the typical trade-off of the monetary policy that results inefficient. A recent investigation on optimal monetary policy under imperfect interest rate pass-through in an economy where retail banking lending rates are different across regions because loan markets are geographically segmented and individual firms can borrow funds only from the corresponding regional banks, which set loan rates according to a Calvo-type rule is proposed by Kobayashi (2008). In this case the incompleteness of the interest rate pass-through creates fluctuations in the average loan rate which, by the cost channel, determines an inefficient allocation of worked hours. Hence, a Central Bank has to stabilize the loan rate when it determines the optimal monetary policy. The previous stabilization involves in a more inertial response of the policy rate in presence of technology and preference shock and in a more sharp response when an exogenous shock directly push up the banking lending rates.

Hülsewig, Mayer and Wollmershäuser (2009) also explore the effects of the cost channel on inflation's dynamics that arise from the presence of an incomplete pass-through. They employ the Calvo' setup for the banking lending rate which allow them to study both the short and the long run pass-through of a monetary policy shock to a interest rate on loans: a larger fraction of banks which charge the last period rate on loans and a less competitiveness in the banking sector imply a more incompleteness of the interest rate pass-through. The cost channel of the monetary policy contributes to reproduce a delayed and inertial dynamics of the price inflation; the incomplete interest rate pass-through attenuates the cost channel effect. Gerali et al. (2010) propose a New Keynesian DSGE model with financial frictions in order to study the role of credit supply factors in explaining the business cycles dynamics and in which banks face quadratic costs for adjusting retail rates. Among other results, they find a definition of the interest rate on loans which, similarly to the Calvo's frictions, depends on its future and past values and on the policy rate: the model estimation suggests the presence of an incomplete interest rate pass-through of policy rates to retail rates which together the imperfect market competition in the banking sector do not only mitigate the amplification of the dynamics of the real variables depending on the cost channel effect as in Hülsewig, Mayer and Wollmershäuser (2009), but involve in an overall attenuator effect of the real economy when a positive policy rate shock hits the economy.[15] Güntner (2011) finds that the degree of monopolistic competition affects the pass-through of policy rates to banking lending rates in the short run. Specifically, when a monetary policy shock hits the economy, a less

[14] Differently from Curdia and Woodford (2009, 2010) our definition of credit spread also depends on the steady states values of the banking lending and policy rate. See also the section (1.4.4).

[15] Goodfriend and McCallum (2007)'s model is able to highlight a banking attenuator effect if the monetary shock has a very large volatility. Similarly to Gerali, Neri, Sessa and Signoretti (2010), the imperfect competition in the financial intermediation sector produces attenuation in Andrés and Arce (2008) and Aslam and Santoro (2008)'s models.

competition among banks provides a financial accelerator effect by changes of deposit rates and an attenuator effect by changes of the banking lending rates reducing the efficiency of the monetary policy.

Finally, the interest rate pass-through can be relevant for the determinacy of the model's equilibrium. Kwapil and Sharler (2006) show that the standard Taylor principle is not sufficient to avoid fluctuations due sunspot shocks: in presence of incomplete interest rate pass-through the monetary policy rate have to rise more than the increase that would occur in the case of perfect pass-through otherwise a no determinate equilibrium may be possible. Further, they also show as a limited pass-through can help to stabilize the fluctuations arising from fundamental shocks. This is especially true when the interest rate pass-through is incomplete in the long run and in bank-based financial systems (Kwapil and Sharler, 2010).

1.4 The Basic NK Model

In this section we consider the basic NK model in which we nest five different ways to describe the banking sector in line with the literature on the subject matter. Hence, after the basic assumption that arbitrage condition holds (banking lending rate equal to deposit rate; Ravenna and Walsh, 2006), we compute the interest rate on loans as (i) a simple mark up of the policy rate (Chowdhury, Hoffmann and Schabert, 2006), (ii) a value which depends on the policy rate as well as on a persistence factor due to the past value of the loan rate (Kaufmann and Sharler, 2009), (iii) the value set by banks when they maximize profits under monopolistic competition subject to a Calvo's rule (Hülsewig, Mayer and Wollmershäuser, 2009), and (iv) the rate determined by the profit maximization of banks facing search and matching friction in the credit market (Wasmar and Weil, 2004; and Becsi and Li, 2005).

1.4.1 Households

There exists a continuum of households of mass one maximizing the expected discounted value of their utility. The preferences of the representative household are defined over a composite consumption good, consisting of the differentiated goods produced by retail firms, and leisure. The household enters each period with a given amount of nominal cash holding M_t and buy retail goods using the money endowments and the wage income $(P_t w_t N_t)$ net of nominal deposits with banks D_t. It follows that $M_t + P_t w_t N_t - D_t$ is spent to purchase consumption goods from retail firms, of value $P_t C_t$. As in Dixit and Stiglitz (1977), it is $C_t = \left(\int_0^1 C_{it}^{\frac{\varepsilon-1}{\varepsilon}} di\right)^{\frac{\varepsilon}{\varepsilon-1}}$, where $C_{it} = (\frac{P_{it}}{P_t})^{-\varepsilon} C_t$ and $\varepsilon > 1$ is the parameter governing the elasticity of individual goods, which are indexed by i. The cost of one unit of the consumption basket is given by the aggregation of the prices of the differentiated products, $P_t = \left(\int_0^1 P_{it}^{1-\varepsilon} di\right)^{\frac{1}{1-\varepsilon}}$. The purchase of consumption goods is subject to the cash in advance (CIA) constraint: $P_t C_t \leq M_t + P_t w_t N_t - D_t$.[16] At the end of the period households receive retail firms' and banks profits' denoted by Π_t^F and Π_t^B, and obtain the reimbursement of their deposits plus the interest on them: $R_t^D D_t = (1 + r_t^D) D_t$.[17] It follows that the amount of money carried over to the following period is: $M_{t+1} = M_t + P_t w_t N_t - D_t - P_t C_t + \Pi_t^F + \Pi_t^B + R_t^D D_t$. Substituting the CIA constraint into this equation we get: $M_{t+1} = \Pi_t^F + \Pi_t^B + R_t^D D_t$. Calculating

[16]The CIA constraint is always binding because the nominal interest rate is positive and agents choose their asset (deposit) holdings after observing the current shock but before entering the good market (Lucas 1982).

[17]When we consider the model with search and matching frictions in the credit market, the firms' profits include both those of retail firms and of the specialized firm which post credit vacancies.

this equation a period backward and substituting the result into the CIA constraint gives: $P_tC_t = P_tw_tN_t + \Pi^F_{t-1} + \Pi^B_{t-1} - D_t + R^D_{t-1}D_{t-1}$. It can be expressed in real terms as:

$$C_t = w_tN_t + \frac{\Pi^F_{t-1}}{P_t} + \frac{\Pi^B_{t-1}}{P_t} - \frac{D_t}{P_t} + R^D_{t-1}\frac{D_{t-1}}{P_t} \tag{1.5}$$

This equation states that consumption and savings are financed by real labor income w_tN_t, the sum generated by previous period deposits, $\frac{R^D_{t-1}D_{t-1}}{P_t}$, and profits from banks and retailers, $\frac{\Pi^F_{t-1} + \Pi^B_{t-1}}{P_t}$. The representative household hence solves the problem:

$$\begin{aligned} J^H_t &= \max\left[\varphi_t U(C_t, N_t) + \beta E_t J^H_{t+1}\right] \\ & \quad s.t. \quad (1.5) \end{aligned}$$

where β is the household's subjective discount factor and φ_t is a preference shock on the wedge between consumption and leisure whose stochastic process is $\varphi_t = \varphi^{\rho^\varphi}_{t-1}e^{\epsilon^\varphi_t}$ with $\epsilon^\varphi_t \overset{i.i.d.}{\sim} N\left(0, \sigma^2_\varphi\right)$. A CRRA specification for $U(C_t, N_t) = \frac{C_t{}^{1-\sigma}}{1-\sigma} - \vartheta_t\bar{\vartheta}\frac{N_t^{1+\phi}}{1+\phi}$ provides the first order conditions which lead to the standard Euler equation of the baseline New Keynesian model and to the definition of the real wage equal to the marginal rate of substitution between consumption and leisure:

$$\lambda_t = R^D_t \beta E_t \frac{P_t}{P_{t+1}}\lambda_{t+1} \tag{1.6}$$

$$w_t = \vartheta_t\bar{\vartheta}\frac{N_t^\phi}{C_t^{-\sigma}} \tag{1.7}$$

where $\lambda_t = \varphi_t C_t^{-\sigma}$ is the marginal utility of consumption, $\bar{\vartheta}$ is a constant term and ϑ_t is a preference shock on leisure whose stochastic process is $\vartheta_t = \vartheta^{\rho^\vartheta}_{t-1}e^{\epsilon^\vartheta_t}$ with $\epsilon^\vartheta_t \overset{i.i.d.}{\sim} N\left(0, \sigma^2_\vartheta\right)$. The unemployment is $U_t = 1 - N_t$.

1.4.2 Wholesale firms

There exists a continuum of wholesale firms in the unit interval producing homogenous goods in a competitive sector. The production function of the representative wholesale firm is:

$$Y^w_t = A_tN^\alpha_t \tag{1.8}$$

where A_t is a productivity shock with unit mean, $E_t(A_t) = 1$, and whose stochastic stationary first-order autoregressive process is $A_t = A^{\rho^A}_{t-1}e^{\epsilon^A_t}$ with $\epsilon^A_t \overset{i.i.d.}{\sim} N\left(0, \sigma^2_A\right)$. The representative firm must determines the labor demand. Its profit maximization problem is:

$$\begin{aligned} \max & \quad \frac{Y^w_t}{\mu_t} - w_tR^L_tN_t \\ s.t. & \quad (1.8) \end{aligned}$$

where μ_t is the is the mark up of the retail sector over the price of the wholesale good, P_t/P^w_t, and the costs depend on the repayment of the loans received by banks, equal to the wage bill to grant to the households plus the interest on loans. The first order condition with respect to the employment yields:

$$\frac{1}{\mu_t} = \frac{w_t R_t^L}{mpl_t} \tag{1.9}$$

where $mpl_t = \alpha A_t N_t^{\alpha-1}$ is the labor marginal productivity. Since the competitiveness of the wholesale sector, the mark up $\frac{1}{\mu_t}$ is equal to the real marginal cost paid by the retail firms to buy the homogenous good. Then $\frac{1}{\mu_t} = mc_t$. Hence, the real marginal cost of the firms is the usual ratio between the labor cost, $w_t R_t^L$, and the labor marginal productivity, mpl_t.

1.4.3 Retail firms

Retail firms purchase the goods produced by the wholesale sector and transform them into the differentiated products purchased by households. Hence, each firm is a monopolist of its sector. Firms set prices according to the Calvo (1983) rule. Each period a firm can adjust its price with probability $1-\omega$. Furthermore, it is $C_{it} = Y_{it}$ and the aggregate resource constraint is $C_t = Y_t$.[18] Moreover, we have $Y_t^w = Y_t f_t$. where $f_t = \int \left(\frac{P_{it}}{P_t}\right)^{-\varepsilon} di$ is a price dispersion factor which disappear in the log linearization version of the model.[19] Then, in a symmetric equilibrium all firms set the price, $P_t^* = P_{it}$, so as to maximize the expected lifetime profits subject to the demand:

$$\max \quad E_t \sum_{l=0}^{\infty} \omega^l \beta^l \frac{\lambda_{t+1}}{\lambda_t} \left[\left(\frac{P_t^*}{P_{t+l}} \right) - mc_{t+l} \right] Y_{it+l}$$

$$s.t. \quad Y_{it} = \left(\frac{P_{it}}{P_t} \right)^{-\varepsilon} Y_t$$

This provides the price equation:

$$\frac{P_t^*}{P_t} = \Theta \frac{E_t \sum_{l=0}^{\infty} \omega^l \beta^l mc_{t+l} \left(\frac{P_{t+l}}{P_t}\right)^{\varepsilon} C_{t+l}^{1-\sigma}}{E_t \sum_{l=0}^{\infty} \omega^l \beta^l \left(\frac{P_{t+l}}{P_t}\right)^{\varepsilon-1} C_{t+l}^{1-\sigma}} \tag{1.10}$$

where: $\Theta = \frac{\varepsilon}{\varepsilon-1}$. Under flexible prices, equation (1.10) reduces to the standard Blanchard and Kiyotaki (1987) equation:

$$\frac{P_t^*}{P_t} = \Theta mc_t \tag{1.11}$$

From (1.10) the usual (log-linearized) New Keynesian Phillips curve (NKPC) is obtained:

$$\pi_t = \beta E_t \pi_{t+1} + \kappa \widehat{mc}_t + \hat{\psi}_t \tag{1.12}$$

where $\kappa = \frac{(1-\beta\omega)(1-\omega)}{\omega}$ and $\hat{\psi}_t = \rho^\psi \hat{\psi}_{t-1} + \epsilon_t^\psi$ with $\epsilon_t^\psi \overset{i.i.d.}{\sim} N\left(0, \sigma_\psi^2\right)$ is the log linearized version of the cost push shock process $\psi_t = \psi_{t-1}^{\rho^\psi} e^{\epsilon_t^\psi}$. The symbol "hat" denotes the percentage deviation of a variable from its steady state value. The NKPC (1.12) can be expressed in terms of the output gap $x_t = \hat{Y}_t - \hat{Y}_t^{qf}$ where $\hat{Y}_t^{qf} = \frac{1+\phi}{[1+\phi+\alpha(\sigma-1)]} \hat{A}_t$ represents the quasi flexible equilibrium output:

$$\pi_t = \beta E_t \pi_{t+1} + \kappa (\hat{R}_t^L + \hat{\vartheta}_t) + \kappa \tau x_t + \hat{\psi}_t \tag{1.13}$$

[18] For all models of section (1.4.4) the equilibrium condition $C_t = Y_t$ holds.
[19] See Galì (2008).

where $\tau = \frac{[1+\phi+\alpha(\sigma-1)]}{\alpha}$.

1.4.4 Banks

In this part of the work we assume five versions of the banking sector that lead to different definitions of the interest rate on loans. In the following we define the interest rate credit spread as $SP_t = R_t^L - R_t^D$ and its log linearized version is $\widehat{SP}_t = \dfrac{R^L \hat{R}_t^L - R^D \hat{R}_t^D}{SP}$. So, it is evident that the dynamics of the credit spread depends on both dynamics and steady state values of the loan and policy rates. Moreover the interest rate pass-through is defined as the percentage deviation of the interest rate on loans from its steady state value, $\hat{R}_t^L$, minus that of the policy rate from own steady state, $\hat{R}_t^D$. Hence we have a complete, incomplete or more than complete interest rate pass-through if $\dfrac{\partial \hat{R}_t^L}{\partial \hat{R}_t^D}$ is equal, less or greater than 1, respectively.

The pure credit economy à la Wicksell

In this section we consider the simplest modelling of the banking sector according to the Wicksell's (1936) pure credit economy. Then we assume that banks do not possess their own capital and they do not hold reserve. Further we assume that each bank operates with no costs, no default problems exist and whole deposits collected from the households are advanced to the firms. The optimal value function of the representative bank is:

$$\begin{aligned} J_t^B &= \max \left(R_t^L \frac{L_t}{P_t} - R_t^D \frac{D_t}{P_t} + \beta E_t \frac{\lambda_{t+1}}{\lambda_t} J_{t+1}^B \right) \\ & \quad s.t. \;\; L_t = D_t + X_t \end{aligned}$$

where L_t and $X_t = M_{t+1} - M_t$ represent the amount of nominal loans (equal to the wage bill) and the net position on the money market (cash injection), respectively. In all models of this work we assume that deposits and money are perfect substitutes for the firms' financing. The bank chooses D_t. Its decision yields the last condition of the Wickesellian pure credit economy, i.e., the rate of interest on loans is equal to that on deposits:

$$R_t^L = R_t^D \qquad (1.14)$$

The latter condition is considered by Ravenna and Walsh (2006) which assume perfect pass-through. Moreover, the steady state version of equation (1.14) is $R^L = R^D$. The log-linearized version of the previous equation is:

$$\hat{R}_t^L = \hat{R}_t^D \qquad (1.15)$$

The price mark-up assumption

In order to show a simple way to insert a price mark up in the relationship between the interest rate on loans and the policy rate, we follow Chowdhury et al. (2006). Instead of providing an explicit microfoundation of the financial imperfection by which the effects of the policy rate on the banking lending rate can be amplified, they consider a continuously differentiable function $\Psi(R_t^D) \in (0,1)$, that summarizes the effects of the policy rate on the return of the loans. Then, the optimal value function of the representative bank is:

$$J_t^B = \max\left(R_t^L\left[1-\Psi(R_t^D)\right]\frac{L_t}{P_t} - R_t^D\frac{D_t}{P_t} + \beta E_t\frac{\lambda_{t+1}}{\lambda_t}J_{t+1}^B\right)$$
$$s.t.\ \ L_t = D_t + X_t$$

Its decision yields:

$$R_t^L\left[1-\Psi(R_t^D)\right] = R_t^D \tag{1.16}$$

The steady state version of equation (1.16) is $R^L = \dfrac{1}{1-\Psi}R^D$; its log-linearized version is:

$$\hat{R}_t^L = (1+\Psi_R)\,\hat{R}_t^D + \hat{\upsilon}_t \tag{1.17}$$

where $\Psi_R = \frac{\Psi' R^D}{1-\Psi}$. Hence, $1+\Psi_R$ can be smaller or larger than one, depending on the sign of the term Ψ_R.[20] When we estimate the model we use the functional form $\Psi_t = \left[1-\Psi_0\left(R_t^D\right)^{\varkappa}\right]$ with $0<\Psi_0<1$ and $\varkappa>0$. Then $\Psi_t' = -\Psi_0\varkappa\left(R_t^D\right)^{\varkappa-1}$ whereas the steady state interest rate on loans becomes $R^L = \dfrac{1}{\Psi_0}\left(R^D\right)^{1-\varkappa}$. Then, $\Psi_R = -\varkappa$ and $\hat{R}_t^L = (1-\varkappa)\,\hat{R}_t^D + \hat{\upsilon}_t$. Furthermore we append the exogenous shock $\hat{\upsilon}_t$ to the equation of the banking lending rate whose no log-linearized stochastic process is $\upsilon_t = \upsilon_{t-1}^{\rho^{\upsilon}}e^{\epsilon_t^{\upsilon}}$ with $\epsilon_t^{\upsilon} \overset{i.i.d.}{\sim} N\left(0,\sigma_{\upsilon}^2\right)$.[21]

The interest rate smoothing assumption

In order to insert smoothness in the loan rate dynamics we follow Kaufmann and Sharler (2009) by assuming that banks are able to create loans using deposits by a function depending on the current and past values of the banking lending rate. In particular, financial intermediaries solve the following problem:

$$J_t^B = \max\left(R_t^L\frac{L_t}{P_t} - R_t^D\frac{D_t}{P_t} + \beta E_t\frac{\lambda_{t+1}}{\lambda_t}J_{t+1}^B\right)$$
$$s.t.\ \ L_t = \Sigma_0\left[\frac{R_t^L}{\left(R_{t-1}^L\right)^{\zeta_0}}\right]^{\zeta_1}(D_t + X_t)$$

where $\Sigma_0 > 0$ and $\zeta_1 > 0$. Their decision yields:

$$\left(R_t^L\right)^{1+\zeta_1}\Sigma_0\left(R_{t-1}^L\right)^{-\zeta_0\zeta_1} = R_t^D \tag{1.18}$$

The steady state version of equation (1.18) is $R^L = \Sigma_1\left(R^D\right)^{\Sigma_2}$ where $\Sigma_1 = \left(\dfrac{1}{\Sigma_0}\right)^{\Sigma_2}$ and $\Sigma_2 = \dfrac{1}{\left[1+(1-\zeta_0)\,\zeta_1\right]}$. Furthermore, the log-linearized version of equation (1.18) provides:

$$\hat{R}_t^L = \frac{1}{1+\zeta_1}\hat{R}_t^D + \frac{\zeta_0\zeta_1}{1+\zeta_1}\hat{R}_{t-1}^L + \hat{\upsilon}_t \tag{1.19}$$

[20] Chowdhury et al. (2006) insert in the profit function of the financial intermediaries a managing cost of the loans that allows to obtain a negative value of the term Ψ_R.

[21] The same shock is appended to the banking lending rate equation of the models reported in the next subsections.

The previous equation states that the banking lending rate depends on the policy rate as well as on the persistence factor due its past value. It is useful to note that when $\zeta_0 = 0$ we obtain the Chowdhury et al. (2006)'s version (1.17) whereas for $\zeta_1 = 0$ we obtain the simple case with no mark-up (1.15).

Monopolistic competition and Calvo's rule

In this section, following Hülsewig et al. (2009) we assume that each wholesale firm holds a loan portfolio diversified over all types of loans $k \in [0, 1]$ offered by a banking sector which advances loans under a monopolistic competition's regime. They are aggregated in the following way:

$$L_t = \left[\int_0^1 L_{kt}^{\frac{\eta-1}{\eta}} dk \right]^{\frac{\eta}{\eta-1}} \tag{1.20}$$

where $\eta > 1$ represents the elasticity of substitution between the different types of loans k. Each firm minimizes the reimbursement of the loans demanded to the each monopolist bank k, L_{kt}, plus the related banking lending rate R_{kt}^L, subject to the demand for loans of the individual firm (1.20):

$$\begin{array}{ll} \min & \int_0^1 L_{kt} R_{kt}^L \\ s.t. & (1.20) \end{array}$$

The first order condition with respect to L_{kt} yields:

$$L_{kt} = \left(\frac{R_{kt}^L}{R_t^L} \right)^{-\eta} L_t \tag{1.21}$$

where the gross loan interest rate is given by the aggregation of the banking lending rates of loan types k: $R_t^L = \left[\int_0^1 \left(R_{kt}^L \right)^{1-\eta} dk \right]^{\frac{1}{1-\eta}}$. Further in this setting we assume that banks face Calvo's frictions when they set their interest rate on loans. Hence, only a fraction of the banks, $1 - \chi$, can be adjust their prices each period t whereas the fraction χ maintain the gross banking lending rate unchanged. Then the aggregate interest rate on loans can be rewritten as:

$$R_t^L = \left[(1 - \chi) \left(R_t^{L*} \right)^{1-\eta} + \chi \left(R_{t-1}^L \right)^{1-\eta} \right]^{\frac{1}{1-\eta}} \tag{1.22}$$

Given each bank k holds the balance sheet $L_{kt} = D_{kt} + X_{kt}$, in a symmetric equilibrium all banks set the price, $R_t^{L*} = R_{kt}^L$, so as to maximize the expected lifetime profits subject to the loan demand of the firms:

$$\begin{array}{ll} \max & E_t \sum_{l=0}^{\infty} \chi^l \beta^l \frac{\lambda_{t+l}}{\lambda_t} \left(R_t^{L*} - R_{t+l}^D \right) \frac{L_{kt+l}}{P_{t+l}} \\ s.t. & (1.21) \end{array}$$

This provides the gross interest rate on loans equation identical for all banks:

$$R_t^{L*} = \Xi \frac{E_t \sum_{l=0}^{\infty} \chi^l \beta^l \frac{\lambda_{t+l}}{\lambda_t} R_{t+l}^D (R_{t+l}^L)^\eta \left(L_{t+l}/P_{t+l} \right)}{E_t \sum_{l=0}^{\infty} \chi^l \beta^l \frac{\lambda_{t+l}}{\lambda_t} (R_{t+l}^L)^\eta \left(L_{t+l}/P_{t+l} \right)} \tag{1.23}$$

where: $\Xi = \frac{\eta}{\eta-1}$. Under flexible prices equation (1.23) implies that the optimal interest rate on loans is a mark-up over the policy rate as already seen in the previous section:

$$R_t^{L*} = \Xi R_t^D \tag{1.24}$$

Furthermore the steady state version of equation (1.23) is $R^L = \Xi R^D$. By log linearizing the equations (1.22) and (1.23) we obtain:[22]

$$\hat{R}_t^L = \frac{\beta\chi}{1+\beta\chi^2} E_t \hat{R}_{t+1}^L + \frac{\chi}{1+\beta\chi^2} \hat{R}_{t-1}^L + \frac{(1-\beta\chi)(1-\chi)}{1+\beta\chi^2} \hat{R}_t^D + \hat{v}_t \tag{1.25}$$

The previous condition states that the interest rate on loans depends on the its backward and future values and on the policy rate. Moreover if $\chi = 0$ we obtain the equality between the banking lending and the policy rates.

Search and matching frictions

In this set up in order to obtain a loan a credit relationship between firms and banks has to created. Hence a credit relation arises by the matching between the number of credit vacancies chosen by banks, V_t^B, and the demand for lines of credit, represented by the number of wholesale firms searching for a bank, $s_t^F = 1 - (1-\rho^B) L_{t-1}^N$, where $\rho^B \in [0,1]$ represents the exogenous separation rate between firms and banks in the credit market, and L_t^N is the number of credit lines chosen by banks. Then the number of new matches in the credit market, which are immediately transformed into lines of credit, are determined by the matching function $H_t = \varsigma (V_t^B)^{\xi} (s_t^F)^{1-\xi}$, which is homogeneous of degree one and increasing in its arguments, where ς is the credit market efficiency constant and ξ is the elasticity of financial matches. Further $p_t^B = H_t / s_t^F$ is the probability that a firm matches with a credit vacancy posted by bank, and $q_t^B = H_t / V_t^B$ is the probability for a bank of filling a posted credit vacancy. Finally, $\theta_t^C \equiv s_t^F / V_t^B$ is the aggregate tightness in the credit market from the viewpoint of the firm. The lines of credit financing firms evolve according to:

$$L_t^N = (1-\rho^B) L_{t-1}^N + H_t \tag{1.26}$$

Then, being $L_t = D_t + X_t$, the problem of the representative bank is:

$$\begin{aligned} J_t^B &= \max \left[(R_t^L - R_t^D) \frac{L_t}{P_t} - k^B R_t^D V_t^B + R_t^D \frac{X_t}{P_t} + \beta E_t \frac{\lambda_{t+1}}{\lambda_t} J_{t+1}^B \right] \\ & \quad s.t. \;\; (1.26) \end{aligned}$$

where k^B is the real posting credit vacancy cost. By maximizing with respect to V_t^B, by remembering that $\frac{L_t}{P_t} = w_t N_t L_t^N$ and by using the envelope theorem with respect to L_{t-1}^N[23] we get what

[22] See the technical appendix for more details.

[23] The bank's profit at time t is given by revenues minus costs. Revenues are given by the repayment of the real loans financing wages plus interest, $R_t^L \left(w_t N_t L_t^N \right)$. Costs are equal to the repayment of deposits and money plus interest, $R_t^D \frac{D_t}{P_t} + R_t^D \frac{X_t}{P_t} = R_t^D \left(w_t N_t L_t^N + k^B V_t^B \right)$. By using the bank's balance sheet, stating that deposits and money finance the loans provided to firms and the repayment of the credit vacancies, $\frac{D_t}{P_t} + \frac{X_t}{P_t} = \frac{L_t}{P_t} + k^B V_t^B$, the profit function of the bank is straightforwardly obtained.

we interpret as the "credit creating condition":

$$\frac{k^B R_t^D}{q_t^B} = (R_t^L - R_t^D) w_t N_t + (1-\rho^B)\beta E_t \frac{\lambda_{t+1}}{\lambda_t} \frac{k^B R_{t+1}^D}{q_{t+1}^B} \tag{1.27}$$

The loan interest rate is determined by the maximization of the Nash product between the firm and bank surplus:

$$\max (S_t^F)^z (S_t^B)^{1-z} \tag{1.28}$$

where z represents the bargaining power of firms and S_t^F and S_t^B represent the surpluses of the bank and of the firm respectively:

$$S_t^F = \frac{Y_t^w}{\mu_t} - w_t R_t^L N_t + (1-\rho^B)\beta E_t \frac{\lambda_{t+1}}{\lambda_t}(1-p_{t+1}^B) S_{t+1}^F \tag{1.29}$$

$$S_t^B = \frac{k^B R_t^D}{q_t^B} \tag{1.30}$$

The maximization of the Nash product yields the interest rate on loans bargained by banks and firms:

$$R_t^L = \frac{(1-z)}{w_t N_t} \frac{Y_t^w}{\mu_t} + \frac{z}{w_t N_t}\left[R_t^D w_t N_t - (1-\rho^B)\beta E_t \frac{\lambda_{t+1}}{\lambda_t} \frac{k^B R_{t+1}^D}{\theta_{t+1}^C}\right] \tag{1.31}$$

The interest rate on loans turns out to be a weighted average of the firm's revenues, on one side, and the rate of interest on deposits net the banks' future expected present saving from maintaining a credit relation with a firm, on the other side. The weights are the relative bargaining powers of the agents. If $z = 1$ firms are able to obtain a loan interest rate equal to deposit interest rate net the banks' saving; if $z = 0$ banks are able to set a loan interest equal to the firm's marginal profit. By using equations (1.6) and (1.9), the log linearized version of equation (1.31) can be written in the following way:

$$\hat{R}_t^L = \Lambda_1 \hat{R}_t^D + \Lambda_2 \left[E_t \hat{\theta}_{t+1}^C - E_t \hat{R}_{t+1}^D + \left(\hat{w}_t + \hat{N}_t - E_t \hat{\pi}_{t+1}\right)\right] + \hat{\upsilon}_t \tag{1.32}$$

The term $\Lambda_1 = \frac{\alpha z}{R^L(\alpha-1+z)}\left[R^D + \frac{(1-\rho^B)p^B}{wN}\frac{k^B}{q^B}\right]$ represents the *direct* pass-through from the policy rate, $\hat{R}_t^D$, to the retail banking lending rate, $\hat{R}_t^L$, whereas the coefficient $\Lambda_2 = \frac{\alpha z}{R^L(\alpha-1+z)}\frac{(1-\rho^B)p^B}{wN}\frac{k^B}{q^B}$ represents the *indirect* pass-through due to the credit frictions depending on the expected credit market tightness $E_t\hat{\theta}_{t+1}^C$ and the expected policy rate $E_t\hat{R}_{t+1}^D$, and on the nominal value of the loan (equal to the wage bill) lent to the generic wholesale firm. It is useful to note that the steady state banking lending interest rate can be written as $R^L = \Upsilon R^D$ where $\Upsilon = \frac{z\left\{1+\frac{(1-\rho^B)\beta p^B}{[1-(1-\rho^B)\beta]}\right\}}{\left\{1-\frac{(1-z)}{\alpha}+\frac{z(1-\rho^B)\beta p^B}{[1-(1-\rho^B)\beta]}\right\}}$ is the mark-up over the steady state policy rate.[24] If $k^B = 0$ then $\Lambda_2 = 0$ and (1.32) reduces to $\hat{R}_t^L = \frac{\alpha z}{(\alpha-1+z)\Upsilon}\hat{R}_t^D$ (mark-up assumption) whereas if $k^B = 0$ and $z = 1$ then $\hat{R}_t^L = \hat{R}_t^D$ (complete pass-through).

Finally, following Becsi, Li and Wang (2005), we can provide a steady state equilibrium condi-

[24]See the technical appendix for the computation of the surplus of the agents, for the log linearization of the interest rate on loans equation and for derivation of its steady state version.

tion for endogenous entry of firms:

$$p^B = \frac{\overline{c}(1-\beta)(1-\beta+\beta\rho^B)}{\beta\left[\left(\frac{Y^w}{\mu} - wR^L N\right) - (1-\beta)(1-\rho^B)\overline{c}\right]} \tag{1.33}$$

where $\overline{c}$ is the firms' entry cost.

1.4.5 Monetary authorities

A central bank employs the following monetary rule to set the policy rate, which we assume for simplicity equal to the rate on deposits:

$$R_t^D = (R_{t-1}^D)^{\rho^R} \left(\frac{P_t}{P_{t-1}}\right)^{(1-\rho^R)\delta_\pi} (x_t)^{(1-\rho^R)\delta_x} \nu_t \tag{1.34}$$

where ρ^R is the degree of interest rate smoothing and δ_π and δ_x are the weights assigned to the targets of inflation (P_t/P_{t-1}) and output gap, respectively. The stochastic term $\nu_t = \nu_{t-1}^{\rho^\nu} e^{\epsilon_t^\nu}$ denotes a stationary first-order autoregressive monetary policy shock with $\epsilon_t^\nu \overset{i.i.d.}{\sim} N\left(0, \sigma_\nu^2\right)$.

1.5 Estimation and Model Comparison

In this section we provide the estimation of the models described above. In particular we use the Bayesian Monte Carlo method which allows an empirical performance comparison of the models according to the information arising from the marginal distributions of the models. The Bayes rule allows to get the posterior distribution of the model parameters conditioning on the prior assumptions on the vector parameters $\kappa \in K$, the model M_j and the sample information $Y_t = \{y_t\}_{t=1}^T$:

$$P(\kappa/Y_T, M_j) = \frac{P(Y_T/\kappa, M_j)P(\kappa, M_j)}{P(Y_T, M_j)} \tag{1.35}$$

where $P(\kappa, M_j)$ is the prior distribution, $P(Y_T/\kappa, M_j)$ represents the conditional distribution and $P(\kappa/Y_T, M_j)$ is the posterior density. The latter distribution is computed by the numerical integration which, operationally, is obtained by the Kalman smother in order to approximate the conditional distribution and by the Metropolis Hastings algorithm to implement the Monte Carlo integration.

Furthermore, Bayesian procedures can be used in order to compare alternative models. This aim is achieved by comparing the Bayes factor, i.e. the ratio between the probabilities of having observed the data conditional to two different models. Hence, by considering the Bayes theorem, assuming that the all alternative models are true, the posterior density in terms of two models is:

$$P(M_j, Y_T) = \frac{P(Y_T/M_j)P(M_j)}{P(Y_T/M_j)P(M_j) + P(Y_T/M_s)P(M_s)} \tag{1.36}$$

where $P(Y_T/M_j) = \int P(Y_T/\kappa_j, M_j)P(\kappa_j, M_j)d\kappa_j$ is the marginal density and $j \neq s$. By considering the ratio between the posterior distributions of two models we get the posterior odds ratio, $PO_{j,s}$, which coincides with the Bayes factor, $B_{j,s}$, when we have no prior model preferences, i.e.

$\frac{P(M_j)}{P(M_s)} = 1$:

$$PO_{j,s} = \frac{P(M_j, Y_T)}{P(M_s, Y_T)} = \frac{P(Y_T/M_j)}{P(Y_T/M_s)} = B_{j,s} \tag{1.37}$$

The Bayes factor is an index which indicates both the acceptance (or not) of a model and its relative evidence compared to another one. Following Schorfheide (2000) we compute the posterior (marginal) log-likelihood of the models by employing the Laplace approximation method. In order to select the model which is more supported by the empirical evidence we employ the Jeffrey's (1961) method which scale the evidences provided by the log-Bayes factors of different models.[25]

In the following we compare the models which can generate an incompleteness of the interest rate pass-through. Hence, we do not consider the pure credit economy scenario where, given the assumptions, the incompleteness in the transmission of the monetary policy cannot exist; instead we study the other four scenarios and we denote the model with the mark-up assumption as model A, the model with the smoothness factor as model B, the model in which there is monopolistic competition in the banking sector and where the pricing is subject to a Calvo's rule as model C, and the model which incorporates search and matching frictions in the credit market as model D.

1.5.1 Sensitivity Analysis: Mapping Stability

The prior assumptions have a relevant role in the Bayesian estimation procedure. As a matter of fact, it is possible that some parameter values which are plausible for a model may not be for another alternative model. Then we employ a stability mapping analysis which identifies the stability domain of the models as well as the values of the parameters driving in indeterminacy and instability. This procedure is helpful in order to choice in a better way the priors. In particular a Monte Carlo simulation is performed in order to detect what parameters mostly drive the model into a specific region.

According to Ratto (2008) we consider two regions: an acceptable stable region G satisfying the standard Blanchard-Kahn rank condition and an unacceptable region $\overline{G}$ caused by the instability and indeterminacy. Hence, in order to explore all the prior space we sample uniformly from the prior distributions defined above and we categorize each parameter into the two alternative regions. The sample is generated using a Sobol's quasi Monte Carlo sequence of dimension $N = 2048$. Hence, we get two subsets, (κ_s/G) of size n and $\left(\kappa_s/\overline{G}\right)$ of size $\overline{n}$ representing draws from the unknown probability density functions $f_n(\kappa_s/G)$ and $f_{\overline{n}}(\kappa_s/G)$ respectively, where κ is the vector of the parameters, s is the parameter's index and $n+\overline{n} = N$. Finally the identification of the parameters (and their relative values) driving in the (un)acceptable region is defined by the comparison of the previous density functions by the two-sided Smirnov-Kolmogorov test:

$$d_{n,\overline{n}} = \sup ||F_n(\kappa_s/G) - F_{\overline{n}}(\kappa_s/G)||$$

where $F_n(\kappa_s/G)$ and $F_{\overline{n}}(\kappa_s/G)$ are the cumulative distribution functions (cdf) of the generic parameter κ_s. Given the null hypothesis $f_n(\kappa_s/G) = f_{\overline{n}}(\kappa_s/G)$ and the significance level at which it is rejected, if for a parameter κ_s the two distributions are significantly different (a larger $d_{n,\overline{n}}$), it is possible define the parameter as a key driver of the model behavior as well as the values of the parameter space leading in one region or in other one. Alternately, if the distance between the distributions is not significant, κ_s is not important for the model's dynamics and its values can

[25] Model j is supported if $B_{j,s} \geq 1$. On the other hand, there are a slight, moderate, decisive or strong evidence against the model j if $10^{-\frac{1}{2}} \leq B_{j,s} < 1$, $10^{-1} \leq B_{j,s} < 10^{-\frac{1}{2}}$, $10^{-2} \leq B_{j,s} < 10^{-1}$ and $B_{j,s} < 10^{-2}$, respectively.

belong, indifferently, either to G or $\overline{G}$.

Par.	Model A			Model B			Model C			Model D		
	Stab	Indet.	Instab.	Stab	Indet.	Instab.	Stab	Indet.	Instab.	Stab	Indet.	Instab.
ϕ	0.1500	0.0783	- - -	0.1610	0.0834	- - -	0.1510	0.0790	- - -	0.1170	0.0492	0.1720
δ_π	0.8620	0.4510	- - -	0.8580	0.4440	- - -	0.8650	0.4520	- - -	0.5780	0.3040	0.4290
δ_x	0.0620	0.0324	- - -	0.0527	0.0272	- - -	0.0469	0.0245	- - -	0.0571	0.0292	0.0861
ρ^R	0.0499	0.0261	- - -	0.0518	0.0268	- - -	0.0398	0.0208	- - -	0.0482	0.0344	0.2440
$\varkappa$	0.0136	0.0071	- - -	-	-	-	-	-	-	-	-	-
Ψ_0	0.0110	0.0057	- - -	-	-	-	-	-	-	-	-	-
ζ_0	-	-	-	0.0200	0.0103	- - -	-	-	-	-	-	-
ζ_1	-	-	-	0.0128	0.0066	- - -	-	-	-	-	-	-
Σ_0	-	-	-	0.0216	0.0112	- - -	-	-	-	-	-	-
χ	-	-	-	-	-	-	0.0233	0.0122	- - -	-	-	-
η	-	-	-	-	-	-	0.0264	0.0138	- - -	-	-	-
ρ^B	-	-	-	-	-	-	-	-	-	0.0711	0.0378	0.1380
ξ	-	-	-	-	-	-	-	-	-	0.0264	0.0192	0.1630
z	-	-	-	-	-	-	-	-	-	0.0426	0.0549	0.7040
k^B	-	-	-	-	-	-	-	-	-	0.0307	0.0141	0.0655
$\overline{c}$	-	-	-	-	-	-	-	-	-	0.1440	0.0936	0.4640
ρ^A	0.0126	0.0066	- - -	0.0096	0.0050	- - -	0.0136	0.0071	- - -	0.0247	0.0100	0.1130
ρ^ν	0.0118	0.0062	- - -	0.0151	0.0078	- - -	0.0107	0.0056	- - -	0.0276	0.0125	0.1010
ρ^υ	0.0113	0.0059	- - -	0.0145	0.0075	- - -	0.0107	0.0056	- - -	0.0262	0.0130	0.0882
ρ^φ	0.0101	0.0053	- - -	0.0114	0.0059	- - -	0.0091	0.0047	- - -	0.0261	0.0151	0.0934
ρ^ϑ	0.0130	0.0068	- - -	0.0096	0.0050	- - -	0.0148	0.0077	- - -	0.0207	0.0121	0.1380
ρ^ψ	0.0144	0.0075	- - -	0.0129	0.0066	- - -	0.0110	0.0057	- - -	0.0331	0.0137	0.0834

Table 1.1: Smirnov-Kolmogorov statistics in driving stability, indetrminacy and instability.

From the Monte Carlo filtering procedure we get that 52.3 percent, 51.7 percent, 52.2 percent and 46 percent of the prior support is stable for model A, B, C and D respectively. The remaining part gives indeterminacy (47.7 percent, 48.3 percent, 47.8 percent and 51.2 percent) and instability (zero, zero, zero and 2.8 per cent). By running the Smirnov-Kolmogorov test we can highlight that, in models A, B, C and D, indeterminacy is essentially driven by δ_π. In particular, by comparing the cdf of the sample producing indeterminacy with the cdf of the original prior sample we find that small values of δ_π drive to indeterminacy. Table 1.1 reports the detailed results of the Smirnov-Kolmogorov tests.

1.5.2 Data

We use 6 observables for the U.S.: real GDP, employment, real wage, inflation, the federal funds rate and the weighted average effective loan rate. For a description of the data, see the appendix. The sample period is 1997:Q2 - 2011:Q4. We use the logarithmic transformation for the quarterly interest rates, i.e. $\log(1 + \frac{r_t^j}{100})$ where $j = D, L$ whereas the inflation rate is computed as the quarter on quarter logarithmic difference of nominal prices. All remaining data are transformed by employing the logarithmic first difference operator. Figure 1.3 plots the transformed data.

1.5.3 Calibrated Parameters

In this section we set the values of the calibrated parameters of the model. Table 1.2 reports them. Due to the large consensus on the quarterly value of the discount factor by the economic literature, we impose β equal to 0.996 so as to obtain a quarterly real steady state rate on deposits $R^D = 1.0035$ (de Walque, Pierrard and Rouabah, 2010). Further, we assume a logarithmic form for the utility function over consumption ($\sigma = 1$). As widely accepted by the literature on the subject matter we calibrate the sticky price parameter $\omega = 0.8$. The previous impositions imply that the coefficient attached to the real marginal costs into the equation (1.12) is $\kappa = \frac{(1-\beta\omega)(1-\omega)}{\omega} = 0.0507$. In line with the empirical observations we calibrate the elasticity of output to employment, α, equal to 0.66. Finally, according to Ravenna and Walsh (2008) we set the steady state employment N

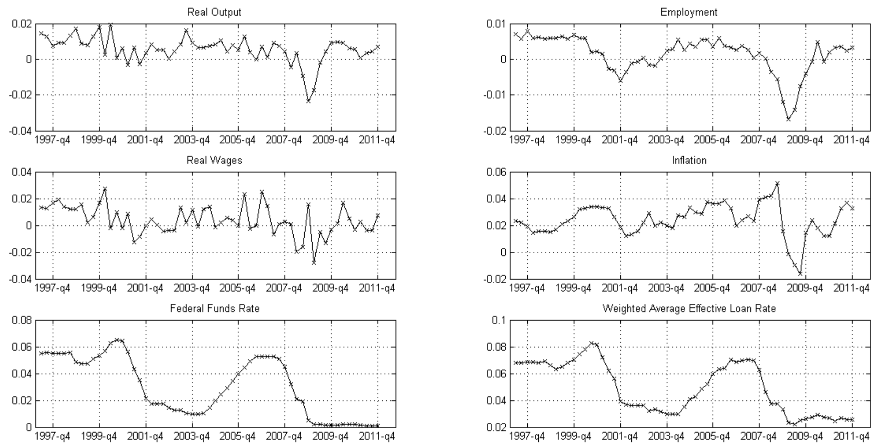

Figure 1.3: Data.

equal to 0.95, and the elasticity of substitution of the individual goods ε equal to 6 such that the mark-up of the retail sector over the price of the wholesale good is 20 per cent (μ =1.2).

Calibrated Parameter	β	σ	ω	α	N	ε
Value	0.996	1	0.8	0.66	0.95	6

Table 1.2: Calibrated Parameters.

1.5.4 Priors

In this section, based on the indications of the sensitivity analysis, we declare the prior distributions of the remaining deep models' parameters. The shape of the distributions is chosen according the standard practise: for parameters defined in a $[0 - 1]$ interval we assume the beta distribution whereas for parameters which can take values over the whole support $\mathbb{R}$ we adopt the normal distribution. For parameters assuming values over the $[0 - \infty]$ interval we assume the gamma distribution. Finally, the reference distribution for the structural shocks is the inverted gamma which is defined over the range $\mathbb{R}^+$.

For the monetary policy rule parameters we employ values widely used by the literature. Hence, for the coefficients attached to the expected inflation and output gap terms, δ_π and δ_x respectively, we assume a normal distribution with prior mean 2.0 and 0.1 and a standard error equal to 1.00 and 0.05 respectively; for the autoregressive coefficient ρ^R defining the degree of the interest rate smoothness we assume a beta distribution with prior mean 0.5 and standard error 0.25. For the all persistence parameters of the autoregressive stochastic processes of the model exogenous shocks, we assume a beta distribution with prior mean of 0.5 and standard deviation of 0.1. The inverse labor supply Frish elasticity parameter ϕ is assumed normal distributed with prior mean equal to 0.5 and standard error equal to 0.25.

Concerning the credit market parameters we have not many references on possible prior values. Kaufmann and Sharler (2009) estimate for the U.S. $\frac{1}{1+\zeta_1} = 0.95$ and $\frac{\zeta_0\zeta_1}{1+\zeta_1} = 0.03$ from which it is possible to get $\zeta_1 = 0.0526$ and $\zeta_0 = 0.6$, and by the steady state version of equation (1.18), $\Sigma_0 = 0.98$. Hence, we decide to use the previous estimates as prior means with ζ_1 and Σ_0 gamma distributed with standard errors equal to 0.0263 and 0.49 respectively and ζ_0 normal distributed with standard error equal to 0.3. Furthermore, by using the identity principle of polynomials[26] between the steady state versions of the banking lending rate by Kaufmann and Sharler (2009) when $\zeta_0 = 0$ and by Chowdhury et al. (2006), we are able to derive the values of the parameters which we use as prior means for the functional form of Ψ_t when the price mark-up assumption is done. In particular, we assume a gamma distribution for $\varkappa$ and Ψ_0, with prior mean equal to 0.05 and 0.97 and standard error equal to 0.25 and 0.485, respectively. Under the scenario in which there is monopolistic competition in the banking sector for the Calvo's parameter describing the share of banks that can adjust their banking lending rates, χ, we assume a uninformative position by employing a beta distribution with prior mean equal to 0.5 and standard error equal to 0.25. Furthermore, for the elasticity of substitution between different loans η, we assume a gamma distribution with mean 6 and standard error 3 subject to the requirement $\eta > 1$. Also for the search and matching framework we have limited evidence. Hence, we adopt a gamma distribution for the credit vacancy posting cost with mean value equal to its labor market counterpart, i.e. $k^B = 0.1$, and standard error equal to 0.05. The prior on the firm's entry cost $\bar{c}$ is harder to set, so we assume a rather widespread gamma distribution with a mean of 25 and a standard deviation of 12.5. For the matching function elasticity ξ and for the firms' bargaining power z we assume an uninformative position by considering a beta distribution with prior mean equal to 0.5 and standard error equal to 0.25 for both. Finally for the separation rate ρ^B we adopt the strategy of setting its value between the minimal (0.07) and maximal (0.02) values of the bankruptcy rate calibrated by Dell'Ariccia and Garibaldi (1998). As a consequence, the separation rate in the credit market is assumed beta distributed with prior mean 0.05 and standard error equal to 0.025.

Finally, for all standard deviation of the exogenous shocks we use the inverted gamma distribution as prior distribution with mean equal to 0.01 with two degrees of freedom.[27]

1.5.5 Posteriors Estimates

Table 1.3 summarizes the posterior mode and the posterior mean for the models' parameters. The panel also shows the 90 percent probability intervals for the models' parameters and the relative prior assumptions. Draws from the posterior distributions are obtained by running the random walk version of the Metropolis-Hastings algorithm. We ran ten parallel chains, each with a length of 100,000 replications.[28]

The posterior mean estimates of the credit market parameters are generally close to the respective modal values with the some exceptions. The model A highlights values of the parameters $\varkappa$

[26] See the technical appendix.

[27] In order to simulate the model we add some measurement equations linking the log-levels of the variables with their log-differences. We assume these equations contain a constant term that we estimate. Hence for these terms, in the estimation phase, we assume a normal distribution and we adopt the strategy to set the prior mean equal to the sample mean of the time series to which the constant refers, and a standard error which implies a prior pseudo-t-value equal to 2. Table 1.3 does not report the constats' estimates. More details are available from the author upon request.

[28] The fraction of drops of the initial parameters vector is set at 20%. The calibration of the scale factor provides acceptance rates between 30 and 45 percent for the ten blocks of the four models. For the application of the Bayesian estimation and of the sensitivity analysis we employ the latest stable version (4.2.1) of the open-source software Dynare.

