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The effects of monetary policy shocks in credit and labor markets with search and matching frictions*

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Abstract

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 bank 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.

J.E.L. Classification: E43, E13, E24, E44.

Keywords: Interest rate pass-through; search and matching; credit market frictions.

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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) 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, 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 empirical investigations based on not-fully microfounded models tend to 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 our paper is twofold. First, we aim to provide a novel explanation of the incomplete loan rate pass-through in a cash in advance New Keynesian DSGE economy with sticky prices and search and matching frictions in both the labor and the credit market. To this first aim, we model the economy so as to rule out by hypothesis the main explanations of this phenomenon which have been provided so far. 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 & 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 & Berger, 1991). Our second aim is to understand whether an incomplete interest rate pass-through has indeed limited effects on the transmission of monetary policy shocks in a fully microfounded DSGE model economy characterized by labor and credit market imperfections.

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

¹See, e.g., Toolsema, Sturm and De Haan (2001); De Bondt (2002); Angeloni and Ehrmann, (2003); Atesoglu (2003); Sander & Kleimeier (2004); Chionis and Leon (2006); Hofmann (2006); Égert, Crespo-Cuaresma and Reininger (2007); Fourcans and Vranceanu (2007).

²See, e.g., Mojon (2000); Angeloni, Kashyap and Mojon (2003); Gambacorta (2004); 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).

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 cash-in-advance 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 and matching on capital markets is characterized by a function having as arguments the amount of households' deposit and the amount of corporate bonds offered by firms. 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 DSGE modelling attempts.

Our main results can be summarized as follows. First, 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 values of the (utility) 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. Second, the transmission of monetary policy shocks to output and inflation is more relevant than suggested by the recent literature, involving significant reactions in many labor and credit market variables, the magnitudes of which depend on several parameters' values. 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 paper is structured as follows. In the next section we describe the model economy. In section 3 we discuss our calibration strategy. In section 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 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 6 concludes.

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 (V_t^B) 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 thus equal to the total number of job vacancies posted by firms (V_t^F). 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.

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 $H_t = v(V_t^B)^\zeta (s_t^F)^{1-\zeta}$, where η and v 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, 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 $V_t^F = s_t^F p_t^B$.

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 in Dixit and Stiglitz (1977) it is $C_{it} = (\frac{P_{it}}{P_t})^{-\varepsilon} C_t$, where $\varepsilon > 1$ 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, $P_t = \left[\int_0^1 P_{it}^{1-\varepsilon} di \right]^{\frac{1}{1-\varepsilon}}$. 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.

The purchase of consumption goods from retail firms is subject to 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"), $W_t h_t N_t$ is the wage income from employment, $(1 - N_t) w^u P_t$ are nominal benefits from unemployment and D_t are nominal deposits with banks.³ At the end of the period households receive profit income from retail firms and from banks net of lump-sum government taxes used to pay benefits to unemployed workers, 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: $B_{t+1} = B_t + W_t h_t N_t + (1 - N_t) w^u P_t - D_t - P_t C_t + \Pi_t^F + \Pi_t^B + R_t^D D_t$. Substituting the CIA constraint into this equation, calculating it a period backward and substituting the result back into the CIA constraint expressed in real terms, we obtain that for the representative household it must be:⁴

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

This equation states that consumption and savings are financed by real labor income, unemployment benefits, the sum generated by previous period deposits and profits from banks and retailers.

³The 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).

⁴The detailed derivation of the model is provided in a technical appendix available from the authors upon request.

The representative household solves the problem:

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

where 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:

$$\lambda_t = R_t^D \beta E_t \frac{P_t}{P_{t+1}} \lambda_{t+1} \quad (2)$$

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

$$N_t = (1 - \rho) N_{t-1} + p_t^F s_t^W \quad (3)$$

where $s_t^W = 1 - (1 - \rho) N_{t-1}$. The exogenous separation rates relative to the firm-worker⁵ 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) 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.⁶ Unemployment is determined *ex post* as: $U_t = 1 - N_t$.

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:

$$Y_t = A h_t^\alpha N_t \quad (4)$$

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. It follows that the aggregate resource constraint is $Y_t = C_t$.

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; Blanchard and Gali, 2010):

$$V_t^F = p_t^B s_t^F \quad (5)$$

⁵Hall (2005) documented that the separation rate does not vary considerably along the business cycle, but this is not uncontroversial (see, e.g., Davis, Haltiwanger e Schush, 1996).

⁶The new matches are calculated in the same period t because we assume that the fraction of households who are searching jobs is formed at the beginning of each period.

