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The Role of Search Frictions and Bargaining for Inflation Dynamics*

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Abstract

This paper develops a dynamic general equilibrium model that integrates labor market search and matching into an otherwise standard New Keynesian model. I allow for changes of the labor input at both the extensive and the intensive margin and develop two alternative specifications of the bargaining process. Under efficient bargaining (EB) hours are determined jointly by the firm and the worker as a part of the same Nash bargain that determines wages. With right to manage (RTM), instead, firms retain the right to set hours of work unilaterally. I show that introducing search and matching frictions affects the cyclical behavior of real marginal costs by way of two different channels: a wage channel under RTM and an extensive margin channel under EB. In both cases, the presence of search and matching frictions may cause a lower elasticity of marginal costs with respect to output and thus help to account for the observed inertia in inflation.

Keywords: Labor Market Search, Wage Bargaining, Business Cycles, Inflation, Monetary Policy Shocks.
JEL Classification: E52, J64, E24, E32, E31.

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1 Introduction

In recent years, New Keynesian (NK) models have made considerable progress in explaining the links between money, inflation and business cycle fluctuations, gaining consensus among both policymakers and macroeconomists.[1] However, when accounting for the joint response of output and inflation to monetary shocks, the standard NK model has a great difficulty in generating the sluggish response of inflation together with the large and persistent response of output that is observed in the data. One key reason for this difficulty is that the model has the labor input adjusting along the intensive margin, which makes real wages very responsive over the cycle unless an implausibly high labor supply elasticity is assumed. This in turn induces firms setting prices as a markup over marginal costs to make large price adjustments and causes inflation in the model to fluctuate more than evidence suggests. Based on these and related considerations, several recent papers have argued that labor market frictions are crucial to understanding business cycle fluctuations, as well as the effects of monetary shocks and the design of monetary policies.[2] The search and matching model, along the lines of the work of Mortensen and Pissarides (1994), is a natural way of thinking about these frictions.

In this paper I develop a dynamic general equilibrium model that integrates labor market search and matching into an otherwise standard NK model with nominal price rigidities.[3] One important feature of the model is that it allows for changes of the labor input at both the extensive and the intensive margin, that is, through changes, respectively, in the number of people working and the number of hours worked by each employed person.

After developing the theoretical model, I clarify how the introduction of search and matching frictions changes the nature of real marginal costs and shapes the dynamics of inflation. In fact, while inflation dynamics in the model are determined by real marginal costs, according to a conventional NK Phillips curve, these may potentially behave quite differently from the baseline NK model. Moreover, I show that the behavior of real marginal costs depends on the assumptions I make about the way firms and workers bargain over wages and hours of work. Specifically, I develop two alternative specifications of the bargaining process and explore their different implications for the dynamics of marginal costs and inflation.

First, as in most search and matching models with variable hours of work, I assume that hours are determined jointly by the firm and the worker as a part of the same Nash bargain that is used to determine wages. Because the outcome of this bargain is privately efficient, I refer to this specification of the bargaining process as the efficient bargaining model (EB). Then, differently

[1] See Galì (2003) for a recent survey.

[2] Among these see Galì, Gertler and Lopez-Salido (2001), Christiano, Eichenbaum and Evans (2005), Smets and Wouters (2003), Levin, Onatski, Williams and Williams (2005).

[3] Early work by Merz (1995), Andolfatto (1996), Hairault (2002) and den Haan, Ramey and Watson (2000) has considered search and matching in a real business cycle model. Cooley and Quadrini (1999) integrate a model of equilibrium unemployment with a limited participation model of money.

from the existing literature, I make the alternative assumption that firms retain the right to set hours of work unilaterally and refer to this specification as the right to manage model (RTM). In the literature, the term right to manage typically refers to a static model of unionized labor markets where firms and unions bargain about the wage but firms retain the right to manage employment unilaterally.[4] In this paper, instead, right to manage refers to a model where employment is the outcome of forward-looking job creation decisions made by firms in a labor market characterized by search and matching frictions, while at the same time firms maintain the right to set hours after wages have been bargained. The main motivation for this assumption is the observed fact that the hours of work are rarely the object of bargaining agreements.