Par.	Prior Dist.		Post. Dist. Model A				Post. Dist. Model B				Post. Dist. Model C				Post. Dist. Model D			
	Dist.	Mean (S. D.)	Mode (S. D.)	Mean	5%	95%	Mode (S. D.)	Mean	5%	95%	Mode (S. D.)	Mean	5%	95%	Mode (S. D.)	Mean	5%	95%
ϕ	$\mathcal{N}$	0.500 (0.250)	0.5007 (0.1205)	0.5486	0.3271	0.7701	0.4997 (0.1203)	0.5609	0.3342	0.7895	0.5037 (0.1210)	0.5614	0.3312	0.7863	0.5004 (0.1205)	0.5419	0.3215	0.7539
δ_π	$\mathcal{N}$	2.000 (1.000)	2.8014 (0.5768)	3.0730	2.0601	4.0974	2.7981 (0.5735)	3.1075	2.0395	4.1337	2.8141 (0.5782)	3.1181	2.0726	4.1847	2.7820 (0.5715)	3.0068	2.0293	4.0001
δ_x	$\mathcal{N}$	0.100 (0.050)	0.1775 (0.0494)	0.1716	0.0909	0.2540	0.1773 (0.0493)	0.1702	0.0867	0.2521	0.1771 (0.0494)	0.1701	0.0879	0.2519	0.1772 (0.0493)	0.1733	0.0907	0.2530
ρ^R	$\mathcal{B}$	0.500 (0.250)	0.7977 (0.0404)	0.7853	0.7146	0.8659	0.7975 (0.0403)	0.7765	0.6905	0.8684	0.7980 (0.0402)	0.7785	0.6972	0.8659	0.7958 (0.0407)	0.7815	0.7080	0.8612
$\varkappa$	$\mathcal{G}$	0.050 (0.025)	0.0354 (0.0198)	0.0433	0.0110	0.0748	- (-)	-	-	-	- (-)	-	-	-	- (-)	-	-	-
Ψ_0	$\mathcal{G}$	0.970 (0.485)	0.7319 (0.4226)	0.9733	0.2226	1.6815	- (-)	-	-	-	- (-)	-	-	-	- (-)	-	-	-
ζ_0	$\mathcal{N}$	0.600 (0.300)	- (-)	-	-	-	0.7047 (0.2994)	0.7261	0.2462	1.2216	- (-)	-	-	-	- (-)	-	-	-
ζ_1	$\mathcal{G}$	0.0526 (0.0263)	- (-)	-	-	-	0.0452 (0.0254)	0.0591	0.0149	0.1015	- (-)	-	-	-	- (-)	-	-	-
Σ_0	$\mathcal{G}$	0.980 (0.490)	- (-)	-	-	-	0.7456 (0.4305)	0.9821	0.2325	1.7112	- (-)	-	-	-	- (-)	-	-	-
χ	$\mathcal{B}$	0.500 (0.250)	- (-)	-	-	-	- (-)	-	-	-	0.1312 (0.0904)	0.1590	0.0241	0.2794	- (-)	-	-	-
η	$\mathcal{G}$	6.000 (3.000)	- (-)	-	-	-	- (-)	-	-	-	5.9404 (3.7053)	6.0283	1.6201	10.339	- (-)	-	-	-
ρ^B	$\mathcal{B}$	0.050 (0.025)	- (-)	-	-	-	- (-)	-	-	-	- (-)	-	-	-	0.0425 (0.0233)	0.0588	0.0159	0.1001
ξ	$\mathcal{B}$	0.500 (0.250)	- (-)	-	-	-	- (-)	-	-	-	- (-)	-	-	-	0.4997 (0.4626)	0.4096	0.0357	0.7547
z	$\mathcal{B}$	0.500 (0.250)	- (-)	-	-	-	- (-)	-	-	-	- (-)	-	-	-	0.9856 (0.0209)	0.9531	0.8999	0.9999
k^B	$\mathcal{G}$	0.100 (0.050)	- (-)	-	-	-	- (-)	-	-	-	- (-)	-	-	-	0.0750 (0.0433)	0.1005	0.0247	0.1761
$\overline{c}$	$\mathcal{G}$	25.00 (12.50)	- (-)	-	-	-	- (-)	-	-	-	- (-)	-	-	-	24.980 (13.800)	22.017	3.895	39.537
ρ^A	$\mathcal{B}$	0.500 (0.100)	0.8639 (0.0327)	0.8601	0.8064	0.9143	0.8639 (0.0327)	0.8592	0.8046	0.9153	0.8641 (0.0326)	0.8593	0.8051	0.9148	0.8643 (0.0327)	0.8604	0.8062	0.9153
ρ^ν	$\mathcal{B}$	0.500 (0.100)	0.5383 (0.0671)	0.5795	0.4090	0.7253	0.5380 (0.0671)	0.5985	0.4587	0.9022	0.5405 (0.0675)	0.6003	0.4263	0.8530	0.5359 (0.0672)	0.5683	0.4084	0.6987
ρ^υ	$\mathcal{B}$	0.500 (0.100)	0.9457 (0.0134)	0.9376	0.9223	0.9529	0.9418 (0.0143)	0.9333	0.9152	0.9529	0.9304 (0.0196)	0.9193	0.8912	0.9528	0.9430 (0.1450)	0.9322	0.9132	0.9529
ρ^φ	$\mathcal{B}$	0.500 (0.100)	0.9000 (0.0201)	0.8903	0.8508	0.9348	0.8999 (0.0201)	0.8856	0.8342	0.9376	0.8994 (0.0202)	0.8854	0.8366	0.9363	0.8993 (0.0201)	0.8901	0.8508	0.9340
ρ^ϑ	$\mathcal{B}$	0.500 (0.100)	0.6103 (0.0723)	0.6273	0.5074	0.7474	0.6102 (0.0723)	0.6305	0.5112	0.7525	0.6121 (0.0724)	0.6303	0.5104	0.7526	0.6104 (0.0724)	0.6262	0.5083	0.7461
ρ^ψ	$\mathcal{B}$	0.500 (0.100)	0.6376 (0.0712)	0.6284	0.5113	0.7438	0.6377 (0.0712)	0.6258	0.5069	0.7431	0.6328 (0.0716)	0.6217	0.5041	0.7394	0.6351 (0.0711)	0.6231	0.5076	0.7385
σ^A	$\mathcal{IG}$	0.010 (2)	0.0058 (0.0006)	0.0060	0.0050	0.0070	0.0058 (0.0006)	0.0060	0.0050	0.0069	0.0058 (0.0005)	0.0060	0.0050	0.0070	0.0058 (0.0005)	0.0060	0.0050	0.0070
σ^ν	$\mathcal{IG}$	0.010 (2)	0.0056 (0.0008)	0.0062	0.0044	0.0078	0.0056 (0.0008)	0.0065	0.0042	0.0088	0.0056 (0.0008)	0.0065	0.0043	0.0084	0.0056 (0.0008)	0.0063	0.0044	0.0078
σ^υ	$\mathcal{IG}$	0.010 (2)	0.0028 (0.0003)	0.0029	0.0025	0.0034	0.0028 (0.0003)	0.0029	0.0024	0.0034	0.0025 (0.0003)	0.0025	0.0020	0.0031	0.0038 (0.0011)	0.0041	0.0026	0.0056
σ^φ	$\mathcal{IG}$	0.010 (2)	0.0653 (0.0111)	0.0690	0.0499	0.0879	0.0652 (0.0111)	0.0687	0.0495	0.0868	0.0654 (0.0110)	0.0687	0.0496	0.0864	0.0647 (0.0110)	0.0680	0.0484	0.0866
σ^ϑ	$\mathcal{IG}$	0.010 (2)	0.098 (0.0009)	0.0103	0.0086	0.0119	0.0098 (0.0009)	0.0103	0.0086	0.0119	0.0098 (0.0009)	0.0103	0.0086	0.0119	0.0098 (0.0009)	0.0102	0.0086	0.0118
σ^ψ	$\mathcal{IG}$	0.010 (2)	0.0039 (0.0006)	0.0039	0.0029	0.0051	0.0039 (0.0006)	0.0038	0.0021	0.0050	0.0039 (0.0006)	0.0038	0.0024	0.0052	0.0039 (0.0006)	0.0040	0.0029	0.0052

Table 1.3: Posterior Estimates: Structural and Shock Process Parameters.

and Ψ which are larger than their modal values. Further, $\varkappa$ is smaller than its prior. The model B shows values of the parameters ζ_0 and ζ_1 which are smaller and larger than their prior means, respectively. The model C presents a value of the elasticity of substitution between the different types of loans, η, which is larger then its modal value but close to its prior mean. Moreover, the fraction of banks which cannot adjust their loan rate, χ, is very low. On other hand, the model D gets a value of the entry cost $\bar{c}$ whose posterior mean is lower than the relative modal and prior values. The estimates of the credit market parameters imply low values of the matching elasticity ξ and of the bargaining power of banks $1-z$. The estimates of the separation rate between firms and banks ρ^B and of the posting cost k^B are in line with their prior and modal values. For all four models the estimates of the monetary policy parameters and of the inverse labor supply Frish elasticity parameter are in line with the literature on the subject matter.

1.6 Simulation

In this section we plot the impulse response functions of the interest rates with respect to the policy and technology shocks of the models described in section 1.4.4 in order to compare the degree of the (in)completeness of the pass-through of the policy rate to the banking lending rate (Figure 1.4), and the dynamics of the credit spread when a productivity shock hits the economy (Figure 1.5).

1.6.1 Monetary Shock

With nominal rigidities on good prices, a monetary tightening implies an increase of the policy rate that produces a higher real interest rate. This rise determines a substitution effect between current and future consumption: households decrease current spending and both the output and the output gap fall. The decrease in the demand of goods implies a lower labor demand by firms: employment and wages fall and the rise in the marginal product of labor leads to lower real marginal costs. By the NKPC, inflation goes down.

In the mark-up scenario the dynamics of the banking lending rate crucially depends on the value of the parameter Ψ_R which reflects the competitiveness of the U.S. financial sector (system): since its estimated value is close to 1 then the responses of the policy and banking lending rates are almost identical. Only in the first three periods we can note a small difference between the interest rates. The magnitude of the previous gap is basically the same if we add a persistence factor like that of model B. Given the estimated value of the factor $\frac{\zeta_0\zeta_1}{1+\zeta_1}$ (0.03), in this case the banking lending rate show a less reaction than that of the policy rate only in the first period. Of course, the higher the value of the smoothness factor, the greater is the persistence of the dynamics of the interest rate on loans.

Under the Calvo's mechanism, by the nominal rigidities on the banking lending rates, only a share of firms can modify the own interest rate on loans, and so the average interest banking lending rate of the economy reacts less than the policy rate. Of course, the magnitude of these reactions depends on the value of the fraction of banks χ that maintains the gross banking lending rate unchanged: the higher the value of χ the greater the degree of incompleteness of the interest rate pass through.

When search and matching frictions are present in the credit market, the decrease in the wage bill attenuates the borrowing demand to the banks. The expected profits of banks decrease. Banks try to reduce their vacancy posting activity such that the number of the new financial matches and of the lines of credit fall. Then the number of firms searching for a line of credit jumps up. As a consequence a more congestion effect in the credit market is highlighted: the credit line finding rate decreases, the credit vacancy filling rate increases and the credit market tightness goes up. The latter dynamics, together the bargaining mechanism of the interest rate on loans affected by the posting costs of the credit vacancies imply that the bargained banking lending rate rises slightly less than the policy rate when a positive policy shock hits the economy. Hence, in the search and matching model the values of the expected posting cost $\frac{k^B R_t^D}{q_t^B}$ and of the banks' bargaining power $(1-z)$ affect the interest rate dynamics such that their larger values imply more incompleteness of the interest rate pass-through.

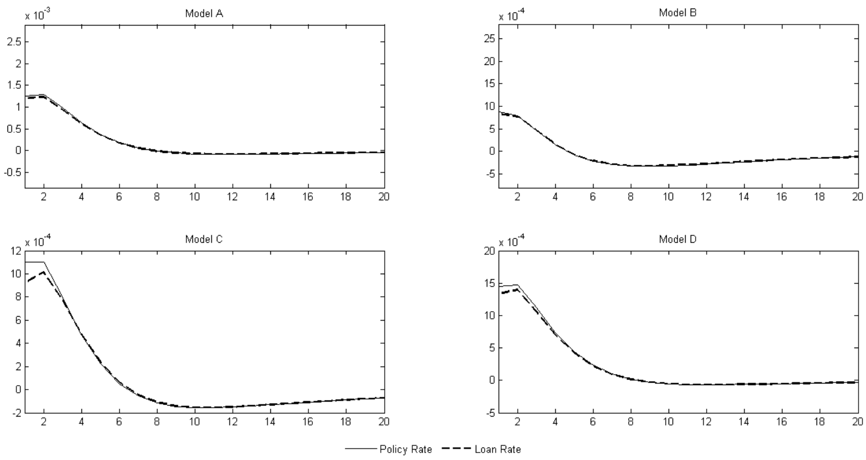

Figure 1.4: IRFs with respect to a monetary shock.

1.6.2 Technology Shock

Due to the sticky prices and to the weak accommodation of the policy rule to the TFP shock, the increase of the productivity implies an increase of the output supplied by firms less than proportional of the increase of the TFP level (Galì and Rabanal, 2004). Since the potential output augments more than the actual output, then the output gap declines. This implies a less labor demand by firms: employment decreases as well as the marginal costs. As a matter of fact only a fraction of the firms can adjust their prices in line with the decline of the marginal costs: if this fraction is sufficiently small and if monetary policy does not strongly accommodate the shock, then the price level of the economy will decrease and the more demand for goods will be satisfied with a less labor input in line with the finding by Galì (1999) (*productivity employment puzzle*). Finally the positive response of the real wage, by equation (1.7), depends on the income effect (which affect the demand for goods) and the substitution effect (which affects the labor demand) influenced by the price dynamics and by the set of parameters used to simulate the models.

Figure 1.5 highlights the response of credit spread with respect to the TFP shock. Similarly to the case in which the economy is hit by a policy rate shock, the dynamics of the Bayesian impulse response function of the credit spread of models A and B are almost identical: a very slight gap is highlighted. A similar dynamics is observable when we simulate a model with monopolistic competition in the banking sector: in this case we obtain a small cushioned dynamics of the interest rate on loans compared to that of the policy rate which determines a less countercyclical behavior of the credit spread than models A and B.

A different evidence is observable by considering the scenario in which the search and matching frictions affect the credit market. In this scheme, since firms do not have their own capital, they must match with a bank in order to obtain a line of credit. The rise in the supply of goods implies an increase in the expected profits of banks: the interest rate on loans depends both on the revenues and on the wage bill of firms, so the larger is the firms' surplus the higher is the interest rate on loans that banks are trying to obtain from firms. As a consequence, there is a more intensive credit vacancy posting activity: financial matches and lines of credit boost. This increase forces the fall of the number of firms searching for a line of credit. In the credit market there is a lower congestion effect from the point of view of firms: the credit vacancy filling rate goes down, the credit line finding rate goes up and the credit market tightness drops. This implies a decrease of the banking lending rate. In this case the interest rate spread becomes more countercyclical than all other models. As a matter of fact, put in other terms, and by referring to Beaubrun-Diant and Tripier (2009), in this scenario when a TFP shock hits the economy, the procyclical effect due to the increase of the banks' profits is more than offset by the countercyclical effect - which is not present in the other three models - due to the modification of the external opportunities (by changes of the threat points and values of matches) of firms which implies more ease of finding a loan or a lower expected time to obtain a line of credit. Furthermore in this scenario the steady state effect encapsuled in the value of R^L has a more weight than the other models in the definition of the magnitude of the credit spread.[29]

1.6.3 Bayesian Comparison

Finally, as anticipated in section (1.5), on the basis of the Bayesian model selection we are able to compare the previous models. Considering the Laplace approximation, the posterior log-likelihoods of models A, B, C and D are 1153.15, 1154.25, 1152.33 and 1150.29 respectively. The Bayes factors are $B_{A,B} = e^{[\log P(Y_T/M_A) - \log P(Y_T/M_B)]} = e^{-1.10}$, $B_{A,C} = e^{[\log P(Y_T/M_A) - \log P(Y_T/M_C)]} = e^{0.82}$, $B_{A,D} = e^{[\log P(Y_T/M_A) - \log P(Y_T/M_D)]} = e^{2.86}$, $B_{B,C} = e^{[\log P(Y_T/M_B) - \log P(Y_T/M_C)]} = e^{1.92}$, $B_{B,D} = e^{[\log P(Y_T/M_B) - \log P(Y_T/M_D)]} = e^{3.96}$ and $B_{C,D} = e^{[\log P(Y_T/M_C) - \log P(Y_T/M_D)]} = e^{2.04}$. This indicates, according to Jeffrey's (1961) scale of equivalence, an evidence in favor of Model B. Hence, a model in which the banking lending rate depends on its past value as well as on the policy rate seems to be more supported than other models emphasizing the role assumed by the past value of the banking lending rate in shaping the interest rate dynamics. Then, we modify the search and matching framework by introducing a backward looking social norm for the banking lending rate in a fashion similar to Christoffel and Linzert (2005) and Hall (2005) for the real wage. We assume that the actual loan rate is equal to a weighted average of its past loan rate and the equilibrium (bargained) loan rate, $\hat{R}_t^{LN}$, defined by equation (1.32):

$$\hat{R}_t^L = (1 - \varrho)\hat{R}_t^{LN} + \varrho\hat{R}_{t-1}^L$$

[29] Beaubrun-Diant and Tripier (2009) show another countercyclical effect due to the modification of the idiosyncratic productivity reservations of the agents. They conclude for an overall countercylical effect of the credit spread.

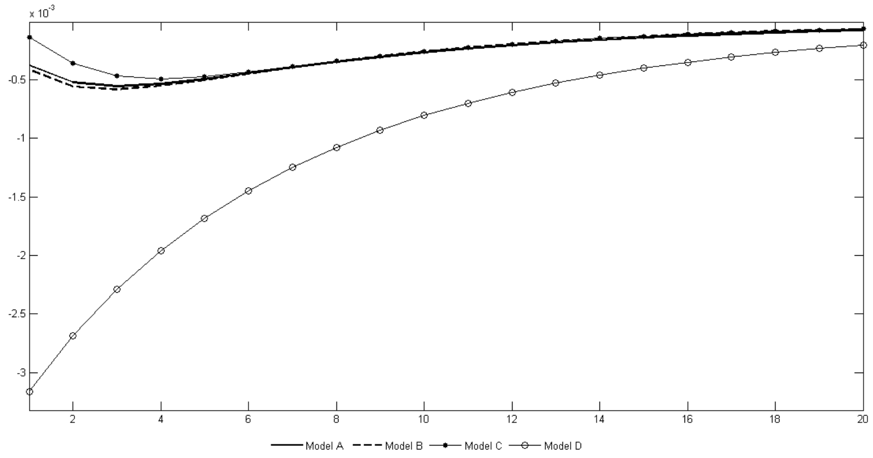

Figure 1.5: IRFs with respect to a technology shock.

where ϱ denotes the degree of the loan rate rigidity. Then we estimate the new model that we label as E by considering the same priors assumed for the model D and by employing a beta distribution with prior mean 0.5 and standard error 0.25 for the degree of loan rate rigidity ϱ.[30]

The Bayesian estimation provides $\varrho = 0.65$ showing a discrete dependence of the actual loan rate on its past value. Figure 1.6 shows the comparison of posterior IRFs of models D and E. In the top panel we can observe that when a positive interest rate shock hits the economy the interest rate pass-through becomes more incomplete compared to the benchmark model whereas the bottom panel shows that in presence of a positive TFP shock the credit spread is slightly procyclical. The first result depends on the loan rate stickiness that adds persistence and on the not optimal adjustment of the banking lending rate when search and matching frictions are present in the credit market. The second finding is determined by a more weight of the procyclical component due to the increase of the banks' profits by the rise of the share of which banks can appropriate given the more firms' revenues.[31] Furthermore, the posterior log-likelihood of model E is 1156.98. Hence the new Bayes factors are: $B_{A,E} = e^{[\log P(Y_T/M_A) - \log P(Y_T/M_E)]} = e^{-3.83}$, $B_{B,E} = e^{[\log P(Y_T/M_B) - \log P(Y_T/M_E)]} = e^{-2.73}$, $B_{C,E} = e^{[\log P(Y_T/M_C) - \log P(Y_T/M_E)]} = e^{-4.65}$ and $B_{D,E} = e^{[\log P(Y_T/M_D) - \log P(Y_T/M_E)]} = e^{-6.43}$. Finally, the Bayesian model selection analysis allow us to highlight a decisive evidence in favor of a model in which the loan rate depends, on one hand, on the price bargained by firms and banks on the basis of their bargaining powers, and on the other hand, on its past value.

[30]Similar results are obtained by fixing $\varrho = 0.5$. It is useful to note that the steady state version of the model does not change because $R^L = R^{LN}$.

[31]A complete description of the estimate of model E is available upon request from the author.

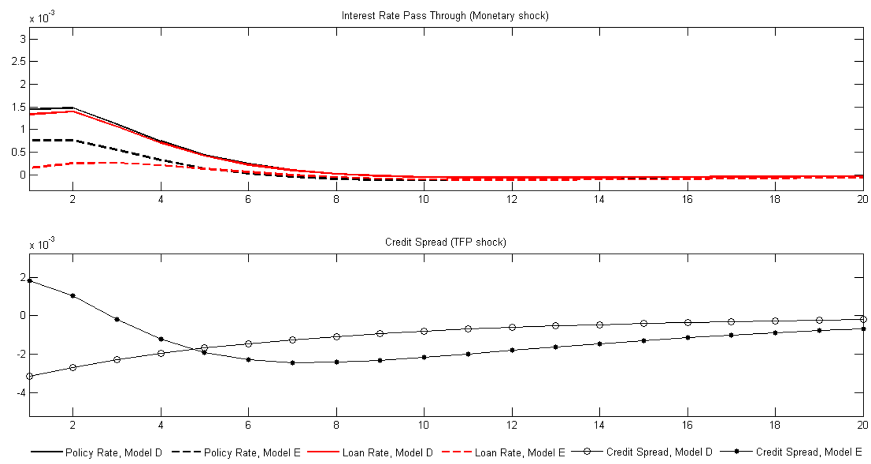

Figure 1.6: Interest rate pass-through (monetary shock) and credit spread (TFP shock) under loan rate rigidity.

1.7 Conclusions

The recent crises has shown that the reduction of the monetary policy rate by major Central Banks has not been completely transmitted to the bank retail rates. In particular, the incompleteness of this pass-through was more prominent in the loan market. So, understanding the causes of this phenomena becomes relevant in order to address the monetary policy strategy.

This chapter helps to clear out the theoretical devices that allow to highlight an imperfect adjustment of the loan rates to variations of policy rate. In particular, after providing a broad description of the theoretical and empirical literature of the phenomenon confirmed by a Bayesian VAR analysis, we survey the main theoretical mechanisms reported by the literature on the subject matter.

By using the Bayesian procedures we estimate and compare four different models: one in which the banking lending rate is a mark-up of the policy rate, one in which it depends on the policy rate as well as on its past value, one characterized by monopolistic competition in the banking sector and another one in which search and matching frictions are present in the credit market. In particular the search and matching frictions' model shows a degree of the incompleteness of interest rate pass-through similar to that of the Calvo's model. The simulation with respect to technology shock provides a larger countercyclical credit spread in the search and matching framework than that of the Calvo's model.

Finally, the Bayesian comparison provides a positive evidence in favor of the models in which the banking lending rate depends on its past value and on policy rate. According to this evidence we employ a model in which the interest rate on loans is a weighted average between its past value and a bargained interest rate on loans depending on search and matching frictions in the credit market. This specification has the greatest favorable evidence among the models presented in this survey.

Bibliography

[1] Agénor, P. R., Bratsiotis, G., and Pfajfar, D (2011), Monetary Shocks and the Cyclical Behavior of Loan Spreads, Centre for Growth and Business Cycle Research, Discussion Paper Series No. 156.

[2] Andrés, J., and Arce, O. (2008), Banking Competition, Housing Prices and Macroeconomic Stability, Bank of Spain Working Paper No. 830.

[3] Angeloni, I., Kashyap, A. K., and Mojon, B., Eds. (2003), *Monetary policy transmission in the Euro Area*, Cambridge, Cambridge University Press.

[4] Aslam, A., and Santoro, E. (2008), Bank Lending, Housing and Spreads, University of Copenaghen, Department of Economics, Discussion Paper No 27.

[5] Beaubrun-Diant, K. E., and Tripier, F. (2009), The Credit Spread Cycle with Matching Friction, Université de Nantes, LEMNA Working Paper, No. 2009/37.

[6] Becsi, Z., Li, V. E., and Wang, P. (2005), Heterogeneous borrowers, liquidity, and the search for credit, *Journal of Economic Dynamics and Control*, 29, 1331-1360.

[7] Banerjee, A., Bystrov, V., and Mizen, P. (2010), Interest rate pass-through in the major European economies - the role of expectations, Department of Economics, University of Birmingham, Discussion Paper No. 10-07.

[8] Berger, A. N., and Udell, G. F. (1992), Some evidence on the empirical significance of credit rationing, *Journal of Political Economy*, 100(5), 1047-1077.

[9] Bernanke, B. S., and Gertler, M. (1995), Inside the Black Box: The Credit Cost Channel of Monetary Policy Transmission, *Journal of Economic Perspectives*, 9, 27-48.

[10] Bernanke, B. S., Gertler, M., and Gilchrist, S. (1996), The Financial Accelerator and the Flight to Quality, *The Review of Economics and Statistics*, 78(1), 1-15.

[11] Bernanke, B. S., Gertler, M., and Gilchrist, S. (1999), The Financial Accelerator in a Quantitative Business Cycle Framework, in Taylor, J. B. and Woodford, M., Eds., Handbook of Macroeconomics, Vol. 1, 1341-1393.

[12] Blanchard, O. J., and Kiyotaki, N. (1987), Monopolistic Competition and the Effects of Aggregate Demand, *American Economic Review*, 77, 647-666.

[13] Burgastaller, J., and Sharler, J. (2010) How do Bank Lending Rates and the Supply of Loans React to Shifts in Loan Demand in the U.K.?, *Journal of Policy Modeling*, 32, 778-791.

[14] Calstrom, C., and Fuerst, T. (1997), Agency Costs, Net Worth, and Business Fluctuations: A Computable General Equilibrium Analysis, *American Economic Review*, 87, 893-910.

[15] Calstrom, C., and Fuerst, T. (1998) Agency Costs and Business Cycles, *Economic Theory*, 12, 583-597.

[16] Calvo, G. (1983), Staggered prices in a utility maximizing framework, *Journal of Monetary Economics*, 12, 383-398.

[17] Chen, N. (1991), Financial Investment Opportunities and the Macroeconomy, *Journal of Finance*, 46, 529-554.

[18] Christiano, L. J., Eichenbaum, M., and Evans, C. L. (2005), Nominal rigidities and the dynamic effects of a shock to monetary policy, *Journal of Political Economy,* 113, 1-45.

[19] Christoffel, K., and Linzert, T. (2010), The Role of Real Wage Rigidity and Labor Market Rigidities for Inflation Persistence, *Journal of Money, Credit, and Banking*, 42, 1435-1446.

[20] Chowdhury, I., Hoffman, M., and Schabert, A. (2006), Inflation Dynamics and the Cost Channel of Monetary Policy, *European Economic Review*, 50, 995-1016.

[21] Čihák, M., Harjes, T., and Stavrev, E. (2009), Euro area monetary policy in uncharted waters, IMF working paper No. 185.

[22] Corvoisier, S., and Gropp, R. (2002), Bank concentration and retail interest rates, *Journal of Banking and Finance*, 26(11), 2155-2189.

[23] Curdia, V., and Woodford, M. (2009), Credit Frictions and Optimal Monetary Policy, BIS Working Paper No. 278.

[24] Curdia, V., and Woodford, M. (2010), Credit Spreads and Monetary Policy, *Journal of Money Credit and Banking*, 42(s1), 3-35, 09.

[25] de Bondt, G. (2005), Interest rate pass-through: Empirical Results for the Euro Area, *German Economic Review*, 6(1), 37-78.

[26] de Bondt, G., Mojon, B., and Valla, N. (2005), Term structure and the sluggishness of retail bank interest rates in Euro Area countries, ECB Working Paper Series No. 518.

[27] Dell'Ariccia, G., and Garibaldi, P. (1998), Bank Lending and Interest Rate Changes in a Dynamic Matching Model, IMF Working Paper No 98/93.

[28] de Walque, G., Pierrard, O., and Rouabah, A. (2010), Financial (in)stability, supervision and liquidity, *Economic Journal*, Royal Economic Society, 120, 1234-1261

[29] Dixit, A., and Stiglitz, J. (1977), Monopolistic competition and optimum product diversity, *American Economic Review*, 67, 297 - 308.

[30] Doan, T., Litterman, R., and Sims, C. (1984), Forecasting and Conditional Projections Using Realistic Prior Distributions, *Econometric Reviews*, 3, 1-100.

[31] Dueker, M. J., and Thornton, D. L. (1997) Do bank loan rates exhibit a countercyclical mark-up?, Federal Reserve Bank of St. Louis, Working Paper No. 1997-004.

[32] Fama, E. F., French, K. R. (1989), Business Conditions and Expected Returns on Stocks and Bonds, *Journal of Financial Economics*, 25, 23-49.

[33] Fernández-Villaverde, J. (2010), The Econometrics of DSGE Models *International Review of Economics*, Springer, 1(1), 3-49.

[34] Fuertes, A. M., Hoffernan, S., and Kalotychou, E. (2010), How do UK Banks React to Changing Central Bank Rates?, *Journal of Financial Services Research*, 37(2), 99-130.

[35] Galí, J. (1999), Technology, Employment, and the Business Cycle: Do Technology Shocks Explain Aggregate Fluctuations?, *American Economic Review*, 89(1), 249-271.

[36] Galí, J., and, Rabanal, P. (2004), Technology Shocks and Aggregate Fluctuations: How Well Does the Real Business Cycle Model Fit Postwar U.S. Data?, IMF Working Paper No 04/234.

[37] Galí, J. (2008) Monetary Policy, Inflation, and the Business Cycle: An Introduction to the New Keynesian Framework, Princeton University Press.

[38] Gambacorta, L. (2008), How do banks set interest rates?, *European Economic Review*, 52(5), 792-819.

[39] Gambacorta, L., and Mistrulli, P. E. (2011), Bank heterogeneity and interest rate setting: What lessons have we learned since Lehman Brothers?, BIS Working Papers No. 359.

[40] Gerali, A., Neri, S., Sessa, L., and Signoretti, F. M. (2010), Credit and Banking in a DSGE Model of the Euro Area, *Journal of Money, Credit and Banking*, 42(6) (Supplement), 107-141.

[41] Gilchrist, S., Yankov, V., and Zakrajsek, E. (2009), Credit market shocks and economic fluctuations: Evidence from corporate bond and stock markets, *Journal of Monetary Economics*, 54(5), 1508-1514

[42] Gilchrist, S., Ortiz, A., and, Zakrajsek, E. (2009), Credit Risk and the Macroeconomy: Evidence from an Estimated DSGE Model, mimeo.

[43] Goodfriend, M., and McCallum, B. T., (2007), Banking and interest rates in monetary policy analysis: A quantitative exploration, *Journal of Monetary Economics*, 54(5), 1480-1507.

[44] Guha, D., and Hiris, L. (2002), The Aggregate Credit Spread and the Business Cycle, *International Review of Financial Analysis*, 11, 219-227.

[45] Güntner, J. H. F. (2011), Competition among Banks and the Pass-Through of Monetary Policy, *Economic Modelling*, 28, 1891-1901.

[46] Hall, R. (2005), Employment Fluctuations with Equilibrium Wage Stickiness, *American Economic Review*, 98, 1692-1706.

[47] Hannan, T., and Berger, A. (1991), The rigidity of prices: Evidence from the banking industry, *American Economic Review*, 95, 50-64.

[48] Hofmann, B. (2006), EMU and the transmission of monetary policy: Evidence from business lending rates, *Empirica*, 33, 209-229.

[49] Hofmann, B., and Mizen, P. (2004), Interest Rate Pass-Through and Monetary Transmission: Evidence from Individual Financial Institutions' Retail Rates, *Economica*, 71, 99-123.

[50] Hubbard, R. G. (1995), Is There a "Credit Channel" for Monetary Policy?, Federal Reserve Bank of St. Luis Review, 77, 63-74.

[51] Hülsewig, O., Mayer, E., Wollmershäuser, T., 2009. Bank behavior, incomplete interest rate pass-through, and the cost channel of monetary transmission, *Economic Modelling*, 26, 1310-1327.

[52] Humala, A. (2005), Interest rate pass-through and financial crises: do switching regimes matter? the case of Argentina, *Applied Financial Economics*, 15(2), 77-94.

[53] International Monetary Fund (2008), Global financial stability report. IMF, Washington D.C.

[54] Jeffrey, H. (1961), Theory of Probability. Oxford University Press, Oxford.

[55] Karagiannis, S., Panagopoulos, Y., and Vlamis, P. (2010), Interest rate pass-through in Europe and the US: Monetary policy after the financial crisis, *Journal of Policy Modeling*, 32, 323-338.

[56] Kaufmann, S., and Scharler, J. (2009), Financial Systems and the Cost Channel Transmission of Monetary Policy Shocks, *Economic Modelling*, 26, 40-46.

[57] Klemperer, P. (1987), Markets with consumer switching costs, *Quarterly Journal of Economics*, 102, 375-394.

[58] Kobayashi, T. (2008), Incomplete interest rate pass-through and optimal monetary policy, *International Journal of Central Banking*, 4, 77-118.

[59] Kwapil, C., and Scharler, S. (2006), Limited Pass-Through from Policy to Retail Interest Rates: Empirical Evidence and Macroeconomic Implications, *Monetary Policy and the Economy*, Q4, 26-36.

[60] Kwapil, C., and Scharler, S. (2010), Interest Rate Pass-Through, Monetary Policy Rules and Macroeconomic Stability, *Journal of International Money and Finance*, 29, 236-251.

[61] Lee, J., and Otsu, K. (2011), The Credit Spread and U.S. Business Cycles, Department of Economics, University of Kent, Studies in Economics No. 1123.

[62] Levin A. T., Natalucci F. M., and Zakrajsek, E. (2004), The magnitude and cyclical behavior of financial market frictions, Board of Governors of the Federal Reserve System (U.S.), Finance and Economics Discussion Series No 70.

[63] Lown C. S., and Morgan, D. P. (2002), Credit Effects in the Monetary Mechanism, Federal Reserve Bank of New York, *Economic Policy Review*, 8(1), 217-235.

[64] Lucas, Robert Jr. (1982), Interest rates and currency prices in a two-country world, *Journal of Monetary Economics*, 10, 335-359.

[65] Lubik, T., and Schorfheide, F. (2005), A Bayesian Look at New Open Economy Macroeconomics, National Bureau of Economic Research, *Macroeconomics Annual 2005*, 313-382.

[66] Meh, C., and Moran, K. (2004), Bank Capital, Agency Costs, and Monetary Policy, Bank of Canada Working Paper No. 6.

[67] McCulley, P., and Toloui, R. (2008), Chasing the Neutral Rate Down: Financial Conditions, Monetary Policy, and the Taylor Rule, *Global Central Bank Focus*, PIMCO, Feb. 20, 2008.

[68] Olivero, M. P. (2010), Market Power in Banking, Countercyclical Margins and the International Transmission of Business Cycles, *Journal of International Economics*, 80, 292-301.

[69] Ratto, M. (2008), Analysing DSGE Models with Global Sensitivity Analysis, *Computational Economics*, 31, 115-139.

[70] Ravenna, F., and Walsh, C. E. (2006), Optimal monetary policy with the cost channel, *Journal of Monetary Economics*, 53, 199-216.

[71] Ravenna, F., and Walsh, C. E. (2008), Vacancies, unemployment and the Phillips curve, *European Economic Review*, 52, 1494-1521.

[72] Sander, H., and Kleimeier, S. (2004), Convergence in Euro-zone retail banking? What interest rate pass-through tells us about monetary policy transmission, competition and integration, *Journal of International Money and Finance*, 23, 461-92.

[73] Schorfheide, F. (2000), Loss function-based evaluation of DSGE models, *Journal of Applied Econometrics*, 15(6), 645-670.

[74] Scharler, J. (2008), Do bank-based financial systems reduce macroeconomic volatility by smoothing interest rates?, *Journal of Macroeconomics*, 30, 1207-1221.

[75] Stiglitz, J., and Weiss, A. (1981), Credit rationing in markets with imperfect information, *American Economic Review*, 71, 393-410.

[76] Stock, J., and Watson, M. W. (1989), New Indexes of Coincident and Leading Indicators, *NBER Macroeconomics*, 4, 351-394.

[77] Van Leuvensteijn, M., Kok Sørensen, C., Bikker, J., and Van Rixtel, A. (2008), Impact of bank competition on the interest rate pass-through in the euro area, ECB working paper no. 885.

[78] Wasmer, E., and Weil, P. (2004), The macroeconomics of labor and credit market imperfections, *American Economic Review*, 94, 944-963.

[79] Wicksell, J. (1898), *Interest and prices*, 1836 Edition, London, Macmillan.

Chapter 2

An Estimated DSGE Model with Search and Matching Frictions in the Credit Market†

Financial frictions have become fundamental to study the business cycle and the dynamics of the credit market. This chapter improves this literature by introducing a search and matching scheme in the financial market into a cash in advance New Keynesian DSGE theoretical model. We provide an alternative explanation of the degree of incompleteness in the pass-through from policy rate to loan rates depending on the credit market tightness, on the search costs sustained by banks, and on the relative powers of the agents in the loan interest rate bargaining. The model is able to reproduce the empirical evidence of a positive response of the real wages and the countercyclical behavior of the credit spread with respect to a positive technology shock without the use of real or nominal wage rigidities. Finally a scenario in which a credit shock hits the economy is proposed. The model is estimated by using the Bayesian procedures.

2.1 Introduction

The recent financial crises has contributed to increase the attention to the credit market. In particular, several works show the existence of frictions in financial markets but their significance in the transmission of exogenous shocks to the economy is controversial. In the financial accelerator literature,[1] in presence of asymmetric information, the amplification of the main macroeconomic variables depends on the firms' ability to borrow, that is linked to a market value of their net worth which is inversely related to the external finance premium.[2] Other recent contributions argue instead that financial frictions - in a modeling set up where the banking sector plays an active role in the determination of the price of credit or the supply of financial assets - produce

†We wish to thank P. Benigno, G. Ciccarone, F. Giuli, S. Neri, F. M. Signoretti, M. Tancioni and the participants in a seminar held at the Bank of Italy on 21st December 2011. The views expressed herein are solely those of the author and do not necessarily reflect the views of the Bank of Italy.

[1]See Bernanke, Gertler and Gilchrist (1996, 1999), Calstrom and Fuerst (1997, 1998) for more details on quantitative analysis in partial and general equilibrium frameworks.

[2]The definition of external finance premium is different from that of corporate credit spread. The former is the wedge between the rate of return on capital and the risk-free rate; the latter one is the difference between the contractual loan interest rate and the risk-free rate. See Levin, Natalucci and Zakrajsek (2004) for more details.

an attenuator effect, i.e., a moderation of the responses of the main macroeconomic variables to expansionary shocks.[3] Further, the experience of the recent financial turmoil has confirmed what a strand of literature had argued before the crises, i.e., that shifts in policy rates were not completely passed through to retail (market) banking lending rates, even though significant differences existed in the degree of incompleteness which was experienced across countries. The phenomenon was particularly sharp in the Euro Area.[4] During the financial crisis, the transmission of policy rate changes to retail rates has become less efficient in this Area (Čihák, Harjes and Stavrev, 2009).

The empirical literature also shows another important finding: the interest rate spread and the banking markups are countercyclical and account for large fraction of the variance of the business cycle fluctuations (Gilchrist, Yankov and Zakrajšek, 2009). Chen (1991) and Fama and French (1989) show as the difference between the average yields on BAA rated and AAA-rated corporate bonds rises during recessions and fall during business cycle booms. Corvoisier and Gropp (2002) confirm the countercyclical movement of the credit spread for 11 European countries. The same result is found by Olivero (2010) for the loan margin of many OECD and no OECD countries by using different methods.[5]

By introducing search and matching frictions in the credit market into the standard New Keynesian DSGE model without wage rigidities, the aim of this chapter is to better understand the role of the financial frictions in shaping the business cycle. First of all we want to investigate on the phenomenon of the interest rate pass-through. In particular we want to show how credit matching frictions help to highlight the limited response of the loan rate charged by commercial banks when a Central Bank modifies the policy rate. Second, we show how the search and matching scheme is useful to study the cyclical behavior of the credit spread - that in this work we define as the difference between the banking lending and the policy rates - with respect to a positive technology shock.[6] Then, we focus on the dynamics of the main macroeconomic variables when positive technology and credit efficiency shocks hit the economy. In particular, we analyze the response of the real wages, employment and inflation. Finally, the use of the Bayesian techniques allow us to estimate some deep market parameters that can be useful for the study of credit and financial markets. As a matter of fact, as stressed by Dell'Ariccia and Garibaldi (1998), the role of these parameters for the credit market is relevant: they show that the bargaining power of banks and the speeds at which new loans become available and at which banks recall existing loans are fundamental in explaining the dynamic relationship between aggregate banking lending and interest rate changes in a model where search and matching between banks and investors are present. In our work, a special attention must be made on the estimated value of the bargaining power of banks which plays a crucial role for the limited response of the banking lending rate to policy rate shock.

In the present economy, before production begins, wholesale competitive firms producing a homogeneous good search for lines of credit posted by banks. The firms matching with a credit vacancy posted by banks obtain from them the advances necessary to pay households for the wage

[3] Goodfriend and McCallum (2007)'s model is able to highlight a banking attenuator effect if the monetary shock has a very large volatility. Gerali, Neri, Sessa and Signoretti (2010) find that the sluggishness of the adjustment of bank retes moderates the amplification effect of the financial frictions of their model. Similarly, the imperfect competition in the financial intermediation sector produces attenuation in Andrés and Arce (2008) and Aslam and Santoro (2008)'s models.

[4] See, e.g., de Bondt (2005); Angeloni, Kashyap and Mojon (2003); Gambacorta (2008); de Bondt, Mojon and Valla (2005); Hofmann (2006). More details are provided by the empirical survey by Kwapail and Scharler (2006). A recent review of the literature on the loan rate pass-through in the euro area is in Kobayashi (2008).

[5] See also Dueker and Thornton (1997) for the U.S.

[6] Beaubrun-Diant and Tripier (2009) study the cyclical behavior of the credit spread by using search and matching frictions in the credit market in a partial equilibrium analysis.

bill. Production can then start. At the end of the period wholesale production is sold to retail firms transforming the homogeneous good into differentiated goods bought by households. Loans are then repaid and households receive profit income from banks and firms, and the principal plus interest on deposits from banks. A fraction of the wholesale firms producing in a given period - determined on the basis of a exogenous separation rate specifying the fraction of credit matches which are destroyed at the end of the production period - obtain loans also in the next period. The other firms have to go afresh into the process of search in the credit market.

We are not the first to analyze the role of search and matching technology in the credit market.[7] Along the lines of Diamond (1990), Becsi, Li and Wang (2005, 2009) introduce search and matching frictions in a credit market where borrowers and lenders try to establish a credit relationship and bargain over the interest rate consistent with the optimal loan contract. De Haan, Ramey and Watson (2003) study the lenders-borrowers relationships in a search and matching framework where the agents contract the liquidity allocation along with the entrepreneur's effort choice. Vesala (2007) applies the matching frictions by an "urn ball" process[8] to the financial markets in an economy with asymmetric information.[9]

This chapter differs from previous cited works on search and matching in the credit market because we consider a general equilibrium model. Furthermore, differently from De Haan, Ramey and Watson (2003), and Becsi, Li and Wang (2005) we disregard the heterogeneity of agents. Moreover, in order to focus on the role of matching frictions, we do not consider the moral hazard problem and the incentive frictions highlighted by Vesala (2007) and Becsi, Li and Wang (2005, 2009). We also depart from the previous contributions in other several aspects. First, whereas in the De Haan, Ramey and Watson (2003)'s model the anticipation of the funds, in terms of goods, is determined by a liquidity allocation rule, we adopt a cash in advance (CIA) setup which requires banks to advance the funds necessary to pay for a variable wage bill depending on the real wage and employment. Households choose consumption, employment and the level of deposits, and the banking sector maximizes its profits with respect to the number of vacancies to post and the lines of credit to offer.[10] As in Becsi, Li and Wang (2005) we improve on the standard pairwise matching model by Diamond (1990) by allowing for the endogenous entry of firms in the steady state equilibrium. Finally, differently from all previous works, in our model the bargained interest rate on loans depends on the policy (deposit) rate: this allows us to study how the monetary

[7]The search and matching scheme is also used to model other markets. In particular, this technology is widely used to study the dynamics of the labor market where firms and workers bargain over the wage rate after obtaining a match (Pissarides, 2000; Shimer, 2005; Gertler, Sala and Trigari, 2008). In housing market matching models, sellers and buyers meet to sell and buy an house, respectively; the housing market price is the result of a bargaining process (Weathon, 1990; Albrecht et al., 2007; Genesove and Han, 2010). Mathä and Pierrard (2011) propose a search and matching scheme for the product market between the wholesale firms offering their products by adversiting and marketing, and retail firms asking for wholesale products in order to refill their stores and enlarge their selection. The trade price is subject to the bargaining mechanism. A first attempt to model the good market by introducing search and matching frictions is in Diamond (1982b). A recent review of the literature on the search and matching theory is provided by the the Royal Swedish Academy of Sciences for the Prize in Economic Sciences 2010.

[8]As compared to the pairwise matching framework of Mortensen and Pissarides (1994), the "urn ball" process allows for the possibility that entrepreneurs have multiple simultaneous contacts with different financiers. The price formation is hence provided by an auction rather than a bargaining mechanism.

[9]Recent works employ models embedding search and matching frictions in several interdipendent markets. Interactions between the good and the labor market are studied by Lehmann and Van der Linden (2010); search frictions in both the credit and labor market are analyzed by Wasmer and Weil (2004), Nicoletti and Pierrard (2006), Beaubrun-Diant and Tripier (2009), Ernst and Semmler (2010) and Petrosky-Nadeau and Wasmer (2010a); a first attempt to study the simultaneos interdipendence of good, labor and credit market under search and matching frictions is provided by Petrosky-Nadeau and Wasmer (2010b).

[10]In the De Haan, Ramey and Watson (2003)'s model there is only a good that can be consumed or invested through lenders, whereas Becsi, Li and Wang (2005) assume lenders as a rudimetal moneyholders which are a fusion of households and financial intermediaries.

policy affects the determination of the banking lending rate and, by this rate, the dynamics of the economic system.

This work contributes to highlight the effects of exogenous shocks on the economy by focusing on the credit (liquidity) market. Our general conclusion is that financial frictions play an important role in shaping the economy's dynamics by the credit cost channel of monetary policy.[11] As compared to the previous work on search and matching frictions in the credit market, this chapter also improves the literature of the degree of (in)completeness of the interest rate pass-through of bank rates to changes of the policy rate. As a matter of fact the theoretical framework we adopt proposes a new explanation of the sluggish adjustment of the banking lending rates to modifications of the policy rate based on the search costs in the credit market and the bargaining mechanism which determines the interest rate on loans.[12] Second, we confirm the countercyclical dynamics of the credit spread[13] in presence of technology shocks depending on the modification of the surplus of firms and banks which affects the bargained loan rate. Third, the response of the model to a productivity shock reproduces the standard dynamics of the main macroeconomic variables including the short run decline of the employment known as the *productivity employment puzzle*. In particular a positive response of the real wage without the introduction of nominal or real wage rigidities is highlighted.[14] Further, we show that an exogenous credit efficiency shock - which we can interpret as a cost push shock - hitting the economy determines, by the financial frictions, a variation of the interest rate on loans such that the real marginal costs vary and then the real activity is affected in a positive way. Finally, we are able to estimate some structural credit market parameters, as the bargaining power of banks, the matching elasticity of the financial matching function and posting cost of credit vacancies, which could help to better evaluate some credit market dynamics and phenomena contributing to the literature on subject.

The chapter is structured as follows. In the next section we describe the model economy. In section 2.3 we discuss the estimation methodology. In section 2.4 we present the dynamic properties of the model. Section 2.5 concludes.

2.2 The Model Economy

We introduce search and matching frictions in the financial market into a cash in advance New Keynesian DSGE model with sticky prices. The economy is composed by four sets of agents: households, firms, banks and a monetary authority. In order to pay the wage bill and produce, firms that do not possess capital must obtain loans from banks. Hence, before production begins, wholesale competitive firms search for lines of credit posted by banks, V_t^B, which also collect deposits, D_t, from households. A bank can match with several firms. Each realized match provides the firm with the funds necessary to pay wages to the workers whose nominal value is $P_t w_t N_t$ where P_t is the price index of the economy, w_t is the real wage and N_t represents the household members

[11] See, e.g., Christiano, Eichenbaum and Evans (2005) and Ravenna and Walsh (2006).

[12] Traditional explanations refer to the banks' collusive behavior and to concentration in the financial market (Sander and Kleimeier, 2004; Van Leuvensteijn et al., 2008), agency costs á la Stiglitz and Weiss (1981), customer switching costs á la Klemperer (1987), fixed adjustment and menú costs depending on the temporal or permanent nature of the policy rate changes, or to the so-called customer reaction hypothesis linked to the degree of the bargaining power of borrowers (Hannan and Berger, 1991).

[13] It is useful to clarify that the interest rate spread highlighted in this work is the difference between the interest rate on loans, which is bargained between banks and firms, and the policy rate. Hence, the absence of asymmetric information, default probabilities and bankruptcy costs implies that the definition of the interest rate spread used here is different from those of external financial premium and of corporate credit spread.

[14] See Blanchard and Galí (2010) and Erceg, Henderson and Levin (2000). For a critical survey on the role of the real and nominal wage rigidities in the New Keynesian models see Riggi (2009).

employed. After wages are paid production occurs. Monopolistic competitive retail firms transform wholesale homogeneous goods into differentiated retail goods which are sold to households. At the end of the period, banks receive from firms the principal plus interest on loans; households receive profit income from financial intermediaries and firms, and the principal plus interest on deposits. A fraction of the existing financial relationships between wholesale firms and banks is separated in each period according to an exogenous separation rate. The firms that do separate from banks obtain loans also in the next period. The monetary authority sets the rate of interest according to a rule to be specified below.