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

$$N_t = (1 - \rho)N_{t-1} + q_t^F V_t^F \quad (6)$$

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:

$$F_t = -f_t s_t^F + \frac{Y_t}{\mu_t} - R_t^L w_t h_t N_t - R_t^L k^F q_t^F V_t^F + \beta E_t \frac{\lambda_{t+1}}{\lambda_t} F_{t+1} \quad (7)$$

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 $P_t^W Y_t / P_t = Y_t / \mu_t$, 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 maximizes (7) subject to (4), (5) and (6). It chooses V_t^F by setting s_t^F and its decision on the credit lines for job vacancies to demand yields:

$$\frac{f_t}{q_t^F p_t^B} + R_t^L k^F = \frac{A h_t^\alpha}{\mu_t} - R_t^L w_t h_t + \beta E_t \frac{\lambda_{t+1}}{\lambda_t} \frac{\partial F_{t+1}}{\partial N_t} \quad (8)$$

By using the envelope theorem we obtain:

$$\frac{\partial F_t}{\partial N_{t-1}} = (1 - \rho) \left(\frac{A h_t^\alpha}{\mu_t} - R_t^L w_t h_t \right) + (1 - \rho) \beta E_t \frac{\lambda_{t+1}}{\lambda_t} \frac{\partial F_{t+1}}{\partial N_t} \quad (9)$$

Combining equations (8) and (9) we get the firm's job creating condition:

$$\frac{f_t}{q_t^F p_t^B} + R_t^L k^F = \frac{A h_t^\alpha}{\mu_t} - R_t^L w_t h_t + (1 - \rho) \beta E_t \frac{\lambda_{t+1}}{\lambda_t} \left(\frac{f_{t+1}}{q_{t+1}^F p_{t+1}^B} + R_{t+1}^L k^F \right) \quad (10)$$

Equation (10) 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 $f_t / (q_t^F p_t^B)$ 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.

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 and S_t^W is the worker's surplus.

S_t^F is equal to the difference between the firms' value if a match is obtained, $S_t^J = \frac{\partial F_t}{\partial N_t}$, and the value if a match is not obtained, $S_t^V = 0$ for the free entry condition. Equation (10) then allows

us to write:⁷

$$S_t^F = \frac{f_t}{q_t^F p_t^B} + R_t^L k^F \quad (11)$$

The worker surplus, S_t^W , is equal to the value the worker enjoys when being matched, S_t^M , relative to not being matched, S_t^N . 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:

$$S_t^M = w_t h_t - \frac{g(h_t)}{\lambda_t} + \beta E_t \frac{\lambda_{t+1}}{\lambda_t} \{ (1-\rho) S_{t+1}^M + [1 - (1-\rho)] [p_{t+1}^F S_{t+1}^M + (1-p_{t+1}^F) S_{t+1}^N] \} \quad (12)$$

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:

$$S_t^N = w^u + \beta E_t \frac{\lambda_{t+1}}{\lambda_t} [p_{t+1}^F S_{t+1}^M + (1-p_{t+1}^F) S_{t+1}^N] \quad (13)$$

Using (12) and (13) the worker surplus is:

$$S_t^W = \left(w_t h_t - \frac{g(h_t)}{\lambda_t} - w^u \right) + (1-\rho) \beta E_t \frac{\lambda_{t+1}}{\lambda_t} (1-p_{t+1}^F) S_{t+1}^W \quad (14)$$

The optimality condition is:

$$(1-d) \delta_t^F S_t^W + d \delta_t^W S_t^F = 0 \quad (15)$$

where $\delta_t^F = \frac{\partial S_t^F}{\partial w_t} = -R_t^L h_t$ and $\delta_t^W = \frac{\partial S_t^W}{\partial w_t} = h_t$.

By substituting (11) and (14) into (15), and using (10), we get the following wage equation:

$$\begin{aligned} w_t = & (1-\chi_t) \left(\frac{mrs_t}{1+\phi} + \frac{w^u}{h_t} \right) + \\ & + \chi_t \left[\frac{mpl_t}{\alpha \mu_t} - R_t^W + \frac{(1-\rho)\beta}{h_t} E_t \frac{\lambda_{t+1}}{\lambda_t} \left(\frac{f_{t+1} \theta_{t+1}^L}{p_{t+1}^B} + R_{t+1}^L k^F p_{t+1}^F \right) \right] + \\ & + \chi_t (1-p_{t+1}^F) \left[\frac{(1-\rho)\beta}{h_t} E_t \frac{\lambda_{t+1}}{\lambda_t} \left(\frac{f_{t+1}}{q_{t+1}^F p_{t+1}^B} + R_{t+1}^L k^F \right) \right] \left[1 - \frac{\chi_{t+1}(1-\chi_t)}{(1-\chi_{t+1})\chi_t} \right] \end{aligned} \quad (16)$$

where $\chi_t = \frac{d}{R_t^L(1-d) + d}$, $mrs_t = \vartheta \frac{h_t^\phi}{\lambda_t}$ is the worker's marginal rate of substitution, $mpl_t = \frac{\partial A h_t^\alpha}{\partial h_t} = A \alpha h_t^{\alpha-1}$ is the marginal product of labor (hours) per worker and $R_t^W = r_t^L w_t$ is the interest paid by the firm on the real wage borrowed from a bank. 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).