The two bargaining models have different implications for marginal costs. In the efficient bargaining model, although hours worked by each employed worker are chosen through bargaining, marginal costs are determined by the marginal disutility from supplying hours of work, much the same way as in a neoclassical labor market. However, while in a neoclassical labor market all variation of the labor input occurs at the intensive margin, which is very costly when the labor supply elasticity is not implausibly high, with equilibrium unemployment firms can change employment at the extensive margin. Thus, as long as part of the adjustment of the labor input occurs at the extensive margin, the elasticity of marginal costs with respect to output will be lower than in the baseline NK model. Under right to manage, instead, firms take the bargained wage as given when choosing the hours of work, implying that real wages determine firms' marginal costs. This implies that any factor that may potentially influence the outcome of the wage bargaining process or affect the degree of wage rigidity will have a direct effect on marginal costs and inflation. As a result, the presence of search and matching frictions can potentially affect marginal costs by way of two different channels: a wage channel under right to manage and an extensive margin channel under efficient bargaining.

To assess the quantitative importance of these two channels, I analyze the response of the model economy to a monetary shock under both specifications of the bargaining process and compare it to a baseline NK model that does not have search and matching frictions but keeps all other features the same. The first result that I obtain is that under the baseline calibration and model specification search and matching frictions do not seem to have a significant impact on the behavior of marginal costs and inflation. This happens because the bargained wage turns out to be almost as volatile as the competitive wage and, at the same time, the model is not able to generate a significant variation of the labor input at the extensive margin.

The failure of the conventional search and matching model to account for the low cyclicality of wages has recently been recognized in the literature.[5] However, it has also been pointed out that the degree of wage rigidity delivered by Nash bargaining is fairly sensitive to the values of the bargaining power and the flow benefit from unemployment. With the only purpose of analyzing the effects

[4] See Nickell and Andrews (1983) for an early example. Note also that this literature typically abstracts from the hours of work decision. One exception is Pencavel and Holmlund (1988).

[5] See in particular Shimer (2005).

of wage rigidity on the dynamic behavior of marginal costs and inflation, I then try alternative calibrations. I show that the resulting wage rigidity translates into less volatile movements in marginal costs and inflation only in the right to manage model, while it has no effect in the efficient bargaining model.

Finally, I turn to the inability of the model to generate a significant response at the extensive margin. This happens because output is demand determined and employment cannot adjust on impact, implying that firms have to rely on adjusting hours of work to meet the higher demand. I then modify the baseline specification of the model to introduce habit persistence in consumption and show that when output responds gradually to the monetary shock a larger part of the fluctuation in total hours occurs at the extensive margin. In fact, the progressive increase in output makes it possible for firms to plan ahead their employment and job creation decisions. Changes at the extensive margin, in turn, reduce the elasticity of marginal costs to output in the efficient bargaining model. Lastly, I show that when the model allows for habit persistence, wage rigidity reduces the volatility of marginal costs and inflation in the efficient bargaining model as well. The channel, though, is different from the right to manage case. Under efficient bargaining, wage rigidity affects the behavior of marginal costs indirectly because it enhances the cyclical movements in firms' hiring incentives and by this way increases employment volatility at the extensive margin relative to the intensive margin. The role of wage rigidity to account for the relatively volatile behavior of employment within a baseline Mortensen and Pissarides model has recently been pointed out in the literature, beginning with Shimer (2005) and Hall (2005a).[6]

A number of recent papers consider search and matching frictions into an otherwise standard NK model. Closely related to this paper are Trigari (2004), Walsh (2005), Krause and Lubik (2005) and Christoffel and Linzert (2005). Trigari (2004) develops and estimates a model that is similar to the one developed in this paper, with adjustments at both the extensive and intensive margin, but that also allows for endogenous job destruction. For tractability reasons, however, it only focuses on the efficient bargaining specification. With endogenous job destruction, output can be changed on impact at both the intensive and the extensive margin, implying that the model is better able to account for the relatively larger response of the labor input at the extensive margin, which in turn reduces the elasticity of marginal costs to output. The model, which is taken to the data, can account reasonably well for the joint response of output, inflation and labor market activity to monetary shocks. Walsh (2005) also shows that labor market search decreases the elasticity of marginal costs to output relative to an otherwise similar model with a Walrasian labor market. Moreover, he investigates the relative role of policy inertia and frictions in accounting for the real effects of monetary policy shocks. Krause and Lubik (2005) focus on the role of wage rigidity. The main difference of the work by Walsh (2005) and Krause and Lubik (2005) with the model presented here is that these authors only allow for changes of the labor input at the extensive margin (but