2.2.1 Matching

In the credit market search frictions prevent some firms from obtaining the lines of credit necessary to borrow funds, and some banks from filling all their posted lines of credit vacancies. Banks choose the number of credit vacancies, V_t^B, they want to post, whereas the demand for lines of credit is represented by the number of wholesale firms searching for a bank, s_t^F. The number of new matches in the credit market is determined by the matching function $H_t = H(V_t^B, s_t^F)$, which is homogeneous of degree one and increasing in its arguments. It follows that $p_t^B = H(V_t^B, s_t^F)/s_t^F$ is the probability that a firm matches with a credit vacancy posted by bank (credit line finding rate), and that $q_t^B = H(V_t^B, s_t^F)/V_t^B$ is the probability for a bank of filling a posted credit vacancy (credit vacancy filling rate). Then, in each period, it must be: $H(V_t^B, s_t^F) = V_t^B q_t^B = s_t^F p_t^B$. As in existing models with search and matching frictions, $p_t^B = p^B(\theta_t^C)$, with $p^{B'}(\theta_t^C) < 0$, is a function of the aggregate tightness in the credit market (from the viewpoint of the firm), $\theta_t^C \equiv s_t^F/V_t^B$. It follows that the matching probability q_t^B is also function of the credit market tightness: $q_t^B = q^B(\theta_t^C)$, with $q^{B'}(\theta_t^C) > 0$. It is possible to define the inverse of credit market tightness as an index of the liquidity of the credit market (Wasmer and Weil, 2004).

In order to describe the matching process, we employ a Cobb-Douglas function for the matches in the credit market: $H_t = \varsigma_t (V_t^B)^{\xi} (s_t^F)^{1-\xi}$, where ς_t represents a credit market efficiency shock whose stochastic stationary first-order autoregressive process is $\varsigma_t = \varsigma_{t-1}^{\rho^{\varsigma}} e^{\epsilon_t^{\varsigma}}$ with $\epsilon_t^{\varsigma} \overset{i.i.d.}{\sim} N\left(0, \sigma_{\varsigma}^2\right)$. Hence, it is possible to specify the credit market probabilities as functions θ_t^C in a form which will be useful when analyzing steady states and log-linearizing the model: $p_t^B = \varsigma_t (1/\theta_t^C)^{\xi}$ or $p_t^B = \varsigma_t (V_t^B)^{\xi} (s_t^F)^{-\xi}$ and $q_t^B = \varsigma_t (\theta_t^C)^{1-\xi}$ or $q_t^B = \varsigma_t (V_t^B)^{\xi-1} (s_t^F)^{1-\xi}$. It follows that: $p_t^B = q_t^B/\theta_t^C$. If credit market tightness increases (because the number of firms searching for a line of credit goes up, or because the number of credit vacancies posted by banks falls), the probability that a firm matches with a line of credit posted by a bank, p_t^B, diminishes, whereas the probability that a credit vacancy is filled, q_t^B, increases.

As in the search and matching models in the labor market, the elasticities with respect to searchers and vacancies in the credit market measure externality effects. In particular: ξ represents the positive externality (the liquidity market effect) caused by banks on searching firms; $\xi - 1$ is the negative effect of the banks on the other financial intermediaries; $-\xi$ represents the congestion effect determined by the firms having a credit relationship with a bank on the firms which do not have a financial relation; $1 - \xi$ measures the positive externality from firms searching for a line of credit to banks.

2.2.2 Households

There exists a continuum of households of mass one maximizing the expected discounted value of their utility. The preferences of the representative household are defined over a composite consumption good, consisting of the differentiated goods produced by retail firms, and leisure. The household enters each period with a given amount of nominal cash holding M_t and buy retail goods using the money endowments and the wage income $(P_t w_t N_t)$ net of nominal deposits with banks D_t. It follows that $M_t + P_t w_t N_t - D_t$ is spent to purchase consumption goods from retail firms, of value $P_t C_t$. As in Dixit and Stiglitz (1977), it is $C_t = \left(\int_0^1 C_{it}^{\frac{\varepsilon-1}{\varepsilon}} di\right)^{\frac{\varepsilon}{\varepsilon-1}}$, where $C_{it} = (\frac{P_{it}}{P_t})^{-\varepsilon} C_t$ and $\varepsilon > 1$ is the parameter governing the elasticity of individual goods, which are indexed by i. The cost of one unit of the consumption basket is given by the aggregation of the prices of the differentiated products, $P_t = \left(\int_0^1 P_{it}^{1-\varepsilon} di\right)^{\frac{1}{1-\varepsilon}}$. Hence, the purchase of consumption goods is subject to the CIA constraint: $P_t C_t \leq M_t + P_t w_t N_t - D_t$.[15] At the end of the period households receive retail firms' and banks' profits, denoted by Π_t^F and Π_t^B, and obtain the reimbursement of their deposits plus the interest on them: $R_t^D D_t = (1 + r_t^D) D_t$. It follows that the amount of money carried over to the following period is: $M_{t+1} = M_t + P_t w_t N_t - D_t - P_t C_t + \Pi_t^F + \Pi_t^B + R_t^D D_t$.[16] By substituting the CIA constraint into this equation we get: $M_{t+1} = \Pi_t^F + \Pi_t^B + R_t^D D_t$. Calculating this equation a period backward and substituting the result into the CIA constraint gives: $P_t C_t = P_t w_t N_t + \Pi_{t-1}^F + \Pi_{t-1}^B - D_t + R_{t-1}^D D_{t-1}$, which can be expressed in real terms as:

$$C_t = w_t N_t + \frac{\Pi_{t-1}^F}{P_t} + \frac{\Pi_{t-1}^B}{P_t} - \frac{D_t}{P_t} + R_{t-1}^D \frac{D_{t-1}}{P_t} \tag{2.1}$$

This equation states that consumption and savings are financed by real labor income $w_t N_t$, the sum generated by previous period deposits, $\frac{R_{t-1}^D D_{t-1}}{P_t}$, and profits from banks and retailers, $\frac{\Pi_{t-1}^F + \Pi_{t-1}^B}{P_t}$. The representative household hence solves the problem:

$$\begin{aligned} J_t^H &= \max \left[\varphi_t U(C_t, N_t) + \beta E_t J_{t+1}^H\right] \\ & \quad s.t. \quad (2.1) \end{aligned}$$

where β is the household's subjective discount factor and φ_t is a preference shock on the wedge between consumption and leisure whose stochastic process is $\varphi_t = \varphi_{t-1}^{\rho^\varphi} e^{\epsilon_t^\varphi}$ with $\epsilon_t^\varphi \overset{i.i.d.}{\sim} N\left(0, \sigma_\varphi^2\right)$. A CRRA specification for $U(C_t, N_t) = \frac{C_t{}^{1-\sigma}}{1-\sigma} - \vartheta_t \bar{\vartheta} \frac{N_t^{1+\phi}}{1+\phi}$ provides the first order conditions which lead to the standard Euler equation of the baseline New Keynesian model and to the definition of the real wage equal to the marginal rate of substitution between consumption and leisure:

$$\lambda_t = R_t^D \beta E_t \frac{P_t}{P_{t+1}} \lambda_{t+1} \tag{2.2}$$

$$w_t = \vartheta_t \bar{\vartheta} \frac{N_t^\phi}{C_t^{-\sigma}} \tag{2.3}$$

where $\lambda_t = \varphi_t C_t^{-\sigma}$ is the marginal utility of consumption, $\bar{\vartheta}$ is a constant term, and ϑ_t is a preference shock on leisure whose stochastic process is $\vartheta_t = \vartheta_{t-1}^{\rho^\vartheta} e^{\epsilon_t^\vartheta}$ with $\epsilon_t^\vartheta \overset{i.i.d.}{\sim} N\left(0, \sigma_\vartheta^2\right)$. The unemployment is $U_t = 1 - N_t$.

[15] The CIA constraint is always binding because the nominal interest rate is positive and agents choose their asset (deposit) holdings after observing the current shock but before entering the good market (Lucas 1982).

[16] The firms' profits are the sum of those of retail and specialized firms. See section (2.2.8).

2.2.3 Wholesale firms

There exists a continuum of wholesale firms in the unit interval producing homogenous goods in a competitive sector. The production function of the representative wholesale firm is:

$$Y_t^w = A_t N_t^\alpha \tag{2.4}$$

where A_t is a productivity shock with unit mean, $E_t(A_t) = 1$, and whose stochastic stationary first-order autoregressive process is $A_t = A_{t-1}^{\rho^A} e^{\epsilon_t^A}$ with $\epsilon_t^A \overset{i.i.d.}{\sim} N\left(0, \sigma_A^2\right)$. The representative firm must determine the labor demand. Its profit maximization problem is:

$$\begin{aligned} \max \quad & \frac{Y_t^w}{\mu_t} - w_t R_t^L N_t \\ s.t. \quad & (2.4) \end{aligned}$$

where μ_t is the is the mark-up of the retail sector over the price of the wholesale good, P_t/P_t^w, and the costs depend on the repayment of the loans received by banks (the wage bill granted to households plus the interest on loans). The first order condition with respect to the employment yields:

$$\frac{1}{\mu_t} = \frac{w_t R_t^L}{mpl_t} \tag{2.5}$$

where $mpl_t = \alpha A_t N_t^{\alpha-1}$ is the labor marginal productivity. Given the competitiveness of the wholesale sector, the mark-up $\frac{1}{\mu_t}$ is equal to the real marginal cost paid by the retail firms to buy the homogenous good. It is thus $\frac{1}{\mu_t} = mc_t$, i.e., the firms' real marginal cost is equal to the usual ratio between the labor cost, $w_t R_t^L$, and the labor marginal productivity, mpl_t.

2.2.4 Retail firms

Retail firms purchase the goods produced by the wholesale sector and transform them into the differentiated products purchased by households. Each firm, which is a monopolist in its sector sets prices according to the Calvo (1983) rule, adjusting its price with probability $1 - \omega$. We assume that credit vacancy posting is "produced" at no cost by a specialized firm. Vacancies are costs for banks and proceeds for the specialized firm which enter aggregate profits that can be spent by households on the basis of the consumption demand for the individual good. This allows us to write $C_{it} = Y_{it}$, or in aggregate terms, $C_t = Y_t$.[17] Then, in a symmetric equilibrium, all firms set the price $P_t^* = P_{it}$, so as to maximize the expected lifetime profits subject to the demand:

$$\begin{aligned} \max \quad & E_t \sum_{l=0}^{\infty} \omega^l \beta^l \frac{\lambda_{t+1}}{\lambda_t} \left[\left(\frac{P_t^*}{P_{t+l}} \right) - mc_{t+l} \right] Y_{it+l} \\ s.t. \quad & Y_{it} = \left(\frac{P_{it}}{P_t} \right)^{-\varepsilon} Y_t \end{aligned}$$

[17] See the section (2.2.8)

This provides the price equation:

$$\frac{P_t^*}{P_t} = \Theta \frac{E_t \sum_{l=0}^{\infty} \omega^l \beta^l mc_{t+l} \left(\frac{P_{t+l}}{P_t}\right)^{\varepsilon} C_{t+l}^{1-\sigma}}{E_t \sum_{l=0}^{\infty} \omega^l \beta^l \left(\frac{P_{t+l}}{P_t}\right)^{\varepsilon-1} C_{t+l}^{1-\sigma}} \tag{2.6}$$

where: $\Theta = \frac{\varepsilon}{\varepsilon-1}$. Under flexible prices, equation (2.6) reduces to the standard Blanchard and Kiyotaki (1987) equation:

$$\frac{P_t^*}{P_t} = \Theta mc_t \tag{2.7}$$

From (2.6) the usual (log-linearized) New Keynesian Phillips curve (NKPC) is obtained:

$$\pi_t = \beta E_t \pi_{t+1} + \kappa \widehat{mc}_t + \hat{\psi}_t \tag{2.8}$$

where $\kappa = \frac{(1-\beta\omega)(1-\omega)}{\omega}$ and $\hat{\psi}_t = \rho^{\psi} \hat{\psi}_{t-1} + \epsilon_t^{\psi}$ with $\epsilon_t^{\psi} \overset{i.i.d.}{\sim} N\left(0, \sigma_{\psi}^2\right)$ is the log-linearized version of the cost push shock process $\psi_t = \psi_{t-1}^{\rho^{\psi}} e^{\epsilon_t^{\psi}}$. The symbol "hat" denotes the percentage deviation of a variable from its steady state value. The NKPC (2.8) can be expressed in terms of the output gap $x_t = \hat{Y}_t - \hat{Y}_t^{qf}$ where $\hat{Y}_t^{qf} = \frac{1+\phi}{[1+\phi+\alpha(\sigma-1)]} \hat{A}_t$ represents the quasi flexible equilibrium output:[18]

$$\pi_t = \beta E_t \pi_{t+1} + \kappa(\hat{R}_t^L + \hat{\vartheta}_t) + \kappa \tau x_t + \hat{\psi}_t \tag{2.9}$$

where $\tau = \frac{[1+\phi+\alpha(\sigma-1)]}{\alpha}$.

2.2.5 Banks

Each match in the credit market provides firms with the funds necessary to pay the wage bill to the households. Production then starts, the proceeds from sales allow firms to repay the loans and to pay the charged interest to the bank. In the following period, if a separation does not occur, each of these firms will continue to have their wage bill financed by banks. The exogenous separation rate in the credit market is denoted $\rho^B \in [0, 1]$. We make the timing assumption that the new matches in the credit market are transformed into lines of credit immediately. Given these assumptions, the lines of credit financing firms evolve according to:

$$L_t^N = (1 - \rho^B) L_{t-1}^N + q_t^B V_t^B \tag{2.10}$$

Assuming that the atomistic wholesale firms have unit mass, the previous equation contributes to determine the fraction of those searching for credit:

$$s_t^F = 1 - (1 - \rho^B) L_{t-1}^N \tag{2.11}$$

[18] The detailed derivation of the model is provided in a technical appendix available from the authors upon request.

The optimal value function of the representative bank is:[19]

$$J_t^B = \max\left[(R_t^L - R_t^D)w_t N_t L_t^N - R_t^D k^B V_t^B + R_t^D \frac{X_t}{P_t} + \beta E_t \frac{\lambda_{t+1}}{\lambda_t} J_{t+1}^B\right] \tag{2.12}$$

where k^B is the real cost of posting a credit vacancy and $X_t = M_{t+1} - M_t$ is the cash injection from the monetary authority. The bank chooses V_t^B by maximizing (2.12) subject to (2.10). Its decision yields:

$$\frac{k^B R_t^D}{q_t^B} - (R_t^L - R_t^D)w_t N_t = \beta E_t \frac{\lambda_{t+1}}{\lambda_t}\frac{\partial J_{t+1}^B}{\partial L_t^N} \tag{2.13}$$

By using the envelope theorem we obtain:

$$\frac{\partial J_t^B}{\partial L_{t-1}^N} = (1-\rho^B)(R_t^L - R_t^D)w_t N_t + \beta(1-\rho^B)E_t \frac{\lambda_{t+1}}{\lambda_t}\frac{\partial J_{t+1}^B}{\partial L_t^N} \tag{2.14}$$

Combining equations (2.13) and (2.14) we get what we interpret as the "credit creating condition":

$$\frac{k^B R_t^D}{q_t^B} = (R_t^L - R_t^D)w_t N_t + (1-\rho^B)\beta E_t \frac{\lambda_{t+1}}{\lambda_t}\frac{k^B R_{t+1}^D}{q_{t+1}^B} \tag{2.15}$$

The condition to offer a new line of credit depends on the bank's discounted stream of earnings and of savings on credit vacancy posting. In particular, the expected cost of financing a matched firm, $\frac{k^B R_t^D}{q_t^B}$, is equal to the marginal profits that bank obtains from the loan advanced to a matched firm plus the expected saving the following period of not having to create a new match. Note that if $k^B = 0$, then it must be $R_t^L = R_t^D$.

2.2.6 Loan interest rate bargaining

The rate of interest on loans is negotiated by banks and firms through a Nash bargaining. The value of an unfilled credit vacancy is:

$$B_t^u = -k^B R_t^D + q_t^B B_t^m + (1-q_t^B)\beta E_t \frac{\lambda_{t+1}}{\lambda_t} B_{t+1}^u \tag{2.16}$$

The value of an unfilled credit vacancy is provided by the cost incurrence $k^B R_t^D$ and by the bank current and (discounted) future values, B_t^m and B_{t+1}^u which a bank gets if a credit match is obtained (with probability q_t^B) or not (with probability $1 - q_t^B$), respectively. Banks open vacancies until it is profitable to do so. Given the free entry condition $B_t^u = 0 \ \forall \ t$, the value of a filled credit vacancy is $B_t^m = \frac{k^B R_t^D}{q_t^B}$ and the bank's surplus, $S_t^B = B_t^m - B_t^u$, is:

$$S_t^B = \frac{k^B R_t^D}{q_t^B} \tag{2.17}$$

[19] The bank's profit at time t is given by revenues minus costs. Revenues are given by the repayment of the real loans financing wages plus interest, $R_t^L\left(w_t N_t L_t^N\right)$. Costs are equal to the repayment of deposits and money plus interest, $R_t^D \frac{D_t}{P_t} + R_t^D \frac{X_t}{P_t} = R_t^D\left(w_t N_t L_t^N + k^B V_t^B\right)$. By using the bank's balance sheet, stating that deposits and money finance the loans provided to firms and the repayment of the credit vacancies, $\frac{D_t}{P_t} + \frac{X_t}{P_t} = \frac{L_t}{P_t} + k^B V_t^B$, the profit function of the bank is straightforwardly obtained. It is useful to note as the nominal cost of posting credit vacancies is $k^B P_t$.

or, from condition (2.15), $S_t^B = (R_t^L - R_t^D)w_t N_t + (1-\rho^B)\beta E_t \frac{\lambda_{t+1}}{\lambda_t}\frac{k^B R_t^D}{q_{t+1}^B}$.

The surplus of a firm is the difference between the value of the firm if a match is obtained, F_t^m, and if it is not obtained, F_t^u. F_t^m is equal to the current profits of the firms plus the expected value in the following period. In period $t+1$ the firm will have a value equal to F_{t+1}^m if it does not experience a separation with the bank $(1-\rho^B)$ or if a separation occurs and it finds a new match in the credit market $(\rho^B p_{t+1}^B)$. The firm's value will be equal to F_{t+1}^u if it does not realize a match in the credit market after a separation, $\rho^B(1-p_{t+1}^B)$. If a firm in period t does not find a match with a bank it does not obtain the funds necessary to start production, its current profits are zero and its current value depends only on its expected value: if in the period $t+1$ it finds a match the value will be F_{t+1}^m; it will be F_{t+1}^u otherwise. So the values of the generic firm are:

$$F_t^m = \frac{Y_t^w}{\mu_t} - w_t R_t^L N_t + \beta E_t \frac{\lambda_{t+1}}{\lambda_t}\left[(1-\rho^B+\rho^B p_{t+1}^B)F_{t+1}^m + \rho^B(1-p_{t+1}^B)F_{t+1}^u\right] \tag{2.18}$$

$$F_t^u = \beta E_t \frac{\lambda_{t+1}}{\lambda_t}\left[p_{t+1}^B F_{t+1}^m + (1-p_{t+1}^B)F_{t+1}^u\right] \tag{2.19}$$

and the firm' surplus is:

$$S_t^F = F_t^m - F_t^u = \frac{Y_t^w}{\mu_t} - w_t R_t^L N_t + (1-\rho^B)\beta E_t \frac{\lambda_{t+1}}{\lambda_t}(1-p_{t+1}^B)S_{t+1}^F \tag{2.20}$$

The loan interest rate is determined by the maximization of the Nash product:

$$\max(S_t^F)^z(S_t^B)^{1-z} \tag{2.21}$$

where z represents the bargaining power of firms. The optimal condition is:

$$(1-z)\gamma_t^B S_t^F + z\gamma_t^F S_t^B = 0 \tag{2.22}$$

where $\gamma_t^B = \frac{\partial S_t^B}{R_t^L} = w_t N_t$ and $\gamma_t^F = \frac{\partial S_t^F}{R_t^L} = -w_t N_t$ are the marginal effects of the loan interest rate on the surplus of the agents. Then the optimal condition is reduced to $(1-z)S_t^F = zS_t^B$. By using the definition of the bank's surplus it is possible to write:

$$S_t^F = \frac{z}{(1-z)}\frac{k^B R_t^D}{q_t^B}. \tag{2.23}$$

By using the credit creating condition (2.15) and the definitions of bank' surplus (2.17) and of firm' surplus (2.20) it is possible to obtain the bargained loan interest rate:

$$R_t^L = \frac{(1-z)}{w_t N_t}\frac{Y_t^w}{\mu_t} + \frac{z}{w_t N_t}\left[R_t^D w_t N_t - (1-\rho^B)\beta E_t \frac{\lambda_{t+1}}{\lambda_t}\frac{k^B R_{t+1}^D}{\theta_{t+1}^C}\right] \tag{2.24}$$

The interest rate on loans turns out to be a weighted average of the firm's revenues, on one side, and the rate of interest on deposits net of the banks' future expected present saving from maintaining a credit relation with a firm, on the other side. The weights are the relative bargaining powers of the agents. If $z=1$ firms are able to obtain a loan interest rate equal to to the deposit interest rate net the bank' saving; if $z=0$ banks are able to set a loan interest equal to the firm's marginal profit.

The interest rate pass-through is defined as the percentage deviation of the interest rate on loans from its steady state value, $\hat{R}_t^L$, minus that of the policy rate from own steady state, $\hat{R}_t^D$. Hence we have a complete, incomplete or more than complete interest rate pass-through if $\frac{\partial \hat{R}_t^L}{\partial \hat{R}_t^D}$ is equal, less or greater than 1, respectively. Hence, in order to highlight the degree of the interest rate pass-through,[20] by using equations (2.2) and (2.5), the log-linearized version of equation (2.24) can be written in the following way:

$$\hat{R}_t^L = \Lambda_1 \hat{R}_t^D + \Lambda_2 \left[E_t \hat{\theta}_{t+1}^C - E_t \hat{R}_{t+1}^D + \left(\hat{w}_t + \hat{N}_t - E_t \hat{\pi}_{t+1} \right) \right] + \hat{\upsilon}_t \tag{2.25}$$

where the stochastic term $\hat{\upsilon}_t = \rho^{\upsilon} \hat{\upsilon}_{t-1} + \epsilon_t^{\upsilon}$ with $\epsilon_t^{\upsilon} \overset{i.i.d.}{\sim} N\left(0, \sigma_{\upsilon}^2\right)$ denotes the log-linearized version of the stochastic stationary first-order autoregressive process of the exogenous shock $\upsilon_t = \upsilon_{t-1}^{\rho^{\upsilon}} e^{\epsilon_t^{\upsilon}}$ appended to the bargained interest rate on loans equation to estimate the model. The term $\Lambda_1 = \frac{\alpha z}{R^L(\alpha - 1 + z)} \left[R^D + \frac{(1-\rho^B)p^B}{wN} \frac{k^B}{q^B} \right]$ represents the *direct* pass-through from the policy rate, $\hat{R}_t^D$, to the retail banking lending rate, $\hat{R}_t^L$, whereas the coefficient $\Lambda_2 = \frac{\alpha z}{R^L(\alpha-1+z)} \frac{(1-\rho^B)p^B}{wN} \frac{k^B}{q^B}$ represents the *indirect* pass-through due to the credit frictions depending on the expected credit market tightness $E_t \hat{\theta}_{t+1}^C$ and the expected policy rate $E_t \hat{R}_{t+1}^D$, and on the nominal value of the loan (equal to the wage bill) lent to the generic wholesale firm. It is useful to note that the steady state banking lending interest rate can be written as $R^L = \Upsilon R^D$ where $\Upsilon = \frac{z\left\{1 + \frac{(1-\rho^B)\beta p^B}{[1-(1-\rho^B)\beta]}\right\}}{\left\{1 - \frac{(1-z)}{\alpha} + \frac{z(1-\rho^B)\beta p^B}{[1-(1-\rho^B)\beta]}\right\}}$ is the mark-up over the steady state policy rate.[21]

By observing equation (2.25) we get the following points:

Proposition 1 *If banks have no bargaining power, i.e.* $z = 1$*, then* $\Upsilon = 1$ *and* $R^L = R^D$*, the direct pass-through is more than complete, i.e.* $\Lambda_1 > 1$*, and the degree of the interest rate pass-through depends on the credit frictions measured by* Λ_2*.*

When banks have no bargaining power, firms are able to obtain a banking lending interest rate which differs from the policy rate only for the presence of the banks' saving. Hence, in this case, the posting costs are paid period by period from banks and they do not affect the steady state interest rate on loans.

Proposition 2 *If the posting cost* $k^B = 0$ *the indirect pass-through is* $\Lambda_2 = 0$ *and the pass-through reduces to the direct pass-through* $\Lambda_1 = \frac{\alpha z}{(\alpha - 1 + z)\Upsilon}$.

When the posting activity is free there are not expected saving in the following period of not creating a new match: search and matching credit frictions do not matter and the banking lending rate is the result of a more simplified weighted average of the current revenues of the firms and the policy rate. The degree of the interest rate pass-through depends on the value of the bargaining power z.

Proposition 3 *If the* $z = 1$ *and* $k^B = 0$ *then* $\Upsilon = 1$, $\Lambda_2 = 0$ *and* $\Lambda_1 = 1$*: the pass-through is perfectly complete and* $R^L = R^D$*.*

When the posting activity is free there and banks have no bargaining power credit frictions do not matter and the firms are able to impose to the banks a lending rate equal to the policy rate both in the short run

[20] We refer to the short run interest rate pass-through.

[21] See the technical appendix for the log-linearization of the interest rate on loans equation and for derivation of its steady state version.

and in the steady state. Hence the interest rate pass-through is perfectly complete.

The other measure we use in the following of the chapter is the interest rate credit spread which we define as $SP_t = R_t^L - R_t^D$ where its log linearized version is $\widehat{SP}_t = \frac{R^L \hat{R}_t^L - R^D \hat{R}_t^D}{SP}$. So, it is evident that the dynamics of the credit spread depends on both dynamics and steady state values of the loan and policy rates.

Differently from the standard literature on search and matching with a bargaining mechanism, and following Becsi, Li and Wang (2005), we assume a steady state equilibrium condition for the endogenous entry of firms. We suppose that the unmatched value of firms is not zero, but that it can be thought of as the firm's reservation value which is associated to a flow entry cost. This allows us to determine the endogenous credit line finding rate of firms.[22] Firms will search for a line of credit as long as their unmatched value exceeds their entry cost, $\overline{c}$. By contrast, firms do not enter the credit market if the entry cost is larger than the unmatched value. Hence, the entry competition among the atomistic wholesale firms implies, in equilibrium, the steady state condition $F^u = \overline{c}$. By using the steady state version of equations (2.18) and (2.19), and by imposing $F^u = \overline{c}$, we obtain the zero profit condition:

$$p^B = \frac{\overline{c}(1-\beta)(1-\beta+\beta\rho^B)}{\beta\left[\left(\frac{Y}{\mu} - wR^L N\right) - (1-\beta)(1-\rho^B)\overline{c}\right]} \tag{2.26}$$

Consistently with the Becsi, Li and Wang (2005) findings, this condition states that the credit line finding rate satisfying the zero profit condition increases with the entry cost, $\overline{c}$, the interest rate on loans, R^L, and the exogenous separation rate, ρ^B, and decreases with the productivity level, A.[23] Given the inverse relationship between the net profits of firms and their probability of obtaining a line of credit, it is possible to highlight the congestion effect in the credit market. As the firms' (expected) profits rise, more firms look for a line of credit in the financial market, the probability to find a line of credit falls and the (extra)profits are reset. Furthermore we can observe that:

Proposition 4 *If $k^B \to 0$ then $q^B \to 0$ and $\frac{k_a^B}{k_b^B} = \frac{q_a^B}{q_b^B}$ such that the expected posting cost $\frac{k^B}{q^B}$ is constant where a and b indicate two different scenarios. Then variations of the degree of the interest rate pass-through depend on changes of the expected posting cost, i.e. $\Delta\left(\frac{k^B}{q^B}\right)$. Moreover since the expected firms entry cost can be rewritten as $\frac{\overline{c}}{p^B} = \frac{k^B R^D}{q^B}\frac{(1-z)(1-\beta)}{z\beta}$, variations of k^B do not modify the ratio $\frac{\overline{c}}{p^B}$.*

Proof. The steady state version of equation (2.15) yields $q^B = \frac{k^B R^D[1-(1-\rho)\beta]}{(R^L - R^D)wN}$. Given ρ^B, N and β, and since R^L, R^D and w are not affected by changes of k^B, if in the scenario a $k^B = k_a^B$ yields $q^B = q_a^B$,

[22] In the present work this issue is implemented only to find a steady state version of the credit line finding rate, p^B, depending on the entry cost $\overline{c}$. As a matter of fact our firms' population is normalized to 1 and the number of firms searching for a relationship with a bank depends on the state variable L_t^N.

[23] It is useful to note that a larger separation rate increases the credit line finding rate if $\beta\left(\frac{Y}{\mu} - wR^L N\right) > (1-\beta)(1-\beta+\beta^2)\overline{c}$ holds.

and in the scenario b $k^B = k^B_b$ yields $q^B = q^B_b$, then we always get $\frac{k^B_a}{q^B_a} = \frac{k^B_b}{q^B_b} = \frac{(R^L - R^D)wN}{R^D[1-(1-\rho)\beta]}$ constant. Moreover, given $F^u = \bar{c}$, the steady state version of the equation (2.19) provides $S^F = \frac{1-\beta}{\beta}\frac{\bar{c}}{p^B}$ whereas that of equation (2.23) is $S^F = \frac{z}{1-z}\frac{k^B R^D}{q^B}$. By equating the previous two definitions we get $\frac{\bar{c}}{p^B} = \frac{k^B R^D}{q^B}\frac{(1-z)(1-\beta)}{z\beta}$.[24]

The previous propositions highlights as the bargaining power z and the expected posting cost $\frac{k^B}{q^B}$ are the determinants of the degree of the pass-through in the short run as well as of the value of the steady state banking lending rate.

2.2.7 Monetary authorities

A central bank employs the following (log-linearized) monetary rule to set the policy rate, which we assume for simplicity equal to the rate on deposits:

$$\hat{R}^D_t = \rho^R \hat{R}^D_{t-1} + (1-\rho^R)\left[\delta_\pi \hat{\pi}_t + \delta_x x_t\right] + \hat{\nu}_t \tag{2.27}$$

where ρ^R is the degree of interest rate smoothing and δ_π and δ_x are the weights assigned to the inflation $\hat{\pi}_t$ and output gap x_t, respectively. The stochastic term $\hat{\nu}_t = \rho^\nu \hat{\nu}_{t-1} + \epsilon^\nu_t$ with $\epsilon^\nu_t \overset{i.i.d.}{\sim} N\left(0, \sigma^2_\nu\right)$ denotes the log-linearized version of the stochastic stationary first-order autoregressive process of the monetary policy shock $\nu_t = \nu^{\rho^\nu}_{t-1} e^{\epsilon^\nu_t}$.

2.2.8 Market clearing

The aggregate resource constraint (ARC) is derived from the aggregate money carried over to the following period in real terms. In particular, being the total labor demand $\int L^N_{jt} N_t dj = L^N_t N_t$ (the labor demand of the L^N_t financed firms which have a relationship with a bank) and the total firms' profits the sum of those obtained by retail $\left(\frac{\Pi^R_t}{P_t}\right)$ and specialized firms $\left(\frac{\Pi^{SP}_t}{P_t}\right)$ the ARC becomes:

$$\frac{X_t}{P_t} = w_t N_t L^N_t - \frac{D_t}{P_t} - C_t + R^D_t \frac{D_t}{P_t} + \frac{\Pi^R_t}{P_t} + \frac{\Pi^B_t}{P_t} + \frac{\Pi^{SP}_t}{P_t} \tag{2.28}$$

The aggregate banks' balance sheet and profit function are $\frac{D_t}{P_t} + \frac{X_t}{P_t} = w_t N_t L^N_t + k^B V^B_t$ and $\frac{\Pi^B_t}{P_t} = R^L_t w_t N_t L^N_t - R^D_t w_t N_t L^N_t - R^D_t k^B V^B_t + R^D_t \frac{X_t}{P_t}$ respectively. By replacing them into equation (2.28) and by remembering that $\frac{\Pi^{SP}_t}{P_t} = k^B V^B_t$ we have:

$$C_t = \frac{\Pi^R_t}{P_t} + R^L_t w_t N_t L^N_t \tag{2.29}$$

[24]For a complete explanation of the relationship between the expected entry cost and the expected posting cost see the the technical appendix.

The total real aggregate wholesale production is $\int L_{jt}^N Y_t^w \frac{P_t^w}{P_t} dj = Y_t^w \frac{P_t^w}{P_t} \int L_{jt}^N dj = L_t^N \frac{Y_t^w P_t^w}{P_t}$. Then the real profits of retail firms are $\frac{\Pi_t^R}{P_t} = Y_t^d - L_t^N \frac{Y_t P_t^w}{P_t}$ where Y_t^d is the aggregate demand for goods. Further the equilibrium in the good market implies $Y_t^d = Y_t$. Then the ARC becomes:

$$C_t = Y_t - L_t^N \frac{Y_t P_t^w}{P_t} + R_t^L w_t N_t L_t^N \tag{2.30}$$

Since its competitiveness the wholesale sector do zero profits. Then it must be: $L_t^N \frac{Y_t P_t^w}{P_t} = L_t^N R_t^L w_t N_t$ By replacing the latter condition into (2.30) we finally have:

$$C_t = Y_t \tag{2.31}$$

Furthermore the wholesale production is linked to the aggregate demand by the following expression:

$$Y_t^w = Y_t f_t \tag{2.32}$$

where $f_t = \int \left(\frac{P_{it}}{P_t}\right)^{-\varepsilon} di$ is a factor of price dispersion. As shown by Galí (2008) this factor is equal to zero up to a first order approximation when we linearized the model in a neighborhood of zero inflation steady state.

2.3 Estimation

The model is estimated by Bayesian methods. In this section, we first discuss the data, the calibrated parameters and the priors, and then we report the parameter estimates. In particular, we estimate the structural credit market and agents' preferences parameters driving the model dynamics and allowing to compute the steady state version of the model. Further we employ a sensitivity analysis in order to identify the stability domain of the model.

2.3.1 Data

We use 7 observables for the U.S.: real GDP, employment, real wage, inflation, the federal funds rate, the weighted average effective loan rate and an index of the credit market tightness. For a description of the data, see the technical appendix. The sample period is 1997:Q2 - 2011:Q4. We use the logarithmic transformation for the quarterly interest rates, i.e. $\log(1 + \frac{r_t^j}{100})$ where $j = D, L$ whereas the credit market tightness index is demeaned and the inflation rate is computed as the quarter on quarter log difference of nominal prices. All remaining data are transformed by employing the logarithmic first difference operator. Figure 2.1 plots the transformed data.

2.3.2 Calibrated Parameters

In this section we set the values of the calibrated parameters of the model. Table 2.1 reports them. Due to the large consensus on the quarterly value of the discount factor by the economic literature, we impose β equal to 0.996 so as to obtain a quarterly real steady state rate on deposits $R^D = 1.0035$ (de Walque, Pierrard and Rouabah, 2010). Further, we assume a logarithmic form for the utility function over consumption ($\sigma = 1$). As widely accepted by the literature on the subject

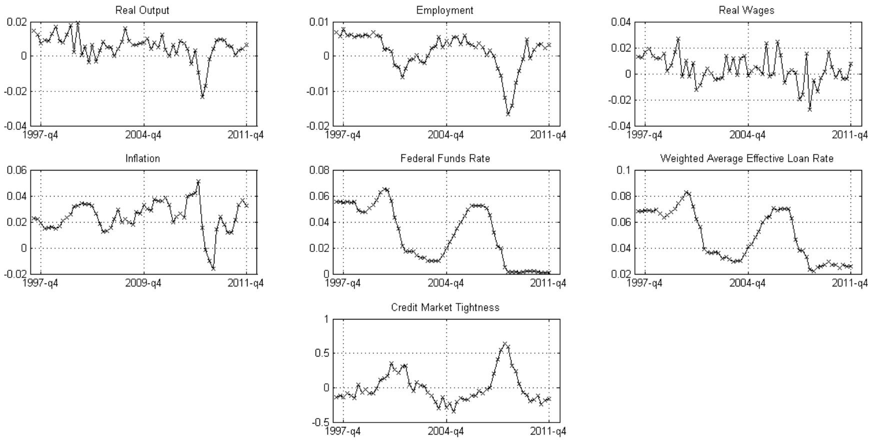

Figure 2.1: Data

matter we calibrate the sticky price parameter $\omega = 0.8$. The previous impositions imply that the coefficient attached to the real marginal costs into the equation (2.8) is $\kappa = \frac{(1-\beta\omega)(1-\omega)}{\omega} = 0.0507$. In line with the empirical observations we calibrate the elasticity of output to employment, α, equal to 0.66. Finally, according to Ravenna and Walsh (2008) we set the steady state employment N equal to 0.95, and the elasticity of substitution of the individual goods ε equal to 6 such that the mark-up of the retail sector over the price of the wholesale good is 20 per cent (μ =1.2).

Calibrated Parameter	β	σ	ω	α	N	ε
Value	0.996	1	0.8	0.66	0.95	6

Table 2.1: Calibrated Parameters.

2.3.3 Priors

In this section we declare the prior distributions of the remaining deep parameters of the model. The shape of the distributions is chosen according to the standard practise: for parameters defined in a $[0-1]$ interval we assume the beta distribution whereas for parameters which can take values over the whole support $\mathbb{R}$ we adopt the normal distribution. For parameters assuming values over the $[0-\infty]$ interval we assume the gamma distribution. Finally, the reference distribution for the structural shocks is the inverted gamma which is defined over the range $\mathbb{R}^+$.

For the monetary policy rule parameters we employ values widely used by the literature. Hence, for the coefficients attached to the expected inflation and output gap terms, δ_π and δ_x respectively, we assume a normal distribution with prior mean 2.0 and 0.1 and a standard error equal to 1.00 and 0.05 respectively; for the autoregressive coefficient ρ^R defining the degree of the interest rate smoothness we assume a beta distribution with prior mean 0.5 and standard error 0.25. For the all persistence parameters of the autoregressive stochastic processes of the exogenous shocks, we assume a beta distribution with prior mean of 0.5 and standard deviation of 0.1. The inverse labor supply Frish elasticity parameter ϕ is assumed normal distributed with prior mean equal to 0.5 and standard error equal to 0.25.

Concerning the credit market parameters we have not references on possible prior values.[25] Then, we adopt a gamma distribution for the credit vacancy posting cost with mean value equal to its labor market counterpart,[26] i.e. $k^B = 0.1$ and standard error equal to 0.05. The prior on the firm's entry cost $\bar{c}$ is harder to set, so we assume a rather widespread gamma distribution with a mean of 25 and a standard deviation of 12.5. For the matching function elasticity ξ and for the firms' bargaining power z we assume an uninformative position by considering a beta distribution with prior mean equal to 0.5 and standard error equal to 0.25 for both. Finally, for the separation rate ρ^B we adopt the strategy of setting its value between the minimal (0.07) and the maximum (0.02) values of the bankruptcy rate calibrated by Dell'Ariccia and Garibaldi (1998). As a consequence the separation rate in the credit market is assumed beta distributed with prior mean 0.05 and standard error equal to 0.025.

Finally, for all standard deviation of the exogenous shocks we use the inverted gamma distribution as prior distribution with mean equal to 0.01 with two degrees of freedom.[27]

2.3.4 Sensitivity Analysis: Mapping Stability

In this section we identify the stability domain of the model. A Monte Carlo simulation is performed in order to detect what parameters mostly drive the model into a specific region.

According to Ratto (2008) we consider two regions: an acceptable stable region G satisfying the standard Blanchard-Kahn rank condition and an unacceptable region $\overline{G}$ caused by the instability and indeterminacy of the model. Hence, in order to explore all the prior space we sample uniformly from the prior distributions defined above and we categorize each parameter into the two alternative regions. The sample is generated using a Sobol's quasi Monte Carlo sequence of dimension $N = 2048$. Hence, we get two subsets, (ϖ_s/G) of size n and $\left(\varpi_s/\overline{G}\right)$ of size $\overline{n}$, representing draws from the unknown probability density functions $f_n\left(\varpi_s/G\right)$ and $f_{\overline{n}}\left(\varpi_s/G\right)$ where ϖ is the vector of the parameters, s is the parameter's index and $n + \overline{n} = N$. Finally the identification of the parameters (and relative values) driving in the (un)acceptable region is defined by the comparison of the previous density functions by the two-sided Smirnov-Kolmogorov test:

$$d_{n,\overline{n}} = \sup ||F_n\left(\varpi_s/G\right) - F_{\overline{n}}\left(\varpi_s/G\right)||$$

where $F_n\left(\varpi_s/G\right)$ and $F_{\overline{n}}\left(\varpi_s/G\right)$ are the cumulative distribution functions (cdf) of the generic parameter ϖ_s. Given the null hypothesis $f_n\left(\varpi_s/G\right) = f_{\overline{n}}\left(\varpi_s/G\right)$ and the significance level at which it is rejected, if for a parameter ϖ_s the two distributions are significantly different (a larger

[25]The only work reporting values for the search and matching credit market parameters is Petrosky-Nadeau and Wasmer (2010a). They employ a trembling hand calibration method by an iterating perturbation of the set of parameters by a random shock drawn from a normal distribution in the space of the parameters to calibrate. See also the section (2.3.5).

[26]The values of posting cost employed by the literature on search and matching frictions in the labor market range between 0.01 (Hairault, 2002; Walsh, 2005) and 0.213 (Shimer, 2005).

[27]In order to simulate the model we add some measurement equations linking the log-levels of the variables with their differences. We assume these equations contain a constant term that we estimate. Hence for these terms, in the estimation phase, we assume a normal distribution and we adopt the strategy to set the prior mean equal to the sample mean of the time series to which the constant refers, and a standard error which implies a prior pseudo-t-value (the ratio between the prior mean and the prior standard deviation) equal to 2. Table 2.3 does not report the constants' estimates. More details are available from the authors upon request.

$d_{n,\overline{n}}$), it is possible define the parameter as a key driver of the model behavior as well the values of the parameter space leading in one region or in other one. Alternatively, if the distance between the distributions is not significant, ϖ_s is not important for the model's dynamics and its values can belong, indifferently, either to G or $\overline{G}$.

From the Monte Carlo filtering procedure we get that the 46 per cent of the prior support is stable. The remaining part gives indeterminacy (51.3 percent) and instability (2.7 percent). By running the Smirnov-Kolmogorov test we can highlight that indeterminacy is essentially driven by δ_π. In particular, by comparing the cdf of the sample producing indeterminacy with the cdf of the original prior sample we find that small values of δ_π drive to indeterminacy. Table 2.2 reports the detailed results of the Smirnov-Kolmogorov tests.

Parameter	**Stab.**	**Indet.**	**Instab.**	**Parameter**	**Stab.**	**Indet.**	**Instab.**
ϕ	0.1170	0.0504	0.1550	ρ^R	0.0482	0.0333	0.2340
δ_π	0.5780	0.3020	0.4290	ρ^A	0.0247	0.0104	0.0841
δ_x	0.0571	0.0295	0.0105	ρ^ν	0.0276	0.0126	0.1070
ρ^B	0.0711	0.0368	0.1240	ρ^ς	0.0207	0.0102	0.1320
ξ	0.0264	0.0186	0.1620	ρ^φ	0.0262	0.0129	0.0912
z	0.0426	0.0543	0.7190	ρ^ϑ	0.0261	0.0146	0.0878
k^B	0.0307	0.0126	0.0856	ρ^ψ	0.0331	0.0149	0.1520
$\overline{c}$	0.1440	0.0935	0.4800	ρ^υ	0.0272	0.0177	0.0873

Table 2.2: Smirnov-Komlogorov statistics in driving stability, indeterminacy and instability.

2.3.5 Posteriors estimates

Table 2.3 summarizes the posterior mode and the posterior mean for the model's parameters. The panel also shows the 90 percent probability intervals for the model parameters and the relative prior assumptions. Draws from the posterior distributions are obtained by running the random walk version of the Metropolis-Hastings algorithm. We ran ten parallel chains, each with a length of 100,000 replications.[28]

The posterior mean estimates are generally close to the respective modal values. The estimates of the credit market parameters imply low values of the matching elasticity ξ and of the bargaining power of banks $1 - z$, and a large value of the separation rate between firms and banks ρ^B. The latter estimate confirms the high mismatch between the financial and productive sectors of the economy experienced in the recent years. The importance of search and matching credit market parameters is stressed by Dell'Ariccia and Garibaldi (1998). Moreover, the values assumed by the bargaining power as well as by the matching elasticity and posting costs are relevant in the credit market in a fashion similar to that assumed by the search and matching model in the labor market (Cooley and Quadrini, 1999; Hagerdon and Manovskii, 2008). Our estimate of the banks' bargaining power is 0.13, a low value similar to that found by Petrosky-Nadeau and Wasmer (2010b) (0.27) in a model with good, labor and financial frictions to accommodate a targeted share of the financial sector in GDP and lower than the value estimated by Petrosky-Nadeau and

[28]The fraction of drops of the initial parameters vector is set at 20%. The calibration of the scale factor provides acceptance rates around 37 percent for the ten blocks. For the application of the Bayesian estimation and of the sensitivity analysis we employ the latest stable version (4.2.1) of the open-source software Dynare.

Parameter	Prior Distribution		Posterior Distribution			
	Distribution	Mean (Std. Dev.)	Mode (Std. Dev.)	**Mean**	**5%**	**95%**
ϕ	$\mathcal{N}$	0.500 (0.250)	0.4805 (0.1184)	0.5231	0.3043	0.7380
δ_π	$\mathcal{N}$	2.000 (1.000)	2.3170 (0.4779)	2.5376	1.6024	3.4222
δ_x	$\mathcal{N}$	0.100 (0.050)	0.1890 (0.0488)	0.1852	0.1044	0.2674
ρ^R	$\mathcal{B}$	0.500 (0.250)	0.7600 (0.0461)	0.7482	0.6664	0.8353
ρ^B	$\mathcal{B}$	0.050 (0.025)	0.0754 (0.0313)	0.0996	0.0439	0.1538
ξ	$\mathcal{B}$	0.500 (0.250)	0.0635 (0.0851)	0.1293	0.0016	0.2576
z	$\mathcal{B}$	0.500 (0.250)	0.9013 (0.0256)	0.8663	0.8119	0.9221
k^B	$\mathcal{G}$	0.100 (0.050)	0.0750 (0.0433)	0.0984	0.0235	0.1699
$\overline{c}$	$\mathcal{G}$	25.00 (12.50)	25.100 (13.205)	15.820	3.643	27.250
ρ^A	$\mathcal{B}$	0.500 (0.100)	0.8679 (0.0324)	0.8643	0.8112	0.9185
ρ^ν	$\mathcal{B}$	0.500 (0.100)	0.5022 (0.0638)	0.5299	0.3837	0.6445
ρ^ς	$\mathcal{B}$	0.500 (0.100)	0.7983 (0.0469)	0.7841	0.7099	0.8596
ρ^φ	$\mathcal{B}$	0.500 (0.100)	0.8931 (0.0207)	0.8847	0.8477	0.9287
ρ^ϑ	$\mathcal{B}$	0.500 (0.100)	0.6035 (0.0719)	0.6218	0.5047	0.7441
ρ^ψ	$\mathcal{B}$	0.500 (0.100)	0.6394 (0.0712)	0.6273	0.5137	0.7445
ρ^υ	$\mathcal{B}$	0.500 (0.100)	0.9329 (0.0176)	0.9297	0.9093	0.9528
σ_A	$\mathcal{IG}$	0.010 (2)	0.0058 (0.0005)	0.0060	0.0050	0.0069
σ_ν	$\mathcal{IG}$	0.010 (2)	0.0057 (0.0008)	0.0063	0.0045	0.0079
σ_ς	$\mathcal{IG}$	0.010 (2)	0.1101 (0.0139)	0.1066	0.0829	0.1309
σ_φ	$\mathcal{IG}$	0.010 (2)	0.0569 (0.0098)	0.0598	0.0429	0.0761
σ_ϑ	$\mathcal{IG}$	0.010 (2)	0.0098 (0.0009)	0.0102	0.0086	0.0118
σ_ψ	$\mathcal{IG}$	0.010 (2)	0.0039 (0.0006)	0.0040	0.0030	0.0052
σ_υ	$\mathcal{IG}$	0.010 (2)	0.0033 (0.0005)	0.0033	0.0026	0.0039

Table 2.3: Posterior Estimates: Structural and Shock Process Parameters.

Wasmer (2010a) (0.92) by using a "trembling hand" calibration method in a model with search and matching frictions in labor and credit markets.

The posting cost k^B and the matching elasticity ξ are larger and lower than the values found by Petrosky-Nadeau and Wasmer (2010a) respectively. The estimates of the monetary policy parameters and of the inverse labor supply Frish elasticity parameter are in line with the literature on the subject matter.[29]

2.4 Dynamic properties of the model

In order to focus on the issues of interest rate pass-though and credit spread as well as of the role of the credit market frictions on the real economy, in this chapter we focus on the dynamics of the model variables with respect to a negative interest rate shock and a positive technology shock. Finally we propose an exercise in which the economy is hit by an exogenous credit market shock.

2.4.1 The monetary policy shock and the interest rate pass-through

Figure 2.2 shows the impulse response functions (IRFs) regarding the main macroeconomic and credit market variables. With nominal rigidities (on good prices), a monetary easing implies a decrease of the policy rate that produces a lower real interest rate. This reduction determines a substitution effect between current and future consumption: households increase current spending and both the output and the output gap rise. The increase in the demand of goods implies a greater labor demand by firms: employment and wages increase and the fall in the marginal product of labor leads to higher real marginal costs. By the NKPC, inflation goes up.

The increase in the wage bill expands the borrowing demand to the banks and their expected profits rise. Banks try to increase the number of firms to finance by opening new lines of credit and their vacancy posting jumps up. Then the new credit matches improve and lines of credit increase. By equation (2.11) the number of firms searching for a line of credit falls starting from the next period.[30] As a consequence in the credit market there is a less congestion effect: the credit line finding rate increases, the credit vacancy filling rate falls and the credit market tightness decreases.