When linearizing the model, it is however useful to employ a different formulation of the bar-

⁷Recall that the defaulting firm leaves the market at no cost.

gained wage which depicts it as 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 future expected net present value from employment:

$$w_t = (1-d) \left(\frac{mrs_t}{1+\phi} + \frac{w^u}{h_t} \right) + \frac{d}{R_t^L} \left[\frac{mpl_t}{\alpha\mu_t} + \frac{(1-\rho)\beta}{h_t} E_t \frac{\lambda_{t+1}}{\lambda_t} \left(\frac{f_{t+1}}{q_{t+1}^F p_{t+1}^B} + R_{t+1}^L k^F \right) \left(1 - \frac{R_t^L (1-p_{t+1}^F)}{R_{t+1}^L} \right) \right] \quad (17)$$

The efficient bargaining determines also the number of hours. The optimality condition is:

$$(1-d)\tau_t^F S_t^W + d\tau_t^W S_t^F = 0 \quad (18)$$

Being $\tau_t^F = \partial S_t^F / \partial h_t = (mpl_t / \mu_t - w_t R_t^L)$ and $\tau_t^W = \partial S_t^W / \partial h_t = (w_t - mrs_t)$, and knowing from equation (15) that $S_t^W = d [(1-d)R_t^L]^{-1} S_t^F$, optimal hours are obtained from the condition $mpl_t / (\mu_t R_t^L) = mrs_t$, that is:

$$h_t = \left(\frac{\vartheta \mu_t R_t^L}{\alpha A \lambda_t} \right)^{\frac{1}{\alpha-1-\phi}} \quad (19)$$

2.5 Retail firms

Retail firms purchase the goods produced by the wholesale sector and transform them 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 . Assuming that in this sector prices are adjusted according to the Calvo (1983) rule, 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 the demand and this provides the standard New Keynesian price equation:

$$\frac{P_t^*}{P_t} = \frac{\varepsilon}{\varepsilon - 1} \frac{E_t \sum_{l=0}^{\infty} \omega^l \beta^l MC_{t+l} \left(\frac{P_{t+l}}{P_t} \right)^\varepsilon C_{t+l}^{1-\sigma}}{E_t \sum_{l=0}^{\infty} \omega^l \beta^l \left(\frac{P_{t+l}}{P_t} \right)^{\varepsilon-1} C_{t+l}^{1-\sigma}} \quad (20)$$

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:

$$H_t = q_t^B V_t^B \quad (21)$$

$$L_t^N = (1 - \rho)L_{t-1}^N + q_t^F H_t \quad (22)$$

Recalling that the funded credit lines for labour vacancy posting that are not transformed into labor matches are destroyed and are not repaid by firms (the bank loses the anticipated funds and the interest on this amount), the value of the representative bank, J_t , can be written as:⁸

$$J_t = (R_t^L - R_t^D)w_t h_t L_t^N + (R_t^L q_t^F - R_t^D)k^F H_t - b_t V_t^B + \beta E_t \frac{\lambda_{t+1}}{\lambda_t} J_{t+1} \quad (23)$$

At any time, the bank chooses H_t by setting V_t^B in order to maximize (23) subject to (21) and (22). Its decision yields:

$$\frac{b_t}{q_t^F q_t^B} - (R_t^L q_t^F - R_t^D) \frac{k^F}{q_t^F} - (R_t^L - R_t^D)w_t h_t = \beta E_t \frac{\lambda_{t+1}}{\lambda_t} \frac{\partial J_{t+1}}{\partial L_t^N} \quad (24)$$

By using the envelope theorem we get:

$$\frac{\partial J_t}{\partial L_{t-1}^N} = (1 - \rho)(R_t^L - R_t^D)w_t h_t + \beta(1 - \rho)E_t \frac{\lambda_{t+1}}{\lambda_t} \frac{\partial J_{t+1}}{\partial L_t^N} \quad (25)$$

Equations (24) and (25) yield the “credit creating condition”:

$$\begin{aligned} \frac{b_t}{q_t^F q_t^B} - (R_t^L q_t^F - R_t^D) \frac{k^F}{q_t^F} &= (R_t^L - R_t^D)w_t h_t + \\ &+ (1 - \rho)\beta E_t \frac{\lambda_{t+1}}{\lambda_t} \left[\frac{b_{t+1}}{q_{t+1}^F q_{t+1}^B} - \left(R_{t+1}^L - \frac{R_{t+1}^D}{q_{t+1}^F} \right) k^F \right] \end{aligned} \quad (26)$$

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.

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

⁸The 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, $R_t^L (w_t h_t L_t^N)$; (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, $R_t^L (q_t^F k^F L_t^N)$. Costs are equal to the sum of: (a) the repayment of deposits plus interest, $R_t^D D_t$; (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 deposits finance the loans provided to firms, $D_t = w_t h_t L_t^N + q_t^F L_t^N k^F$, equation (23) is straightforwardly obtained.