[6] These analyses, however, differ from the one conducted in this paper as they study non monetary models and only consider the extensive margin. See Hall (2005b) for a survey.

have endogenous job destruction). This is possibly a reason that explains why Krause and Lubik (2005) find that introducing wage rigidity, in the form of an *ad hoc* wage rule, only weakly affects the dynamics of marginal costs and inflation. In fact, I show that one important channel through which search frictions affect marginal costs is by changing the relative share of fluctuations that take place at the extensive and intensive margin. Finally, a recent paper by Christoffel and Linzert (2005) extends the efficient bargaining and right to manage models developed here by introducing a similar *ad hoc* wage rule. They show that this form of wage rigidity translates into less volatile and more persistent movements in inflation only in the right to manage model. The reason for this, however, is likely to be related to the inability of the model to generate significant variations of the labor input at the extensive margin, as is the case in this paper when there is no habit formation in consumption preferences.

The remainder of the paper is organized as follows: Section 2 describes the model, Section 3 analyses the determination of marginal costs under both specifications of the bargaining process, Section 4 presents the dynamics of the model around the steady state, Section 5 describes the calibration, Section 6 presents the results and, finally, Section 7 concludes.

2 The model

The proposed model with nominal price rigidities and search and matching in the labor market has four sectors. The sectors include the households, the intermediate goods firms, the retail firms and a monetary authority. Each sector's environment is discussed in detail below.

2.1 Households

Each household is thought of as a very large extended family which contains a continuum of members with names on the unit interval. In equilibrium, some members will be unemployed while some others will be working for firms. Each member has the following period utility function:

$$u(c_t) - g\left(h_t\right), \tag{1}$$

where

$$u(c_t) = \log\left(c_t\right) \tag{2}$$

and

$$g\left(h_t\right) = \kappa_h \frac{h_t^{1+\phi}}{1+\phi}. \tag{3}$$

The variable c_t is consumption of a final good in t and h_t is the hours of work supplied at time t.

The representative household maximizes lifetime utility:

$$E_t \sum_{s=0}^{\infty} \beta^s \left[u(c_{t+s}) - G_{t+s}\right], \tag{4}$$

where $\beta \in (0,1)$ is the intertemporal discount factor and c_t is per capita consumption of each family member at date t.[7] The variable G_t denotes the family's disutility from supplying hours of work at date t, i.e., the sum of the disutilities of the members who are employed and supply hours of work. The representative household does not choose hours of work. These are determined through decentralized bargaining between firms and workers or unilaterally by firms. Therefore, for simplicity, I do not make explicit the family's disutility term at this point.[8]

Households own all firms in the economy and face, in each period, the following budget constraint:

$$c_t + \frac{B_t}{p_t r_t^n} = d_t + \frac{B_{t-1}}{p_t}, \tag{5}$$

where p_t is the aggregate price level, B_t is per capita holdings of a nominal one-period bond and r_t^n is the gross nominal interest rate on this bond, which is certain at the issuing date. The variable d_t is the per capita family income in period t.[9]

The representative household chooses consumption and asset holdings to maximize (4) subject to (5), which yields

$$\lambda_t = \beta E_t \left[r_t \lambda_{t+1} \right], \tag{6}$$

where λ_t is the marginal utility of consumption at date t and r_t is the gross real interest rate.

2.2 Firms and the labor market

The model that I develop in this paper is characterized by two main building blocks: nominal rigidities in price setting and search and matching frictions in the labor market. One complication is that when firms set prices on a staggered basis the job creation decision becomes highly intractable. To avoid this problem I distinguish between two types of firms: retail firms and intermediate goods firms.[10] For simplicity, I will often refer to retail firms as retailers and to intermediate goods firms as simply firms. Firms produce intermediate goods in competitive markets using labor as their only input, and then sell their output to retailers who are monopolistic competitive. Retailers, finally, sell final goods to the households. Then, I assume that price rigidities arise at the retail level, while search frictions occur in the intermediate goods sector. In this section I describe the problem of intermediate goods firms.