In order to highlight the response of the banking lending rate we can observe equation (2.24) which shows that banks aspire to capture a value equal to the marginal revenues of the firms, whereas firms want set a loan rate lower than the policy rate by trying to appropriate of the banks' saving. Then, the determination of the cost of credit depends on the dynamics and the steady state effects of the model's variables as well as on the distribution of the joint surplus by the relative bargaining power of the agents. Hence, on one hand, the fall in the labor marginal productivity and the increase in real wages contribute to the negative dynamics of the firms revenues and, on the other hand, even though the decrease in the credit market tightness is milder than the increase in the wage bill, by the steady state value of the banks' saving, we obtain a decrease of the value of which firms want seize. Furthermore, by considering the bargaining power of the agents it is possible to observe a dampening effect (from the estimation we obtain that the banks' bargaining power, $1 - z = 0.13$, is smaller than that of the firms, $z = 0.87$) such that the log-linearization version of the term $(1-z)\frac{(1-z)}{w_t N_t}\frac{Y_t}{\mu_t}$ decreases less than $z\Big[R_t^D - (1-\rho^B)\beta E_t \frac{\lambda_{t+1}}{\lambda_t}\frac{k^B R_{t+1}^D}{w_t N_t \theta_{t+1}^C}\Big]$. Since

[29] The estimation values reported in table 2.3 imply the following realistic and acceptable steady state values: $p^B = 0.03$, $q^B = 0.30$, $R^L = 1.07$, $w = 0.52$ and $L^N = 0.21$. For a description of the steady state version of the model see the technical appendix.

[30] Since the number of searching of firms at time t depends on the lines of credit at time $t-1$, the impact response of s_t^F is always zero.

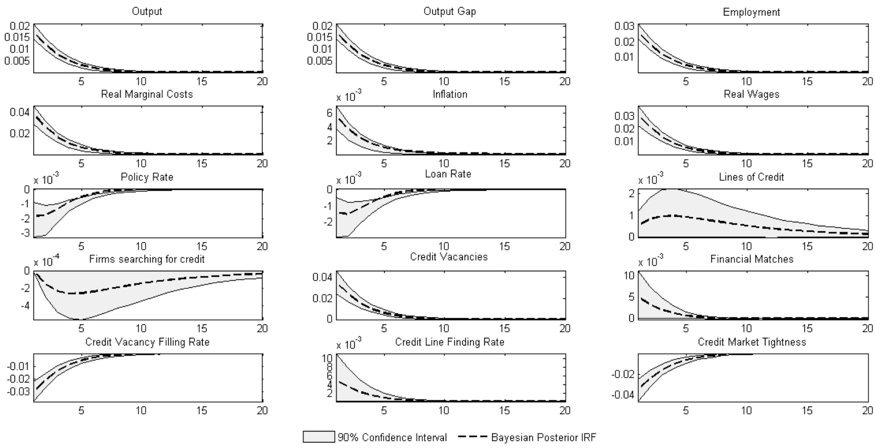

Figure 2.2: IRFs with respect to a monetary shock

both the previous values fall less than the policy rate, the banking lending rate also drops less the policy rate and firms are willing to accept a higher banking lending rate than they would like. This is shown in figure 2.2. Put in other words, given the estimated values of the model's parameters it is possible to observe that the coefficient Λ_1 of equation (2.25) is greater than 1. This means that the incompleteness of the pass-through depends on the term Λ_2 which measures the indirect effect due to the presence of credit frictions.

Bargaining power of banks and interest rate pass-through

In this section we analyze the scenario in which the banking sector has a different market power in the negotiation of the loan interest rate. We simulate the model when z decreases whereas all other deep parameters remain equal to their estimated values. The variations of the IRFs compared to the benchmark model are minimal. Then we focus on the degree of the interest rate pass-through.

A lower bargaining power of firms (or a higher bargaining power of banks) produces a lower fall of the banking lending rate due to the change of the steady state values of the variables and to the distribution effect of the agents' joint surplus. These effects imply a decrease of the linearized version of the term $(1-z)\frac{(1-z)}{w_t N_t}\frac{Y_t^w}{\mu_t}$ which is relatively smaller than the fall of the linearized version of the factor $z\Big[R_t^D - (1-\rho^B)\beta E_t \frac{\lambda_{t+1}}{\lambda_t}\frac{k^B R_{t+1}^D}{w_t N_t \theta_{t+1}^C}\Big]$. As a matter of fact when banks have more bargaining power they have more possibilities to appropriate of firms' profits, so their expected profits increase boosting the credit vacancy posting, the financial matches and the lines of credit. Equation (2.11) determines a lower reduction in the number of firms searching for a line of credit. Hence, the credit vacancy filling rate decreases more, the credit line finding rate rises more and the credit market tightness from the firms point of view falls more than the benchmark model. This changes feed back, by equation (2.24), on the determination of the loan interest rate, which decreases less than the benchmark model implying a more incomplete interest rate pass-through (figure 2.3). Further, the variation of the banking lending rate is such that it is not sufficient to significantly influence the real marginal costs and inflation does not vary. Since the policy rate is set by the Taylor's rule (2.27), the not significant variation of the inflation's response implies a very small variation of R_t^D. No substitution effect between current and future households' spending hence arises and output (and output gap) does not exhibits significant differences as compared to the benchmark case. The constancy of the output gap and of inflation feed back, by equation (2.27), on the policy rate. Finally it is possible to observe as small variations of z determines large modifications of the loan rate response that may even lead to its overshooting. The opposite chain of effects is produced by an increase in the firms' bargaining power.

Proposition 5 *When $0 < z < 1$ and $k^B > 0$, the greater is the banks' bargaining power, $(1 - z)$, the more incomplete is the interest rate pass-through.*

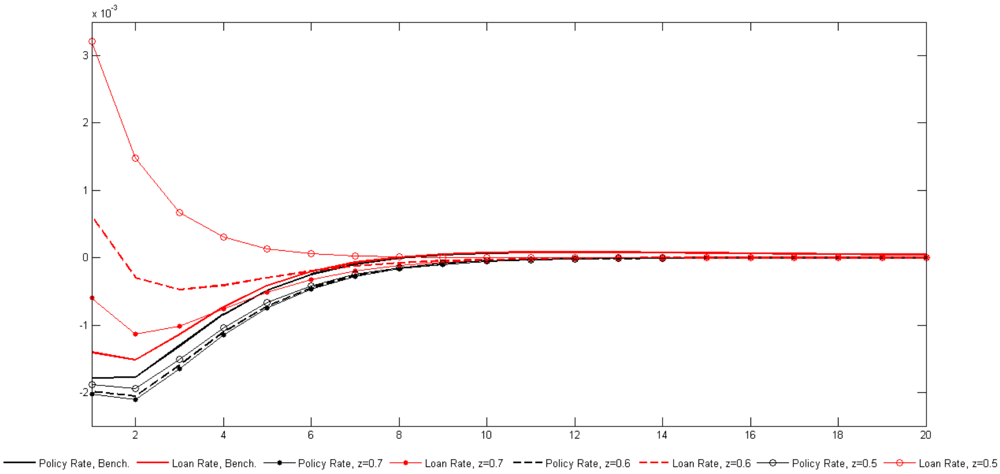

Figure 2.3: Interest rate pass-through with respect a monetary shock

2.4.2 The technology shock: credit spread and real wages' dynamics

Figure 2.4 shows the IRFs of the main macroeconomic and credit market variables with respect to a positive TFP shock. An increase in productivity implies an increase in the supply of goods by firms. This implies a rise of the firms revenues: the larger is the firms' surplus the higher is the interest rate on loans that banks will try to obtain from firms. Then the banks' expected profits boost. As a matter of fact, as stressed by Galì and Rabanal (2004) in presence of staggered prices and weak accommodation of the policy rule to the TFP shock, the potential output increases more than the actual output.[31] This implies a less use of the labor input which determines a first reduction of the firms marginal costs. However, only a share of firms can lower their prices such that the aggregate price level decreases in a not optimal way. Then the increase in aggregate demand is less than proportional to that of the productivity and hence it will be satisfied with lower employment (*productivity employment puzzle*), in line with the evidence proposed by a recent

[31] They consider a model where the Taylor rule depends on the level of the output.

strand of the literature (Basu, Fernald and Kimball 2006, Galí 1999). Moreover, they show that the effect on the real wage is ambiguous because depends on the relative strength of the income and substitution effects as well as on the set of model parameters. In this chapter by the households' first order condition (2.3), the real wage increases. Thus, the characteristics of the present model allow for a positive response of the real wages without making use of wage rigidities. Although the fall of the employment, the increase in real wage is such that the wage bill soars as well as the banks' expected profits. As a consequence, there is a more intense credit vacancy posting activity: financial matches and lines of credit boost. This increase, by equation (2.11), forces the number of firms searching for a line of credit to fall. In the credit market there is a lower congestion effect from the point of view of firms: the credit vacancy filling rate goes down, the credit line finding rate goes up and the credit market tightness drops determining a diminishing of the banking lending rate which together the increase of the labor marginal productivity further lower the real marginal costs, and so the inflation. The latter decrease together the fall of the output gap lower the policy rate by the NKPC.

The credit market frictions contribute to produce countercyclical dynamics of the spread between the banking lending rate and the policy (deposit) rate which are similarly to those observed by the literature (see figure 2.5). Put in other terms, and by referring to Beaubrun-Diant and Tripier (2009), in the previous scenario when a TFP shock hits the economy, the procyclical effect due to the increase of the banks' profits is more than offset by the countercyclical effect due to the modification of the external opportunities (by changes of the threat points and values of matches) of firms which implies more ease of finding funding.[32] In order to clarify the previous considerations we can rewrite the credit spread by using equation (2.24):

$$SP_t = \frac{(1-z)}{w_t N_t}\frac{Y_t^w}{\mu_t} - (1-z)R_t^D - \frac{z(1-\rho^B)\beta}{w_t N_t} E_t \frac{\lambda_{t+1}}{\lambda_t}\frac{k^B R_{t+1}^D}{\theta_{t+1}^C} \tag{2.33}$$

The previous equation points out that the credit spread depends on three terms: the first two are procyclical, the other one is countercyclical. As in Beaubrun-Diant and Tripier (2009) the term $\frac{(1-z)}{w_t N_t}\frac{Y_t^w}{\mu_t}$ increases when a positive TFP shock hits the economy: even though the wage bill rises, the fall in real marginal costs and the increase of output improve the firms' revenues. Hence, for a given ρ^B, when banks have a positive bargaining power ($z < 1$) they can obtain a higher interest rate on loans such that the credit spread rises. Differently to Beaubrun-Diant and Tripier (2009) we can observe another procyclical effect due to the term $-(1-z)R_t^D$: in our general equilibrium model an increase in productivity provokes a fall in output gap and inflation such that, by the Taylor's rule (2.27), the policy rate decreases by widening the credit spread. Finally, as described above, a positive technological shock improves the expected profits of banks causing a less congestion effect in the credit market for firms. Hence, by observing the term $-\frac{z(1-\rho^B)\beta}{w_t N_t} E_t \frac{\lambda_{t+1}}{\lambda_t}\frac{k^B R_{t+1}^D}{\theta_{t+1}^C}$, even though the wage bill and the real interest rate rise the fall of the credit market tightness implies more external opportunities for firms and a lower expected time to obtain a line of credit. Then firms can negotiate a lower banking lending rate tightening the credit spread. Finally, it is useful to note that, as clarified in section (2.2.6), the magnitude of the response of the percent deviation of the credit spread from its steady state crucially depends on the steady state value of $\frac{1}{SP}$. The overall countercyclical dynamics of the credit spread indicates

[32] Beaubrun-Diant and Tripier (2009) show another countercyclical effect due to the modification of the idiosyncratic productivity reservations of the agents. They conclude for an overall countercylical effect of the credit spread.

that the countercyclical effect depending on the search and matching frictions is stronger than those procyclical due to the profits of firms and to the policy rate.

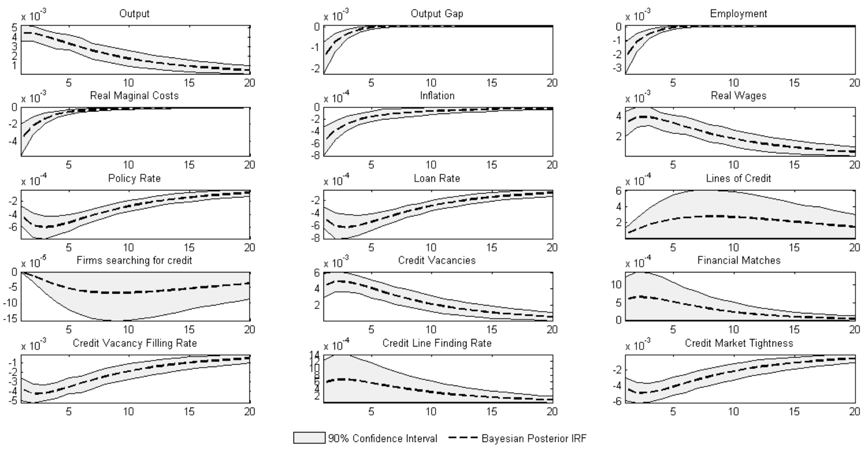

Figure 2.4: IRFs with respect to a technology shock

Bargaining power of banks and credit spread

As in section (2.4.1) we analyze the scenario in which the banking sector has a more bargaining power in the negotiation of the loan interest rate in order to understand how changes the cyclical behavior of the credit spread. Also in this case the magnitude of the IRFs of the main macroeconomic and credit market variables do not change significantly Then modification of the behavior of the credit spread is attributable to the variation of the sharing of the total surplus of the credit match.

A more bargaining power of banks amplifies the magnitude of the procyclical effects analyzed in the previous section by improving the share of firms' revenues of which the lenders may appropriate. Further it mitigates the countercyclical role of the credit market frictions. However, all these effects are smaller than the benchmark model because a decrease of z, by augmenting the steady state banking lending rate R^L, lowers the scale factor $\frac{1}{SP}$. Hence, as shown by figure 2.5 the final effect is a more diminishing of the credit spread compared to the benchmark model. Moreover, it is useful to note as, differently to the policy rate shock case, small variations of z implies small changes in the credit spread.

Proposition 6 *When $0 < z < 1$ and $k^B > 0$, in presence of exogenous positive productivity shock, the greater is the banks' bargaining power, $(1 - z)$, the more countercyclical is the credit spread.*

2.4.3 The credit shock

In this section we study the IRFs produced by the model when a credit efficiency shock hits the credit market (figure 2.6). An increase in the efficacy of the credit market can be thought as

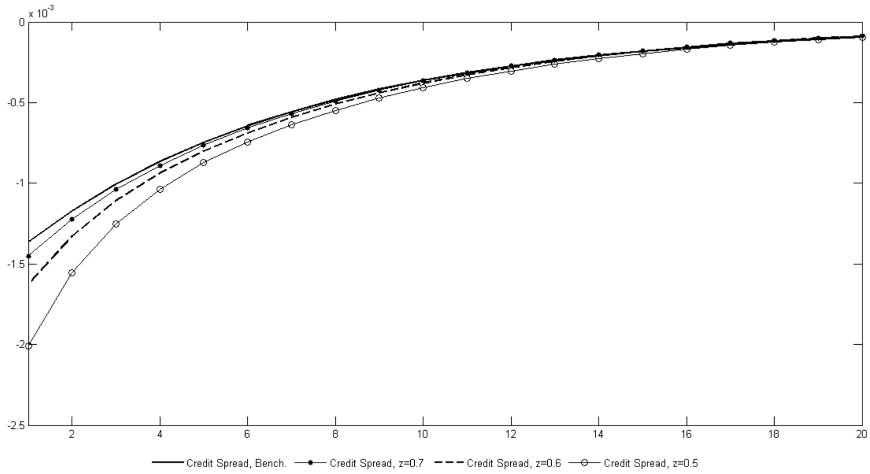

Figure 2.5: Credit spread with respect to a technology shock

an improvement of the structural and technology reforms of the financial market. As Becsi, Li and Wang (2005) argue, a positive shock to ς_t may represents a better efficiency of the financial intermediation arising from being to identify easier banking lending and borrowing opportunities. At the same time this kind of shock can be interpreted as a cost push shock which affects the real marginal costs, and so inflation, by the credit market tightness channel.

The first consequence of this shock is an increase in the number of financial matches. Then, by equation (2.10), the number of lines of credit rises. This improvement determines a fall in the number of firms searching for a line of credit (s_t^F): the credit line finding rate goes up. At the same time, the increase of the lines of credit determines a rise in the banks' expected profits (see equation 2.12) and so a more intensive vacancy posting activity. This increases, however, less than financial matches. As a consequence, the credit vacancy filling rate rises less than the credit line finding rate so that the credit market tightness falls,[33] the interest rate on loans decreases (see equation 2.24), real marginal costs and inflation go down. Since the inverse of the credit market tightness is an index of the liquidity of the credit market (Wasmer and Weil, 2004), according to Becsi, Li and Wang (2005), we obtain that an improvement in the matching efficiency generates more matches increasing the market liquidity. By the monetary rule, the policy rate decreases such that the real interest rate falls: current and future spending (output and output gap) rises and drops, respectively. The increase in the demand for goods requires more labor input: employment and the real wages rise. Finally it is useful to note as the initial rise of the inflation due to the increase of the financial matches is more than offset by the decrease of the inflation due to the fall of the credit market tightness.

[33]It is useful to note that the usual dynamics of the matching probabilities which depend on the sign of the credit market tightness change by the magnitude of the credit effciency shock and the value of the externality ξ. As a matter of fact the matching probabilities can be rewritten as $\hat{p}_t^B = \hat{\varsigma}_t - \xi\hat{\theta}_t^C$ and $\hat{q}_t^B = \hat{\varsigma}_t + (1-\xi)\,\hat{\theta}_t^C$. In our case since the increase of the $\hat{\varsigma}_t$ is greater than the decrease of $(1-\xi)\,\hat{\theta}_t^C$ the dynamics of the credit vacancy filling rate is increasing and not decreasing.

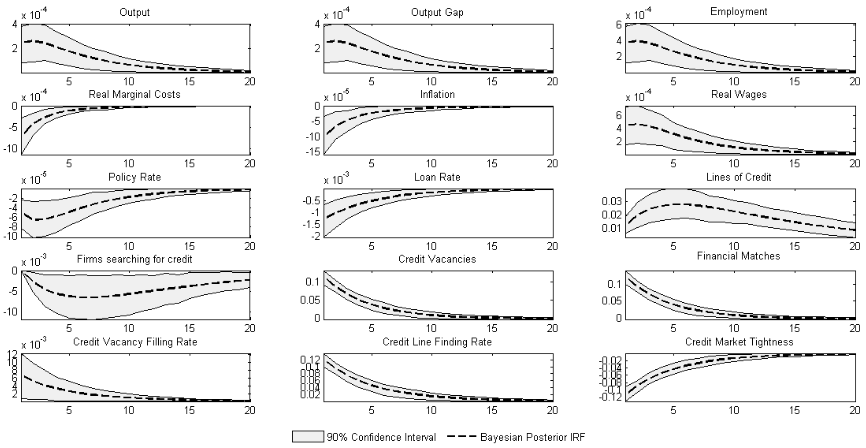

Figure 2.6: IRFs with respect to a credit shock

2.5 Conclusions

In this chapter we have introduced search and matching frictions in the credit market into a cash in advance New Keynesian DSGE theoretical model with sticky prices. In this economy households are depicted in a standard fashion, and so are retail firms producing under monopolistic competition differentiated goods consumed by households. Before starting production, wholesale competitive firms, producing a homogeneous good, search for credit offered by banks posting lines of credit. The firms obtaining loans pay the wage to workers and production can start. At the end of the period their production is sold to retail firms, loans are repaid and households receive profit income from financial intermediaries and firms, and the principal plus interest on deposits. The interest rate on loans is determined according to a Nash bargaining procedure. A fraction of the wholesale firms producing in a given period - determined on the basis of an exogenous separation rate specifying the fraction of credit matches which is destructed at the end of the production period - obtains loans also in the next period.

The model is estimated by using the Bayesian methods. Given prior assumptions on the model's parameters in line with the empirical literature, in order to run the estimation we use seven observed series in the sample 1997:Q2-2011:Q4. Further, we identify the stability domain of the model by the two-sided Smirnov-Kolmogorov test.

The dynamic properties of our model are consistent with the main cyclical evidence reported in the NK DSGE literature, but the model provides some main new findings. First, it is able to highlight an incomplete pass-through of policy rate changes to the interest rate on loans. Second, when the model is hit by a positive technology shock it provides a response of the real wages which is in line with the empirical evidence, without having to rely on any real or nominal wage rigidity. Furthermore the model confirms the countercyclical behavior of the credit spread with respect positive technology shocks. All the previous findings depend on the search and matching frictions in the credit market and on the bargaining mechanism over the loan interest rate, which affect the responses of the main real macroeconomic variables to expansionary shocks. In particular a more banks' bargaining power in the setting of the banking lending rate exacerbates the incompleteness of the adjustment of the loan rate to variation of the policy rate and provides a more countercyclical behavior of the credit spread with respect to a positive technology shock. Moreover, by using the Bayesian techniques, we provide the estimated values of some structural parameters of the credit market useful to the study of the financial markets. Finally, a simple exercise in which the economy is hit by an exogenous credit shock confirms the importance of the channel represented by the credit market tightness in the determination of a banking lending rate affecting the market liquidity and the dynamics of the main real macroeconomic variables.

Bibliography

[1] Albrecht, J., Anderson, E. S., and Vroman, S. (2007), Opportunistic matching in the housing market, *International Economic Review*, 48, 641-664.

[2] Andrés, J., and Arce, O. (2008), Banking Competition, Housing Prices and Macroeconomic Stability, Bank of Spain Working Paper No. 830.

[3] Angeloni, I., Kashyap, A. K., and Mojon, B., Eds. (2003), *Monetary policy transmission in the Euro Area*, Cambridge, Cambridge University Press.

[4] Aslam, A., and Santoro, E. (2008), Bank Lending, Housing and Spreads, University of Copenaghen, Department of Economics, Discussion Paper No 27.

[5] Basu, S., Fernald, J. G., and Kimball, M., S. (2004), Are Technology Improvements Contractionary?, *American Economic Review*, 96(5), 1418-1448.

[6] Beaubrun-Diant, K. E., and Tripier, F. (2009), The Credit Spread Cycle with Matching Friction, Université de Nantes, LEMNA Working Paper, No. 2009/37.

[7] Becsi, Z., Li, V. E., and Wang, P. (2005), Heterogeneous borrowers, liquidity, and the search for credit, *Journal of Economic Dynamics and Control*, 29, 1331-1360.

[8] Becsi, Z., Li, V. E., and Wang, P. (2009), Credit mismatch and breakdown, Villanova School of Business Department of Economics and Statistics Working Paper Series No. 7.

[9] Bernanke, B. S., Gertler, M., and Gilchrist, S. (1996), The Financial Accelerator and the Flight to Quality, *The Review of Economics and Statistics*, 78(1), 1-15.

[10] Bernanke, B. S., Gertler, M., and Gilchrist, S. (1999), The Financial Accelerator in a Quantitative Business Cycle Framework, in Taylor, J. B. and Woodford, M., Eds., Handbook of Macroeconomics, Vol. 1, 1341-1393.

[11] Blanchard, O. J., and Galì, J. (2010), Labor market frictions and monetary policy: A New Keynesian Model with unemployment, *American Economic Journal: Macroeconomics*, 2, 1-30.

[12] Blanchard, O. J., and Kiyotaki, N. (1987), Monopolistic Competition and the Effects of Aggregate Demand, *American Economic Review*, 77, 647-666.

[13] Calstrom, C., and Fuerst, T. (1997), Agency Costs, Net Worth, and Business Fluctuations: A Computable General Equilibrium Analysis, *American Economic Review*, 87, 893-910.

[14] Calstrom, C., and Fuerst, T. (1998) Agency Costs and Business Cycles, *Economic Theory*, 12, 583-597.

[15] Calvo, G. (1983), Staggered prices in a utility maximizing framework, *Journal of Monetary Economics*, 12, 383-398.

[16] Chen, N. (1991), Financial Investment Opportunities and the Macroeconomy, *Journal of Finance*, 46, 529-554.

[17] Christiano, L. J., Eichenbaum, M., and Evans, C. L. (2005), Nominal rigidities and the dynamic effects of a shock to monetary policy, *Journal of Political Economy,* 113, 1-45.

[18] Čihák, M., Harjes, T., and Stavrev, E. (2009), Euro area monetary policy in uncharted waters, IMF working paper No. 185.

[19] Cooley, T. F., and Quadrini, V., 1999. A neoclassical model of the Phillips curve relation, *Journal of Monetary Economics*, 44, 165-193.

[20] Corvoisier, S., and Gropp, R. (2002), Bank concentration and retail interest rates, *Journal of Banking and Finance*, 26(11), 2155-2189.

[21] de Bondt, G. (2005), Interest rate pass-through: Empirical Results for the Euro Area, *German Economic Review*, 6(1), 37-78.

[22] de Bondt, G., Mojon, B., and Valla, N. (2005), Term structure and the sluggishness of retail bank interest rates in Euro Area countries, ECB Working Paper Series No. 518.

[23] De Haan, W., Ramey, G., and Watson, J. (2003), Liquidity flows and fragility of business enterprises, *Journal of Monetary Economics*, 50, 1215-1241.

[24] Dell'Ariccia, G., and Garibaldi, P. (1998), Bank Lending and Interest Rate Changes in a Dynamic Matching Model, IMF Working Paper No 98/93.

[25] de Walque, G., Pierrard, O., and Rouabah, A. (2010), Financial (in)stability, supervision and liquidity, *Economic Journal*, Royal Economic Society, 120, 1234-1261

[26] Diamond, P. (1982b), Aggregate demand management in search equilibrium, *Journal of Political Economy*, 90, 881-894.

[27] Diamond, P. (1990), Pairwise credit in search equilibrium, *Quarterly Journal of Economics*, 105, 285–319.

[28] Dixit, A., and Stiglitz, J. (1977), Monopolistic competition and optimum product diversity, *American Economic Review*, 67, 297 - 308.

[29] Dueker, M. J., and Thornton, D. L. (1997) Do bank loan rates exhibit a countercyclical mark-up?, Federal Reserve Bank of St. Louis, Working Paper No. 1997-004.

[30] Erceg, C., Henderson, D., and Levin, A. (2000), Optimal Monetary Policy with Staggered Wage and price Contracts, *Journal of Monetary Economics*, 46(2), 281-313.

[31] Ernst, E. and Semmler, W. (2010), Global dynamics in a model with search and matching in labor and capital markets, *Journal of Economic Dynamics and Control*, 34, 1651-1679.

[32] Fama, E. F., French, K. R. (1989), Business Conditions and Expected Returns on Stocks and Bonds, *Journal of Financial Economics*, 25, 23-49.

[33] Fernández-Villaverde, J. (2010), The Econometrics of DSGE Models *International Review of Economics*, Springer, 1(1), 3-49.

[34] Galí, J. (1999), Technology, Employment, and the Business Cycle: Do Technology Shocks Explain Aggregate Fluctuations?, *American Economic Review*, 89(1), 249-271.

[35] Galí, J., and, Rabanal, P. (2004), Technology Shocks and Aggregate Fluctuations: How Well Does the Real Business Cycle Model Fit Postwar U.S. Data?, IMF Working Paper No 04/234.

[36] Galí, J. (2008) Monetary Policy, Inflation, and the Business Cycle: An Introduction to the New Keynesian Framework, Princeton University Press.

[37] Gambacorta, L. (2008), How do banks set interest rates?, *European Economic Review*, 52(5), 792-819.

[38] Genesove, D., and Han, Lu (2010), Search and matching in housing market, CEPR Discussion Paper No. 7777.

[39] Gerali, A., Neri, S., Sessa, L., and Signoretti, F.M. (2010), Credit and Banking in a DSGE Model of the Euro Area, *Journal of Money, Credit and Banking*, 42(6) (Supplement), 107-141.

[40] Gertler, M., Sala L., and Trigari, A. (2008), An estimated monetary DSGE model with unemployment and staggered nominal wage bargaining, *Journal of Money, Credit and Banking*, 40, 1713-1764.

[41] Gilchrist, S., Yankov, V., and Zakrajsek, E. (2009), Credit market shocks and economic fluctuations: Evidence from corporate bond and stock markets, *Journal of Monetary Economics*, 54(5), 1508-1514

[42] Goodfriend, M., and McCallum, B. T., (2007), Banking and interest rates in monetary policy analysis: A quantitative exploration, *Journal of Monetary Economics*, 54(5), 1480-1507.

[43] Hagerdon, M., and Manovskii, I. (2008), The cyclical behavior of equilibrium unemployment and vacancies revisited, *American Economic Review*, 98, 1692-1706.

[44] Hairault, J. O. (2002), Labor market search and international business cycles, *Review of Economic Dynamics* 5, 535-558.

[45] Hannan, T., and Berger, A. (1991), The rigidity of prices: Evidence from the banking industry, *American Economic Review*, 81, 938-945.

[46] Hofmann, B. (2006), EMU and the transmission of monetary policy: Evidence from business lending rates, *Empirica*, 33, 209-229.

[47] Klemperer, P. (1987), Markets with consumer switching costs, *Quarterly Journal of Economics*, 102, 375-394.

[48] Kobayashi, T. (2008), Incomplete interest rate pass-through and optimal monetary policy, *International Journal of Central Banking*, 4, 77-118.

[49] Kwapil, C., and Scharler, S. (2006), Limited Pass-Through from Policy to Retail Interest Rates: Empirical Evidence and Macroeconomic Implications, *Monetary Policy and the Economy*, Q4, 26-36.

[50] Lehmann, E., and Van der Linden, B. (2010), Search frictions on product and labor markets: money in the matching function, *Macroeconomic Dynamics*, 14, 56-92.

[51] Levin A. T., Natalucci F. M., and Zakrajsek, E. (2004), The magnitude and cyclical behavior of financial market frictions, Board of Governors of the Federal Reserve System (U.S.), Finance and Economics Discussion Series No 70.

[52] Lucas, Robert Jr. (1982), Interest rates and currency prices in a two-country world, *Journal of Monetary Economics*, 10, 335-359.

[53] Mathä, T. Y., and Pierrard, O. (2011), Search in the product market and the real business cycle, *Journal of Economic Dynamics and Control*, 35(8), 1172-1191.

[54] Mortensen, D., and Pissarides, C. A. (1994), Job creation and job destruction in the theory of unemployment, *Review of Economic Studies*, 61, 397-415.

[55] Nicoletti, G., and Pierrard, O. (2006), Capital market frictions and the business cycle, Département des sciences économiques de l'Université Catholique de Louvain, Discussion Paper No. 53.

[56] Olivero, M. P. (2010), Market Power in Banking, Countercyclical Margins and the International Transmission of Business Cycles, *Journal of International Economics*, 80, 292-301.

[57] Petrosky-Nadeau, N. and Wasmer, E. (2010a), The cyclical volatility of labor markets under frictional financial markets, IZA Discussion Paper No 5131.

[58] Petrosky-Nadeau, N. and Wasmer, E. (2010b), The propagation of technology shocks: do good, labour and credit market imperfections matter and how much?, mimeo.

[59] Pissarides, C. A. (2000), *Equilibrium Unemployment Theory*, Basil-Blackwell, second edition, MIT Press.

[60] Ratto, M. (2008), Analysing DSGE Models with Global Sensitivity Analysis, *Computational Economics*, 31, 115-139.

[61] Ravenna, F., and Walsh, C. E. (2006), Optimal monetary policy with the cost channel, *Journal of Monetary Economics*, 53, 199-216.

[62] Ravenna, F., and Walsh, C. E. (2008), Vacancies, unemployment and the Phillips curve, *European Economic Review*, 52, 1494-1521.

[63] Riggi, M. (2009), Nominal and Real Wage Rigidities in New Keynesian Models: a Critical Survey, *Journal of Economic Surveys*, 24(3), 539–572.

[64] Royal Swedish Academy of Sciences (2010), Market with search costs, *The Prize in Economic Sciences 2010*.

[65] Sander, H., and Kleimeier, S. (2004), Convergence in Euro-zone retail banking? What interest rate pass-through tells us about monetary policy transmission, competition and integration, *Journal of International Money and Finance*, 23, 461-92.

[66] Shimer, R. (2005), The ciclical behavior of equilibrium unemployment and vacancies, *Amercian Economic Review*, 95, 25-49.

[67] Stiglitz, J., and Weiss, A. (1981), Credit rationing in markets with imperfect information, *American Economic Review*, 71, 393-410.

[68] Vesala, T. (2007), Financial matching, asymmetric information and entrepreneurial risk taking, *Scandinavian Journal of Economics*, 109(3), 469-485.

[69] Van Leuvensteijn, M., Kok Sørensen, C., Bikker, J., and Van Rixtel, A. (2008), Impact of bank competition on the interest rate pass-through in the euro area, ECB working paper no. 885.

[70] Walsh, C. E., (2003) Monetary Theory and Policy, 2nd edition, Massachusetts Institute of Technology, the MIT Press.

[71] Walsh, C. E. (2005), Labor market search, sticky prices, and interest rate policies, *Review of Economic Dynamics*, 8, 829-849.

[72] Wasmer, E., and Weil, P. (2004), The macroeconomics of labor and credit market imperfections, *American Economic Review*, 94, 944-963.

[73] Wheaton, W. (1990), Vacancy, search, and prices in a housing market matching model, *Journal of Political Economy*, 98, 1270-1292.

Chapter 3

Incomplete interest rate pass-through under credit and labor market frictions†

By introducing search and matching frictions in both the labor and the credit markets into a cash in advance New Keynesian DSGE model, we provide a novel explanation of the incomplete pass-through from policy rates to loan rates. We show that this phenomenon is ineradicable if banks possess some power in the bargaining over the loan rate of interest, if the cost of posting job vacancies is positive and if firms and banks sustain costs when searching for lines of credit and when posting credit vacancies, respectively. We also show that the presence of credit market frictions moderates the reactions of output and wages to a monetary shock, and that the transmission of monetary policy shocks to output and inflation is more relevant than suggested by the recent literature.

3.1 Introduction

Several empirical contributions that appeared before the recent financial crises provided convincing evidence that shifts in policy rates were not completely passed through to retail (market) banking lending rates, even though significant differences existed in the degree of incompleteness which was experienced across countries.[1] According to this evidence, the phenomenon was particularly sharp in the Euro Area.[2] During the financial crisis, the transmission of policy rate changes to retail rates has become less efficient in this Area (Čihák, Harjes and Stavrev, 2009). The interest rate pass-through to the short-term rates has been however less affected than in the United States,

†This chapter is a joint work with Giuseppe Ciccarone (Sapienza University of Rome) and Francesco Giuli (University of Rome 3). We wish to thank P. Benigno, E. Marchetti, M. Tancioni, R. Tilli, the participants in a seminar held at the Bank of Italy on 14th December 2010 and an anonymus referee for comments and suggestions. The views expressed herein are solely those of the author and do not necessarily reflect the views of the Bank of Italy.

[1] The literature is wide. Recent contributions are, e.g., Angeloni and Ehrmann, (2003); Sander and Kleimeier (2004); Hofmann (2006); Égert, Crespo-Cuaresma and Reininger (2007); Fourcans and Vranceanu (2007).

[2] See, e.g., Mojon (2000); Angeloni, Kashyap and Mojon (2003); Gambacorta (2008); de Bondt, Mojon and Valla (2005); Kok Sørensen and Werner (2006); Gropp, Kok Sørensen, and Lichtenberger (2007). A recent review of the literature on the loan rate pass-through in the euro area is in Kobayashi (2008, section 2).

whereas that to the long-term rates has been heavily impaired in both economies (IMF, 2008). The existence of an incomplete pass-through of policy rate changes to the loan rates in the Euro Area and in the United States is confirmed by a recent study by Karagiannis, Panagopoulos and Vlamis (2010).

The theoretical relevance of the issue for New Keynesian DSGE models is demonstrated, e.g., by the changes in the optimal monetary policy which are produced by the presence of an incomplete interest rate pass-through (Chowdhury et al., 2006; Kobayashi, 2008). The relevance of this incompleteness is however especially important from an empirical viewpoint in the presence of a cost channel of monetary policy (e.g., Christiano, Eichenbaum and Evans, 2005; Ravenna and Walsh, 2006). The existence of an incomplete interest rate pass-through may in fact mitigate the strength of the cost channel as banks shelter firms from monetary policy shocks. Yet, while confirming this intuition, recent contributions based on a not-fully microfounded model, suggest that an incomplete loan interest rate pass-through produces limited effects on the transmission of monetary policy shocks to output and inflation (Hülsewig et al. 2009; Kaufmann and Scharler, 2009).

The goal of this chapter is to understand whether an incomplete interest rate pass-through has also limited effects on the transmission of monetary policy shocks in a fully microfounded New Keynesian DSGE model economy with sticky prices and search and matching frictions in both the labor and the credit market. This allows us to provide a novel explanation of the incomplete loan rate pass-through in an economy where the main explanations of this phenomenon which have been provided so far are ruled out by hypothesis. First of all, we do not rely either on exogenous cost functions associated with changes in retail interest rates (Chowdhury et al., 2006; Scharler, 2008; Kaufmann and Scharler, 2009), or on monopolistically competitive retail market where regional banks set loan rates according to a Calvo-type rule (Kobayashi, 2008). Further, by assuming perfect competition in the credit sector, we exclude the possibility of banks' collusive behavior and concentration in the financial market (Sander and Kleimeier, 2004; Van Leuvensteijn et al., 2008). Finally, agency costs à la Stiglitz and Weiss (1981) and customer switching costs à la Klemperer (1987) are absent, banks face no fixed costs when changing their loan rates and borrowers do not strongly react to rate changes in the way suggested by the customer reaction hypothesis (Hannan and Berger, 1991).

In our economy, before production begins, wholesale competitive firms producing a homogeneous good search for lines of credit posted by banks; the firms that have lines of credit granted may then post vacancies in the labor market, where unemployed workers are searching for jobs. The firms matching with workers obtain from banks the advances necessary to pay for the wage bill. Those that obtain the loans financing job vacancy posting but that are unable to match with workers cannot start production and cannot repay their debt with the banks. At the end of the period, wholesale production is sold to retail firms transforming the homogeneous good into differentiated goods bought by households. Loans are then repaid and households receive profit income from banks and firms, and the principal plus interest on deposits from banks. A fraction of the wholesale firms producing in a given period - determined on the basis of exogenous separation rates specifying the fractions of labor matches and of credit matches which are destroyed at the end of the production period - obtain loans also in the next period. The other firms have to go afresh into the whole process of search, starting from the credit market.

This model economy shares similarities with some recent attempts that extended the labor market matching framework to financial markets (e.g., Wasmer and Weil, 2004; Nicoletti and Pierrard, 2006; Ernst and Semmler, 2010; Petrosky-Nadeau and Wasmer, 2010), but we depart from these contributions in several respects. First, our setting requires that banks advance the funds necessary to pay for both the cost of the job vacancies and for the wage bill, whereas in Nicoletti and Pierrard (2006), Wasmer and Weil (2004) and Petrosky-Nadeau and Wasmer (2010) the wage bill is not borrowed from the banks but is paid *post factum* by the firms. Second, firms demand a variable quantity of loans, rather than looking for a match with only one bank, as it is instead assumed in those three contributions. Third, we assume that firms produce a quantity of output which depends on total hours worked, while Nicoletti and Pierrard (2006) assume that firms produce a unit of output with one worker and one unit of capital provided by banks, even though capital plays a rather artificial role, as it is necessary to look for a worker but it does not enter the production function. Ernst and Semmler (2010) assume that the firm needs external finance to increase its capital stock, but the financial sector is represented by a bond market. Fourth, the wage and the interest rate on loans are determined according to a sequential Nash bargaining framework, a procedure which is present in Wasmer and Weil (2004), but it is absent in the more recent modelling attempts.

Our main results can be summarized as follows. First, the transmission of monetary policy shocks to output and inflation is more relevant than suggested by the recent literature, involving significant reactions in labor and credit markets, the magnitudes of which depend on several parameters' values. Second, imperfection in the pass-through from policy rates to loan rates is an inner and ineradicable feature of any economy where matching frictions exist in labor and credit markets, as it depends on the endogenous reaction of several variables to the monetary policy shock. A first group of variables is related to the amount of loans borrowed by firms; a second group concerns the size of surplus generated by the existence of a productive credit relation, which affects the bargaining between the firm and the bank over the loan interest rate. The degree of incompleteness depends on the value of some key parameters such as the cost of posting labor vacancies (which influences also the cost that banks sustain in order to finance producing firms), the firm's bargaining powers in the labor and in the credit markets, and the costs that firms have to bear in order to look for lines of credit and that banks sustain in order to post their credit vacancies. These conclusions contribute to better understand the effects produced in New Keynesian DSGE models by the interplay of imperfections in several markets, a field where contributions are limited and the joint effects of labor and financial markets imperfections remain a mostly unexplored frontier of research.

The chapter is structured as follows. In the next section we describe the model economy. In section 3.3 we discuss our calibration strategy. In section 3.4 we present the dynamic properties of the benchmark model and we compare them with those which obtain when search and matching frictions are present only in the labor market and the interest rate pass-through is complete. In section 3.5 we discuss the effects on the model dynamics produced by changes in the main parameters influencing the degree of the loan interest rate pass-through. Section 3.6 concludes.

3.2 The Model Economy

Building on the original intuition by Wasmer and Weil (2004), we introduce search and matching frictions in both the labor and the credit markets into a cash in advance New Keynesian DSGE model with sticky prices. The economy is composed of four sets of agents: households, firms, banks and a monetary authority. Since firms do not possess their own cash, in order to produce they must obtain loans from banks that allow them to pay for the cost of job vacancy posting and for the wage bill. Before production begins, wholesale competitive firms, in order to finance their labor vacancy posting, hence search in the credit market for lines of credit vacancies $\left(V_t^B\right)$ posted by banks. Each realized match between a firm and a bank provides the firm with one line of credit of real value k^F, which is also the cost that must be sustained in order to post one vacancy in the labour market, where unemployed workers are searching for jobs. As a bank can provide several lines of credit to a firm, in each period t, the total number of matched credit lines which finance job vacancies (H_t) is equal to the total number of job vacancies posted by firms $\left(V_t^F\right)$. If the firm which has matched with a bank does not find a match in the labor market, it will be unable to produce and it will have to start, in the next period, the searching process afresh. A job vacancy which is not filled thus produces a default on the corresponding line of credit. We assume that the cost of default is borne by the banks, which also collect deposits (D_t) from households. Finally, the producing firm obtains from the bank L_t^N lines of credit which allow it to pay the nominal wage $W_t h_t$ to N_t workers, where h_t is the number of hours worked and W_t is the nominal hourly wage.

After wages are paid the wholesale production occurs. Monopolistic competitive retail firms then transform the wholesale homogeneous goods into differentiated retail goods which are sold to households. At the end of the period, banks receive from firms the principal plus interest on loans and households receive profit income from financial intermediaries and firms, and the principal plus interest on deposits. A fraction of the wholesale firms that produce in a given period obtain loans also in the next period. This fraction is determined by exogenous separation rates specifying the fraction of labor matches and of credit matches which are destroyed at the end of the production period. The monetary authority sets the rate of interest according to a rule to be specified below.

3.2.1 Matching

In the labor market, the search for workers is costly and the existence of search frictions prevents some workers from finding jobs and some posted job vacancies from being filled. Similarly, search frictions in the credit market prevent some firms from obtaining lines of credit and some banks from filling all their posted credit vacancies. Banks and wholesale firms choose the number of vacancies they want to post (V_t^B and V_t^F, respectively). Denoting s_t^F and s_t^W the demand for lines of credit by firms and the fraction of workers searching for jobs, respectively, the number of new matches in the markets for labor and for lines of credit are determined by the Cobb-Douglas matching functions $M_t = \eta (V_t^F)^{\xi} (s_t^W)^{1-\xi}$ and $H_t = \upsilon (V_t^B)^{\zeta} (s_t^F)^{1-\zeta}$, where η and υ are scale parameters. $p_t^B = H_t / s_t^F$ is the probability that a line of credit demanded by a firm matches with a credit vacancy posted by a bank, $q_t^F = M_t / V_t^F$ is the probability that a firm matches with a worker. By defining $\theta_t^L = V_t^F / s_t^W$ and $\theta_t^C = s_t^F / V_t^B$ as the aggregate labor and credit market tightnesses (from the firm's viewpoint), respectively, it follows that the probability that a worker matches with a firm is $p_t^F = \theta_t^L q_t^F$ and that the probability for a bank of filling a posted credit vacancy is $q_t^B = \theta_t^C p_t^B$. In each period it must hence be: $M_t = s_t^W p_t^F = V_t^F q_t^F$ and $H_t = V_t^B q_t^B = s_t^F p_t^B$. If θ_t^L increases, q_t^F diminishes and p_t^F increases. If θ_t^C increases, p_t^B falls and q_t^B increases. It is worth noticing here that the four matching probabilities (the two markets) are interdependent, as we shall obtain that $V_t^F = s_t^F p_t^B$.

3.2.2 Households

There exists a continuum of households of mass one maximizing the expected discounted value of their utility. The preferences of the representative household are defined over leisure and a composite consumption good $C_t = \left[\int_0^1 C_{it}^{\frac{\varepsilon-1}{\varepsilon}} di\right]^{\frac{\varepsilon}{\varepsilon-1}}$, consisting of the differentiated goods (C_{it})

produced by retail firms. As usual, it is $C_{it} = (\frac{P_{it}}{P_t})^{-\varepsilon} C_t$, where $\varepsilon > 1$ is the parameter governing the elasticity of substitution between differentiated goods, which are indexed by i. The cost of one unit of the consumption basket is given by the aggregation of the prices of the differentiated products, $P_t = \left[\int_0^1 P_{it}^{1-\varepsilon} di\right]^{\frac{1}{1-\varepsilon}}$. Household members can be either employed (N_t) in a labor match with wholesale firms, earning the efficiently bargained real wage $w_t = W_t/P_t$, or unemployed $(1 - N_t)$, enjoying a fixed amount of benefits, w^u, paid by lump sum taxes on banks' and retailers' profits. The employed worker works h_t hours (intensive margin), where h_t is determined by the efficient Nash bargaining to be described below. The separability of the utility function allows us to make the usual assumption that consumption risks are fully pooled within the household. All households hence solve the same problem:

$$G_t = \max_{C_t, D_t} \left[\frac{C_t^{1-\sigma}}{1-\sigma} - \vartheta \frac{h_t^{1+\phi}}{1+\phi} + \beta E_t G_{t+1} \right]$$

$$s.t.\ \ C_t = w_t h_t N_t + (1 - N_t) w^u + \frac{\Pi_{t-1}^F}{P_t} + \frac{\Pi_{t-1}^S}{P_t} + \frac{\Pi_{t-1}^B}{P_t} - \frac{D_t}{P_t} + R_{t-1}^D \frac{D_{t-1}}{P_t}$$

The constraint is obtained by taking into account the CIA constraint, $P_t C_t \leq B_t + W_t h_t N_t + (1 - N_t) w^u P_t - D_t$, where B_t is nominal cash holding ("bank notes"), and the amount of money carried over to the following period, $B_{t+1} = B_t + W_t h_t N_t + (1 - N_t) w^u P_t - D_t - P_t C_t + \Pi_t^B + \Pi_t^S + \Pi_t^F + R_t^D D_t$.[3] Consumption and savings are hence financed by: real labor income, $w_t h_t N_t$; unemployment benefits, $(1 - N_t) w^u$; the sum generated by previous period deposits, $R_{t-1}^D D_{t-1} = (1 + r_{t-1}^D) D_{t-1}$, where r_t^D is the rate of interest on deposits; profits from banks, the specialized firm posting the wholesale firms' vacancies and retailers, net of lump-sum government taxes used to pay unemployment benefits, Π_t^F, Π_t^S and Π_t^B. β is the household's subjective discount factor and ϑ is a scale parameter. The solution of this problem leads to the standard Euler equation:

$$\lambda_t = R_t^D \beta E_t \frac{P_t}{P_{t+1}} \lambda_{t+1} \quad (3.1)$$

where $\lambda_t = C_t^{-\sigma}$ is the marginal utility of consumption. The aggregate dynamics of employment is described by:

$$N_t = (1 - \rho) N_{t-1} + p_t^F s_t^W \quad (3.2)$$

where $s_t^W = 1 - (1 - \rho) N_{t-1}$. The exogenous separation rates relative to the firm-worker[4] and the firm-bank relations are $\rho^F \in [0, 1]$ and $\rho^B \in [0, 1]$, respectively. We assume that separation in one market (labor or credit) implies also separation in the other one. If one separation occurs, the firm will have to go once again through all the matching phases, starting from the demand for lines of credit. It follows that $\rho = \rho^F + \rho^B - \rho^F \rho^B$. The first term on the right hand side of equation (3.2) hence represents the number of workers who have not separated from firms that were producing in the previous period and that maintain the lines of credit allowing them to finance the wages to be paid to those workers. The second term represents the new matches in the labor market, to be further analyzed below. Unemployment is determined *ex post* as: $U_t = 1 - N_t$.

[3] The constraint is obtained by substituting the CIA constraint into the equation for B_{t+1}, calculating it a period backward and substituting the result back into the CIA constraint expressed in real terms. The detailed derivation and the linearization of the model are provided in a technical appendix available from the authors upon request.

[4] Hall (2005) documented that the separation rate does not vary considerably along the business cycle.

3.2.3 Wholesale firms

A continuum of competitive wholesale firms of mass one produce an homogenous good. The production function of the representative firm is:

$$Y_t^w = Ah_t^\alpha N_t \tag{3.3}$$

where A is the productivity factor.