$S_t^{VB} = 0$ for the free entry condition. We hence obtain:

$$S_t^B = (R_t^L - R_t^D)w_t h_t + (1 - \rho)\beta E_t \frac{\lambda_{t+1}}{\lambda_t} \left[\frac{b_{t+1}}{q_{t+1}^F q_{t+1}^B} - (R_{t+1}^L q_{t+1}^F - R_{t+1}^D) \frac{k^F}{q_{t+1}^F} \right] \quad (27)$$

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:

$$(1 - z)\gamma_t^B S_t^F + z\gamma_t^F S_t^B = 0 \quad (28)$$

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 $\gamma_t^F = \partial S_t^F / \partial R_t^L$. Substituting (11) and (27) into (28) we get:⁹

$$R_t^L = \frac{\psi_t}{w_t} \left[\frac{mpl_t}{\alpha \mu_t} + \frac{(1 - \rho)\beta}{h_t} E_t \frac{\lambda_{t+1}}{\lambda_t} \left(\frac{f_{t+1}}{q_{t+1}^F p_{t+1}^B} + R_{t+1}^L k^F \right) \right] + \quad (29)$$

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

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

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

Equation (29) allows us to write the interest rate spread in terms of the market tightnesses:

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

$$- \frac{(1 - \psi_t)}{w_t} \left\{ \frac{(1 - \rho)\beta}{h_t} E_t \frac{\lambda_{t+1}}{\lambda_t} \left[\frac{b_{t+1}}{\eta v \frac{(\theta_{t+1}^C)^{1-\zeta}}{(\theta_{t+1}^L)^{1-\xi}}} - \left(R_{t+1}^L - \frac{R_{t+1}^D}{\eta \left(\frac{1}{\theta_{t+1}^L} \right)^{1-\xi}} \right) k^F \right] \right\} \quad (30)$$

This equation clarifies that if search costs are absent ($k^F = b = 0$) 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, where the banking system can be conceived as a “veil”.¹⁰ The interest rate pass-through, defined as the percentage deviation of the loan rate of interest from

⁹It is straightforward to compute:

$$\gamma_t^B = w_t h_t + (R_t^L - R_t^D) (\epsilon_t^W h_t + \epsilon_t^H w_t)$$

$$\gamma_t^F = \frac{mpl_t}{\mu_t} \epsilon_t^H - w_t h_t - R_t^L (\epsilon_t^W h_t + \epsilon_t^H w_t)$$

$$\epsilon_t^W = \frac{\partial w_t}{\partial R_t^L} = -\frac{d}{(R_t^L)^2} \left[\frac{mpl_t}{\alpha \mu_t} + (1 - \rho)\beta \frac{1}{h_t} E_t \frac{\lambda_{t+1}}{\lambda_t} \left(\frac{f_{t+1}}{q_{t+1}^F p_{t+1}^B} + R_{t+1}^L k^F \right) \right]$$

$$\epsilon_t^H = \frac{\partial h_t}{\partial R_t^L} = \frac{1}{\alpha - 1 - \phi} \frac{h_t}{R_t^L}$$

¹⁰This 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.

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 to the bank, the intermediary can obtain a rate of interest on loans greater than that on deposits according to its bargain 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 (30) 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 the labour market tightness via their effects on the firm's surplus that the bank aims to capture (which increases with the credit market tightness and the labor market tightness), 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).

2.8 Monetary authorities

We assume for simplicity that the policy rate is equal to the rate on deposits and that a central bank employs the following monetary rule:

$$R_t^D = (R_{t-1}^D)^{\rho_R} \left(\frac{P_t}{P_{t-1}} \right)^{(1-\rho_R)\delta_\pi} (Y_t)^{(1-\rho_R)\delta_Y} \nu_t \quad (31)$$

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 Benchmark parametrization

In order to focus on the interest rate pass-through, in this paper 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 (see Appendix) and assign to some model's parameters the most recent values employed in the literature. The other coefficients are obtained from steady state conditions. 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, (2009). 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, 2009).

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 .¹¹

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

4.1 The dynamic behavior of the benchmark model

Figure 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 1. Impulse responses to a monetary policy shock

¹¹The new values which we obtain for the steady state variables are specified below, case by case.

Figure 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 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 2. With our benchmark parametrization, banks'

supply of lines of credit increases.¹² 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 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 29) 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 2, where the interest rate on loans falls less than the deposit rate, with a response to the shock depicting an humped-shaped pattern.

4.2 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 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.¹³ 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

¹²The 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.

¹³Remember that the production function exhibits constant (decreasing) returns to scale with respect to the extensive (intensive) margin.

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-through. 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 table.

Table 1. - Impact responses of output and inflation to a monetary policy shock
(percentage deviations from steady states)

	Benchmark	Complete pass-through
Output	1.738	1.853
Inflation	0.695	0.643

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

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).