[7] To avoid distributional issues from heterogeneity, I follow Merz (1995) and Andolfatto (1996) in assuming that family members perfectly insure each other against fluctuations in consumption.

[8] This term is nevertheless important to derive the surplus from employment for a worker from the family problem. See the Appendix for details.

[9] The family income is the sum of the wage income earned by employed family members, the benefits earned by unemployed family members and the family share of aggregate profits from retailers and matched firms, net of a government lump-sum tax used to finance unemployment benefits.

[10] This modelling device has first been introduced by Bernanke, Gertler and Gilchrist (1999) in their study of the financial accelerator mechanism.

2.2.1 Matching market and production

In order to match with a worker, firms must actively search for workers in the unemployment pool. This idea is formalized by assuming that firms post vacancies. On the other hand, unemployed workers must look for firms. I assume that all unemployed workers search passively for jobs.

Each firm has a single job that can either be filled or vacant and searching for a worker. Workers can be either employed or unemployed and searching for a job.[11]

Vacancies, v_t, are matched to workers seeking for a job, u_t, according to the following CRS matching function:

$$m_t = \sigma_m u_t^{\sigma} v_t^{1-\sigma}, \tag{7}$$

where σ_m is a scale parameter reflecting the efficiency of the matching process.

The probability that any open vacancy is matched with a searching worker at date t is denoted with q_t and is given by:

$$q_t = \frac{m_t}{v_t}. \tag{8}$$

Similarly, the probability that any worker looking for a job is matched with an open vacancy at time t is denoted with s_t and is given by:

$$s_t = \frac{m_t}{u_t}. \tag{9}$$

If the search process is successful, the firm operates a production function $f(h_t) = zh_t^{\alpha}$, where z is a technology factor common to the whole intermediate sector, h_t is the time spent working at time t and $\alpha \in (0,1)$. Employment relationships might be severed for exogenous reasons at the beginning of any given period. I denote with ρ the probability of separation. If separation occurs, production does not take place.

Employment evolves according to the following dynamic equation:

$$n_t = (1-\rho)\, n_{t-1} + m_{t-1}, \tag{10}$$

which simply says that the number of matched workers at the beginning of period t, n_t, is given by the fraction of matches in $t-1$ that survives to the next period, $(1-\rho)\, n_{t-1}$, plus the newly-formed matches, m_{t-1}.

The labor force being normalized to one, the number of unemployed workers at the beginning of any given period is $1 - n_t$. This is different from the number of searching workers in period t, u_t, which is given by:

$$u_t = 1 - (1-\rho)\, n_t \tag{11}$$

since some of the employed workers discontinue their match and search for a new job in the same period.

[11] All unmatched workers are assumed to be part of the unemployed pool, i.e., I abstract from workers' labor force participation decisions.

2.2.2 Bellman equations

To make the exposition of the following sections easier, I describe here the Bellman equations that characterize the problem of firms and workers.

Denote with J_t the value of a job for a firm at time t measured in terms of current consumption of the final good. This is given by:

$$J_t = x_t f(h_t) - w_t h_t + E_t \beta_{t,t+1} (1-\rho) J_{t+1}, \tag{12}$$

where x_t and w_t denote, respectively, the relative price of the intermediate good and the hourly wage rate at date t. The value of the job is the current profits $x_t f(h_t) - w_t h_t$ plus the continuation value. Next period, with probability $1-\rho$ the match is not severed. In this event the firm obtains the future expected value of a job, J_{t+1}. With probability ρ, instead, the match is discontinued in $t+1$ and the firm obtains a future payoff equal to zero. Finally, the expected future value of the job is discounted according to the factor $\beta_{t,t+1}$, where $\beta_{t,t+s} = \frac{\beta^s \lambda_{t+s}}{\lambda_t}$.[12]

Denote with V_t the value of an open vacancy for a firm at time t expressed in terms of current consumption. Letting κ be the utility cost of keeping a vacancy open, V_t can be written as:

$$V_t = -\frac{\kappa}{\lambda_t} + E_t \beta_{t,t+1} \left[q_t (1-\rho) J_{t+1} + (1-q_t) V_{t+1} \right], \tag{13}$$

where $\frac{\kappa}{\lambda_t}$ is the utility cost expressed in terms of current consumption.