The representative firm must determine the optimal number of job vacancies to post. Vacancies are costs for producing firms and proceeds for a specialized firm "producing" posting at no costs. These proceeds enter aggregate profits that can be spent by households. The number of job vacancies posted by each firm at time t is equal to the realized matches in the credit market. We make the timing assumption that credit lines are transformed into job vacancies immediately (e.g., Ravenna and Walsh, 2008; Gertler, Sala and Trigari, 2008):

$$V_t^F = p_t^B s_t^F \tag{3.4}$$

The number of workers available for production in each firm at time t is:

$$N_t = (1-\rho)N_{t-1} + M_t \tag{3.5}$$

where $M_t = q_t^F V_t^F$ are the labor matches, given by the vacancies posted by the firm (that has obtained the necessary credit lines) multiplied by the probability that a vacancy is filled. The value of the firm, F_t, is:

$$F_t = -f_t s_t^F + \frac{Y_t}{\mu_t} - R_t^L w_t h_t N_t - R_t^L k^F q_t^F V_t^F + \beta E_t \frac{\lambda_{t+1}}{\lambda_t} F_{t+1} \tag{3.6}$$

where $f_t = f/\lambda_t$ denotes a utility unit cost born by the firm and k^F is the financial cost (in real terms) of posting a job vacancy financed after the credit match. As wholesale firms sell goods at the competitive price P_t^w, the real value of a firm's output expressed in terms of consumption goods is $P_t^w Y_t^w / P_t = Y_t^w/\mu_t$, where $\mu_t = P_t/P_t^w$ is the mark up of the retail sector over the price of the wholesale good. Recalling that the representative wholesale firm borrows from the bank, at the nominal interest rate factor on loans R_t^L, the funds necessary to post its vacancies and to hire workers, $(R_t^L w_t h_t N_t + R_t^L k^F q_t^F V_t^F)$ represents the firm's real repayment to the bank. Finally, $\beta E_t \frac{\lambda_{t+1}}{\lambda_t}$ is the firm's discount rate.

At any time, the firm chooses V_t^F by setting s_t^F so as to maximize (3.6) subject to (3.3), (3.4) and (3.5). By using the envelope theorem we get the firm's job creating condition:

$$\frac{f_t}{q_t^F p_t^B} + R_t^L k^F = \frac{Ah_t^\alpha}{\mu_t} - R_t^L w_t h_t + (1-\rho)\beta E_t \frac{\lambda_{t+1}}{\lambda_t}\left(\frac{f_{t+1}}{q_{t+1}^F p_{t+1}^B} + R_{t+1}^L k^F\right) \tag{3.7}$$

Equation (3.7) shows that the condition to demand a new line of credit at time t depends on the firm's stream of present earnings and of discounted future savings on job vacancy posting. The term $f_t/\left(q_t^F p_t^B\right)$ represents the time it takes for a firm to become active (i.e., to find a match with a bank as well as with a worker) and $R_t^L k^F$ is the financial cost of the line of credit obtained for job vacancy posting.

3.2.4 Wage and hours bargaining

The real wage, determined by an efficient Nash bargaining between the firm and the worker, is obtained by maximizing $(S_t^F)^{1-d}(S_t^W)^d$ with respect to w_t, where d represents the bargaining power of the worker and $(1-d)$ that of the firm, S_t^F is the firm's surplus (the difference between the firms' values if a match is obtained and if a match is not obtained) and S_t^W is the worker's surplus (the value the worker enjoys when being matched relative to not being matched). The free entry condition and equation (3.7) allow us to write:[5]

$$S_t^F = \frac{f_t}{q_t^F p_t^B} + R_t^L k^F \tag{3.8}$$

The worker surplus is:

$$S_t^W = \left(w_t h_t - \frac{g(h_t)}{\lambda_t} - w^u\right) + (1-\rho)\beta E_t \frac{\lambda_{t+1}}{\lambda_t}(1-p_{t+1}^F)S_{t+1}^W \tag{3.9}$$

and the optimality condition of the Nash bargaining is:

$$(1-d)\delta_t^F S_t^W + d\delta_t^W S_t^F = 0 \tag{3.10}$$

where $\delta_t^F = \dfrac{\partial S_t^F}{\partial w_t} = -R_t^L h_t$ and $\delta_t^W = \dfrac{\partial S_t^W}{\partial w_t} = h_t$. By substituting (3.8) and (3.9) into (3.10), and using (3.7), we get the wage equation,

$$\begin{aligned} w_t = {} & (1-d)\left(\frac{mrs_t}{1+\phi} + \frac{w^u}{h_t}\right) + \\ & + \frac{d}{R_t^L}\left[\frac{mpl_t}{\alpha\mu_t} + \frac{(1-\rho)\beta}{h_t} E_t \frac{\lambda_{t+1}}{\lambda_t}\left(\frac{f_{t+1}}{q_{t+1}^F p_{t+1}^B} + R_{t+1}^L k^F\right)\left(1 - \frac{R_t^L(1-p_{t+1}^F)}{R_{t+1}^L}\right)\right] \end{aligned} \tag{3.11}$$

where $mrs_t = \vartheta \dfrac{h_t^\phi}{\lambda_t}$ is the worker's marginal rate of substitution and $mpl_t = \dfrac{\partial A h_t^\alpha}{\partial h_t} = A\alpha h_t^{\alpha-1}$ is the marginal product of labor (hours) per worker. Equation (3.11) depicts that real wage is a weighted average of the worker's disutility from supplying hours of work plus the foregone flow benefit from unemployment, and the firm's revenues plus the future expected net present value when remaining in the match in the following period.

Hours worked are also determined by an efficient bargaining. The optimality condition is:

$$(1-d)\tau_t^F S_t^W + d\tau_t^W S_t^F = 0 \tag{3.12}$$

Being $\tau_t^F = \partial S_t^F/\partial h_t = \left(mpl_t/\mu_t - w_t R_t^L\right)$ and $\tau_t^W = \partial S_t^W/\partial h_t = (w_t - mrs_t)$, and using equation (3.10), optimal hours are obtained from the condition $mpl_t/\left(\mu_t R_t^L\right) = mrs_t$, that is:

$$h_t = \left(\frac{\vartheta \mu_t R_t^L}{\alpha A \lambda_t}\right)^{\frac{1}{\alpha-1-\phi}} \tag{3.13}$$

[5] Recall that the defaulting firm leaves the market at no cost.

3.2.5 Retail firms

Retail firms purchase the goods produced by the wholesale sector and transform them by a one-to-one technology, into the differentiated products purchased by households. Cost minimization provides the condition that the retail firm's nominal marginal cost (mc_t^n) be equal to the price charged by the wholesale firm for its product P_t^w. In this sector prices are adjusted according to the Calvo rule, so that in each period a firm can adjust its price with probability $1-\omega$. In a symmetric equilibrium all firms set the price so as to maximize the expected lifetime profits subject to demand and this provides the standard New Keynesian price equation:

$$\frac{P_t^*}{P_t} = \frac{\varepsilon}{\varepsilon-1} \frac{E_t \sum_{l=0}^{\infty} \omega^l \beta^l mc_{t+l} \left(\frac{P_{t+l}}{P_t}\right)^{\varepsilon} C_{t+l}^{1-\sigma}}{E_t \sum_{l=0}^{\infty} \omega^l \beta^l \left(\frac{P_{t+l}}{P_t}\right)^{\varepsilon-1} C_{t+l}^{1-\sigma}} \tag{3.14}$$

3.2.6 Banks

The representative bank, operating in a competitive market, collects deposits from households at the interest rate on deposits r_t^D, posts credit vacancies in the credit market sustaining the utility unit cost $b_t = b/\lambda_t$ and provides wholesale firms with the loans upon which the interest rate r_t^L is charged. Each match in the credit market (their total number being equal to $q_t^B V_t^B$) provides firms with the funds necessary to post one vacancy in the labor market (their total number being equal to $k^F V_t^F$) and matched credit lines are immediately transformed into lines of credit financing labor vacancies, only a share of which finds a match with workers. Each of these realized matches provides the lines of credit which allow the firm to pay the wage ($w_t h_t$) to be anticipated to matched workers. The proceeds from sales allow the firm to repay the loans and to pay the interest to the bank. In the following period, each of these firms will continue to have their wage bill financed by banks, unless a separation occurs in at least one market. Given these assumptions, the lines of credit financing vacancies (credit matches) and those financing wages evolve, respectively, according to:

$$H_t = q_t^B V_t^B \tag{3.15}$$

$$L_t^N = (1-\rho) L_{t-1}^N + q_t^F H_t \tag{3.16}$$

Recalling that the funded credit lines for labour vacancy posting that are not transformed into labor matches are destroyed and that in this case the bank looses the anticipated funds and the interest on this amount, the value of the representative bank, J_t, can be written as:[6]

$$J_t = (R_t^L - R_t^D) w_t h_t L_t^N + (R_t^L q_t^F - R_t^D) k^F H_t + R_t^D \frac{X_t}{P_t} - b_t V_t^B + \beta E_t \frac{\lambda_{t+1}}{\lambda_t} J_{t+1} \tag{3.17}$$

where $X_t/P_t = \dfrac{B_{t+1} - B_t}{P_t}$. At any time, the bank chooses H_t by setting V_t^B in order to maximize (3.17) subject to (3.15) and (3.16). By using the envelope theorem we get the bank's "credit

[6] The bank's profit at time t is given by revenues minus costs. Revenues are given by the sum of: (i) the repayment of the loans financing wages plus interest, $R_t^L \left(w_t h_t L_t^N\right)$; (ii) the repayment of the loans financing the posting of job vacancies, which depends on the probability that the firm fills a labor vacancy, plus interest, $R_t^L \left(q_t^F k^F H_t\right)$. Costs are equal to the sum of: (a) the repayment of real deposits plus interest, $R_t^D D_t/P_t$; (b) the sweat cost related to the posting of credit vacancies, $b_t V_t^B$. By using the bank's balance sheet, stating that real deposits and money growth, X_t/P_t,finance the loans provided to firms, $D_t/P_t + X_t/P_t = w_t h_t L_t^N + k^F H_t$, equation (3.17) is straightforwardly obtained.

creating condition":

$$\frac{b_t}{q_t^F q_t^B} - (R_t^L q_t^F - R_t^D)\frac{k^F}{q_t^F} = (R_t^L - R_t^D) w_t h_t + \\ +(1-\rho)\beta E_t \frac{\lambda_{t+1}}{\lambda_t}\left[\frac{b_{t+1}}{q_{t+1}^F q_{t+1}^B} - \left(R_{t+1}^L - \frac{R_{t+1}^D}{q_{t+1}^F}\right) k^F\right] \tag{3.18}$$

Similar to the firm's case, the condition to offer a new line of credit at time t depends on the bank's stream of present earnings and of discounted future savings on credit vacancy posting and on defaults.

3.2.7 Loan Rate Bargaining

In line with Wasmer and Weil (2004), we assume a sequential bargaining framework: the rate of interest on loans is first negotiated by banks and firms; workers and firms then bargain over the wage and hours. We hence solve the problem backward, taking into account the effect of R_t^L on w_t and on h_t.

The bank's surplus, $S_t^B = S_t^C - S_t^{VB}$, is equal to the value the bank enjoys if a match with the firm is realized, $S_t^C = \partial J_t / \partial L_t^N$, less the value which obtains if a match is not generated, which is $S_t^{VB} = 0$ for the free entry condition. We hence obtain:

$$S_t^B = (R_t^L - R_t^D) w_t h_t + (1-\rho)\beta E_t \frac{\lambda_{t+1}}{\lambda_t}\left[\frac{b_{t+1}}{q_{t+1}^F q_{t+1}^B} - (R_{t+1}^L q_{t+1}^F - R_{t+1}^D)\frac{k^F}{q_{t+1}^F}\right] \tag{3.19}$$

The interest rate on loans is obtained by maximizing the Nash product $(S_t^B)^{1-z}(S_t^F)^z$. The optimality condition is:

$$(1-z)\gamma_t^B S_t^F + z\gamma_t^F S_t^B = 0 \tag{3.20}$$

where z and $(1-z)$ are the bargaining powers of firms and of banks, respectively, $\gamma_t^B = \partial S_t^B / \partial R_t^L$ and $\gamma_t^F = \partial S_t^F / \partial R_t^L$, and where both coefficients depend on $\epsilon_t^W = \frac{\partial w_t}{\partial R_t^L}$ and $\epsilon_t^H = \frac{\partial h_t}{\partial R_t^L}$.[7] Substituting (3.8) and (3.19) into (3.20) we get:

$$R_t^L = \frac{\psi_t}{w_t}\left[\frac{mpl_t}{\alpha\mu_t} + \frac{(1-\rho)\beta}{h_t} E_t \frac{\lambda_{t+1}}{\lambda_t}\left(\frac{f_{t+1}}{q_{t+1}^F p_{t+1}^B} + R_{t+1}^L k^F\right)\right] + \\ + \frac{(1-\psi_t)}{w_t}\left\{w_t R_t^D - \frac{(1-\rho)\beta}{h_t} E_t \frac{\lambda_{t+1}}{\lambda_t}\left[\frac{b_{t+1}}{q_{t+1}^F q_{t+1}^B} - \left(R_{t+1}^L - \frac{R_{t+1}^D}{q_{t+1}^F}\right) k^F\right]\right\} \tag{3.21}$$

where $\psi_t = \dfrac{[(1-z)\gamma_t^B]}{[(1-z)\gamma_t^B - z\gamma_t^F]}$.

The interest rate on loans is a weighted average of the firm's revenues plus future expected net present value from entering a credit relation, on the one side, and the rate of interest on deposits plus the bank's future expected net present value from entering a credit relation, on the other side.

---

[7] It is straightforward to compute:
$\gamma_t^B = w_t h_t + (R_t^L - R_t^D)\left(\epsilon_t^W h_t + \epsilon_t^H w_t\right)$
$\gamma_t^F = \frac{mpl_t}{\mu_t}\epsilon_t^H - w_t h_t - R_t^L\left(\epsilon_t^W h_t + \epsilon_t^H w_t\right)$
where:
$\epsilon_t^W = \frac{\partial w_t}{\partial R_t^L} = -\frac{d}{(R_t^L)^2}\left[\frac{mpl_t}{\alpha\mu_t} + (1-\rho)\beta\frac{1}{h_t}E_t\frac{\lambda_{t+1}}{\lambda_t}\left(\frac{f_{t+1}}{q_{t+1}^F p_{t+1}^B} + R_{t+1}^L k^F\right)\right]$
$\epsilon_t^H = \frac{\partial h_t}{\partial R_t^L} = \frac{1}{\alpha-1-\phi}\frac{h_t}{R_t^L}$

The weights depend not only on the relative bargaining power z, but also on γ_t^B and γ_t^F, which encapsulate wage relative allocational effect and the influence of worked hours h_t.

Equation (3.21) allows us to write the interest rate spread in terms of the market tightnesses:

$$R_t^L - R_t^D = \frac{\psi_t}{w_t}\left[\frac{mpl_t}{\alpha\mu_t} - w_t R_t^D + \frac{(1-\rho)\beta}{h_t} E_t \frac{\lambda_{t+1}}{\lambda_t}\left(\frac{f_{t+1}\theta_{t+1}^C}{\eta\upsilon\frac{\left(\theta_{t+1}^C\right)^{1-\varsigma}}{\left(\theta_{t+1}^L\right)^{1-\xi}}} + R_{t+1}^L k^F\right)\right] +$$

$$-\frac{(1-\psi_t)}{w_t}\left\{\frac{(1-\rho)\beta}{h_t} E_t \frac{\lambda_{t+1}}{\lambda_t}\left[\frac{b_{t+1}}{\eta\upsilon\frac{\left(\theta_{t+1}^C\right)^{1-\varsigma}}{\left(\theta_{t+1}^L\right)^{1-\xi}}} - \left(R_{t+1}^L - \frac{R_{t+1}^D}{\eta\left(\frac{1}{\theta_{t+1}^L}\right)^{1-\xi}}\right)k^F\right]\right\} \quad (3.22)$$

This equation clarifies that if $k^F = b = 0$ and the firm has the maximum bargaining power ($\psi_t = 0$, i.e., $z = 1$) in our model the rate of interest on loans is equal to that on deposits (the interest rate spread is zero) and the economy collapses to a standard frictionless cost channel model with labor market frictions, as in Ravenna and Walsh (2006), where the banking system can be conceived as a "veil".[8] The interest rate pass-through, defined as the percentage deviation of the loan rate of interest from its steady state value ($\hat{r}_t^L$) minus that of the rate on deposits from its steady state ($\hat{r}_t^D$), is in this case complete, i.e., $\partial\hat{r}_t^L/\partial\hat{r}_t^D = 1$, where the hatted variables denote percent deviations from steady state values.

If there exist no search costs ($k^F = b = f = 0$) but the bank has some bargaining power, the loan rate of interest becomes equal to a weighted average depending on the firm's revenues and the interest rate on deposits: $R_t^L = \psi_t \frac{mpl_t}{w_t\alpha\mu_t} + (1-\psi_t) R_t^D$. The interest rate spread, $R_t^L - R_t^D = \frac{\psi_t}{w_t}\left(\frac{mpl_t}{\alpha\mu_t} - w_t R_t^D\right)$, can then be equal to zero, and the pass-through can be complete, only if the firm's revenue is exactly equal to the wage cost (wage plus interest to be paid to the bank). This implies that the wage is exactly equal to the minimum amount that can be accepted by the worker, $w_t = \left(\frac{mrs_t}{1+\phi} + \frac{w^u}{h_t}\right)$, so that the bargaining powers in both the labor and the credit markets do not play any role. If the the firm's revenue is greater than the wage cost, the intermediary can obtain a rate of interest on loans greater than that on deposits according to its bargaining power. In this case, the pass-through will not generally turn out to be complete, as the derivative $\partial\hat{r}_t^L/\partial\hat{r}_t^D$ is determined by a complicated convolution of steady state values which can be equal to one only by chance. The conclusion is the same when costs are introduced into labor and credit markets. The sharing rule now becomes more complex because search and matching creates surpluses to be shared between the bank and the firm and the interest rate spread increases with the share of the firm's savings on future costs that the bank aspires to obtain and decreases with the bank's savings on future costs that the firm is not willing to correspond to the bank. The interest rate spread can hence be equal to zero only if the share of the firm's surplus of an existing match the bank is capturing (net of the wage cost) is exactly equal to the share of the bank's savings on future costs that is appropriated by the firm. If this is not the case, the derivative $\partial\hat{r}_t^L/\partial\hat{r}_t^D$, which is now determined by an even more complicated convolution of steady state values, is generally different from one.

Finally, equation (3.22) highlights that the interest rate spread depends on the interplay of the existing imperfections in both markets, as it depends also on the relative values of the credit and

[8] This is Wicksell's (1936, chapter 9, section B) pure credit economy, where the description of the banking system is based on four fundamental assumptions: (a) banks do not possess their own capital; (b) they do not hold reserve assets; (c) their operating costs are zero; (d) the rate of interest on loans is equal to that on deposits.

the labour market tightness via their effects on the firm's surplus that the bank aims to capture (which increases with the credit and the labor market tightnesses), the bank's savings on future posting that the firm does not want to correspond to the bank (which decreases with the weighted ratio of the credit market tightness to the labor market tightness) and the expected savings on screening cost that the bank sustains in order to give credit to producing firms (which increases with the labor market tightness).

3.2.8 Monetary authorities

As usual in the literature, we assume that the policy rate is equal to the rate on deposits and that the central bank employs the following monetary rule:

$$R_t^D = (R_{t-1}^D)^{\rho_R} \left(\frac{P_t}{P_{t-1}}\right)^{(1-\rho_R)\delta_\pi} (Y_t)^{(1-\rho_R)\delta_Y} \nu_t \tag{3.23}$$

where ρ^R is the degree of interest rate smoothing; δ_π and δ_Y are the weights assigned to the targets of inflation (P_t/P_{t-1}) and output, respectively. The stochastic term $\nu_t = \nu_{t-1}^{\rho_\nu} e^{\varepsilon_t^\nu}$ denotes a stationary first-order autoregressive monetary policy shock.

3.2.9 Market clearing

The aggregate resource constraint is derived from the aggregate money carried over to the following period in real terms, taking into account the government budget constraint. Substituting into this equation the profits of the specialized firm, of the retail firms and of the banks, taking into account the bank balance sheet, it is straightforward to obtain: $C_t = Y_t - \frac{Y_t^w}{\mu_t} + R_t^L \left(w_t h_t L_t^N + q_t^F k^F H_t\right) + (w_t h_t)\left(N_t - L_t^N\right)$. Since wholesale firms make zero profits, it is possible to write $\frac{Y_t^w}{\mu_t} = R_t^L \left(w_t h_t N_t + q_t^F k^F V_t^F\right)$. Using this equation and recalling the good market equilibrium, $Y_t = Y_t^d$, and that $H_t = V_t^F$, we obtain:

$$C_t = Y_t + \left(1 - R_t^L\right) w_t h_t \left(N_t - L_t^N\right)$$

Using the lag operator Γ, equations (3.5) and (3.16) can be written as: $N_t = [1-(1-\rho)\Gamma]^{-1} q_t^F V_t^F = \sum_{i=0}^{\infty}(1-\rho)^i q_{t-i}^F V_{t-i}^F$ and $L_t^N = [1-(1-\rho)\Gamma]^{-1} q_t^F V_t^F = \sum_{i=0}^{\infty}(1-\rho)^i q_{t-i}^F V_{t-i}^F$. This shows that $N_t = L_t^N$. It follows that the aggregate resource constraint is:

$$C_t = Y_t$$

Furthermore the wholesale production is linked to the aggregate demand by the following expression:

$$Y_t^w = Y_t v_t \tag{3.24}$$

where $v_t = \int \left(\frac{P_{it}}{P_t}\right)^{-\varepsilon} di$ is a factor of price dispersion. As shown by Galí (2008) this factor is equal to zero up to a first order approximation when we linearized the model in a neighborhood of zero inflation steady state.

3.3 Benchmark parametrization

In order to focus on the interest rate pass-through, we limit our attention to the response of the model's variables to a negative interest rate shock. We aim to show that the general dynamic properties of the model are fully coherent with those of new Keynesian DSGE models with search and matching frictions only in the labor market, and to highlight the role played by credit market variables in influencing the economy's dynamics. To this aim, we linearize the model's equations around the steady state values and assign to some model's parameters the most recent values employed in the literature. The other coefficients are obtained from steady state conditions (see the technical appendix). In particular, since there exists very limited evidence on players' relative power in interest rate bargaining and on the (utility) cost borne by banks and by firms when offering and demanding credit, we solve the system of steady state equations so as to endogenously determine the values of z, f and b.

In the exercise we present here, we use the log version of the utility function by assuming $\sigma = 1$. In this model the elasticity of output to hours does not correspond to the labor share as it depends on the outcome of the bargaining process. Then, in our benchmark calibration we choose to set $\alpha = 0.75$ such that the production function exhibits decreasing returns to scale with respect to the intensive margin, and which is between the values 0.66 proposed by Christoffel, Kuester and Linzert (2009) and 0.99 used by Christoffel et al. (2009). We set the quarterly discount factor ($\beta = 0.996$) so as to obtain a quarterly real steady state rate of interest on deposits $R^D = 1.0035$ as in de Walque, Pierrard and Rouabah, (2010). The firm's bargaining power over the rate of interest ($z = 0.92$) is set so as to target a steady state value of the interest rate on loans equal to $R^L = 1.016$ (de Walque, Pierrard and Rouabah, 2010).

Steady state output is normalized to one ($Y = 1$) and the TFP steady state level is set accordingly. The steady state employment rate N is calibrated at 0.8, a value lower than in the data because we interpret the unmatched workers as being both unemployed and partly out of the labor force, in line with the abstraction we made from labor force participation decisions (Trigari, 2006). The elasticity of substitution between differentiated goods is conventionally set at $\varepsilon = 6$, which implies a 20 per cent retail mark-up on wholesale prices (e.g., Ravenna and Walsh, 2008). We impose that the cost of posting a labor vacancy is $k^F = 0.07$ (Ernst and Semmler, 2010). The replacement rate is set at $\varpi = 0.54$, which is between the values of 0.4 proposed by Shimer (2005) and 0.85 used by Hall (2009), the latter being based on a broader interpretation that permits utility from leisure and from home production. Firm's probability of not adjusting prices is the conventional value $\omega = 0.75$.

The elasticity of intertemporal substitution in the supply of hours is equal to $1/\phi$. In the face of the existing controversy on the value of this coefficient, we follow the standard business cycle literature and set ϕ equal to one. As for the policy rule, we set the interest rate smoothing coefficient, ρ^R, equal to 0.65 and the parameters attached to inflation, δ_π, and to output, δ_Y, equal to 2.5 and to 0.25, respectively. As for the autoregressive coefficient of the monetary policy shock, we set $\rho_\nu = 0.5$. Finally, we normalize the value of the time spent working in the steady state, h, to 1 and obtain the value of ϑ (the coefficient multiplying the CRRA equations for hours) which is coherent with this normalization. Whereas the literature has usually adopted the conventional value $d = 0.5$, we set $d = 0.15$, in line with the recent estimates suggesting a much lower value of the workers' bargaining power (e.g., Cooley and Quadrini, 1999; Hagerdon and Manovskii, 2008).

As for the credit parameters for which we have limited evidence, we set their values equal to their labor market counterparts. We hence calibrate the separation rates in both the labor and the credit market at 0.05, so as to obtain $\rho = 0.097$, which is close the value 0.1 chosen by Ravenna and Walsh (2008). We set the elasticity of matches to labor market searchers according to the evidence provided by Hagerdon and Manovskii (2008), which is also the midpoint of the evidence typically cited in the literature (Gertler, Sala and Trigari, 2008), and we do the same for credit market matches, so as to calibrate $\xi = \zeta = 0.5$. The steady state job vacancy filling rate is taken as a summary from wide evidence, and the same value is used also for its credit market counterpart: $q^F = q^B = 0.7$. The steady state probability that a firm matches with a bank is also set at $p^B = 0.7$.

The efficiency of matching in both markets (η and ν) are endogenously determined so as to assure coherence between the matches obtained using the given probabilities with those obtained with the matching functions. With this baseline parameterization, we endogenously obtain the steady state values of the real wage ($w = 0.94$) and the values of the utility costs borne in the credit market by firms ($f = 0.36$) and banks ($b = 0.04$).

We discuss below the way the model dynamics change when the key exogenous parameters vary and all the other ones remain constant, including f, b and z.[9]

3.4 Dynamic properties of the model and the interest rate pass-through

3.4.1 The dynamic behavior of the benchmark model

Figure 3.1 shows that the main impulse response functions (IRFs) regarding the macroeconomic variables which we obtain by employing the baseline calibration (solid lines) are in line with the existing New Keynesian DSGE models with search and matching frictions in the labor market. An expansionary monetary shock increases output, employment, hours worked, the wage, the marginal cost and inflation.

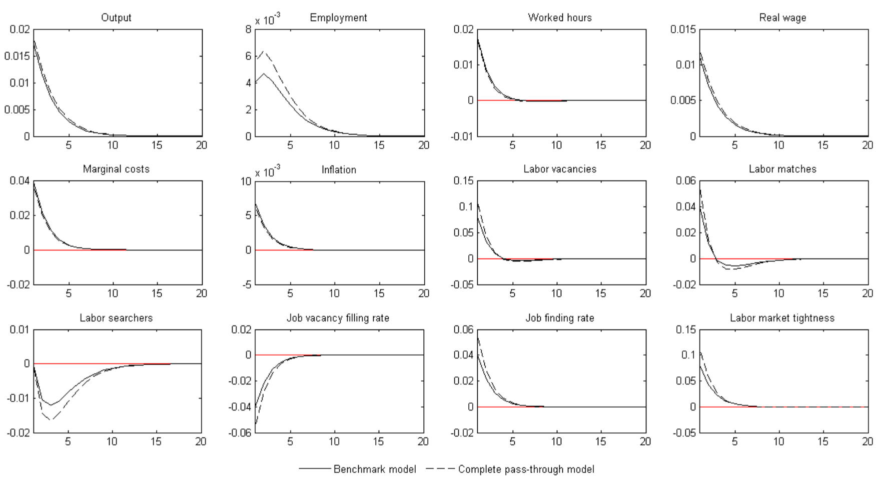

Figure 3.1: Impulse responses to a monetary policy shock.

[9]The new values which we obtain for the steady state variables are specified below, case by case.

Figure 3.1 summarizes also the main IRFs regarding the matching processes. In the labor market the dynamics of posted vacancies, labor matches (hiring), searchers, the job finding rate, the job vacancy filling rate and the labor market tightness are also coherent with the existing New Keynesian DSGE models with search and matching frictions. The explanation of labor market dynamics is standard. With nominal rigidities a reduction in the policy interest rate produces a lower real interest rate; this induces households to increase consumption. The consequent increase in production requires additional labor input. The response of employment (the extensive margin) is lower and more persistent than the response of hours worked per employee (the intensive margin) because firms can immediately adjust hours without sustaining any cost in response to the increase in the demand for output. Yet, the rise in demand also stimulates wholesale firms' expected profits and this boosts job vacancy posting. Since there is more hiring, the number of searchers (determined by the dynamics of employment) falls. As a consequence, the job vacancy filling rate decreases whereas the job finding rate and the labor market tightness go up. In anticipation of a tighter labor market and higher profits the value of an existing match increases; together with greater disutility from supplying hours of work, this allows workers to negotiate higher wages. The raise in wages and the fall in the marginal product of labor lead to higher marginal costs and inflation.

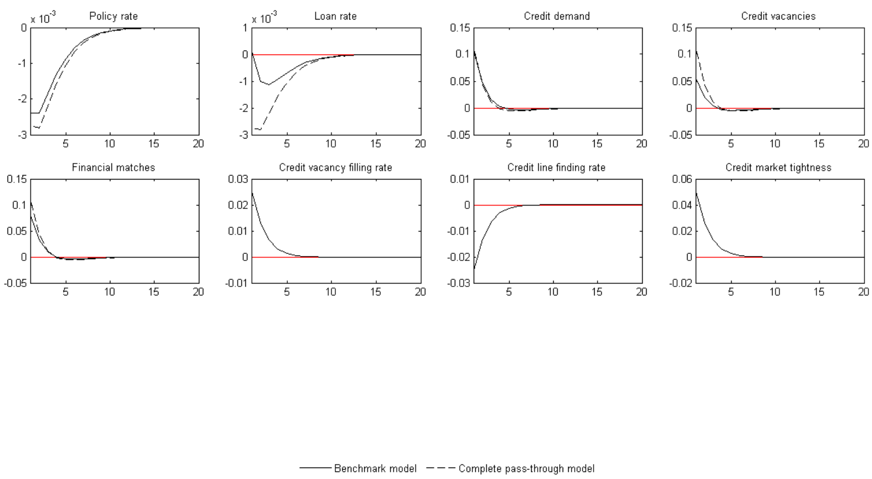

Figure 3.2: Impulse responses to a monetary policy shock.

As for the credit market, in our model firms choose labor vacancies by setting the demand for credit. It follows that the increase in job vacancy posting requires that firms expand their demand for lines of credit, as shown in Figure 3.2. With our benchmark parametrization, banks' supply of lines of credit increases.[10] The overall effect is an increase in credit matches, the credit vacancy filling rate and the credit market tightness (from the point of view of firms), whereas the

[10]The two matching functions present an important difference. In the labor market the dynamics of searchers is guided by a state variable (employment) and by the exogenous separation rate, whereas in the credit market the state variable plays no role in determining credit vacancies which are chosen by banks by equalizing costs and benefits of marginal posting. Depending on the model's parametrization, and in particular on the utility cost b, banks' optimal reaction to an increase in credit demand can be to vary their (costly) vacancy posting more or less than demand.

credit line finding rate and the inverse of the tightness, what Wasmer and Weil (2004) define the liquidity of the credit market, fall. The decrease in the policy (deposit) rate lowers the costs the bank sustains, and is partly rewarded for, when supplying lines of credit, but the increase in credit market tightness raises the firm's surplus of an existing match (see equation 3.21) and the bank (that wants to capture a share of this surplus) may aspire to negotiate an higher interest rate. The latter effect contrasts the former one and this leads to an incomplete pass-through of the policy rate to the interest rate on loans. This is shown in Figure 3.2, where the interest rate on loans falls less than the deposit rate, with a response to the shock depicting an humped-shaped pattern.

3.4.2 Comparison with the complete pass-through model

We can now compare the dynamics generated by the benchmark model with those which obtain when search and matching frictions are present only in the labor market and the interest rate pass-through is complete, i.e., with no distinction between R_t^D and R_t^L (dashed lines). As described in subsection 2.7, in this version of the model any source of surplus arising from a match between firms and banks (the cost of posting credit vacancies, b, and the financial cost of a labor vacancy, k^F) are eliminated and no banks' bargaining power exists ($z = 1$). In order to keep a frictional labor market, the search cost f is now interpreted as the entry cost to be sustained in order to participate in the labor matching process.

As shown in Figure 3.1, the monetary policy shock is slightly more expansionary on output (and consumption) in the complete pass-through model than in the benchmark model. Besides the common effect developing through the demand channel and other things being equal, this depends on the different reactions of the marginal costs which vary more in the benchmark model than in the complete pass-through model because R_t^L does not fall as much as R_t^D does (incomplete pass-through). The strength of the cost channel effect in the complete pass-through model hence mitigates the increase of marginal cost and inflation. The implications of this argument on R_t^D are straightforward.

In the complete pass-through model the stronger increase in output asks for a sharper increase in labor input. The complete pass-through and the absence of credit search frictions lower the expected cost of filling a job vacancy (which is equal to $\frac{f_t}{q_t^F}$ instead of $\frac{f_t}{q_t^F p_t^B} + R_t^L k^F$) and induce firms to meet this need by expanding the extensive margin with only negligible effects on the intensive one.[11] The job vacancy filling rate hence falls more, whereas the labor market tightness and the value of an existing match increase more. The tighter labor market and the higher profits increase the value of an existing match so much as to allow workers to negotiate a slightly higher wage. The introduction of credit market frictions may hence help to moderate the reaction of wages to an expansionary policy shock.

The exercise carried out in this subsection might suggest that an incomplete pass-through generated by credit market frictions has a limited effect on the transmission of monetary policy shocks to output and inflation, thus confirming the results obtained by Kaufmann and Scharler (2009) in a model where the loan rate equation is not microfounded. This conclusion would not however be completely accurate. Kaufmann and Scharler's claim is in fact based on the examination of the impact responses to a monetary policy shock, which in their model are indeed identical in the presence of "high" or "low" degrees of incompleteness in the interest rate pass-though. If we perform the same experiment with our benchmark and complete pass-through models, the differences which obtain in terms of impact responses are however quite different, as summarized in the following

[11] Remember that the production function exhibits constant (decreasing) returns to scale with respect to the extensive (intensive) margin.

table.

Furthermore, the values of the ratio of the standard deviations of inflation and output are also

	Benchmark	Complete pass-through
Output	1.738	1.853
Inflation	0.695	0.643

Table 3.1: Impact responses of output and inflation to a monetary policy shock. Percentage deviations from steady states.

significantly different, being equal to 0.35 in the benchmark model and to 0.29 in the complete pass-through model. Finally, our model allows us to highlight that the economic mechanism transmitting monetary policy shocks to output and inflation is based on the reactions of several labor and credit market variables. The magnitudes of these reactions depend on the values taken up by some key parameters, as we now aim to show.

3.5 Determinants of the interest rate pass-through

In this section we summarize the effects on the model dynamics produced by the main parameters influencing the degree of the loan interest rate pass-through. We focus, in particular, on the bargaining powers of the worker over the wage (d) and of the bank over the loan rate (z), and on the cost of posting labor and credit vacancies ($k^F$and b, respectively).

3.5.1 Bargaining powers

The dotted lines in Figures 3.3 and 3.4 depict the dynamic behavior of the model when $d = 0.05$ (the median value proposed by Cooley and Quadrini, 1999).[12] In this case, due to the reduced bargaining power of the worker, the contracted hourly wage increases less than in the benchmark model following a negative shock on the policy rate, whereas the output increase remains substantially unchanged. This is due to the sharper fall in the interest rate on loans (to be discussed below) which, according to the optimal condition on hours, $mpl_t / \left(\mu_t R_t^L\right) = mrs_t$, asks for a sharper fall in the marginal product of labor. As a consequence, firms adjust more on the intensive margin and less on the extensive one. The lower increase in hiring asks for a milder reaction of labor vacancies and lowers the reaction of workers in search. The net effect is that the probability that a worker finds a firm increases less, whereas the probability of filling a labor vacancy falls less. As a consequence, the labor market tightness (from the point of view of firms) and the labor matches increase less than in the benchmark model.

In the credit market, the milder reaction of labor vacancies generates a lower increase in the demand for lines of credit and the same occurs to the supply of credit, and hence in the credit matches. The probability that a firm finds a bank falls less and the probability of filling a credit vacancy increases less than in the benchmark model, so that the credit market tightness (from the point of view of firms) displays a less positive reaction. This effect on the tightness implies a lower increase in the surplus of an existing credit match which, as explained above, counteracts

[12] Under this parametrization the new values of the matching probabilities are: $q^B = 0.9$ and $p^B = 0.54$, $q^F = 0.57$, $p^F = 0.34$. Further, the steady state rate of interest on loans and of the real wage are respectively $R^L = 1.019$ and $w = 0.90$.

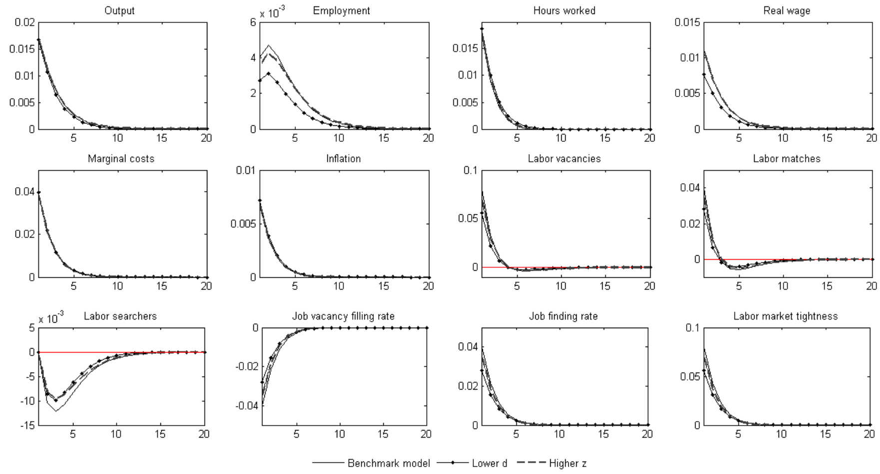

Figure 3.3: Impulse responses to a monetary policy shock: lower d and higher z.

the decrease in the policy rate lowering the costs the bank is rewarded for when supplying lines of credit. When the worker's bargaining power decreases, the milder reaction of the surplus hence produces a sharper fall of the rate of interest on loans and the pass-though becomes less incomplete. The opposite chain of effects is produced by an increase in d.

The dashed lines in Figures 3.3 and 3.4 show the behavior of the model when $z = 0.95$.[13] The lower bargaining power of the bank allows the interest rate on loans to decreases more than in the benchmark case even though the credit market tightness rises more. To understand this, consider that the higher z produces two effects: (i) lower bank's expected profits induce credit vacancy posting and credit matches to increase less than in the benchmark model following an expansionary monetary policy shock; (ii) as in the case of a lower d, the optimal condition on hours implies a sharper fall in the marginal product of labor, a sharper reaction of worked hours and a lower reaction of employment. This explains the lower reaction of labor vacancies and of workers in search, together with the associated changes in the dynamics of the other labour market variables. In the credit market the demand for lines of credit reacts slightly less than in the benchmark model, whereas the positive reaction of the supply of credit is much less acute. It follows that the credit line finding rate decreases more, whereas the credit vacancy filling rate and the credit market tightness rise more than in the benchmark model. The firm's surplus of an existing match the bank aims at capturing is hence higher, but it is weighted by a lower (modified) bargaining power, ψ_t. Furthermore, as clarified by equation (3.21), a greater role in the determination of R_t^L continues to be played by the cost sustained by the bank that the firm is willing to correspond in the interest rate bargaining. The opposite chain of effects is produced by an increase in the bank's bargaining power.

The findings of this subsection can be summarized by stating that the degree of pass-through from policy rates to loan rates increases with the firm's bargaining powers in wage and in interest

[13]Under this parametrization the new values of the matching probabilities in the credit and labor market are: $q^B = 0.87$, $p^B = 0.57$, $q^F = 0.79$, $p^F = 0.25$. Further, the steady state rate of interest on loans and of the real wage are respectively $R^L = 1.012$ and $w = 0.94$.

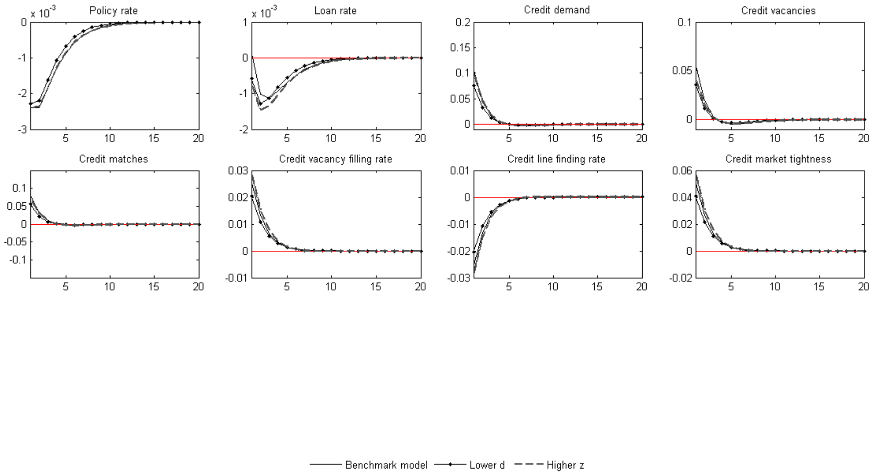

Figure 3.4: Impulse responses to a monetary policy shock: lower d and higher z.

rate bargaining.

3.5.2 Posting costs

In Figure 3.5, the dashed lines depict the dynamics of the model's variables which react the most when the cost of posting labor vacancies tends to zero ($k^F = 0.0001$).[14] In this case the substantial absence of a financial cost to be sustained when posting a labor vacancy induces firms, with respect to the benchmark model, to expand more on the extensive margin. It follows that labor vacancies increase more and searchers decrease more; the labor market tightness increase more. As for the credit market, it should first be noted that in the benchmark model the term $(R_t^L q_t^F - R_t^D)k^F/q_t^F$ is negative. It can thus be interpreted as a screening cost that banks sustain in order to give credit to producing firms. The elimination of k^F hence reduces the cost that banks sustain to finance producing firms and induces intermediaries to increase credit vacancy posting. A congestion effect is produced: the probability for a bank to fill a credit vacancy increases less (it becomes more difficult for the bank to fill a credit vacancy) and the probability that a firm finds a line of credit falls less than in the benchmark model; the credit market tightness (from the point of view of firms) increases by less. In the loan rate bargaining, the firm's expected savings on labor vacancy posting disappear and this mitigates the bank's aspiration to negotiate a higher interest rate. Moreover, the sharper decrease in the policy (deposit) rate and the vanishing of the bank's screening costs[15] further reduces the bank's reward for the costs it sustains when supplying lines of credit. All these effects allow the loan interest rate to fall more than under the benchmark calibration and the degree of incompleteness in the interest rate pass-through decreases.

The last results we describe here, without however presenting any figure due the limited changes

[14] Under this parametrization the new values of the matching probabilities are: $q^B = 0.91$ and $p^B = 0.54$, $q^F = 0.82$, $p^F = 0.24$. Further, the steady state rate of interest on loans and of the real wage are respectively $R^L = 1.017$ and $w = 0.93$.

[15] In the benchmark model these costs positively react to a monetary easening due to the decrease in the job vacancy filling rate.

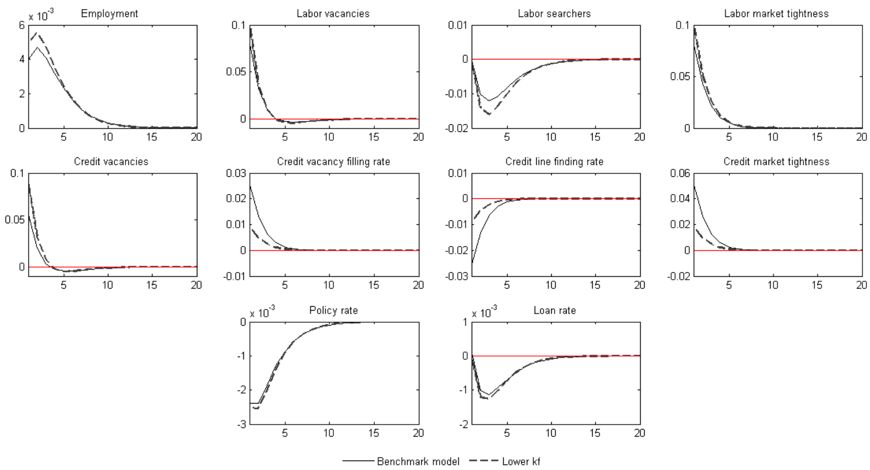

Figure 3.5: Impulse responses to a monetary policy shock: lower k^F.

which we obtain, are those produced by an increase in the cost to be sustained by the bank when offering lines of credit. The greater the value of b the less banks increase credit vacancies as compared to the benchmark model; as a consequence, credit matches, and hence labor matches and employment, react the less. This implies that firms post less vacancies and hence ask for less lines of credit. With our parametrization, and in particular with the chosen value for the cost f, the reaction of firms in their attempt to mitigate their (costly) search in the credit market is stronger than that of banks and the credit market tightness increases less than in the benchmark case. A greater b also means greater bank's savings on future costs and hence a sharper reaction, as compared to the benchmark model, of this component that the firm is not willing to correspond to the bank. Both effects contribute to generate a stronger reaction of the loan interest rate to an expansionary monetary policy shock and thus to reduce the incompleteness of the pass-through.

3.6 Conclusions

In this chapter we have extended to a cash in advance New Keynesian DSGE theoretical model with sticky prices Wasmer and Weil's (2004) suggestion to introduce search and matching frictions in both the labor and the financial markets. In this economy households are depicted in a standard fashion, and so are retail firms producing under monopolistic competition the differentiated goods consumed by households. Before starting production, wholesale competitive firms, producing a homogeneous good, search for credit by banks posting loan offers; the firms that match with banks may post vacancies in the labor market, where unemployed workers are searching for jobs. The firms that have filled their vacancies obtain from banks the funds necessary to pay for the wage bill. They then sell production to retail firms, loans are repaid and households receive profit income from financial intermediaries and firms, and the principal plus interest on deposits. The wage and the interest rate on loans are determined according to a sequential Nash bargaining procedure. A fraction of the wholesale firms producing in a given period - determined on the basis of a separation rate specifying the fraction of labor and credit matches which are destructed at the end of the production period - obtains loans also in the next period. The firms matching with banks and obtaining the loans necessary to post vacancies in the labor market may not be able to match with workers and so to start production. They hence cannot repay their debt with the banks and default on the corresponding loans.

The dynamic properties of the macroeconomic variables of our model with respect to a monetary shock are consistent with the main cyclical evidence reported in the New Keynesian DSGE literature and the same holds for the other labor market variables. Yet, by comparing the benchmark model with the model where no distinction is made between R_t^D and R_t^L (complete cost channel model), we showed that the presence of credit market frictions moderates the reactions of both output and wages to an expansionary policy shock. We also documented that the difference between the impact responses of output and inflation which we obtain with the benchmark model and with the complete cost channel model is more relevant than suggested by the recent literature.

The model also allows us to propose a novel explanation of the incomplete pass-through of policy rate changes to bank loan rates in an economy where asymmetric informations are absent and banks are perfectly competitive. In a model with search and matching frictions in labor and credit markets, the interest rate pass-through is in fact necessarily incomplete if banks possess some power in the bargaining over the loan rate of interest, if the cost of posting job vacancies (which also influences the cost that bank have to bear before being able to finance producing firms) is positive and if firms and bank sustain costs when searching for lines of credit and when posting credit vacancies, respectively. Finally, as the interest rate spread increases with the share of the firm's savings on future costs that the bank aspires to obtain and decreases with the bank's savings on future costs that the firm is not willing to correspond to the bank, and since these magnitudes depend also on the labor market tightness, the interplay of imperfections in labour and credit markets plays an important role in determining the model's behavior.

This conclusion might suggest that the less incomplete interest rate pass-through that empirical investigations documented for the United States vis à vis the Euro Area before the recent financial crisis could be explained by the lower bargaining power of banks (due to the relatively more important role played by capital markets vis à vis banks) and the lower costs in the functioning of the credit market which are present in the former economy. The recent financial crisis, by disrupting credit markets and by increasing these costs more in the United States than in the Euro Area, may have favoured the emergence of a similar degree of incompleteness of the interest bank loan rate pass-through in the two economies.

Bibliography

[1] Angeloni, I., and Ehrmann, M. (2003), *Monetary transmission in the euro area: Early evidence. Economic Policy*, 18, 469-501.

[2] Angeloni, I., Kashyap, A. K., and Mojon, B., Eds. (2003), *Monetary policy transmission in the Euro Area*, Cambridge, Cambridge University Press.

[3] Chowdhury, I., Hoffman, M., and Schabert, A. (2006), Inflation Dynamics and the Cost Channel of Monetary Policy, *European Economic Review*, 50, 995-1016.

[4] Christiano, L. J., Eichenbaum, M., and Evans, C. L. (2005), Nominal rigidities and the dynamic effects of a shock to monetary policy, *Journal of Political Economy,* 113, 1-45.

[5] Christoffel, K., Costain, J., de Walque, G., Kuester, K., Linzert, T., Millard, S., and Pierrard, O. (2009), Inflation dynamics with labour market matching assessing alternative specifications, ECB Working Paper No. 1053.

[6] Christoffel, K., Kuester, K., and Linzert, T. (2009), The role of labor markets for euro area monetary policy, *European Economic Review*, 53, 908-936

[7] Čihák, M., Harjes, T., and Stavrev, E. (2009), Euro area monetary policy in uncharted waters, IMF working paper No. 185.

[8] Cooley, T. F., and Quadrini, V., 1999. A neoclassical model of the Phillips curve relation, *Journal of Monetary Economics*, 44, 165-193.