5.1 Bargaining powers

The dotted lines in Figures 3 and 4 depict the dynamic behavior of the model when $d = 0.05$ (the median value proposed by Cooley and Quadrini, 1999).¹⁴ 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, $mpl_t / (\mu_t R_t^L) = mrs_t$, 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.

¹⁴Under 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. Impulse responses to a monetary policy shock: lower d and higher z

Figure 4. Impulse responses to a monetary policy shock: lower d and higher z

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 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-through becomes less incomplete. The opposite chain of effects is produced by an increase in d .

The dashed lines in Figures 3 and 4 show the behavior of the model when $z = 0.95$.¹⁵ The lower bargaining power of the bank allows the interest rate on loans to decrease more than in the benchmark case even though the credit market tightness rises more. To understand this, consider that the lower 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 (29), 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 rate bargaining.

5.2 Posting costs

In Figure 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 ($k^F = 0.0001$).¹⁶ 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

¹⁵Under 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 $w = 0.94$.

¹⁶Under 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 $w = 0.93$.

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 costs¹⁷ 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.

Figure 5. Impulse responses to a monetary policy shock: lower k^F

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

¹⁷In the benchmark model these costs positively react to a monetary easing due to the decrease in the job vacancy filling rate.

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.

6 Conclusions

In this paper 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 impor-

tant 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.

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7 Appendix

7.1 Steady state analysis

The steady state of the model is recursively derived from the equations describing the non linear model. We indicate the steady state of the variables by omitting the time index.

Given the calibrated value for R^D , from equation (2) we obtain the value of the discount factor $\beta = 1/R^D$. Given the calibrated values for N and q^F , from employment dynamics (equation 6) we get the steady state value of the job vacancies posted by firms: $V^F = \rho N/q^F$. From the (equation 6), given p^B and by using the definition of job vacancies ($V^F = p^B s^F$) we also get: $\rho N = q^F p^B s^F$. By using it in the lines of credit financing wages ($\rho L^N = q^F p^B s^F$), it follows that: $N = L^N$.

Given L^N and q^B , from equation (22) we obtain the steady state value of the credit vacancies posted by banks: $V^B = (\rho L^N) / (q^F q^B)$. Workers searching for jobs in steady state are given by $s^W = 1 - (1 - \rho) N$ and unemployment by $U = 1 - N$. From the definition of the labor market tightness, we get: $\theta^L = V^F/s^W$. Given q^F , the job finding rate can be written as: $p^F = \theta^L q^F$. Given p^B , q^B and V^B we obtain $H = q^B V^B$ and $s^F = H/p^B$. From the definition of the credit market tightness we get $\theta^C = s^F/V^B$.

By equating $M = V^F q^F$ and $M = \eta (V^F)^\xi (s^W)^{1-\xi}$ we obtain the constant in the labor matches equation: $\eta = q^F (s^W/V^F)^{\xi-1} = q^F (\theta^L)^{1-\xi}$. A similar computation is used to obtain the constant of the credit matches equation. Given $H = V^B q^B$, from $H = v (V^B)^\zeta (s^F)^{1-\zeta}$ it follows that: $v = q^B (s^F/V^B)^{\zeta-1} = (\theta^C)^{\zeta-1} q^B$.

Being N and h calibrated, and normalizing $Y = 1$, from the aggregate production function and the aggregate resource constraint we get $A = Y/Nh^\alpha$ and $Y = C$. It follows that the Lagrangian multiplier is given by $\lambda = C^{-\sigma}$.

Given the calibrated value for R^L , from the equation describing the marginal effect of the loan rate on hours we obtain: $\epsilon^H = (\alpha - 1 - \phi)^{-1} (h/R^L)$. From the condition for optimal hours (equation 19) we get: $\vartheta = (R^L \mu)^{-1} \alpha A \lambda (h)^{\alpha-1-\phi}$. The marginal product of labor and the marginal rate of substitution are: $mpl = \alpha A h^{\alpha-1}$ and $mrs = \vartheta h^\phi / \lambda$.

We calibrate the replacement rate ϖ and write the steady state relationship $w^u = \varpi w h$ (to be determined below).

From (10) evaluated at the steady state we obtain:

$$\frac{f}{\lambda} = \frac{q^F p^B}{[1 - \beta(1 - \rho)]} \left[\frac{A h^\alpha}{\mu} - R^L \{ [1 - \beta(1 - \rho)] k^F + w h \} \right]$$

The steady state real wage (equation 17) is:

$$w = (1 - d) \left(\frac{mrs}{1 + \phi} + \frac{w^u}{h} \right) + \frac{d}{R^L} \left[\frac{mpl}{\alpha \mu} + \frac{(1 - \rho) \beta \lambda}{h} \left(\frac{f}{\lambda q^F p^B} + R^L k^F \right) \left(1 - \frac{R^L (1 - p^F)}{R^L} \right) \right]$$

By inserting the steady state utility cost (f/λ) into the previous equation, using the definition of the reservation wage, $w^u = \varpi w h$, and solving with respect to the real wage, we obtain after some algebra:

$$w = \frac{[1 - \beta(1 - \rho)]}{[1 - \beta(1 - \rho)] [1 - (1 - d)\varpi] + (1 - \rho) \beta d p^F} \left\{ (1 - d) \frac{mrs}{1 + \phi} + \frac{d}{R^L} \left[\frac{mpl}{\alpha \mu} + \frac{(1 - \rho) \beta p^F}{h [1 - \beta(1 - \rho)]} \frac{A h^\alpha}{\mu} \right] \right\}$$

This equation allows us to compute $w^u = \varpi wh$.