Denote now with W_t and U_t, respectively, the employment and the unemployment value for a worker at time t expressed in terms of current consumption.[13] The value of employment W_t can be written as:

$$W_t = w_t h_t - \frac{g(h_t)}{\lambda_t} + E_t \beta_{t,t+1} \left[(1-\rho)(W_{t+1} - U_{t+1}) + U_{t+1} \right], \tag{14}$$

where $\frac{g(h_t)}{\lambda_t}$ is the disutility from supplying hours of work expressed in terms of current consumption.

Finally, the value of unemployment U_t is given by:

$$U_t = b + E_t \beta_{t,t+1} \left[s_t (1-\rho)(W_{t+1} - U_{t+1}) + U_{t+1} \right], \tag{15}$$

where b is the flow value of being unemployed, taken to be unemployment benefits.

2.2.3 Vacancy posting

As long as the value of a vacancy V_t is greater than zero, firms will open new vacancies. In equilibrium, free entry ensures that $V_t = 0$ at any time t. Hence, from (13) the condition for the

[12] The use of this discount factor effectively evaluates profits in terms of the values attached to them by the households, who ultimately own firms.

[13] Because there is perfect income insurance it is not straightforward to define these values. In the Appendix, I show how the worker surplus, $W_t - U_t$, can be derived from the family problem.

posting of new vacancies is:

$$\frac{\kappa}{\lambda_t q_t} = E_t \beta_{t,t+1} (1-\rho) J_{t+1}. \tag{16}$$

Noting that $1/q_t$ is the expected duration of an open vacancy, equation (16) simply says that in equilibrium the expected cost of hiring a worker is equal to the expected value of a match.

Equation (16) implies that, holding constant λ_t, an increase in the sum of expected future profits must be associated with a decrease in q_t. Given the specification of the matching function, this requires an increase in the number of vacancies posted, v_t. The increase in the number of posted vacancies, in turn, causes an increase in next period employment, $n_{t+1.}$ Monetary policy shocks will affect the rate at which vacancies are posted and, consequently, employment through the above mechanism. A persistent fall in the nominal interest rate, which results in a decrease in the real interest rate due to price rigidities, modifies the aggregate consumption behavior of the households and raises current and future aggregate demand. Since monopolistic competitive retailers produce to meet demand, this raises their current and future demand for intermediate goods, which they use as inputs. The resulting persistent raise in the relative price of intermediate goods, x_t, leads to an increase in firms' expected future profits. The increase in profits, finally, raises the number of posted vacancies and increases employment next period.

Finally, note that equation (16) can be rearranged to a first-order difference equation in q_t:

$$\frac{\kappa}{\lambda_t q_t} = E_t \beta_{t,t+1} (1-\rho) \left(x_{t+1} f(h_{t+1}) - w_{t+1} h_{t+1} + \frac{\kappa}{\lambda_{t+1} q_{t+1}} \right). \tag{17}$$

2.3 Two models of bargaining

In this section I describe the determination of hours worked and wages. I assume that firms and workers negotiate through Nash bargains, so that the outcome of the bargaining process maximizes the Nash product

$$(W_t - U_t)^{\eta} (J_t - V_t)^{1-\eta}, \tag{18}$$

where the first term in brackets is the worker surplus, the second is the firm surplus, and η reflects the relative bargaining power. Bargaining can take place along two dimensions, according to whether the firm retains the right to manage hours. If it does, the firm and the worker bargain over the real wage, and the firm then unilaterally chooses the hours of work for a given bargained wage. The alternative assumption is that the worker and the firm bargain about both the wage and the hours of work equally.