[9] de Bondt, G., Mojon, B., and Valla, N. (2005), Term structure and the sluggishness of retail bank interest rates in Euro Area countries, ECB Working Paper Series No. 518.

[10] de Walque, G., Pierrard, O., and Rouabah, A. (2010), Financial (in)stability, supervision and liquidity, *Economic Journal*, Royal Economic Society, 120, 1234-1261.

[11] Égert, B., Crespo-Cuaresma, J., and Reininger, T. (2007), Interest rate pass-through in Central and Eastern Europe: Reborn from ashes merely to pass away?, *Journal of Policy Modeling*, 29, 209-225.

[12] Ernst, E. and Semmler, W. (2010), Global dynamics in a model with search and matching in labor and capital markets, *Journal of Economic Dynamics and Control*, 34, 1651-1679.

[13] Fourcans, A., and Vranceanu, R. (2007), The ECB monetary policy: Choices and challenges, *Journal of Policy Modeling*, 29, 181-194.

[14] Gambacorta, L. (2008), How do banks set interest rates?, *European Economic Review*, 52(5), 792-819.

[15] Gertler, M., Sala L., and Trigari, A. (2008), An estimated monetary DSGE model with unemployment and staggered nominal wage bargaining, *Journal of Money, Credit and Banking*, 40, 1713-1764.

[16] Gropp, R., Kok Sørensen, C. and Lichtenberger, J. (2007), The dynamics of bank spreads and financial structure, ECB Working Paper Series No. 714.

[17] Hagerdon, M., and Manovskii, I. (2008), The cyclical behavior of equilibrium unemployment and vacancies revisited, *American Economic Review*, 98, 1692-1706.

[18] Hall, R. E. (2005), Job loss, job finding, and unemployment in the U.S. economy over the past fifty years, National Bureau of Economic Research, *Macroeconomics Annual 2005*, 101-137.

[19] Hall, R.E. (2009), Reconciling cyclical movements in the marginal value of time and the marginal product of labor, *Journal of Political Economy*, 117, 281-323.

[20] Hannan, T., and Berger, A. (1991), The rigidity of prices: Evidence from the banking industry, *American Economic Review*, 95, 50-64.

[21] Hofmann, B. (2006), EMU and the transmission of monetary policy: Evidence from business lending rates, *Empirica*, 33, 209-229.

[22] Hülsewig, O., Mayer, E., Wollmershäuser, T., 2009. Bank behavior, incomplete interest rate pass-through, and the cost channel of monetary transmission, *Economic Modelling*, 26, 1310-1327.

[23] International Monetary Fund, 2008. Global financial stability report. IMF, Washington D.C.

[24] Karagiannis, S., Panagopoulos, Y., and Vlamis, P. (2010), Interest rate pass-through in Europe and the US: Monetary policy after the financial crisis, *Journal of Policy Modeling*, 32, 323-338.

[25] Kaufmann, S., and Scharler, J. (2009), Financial Systems and the Cost Channel Transmission of Monetary Policy Shocks, *Economic Modelling*, 26, 40-46.

[26] Klemperer, P. (1987), Markets with consumer switching costs, *Quarterly Journal of Economics*, 102, 375-394.

[27] Kobayashi, T. (2008), Incomplete interest rate pass-through and optimal monetary policy, *International Journal of Central Banking*, 4, 77-118.

[28] Kok Sørensen, C., and Werner, T. (2006), Bank interest rate pass-through in the Euro Area: A cross country comparison, ECB Working Paper No. 580.

[29] Mojon, B. (2000) Financial structure and the interest rate channel of the ECB monetary policy, ECB Working Paper No. 40.

[30] Nicoletti, G., and Pierrard, O. (2006), Capital market frictions and the business cycle, Département des sciences économiques de l'Université Catholique de Louvain, Discussion Paper No. 53.

[31] Petrosky-Nadeau, N. and Wasmer, E. (2010a), The cyclical volatility of labor markets under frictional financial markets, IZA Discussion Paper No 5131.

[32] Ravenna, F., and Walsh, C. E. (2006), Optimal monetary policy with the cost channel, *Journal of Monetary Economics*, 53, 199-216.

[33] Ravenna, F., and Walsh, C. E. (2008), Vacancies, unemployment and the Phillips curve, *European Economic Review*, 52, 1494-1521.

[34] Sander, H., and Kleimeier, S. (2004), Convergence in Euro-zone retail banking? What interest rate pass-through tells us about monetary policy transmission, competition and integration, *Journal of International Money and Finance*, 23, 461-92.

[35] Scharler, J. (2008), Do bank-based financial systems reduce macroeconomic volatility by smoothing interest rates?, *Journal of Macroeconomics*, 30, 1207-1221.

[36] Shimer, R. (2005), The ciclical behavior of equilibrium unemployment and vacancies, *American Economic Review*, 95, 25-49.

[37] Stiglitz, J., and Weiss, A. (1981), Credit rationing in markets with imperfect information, *American Economic Review*, 71, 393-410.

[38] Trigari, A. (2009) Equilibrium unemployment, job flows and inflation dynamics, *Journal of Money, Credit and Banking*, 41, 1-33.

[39] Trigari, A. (2006) The role of search frictions and bargaining for inflation dynamics, IGIER Working Paper No. 304.

[40] Van Leuvensteijn, M., Kok Sørensen, C., Bikker, J., and Van Rixtel, A. (2008), Impact of bank competition on the interest rate pass-through in the euro area, ECB working paper no. 885.

[41] Walsh, C. E. (2003), Labor market search and monetary shocks, in: Altug, S., Chadha, J. and Nolan, C., Eds., *Elements of dynamic macroeconomic analysis*, Cambridge, Cambridge University Press, 451-486.

[42] Wasmer, E., and Weil, P. (2004), The macroeconomics of labor and credit market imperfections, *American Economic Review*, 94, 944-963.

[43] Wicksell, J. (1898), *Interest and prices*, 1836 Edition, London, Macmillan.

Technical Appendices

Appendix A

Appendix to Chapter 1

Data and Sources

Real GDP: Quarterly Real Gross Domestic Product, Seasonally Adjusted, U.S. Department of Commerce: Bureau of Economic Analysis and Federal Reserve Economic Data of Saint Luis.

Employment: Monthly Employees, Seasonally Adjusted, U.S. Department of Labor: Bureau of Labor Statistics and Federal Reserve Economic Data of Saint Luis.

Nominal Wages: Monthly wage and salary disbursements, Seasonally Adjusted, U.S. Department of Commerce: Bureau of Economic Analysis and Federal Reserve Economic Data of Saint Luis.

Price Index: Monthly Consumer Price Index for All Urban Consumers, Seasonally Adjusted, U.S. Department of Labor: Bureau of Labor Statistics and Federal Reserve Economic Data of Saint Luis.

Policy Rate: Monthly Effective Federal Funds Rate, U.S. Department of Labor: Bureau of Labor Statistics and Federal Reserve Economic Data of Saint Luis.

Interest rate on loans: Quarterly Weighted-Average Effective Loan Rate for All C&I Loans, All Commercial Banks, U.S. Department of Labor: Bureau of Labor Statistics and Federal Reserve Economic Data of Saint Luis.

We compute the average of the monthly flows to transform the monthly time series into quarterly data. In line with Fernández-Villaverde (2010) we compute the real wages by deflating the relative nominal series by the consumer price index. The inflation rate is computed as the quarter on quarter log differences in the Consumer Price Index. Finally, the series of the real GDP, the employment and the real wages are made stationary by the first-difference transformation.

BVAR Construction

Consider the VAR(p) model presented in section (1.2):

$$Y = XB + U$$

The prior of the BVAR model is obtained by combining two types of priors. The first component is determined by a diffuse (or Jeffreys' improper) prior necessary to insure the existence of the prior expectation of Σ:

$$p_1(\Sigma) \propto |\Sigma|^{-\frac{n+1}{2}} \tag{A.1}$$

The second kind of prior relies on a set of $T^{\mathbf{P}}$ dummy observations, $(Y^{\mathbf{P}}, X^{\mathbf{P}})$, whose (normal) likelihood is:

$$p_2(Y^{\mathbf{P}}|B,\Sigma,X^{\mathbf{P}}) \propto |\Sigma|^{-\frac{T^{\mathbf{P}}}{2}} \exp\left\{-\frac{1}{2}Tr(\Sigma^{-1}(Y^{\mathbf{P}} - X^{\mathbf{P}}B)'(Y^{\mathbf{P}} - X^{\mathbf{P}}B))\right\} \tag{A.2}$$

According to Doan, Litterman and Sims (1984) and by following Lubik and Schorfheide (2005) we employ the Minnesota approach for the coefficients of the lags of the BVAR model. The implementation of the Minnesota prior requires to set values for parameters governing the overall tightness of the prior (τ) and the decay factor for scaling down the coefficients of lagged values (d). Moreover we set the length of the presample Y^0 in order to compute its mean and variance (σ^2).[1] In our case for $n = 6$ and $p = 8$. The coefficients of the matrix B are assumed to be a priori independent and normally distributed. The generic autoregressive matrix at the lag h is:

$$\beta_h = \begin{bmatrix} \beta_{h,11} & \cdots & \cdots & \beta_{h,61} \\ \vdots & \ddots & \ddots & \vdots \\ \vdots & \ddots & \ddots & \vdots \\ \beta_{h,61} & \cdots & \cdots & \beta_{h,66} \end{bmatrix}$$

The priors on the coefficients are set in order to reflect the following beliefs:

$$E(\beta_{h,ij}) = \begin{cases} 1 & \text{if } i = j \text{ and } h = 1 \\ 0 & \text{otherwise} \end{cases}$$

Hence, on average, we impose the following dummies:

1. for the coefficients on the first lag:

$$\begin{bmatrix} \delta\tau\sigma_1 & 0 & \cdots & 0 \\ 0 & \delta\tau\sigma_2 & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ 0 & \cdots & 0 & \delta\tau\sigma_6 \end{bmatrix} = \begin{bmatrix} \tau\sigma_1 & 0 & \cdots & 0 & \\ 0 & \tau\sigma_2 & \ddots & \vdots & \underset{6\times 43}{\mathbf{0}} \\ \vdots & \ddots & \ddots & 0 & \\ 0 & \cdots & 0 & \tau\sigma_6 & \end{bmatrix} \begin{bmatrix} \underset{49\times 6}{B} \end{bmatrix} + u'$$

where the shrinkage parameter δ governing the relative importance of the lags of the variables is set equal to 1;

[1] We employ the default calibration proposed by the Dynare BVAR toolbox. Hence we set $\tau = 3$, $d = 0.5$ and the length of Y^0 needed to initialize the lags of the VAR model equal to first 20 observations.

2. for those on the second lag:

$$\left[\underset{6\times 6}{\mathbf{0}}\right] = \left[\begin{array}{cccccc} & \tau\sigma_1 2^d & 0 & \dots & 0 & \\ \underset{6\times 6}{\mathbf{0}} & 0 & \tau\sigma_2 2^d & \ddots & \vdots & \underset{6\times 37}{\mathbf{0}} \\ & \vdots & \ddots & \ddots & 0 & \\ & 0 & \dots & 0 & \tau\sigma_6 2^d & \end{array}\right]\left[\underset{49\times 6}{B}\right] + u'$$

3. for those on the third lag:

$$\left[\underset{6\times 6}{\mathbf{0}}\right] = \left[\begin{array}{cccccc} & \tau\sigma_1 3^d & 0 & \dots & 0 & \\ \underset{6\times 12}{\mathbf{0}} & 0 & \tau\sigma_2 3^d & \ddots & \vdots & \underset{6\times 31}{\mathbf{0}} \\ & \vdots & \ddots & \ddots & 0 & \\ & 0 & \dots & 0 & \tau\sigma_6 3^d & \end{array}\right]\left[\underset{49\times 6}{B}\right] + u'$$

4. and so on for the other five lags.

The previous dummies imply:

$$Var\left(\beta_{h,ij}\right) = \begin{cases} \dfrac{\Sigma_{u,ii}}{\tau^2 h^{2d}\sigma_i^2} & \text{if } i = j \\ \dfrac{\Sigma_{u,jj}}{\tau^2 h^{2d}\sigma_i^2} & \text{otherwise} \end{cases}$$

Furthermore, according to Lubik and Schorfheide (2005), we employ some additional dummies, depending on the hyperparameters which control the tightness of the prior over Σ and the degrees of the co-persistence and persistence matrices.[2]

By combining (A.1) and (A.2) we obtain the final prior:

$$\begin{aligned} p(B,\Sigma) &= p_1(\Sigma)p_2(Y^{\mathbf{P}}|B,\Sigma,X^{\mathbf{P}}) \\ &\propto |\Sigma|^{-\frac{(df^{\mathbf{P}}+n+1+k)}{2}} \exp\left\{-\frac{1}{2}Tr(\Sigma^{-1}(Y^{\mathbf{P}} - X^{\mathbf{P}}B)'(Y^{\mathbf{P}} - X^{\mathbf{P}}B))\right\} \end{aligned} \qquad (A.3)$$

where $df^{\mathbf{P}} = T^{\mathbf{P}} - k$. By defining $\hat{B}^{\mathbf{P}} = (X^{\mathbf{P}'}X^{\mathbf{P}})^{-1}X^{\mathbf{P}'}X^{\mathbf{P}}$ and $S^{\mathbf{P}} = (Y^{\mathbf{P}} - X^{\mathbf{P}}\hat{B}^{\mathbf{P}})'(Y^{\mathbf{P}} - X^{\mathbf{P}}\hat{B}^{\mathbf{P}})$, after some computations we are able to write:

$$\begin{aligned} p(B,\Sigma) &\propto |\Sigma|^{-\frac{(df^{\mathbf{P}}+n+1)}{2}} \exp\left\{-\frac{1}{2}Tr(\Sigma^{-1}S^{\mathbf{P}})\right\} \times \\ & \quad |\Sigma|^{-\frac{k}{2}} \exp\left\{-\frac{1}{2}Tr(\Sigma^{-1}(B-\hat{B}^{\mathbf{P}})'X^{\mathbf{P}'}X^{\mathbf{P}}(B-\hat{B}^{\mathbf{P}}))\right\} \end{aligned}$$

[2]The hyperparameters ω, λ and μ of the Dynare BVAR toolbox control the tightness of the prior over Σ and the degrees of the co-persistence and persistence prior dummies respectively; we set $\omega = 1$, $\lambda = 5$ and $\mu = 2$. Then the total number of dummies is $T^{\mathbf{P}} = n(p + \omega + 1) + 1$.

which is equation (1.1) of the text. The previous prior density has a Normal inverted Wishart form:[3]

$$\Sigma \sim i\mathcal{W}\left(S^{\mathbf{P}}, df^{\mathbf{P}}\right)$$
$$vec\left(B\right)|\Sigma \sim \mathcal{N}\left(vec\left(\hat{B}^{\mathbf{P}}\right), \Sigma \otimes \left(X^{\mathbf{P}\prime}X^{\mathbf{P}}\right)^{-1}\right)$$

Now we consider the model augmented with the dummies:

$$\underset{T^{\mathcal{P}}\times n}{Y^{\mathcal{P}}} = \underset{T^{\mathcal{P}}\times k}{X^{\mathcal{P}}}\underset{k\times n}{B} + \underset{T^{\mathcal{P}}\times n}{U^{\mathcal{P}}}$$

where $X^{\mathcal{P}} = \begin{bmatrix} X^{\mathbf{P}} \\ X \end{bmatrix}$, $Y^{\mathcal{P}} = \begin{bmatrix} Y^{\mathbf{P}} \\ Y \end{bmatrix}$, $U^{\mathcal{P}} = \begin{bmatrix} U^{\mathbf{P}} \\ U \end{bmatrix}$ and $T^{\mathcal{P}} = T + T^{\mathbf{P}}$.

The posterior distribution is obtained by using the Bayes theorem:

$$p(B,\Sigma|Y,X) = \frac{p(Y|B,\Sigma,X)p(B,\Sigma)}{p(Y|X)} \propto p(Y|B,\Sigma,X)p(B,\Sigma) \tag{A.4}$$

Then we get:

$$p(B,\Sigma|Y,X) \propto |\Sigma|^{-\frac{(df^{\mathcal{P}}+n+1+k)}{2}} \exp\left\{-\frac{1}{2}Tr(\Sigma^{-1}(Y^{\mathcal{P}} - X^{\mathcal{P}}B)'(Y^{\mathcal{P}} - X^{\mathcal{P}}B))\right\}$$

or after some manipulations

$$\begin{aligned} p(B,\Sigma|Y,X) \quad \propto \quad & |\Sigma|^{-\frac{(df^{\mathcal{P}}+n+1)}{2}} \exp\left\{-\frac{1}{2}Tr(\Sigma^{-1}S^{\mathcal{P}})\right\} \times \\ & |\Sigma|^{-\frac{k}{2}} \exp\left\{-\frac{1}{2}Tr(\Sigma^{-1}(B-\hat{B}^{\mathcal{P}})'X^{\mathcal{P}\prime}X^{\mathcal{P}}(B-\hat{B}^{\mathcal{P}}))\right\} \end{aligned}$$

which is equation (1.4) of the text, where $\hat{B}^{\mathcal{P}} = (X^{\mathcal{P}\prime}X^{\mathcal{P}})^{-1}X^{\mathcal{P}\prime}X^{\mathcal{P}}$, $S^{\mathcal{P}} = (Y^{\mathcal{P}} - X^{\mathcal{P}}\hat{B}^{\mathcal{P}})'(Y^{\mathcal{P}} - X^{\mathcal{P}}\hat{B}^{\mathcal{P}})$ and $df^{\mathcal{P}} = T^{\mathcal{P}} - k$. The posterior density shows a Normal inverse Wishart distribution:

$$\Sigma \sim i\mathcal{W}\left(S^{\mathcal{P}}, df^{\mathcal{P}}\right)$$
$$vec\left(B\right)|\Sigma \sim \mathcal{N}\left(vec\left(\hat{B}^{\mathcal{P}}\right), \Sigma \otimes \left(X^{\mathcal{P}\prime}X^{\mathcal{P}}\right)^{-1}\right)$$

The Lending Rate Equation

In the following the log-linearization and the steady state versions of the lending rate equation are provided.

The mark-up case

The log-linearization of equation (1.16) provides:

[3] The inverse-Wishart distribution requirement on the number of degrees of freedom, $df^{\mathbf{P}} \geq n$, is satisfied.

$$R^L \hat{R}_t^L - R^L \Psi(R^D)\hat{R}_t^L - R^L \Psi'(R^D)R^D \hat{R}_t^D - R^D \hat{R}_t^D = 0$$

By rearranging we have:

$$R^L \left[1 - \Psi(R^D)\right] \hat{R}_t^L = \left[R^D + R^L \Psi'(R^D)R^D\right] \hat{R}_t^D$$

by remembering that $R^L \left[1 - \Psi(R^D)\right] = R^D$ we finally have:

$$\hat{R}_t^L = (1 + \Psi_R)\, \hat{R}_t^D$$

where $\Psi_R = \frac{\Psi' R^D}{1-\Psi}$. The previous equation is the (1.17) of the text.

The persistence factor case

From equation (1.18) we have:

$$\hat{R}_t^L + \zeta_1 \left(\hat{R}_t^L - \zeta_0 \hat{R}_{t-1}^L\right) - \hat{R}_t^D = 0$$

Then:

$$(1 + \zeta_1)\, \hat{R}_t^L - \zeta_1 \zeta_0 \hat{R}_{t-1}^L = \hat{R}_t^D$$

Finally we have:

$$\hat{R}_t^L = \frac{1}{1 + \zeta_1} \hat{R}_t^D + \frac{\zeta_1 \zeta_0}{1 + \zeta_1} \hat{R}_{t-1}^L$$

which is (1.19) of the text.

The monopolistic competition case

From equation (1.22) we have:

$$1 = (1 - \chi) \left(\frac{R_t^{L*}}{R_t^L}\right)^{1-\eta} + \chi \left(\frac{R_{t-1}^L}{R_t^L}\right)^{1-\eta}$$

The log-linearization of the previous equation yields:

$$0 = (1 - \chi)(1 - \eta) \left(\frac{R^{L*}}{R^L}\right)^{-\eta} \left(\hat{R}_t^{L*} - \hat{R}_t^L\right) - \chi(1 - \eta) \left(\frac{R^L}{R^L}\right)^{-\eta} \left(\hat{R}_t^L - \hat{R}_{t-1}^L\right)$$

Since $R^{L*} = R^L$, by solving with respect to $\hat{R}_t^L$ we obtain:

$$\hat{R}_t^{L*} = \frac{1}{1 - \chi} \hat{R}_t^L - \frac{\chi}{1 - \chi} \hat{R}_{t-1}^L \tag{A.5}$$

Rearranging equation (1.23) we have:

$$R_t^{L*} E_t \sum_{l=0}^{\infty} \chi^l \beta^l C_{t+l}^{-\sigma} (R_{t+l}^L)^{\eta} \frac{L_{t+l}}{P_{t+l}} = \Xi E_t \sum_{l=0}^{\infty} \chi^l \beta^l C_{t+l}^{-\sigma} R_{t+l}^D (R_{t+l}^L)^{\eta} \frac{L_{t+l}}{P_{t+l}}$$

The log-linearization of the left side of the previous equation yields:

$$\frac{L}{P}\frac{(R^L)^{1+\eta}C^{-\sigma}}{1-\chi\beta}\hat{R}_t^{L*}+\frac{L}{P}(R^L)^{1+\eta}C^{-\sigma}\sum_{l=0}^{\infty}\chi^l\beta^l\left(E_t\hat{L}_{t+l}-E_t\hat{P}_{t+l}+\eta E_t\hat{R}_{t+l}^L-\sigma\hat{E}_tC_{t+l}\right)$$

By remembering that $\Xi R^D=R^L$ the right side provides:

$$\frac{L}{P}(R^L)^{1+\eta}C^{-\sigma}\sum_{l=0}^{\infty}\chi^l\beta^l\left(E_t\hat{L}_{t+l}-E_t\hat{P}_{t+l}+\eta E_t\hat{R}_{t+l}^L-\sigma E_t\hat{C}_{t+l}+E_t\hat{R}_{t+l}^D\right)$$

By equating and simplifying the two sides we have:

$$\hat{R}_t^{L*}=(1-\chi\beta)\sum_{l=0}^{\infty}\chi^l\beta^lE_t\hat{R}_{t+l}^D \tag{A.6}$$

By iteration solution equation (A.6) can be written as:

$$\hat{R}_t^{L*}=(1-\chi\beta)\hat{R}_t^D+\chi\beta\hat{R}_{t+1}^{L*} \tag{A.7}$$

By using equation (A.5) into (A.6) we have:

$$\frac{1}{1-\chi}\hat{R}_t^L-\frac{\chi}{1-\chi}\hat{R}_{t-1}^L=(1-\chi\beta)\hat{R}_t^D+\frac{\chi\beta}{1-\chi}\hat{R}_{t+1}^L-\frac{\chi^2\beta}{1-\chi}\hat{R}_t^L$$

By solving with respect to the $\hat{R}_t^L$ we obtain:

$$\hat{R}_t^L=\frac{\beta\chi}{1+\beta\chi^2}E_t\hat{R}_{t+1}^L+\frac{\chi}{1+\beta\chi^2}\hat{R}_{t-1}^L+\frac{(1-\beta\chi)(1-\chi)}{1+\beta\chi^2}\hat{R}_t^D$$

which is equation (1.25) of the text.

The search and matching case

The first order condition and the envelope theorem of the bank's problem in the search and matching framework are:

$$\text{for } V_t^B\text{: } \frac{k^BR_t^D}{q_t^B}-(R_t^L-R_t^D)w_tN_t=\beta E_t\frac{\lambda_{t+1}}{\lambda_t}\frac{\partial J_{t+1}^B}{\partial L_t^N} \tag{A.8}$$

$$\text{for } L_{t-1}^N\text{: } \frac{\partial J_t^B}{\partial L_{t-1}^N}=(1-\rho)(R_t^L-R_t^D)w_tN_t+\beta(1-\rho^B)E_t\frac{\lambda_{t+1}}{\lambda_t}\frac{\partial J_{t+1}^B}{\partial L_t^N} \tag{A.9}$$

By replacing (A.8) into (A.9) we obtain:

$$\frac{\partial J_t^B}{\partial L_{t-1}^N}=(1-\rho^B)\frac{k^BR_{t+1}^D}{q_t^B} \tag{A.10}$$

By updating equation (A.10) and then by replacing into (A.8), we then get:

$$\frac{k^BR_t^D}{q_t^B}=(R_t^L-R_t^D)w_tN_t+(1-\rho^B)\beta E_t\frac{\lambda_{t+1}}{\lambda_t}\frac{k^BR_{t+1}^D}{q_{t+1}^B}$$

which is equation (1.27) of the text. The surpluses of a bank and of a firm are:

$$S_t^B = B_t^m - B_t^u \tag{A.11}$$

and

$$S_t^F = F_t^m - F_t^u \tag{A.12}$$

The value of a unfilled credit vacancy is:

$$B_t^u = -k^B R_t^D + q_t^B B_t^m + (1 - q_t^B)\beta E_t \frac{\lambda_{t+1}}{\lambda_t} B_{t+1}^u \tag{A.13}$$

Since the free entry condition, $B_t^u = 0 \; \forall \; t$, the value of a filled credit vacancy is equal to the bank surplus:

$$B_t^m = S_t^B = \frac{k^B R_t^D}{q_t^B}. \tag{A.14}$$

or by remembering the equation (1.27) $S_t^B = (R_t^L - R_t^D) w_t N_t + (1 - \rho^B)\beta E_t \frac{\lambda_{t+1}}{\lambda_t} \frac{k^B R_{t+1}^D}{q_{t+1}^B}$.

The values of a filled and unfilled credit vacancy are respectively:

$$F_t^m = \frac{Y_t^w}{\mu_t} - w_t R_t^L N_t + \beta E_t \frac{\lambda_{t+1}}{\lambda_t} \left[(1 - \rho^B + \rho^B p_{t+1}^B) F_{t+1}^m + \rho^B (1 - p_{t+1}^B) F_{t+1}^u \right] \tag{A.15}$$

$$F_t^u = \beta E_t \frac{\lambda_{t+1}}{\lambda_t} \left[p_{t+1}^B F_{t+1}^m + (1 - p_{t+1}^B) F_{t+1}^u \right] \tag{A.16}$$

Then the surplus of the firm is:

$$S_t^F = F_t^m - F_t^u = \frac{Y_t^w}{\mu_t} - w_t R_t^L N_t + (1 - \rho^B)\beta E_t \frac{\lambda_{t+1}}{\lambda_t} (1 - p_{t+1}^B) S_{t+1}^F \tag{A.17}$$

The optimal condition of the problem (1.28) of the text is:

$$(1 - z)\gamma_t^B S_t^F + z\gamma_t^F S_t^B = 0 \tag{A.18}$$

where $\gamma_t^B = \frac{\partial S_t^B}{\partial R_t^L} = w_t N_t$ and $\gamma_t^F = \frac{\partial S_t^F}{\partial R_t^L} = -w_t N_t$. From the previous equation we have:

$$S_t^F = \frac{z}{(1 - z)} \frac{k^B R_t^D}{q_t^B}. \tag{A.19}$$

By replacing equation (A.19) one period ahead in the firms' surplus definition (A.17) we obtain:

$$S_t^F = \frac{Y_t^w}{\mu_t} - w_t R_t^L N_t + (1 - \rho^B) \frac{z}{(1 - z)} \beta E_t \frac{\lambda_{t+1}}{\lambda_t} (1 - p_{t+1}^B) \frac{k^B R_{t+1}^D}{q_{t+1}^B} \tag{A.20}$$

By replacing equations (A.20) and (A.14) into (A.18), and rearranging we obtain:

$$\frac{(1 - z)Y_t^w}{\mu_t} - (1 - z) w_t R_t^L N_t + (1 - \rho^B) z \beta E_t \frac{\lambda_{t+1}}{\lambda_t} \frac{k^B R_{t+1}^D}{q_{t+1}^B} - (1 - \rho^B) z \beta E_t \frac{\lambda_{t+1}}{\lambda_t} \frac{k^B R_{t+1}^D}{\theta_{t+1}^C} = z \frac{k^B R_t^D}{q_t^B}$$

By using the the credit creating condition and by solving with respect to the interest rate on loans we obtain:

$$R_t^L = \frac{(1-z)}{w_t N_t}\frac{Y_t^w}{\mu_t} + \frac{z}{w_t N_t}\left[R_t^D w_t N_t - (1-\rho^B)\beta E_t \frac{\lambda_{t+1}}{\lambda_t}\frac{k^B R_{t+1}^D}{\theta_{t+1}^C}\right]$$

which is equation (1.31) of the text. By using equations (1.6) and (1.9) of the text, the previous equation can be written in the following way:

$$R_t^L = \frac{(1-z)}{\alpha} R_t^L + z R_t^D - \frac{z(1-\rho^B)}{w_t N_t}\frac{1}{R_t^D} E_t \frac{P_{t+1}}{P_t}\frac{k^B R_{t+1}^D}{\theta_{t+1}^C}$$

Then, the log-linearization of the previos equation is:

$$\begin{aligned} R^L \hat{R}_t^L &= \frac{(1-z)}{\alpha} R_t^L \hat{R}_t^L + z R_t^D \hat{R}_t^D + \\ &- \frac{z(1-\rho^B)}{wN}\frac{R^D}{R^D}\frac{k^B}{\theta^C}\left[E_t \hat{P}_{t+1} - \hat{P}_t - \hat{w}_t - \hat{N}_t - \hat{R}_t^D + E_t \hat{R}_{t+1}^D - E_t \hat{\theta}_{t+1}^C\right] \end{aligned}$$

By solving with respect to $\hat{R}_t^L$ we have:

$$\begin{aligned} \hat{R}_t^L &= \frac{\alpha z}{R^L(\alpha - 1 + z)}\left[R^D + \frac{(1-\rho^B)\beta p^B}{wN}\frac{k^B}{q^B}\right]\hat{R}_t^D + \\ &+ \frac{\alpha z(1-\rho^B) p^B k^B}{R^L(\alpha - 1 + z) wN q^B}\left[E_t \hat{\theta}_{t+1}^C - E_t \hat{R}_{t+1}^D + \left(\hat{w}_t + \hat{N}_t - E_t \hat{\pi}_{t+1}\right)\right] \end{aligned}$$

which is equation (1.32) of the text.
From the steady state version of equation (A.15) we are able to obtain:

$$(F^m - F^u) = \frac{\frac{Y^w}{\mu} - wR^L N - (1-\beta) F^u}{(1-\beta) + \beta\rho^B (1 - p^B)} \tag{A.21}$$

From he steady state version of equation equation (A.16) we have:

$$(F^m - F^u) = \frac{(1-\beta) F^u}{\beta p^B} \tag{A.22}$$

By equating equations (A.21) and (A.22), and by assuming that the unmatched value of firms, F^u, is equal to a no zero flow cost $\bar{c}$, we have:

$$\frac{(1-\beta)\bar{c}}{\beta p^B} = \frac{\frac{Y^w}{\mu} - wR^L N - (1-\beta)\bar{c}}{(1-\beta) + \beta\rho^B(1-p^B)}$$

By solving with respect to credit line finding rate we get:

$$p^B = \frac{\bar{c}(1-\beta)(1-\beta+\beta\rho^B)}{\beta\left[\left(\frac{Y^w}{\mu} - wR^L N\right) - (1-\beta)(1-\rho^B)\bar{c}\right]}$$

which is equation (1.33) of the text.

The identity principle of polynomials

Kaufmann and Sharler (2009) estimate $\frac{1}{1+\zeta_1} = 0.95$ from which it is possible to get $\zeta_1 = 0.053$. Moreover, they estimate $\frac{\zeta_0\zeta_1}{1+\zeta_1} = 0.03$ which implies $\zeta_0 = 0.6$.
The steady state version of equation (1.18) is

$$R^L = \left(\frac{1}{\Sigma_0}\right)^{\frac{1}{[1+(1-\zeta_0)\zeta_1]}} \left(R^D\right)^{\frac{1}{[1+(1-\zeta_0)\zeta_1]}}$$

By computing the sample mean of R_t^L and R_t^D we can compute $\Sigma_0 = \frac{\bar{R}^D}{\left(\bar{R}^L\right)^{[1+(1-\zeta_0)\zeta_1]}} = 0.9807$.
Further, if we assume $\zeta_0 = 0$ we obtain a formulation consistent with Chowdhury et al. (2006):

$$R^L = \left(\frac{1}{\Sigma_0}\right)^{\frac{1}{1+\zeta_1}} \left(R^D\right)^{\frac{1}{1+\zeta_1}} \tag{A.23}$$

In this case we are able to compute $\Sigma_0 = \frac{\bar{R}^D}{\left(\bar{R}^L\right)^{1+\zeta_1}} = 0.9792$. Furthermore, equation (A.23) can be rewritten as $R^L = a\left(R^D\right)^b$ where $a = \left(\frac{1}{\Sigma_0}\right)^{\frac{1}{1+\zeta_1}}$ and $b = \frac{1}{1+\zeta_1}$.
The steady state version of equation (1.16) is

$$R^L = \frac{1}{\Psi_0}\left(R^D\right)^{1-\varkappa} \tag{A.24}$$

The previous equation can be rewritten as $R^L = c\left(R^D\right)^d$ where $c = \frac{1}{\Psi_0}$ and $d = 1 - \varkappa$.
Equations (A.23) and (A.24) have the same form. Hence, by the identity principle of polynomials, it has to be $a = c$ and $b = d$, or $\left(\frac{1}{\Sigma_0}\right)^{\frac{1}{1+\zeta_1}} = \frac{1}{\Psi_0}$ and $\frac{1}{1+\zeta_1} = 1 - \varkappa$. Hence, given the values of Σ_0 and ζ_1 we are able to compute $\Psi_0 = 0.9717$ and $\varkappa = 0.05$.

Appendix B

Appendix to Chapter 2

Data and Sources

Real GDP: Quarterly Real Gross Domestic Product, Seasonally Adjusted, U.S. Department of Commerce: Bureau of Economic Analysis and Federal Reserve Economic Data of Saint Luis.

Employment: Monthly Employees, Seasonally Adjusted, U.S. Department of Labor: Bureau of Labor Statistics and Federal Reserve Economic Data of Saint Luis.

Nominal Wages: Monthly wage and salary disbursements, Seasonally Adjusted, U.S. Department of Commerce: Bureau of Economic Analysis and Federal Reserve Economic Data of Saint Luis.

Price Index: Monthly Consumer Price Index for All Urban Consumers, Seasonally Adjusted, U.S. Department of Labor: Bureau of Labor Statistics and Federal Reserve Economic Data of Saint Luis.

Policy Rate: Monthly Effective Federal Funds Rate, U.S. Department of Labor: Bureau of Labor Statistics and Federal Reserve Economic Data of Saint Luis.

Interest rate on loans: Quarterly Weighted-Average Effective Loan Rate for All C&I Loans, All Commercial Banks, U.S. Department of Labor: Bureau of Labor Statistics and Federal Reserve Economic Data of Saint Luis.

Credit market tightness: Quarterly Net Percentage of Domestic Respondents Tightening Standards for Commercial and Industrial Loans Small Firms, Board of Governors of the Federal Reserve System and Federal Reserve Economic Data of Saint Luis.

The quarterly net percentage of Domestic Respondents Tightening Standards for commercial and industrial loans small firms - the series that we interpret as the tightness index of the credit market - is provided by the Senior Loan Officer Opinion Survey on Bank Lending Practices from 1990:Q2. This index reports the evaluation of the U.S. banks about the conditions of the credit market according to the more or less tight banks' standards applied to the small firms. Hence the tightness of the credit market is evaluated from the point of view of the firms. The survey is based on the responses from 57 domestic banks and 23 U.S. branches and agencies of foreign banks. The small business' definition by the U.S. Small Business Administration varies by industry, ranging from fewer than 100 employees (e.g. for the wholesale trade) and fewer than 1500 workers (e.g. for the telecommunications). Hence, even when considering only those with fewer than 100 employees (including nonemployer firms)[1] we are able to represent about 99.5 % of the total U.S. firms. Then the previous tightness index can be considered a good proxy of the thickness in the credit market for all U.S. businesses.

We compute the average of the monthly flows to transform the monthly time series into quarterly data. In line with Fernández-Villaverde (2010) we compute the real wages by deflating the relative nominal series by the consumer price index. The inflation rate is computed as the quarter on quarter log differences in the Consumer Price Index. Finally, the series of the real GDP, the employment and the real wages are made stationary by the first-difference transformation.

Agents' problems, first order conditions and bargaining on interest rate on loans

Households

The CIA constraint is:

$$P_t C_t \leq M_t + P_t w_t N_t - D_t \tag{B.1}$$

The amount of money carried over to the following period is:

$$M_{t+1} = M_t + P_t w_t N_t - D_t - P_t C_t + \Pi_t^F + \Pi_t^B + R_t^D D_t \tag{B.2}$$

Substituting the binding version of (B.1) into (B.2) we have: $M_{t+1} = \Pi_t^F + \Pi_t^B + R_t^D D_t$. Calculating this equation a period backward and substituting the result into (B.1) we have the intertemporal budget constraint that can be expressed in real terms in the following way:

$$C_t = w_t N_t + \frac{\Pi_{t-1}^F}{P_t} + \frac{\Pi_{t-1}^B}{P_t} - \frac{D_t}{P_t} + R_{t-1}^D \frac{D_{t-1}}{P_t} \tag{B.3}$$

The household solves the problem:

$$\begin{aligned} J_t^H &= \max \left[\varphi_t U(C_t, N_t) + \beta E_t J_{t+1}^H \right] \\ & \quad s.t. \ \ (\text{B.3}) \end{aligned}$$

where $U(C_t, N_t) = \frac{{C_t}^{1-\sigma}}{1-\sigma} - \vartheta_t \bar{\vartheta} \frac{N_t^{1+\phi}}{1+\phi}$. The separability of the utility function allows us to make the usual assumption that consumption risks are fully pooled within the household. All households hence solve the same problem by choosing the optimal levels of consumption, deposits and employment. The first order conditions then are:

$$\text{for } C_t\text{: } \lambda_t = \varphi_t C_t^{-\sigma} \tag{B.4}$$

$$\text{for } D_t\text{: } \lambda_t = R_t^D \beta E_t \frac{P_t}{P_{t+1}} \lambda_{t+1} \tag{B.5}$$

[1] See the statistics about the business size from the U.S. Census Bureau.

$$\text{for } N_t\text{: } w_t = \varphi_t \vartheta_t \bar{\vartheta} \frac{N_t^{\phi}}{\lambda_t} \tag{B.6}$$

The latter two conditions yield the Euler equation (2.2) and the definition of the real wage (2.3) of the text respectively.

Wholesale firms

Wholesale firms solve the problem:

$$\max \left(\frac{Y_t^w}{\mu_t} - R_t^L w_t N_t \right)$$
$$s.t.\ Y_t^w = A_t N_t^{\alpha}$$

The first order condition with respect to N_t is:

$$\frac{1}{\mu_t} = \frac{w_t R_t^L}{mpl_t} \tag{B.7}$$

which is equation (2.5) of the text. Hence, the previous equation represents the real marginal costs, mc_t, of firms.

Retail firms

The retail firms solve the following problem:

$$\max E_t \sum_{l=0}^{\infty} \omega^l \beta^l \frac{\lambda_{t+1}}{\lambda_t} \left[\left(\frac{P_{it}}{P_{t+l}} \right) - mc_{t+l} \right] Y_{it+l}$$
$$s.t.\ \ Y_{it} = \left(\frac{P_{it}}{P_t} \right)^{-\varepsilon} Y_t$$

In a symmetric equilibrium, the standard first order condition for $P_{it} = P_t^*$ is:

$$\frac{P_t^*}{P_t} = \frac{\varepsilon}{\varepsilon - 1} \frac{E_t \sum_{l=0}^{\infty} \omega^l \beta^l MC_{t+l} \left(\frac{P_{t+l}}{P_t} \right)^{\varepsilon} C_{t+l}^{1-\sigma}}{E_t \sum_{l=0}^{\infty} \omega^l \beta^l \left(\frac{P_{t+l}}{P_t} \right)^{\varepsilon-1} C_{t+l}^{1-\sigma}} \tag{B.8}$$

which is equation (2.6) of the text.

Banks

The bank solves the following problem:

$$J_t^B = \max \left[(R_t^L - R_t^D) w_t N_t L_t^N - k^B R_t^D V_t^B + R_t^D \frac{X_t}{P_t} + \beta E_t \frac{\lambda_{t+1}}{\lambda_t} J_{t+1}^B \right]$$
$$s.t.\ L_t^N = (1 - \rho^B) L_{t-1}^N + q_t^B V_t^B$$

The first order condition and the envelope theorem yield:

$$\text{for } V_t^B\text{:}\ \frac{k^B R_t^D}{q_t^B} - (R_t^L - R_t^D) w_t N_t = \beta E_t \frac{\lambda_{t+1}}{\lambda_t} \frac{\partial J_{t+1}^B}{\partial L_t^N} \tag{B.9}$$

$$\text{for } L_{t-1}^N\text{:}\ \frac{\partial J_t^B}{\partial L_{t-1}^N} = (1-\rho^B)(R_t^L - R_t^D) w_t N_t + \beta(1-\rho^B) E_t \frac{\lambda_{t+1}}{\lambda_t} \frac{\partial J_{t+1}^B}{\partial L_t^N} \tag{B.10}$$

By replacing (B.9) into (B.10) we obtain:

$$\frac{\partial J_t^B}{\partial L_{t-1}^N} = (1-\rho^B) \frac{k^B R_t^D}{q_t^B} \tag{B.11}$$

By updating equation (B.11) and then by replacing into (B.9), we then get:

$$\frac{k^B R_t^D}{q_t^B} = (R_t^L - R_t^D) w_t N_t + (1-\rho^B) \beta E_t \frac{\lambda_{t+1}}{\lambda_t} \frac{k^B R_{t+1}^D}{q_{t+1}^B} \tag{B.12}$$

which is equation (2.15) of the text.

Loan Interest Rate Bargaining

The loan interest rate Nash bargaining is:

$$\max_{R_t^L} (S_t^F)^z (S_t^B)^{1-z} \tag{B.13}$$

where:

$$S_t^B = B_t^m - B_t^u \tag{B.14}$$

and

$$S_t^F = F_t^m - F_t^u \tag{B.15}$$

The value of a unfilled credit vacancy is:

$$B_t^u = -k^B R_t^D + q_t^B B_t^m + (1-q_t^B) \beta E_t \frac{\lambda_{t+1}}{\lambda_t} B_{t+1}^u \tag{B.16}$$

Since the free entry condition, $B_t^u = 0\ \forall\ t$, the value of a filled credit vacancy is equal to the bank surplus:

$$B_t^m = S_t^B = \frac{k^B R_t^D}{q_t^B}. \tag{B.17}$$

or by remembering the equation (B.12): $S_t^B = (R_t^L - R_t^D) w_t N_t + (1-\rho^B)\beta E_t \frac{\lambda_{t+1}}{\lambda_t} \frac{k^B R_{t+1}^D}{q_{t+1}^B}$.
The values of a firm when it has, or not, a credit match are respectively:

$$F_t^m = \frac{Y_t^w}{\mu_t} - w_t R_t^L N_t + \beta E_t \frac{\lambda_{t+1}}{\lambda_t} \left[(1-\rho^B+\rho^B p_{t+1}^B) F_{t+1}^m + \rho^B (1-p_{t+1}^B) F_{t+1}^u \right] \tag{B.18}$$

$$F_t^u = \beta E_t \frac{\lambda_{t+1}}{\lambda_t} \left[p_{t+1}^B F_{t+1}^m + (1-p_{t+1}^B) F_{t+1}^u \right] \tag{B.19}$$

Then the surplus of the firm is:

$$S_t^F = F_t^m - F_t^u = \frac{Y_t^w}{\mu_t} - w_t R_t^L N_t + (1-\rho^B)\beta E_t \frac{\lambda_{t+1}}{\lambda_t}(1-p_{t+1}^B)S_{t+1}^F \tag{B.20}$$

The optimal condition of the problem (B.13) is:

$$(1-z)\gamma_t^B S_t^F + z\gamma_t^F S_t^B = 0 \tag{B.21}$$

where:

$$\gamma_t^B = \frac{\partial S_t^B}{\partial R_t^L} = w_t N_t \tag{B.22}$$

and:

$$\gamma_t^F = \frac{\partial S_t^F}{\partial R_t^L} = -w_t N_t \tag{B.23}$$

The the optimal condition becomes:

$$(1-z)S_t^F = zS_t^B \tag{B.24}$$

From the previous equation we have:

$$S_t^F = \frac{z}{(1-z)}\frac{k^B R_t^D}{q_t^B}. \tag{B.25}$$

By replacing equation (B.25) one period ahead in the firms' surplus definition (B.20) we obtain:

$$S_t^F = \frac{Y_t^w}{\mu_t} - w_t R_t^L N_t + (1-\rho^B)\frac{z}{(1-z)}\beta E_t \frac{\lambda_{t+1}}{\lambda_t}(1-p_{t+1}^B)\frac{k^B R_{t+1}^D}{q_{t+1}^B} \tag{B.26}$$

By replacing equations (B.26) and (B.17) into (B.24) we obtain:

$$(1-z)\left[\frac{Y_t^w}{\mu_t} - w_t R_t^L N_t + (1-\rho^B)\frac{z}{(1-z)}\beta E_t \frac{\lambda_{t+1}}{\lambda_t}(1-p_{t+1}^B)\frac{k^B R_{t+1}^D}{q_{t+1}^B}\right] = z\frac{k^B R_t^D}{q_t^B}$$

Rearranging:

$$\frac{(1-z)Y_t^w}{\mu_t} - (1-z)w_t R_t^L N_t + (1-\rho^B)z\beta E_t \frac{\lambda_{t+1}}{\lambda_t}\frac{k^B R_{t+1}^D}{q_{t+1}^B} - (1-\rho^B)z\beta E_t \frac{\lambda_{t+1}}{\lambda_t}\frac{k^B R_{t+1}^D}{\theta_{t+1}^C} = z\frac{k^B R_t^D}{q_t^B}$$

By using the the credit creating condition (B.12) we obtain:

$$0 = \frac{(1-z)Y_t^w}{\mu_t} - (1-z)w_t R_t^L N_t + z\left(R_t^D - R_t^L\right)w_t N_t - (1-\rho^B)z\beta E_t \frac{\lambda_{t+1}}{\lambda_t}\frac{k^B R_{t+1}^D}{\theta_{t+1}^C}$$

By solving with respect to the interest rate on loans we finally have:

$$R_t^L = \frac{(1-z)}{w_t N_t}\frac{Y_t^w}{\mu_t} + \frac{z}{w_t N_t}\left[R_t^D w_t N_t - (1-\rho^B)\beta E_t \frac{\lambda_{t+1}}{\lambda_t}\frac{k^B R_{t+1}^D}{\theta_{t+1}^C}\right] \tag{B.27}$$

which is equation (2.24) of the text.

Market Clearing

For each agent it must be:

$$X_{it} = W_t N_{it} - D_{it} - P_t C_{it} + R_t^D D_{it} + \Pi_{it}^F + \Pi_{it}^B \tag{B.28}$$

where $X_{it} = M_{it+1} - M_{it}$ and $\Pi_{it}^F = \Pi_{it}^R + \Pi_{it}^{SP}$. By aggregating and by remembering that the total labor demand $\int L_{jt}^N N_t dj = L_t^N N_t$ the ARC is:

$$\frac{X_t}{P_t} = w_t N_t L_t^N - \frac{D_t}{P_t} - C_t + R_t^D \frac{D_t}{P_t} + \frac{\Pi_t^R}{P_t} + \frac{\Pi_t^B}{P_t} + \frac{\Pi_t^{SP}}{P_t} \tag{B.29}$$

The aggregate banks' balance sheet and profit function are $\frac{D_t}{P_t} + \frac{X_t}{P_t} = w_t N_t L_t^N + k^B V_t^B$ and $\frac{\Pi_t^B}{P_t} = R_t^L w_t N_t L_t^N - R_t^D w_t N_t L_t^N - R_t^D k^B V_t^B + R_t^D \frac{X_t}{P_t}$ respectively. By replacing them into equation (B.29) and by remembering that $\frac{\Pi_t^{SP}}{P_t} = k^B V_t^B$ we have:

$$\frac{X_t}{P_t} = w_t N_t L_t^N - \frac{D_t}{P_t} - C_t + R_t^D \frac{D_t}{P_t} + \frac{\Pi_t^R}{P_t} + R_t^L w_t N_t L_t^N - R_t^D w_t N_t L_t^N - R_t^D k^B V_t^B + R_t^D \frac{X_t}{P_t} + k^B V_t^B$$

$$0 = -C_t + R_t^D \frac{D_t}{P_t} + R_t^D \frac{X_t}{P_t} - R_t^D w_t N_t L_t^N - R_t^D k^B V_t^B + \frac{\Pi_t^R}{P_t} + R_t^L w_t N_t L_t^N$$

$$0 = -C_t + \frac{\Pi_t^R}{P_t} + R_t^L w_t N_t L_t^N$$

Finally we have:

$$C_t = \frac{\Pi_t^R}{P_t} + R_t^L w_t N_t L_t^N \tag{B.30}$$

The total real aggregate wholesale production is $\int L_{jt}^N Y_t^w \frac{P_t^w}{P_t} dj = Y_t^w \frac{P_t^w}{P_t} \int L_{jt}^N dj = L_t^N \frac{Y_t^w P_t^w}{P_t}$. Then the real profits of retail firms are $\frac{\Pi_t^R}{P_t} = Y_t^d - L_t^N \frac{Y_t P_t^w}{P_t}$ where Y_t^d is the aggregate demand for goods. Further the equilibrium in the good market implies $Y_t^d = Y_t$. Then the ARC becomes:

$$C_t = Y_t - L_t^N \frac{Y_t P_t^w}{P_t} + R_t^L w_t N_t L_t^N \tag{B.31}$$

Since its competitiveness the wholesale sector do zero profits. Then it must be: $L_t^N \frac{Y_t P_t^w}{P_t} = L_t^N R_t^L w_t N_t$. By replacing the latter condition into (B.31) we finally have:

$$C_t = Y_t \tag{B.32}$$

Steady state model and endogenous entry condition

We report the steady state version of the model used in the estimation phase in order to rewrite the model only in terms of parameters. The parameters σ, β, α , N, ε are calibrated whereas $\overline{c}$, k^B, z, ρ^B and ξ are estimated. The steady state system is here recursively derived.