Solving the credit condition (equation 26) for b/λ , we get:

$$\frac{b}{\lambda} = \frac{q^B q^F (R^L - R^D)}{[1 - \beta(1 - \rho)]} wh + q^B (R^L q^F - R^D) k^F$$

From the equation describing the marginal effect of the loan rate on the bargained wage we have:

$$\epsilon^W = -\frac{d}{(R^L)^2} \left[\frac{mpl}{\alpha\mu} + (1 - \rho)\beta \frac{1}{h} \left(\frac{f}{\lambda q^F p^B} + R^L k^F \right) \right]$$

The values of γ^B and γ^F are then determined by:

$$\begin{aligned} \gamma^B &= wh + (R^L - R^D) (\epsilon^W h + \epsilon^H w) \\ \gamma^F &= \frac{mpl}{\mu} \epsilon^H - wh - R^L (\epsilon^W h + \epsilon^H w) \end{aligned}$$

From the bargained interest rate (29) evaluated at the steady state, after tedious algebra we obtain the relative bargaining power in the loan interest rate bargaining: $\psi = \frac{(R^L - T)}{(X - T)}$, where

$$\begin{aligned} X &= \frac{1}{w} \left[\frac{mpl}{\alpha\mu} + \frac{(1 - \rho)\beta}{h} \left(\frac{f}{\lambda q^F p^B} + R^L k^F \right) \right] \\ T &= \frac{1}{w} \left\{ w R^D - \frac{(1 - \rho)\beta}{h} \left[\frac{b}{\lambda q^F q^B} - \frac{(R^L q^F - R^D) k^F}{q^F} \right] \right\} \end{aligned}$$

Since ψ is also defined as $\psi = \frac{[(1 - z)\gamma^B]}{[(1 - z)\gamma^B - z\gamma^F]}$, by solving this equation with respect to z we obtain the firm's bargaining power in the loan interest rate bargaining: $z = \frac{\gamma^B(\psi - 1)}{[\gamma^B(\psi - 1) + \psi\gamma^F]}$.

7.2 The linear model

The complete linear model is obtained by log-linearizing the model equations around the steady state (the hat denotes the percent deviation of a variable from its steady state value).

Consumption Euler equation:

$$\hat{\lambda}_t = \hat{R}_t^D - E_t \hat{\pi}_{t+1} + E_t \hat{\lambda}_{t+1} \quad (32)$$

Marginal utility of consumption:

$$\hat{\lambda}_t = -\sigma \hat{C}_t \quad (33)$$

Job vacancies:

$$\hat{V}_t^F = \hat{p}_t^B + \hat{s}_t^F \quad (34)$$

Employment:

$$\hat{N}_t = (1 - \rho)\hat{N}_{t-1} + \rho\hat{M}_t \quad (35)$$

Searchers:

$$\hat{s}_t^W = -\frac{(1 - \rho)N}{s^W} \hat{N}_{t-1} \quad (36)$$

Unemployment:

$$\hat{U}_t = -\frac{N}{1 - N} \hat{N}_t \quad (37)$$

Production function:

$$\hat{Y}_t = \alpha \hat{h}_t + \hat{N}_t \quad (38)$$

Job creating condition:

$$\begin{aligned} & \frac{Ah^\alpha}{\mu} \left(\alpha \hat{h}_t + \hat{\mu}_t \right) - R^L w h \left(\hat{R}_t^L + \hat{w}_t + \hat{h}_t \right) = \\ & k^F R^L \left[\hat{R}_t^L - (1 - \rho) \beta \left(E_t \hat{\lambda}_{t+1} - \hat{\lambda}_t + E_t \hat{R}_{t+1}^L \right) \right] + \\ & - \frac{f}{\lambda q^F p^B} \left[\left(\hat{\lambda}_t + \hat{q}_t^F + \hat{p}_t^B \right) - (1 - \rho) \beta \left(\hat{\lambda}_t + E_t \hat{q}_{t+1}^F + E_t \hat{p}_{t+1}^B \right) \right] \end{aligned} \quad (39)$$