Most search and matching models with variable hours of work assume that hours are determined jointly by the firm and the worker as a part of the same Nash bargain that is used to determine wages. The outcome of this bargain is privately efficient and is equivalent to a model where hours are chosen to maximize the joint surplus of the match, while the wage is set to split the surplus according to the parameter η. I will refer to this specification of the bargaining process as the efficient bargaining model (EB).[14] Differently from the existing literature, I also consider the assumption that firms retain the right to set hours of work unilaterally and refer to this alternative specification as the right to manage model (RTM). In the literature, the term RTM typically refers to a static model of unionized labor markets where firms and unions bargain about the wage but firms retain the right to manage employment unilaterally. In this paper, instead, RTM refers to a model where employment is the outcome of forward-looking job creation decisions made by firms in a labor market characterized by search and matching frictions, while at the same time firms maintain the right to choose the hours worked by their employees after wages have been bargained. Differently from the EB model, the allocation of resources within the match is inefficient in that at least one of the two parties could be better off by bargaining over hours as well as wages. While this raises the question of why firms are not willing to bargain over hours as well, the assumption is motivated by the observed fact that the labor input, both in the dimension of employment and the hours of work per employee, is rarely the object of bargaining agreements.

Below I characterize the equilibrium wage and working hours under both specifications of the bargaining process. Then, in the following sections I discuss extensively their different implications for the determination of marginal costs.

2.3.1 Efficient bargaining

Under EB, the firm and the worker choose the real wage w_t and the hours of work h_t to maximize the Nash product. The wage w_t chosen by the match satisfies the optimality condition

$$\eta J_t = (1-\eta)(W_t - U_t). \tag{19}$$

As mentioned above, this condition implies that the total surplus that a job match creates is shared according to the parameter η. Substituting the expressions for J_t, W_t and U_t yields:

$$w_t h_t = \eta\left(x_t f(h_t) + f_t^F\right) + (1-\eta)\left(\frac{g(h_t)}{\lambda_t} + b - f_t^W\right), \tag{20}$$

where f_t^F and f_t^W denote the future expected net present values from employment to the firm and the worker, respectively.[15] The wage shares costs and benefits from the activity of the match according to the parameter η. Precisely, the worker is rewarded for a fraction η of both the firm's revenues and the firm's future expected net present value from employment and compensated for a fraction $1-\eta$ of the disutility he suffers from supplying hours of work, the foregone flow benefit from unemployment and the foregone future expected net present value from unemployment (equal to minus the future expected net present value from employment). Finally, using also (16) and

[14] It must be emphasized that the outcome predicted by the Nash bargaining model is generally *not* efficient from the viewpoint of society as a whole (Hosios, 1990).

[15] From equations (12), (14) and (15), $f_t^F = E_t\beta_{t+1}(1-\rho)J_{t+1}$ and $f_t^W = E_t\beta_{t+1}(1-\rho)(1-s_t)(W_{t+1}-U_{t+1})$.

(19), equation (20) can be rearranged to include only contemporaneous variables:

$$w_t = \eta \left(\frac{x_t mpl_t}{\alpha} + \frac{\kappa}{\lambda_t} \frac{\theta_t}{h_t} \right) + (1-\eta) \left(\frac{mrs_t}{1+\phi} + \frac{b}{h_t} \right), \tag{21}$$

where $\theta_t = v_t/u_t$ is the labor market tightness, $mpl_t = f_h(h_t)$ is the marginal product of labor and $mrs_t = g_h(h_t)/\lambda_t$ is the marginal rate of substitution.

In a neoclassical labor market, the wage would adjust to equate the marginal rate of substitution between consumption and leisure and the marginal product of labor. With search and matching frictions and efficient bargaining the wage does not equal (although is related to) the marginal rate of substitution or the marginal product of labor. In particular, the wage also depends on the state of the labor market, as it is measured by the labor market tightness, and the flow benefit from unemployment. The bargained wage, then, may potentially behave quite differently from the competitive wage.