From equation (B.5) we obtain the value of the discount factor: $R^D = \frac{1}{\beta}$.

From the production function we get the steady state output $Y^w = AN^\alpha$.

Since the price dispersion is $f = 1$ then $Y = Y^w$. The aggregate resource constraint is: $C = Y$.

From equation (B.4) the marginal utility of consumption is: $\lambda = C^{-\sigma}$.

From the steady state marginal product of labor we have: $mpl = \alpha AN^{\alpha-1}$.

From equation (B.7), the real marginal costs are $mc = \frac{1}{\mu} = \frac{\varepsilon - 1}{\varepsilon}$.

The steady state credit line finding rate and the steady state condition for the endogenous entry of firms are derived as follows. From equation (B.18) we have:

$$F^m = \frac{Y^w}{\mu} - wR^L N + \beta \left[(1 - \rho^B + \rho^B p^B)F^m + \rho^B(1 - p^B)F^u\right]$$

$$(1 - \beta)\, F^m = \frac{Y^w}{\mu} - wR^L N - \beta\rho^B \left(1 - p^B\right)(F^m - F^u)$$

By subtracting in the both sides of the previous equation the term $(1 - \beta)\, F^u$ we have:

$$(1 - \beta)\,(F^m - F^u) = \frac{Y^w}{\mu} - wR^L N - \beta\rho^B \left(1 - p^B\right)(F^m - F^u) - (1 - \beta)\, F^u$$

Then we obtain:

$$(F^m - F^u) = \frac{\frac{Y^w}{\mu} - wR^L N - (1 - \beta)\, F^u}{(1 - \beta) + \beta\rho^B\,(1 - p^B)} \tag{B.33}$$

From equation (B.19) we have:

$$F^u = \beta\left[p^B F^m + (1 - p^B)F^u\right]$$

$$F^u - \beta F^u = \beta p^B F^m - \beta p^B F^u$$

Finally we have:

$$(F^m - F^u) = \frac{(1 - \beta)\, F^u}{\beta p^B} \tag{B.34}$$

By equating equations (B.33) and (B.34), and by assuming that the unmatched value of firms, F^u, is equal to a no zero flow cost $\bar{c}$, we have:

$$\frac{(1-\beta)\,\bar{c}}{\beta p^B} = \frac{\frac{Y^w}{\mu} - wR^L N - (1-\beta)\,\bar{c}}{(1-\beta) + \beta\rho^B\,(1-p^B)}$$

By solving with respect to credit line finding rate we get:

$$\frac{(1-\beta)\,\bar{c}\left[(1-\beta) + \beta\rho^B\left(1-p^B\right)\right] + (1-\beta)\,\bar{c}\beta p^B}{\beta p^B} = \frac{Y^w}{\mu} - wR^L N$$

$$\left[(1-\beta) + \beta\rho^B\left(1-p^B\right) + \beta p^B\right](1-\beta)\,\bar{c} = \left(\frac{Y^w}{\mu} - wR^L N\right)\beta p^B$$

$$\left[(1-\beta)^2 + \beta\,(1-\beta)\left(\rho^B + p^B - \rho^B p^B\right)\right]\bar{c} = \left(\frac{Y^w}{\mu} - wR^L N\right)\beta p^B$$

$$\left[(1-\beta)^2 + \beta\,(1-\beta)\,\rho^B\right]\bar{c} = \left(\frac{Y^w}{\mu} - wR^L N\right)\beta p^B - \beta\,(1-\beta)\left(1-\rho^B\right)\bar{c}p^B$$

Finally being $wR^L = mc \cdot mpl$, we have:

$$p^B = \frac{\bar{c}(1-\beta)(1-\beta+\beta\rho^B)}{\beta\left[\left(\frac{Y^w}{\mu} - mc\cdot mplN\right) - (1-\beta)(1-\rho^B)\bar{c}\right]} \tag{B.35}$$

which is equation (2.26) of the text. Furthermore, since $S^F = F^m - F^u$ from equations (B.25) and (B.34) we have: $\frac{(1-\beta)\,\bar{c}}{\beta p^B} = \frac{z}{(1-z)}\frac{k^B R^D}{q^B}$. This yields: $p^B = \frac{\bar{c}q^B}{k^B R^D}\frac{(1-z)(1-\beta)}{z\beta}$ or $k^B = \frac{\bar{c}q^B}{p^B R^D}\frac{(1-z)(1-\beta)}{z\beta}$. If $k^B = 0$ the left side of the previous equation must be equal to zero. There are three possibilities: $\bar{c} = 0$, $q^B = 0$ or $z = 1$. We build the steady state system useful to solve and estimate the log-linearized version of the model such that variations of k^B modify the values of q^B whereas the deep parameters $\bar{c}$ and z do not change. Hence, if $k^B \to 0$ then $q^B \to 0$ and we are able to evaluate the role of z and $\bar{c}$ in affecting the bargained loan rate dynamics.

Moreover it is useful to note that the marginal effect of the separation rate on the credit line finding rate is:

$$\frac{\partial p^B}{\partial \rho^B} = \frac{\beta(1-\beta)\bar{c}\left[\beta\left(\frac{Y^w}{\mu} - wR^L N\right) - \beta(1-\beta)(1-\rho^B)\bar{c}\right] - \bar{c}(1-\beta)(1-\beta+\beta\rho^B)(1-\beta)\beta\bar{c}}{\beta^2\left[\left(\frac{Y^w}{\mu} - wR^L N\right) - (1-\beta)(1-\rho^B)\bar{c}\right]^2} \tag{B.36}$$

The denominator is always positive. Then, the marginal effect is positive if the numerator is also positive:

$$\beta^2(1-\beta)\bar{c}\left(\frac{Y^w}{\mu} - wR^L N\right) - \beta^2(1-\beta)^2\bar{c}^2(1-\rho^B) - \bar{c}^2(1-\beta)^3\beta - \beta^2(1-\beta)^2\bar{c}^2\rho^B > 0$$

$$\beta^2(1-\beta)\bar{c}\left(\frac{Y^w}{\mu}-wR^LN\right)-\beta^2(1-\beta)^2\bar{c}^2-\bar{c}^2(1-\beta)^3\beta>0$$

$$\beta(1-\beta)\bar{c}\left\{\beta\left(\frac{Y^w}{\mu}-wR^LN\right)-(1-\beta)\bar{c}\left[\beta-(1-\beta)^2\right]\right\}>0$$

$$\beta(1-\beta)\bar{c}\left[\beta\left(\frac{Y^w}{\mu}-wR^LN\right)-(1-\beta)\bar{c}\left(1-\beta+\beta^2\right)\right]>0$$

Then an increase of the quit rate rises the credit line finding rate if:

$$\beta\left(\frac{Y^w}{\mu}-wR^LN\right)>(1-\beta)(1-\beta+\beta^2)\bar{c}.$$

The steady state version of equation (B.27) is:

$$R^L=\frac{(1-z)}{wN}\frac{Y^w}{\mu}+zR^D-\frac{z}{wN}\left(1-\rho^B\right)\beta k^BR^D\frac{p^B}{q^B}.$$

By using the steady state version of equations (B.7) and (B.12) we are able to write:

$$R^L=\frac{(1-z)}{\alpha}R^L+zR^D-\frac{z\left(R^L-R^D\right)\left(1-\rho^B\right)\beta p^B}{\left[1-\left(1-\rho^B\right)\beta\right]}.$$

By solving with respect to R^L we have: $R^L=\dfrac{z\left\{1+\frac{(1-\rho^B)\beta p^B}{[1-(1-\rho^B)\beta]}\right\}}{\left\{1-\frac{(1-z)}{\alpha}+\frac{z(1-\rho^B)\beta p^B}{[1-(1-\rho^B)\beta]}\right\}}R^D.$

From equation (B.7), the real wage is $w=\dfrac{mc\cdot mpl}{R^L}$.

From equation (B.6), the constant attached to the CRRA specification of the utility function is $\bar{\vartheta}=\dfrac{w\lambda}{N^\phi}$.

From the steady state version of equation (B.12) we have: $q^B=\dfrac{k^BR^D\left[1-\left(1-\rho^B\right)\beta\right]}{\left(R^L-R^D\right)wN}$.

From the definitions of the searchers and of the dynamics of the lines of credit we get the steady state of the lines of credit: $L^N=\dfrac{p^B}{(\rho^B+p^B-p^B\rho^B)}$.

The steady state value of firms searching for credit is $s^F=1-(1-\rho^B)L^N$.

From the dynamics of the lines of credit we get the steady state of the number of credit vacancies $V^B=\dfrac{\rho^BL^N}{q^B}$.

The steady state credit market tightness is straightforwardly obtained as $\theta^C=\dfrac{s^F}{V^B}$.

The Linearized Model

In this section we compute the aggregate log-linearized version of the symmetric equilibrium of the model.

From equation (B.5), the log-linearized Euler equation is: $\hat{\lambda}_t = \hat{R}_t^D + \hat{P}_t - E_t\hat{P}_{t+1} + E_t\hat{\lambda}_{t+1}$. Since $\pi = 0$, we can write: $E_t\hat{P}_{t+1} - \hat{P}_t = E_t\left(\hat{P}_{t+1} - \hat{P}_t\right) = \hat{\pi}_{t+1}$ and so:

$$\hat{\lambda}_t = \hat{R}_t^D - E_t\hat{\pi}_{t+1} + E_t\hat{\lambda}_{t+1} \tag{B.37}$$

From equation (B.4), the log-linearized version of the marginal utility of consumption equation is:

$$\hat{\lambda}_t = \hat{\varphi}_t - \sigma\hat{C}_t \tag{B.38}$$

From equation (B.6) we compute the log-linearized version equation of the real wage $\hat{w} = \hat{\varphi}_t + \hat{\vartheta}_t + \phi\hat{N}_t - \hat{\lambda}_t$ or $\hat{w} = \hat{\varphi}_t + \hat{\vartheta}_t + \phi\hat{N}_t + \sigma\hat{C}_t - \hat{\varphi}_t$. It yields:

$$\hat{w} = \hat{\vartheta}_t + \phi\hat{N}_t + \sigma\hat{C}_t \tag{B.39}$$

From the dynamics of the firms searching for a line of credit, $s_t^F = 1 - (1-\rho^B)L_{t-1}^N$, we compute: $s^F\hat{s}_t^F = -(1-\rho^B)L^N\hat{L}_{t-1}^N$. This implies that searchers are:

$$\hat{s}_t^F = -\frac{(1-\rho^B)L^N}{s^F}\hat{L}_{t-1}^N \tag{B.40}$$

Since $q_t^B V_t^B = p_t^B s_t^F = H_t$ the equations of the dynamics of the lines of credit reduce to $L_t^N = (1-\rho)L_{t-1}^N + H_t$. Then by remembering the equation of the firms searching for credit, the log-linearized version of the previous equation is:

$$\hat{L}_t^N = (1-\rho^B)\hat{L}_{t-1}^N + \rho^B\hat{H}_t \tag{B.41}$$

The log-linearized version of the unemployment's definition $U_t = 1 - N_t$ is: $U\hat{U}_t = -N\hat{N}_t$. Being $U = 1 - N$ we can hence write it as:

$$\hat{U}_t = -\frac{N}{1-N}\hat{N}_t \tag{B.42}$$

Log-linearizing the production function $Y_t^w = A_t N_t^\alpha$ we obtain:

$$\hat{Y}_t^w = \hat{A}_t + \alpha\hat{N}_t \tag{B.43}$$

Considering the aggregate resource constraint $Y_t = C_t$ we straightforwardly derive:

$$\hat{Y}_t = \hat{C}_t \tag{B.44}$$

As shown by Galí (2008) the price dispersion across firms in a neighborhood of zero inflation steady state is equal to zero up to a first order approximation ($\hat{f}_t = 0$). Then we have:

$$\hat{Y}_t^w = \hat{Y}_t \tag{B.45}$$

From equation $mpl_t = \alpha A_t N_t^{\alpha-1}$ we may write the marginal productivity of labor as:

$$\widehat{mpl}_t = \hat{A}_t + (\alpha - 1)\,\hat{N}_t \tag{B.46}$$

In order to describe the derivation of the flexible prices output we can note that when prices are flexible the first order condition of retail firms reduce to $mc_t = \dfrac{1}{\mu_t} = \dfrac{\varepsilon - 1}{\varepsilon}$ which is a constant term. Hence, from equations (B.6) and (B.7) by solving end equating with respect to the real wage, and remembering log-linearizations (B.46) and (B.38) we have:

$$\hat{\vartheta}_t + \phi\hat{N}_t + \sigma\hat{Y}_t^f = \hat{A}_t + (\alpha - 1)\,\hat{N}_t - \hat{R}_t^L$$

$$\hat{\vartheta}_t + \phi\left(\frac{\hat{Y}_t^f}{\alpha} - \frac{\hat{A}_t}{\alpha}\right) + \sigma\hat{Y}_t^f = \hat{A}_t + (\alpha - 1)\left(\frac{\hat{Y}_t^f}{\alpha} - \frac{\hat{A}_t}{\alpha}\right) - \hat{R}_t^L$$

$$\left[\frac{1+\phi+\alpha(\sigma-1)}{\alpha}\right]\hat{Y}_t^f = \left(\frac{1+\phi}{\alpha}\right)\hat{A}_t - \hat{R}_t^L - \hat{\vartheta}_t$$

$$\hat{Y}_t^f = \left[\frac{1+\phi}{1+\phi+\alpha(\sigma-1)}\right]\hat{A}_t - \left[\frac{\alpha}{1+\phi+\alpha(\sigma-1)}\right]\left(\hat{R}_t^L + \hat{\vartheta}_t\right)$$

where $\hat{Y}_t^f$ represents the flexible prices output. Finally the quasi flexible equilibrium output is:

$$\hat{Y}_t^{qf} = \hat{Y}_t^f + \left[\frac{\alpha}{1+\phi+\alpha(\sigma-1)}\right]\left(\hat{R}_t^L + \hat{\vartheta}_t\right) \tag{B.47}$$

From equation (B.7) and by remembering equations (B.39), (B.43), (B.44) and (B.46) the real marginal costs can be rewritten in the following way:

$$\widehat{mc}_t = \hat{R}_t^L + \hat{\vartheta}_t + \phi\hat{N}_t + \sigma\hat{Y}_t - \hat{A}_t - (\alpha - 1)\,\hat{N}_t$$

$$\widehat{mc}_t = \hat{R}_t^L + \hat{\vartheta}_t + \phi\left(\frac{\hat{Y}_t}{\alpha} - \frac{\hat{A}_t}{\alpha}\right) + \sigma\hat{Y}_t - \hat{A}_t - (\alpha - 1)\left(\frac{\hat{Y}_t}{\alpha} - \frac{\hat{A}_t}{\alpha}\right)$$

$$\widehat{mc}_t = \hat{R}_t^L + \hat{\vartheta}_t + \left[\frac{1+\phi+\alpha(\sigma-1)}{\alpha}\right]\hat{Y}_t - \left(\frac{1+\phi}{\alpha}\right)\hat{A}_t$$

$$\widehat{mc}_t = \hat{R}_t^L + \hat{\vartheta}_t + \left[\frac{1+\phi+\alpha(\sigma-1)}{\alpha}\right]\hat{Y}_t - \left[\frac{1+\phi+\alpha(\sigma-1)}{\alpha}\right]\left(\frac{1+\phi}{1+\phi+\alpha(\sigma-1)}\right)\hat{A}_t$$

$$\widehat{mc}_t = \hat{R}_t^L + \hat{\vartheta}_t + \left[\frac{1+\phi+\alpha(\sigma-1)}{\alpha}\right]\left(\hat{Y}_t - \hat{Y}_t^{qf}\right)$$

The latter equation can be rewritten in terms of output gap, $x_t = \hat{Y}_t - \hat{Y}_t^{qf}$, as:

$$\widehat{mc}_t = \hat{R}_t^L + \hat{\vartheta}_t + \left[\frac{1+\phi+\alpha(\sigma-1)}{\alpha}\right]x_t \tag{B.48}$$

or also $\widehat{mc}_t = -\hat{\mu}_t$.

The derivation of the Phillips curve is standard (e.g., Walsh 2003). Define $Q_t = \dfrac{P_t^*}{P_t}$ and rewrite equation (B.8) as:

$$E_t\sum_{l=0}^{\infty}\omega^l\beta^l\left(\frac{P_{t+l}}{P_t}\right)^{\varepsilon-1}C_{t+l}^{1-\sigma}Q_t = \frac{\varepsilon}{\varepsilon-1}E_t\sum_{l=0}^{\infty}\omega^l\beta^l MC_{t+l}\left(\frac{P_{t+l}}{P_t}\right)^{\varepsilon}C_{t+l}^{1-\sigma}$$

The linearization of the left hand side of this equation yields

$\frac{C^{1-\sigma}}{1-\omega\beta}\hat{Q}_t + C^{1-\sigma}\sum_{l=0}^{\infty}\omega^l\beta^l\left[(1-\sigma)E_t\hat{C}_{t+l} + (\varepsilon-1)\left(\hat{P}_{t+l}-\hat{P}_t\right)\right]$ and linearization of the right hand side gives:
$C^{1-\sigma}E_t\sum_{l=0}^{\infty}\omega^l\beta^l\left[\widehat{mc}_{t+l} + \varepsilon\left(\hat{P}_{t+l}-\hat{P}_t\right) + (1-\sigma)\hat{C}_{t+l}\right]$. Equating these two equations and simplifying we get: $\hat{Q}_t + \hat{P}_t = (1-\omega\beta)E_t\sum_{l=0}^{\infty}\omega^l\beta^l\left(\hat{P}_{t+l} + \widehat{mc}_{t+l}\right)$. By forward solution this equation can be rewritten as:

$$\hat{Q}_t = (1-\omega\beta)\widehat{mc}_t + \omega\beta\left(\hat{Q}_{t+1} + \hat{\pi}_{t+1}\right) \tag{B.49}$$

The Calvo's assumption that only the share $(1-\omega)$ of firms can adjust their prices at time t and the Dixit-Stiglitz price aggregator lead to the economy's average price index: $1 = (1-\omega)(Q_t)^{1-\varepsilon} + \omega\left(\frac{P_{t-1}}{P_t}\right)^{1-\varepsilon}$. Approximating this equation around the steady state with zero inflation we obtain $\hat{Q}_t = \frac{\omega}{1-\omega}\hat{\pi}_t$. Substituting this equation into (B.49) we derive the standard New Keynesian Phillips Curve:

$$\hat{\pi}_t = \beta E_t\hat{\pi}_{t+1} + \frac{(1-\omega\beta)(1-\omega)}{\omega}\widehat{mc}_t + \hat{\psi}_t \tag{B.50}$$

where $\hat{\psi}_t$ represents a cost push shock.

The NKPC can be rewritten in terms output gap by using equation (B.48):

$$\hat{\pi}_t = \beta E_t\hat{\pi}_{t+1} + \kappa\left(\hat{R}_t^L + \hat{\vartheta}_t\right) + \kappa\tau x_t + \hat{\psi}_t \tag{B.51}$$

which is equation (2.9) of the text, where $\tau = \left[\frac{1+\phi+\alpha(\sigma-1)}{\alpha}\right]$ and $\kappa = \frac{(1-\omega\beta)(1-\omega)}{\omega}$.

Linearizing equation (B.12) we have:

$$\begin{aligned}\frac{k^B R^D}{q^B}\left(\hat{R}_t^D - \hat{q}_t^B\right) &= R^L wN\left(\hat{R}_t^L + \hat{w}_t + \hat{N}_t\right) - R^D wN\left(\hat{R}_t^D + \hat{w}_t + \hat{N}_t\right) + \\ &+ (1-\rho^B)\beta\frac{k^B R^D}{q^B}\left(E_t\hat{\lambda}_{t+1} - \hat{\lambda}_t + E_t\hat{R}_{t+1}^D - E_t\hat{q}_{t+1}^B\right)\end{aligned} \tag{B.52}$$

By using equations (B.5) and (B.7) into (B.27) the lending rate can be written in the following way:

$$R_t^L = \frac{(1-z)}{\alpha}R_t^L + zR_t^D - z\frac{(1-\rho^B)}{w_t N_t}\frac{1}{R_t^D}E_t\frac{P_{t+1}}{P_t}\frac{k^B R_{t+1}^D}{\theta_{t+1}^C}$$

Then, the log-linearization yields:

$$\begin{aligned}R^L\hat{R}_t^L &= \frac{(1-z)}{\alpha}R_t^L\hat{R}_t^L + zR_t^D\hat{R}_t^D + \\ &-z\frac{(1-\rho^B)}{wN}\frac{R^D}{R^D}\frac{k^B}{\theta^C}\left[E_t\hat{P}_{t+1} - \hat{P}_t - \hat{w}_t - \hat{N}_t - \hat{R}_t^D + E_t\hat{R}_{t+1}^D - E_t\hat{\theta}_{t+1}^C\right]\end{aligned}$$

By solving with respect to $\hat{R}_t^L$ we have:

$$\hat{R}_t^L = \Lambda_1 \hat{R}_t^D + \Lambda_2 \left[E_t \hat{\theta}_{t+1}^C - E_t \hat{R}_{t+1}^D + \left(\hat{w}_t + \hat{N}_t - E_t \hat{\pi}_{t+1} \right) \right] + \hat{v}_t \tag{B.53}$$

where $\Lambda_1 = \frac{\alpha z}{R^L(\alpha-1+z)} \left[R^D + \frac{(1-\rho^B)p^B}{wN} \frac{k^B}{q^B} \right]$ and $\Lambda_2 = \frac{\alpha z}{R^L(\alpha-1+z)} \frac{(1-\rho^B)p^B}{wN} \frac{k^B}{q^B}$.

From equation $\theta_t^C = s_t^F / V_t^B$ we may write the credit market tightness as:

$$\hat{\theta}_t^C = \hat{s}_t^F - \hat{V}_t^B \tag{B.54}$$

From equation $H_t = \varsigma_t (V_t^B)^\xi (s_t^F)^{1-\xi}$ the credit matches are:

$$\hat{H}_t = \hat{\varsigma}_t + \xi \hat{V}_t^B + (1-\xi)\, \hat{s}_t^F \tag{B.55}$$

The log-linearized monetary policy rule is:

$$\hat{R}_t^D = \rho_R \hat{R}_{t-1}^D + (1-\rho_R)\left[\delta_\pi \hat{\pi}_t + \delta_x x_t\right] + \hat{\nu}_t \tag{B.56}$$

The log-linearization of equation $p_t^B = H_t / s_t^F$ straightforwardly gives the credit line finding rate:

$$\hat{p}_t^B = \hat{H}_t - \hat{s}_t^F \tag{B.57}$$

The log-linearization of equation $q_t^B = H_t / V_t^B$ straightforwardly gives the credit vacancy filling rate:

$$\hat{q}_t^B = \hat{H}_t - \hat{V}_t^B \tag{B.58}$$

From equation $\nu_t = \nu_{t-1}^{\rho^\nu} e^{\epsilon_t^\nu}$ the process of the monetary policy shock is:

$$\hat{\nu}_t = \rho^\nu \hat{\nu}_{t-1} + \epsilon_t^\nu \tag{B.59}$$

From equation $A_t = A_{t-1}^{\rho^A} e^{\epsilon_t^\nu}$ the process of the technology shock is:

$$\hat{A}_t = \rho^A \hat{A}_{t-1} + \epsilon_t^A \tag{B.60}$$

From equation $\varsigma_t = \varsigma_{t-1}^{\rho^\varsigma} e^{\epsilon_t^\varsigma}$ the process of the credit market shock is:

$$\hat{\varsigma}_t = \rho^\varsigma \hat{\varsigma}_{t-1} + \epsilon_t^\varsigma \tag{B.61}$$

From equation $\varphi_t = \varphi_{t-1}^{\rho^\varphi} e^{\epsilon_t^\varphi}$ the process of the preference shock on the wedge between consumption and leisure is:

$$\hat{\varphi}_t = \rho^\varphi \hat{\varphi}_{t-1} + \epsilon_t^\varphi \tag{B.62}$$

From equation $\vartheta_t = \vartheta_{t-1}^{\rho^\vartheta} e^{\epsilon_t^\vartheta}$ the process of the preference shock on leisure is:

$$\hat{\vartheta}_t = \rho^\vartheta \hat{\vartheta}_{t-1} + \epsilon_t^\vartheta \tag{B.63}$$

From equation $\psi_t = \psi_{t-1}^{\rho^\psi} e^{\epsilon_t^\psi}$ the process of the cost push shock on inflation dynamics is:

$$\hat{\psi}_t = \rho^\psi \hat{\psi}_{t-1} + \epsilon_t^\psi \tag{B.64}$$

From equation $\upsilon_t = \upsilon_{t-1}^{\rho^\upsilon} e^{\epsilon_t^\upsilon}$ the process of the exogenous shock in interest rate on loans' equation is:

$$\hat{\upsilon}_t = \rho^{\upsilon}\hat{\upsilon}_{t-1} + \epsilon_t^{\upsilon} \tag{B.65}$$

Appendix C

Appendix to Chapter 3

Agents' problems, first order conditions and bargainings

Households

The CIA constraint is:

$$P_t C_t \leq B_t + W_t h_t N_t + (1 - N_t) w^u P_t - D_t \tag{C.1}$$

The amount of money carried over to the following period is:

$$B_{t+1} = B_t + W_t h_t N_t + (1 - N_t) w^u P_t - D_t - P_t C_t + \Pi_t^F + \Pi_t^S + \Pi_t^B + R_t^D D_t \tag{C.2}$$

Substituting the binding version of (C.1) into (C.2) we have: $B_{t+1} = \Pi_t^F + \Pi_t^S + \Pi_t^B + R_t^D D_t$. Calculating this equation a period backward and substituting the result into (C.1) gives the intertemporal budget constraint that can be expressed in real terms in the following way:

$$C_t = w_t h_t N_t + w^u (1 - N_t) + \frac{\Pi_{t-1}^F}{P_t} + \frac{\Pi_{t-1}^S}{P_t} + \frac{\Pi_{t-1}^B}{P_t} - \frac{D_t}{P_t} + R_{t-1}^D \frac{D_{t-1}}{P_t} \tag{C.3}$$

The household solves the problem:

$$\begin{aligned} G_t &= \max \left[U(C_t, h_t) + \beta E_t G_{t+1} \right] \\ & \quad s.t. \;\; (C.3) \end{aligned}$$

where $U(C_t, h_t) = \frac{C_t^{1-\sigma}}{1-\sigma} - \vartheta \frac{h_t^{1+\phi}}{1+\phi}$. The separability of the utility function allows us to make the usual assumption that consumption risks are fully pooled within the household. All households solve the same problem. The first order conditions then are:

$$\text{for } C_t\text{: } \lambda_t = C_t^{-\sigma}$$

$$\text{for } D_t\text{: } \lambda_t = R_t^D \beta E_t \frac{P_t}{P_{t+1}} \lambda_{t+1}$$

The latter condition yields the Euler equation (3.1) of the text.

Wholesale firms

Wholesale firms solve the problem:

$$\begin{aligned} F_t^V &= \max\left[-\frac{f}{\lambda_t}s_t^F + \frac{Y_t^w}{\mu_t} - R_t^L w_t h_t N_t - R_t^L k^F q_t^F V_t^F + \beta E_t \frac{\lambda_{t+1}}{\lambda_t} F_{t+1}^V\right] \\ & s.t.\ Y_t^w = A h_t^\alpha N_t \\ & \quad V_t^F = p_t^B s_t^F \\ & \quad N_t = (1-\rho)N_{t-1} + q_t^F V_t^F \end{aligned}$$

Denoting $f_t = \frac{f}{\lambda_t}$, the first order condition and the envelope theorem yield:

$$\text{for } s_t^F\text{:}\ \frac{f_t}{q_t^F p_t^B} + R_t^L k^F = \frac{A h_t^\alpha}{\mu_t} - R_t^L w_t h_t + \beta E_t \frac{\lambda_{t+1}}{\lambda_t}\frac{\partial F_{t+1}^V}{\partial N_t} \tag{C.4}$$

$$\text{for } N_{t-1}\text{:}\ \frac{\partial F_t^V}{\partial N_{t-1}} = (1-\rho)\left(\frac{A h_t^\alpha}{\mu_t} - R_t^L w_t h_t\right) + (1-\rho)\beta E_t \frac{\lambda_{t+1}}{\lambda_t}\frac{\partial F_{t+1}^V}{\partial N_t} \tag{C.5}$$

Replacing (C.4) into (C.5) we obtain:

$$\frac{\partial F_t^V}{\partial N_{t-1}} = (1-\rho)\left(\frac{f_t}{q_t^F p_t^B} + R_t^L k^F\right) \tag{C.6}$$

Updating equation (C.6) and then replacing into (C.4), we then get:

$$\frac{f_t}{q_t^F p_t^B} + R_t^L k^F = \frac{A h_t^\alpha}{\mu_t} - R_t^L w_t h_t + (1-\rho)\beta E_t \frac{\lambda_{t+1}}{\lambda_t}\left(\frac{f_{t+1}}{q_{t+1}^F p_{t+1}^B} + R_{t+1}^L k^F\right) \tag{C.7}$$

which is equation (3.7) of the text.

Real Wage and Hours Bargaining

In this and next sections we compute the bargainings on the real wage and on hours worked. The real wage Nash bargaining is:

$$\max_{w_t} (S_t^F)^{1-d}(S_t^W)^d$$

where the surplus of the firm is:

$$S_t^F = S_t^J - S_t^V \tag{C.8}$$

with:

$$S_t^J = \frac{\partial F_t^V}{\partial N_t} = \frac{A h_t^\alpha}{\mu_t} - R_t^L w_t h_t + \beta E_t \frac{\lambda_{t+1}}{\lambda_t}\left[\rho S_{t+1}^V + (1-\rho) S_{t+1}^J\right] \tag{C.9}$$

and:

$$S_t^V = -f_t + p_t^B\left[q_t^F\left(-R_t^L k^F + S_t^J\right) + (1-q_t^F)\beta E_t \frac{\lambda_{t+1}}{\lambda_t} S_{t+1}^V\right] + (1-p_t^B)\beta E_t \frac{\lambda_{t+1}}{\lambda_t} S_{t+1}^V \tag{C.10}$$

From (C.9) and (C.10) and using the free-entry condition, $S_t^V = 0 \; \forall \; t$ it is possible to obtain equation (3.7) of the text. Further from (C.10) and the free-entry condition we have:

$$S_t^J = \frac{f_t}{q_t^F p_t^B} + R_t^L k^F \tag{C.11}$$

Then, replacing (C.11) and the free-entry condition into (C.8) we get that $S_t^F = S_t^J$, or, using (C.7):

$$S_t^F = \frac{Ah_t^\alpha}{\mu_t} - R_t^L w_t h_t + (1-\rho)\beta E_t \frac{\lambda_{t+1}}{\lambda_t}\left(\frac{f_{t+1}}{q_{t+1}^F p_{t+1}^B} + R_{t+1}^L k^F\right) \tag{C.12}$$

The worker's surplus is the difference between value the worker enjoys when being matched and that when not being matched:

$$S_t^W = S_t^M - S_t^N \tag{C.13}$$

S_t^M is equal to the wage obtained in period t net of labor (hours) disutility, $g(h_t) = \vartheta \frac{h_t^{1+\phi}}{1+\phi}$, plus the expected values of the possible states of the worker entering the following period: the worker can still be in a match with a firm which has not separated from a bank and enjoy the value S_{t+1}^M, or be in search because at least one separation occurred. In the latter case, the worker obtains S_{t+1}^M if both matches (credit and labor) are generated and S_{t+1}^N otherwise. Then we have:

$$S_t^M = w_t h_t - \frac{g(h_t)}{\lambda_t} + \beta E_t \frac{\lambda_{t+1}}{\lambda_t}\left\{(1-\rho)S_{t+1}^M + \rho[p_{t+1}^F S_{t+1}^M + (1-p_{t+1}^F)S_{t+1}^N]\right\}$$

where $g(h_t) = \vartheta \frac{h_t^{1+\phi}}{1+\phi}$.

S_t^N is given by the sum of unemployment benefits (expressed in terms of consumption goods) and the discounted value for a worker entering the following period without being employed in a match:

$$S_t^N = w^u + \beta E_t \frac{\lambda_{t+1}}{\lambda_t}\left[p_{t+1}^F S_{t+1}^M + (1-p_{t+1}^F)S_{t+1}^N\right]$$

Using the last two equations in (C.13) we obtain:

$$S_t^W = \left(w_t h_t - \frac{g(h_t)}{\lambda_t} - w^u\right) + (1-\rho)\beta E_t \frac{\lambda_{t+1}}{\lambda_t}(1-p_{t+1}^F)S_{t+1}^W \tag{C.14}$$

The optimality condition of the Nash bargaining is:

$$(1-d)\delta_t^F S_t^W + d\delta_t^W S_t^F = 0 \tag{C.15}$$

where:

$$\delta_t^F = \frac{\partial S_t^F}{\partial w_t} = -R_t^L h_t \tag{C.16}$$

and:

$$\delta_t^W = \frac{\partial S_t^W}{\partial w_t} = h_t \tag{C.17}$$

Further, the surplus of a worker in the next period is:

$$S_{t+1}^W = \frac{d}{(1-d)R_{t+1}^L} S_{t+1}^F = \frac{d}{(1-d)R_{t+1}^L}\left(\frac{f_{t+1}}{q_{t+1}^F p_{t+1}^B} + R_{t+1}^L k^F\right) \tag{C.18}$$

Replacing (C.12), (C.14), (C.16), (C.17) and (C.18) into (C.15) we obtain:

$$R_t^L(1-d)\left[\left(\frac{g(h_t)}{\lambda_t}+w^u-w_th_t\right)-(1-\rho)\beta E_t\frac{\lambda_{t+1}}{\lambda_t}(1-p_{t+1}^F)S_{t+1}^W\right]+$$
$$+d\left[\frac{Ah_t^\alpha}{\mu_t}-R_t^Lw_th_t+(1-\rho)\beta E_t\frac{\lambda_{t+1}}{\lambda_t}\left(\frac{f_{t+1}}{q_{t+1}^Fp_{t+1}^B}+R_{t+1}^Lk^F\right)\right]=0 \qquad (C.19)$$

Rearranging the previous equation we have:

$$\begin{aligned} w_th_t &= \frac{d}{d+(1-d)R_t^L}\left[\frac{Ah_t^\alpha}{\mu_t}-r_t^Lw_th_t+(1-\rho)\beta E_t\frac{\lambda_{t+1}}{\lambda_t}\left(\frac{f_{t+1}}{q_{t+1}^Fp_{t+1}^B}+R_{t+1}^Lk^F\right)\right]+ \\ &+\frac{(1-d)R_t^L}{d+(1-d)R_t^L}\left[\left(\frac{g(h_t)}{\lambda_t}+w^u\right)-(1-\rho)\beta E_t\frac{\lambda_{t+1}}{\lambda_t}(1-p_{t+1}^F)S_{t+1}^W\right] \end{aligned}$$

We denote $R_t^W=r_t^Lw_t$ is the interest paid by the firm on the real wage borrowed from a bank and $\chi_t=\frac{d}{d+(1-d)R_t^L}$. Further $mrs_t=\vartheta\frac{h_t^\phi}{\lambda_t}$. Then, using (C.18), we can write $S_{t+1}^W=\frac{\chi_{t+1}}{1-\chi_{t+1}}S_{t+1}^F$. Finally, the bargained real wage is:

$$\begin{aligned} w_t &= (1-\chi_t)\left(\frac{mrs_t}{1+\phi}+\frac{w^u}{h_t}\right)+ \\ &+\chi_t\left[\frac{mpl_t}{\alpha\mu_t}-R_t^W+(1-\rho)\beta\frac{1}{h_t}E_t\frac{\lambda_{t+1}}{\lambda_t}\left(\frac{f_{t+1}\theta_{t+1}^L}{p_{t+1}^B}+R_{t+1}^Lk^Fp_{t+1}^F\right)\right]+ \\ &+\chi_t(1-p_{t+1}^F)\left[(1-\rho)\beta\frac{1}{h_t}E_t\frac{\lambda_{t+1}}{\lambda_t}\left(\frac{f_{t+1}}{q_{t+1}^Fp_{t+1}^B}+R_{t+1}^Lk^F\right)\right]\left[1-\chi_t\frac{\chi_{t+1}(1-\chi_t)}{(1-\chi_{t+1})\chi_t}\right] \end{aligned}$$

We hence obtain a variation of the conventional sharing rule (Trigari, 2006) where the relative share χ_t depends not only on the bargaining power, but also on the effect of the wage on the firms's surplus (relative allocational effect). From (C.19) it is also possible to obtain:

$$R_t^Lw_th_t=(1-d)R_t^L\left[\left(\frac{g(h_t)}{\lambda_t}+w^u\right)-(1-\rho)\beta E_t\frac{\lambda_{t+1}}{\lambda_t}(1-p_{t+1}^F)S_{t+1}^W\right]+$$
$$+d\left[\frac{Ah_t^\alpha}{\mu_t}+(1-\rho)\beta E_t\frac{\lambda_{t+1}}{\lambda_t}\left(\frac{f_{t+1}}{q_{t+1}^Fp_{t+1}^B}+R_{t+1}^Lk^F\right)\right]$$

Using (C.18) and recalling that $mrs_t=\vartheta\frac{h_t^\phi}{\lambda_t}$ and $mpl_t=\alpha Ah_t^{\alpha-1}$, we get:

$$w_t=(1-d)\left(\frac{mrs_t}{1+\phi}+\frac{w^u}{h_t}\right)-\frac{(1-\rho)}{h_t}\beta E_t\frac{\lambda_{t+1}}{\lambda_t}\frac{d(1-p_{t+1}^F)}{R_{t+1}^L}\left(\frac{f_t}{q_{t+1}^Fp_{t+1}^B}+R_{t+1}^Lk^F\right)+$$
$$+\frac{d}{R_t^L}\left[\frac{mpl_t}{\alpha\mu_t}+\frac{1}{h_t}(1-\rho)\beta E_t\frac{\lambda_{t+1}}{\lambda_t}\left(\frac{f_{t+1}}{q_{t+1}^Fp_{t+1}^B}+R_{t+1}^Lk^F\right)\right]$$

Rearranging the previous equation we have:

$$w_t = (1-d)\left(\frac{mrs_t}{1+\phi} + \frac{w^u}{h_t}\right) +$$
$$+\frac{d}{R_t^L}\left[\frac{mpl_t}{\alpha\mu_t} + \frac{1}{h_t}(1-\rho)\beta E_t \frac{\lambda_{t+1}}{\lambda_t}\left(\frac{f_{t+1}}{q_{t+1}^F p_{t+1}^B} + R_{t+1}^L k^F\right)\left(1 - \frac{R_t^L(1-p_{t+1}^F)}{R_{t+1}^L}\right)\right]$$

which is equation (3.11) of the text.

The hours Nash bargaining is:

$$\max_{h_t} (S_t^F)^{1-d}(S_t^W)^d$$

The optimality condition is:

$$(1-d)\tau_t^F S_t^W + d\tau_t^W S_t^F = 0 \tag{C.20}$$

where:

$$\tau_t^F = \frac{\partial S_t^F}{\partial h_t} = \left(\frac{mpl_t}{\mu_t} - w_t R_t^L\right) \tag{C.21}$$

and:

$$\tau_t^W = \frac{\partial S_t^W}{\partial h_t} = (w_t - mrs_t) \tag{C.22}$$

Replacing (C.21) and (C.22) into (C.20) and recalling that $S_t^W = \dfrac{d}{(1-d)R_t^L} S_t^F$ we obtain:

$$(1-d)\left(\frac{mpl_t}{\mu_t} - w_t R_t^L\right)\frac{d}{(1-d)R_t^L} S_t^F + d(w_t - mrs_t)S_t^F = 0$$

Simplifying this equation we have:

$$\frac{mpl_t}{\mu_t R_t^L} = mrs_t$$

Using the definitions of the labor marginal productivity and of the marginal rate of substitution we obtain the condition on bargained hours:

$$h_t = \left(\frac{\vartheta\mu_t R_t^L}{\alpha A\lambda_t}\right)^{\frac{1}{\alpha-1-\phi}}$$

which is equation (3.13) of the text.

Retail firms

The retail firms solve the following problem:

$$\max E_t \sum_{l=0}^{\infty} \omega^l \beta^l \frac{\lambda_{t+1}}{\lambda_t}\left[\left(\frac{P_{it}}{P_{t+l}}\right) Y_{it+l} - mc_{t+l} Y_{it+l}\right]$$
$$s.t.\ \ Y_{it} = \left(\frac{P_{it}}{P_t}\right)^{-\varepsilon} Y_t$$

In a symmetric equilibrium, the standard first order condition for $P_{it} = P_t^*$ is:

$$\frac{P_t^*}{P_t} = \frac{\varepsilon}{\varepsilon - 1} \frac{E_t \sum_{l=0}^{\infty} \omega^l \beta^l mc_{t+l} \left(\frac{P_{t+l}}{P_t}\right)^{\varepsilon} C_{t+l}^{1-\sigma}}{E_t \sum_{l=0}^{\infty} \omega^l \beta^l \left(\frac{P_{t+l}}{P_t}\right)^{\varepsilon-1} C_{t+l}^{1-\sigma}}$$

which is equation (3.14) of the text.

Banks

The bank solves the following problem:

$$\begin{aligned} J_t^V &= \max \left[(R_t^L - R_t^D) w_t h_t L_t^N + (R_t^L q_t^F - R_t^D) k^F L_t^V + R_t^D \frac{X_t}{P_t} - \frac{b}{\lambda_t} V_t^B + \beta E_t \frac{\lambda_{t+1}}{\lambda_t} J_{t+1}^V \right] \\ & s.t.\ L_t^V = q_t^B V_t^B \\ & \quad L_t^N = (1-\rho) L_{t-1}^N + q_t^F q_t^B V_t^B \end{aligned}$$

Denoting $b_t = \frac{b}{\lambda_t}$, the first order condition and the envelope theorem yield:

$$\text{for } V_t^B\text{: } \frac{b_t}{q_t^F q_t^B} - (R_t^L q_t^F - R_t^D) \frac{k^F}{q_t^F} - (R_t^L - R_t^D) w_t h_t = \beta E_t \frac{\lambda_{t+1}}{\lambda_t} \frac{\partial J_{t+1}^V}{\partial L_t^N} \tag{C.23}$$

$$\text{for } L_{t-1}^N\text{: } \frac{\partial J_t^V}{\partial L_{t-1}^N} = (1-\rho)(R_t^L - R_t^D) w_t h_t + \beta (1-\rho) E_t \frac{\lambda_{t+1}}{\lambda_t} \frac{\partial J_{t+1}^V}{\partial L_t^N} \tag{C.24}$$

By replacing (C.23) into (C.24) we obtain:

$$\frac{\partial J_t^V}{\partial L_{t-1}^N} = (1-\rho) \left[\frac{b_t}{q_t^F q_t^B} - (R_t^L q_t^F - R_t^D) \frac{k^F}{q_t^F} \right] \tag{C.25}$$

By updating equation (C.25) and then by replacing into (C.23), we then get:

$$\frac{b_t}{q_t^F q_t^B} - (R_t^L q_t^F - R_t^D) \frac{k^F}{q_t^F} = (R_t^L - R_t^D) w_t h_t + (1-\rho) \beta E_t \frac{\lambda_{t+1}}{\lambda_t} \left[\frac{b_{t+1}}{q_{t+1}^F q_{t+1}^B} - (R_{t+1}^L q_{t+1}^F - R_{t+1}^D) \frac{k^F}{q_{t+1}^F} \right] \tag{C.26}$$

which is equation (3.18) of the text.

Loan Interest Rate Bargaining

The loan interest rate Nash bargaining is:

$$\max_{R_t^L} (S_t^B)^{1-z} (S_t^F)^z$$

where:

$$S_t^B = S_t^C - S_t^{VB} \tag{C.27}$$

with:

$$S_t^C = \frac{\partial J_t^V}{\partial L_t^N} = (R_t^L - R_t^D) w_t h_t + \beta E_t \frac{\lambda_{t+1}}{\lambda_t} \left[(1-\rho) S_{t+1}^C + \rho S_{t+1}^{VB} \right] \tag{C.28}$$

and:

$$S_t^{VB} = -b_t + q_t^B \left\{ -k^F R_t^D + q_t^F \left(R_t^L k^F + S_t^C \right) + (1-q_t^F)\beta E_t \frac{\lambda_{t+1}}{\lambda_t} S_{t+1}^{VB} \right\} + (1-q_t^B)\beta E_t \frac{\lambda_{t+1}}{\lambda_t} S_{t+1}^{VB} \tag{C.29}$$

From (C.28) and (C.29) and using free-entry condition, $S_t^{VB} = 0 \ \forall \ t$, it is possible to obtain equation (3.18) of the text. Further, from (C.29) and the free-entry condition we have:

$$S_t^C = \frac{b_t}{q_t^F q_t^B} - (R_t^L q_t^F - R_t^D) \frac{k^F}{q_t^F} \tag{C.30}$$

Then, replacing (C.30) and the free-condition into (C.27) we get $S_t^B = S_t^C$ or, using (C.26):

$$S_t^B = (R_t^L - R_t^D) w_t h_t + (1-\rho)\beta E_t \frac{\lambda_{t+1}}{\lambda_t} \left[\frac{b_{t+1}}{q_{t+1}^F q_{t+1}^B} - (R_{t+1}^L q_{t+1}^F - R_{t+1}^D) \frac{k^F}{q_{t+1}^F} \right] \tag{C.31}$$

The optimality condition is:

$$(1-z)\gamma_t^B S_t^F + z\gamma_t^F S_t^B = 0 \tag{C.32}$$

where:

$$\gamma_t^B = \frac{\partial S_t^B}{\partial R_t^L} = w_t h_t + (R_t^L - R_t^D) \left(\epsilon_t^W h_t + \epsilon_t^H w_t \right) \tag{C.33}$$

and:

$$\gamma_t^F = \frac{\partial S_t^F}{\partial R_t^L} = \frac{mpl_t}{\mu_t} \epsilon_t^H - w_t h_t - R_t^L \left(\epsilon_t^W h_t + \epsilon_t^H w_t \right) \tag{C.34}$$

with:

$$\epsilon_t^W = \frac{\partial w_t}{\partial R_t^L} = -\frac{d}{(R_t^L)^2} \left[\frac{mpl_t}{\alpha \mu_t} + (1-\rho)\beta \frac{1}{h_t} E_t \frac{\lambda_{t+1}}{\lambda_t} \left(\frac{f_{t+1}}{q_{t+1}^F p_{t+1}^B} + R_{t+1}^L k^F \right) \right] \tag{C.35}$$

and:

$$\epsilon_t^H = \frac{\partial h_t}{\partial R_t^L} = \frac{1}{\alpha - 1 - \phi} \left(\frac{\vartheta \mu_t R_t^L}{\alpha A \lambda_t} \right)^{\frac{1}{\alpha-1-\phi} - 1} \frac{\vartheta \mu_t}{\alpha A \lambda_t}$$

$$\epsilon_t^H = \frac{1}{\alpha - 1 - \phi} \left(\frac{\vartheta \mu_t R_t^L}{\alpha A \lambda_t} \right)^{\frac{1}{\alpha-1-\phi}} \frac{1}{R_t^L}$$

or:

$$\epsilon_t^H = \frac{1}{\alpha - 1 - \phi} \frac{h_t}{R_t^L} \tag{C.36}$$

Substituting (C.12), (C.31), (C.33), (C.34), (C.35) and (C.36) into (C.32) we obtain:

$$(1-z)\gamma_t^B \left[\frac{Ah_t^\alpha}{\mu_t} - R_t^L w_t h_t + (1-\rho)\beta E_t \frac{\lambda_{t+1}}{\lambda_t} \left(\frac{f_{t+1}}{q_{t+1}^F p_{t+1}^B} + R_{t+1}^L k^F \right) \right] +$$

$$+ z\gamma_t^F \left\{ (R_t^L - R_t^D) w_t h_t + (1-\rho)\beta E_t \frac{\lambda_{t+1}}{\lambda_t} \left[\frac{b_{t+1}}{q_{t+1}^F q_{t+1}^B} - (R_{t+1}^L q_{t+1}^F - R_{t+1}^D) \frac{k^F}{q_{t+1}^F} \right] \right\} = 0$$

Rearranging:

$$
\begin{aligned}
&(1-z)\gamma_t^B\left[\frac{Ah_t^\alpha}{\mu_t}+(1-\rho)\beta E_t\frac{\lambda_{t+1}}{\lambda_t}\left(\frac{f_{t+1}}{q_{t+1}^F p_{t+1}^B}+R_{t+1}^L k^F\right)\right]+\\
&+z\gamma_t^F\left\{-R_t^D w_t h_t+(1-\rho)\beta E_t\frac{\lambda_{t+1}}{\lambda_t}\left[\frac{b_{t+1}}{q_{t+1}^F q_{t+1}^B}-(R_{t+1}^L q_{t+1}^F-R_{t+1}^D)\frac{k^F}{q_{t+1}^F}\right]\right\}=\\
&=R_t^L w_t[(1-z)\gamma_t^B-z\gamma_t^F]
\end{aligned}
$$

Denoting $\psi_t=\frac{(1-z)\gamma_t^B}{[(1-z)\gamma_t^B-z\gamma_t^F]}$, the bargained loan interest rate is:

$$
\begin{aligned}
R_t^L \;=\; &\psi_t\frac{1}{w_t}\left[\frac{mpl_t}{\alpha\mu_t}+\frac{(1-\rho)\beta}{h_t}E_t\frac{\lambda_{t+1}}{\lambda_t}\left(\frac{f_{t+1}\theta_{t+1}^C}{q_{t+1}^F q_{t+1}^B}+R_{t+1}^L k^F\right)\right]+\\
&+(1-\psi_t)\frac{1}{w_t}\left\{w_t R_t^D-\frac{(1-\rho)\beta}{h_t}E_t\frac{\lambda_{t+1}}{\lambda_t}\left[\frac{b_{t+1}}{q_{t+1}^F q_{t+1}^B}-(R_{t+1}^L q_{t+1}^F-R_{t+1}^D)\frac{k^F}{q_{t+1}^F}\right]\right\}
\end{aligned}
$$

which is equation (3.21) of the text.