Bargained real wage:

$$\begin{aligned} \hat{w}_t = & \frac{(1-d)}{w} \left(\frac{mrs}{1+\phi} \widehat{mrs}_t - \frac{w^u}{h} \hat{h}_t \right) + \frac{d}{w R^L} \frac{mpl}{\alpha \mu} \left(\widehat{mpl}_t - \hat{R}_t^L - \hat{\mu}_t \right) + \\ & + \frac{d(1-\rho)\beta}{wh} \left\{ \begin{aligned} & \left[\frac{f}{R^L \lambda q^F p^B} + k^F \right] \left(E_t \hat{R}_{t+1}^L - \hat{R}_t^L \right) + \\ & - p^F \left[\frac{f}{R^L \lambda q^F p^B} \left(E_t \hat{R}_{t+1}^L + \hat{h}_t + \hat{\lambda}_t + E_t \hat{q}_{t+1}^F + E_t \hat{p}_{t+1}^B - E_t \hat{p}_{t+1}^F \right) + \right. \\ & \quad \left. - k^F \left(E_t \hat{\lambda}_{t+1} - \hat{\lambda}_t - \hat{h}_t + E_t \hat{p}_{t+1}^F \right) \right] \end{aligned} \right\} \end{aligned} \quad (40)$$

Marginal productivity of labor:

$$\widehat{mpl}_t = (\alpha - 1) \hat{h}_t \quad (41)$$

Marginal rate of substitution:

$$\widehat{mrs}_t = \phi \hat{h}_t - \hat{\lambda}_t \quad (42)$$

Real marginal costs:

$$\widehat{MC}_t = -\hat{\mu}_t \quad (43)$$

New Keynesian Phillips Curve:

$$\hat{\pi}_t = \beta E_t \hat{\pi}_{t+1} + \frac{(1 - \beta \omega)(1 - \omega)}{\omega} \widehat{MC}_t \quad (44)$$

Lines of credit financing wages:

$$\hat{L}_t^N = (1 - \rho) \hat{L}_{t-1}^N + \rho \left(\hat{q}_t^F + \hat{H}_t \right) \quad (45)$$

Credit creating condition:

$$\begin{aligned} & \frac{R^D k^F}{q^F} \left[\left(\hat{R}_t^D - \hat{q}_t^F \right) - (1 - \rho) \beta \left(\hat{\lambda}_{t+1} - \hat{\lambda}_t + \hat{R}_{t+1}^D - \hat{q}_{t+1}^F \right) \right] = \\ = & wh \left[R^L \left(\hat{R}_t^L + \hat{w}_t + \hat{h}_t \right) - R^D \left(\hat{R}_t^D + \hat{w}_t + \hat{h}_t \right) \right] + \\ & + \frac{b}{\lambda q^F q^B} \left[\left(\hat{\lambda}_t + \hat{q}_t^F + \hat{q}_t^B \right) - (1 - \rho) \beta \left(\hat{\lambda}_t + E_t \hat{q}_{t+1}^F + E_t \hat{q}_{t+1}^B \right) \right] + \\ & + k^F R^L \left[\hat{R}_t^L - (1 - \rho) \beta \left(\hat{\lambda}_{t+1} - \hat{\lambda}_t + \hat{R}_{t+1}^L \right) \right] \end{aligned} \quad (46)$$

Bargained loan interest rate:

$$\begin{aligned}
\hat{R}_t^L = & \frac{\psi mpl}{\alpha \mu w R^L} \left(\hat{\psi}_t + \widehat{mpl}_t - \hat{\mu}_t \right) + \frac{(1 - \psi) w R^D \left(\hat{w}_t + \hat{R}_t^D \right)}{w R^L} + \\
& + \frac{\psi(1 - \rho)\beta}{hw R^L} \left[\frac{\theta^C f}{\lambda q^F q^B} \left(\hat{\psi}_t - \hat{h}_t + E_t \hat{\theta}_{t+1}^C - \hat{\lambda}_t - E_t \hat{q}_{t+1}^F - E_t \hat{q}_{t+1}^B \right) + \right. \\
& \quad \left. + R^L k^F \left(\hat{\psi}_t - \hat{h}_t + E_t \hat{\lambda}_{t+1} - \hat{\lambda}_t + E_t \hat{R}_{t+1}^L \right) \right] + \\
& + \frac{(1 - \psi)(1 - \rho)\beta}{w R^L h} \left[\frac{b}{\lambda q^F q^B} \left(\hat{h}_t + \hat{\lambda}_t + E_t \hat{q}_{t+1}^F + E_t \hat{q}_{t+1}^B \right) + \right. \\
& \quad + R^L k^F \left(E_t \hat{\lambda}_{t+1} - \hat{\lambda}_t - \hat{h}_t + E_t \hat{R}_{t+1}^L \right) + \\
& \quad \left. - \frac{R^D k^F}{q^F} \left(E_t \hat{\lambda}_{t+1} - \hat{\lambda}_t - \hat{h}_t + E_t \hat{R}_{t+1}^D - E_t \hat{q}_{t+1}^F \right) \right] + \\
& - \frac{\psi}{w R^L} \left\{ w R^D - \frac{(1 - \rho)\beta}{h} \left[\frac{b}{\lambda q^F q^B} - \left(R^L k^F - \frac{R^D k^F}{q^F} \right) \right] \right\} \hat{\psi}_t - \hat{w}_t
\end{aligned} \tag{47}$$