Market clearing

Considering the aggregate money carried over to the following period in real terms and writing profits gross of taxes we have:

$$\frac{X_t}{P_t}=w_t h_t N_t-C_t+(1-N_t)w^u+\left(\frac{\Pi_t^{FL}}{P_t}-T^F\right)+\left(\frac{\Pi_t^{BL}}{P_t}-T^B\right)+\left(\frac{\Pi_t^{SL}}{P_t}-T^S\right)-\frac{D_t}{P_t}+R_t^D\frac{D_t}{P_t}$$

Taking into account the government budget constraint, $T=T^F+T^B+T^S=(1-N_t)w^u$, it follows that:

$$\frac{X_t}{P_t}=w_t h_t N_t-C_t+\frac{\Pi_t^F}{P_t}+\frac{\Pi_t^B}{P_t}+\frac{\Pi_t^S}{P_t}-\frac{D_t}{P_t}+R_t^D\frac{D_t}{P_t}$$

We recall that the bank balance sheet is: $D_t/P_t=w_t h_t L_t^N+k^F H_t-X_t/P_t$. Hence:

$$\frac{X_t}{P_t}=w_t h_t N_t-C_t+\frac{\Pi_t^F}{P_t}+\frac{\Pi_t^B}{P_t}+\frac{\Pi_t^S}{P_t}-\left(w_t h_t L_t^N+k^F H_t-\frac{X_t}{P_t}\right)+R_t^D\left(w_t h_t L_t^N+k^F H_t-\frac{X_t}{P_t}\right)$$

Or:

$$C_t=w_t h_t N_t+\frac{\Pi_t^F}{P_t}+\frac{\Pi_t^B}{P_t}+\frac{\Pi_t^S}{P_t}-\left(w_t h_t L_t^N+k^F H_t\right)+R_t^D\left(w_t h_t L_t^N+k^F H_t\right)-R_t^D X_t/P_t$$

We use the bank's profits, $\left(R_t^L-R_t^D\right)w_t h_t L_t^N+\left(R_t^L q_t^F-R_t^D\right)k^F H_t+R_t^D\left(X_t/P_t\right)$, to get:

$$
\begin{aligned}
&C_t=w_t h_t N_t+\frac{\Pi_t^F}{P_t}+\left(R_t^L-R_t^D\right)w_t h_t L_t^N+\left(R_t^L q_t^F-R_t^D\right)k^F H_t+\\
&+\frac{\Pi_t^S}{P_t}-\left(w_t h_t L_t^N+k^F H_t\right)+R_t^D\left(w_t h_t L_t^N+k^F H_t\right)
\end{aligned}
$$

Substituting the profits of the specialized firm: $\frac{\Pi_t^S}{P_t}=k^F V_t^F$ and recalling that $H_t=V_t^F$ we have:

$$C_t = \frac{\Pi_t^F}{P_t} + \left(R_t^L - R_t^D\right) w_t h_t L_t^N + \left(R_t^L q_t^F - R_t^D\right) k^F H_t +$$
$$+ w_t h_t N_t + k^F H_t - \left(w_t h_t L_t^N + k^F H_t\right) + R_t^D \left(w_t h_t L_t^N + k^F H_t\right)$$

By simplifying:

$$C_t = \tfrac{\Pi_t^F}{P_t} + R_t^L \left(w_t h_t L_t^N + q_t^F k^F H_t\right) + \left(w_t h_t N_t - w_t h_t L_t^N\right)$$

Substituting the profits of retail firms, $\frac{\Pi_t^F}{P_t} = Y_t^d - \frac{Y_t^w}{\mu_t}$, we obtain:

$$C_t = Y_t^d - \tfrac{Y_t^w}{\mu_t} + \left(R_t^L\right)\left(w_t h_t L_t^N + q_t^F k^F H_t\right) + \left(w_t h_t\right)\left(N_t - L_t^N\right)$$

Wholesale firms make zero profits. Hence:

$\frac{Y_t^w}{\mu_t} - R_t^L q_t^F k^F V_t^F = R_t^L w_t h_t N_t$ or $\frac{Y_t^w}{\mu_t} = R_t^L \left(w_t h_t N_t + q_t^F k^F V_t^F\right)$

Using this equation and recalling again that $H_t = V_t^F$:

$$C_t = Y_t^d - R_t^L \left(w_t h_t N_t + q_t^F k^F H_t\right) + \left(R_t^L\right)\left(w_t h_t L_t^N + q_t^F k^F H_t\right) + \left(w_t h_t\right)\left(N_t - L_t^N\right)$$

$$C_t = Y_t^d + \left(1 - R_t^L\right) w_t h_t \left(N_t - L_t^N\right)$$

The dynamics of employment and of the lines of credit are:

$$N_t - (1-\rho) N_{t-1} = q_t^F V_t^F$$

$$L_t^N - (1-\rho) L_{t-1}^N = q_t^F H_t = q_t^F V_t^F$$

Being $(1-\rho) < 1$, we may use the lag operator Γ to write:

$$\left[1 - (1-\rho)\Gamma\right] N_t = q_t^F V_t^F$$

$$\left[1 - (1-\rho)\Gamma\right] L_t^N = q_t^F V_t^F$$

Or:

$$N_t = \left[1 - (1-\rho)\Gamma\right]^{-1} q_t^F V_t^F = \textstyle\sum_{i=0}^{\infty} (1-\rho)^i q_{t-i}^F V_{t-i}^F$$

$$L_t^N = \left[1 - (1-\rho)\Gamma\right]^{-1} q_t^F V_t^F = \textstyle\sum_{i=0}^{\infty} (1-\rho)^i q_{t-i}^F V_{t-i}^F$$

It is hence: $N_t = L_t^N$

It follows that the aggregate resurce constraint is:

$$C_t = Y_t^d$$

Further the equilibrium in the good market, $Y_t^d = Y_t$, implies:

$$C_t = Y_t$$

The symmetric equilibrium of the model

The symmetric equilibrium of the model is provided by the following equations which, for the reader's convenience, are listed according to the sequence we follow, in the next section, in order to recursively determine the steady state of the model.

Consumption Euler equation:

$$\lambda_t = R_t^D \beta E_t \frac{P_t}{P_{t+1}} \lambda_{t+1} \tag{C.37}$$

Unemployment:

$$U_t = 1 - N_t \tag{C.38}$$

Employment dynamics:

$$N_t = (1-\rho)N_{t-1} + M_t \tag{C.39}$$

Job vacancies:

$$V_t^F = p_t^B s_t^F \tag{C.40}$$

Credit line finding rate:

$$p_t^B = H_t / s_t^F \tag{C.41}$$

Credit vacancy filling rate:

$$q_t^B = H_t / V_t^B \tag{C.42}$$

Lines of credit financing wages:

$$L_t^N = (1-\rho)L_{t-1}^N + q_t^F H_t \tag{C.43}$$

Searchers:

$$s_t^W = 1 - (1-\rho)N_{t-1} \tag{C.44}$$

Labor market tightness:

$$\theta_t^L = V_t^F / s_t^W \tag{C.45}$$

Job vacancy filling rate:

$$q_t^F = M_t / V_t^F \tag{C.46}$$

Job finding rate:

$$p_t^F = M_t / s_t^W \tag{C.47}$$

Credit market tightness:

$$\theta_t^C = s_t^F / V_t^B \tag{C.48}$$

Labor market matches:

$$M_t = \eta (V_t^F)^{\xi} (s_t^W)^{1-\xi} \tag{C.49}$$

Financial matches:

$$H_t = \upsilon (V_t^B)^{\zeta} (s_t^F)^{1-\zeta} \tag{C.50}$$

Production function:

$$Y_t^w = Ah_t^\alpha N_t \tag{C.51}$$

Aggregate resources constraint:

$$Y_t = C_t \tag{C.52}$$

$$Y_t^w = Y_t v_t \tag{C.53}$$

Marginal utility of consumption:

$$\lambda_t = C_t^{-\sigma} \tag{C.54}$$

Marginal effect of the loan rate of interest on hours worked:

$$\epsilon_t^H = \frac{\partial h_t}{\partial R_t^L} = \frac{1}{\alpha - 1 - \phi}\frac{h_t}{R_t^L} \tag{C.55}$$

Condition on hours worked:

$$h_t = \left(\frac{\vartheta \mu_t R_t^L}{\alpha A \lambda_t}\right)^{\frac{1}{\alpha-1-\phi}} \tag{C.56}$$

Marginal productivity of labor:

$$mpl_t = \alpha A h_t^{\alpha-1} \tag{C.57}$$

Marginal rate of substitution:

$$mrs_t = \vartheta \frac{h_t^\phi}{\lambda_t} \tag{C.58}$$

Job creating condition:

$$\frac{f_t}{q_t^F p_t^B} + R_t^L k^F = \frac{Ah_t^\alpha}{\mu_t} - R_t^L w_t h_t + (1-\rho)\beta E_t \frac{\lambda_{t+1}}{\lambda_t}\left(\frac{f_{t+1}}{q_{t+1}^F p_{t+1}^B} + R_{t+1}^L k^F\right) \tag{C.59}$$

Bargained real wage:

$$\begin{aligned} w_t = {} & (1-d)\left(\frac{mrs_t}{1+\phi} + \frac{w^u}{h_t}\right) + \\ & + \frac{d}{R_t^L}\left[\frac{mpl_t}{\alpha\mu_t} + \frac{1}{h_t}(1-\rho)\beta E_t \frac{\lambda_{t+1}}{\lambda_t}\left(\frac{f_{t+1}}{q_{t+1}^F p_{t+1}^B} + R_{t+1}^L k^F\right)\left(1 - \frac{R_t^L(1-p_{t+1}^F)}{R_{t+1}^L}\right)\right] \end{aligned} \tag{C.60}$$

Marginal effect of the loan interest rate on the real wage:

$$\epsilon_t^W = \frac{\partial w_t}{\partial R_t^L} = -\frac{d}{(R_t^L)^2}\left[\frac{mpl_t}{\alpha\mu_t} + (1-\rho)\beta\frac{1}{h_t}E_t\frac{\lambda_{t+1}}{\lambda_t}\left(\frac{f_{t+1}}{q_{t+1}^F p_{t+1}^B} + R_{t+1}^L k^F\right)\right] \tag{C.61}$$

Credit creating condition:

$$\frac{b_t}{q_t^F q_t^B} - (R_t^L q_t^F - R_t^D)\frac{k^F}{q_t^F} = (R_t^L - R_t^D) w_t h_t + (1-\rho)\beta E_t \frac{\lambda_{t+1}}{\lambda_t}\left[\frac{b_{t+1}}{q_{t+1}^F q_{t+1}^B} - (R_{t+1}^L q_{t+1}^F - R_{t+1}^D)\frac{k^F}{q_{t+1}^F}\right] \tag{C.62}$$

Marginal effect of the loan interest rate on the banks' surplus:

$$\gamma_t^B = \frac{\partial S_t^B}{\partial R_t^L} = w_t h_t + (R_t^L - R_t^D)\left(\epsilon_t^W h_t + \epsilon_t^H w_t\right) \tag{C.63}$$

Marginal effect of the loan interest rate on the firms' surplus:

$$\gamma_t^F = \frac{\partial S_t^F}{\partial R_t^L} = \frac{mpl_t}{\mu_t}\epsilon_t^H - w_t h_t - R_t^L\left(\epsilon_t^W h_t + \epsilon_t^H w_t\right) \tag{C.64}$$

Bargained loan interest rate:

$$\begin{aligned} R_t^L \quad = \quad & \psi_t \frac{1}{w_t}\left[\frac{mpl_t}{\alpha\mu_t} + \frac{(1-\rho)\beta}{h_t}E_t\frac{\lambda_{t+1}}{\lambda_t}\left(\frac{f_{t+1}\theta_{t+1}^C}{q_{t+1}^F q_{t+1}^B} + R_{t+1}^L k^F\right)\right] + \\ & +(1-\psi_t)\frac{1}{w_t}\left\{w_t R_t^D - \frac{(1-\rho)\beta}{h_t}E_t\frac{\lambda_{t+1}}{\lambda_t}\left[\frac{b_{t+1}}{q_{t+1}^F q_{t+1}^B} - (R_{t+1}^L q_{t+1}^F - R_{t+1}^D)\frac{k^F}{q_{t+1}^F}\right]\right\} \end{aligned} \tag{C.65}$$

Modified relative bargaining power of banks:

$$\psi_t = \frac{(1-z)\gamma_t^B}{[(1-z)\gamma_t^B - z\gamma_t^F]} \tag{C.66}$$

Price rule:

$$\frac{P_t^*}{P_t} = \frac{\varepsilon}{\varepsilon - 1}\frac{E_t\sum_{l=0}^{\infty}\omega^l\beta^l mc_{t+l}\left(\frac{P_{t+l}}{P_t}\right)^{\varepsilon}C_{t+l}^{1-\sigma}}{E_t\sum_{l=0}^{\infty}\omega^l\beta^l\left(\frac{P_{t+l}}{P_t}\right)^{\varepsilon-1}C_{t+l}^{1-\sigma}} \tag{C.67}$$

Real marginal costs:

$$mc_t = \frac{1}{\mu_t} \tag{C.68}$$

Monetary rule:

$$R_t^D = (R_{t-1}^D)^{\rho_R}\left(\frac{P_t}{P_{t-1}}\right)^{(1-\rho_R)\delta_\pi}(Y_t)^{(1-\rho_R)\delta_Y}\nu_t \tag{C.69}$$

Monetary policy shock:

$$\nu_t = \nu_{t-1}^{\rho_\nu} e^{\varepsilon_t^\nu} \tag{C.70}$$

Steady States

We fix the steady state values of the following variables (see setion 3 of the text): R^D, R^L, N, q^F, p^B, q^B, and h. The other steady state variables (and some parameters) are here recursively derived.

Given R^D, from equation (C.37) we obtain the value of the discount factor: $\beta = \frac{1}{R^D}$.

Given N, from equation (C.38) we get that the steady state unemployment is: $U = 1 - N$.

Given q^F and equation (C.39), being $M = V^F q^F$, we obtain the steady state value of the job vacancies posted by firms: $V^F = \rho N / q^F$.

We can then compute: $M = V^F q^F = \rho N$.

From equations (C.39) and (C.40) we have: $\rho N = q^F p^B s^F$. From equations (C.43) and being $H = q^B V^B$ we have: $\rho L^N = q^F q^B V^B$ and hence $V^B = \frac{\rho L^N}{q^F q^B}$. Furthermore, since equations

(C.41) and (C.42) imply $p^B s^F = q^B V^B = H$, we also obtain $s^F = \dfrac{H}{p^B}$ and $N = L^N$.

From equation (C.44) we obtain: $s^W = 1 - (1-\rho)\, N$.

From equation (C.45) we have the steady state labor market tightness: $\theta^L = \dfrac{V^F}{s^W}$.

From equation (C.39) and being $M = p^F s^W = V^F q^F$ we get the job finding rate: $p^F = \dfrac{\rho N}{s^W}$ (being $p^F = \theta^L q^F$, it can also be directly calculated once θ^L is obtained).

The steady state credit market tightness is straightforwardly obtained from equation (C.48): $\theta^C = \dfrac{s^F}{V^B}$.

From equations (C.46) and (C.49) we get the scale parameter $\eta = q^F \left(\frac{s^W}{V^F}\right)^{\xi-1} = q^F (\theta^L)^{1-\xi}$.

From equations (C.42) and (C.50) we get the scale parameter $\upsilon = q^B \left(\frac{s^F}{V^B}\right)^{\zeta-1} = q^B \left(\theta^C\right)^{\zeta-1}$.

Being N calibrated, and setting $Y^w = 1$, from the production function (C.51) we get the productivity factor $A = \dfrac{Y^w}{N h^\alpha}$.

Since the price dispersion is $v = 1$ then $Y = Y^w$. The aggregate resource constraint (C.53) is: $Y = C$.

From equation (C.54) the marginal utility of consumption is: $\lambda = C^{-\sigma}$.

Given R^L, from equation (C.55) we obtain: $\epsilon^H = \dfrac{1}{\alpha - 1 - \phi} \dfrac{h}{R^L}$.

Given h we can solve the condition for optimal hours (C.56) with respect to the constant ϑ and obtain: $\vartheta = \dfrac{\alpha A \lambda}{R^L \mu \,(h)^{1+\phi-\alpha}}$.

From equation (C.57) we obtain the steady state marginal product of labor: $mpl = \alpha A h^{\alpha-1}$.

From equation (C.58) we obtain the steady state marginal rate of substitution: $mrs = \vartheta \dfrac{h^\phi}{\lambda}$.

We calibrate the replacement rate ϖ and write the steady state relationship $w^u = \varpi w h$ (to be determined below).

Solving the job creating condition (C.59) for f/λ we have:

$$\frac{f}{\lambda} = \frac{q^F p^B}{[1-\beta(1-\rho)]} \left[\frac{A h^\alpha}{\mu} - R^L \left\{ [1-\beta(1-\rho)]\, k^F + wh \right\} \right]$$

We now insert this equation into the steady state version of the real wage (obtained from equation C.60), $w = (1-d)\left(\frac{mrs}{1+\phi} + \frac{w^u}{h}\right) + \frac{d}{R^L}\left[\frac{mpl}{\alpha\mu} + \frac{(1-\rho)\beta}{h}\left(\frac{f}{\lambda q^F p^B} + R^L k^F\right)\left(1 - \frac{R^L(1-p^F)}{R^L}\right)\right]$, and use the definition of the reservation wage, $w^u = \varpi w h$, to obtain:

$$w = (1-d)\left(\frac{mrs}{1+\phi} + \frac{\varpi w h}{h}\right) + \\ + \frac{d}{R^L}\left[\frac{mpl}{\alpha\mu} + \frac{(1-\rho)\beta}{h}\left(\frac{1}{[1-\beta(1-\rho)]}\left[\frac{Ah^\alpha}{\mu} - R^L\left\{[1-\beta(1-\rho)]\,k^F + wh\right\}\right] + R^L k^F\right) p^F\right]$$

Solving this equation with respect to the real wage we get:

$$w = \frac{[1-\beta(1-\rho)]}{[1-\beta(1-\rho)]\,[1-(1-d)\varpi] + (1-\rho)\beta d p^F}\left\{(1-d)\frac{mrs}{1+\phi} + \frac{d}{R^L}\left[\frac{mpl}{\alpha\mu} + \frac{(1-\rho)\beta p^F}{h\,[1-\beta(1-\rho)]}\frac{Ah^\alpha}{\mu}\right]\right\}$$

We can then compute $w^u = \varpi w h$ and $\frac{f}{\lambda} = \frac{q^F p^B}{[1-\beta(1-\rho)]}\left[\frac{Ah^\alpha}{\mu} - R^L\left\{[1-\beta(1-\rho)]\,k^F + wh\right\}\right]$.

From equation (C.61) we have: $\epsilon^W = -\frac{d}{(R^L)^2}\left[\frac{mpl}{\alpha\mu} + (1-\rho)\beta\frac{1}{h}\left(\frac{f}{\lambda q^F p^B} + R^L k^F\right)\right]$.

Given R^L. we can solve the credit creating condition (C.62) with respect to b/λ and obtain:

$$\frac{b}{\lambda} = \frac{q^B q^F (R^L - R^D)}{[1-\beta(1-\rho)]} wh + q^B (R^L q^F - R^D) k^F$$

From equation (C.63) the marginal effect of the interest rate on loans on the surplus of the banks is: $\gamma^B = wh + (R^L - R^D)\left(\epsilon^W h + \epsilon^H w\right)$

Furthermore, from equation (C.64) the marginal effect of the interest rate on loans on the surplus of the firms is: $\gamma^F = \frac{mpl}{\mu}\epsilon^H - wh - R^L\left(\epsilon^W h + \epsilon^H w\right)$

In order to obtain the relative bargaining power in the loan interest rate bargaining, first rewrite equation (C.65) as $R^L = \psi X + (1-\psi)T$, where: $X = \frac{1}{w}\left[\frac{mpl}{\alpha\mu} + \frac{(1-\rho)\beta}{h}\left(\frac{f}{\lambda q^F p^B} + R^L k^F\right)\right]$ and $T = \frac{1}{w}\left\{wR^D - \frac{(1-\rho)\beta}{h}\left[\frac{b}{\lambda q^F q^B} - \frac{(R^L q^F - R^D)k^F}{q^F}\right]\right\}$. Solving for ψ we can then calculate: $\psi = \frac{(R^L - T)}{(X - T)}$.

From equation (C.66) we have $\psi = \frac{[(1-z)\gamma^B]}{[(1-z)\gamma^B - z\gamma^F]}$. By solving with respect to z we obtain the firm's bargaining power in the loan interest rate bargaining: $z = \frac{\gamma^B(\psi-1)}{[\gamma^B(\psi-1) + \psi\gamma^F]}$

From equation (C.68) we have: $\frac{1}{mc}$.

The Linearized Model

In this section we compute the aggregate log-linearized version of the model.

From equation (C.37), the log-linearized Euler equation is: $\hat{\lambda}_t = \hat{R}_t^D + \hat{P}_t - E_t\hat{P}_{t+1} + E_t\hat{\lambda}_{t+1}$. Since $\pi = 0$, we can write: $E_t\hat{P}_{t+1} - \hat{P}_t = E_t\left(\hat{P}_{t+1} - \hat{P}_t\right) = \hat{\pi}_{t+1}$ and so:

$$\hat{\lambda}_t = \hat{R}_t^D - E_t\hat{\pi}_{t+1} + E_t\hat{\lambda}_{t+1} \tag{C.71}$$

From equation (C.54), the log-linearizing version equation of the marginal utility of consumption is: $\lambda\hat{\lambda}_t = -\sigma C^{-\sigma}\hat{C}_t$. We may then write the Lagrange multiplier as:

$$\hat{\lambda}_t = -\sigma\hat{C}_t \tag{C.72}$$

From equation (C.40), the log-linearized version of the job vacancies is:

$$\hat{V}_t^F = \hat{p}_t^B + \hat{s}_t^F \tag{C.73}$$

From equation (C.39) we get: $N\hat{N}_t = (1-\rho)N\hat{N}_{t-1} + M\hat{M}_t$. Being $M = \rho N$. The employment dynamics is hence:

$$\hat{N}_t = (1-\rho)\hat{N}_{t-1} + \rho\hat{M}_t \tag{C.74}$$

From equation (C.44) we compute: $s^W\hat{s}_t^W = -(1-\rho)N\hat{N}_{t-1}$. This implies that searchers are:

$$\hat{s}_t^W = -\frac{(1-\rho)N}{s^W}\hat{N}_{t-1} \tag{C.75}$$

The log-linearized version of equation (C.38) is: $U\hat{U}_t = -N\hat{N}_t$. Being $U = 1 - N$ we can hence write unemployment as:

$$\hat{U}_t = -\frac{N}{1-N}\hat{N}_t \tag{C.76}$$

Log-linearizing equation (C.51) we obtain:

$$\hat{Y}_t^w = \alpha\hat{h}_t + \hat{N}_t \tag{C.77}$$

The derivation of the Phillips curve is standard (e.g., Walsh 2003). Define $Q_t = \dfrac{P_t^*}{P_t}$ and rewrite equation (C.67) as:

$$E_t\sum_{l=0}^{\infty}\omega^l\beta^l\left(\frac{P_{t+l}}{P_t}\right)^{\varepsilon-1}C_{t+l}^{1-\sigma}Q_t = \frac{\varepsilon}{\varepsilon-1}E_t\sum_{l=0}^{\infty}\omega^l\beta^l mc_{t+l}\left(\frac{P_{t+l}}{P_t}\right)^{\varepsilon}C_{t+l}^{1-\sigma}$$

The linearization of the left hand side of this equation yields
$\dfrac{C^{1-\sigma}}{1-\omega\beta}\hat{Q}_t + C^{1-\sigma}\sum_{l=0}^{\infty}\omega^l\beta^l\left[(1-\sigma)E_t\hat{C}_{t+l} + (\varepsilon-1)\left(\hat{P}_{t+l} - \hat{P}_t\right)\right]$ and linearization of the right hand side gives:
$C^{1-\sigma}E_t\sum_{l=0}^{\infty}\omega^l\beta^l\left[\widehat{mc}_{t+l} + \varepsilon\left(\hat{P}_{t+l} - \hat{P}_t\right) + (1-\sigma)\hat{C}_{t+l}\right]$. Equating these two equations and simplifying we get: $\hat{Q}_t + \hat{P}_t = (1-\omega\beta)E_t\sum_{l=0}^{\infty}\omega^l\beta^l\left(\hat{P}_{t+l} + \widehat{mc}_{t+l}\right)$. By forward solution this equa-

tion can be rewritten as:

$$\hat{Q}_t = (1-\omega\beta)\,\widehat{mc}_t + \omega\beta\left(\hat{Q}_{t+1} + \hat{\pi}_{t+1}\right) \tag{C.78}$$

The Calvo's assumption that only the share $(1-\omega)$ of firms can adjust their prices at time t and the Dixit-Stiglitz price aggregator lead to the economy's average price index: $1 = (1-\omega)\left(Q_t\right)^{1-\varepsilon} + \omega\left(\frac{P_{t-1}}{P_t}\right)^{1-\varepsilon}$. Approximating this equation around the steady state with zero inflation we obtain $\hat{Q}_t = \frac{\omega}{1-\omega}\hat{\pi}_t$. Substituting this equation into (C.78) we derive the standard New Keynesian Phillips Curve:

$$\hat{\pi}_t = \beta E_t\hat{\pi}_{t+1} + \frac{(1-\omega\beta)(1-\omega)}{\omega}\widehat{mc}_t \tag{C.79}$$

where, from equation (C.68), $\widehat{mc}_t = -\widehat{\mu}_t$.

From equation (C.53) we straightforwardly derive the log-linearized aggregate resource constraint:

$$\hat{Y}_t = \hat{C}_t \tag{C.80}$$

As shown by Galí (2008) the price dispersion across firms in a neighborhood of zero inflation steady state is equal to zero up to a first order approximation ($\hat{v}_t = 0$). Then we have:

$$\hat{Y}^w_t = \hat{Y}_t \tag{C.81}$$

The log-linearization of equation (C.59) provides:

$$\begin{aligned}
&-\frac{f}{\lambda q^F p^B}\left(\hat{\lambda}_t + \hat{q}^F_t + \hat{p}^B_t\right) + k^F R^L \hat{R}^L_t = \frac{Ah^\alpha}{\mu}\left(\alpha\hat{h}_t + \hat{\mu}_t\right) - R^L wh\left(\hat{R}^L_t + \hat{w}_t + \hat{h}_t\right) + \\
&-(1-\rho)\beta\frac{f}{\lambda q^F p^B}\left(\hat{\lambda}_t + E_t\hat{q}^F_{t+1} + E_t\hat{p}^B_{t+1}\right) + (1-\rho)\beta R^L k^F\left(E_t\hat{\lambda}_{t+1} - \hat{\lambda}_t + E_t\hat{R}^L_{t+1}\right)
\end{aligned}$$

Rearranging we get the job creating condition:

$$\begin{aligned}
&\frac{Ah^\alpha}{\mu}\left(\alpha\hat{h}_t + \hat{\mu}_t\right) - R^L wh\left(\hat{R}^L_t + \hat{w}_t + \hat{h}_t\right) = k^F R^L\left[\hat{R}^L_t - (1-\rho)\beta\left(E_t\hat{\lambda}_{t+1} - \hat{\lambda}_t + E_t\hat{R}^L_{t+1}\right)\right] + \\
&-\frac{f}{\lambda q^F p^B}\left[\left(\hat{\lambda}_t + \hat{q}^F_t + \hat{p}^B_t\right) - (1-\rho)\beta\left(\hat{\lambda}_t + E_t\hat{q}^F_{t+1} + E_t\hat{p}^B_{t+1}\right)\right]
\end{aligned} \tag{C.82}$$

Linearizing equation (C.60) we have:

$$\begin{aligned}
&w\hat{w}_t = (1-d)\left(\frac{mrs}{1+\phi}\widehat{mrs}_t - \frac{w^u}{h}\hat{h}_t\right) + \frac{d}{R^L}\frac{mpl}{\alpha\mu}\left(\widehat{mpl}_t - \hat{R}^L_t - \hat{\mu}_t\right) + \\
&-\frac{d(1-\rho)\beta}{R^L h}\frac{f}{\lambda q^F p^B}\left(\hat{R}^L_t + \hat{h}_t + \hat{\lambda}_t + E_t\hat{q}^F_{t+1} + E_t\hat{p}^B_{t+1}\right) + \\
&+\frac{d(1-\rho)\beta}{h}k^F\left(E_t\hat{\lambda}_{t+1} - \hat{\lambda}_t + E_t\hat{R}^L_{t+1} - \hat{R}^L_t - \hat{h}_t\right) + \\
&+\frac{d(1-\rho)\beta}{R^L h}\frac{f}{\lambda q^F p^B}\left(E_t\hat{R}^L_{t+1} + \hat{h}_t + \hat{\lambda}_t + E_t\hat{q}^F_{t+1} + E_t\hat{p}^B_{t+1}\right) - \frac{d(1-\rho)\beta}{h}k^F\left(E_t\hat{\lambda}_{t+1} - \hat{\lambda}_t - \hat{h}_t\right) + \\
&-\frac{d(1-\rho)\beta}{R^L h}\frac{fp^F}{\lambda q^F p^B}\left(E_t\hat{R}^L_{t+1} + \hat{h}_t + \hat{\lambda}_t + E_t\hat{q}^F_{t+1} + E_t\hat{p}^B_{t+1} - E_t\hat{p}^F_{t+1}\right) +
\end{aligned}$$

$$+\frac{d(1-\rho)\beta}{h}k^F\left(E_t\hat{\lambda}_{t+1}-\hat{\lambda}_t-\hat{h}_t+E_t\hat{p}^F_{t+1}\right)$$

Rearranging we get:

$$\begin{aligned}
&w\hat{w}_t=(1-d)\left(\frac{mrs}{1+\phi}\widehat{mrs}_t-\frac{w^u}{h}\hat{h}_t\right)+\frac{d}{R^L}\frac{mpl}{\alpha\mu}\left(\widehat{mpl}_t-\hat{R}^L_t-\hat{\mu}_t\right)+\\
&+\frac{d(1-\rho)\beta}{h}\left(\frac{f}{R^L\lambda q^F p^B}+k^F\right)\left(E_t\hat{R}^L_{t+1}-\hat{R}^L_t\right)+\\
&-\frac{d(1-\rho)\beta}{R^L h}\frac{fp^F}{\lambda q^F p^B}\left(E_t\hat{R}^L_{t+1}+\hat{h}_t+\hat{\lambda}_t+E_t\hat{q}^F_{t+1}+E_t\hat{p}^B_{t+1}-E_t\hat{p}^F_{t+1}\right)+\\
&+\frac{d(1-\rho)\beta}{h}k^F p^F\left(E_t\hat{\lambda}_{t+1}-\hat{\lambda}_t-\hat{h}_t+E_t\hat{p}^F_{t+1}\right)
\end{aligned}$$

The bargained real wage is hence:

$$\begin{aligned}
\hat{w}_t\ =\ &\frac{(1-d)}{w}\left(\frac{mrs}{1+\phi}\widehat{mrs}_t-\frac{w^u}{h}\hat{h}_t\right)+\frac{d}{wR^L}\frac{mpl}{\alpha\mu}\left(\widehat{mpl}_t-\hat{R}^L_t-\hat{\mu}_t\right)+\\
&+\frac{d(1-\rho)\beta}{wh}\left\{\begin{array}{c}\left(\frac{f}{R^L\lambda q^F p^B}+k^F\right)\left(E_t\hat{R}^L_{t+1}-\hat{R}^L_t\right)+\\ -p^F\left[\begin{array}{c}\frac{f}{R^L\lambda q^F p^B}\left(E_t\hat{R}^L_{t+1}+\hat{h}_t+\hat{\lambda}_t+E_t\hat{q}^F_{t+1}+E_t\hat{p}^B_{t+1}-E_t\hat{p}^F_{t+1}\right)+\\ -k^F\left(E_t\hat{\lambda}_{t+1}-\hat{\lambda}_t-\hat{h}_t+E_t\hat{p}^F_{t+1}\right)\end{array}\right]\end{array}\right\}
\end{aligned}\tag{C.83}$$

From equation (C.55) we obtain the log-linearized version of the marginal effect of the loan interest rate on worked hours: $\epsilon^H\hat{\epsilon}^H_t=\frac{1}{\alpha-1-\phi}\frac{h}{R^L}\left(\hat{h}_t-\hat{R}^L_t\right)$. We hence have:

$$\hat{\epsilon}^H_t=\hat{h}_t-\hat{R}^L_t\tag{C.84}$$

From equations (C.43) we obtain: $L^N\hat{L}^N_t=(1-\rho)L^N\hat{L}^N_{t-1}+qH\left(\hat{q}^F_t+\hat{H}_t\right)$. Being $\rho L^N=qH$ the the log-linearized lines of credit financing wages are:

$$\hat{L}^N_t=(1-\rho)\hat{L}^N_{t-1}+\rho\left(\hat{q}^F_t+\hat{H}_t\right)\tag{C.85}$$

Linearizing equation (C.62) we have:

$$\begin{aligned}
&-\frac{b}{\lambda q^F q^B}\left(\hat{\lambda}_t+\hat{q}^F_t+\hat{q}^B_t\right)-k^F R^L\hat{R}^L_t+\frac{R^D k^F}{q^F}\left(\hat{R}^D_t-\hat{q}^F_t\right)=\\
&=R^L wh\left(\hat{R}^L_t+\hat{w}_t+\hat{h}_t\right)-R^D wh\left(\hat{R}^D_t+\hat{w}_t+\hat{h}_t\right)-(1-\rho)\beta\frac{b}{\lambda q^F q^B}\left(\hat{\lambda}_t+E_t\hat{q}^F_{t+1}+E_t\hat{q}^B_{t+1}\right)+\\
&-(1-\rho)\beta R^L k^F\left(\hat{\lambda}_{t+1}-\hat{\lambda}_t+\hat{R}^L_{t+1}\right)+(1-\rho)\beta\frac{R^D k^F}{q^F}\left(\hat{\lambda}_{t+1}-\hat{\lambda}_t+\hat{R}^D_{t+1}-\hat{q}^F_{t+1}\right)
\end{aligned}$$

Rearranging we get the log-linearized credit creating condition:

$$\begin{aligned}
&\frac{R^D k^F}{q^F}\left[\left(\hat{R}_t^D-\hat{q}_t^F\right)-(1-\rho)\beta\left(\hat{\lambda}_{t+1}-\hat{\lambda}_t+\hat{R}_{t+1}^D-\hat{q}_{t+1}^F\right)\right]=\\
&wh\left[R^L\left(\hat{R}_t^L+\hat{w}_t+\hat{h}_t\right)-R^D\left(\hat{R}_t^D+\hat{w}_t+\hat{h}_t\right)\right]+\\
&+\frac{b}{\lambda q^F q^B}\left[\left(\hat{\lambda}_t+\hat{q}_t^F+\hat{q}_t^B\right)-(1-\rho)\beta\left(\hat{\lambda}_t+E_t\hat{q}_{t+1}^F+E_t\hat{q}_{t+1}^B\right)\right]+\\
&+k^F R^L\left[\hat{R}_t^L-(1-\rho)\beta\left(\hat{\lambda}_{t+1}-\hat{\lambda}_t+\hat{R}_{t+1}^L\right)\right]
\end{aligned} \tag{C.86}$$

The log-linearization of equation (C.65) provides:

$$\begin{aligned}
&wR^L\left(\hat{w}_t+\hat{R}_t^L\right)=\frac{\psi mpl}{\alpha\mu}\left(\hat{\psi}_t+\widehat{mpl}_t-\hat{\mu}_t\right)+\\
&+\frac{\psi(1-\rho)\beta}{h}\frac{\theta^C f}{\lambda q^F q^B}\left(\hat{\psi}_t-\hat{h}_t+E_t\hat{\theta}_{t+1}^C-\hat{\lambda}_t-E_t\hat{q}_{t+1}^F-E_t\hat{q}_{t+1}^B\right)+\\
&+\frac{\psi(1-\rho)\beta}{h}R^L k^F\left(\hat{\psi}_t-\hat{h}_t+E_t\hat{\lambda}_{t+1}-\hat{\lambda}_t+E_t\hat{R}_{t+1}^L\right)+wR^D\left(\hat{w}_t+\hat{R}_t^D\right)+\\
&-\psi wR^D\left(\hat{\psi}_t+\hat{w}_t+\hat{R}_t^D\right)+\frac{(1-\rho)\beta}{h}\frac{b}{\lambda q^F q^B}\left(\hat{h}_t+\hat{\lambda}_t+E_t\hat{q}_{t+1}^F+E_t\hat{q}_{t+1}^B\right)+\\
&+\frac{\psi(1-\rho)\beta}{h}\frac{b}{\lambda q^F q^B}\left(\hat{\psi}_t-\hat{h}_t-\hat{\lambda}_t-E_t\hat{q}_{t+1}^F-E_t\hat{q}_{t+1}^B\right)+\\
&+\frac{(1-\rho)\beta}{h}R^L k^F\left(E_t\hat{\lambda}_{t+1}-\hat{\lambda}_t-\hat{h}_t+E_t\hat{R}_{t+1}^L\right)+\\
&-\frac{(1-\rho)\beta}{h}\frac{R^D k^F}{q^F}\left(E_t\hat{\lambda}_{t+1}-\hat{\lambda}_t-\hat{h}_t+E_t\hat{R}_{t+1}^D-E_t\hat{q}_{t+1}^F\right)+\\
&-\frac{\psi(1-\rho)\beta}{h}R^L k^F\left(\hat{\psi}_t+E_t\hat{\lambda}_{t+1}-\hat{\lambda}_t-\hat{h}_t+E_t\hat{R}_{t+1}^L\right)+\\
&+\frac{\psi(1-\rho)\beta}{h}\frac{R^D k^F}{q^F}\left(\hat{\psi}_t+E_t\hat{\lambda}_{t+1}-\hat{\lambda}_t-\hat{h}_t+E_t\hat{R}_{t+1}^D-E_t\hat{q}_{t+1}^F\right)
\end{aligned}$$

Rearranging we obtain the linearized loan interest rate:

$$\begin{aligned}
&\hat{R}_t^L=\frac{\psi mpl}{\alpha\mu wR^L}\left(\hat{\psi}_t+\widehat{mpl}_t-\hat{\mu}_t\right)+\\
&+\frac{\psi(1-\rho)\beta}{hwR^L}\left[\begin{array}{c}\frac{\theta^C f}{\lambda q^F q^B}\left(\hat{\psi}_t-\hat{h}_t+E_t\hat{\theta}_{t+1}^C-\hat{\lambda}_t-E_t\hat{q}_{t+1}^F-E_t\hat{q}_{t+1}^B\right)+\\+R^L k^F\left(\hat{\psi}_t-\hat{h}_t+E_t\hat{\lambda}_{t+1}-\hat{\lambda}_t+E_t\hat{R}_{t+1}^L\right)\end{array}\right]+\\
&+\frac{(1-\psi)}{wR^L}\left\{wR^D\left(\hat{w}_t+\hat{R}_t^D\right)+\frac{(1-\rho)\beta}{h}\left[\begin{array}{c}\frac{b}{\lambda q^F q^B}\left(\hat{h}_t+\hat{\lambda}_t+E_t\hat{q}_{t+1}^F+E_t\hat{q}_{t+1}^B\right)+\\+R^L k^F\left(E_t\hat{\lambda}_{t+1}-\hat{\lambda}_t-\hat{h}_t+E_t\hat{R}_{t+1}^L\right)+\\-\frac{R^D k^F}{q^F}\left(E_t\hat{\lambda}_{t+1}-\hat{\lambda}_t-\hat{h}_t+E_t\hat{R}_{t+1}^D-E_t\hat{q}_{t+1}^F\right)\end{array}\right]\right\}+\\
&-\frac{\psi}{wR^L}\left\{wR^D-\frac{(1-\rho)\beta}{h}\left[\frac{b}{\lambda q^F q^B}-\left(R^L k^F-\frac{R^D k^F}{q^F}\right)\right]\right\}\hat{\psi}_t-\hat{w}_t
\end{aligned} \tag{C.87}$$

The log-linearization of equation (C.66) gives: $\psi\hat{\psi}_t=-\frac{(1-z)^2\left(\gamma^B\right)^2}{[(1-z)\gamma^B-z\gamma^F]^2}\hat{\gamma}_t^B+\frac{(1-z)\gamma^B z\gamma^F}{[(1-z)\gamma^B-z\gamma^F]^2}\hat{\gamma}_t^F+$

$\dfrac{(1-z)\gamma^B}{[(1-z)\gamma^B - z\gamma^F]}\hat{\gamma}_t^B$. Since it is $\psi = \dfrac{(1-z)\gamma^B}{[(1-z)\gamma^B - z\gamma^F]}$ and $1-\psi = \dfrac{-z\gamma^F}{[(1-z)\gamma^B + z\gamma^F]}$, it follows that: $\hat{\psi}_t = -\psi\hat{\gamma}_t^B - (1-\psi)\,\hat{\gamma}_t^F + \hat{\gamma}_t^B$. From this equation we derive the modified relative bargaining power of the bank:

$$\hat{\psi}_t = (1-\psi)\left(\hat{\gamma}_t^B - \hat{\gamma}_t^F\right) \tag{C.88}$$

Equation (C.63) is log-linearized in the following way:

$$\gamma^B\hat{\gamma}_t^B = wh\left(\hat{w}_t + \hat{h}_t\right) + R^L\epsilon^W h\left(\hat{R}_t^L + \hat{\epsilon}_t^W + \hat{h}_t\right) - R^D\epsilon^W h\left(\hat{R}_t^D + \hat{\epsilon}_t^W + \hat{h}_t\right) +$$
$$+R^L\epsilon^H w\left(\hat{R}_t^L + \hat{\epsilon}_t^H + \hat{w}_t\right) - R^D\epsilon^H w\left(\hat{R}_t^D + \hat{\epsilon}_t^H + \hat{w}_t\right)$$

Rearranging we get:

$$\gamma^B\hat{\gamma}_t^B = wh\left(\hat{w}_t + \hat{h}_t\right) + \left(R^L\hat{R}_t^L - R^D\hat{R}_t^D\right)\left(\epsilon^W h + \epsilon^H w\right) +$$
$$+h\epsilon^W\left(R^L - R^D\right)\left(\hat{\epsilon}_t^W + \hat{h}_t\right) + w\epsilon^H\left(R^L - R^D\right)\left(\hat{\epsilon}_t^H + \hat{w}_t\right)$$

We can hence write the marginal effect of the loan interest rate on the bank's surplus as:

$$\begin{aligned}\hat{\gamma}_t^B &= \frac{wh}{\gamma^B}\left(\hat{w}_t + \hat{h}_t\right) + \frac{\left(R^L\hat{R}_t^L - R^D\hat{R}_t^D\right)}{\gamma^B}\left(\epsilon^W h + \epsilon^H w\right) + \\ &\quad + \frac{\left(R^L - R^D\right)}{\gamma^B}\left[h\epsilon^W\left(\hat{\epsilon}_t^W + \hat{h}_t\right) + w\epsilon^H\left(\hat{\epsilon}_t^H + \hat{w}_t\right)\right]\end{aligned} \tag{C.89}$$

Equation (C.64) is log-linearized in the following way:

$$\gamma^F\hat{\gamma}_t^F = \frac{mpl}{\mu}\epsilon^H\left(\widehat{mpl}_t - \hat{\mu}_t + \hat{\epsilon}_t^H\right) - wh\left(\hat{w}_t + \hat{h}_t\right) +$$
$$-R^L\epsilon^W h\left(\hat{R}_t^L + \hat{\epsilon}_t^W + \hat{h}_t\right) - R^L\epsilon^H w\left(\hat{R}_t^L + \hat{\epsilon}_t^H + \hat{w}_t\right)$$

Rearranging we obtain the marginal effect of the loan interest rate on the firm's surplus:

$$\begin{aligned}\hat{\gamma}_t^F &= \frac{mpl}{\gamma^F\mu}\epsilon^H\left(\widehat{mpl}_t - \hat{\mu}_t + \hat{\epsilon}_t^H\right) - \frac{wh}{\gamma^F}\left(\hat{w}_t + \hat{h}_t\right) + \\ &\quad - \frac{R^L}{\gamma^F}\left\{\hat{R}_t^L\left(\epsilon^W h + \epsilon^H w\right) + \left[\epsilon^W h\left(\hat{\epsilon}_t^W + \hat{h}_t\right) + \epsilon^H w\left(\hat{\epsilon}_t^H + \hat{w}_t\right)\right]\right\}\end{aligned} \tag{C.90}$$

From equation (C.61) we obtain :

$$\epsilon^W\hat{\epsilon}_t^W = -\frac{d}{(R^L)^2}\frac{mpl}{\alpha\mu}\left(\widehat{mpl}_t - \hat{\mu}_t - 2\hat{R}_t^L\right)$$
$$+\frac{d}{(R^L)^2}\frac{(1-\rho)\beta}{h}\frac{f}{\lambda q^F p^B}\left(\hat{h}_t + \hat{\lambda}_t + E_t\hat{q}_{t+1}^F + E_t\hat{p}_{t+1}^B + 2\hat{R}_t^L\right) +$$
$$-\frac{d}{R^L}\frac{(1-\rho)\beta}{h}k^F\left(E_t\hat{\lambda}_{t+1} - \hat{\lambda}_t + E_t\hat{R}_{t+1}^L - 2\hat{R}_t^L - \hat{h}_t\right)$$

Rearranging we derive the log-linearized version of the marginal effect of the loan interest rate on the real wage:

$$\hat{\epsilon}_t^W = \frac{1}{\epsilon^W}\frac{d}{(R^L)^2}\left\{ \begin{array}{c} \frac{(1-\rho)\beta}{h}\left[\begin{array}{c} \frac{f}{\lambda q^F p^B}\left(\hat{h}_t + \hat{\lambda}_t + E_t\hat{q}_{t+1}^F + E_t\hat{p}_{t+1}^B + 2\hat{R}_t^L\right) + \\ -R^L k^F\left(E_t\hat{\lambda}_{t+1} - \hat{\lambda}_t + E_t\hat{R}_{t+1}^L - 2\hat{R}_t^L - \hat{h}_t\right) \end{array} \right] + \\ -\frac{mpl}{\alpha\mu}\left(\widehat{mpl}_t - \hat{\mu}_t - 2\hat{R}_t^L\right) \end{array} \right\} \tag{C.91}$$

The condition on worked hours (C.56) yields: $h\hat{h}_t = \frac{1}{\alpha-1-\phi}\left(\vartheta\frac{\mu R^L}{\alpha A\lambda}\right)^{\frac{1}{\alpha-1-\phi}}\left(\hat{\mu}_t + \hat{R}_t^L - \hat{\lambda}_t\right)$.

Recalling that $h = \left(\vartheta\frac{\mu R^L}{\alpha A\lambda}\right)^{\frac{1}{\alpha-1-\phi}}$ we may write:

$$\hat{h}_t = \frac{1}{\alpha-1-\phi}\left(\hat{\mu}_t + \hat{R}_t^L - \hat{\lambda}_t\right) \tag{C.92}$$

From equation (C.57) we may write the marginal productivity of labor as:

$$\widehat{mpl}_t = (\alpha-1)\,\hat{h}_t \tag{C.93}$$

From equation (C.58) we get the marginal rate of substitution:

$$\widehat{mrs}_t = \phi\hat{h}_t - \hat{\lambda}_t \tag{C.94}$$

From equation (C.68) we obtain the real marginal cost:

$$\widehat{mc}_t = -\hat{\mu}_t \tag{C.95}$$

From equation (C.48) we may write the credit market tightness as:

$$\hat{\theta}_t^C = \hat{s}_t^F - \hat{V}_t^B \tag{C.96}$$

From equation (C.45), the labor market tightness is:

$$\hat{\theta}_t^L = \hat{V}_t^F - \hat{s}_t^W \tag{C.97}$$

From equation (C.50), the credit matches are:

$$\hat{H}_t = \zeta\hat{V}_t^B + (1-\zeta)\,\hat{s}_t^F \tag{C.98}$$

From equation (C.49), the labor market matches are:

$$\hat{M}_t = \xi\hat{V}_t^F + (1-\xi)\,\hat{s}_t^W \tag{C.99}$$

From equation (C.69) we may write the monetary rule as:

$$\hat{R}_t^D = \rho_R\hat{R}_{t-1}^D + (1-\rho_R)\left(\delta_\pi\hat{\pi}_t + \delta_Y\hat{Y}_t\right) + \log\nu_t \tag{C.100}$$

The log-linearization of equation (C.46) straightforwardly gives the job vacancy filling rate:

$$\hat{q}_t^F = \hat{M}_t - \hat{V}_t^F \tag{C.101}$$

The log-linearization of equation (C.47) straightforwardly gives the job finding rate:

$$\hat{p}_t^F = \hat{M}_t - \hat{s}_t^W \tag{C.102}$$

The log-linearization of equation (C.41) straightforwardly gives the credit line finding rate:

$$\hat{p}_t^B = \hat{H}_t - \hat{s}_t^F \tag{C.103}$$

The log-linearization of equation (C.42) straightforwardly gives the credit vacancy filling rate:

$$\hat{q}_t^B = \hat{H}_t - \hat{V}_t^B \tag{C.104}$$

From equation (C.70) the monetary policy shock is:

$$\log \nu_t = \rho_\nu \log \nu_{t-1} + \varepsilon_t^\nu \tag{C.105}$$