Modified relative bargaining power of banks:

$$\hat{\psi}_t = (1 - \psi) (\hat{\gamma}_t^B - \hat{\gamma}_t^F) \tag{48}$$

Marginal effect of the loan interest rate on the banks' surplus:

$$\begin{aligned}
\hat{\gamma}_t^B = & \frac{wh}{\gamma^B} \left(\hat{w}_t + \hat{h}_t \right) + \frac{\left(R^L \hat{R}_t^L - R^D \hat{R}_t^D \right)}{\gamma^B} \left(\epsilon^W h + \epsilon^H w \right) + \\
& + \frac{\left(R^L - R^D \right)}{\gamma^B} \left[h \epsilon^W \left(\hat{\epsilon}_t^W + \hat{h}_t \right) + w \epsilon^H \left(\hat{\epsilon}_t^H + \hat{w}_t \right) \right]
\end{aligned} \tag{49}$$

Marginal effect of the loan interest rate on the firms' surplus:

$$\begin{aligned}
\hat{\gamma}_t^F = & \frac{mpl}{\gamma^F \mu} \epsilon^H \left(\widehat{mpl}_t - \hat{\mu}_t + \hat{\epsilon}_t^H \right) - \frac{wh}{\gamma^F} \left(\hat{w}_t + \hat{h}_t \right) + \\
& - \frac{R^L}{\gamma^F} \left[\hat{R}_t^L \left(\epsilon^W h + \epsilon^H w \right) + \epsilon^W h \left(\hat{\epsilon}_t^W + \hat{h}_t \right) + \epsilon^H w \left(\hat{\epsilon}_t^H + \hat{w}_t \right) \right]
\end{aligned} \tag{50}$$

Marginal effect of the loan interest rate on the real wage:

$$\hat{\epsilon}_t^W = \frac{d}{\epsilon^W (R^L)^2} \left\{ \frac{(1 - \rho)\beta}{h} \left[\frac{f}{\lambda q^F p^B} \left(\hat{h}_t + \hat{\lambda}_t + E_t \hat{q}_{t+1}^F + E_t \hat{p}_{t+1}^B + 2 \hat{R}_t^L \right) + \right. \right. \\
\left. \left. - R^L k^F \left(E_t \hat{\lambda}_{t+1} - \hat{\lambda}_t + E_t \hat{R}_{t+1}^L - 2 \hat{R}_t^L - \hat{h}_t \right) \right] + \right. \\
\left. - \frac{mpl}{\alpha \mu} \left(\widehat{mpl}_t - \hat{\mu}_t - 2 \hat{R}_t^L \right) \right\} \tag{51}$$

Marginal effect of the loan rate of interest on worked hours:

$$\hat{\epsilon}_t^H = \hat{h}_t - \hat{R}_t^L \tag{52}$$

Condition on hours worked:

$$\hat{h}_t = \frac{1}{\alpha - 1 - \phi} \left(\hat{\mu}_t + \hat{R}_t^L - \hat{\lambda}_t \right) \tag{53}$$

Credit market tightness:

$$\hat{\theta}_t^C = \hat{s}_t^F - \hat{V}_t^B \quad (54)$$

Labor market tightness:

$$\hat{\theta}_t^L = \hat{V}_t^F - \hat{s}_t^W \quad (55)$$

Financial matches:

$$\hat{H}_t = \zeta \hat{V}_t^B + (1 - \zeta) \hat{s}_t^F \quad (56)$$

Labor market matches:

$$\hat{M}_t = \xi \hat{V}_t^F + (1 - \xi) \hat{s}_t^W \quad (57)$$

Monetary rule:

$$\hat{R}_t^D = \rho_R \hat{R}_{t-1}^D + (1 - \rho_R) \left(\delta_\pi \hat{\pi}_t + \delta_Y \hat{Y}_t \right) + \log \nu_t \quad (58)$$

Job vacancy filling rate:

$$\hat{q}_t^F = \hat{M}_t - \hat{V}_t^F \quad (59)$$

Job finding rate:

$$\hat{p}_t^F = \hat{M}_t - \hat{s}_t^W \quad (60)$$

Credit line finding rate:

$$\hat{p}_t^B = \hat{H}_t - \hat{s}_t^F \quad (61)$$

Credit vacancy filling rate:

$$\hat{q}_t^B = \hat{H}_t - \hat{V}_t^B \quad (62)$$

Aggregate resources constraint:

$$\hat{Y}_t = \hat{C}_t \quad (63)$$

Monetary policy shock:

$$\log \nu_t = \rho_\nu \log \nu_{t-1} + \varepsilon_t^\nu \quad (64)$$

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