Let us now turn to the determination of hours. Because firms and workers bargain over both hours and wages, the choice of hours is privately efficient and satisfies the following optimality condition:

$$\eta J_t \left(mrs_t - w_t \right) = (1-\eta) \left(W_t - U_t \right) \left(x_t mpl_t - w_t \right), \tag{22}$$

which can be simplified, using (19), to:

$$x_t mpl_t = mrs_t, \tag{23}$$

where the value of the marginal product of hours is equated to the the marginal rate of substitution. Thus, the first order condition determining the hours worked is exactly the same as in a neoclassical labor market. This happens because under EB the correct measure of labor costs to the firm is the marginal disutility of supplying hours of work (normalized by the marginal utility of consumption), rather than the wage. In other words, the wage does not play an allocational role for hours.

2.3.2 Right to manage bargaining

Under RTM, the firm unilaterally chooses the hours of work, for a given bargained wage, to maximize the value of a job J_t. This yields the following condition for the choice of hours:

$$x_t mpl_t = w_t. \tag{24}$$

Because firms take the bargained wage as given when choosing hours, the value of the marginal product of labor is equated to the real wage, rather than to the marginal rate of substitution, as it is the case under efficient bargaining. This implies that the wage is allocational for hours. Finally, it will be convenient to have (24) written as:

$$h_t = f_h^{-1} \left(\frac{w_t}{x_t} \right) \equiv h\left(w_t \right). \tag{25}$$

Before the firm sets the optimal hours as in (25), the firm and the worker choose the wage so as to maximize the Nash product, taking as given the effect of wages on hours given by (25). Then, the wage chosen by the match satisfies the optimality condition

$$\eta \delta_t^W J_t = (1-\eta)\, \delta_t^F \,(W_t - U_t)\,, \tag{26}$$

where δ_t^W and δ_t^F denote, respectively, the net marginal benefits from an increase in the wage to the worker and to the firm. Thus, the wage is set to equate the proportional net marginal benefits to each party, weighted by each party's bargaining strength. The net marginal benefits to the worker and the firm are:

$$\delta_t^W = h_t + w_t h_w(w_t) - mrs_t h_w(w_t) = \frac{h_t}{1-\alpha}\left(\frac{mrs_t}{w_t} - \alpha\right) \tag{27}$$

and

$$\delta_t^F = -\left[x_t mpl_t h_w(w_t) - h_t - w_t h_w(w_t)\right] = h_t. \tag{28}$$

Substituting the expressions for J_t, W_t and U_t and rearranging yields a similar wage equation to the one obtained under efficient bargaining:

$$w_t h_t = \chi_t\left(x_t f(h_t) + f_t^F\right) + (1-\chi_t)\left(\frac{g(h_t)}{\lambda_t} + b - f_t^W\right), \tag{29}$$

where

$$\chi_t = \frac{\eta \delta_t^W}{\eta \delta_t^W + (1-\eta)\,\delta_t^F}. \tag{30}$$

As before, the wage turns out to be a weighted average of the firm's revenues plus future expected net present value from employment and the worker's disutility from supplying hours of work, plus the foregone flow benefit from unemployment, plus the foregone future expected net present value from unemployment. In equation (29), however, the weights not only depend on the relative bargaining power η but also on the wage relative allocational effect, as it is captured by δ_t^W and δ_t^F. Finally, using also (16) and (26), yields the following wage equation:

$$w_t = \chi_t\left(\frac{x_t mpl_t}{\alpha} + \frac{\kappa}{\lambda_t}\frac{\theta_t}{h_t}\right) + (1-\chi_t)\left(\frac{mrs_t}{1+\phi} + \frac{b}{h_t}\right) + \chi_t(1-s_t)\frac{k}{\lambda_t q_t}\left(1 - \frac{1-\chi_t}{\chi_t}\frac{\chi_{t+1}}{1-\chi_{t+1}}\right). \tag{31}$$

2.4 Retailers and price setting

There is a continuum of monopolistic competitive retailers indexed by i on the unit interval. Retailers do nothing other than buy intermediate goods from firms, differentiate them with a technology that transforms one unit of intermediate goods into one unit of retail goods, then re-sell them to the households. Note that the relative price of intermediate goods, x_t, coincides with the real marginal cost faced by retailers.

Let y_{it} be the quantity of output sold by retailer i and let p_{it} be the nominal sale price. Final goods, denoted with y_t, are the following composite of individual retail goods:

$$y_t = \left[\int_0^1 y_{it}^{\frac{\varepsilon-1}{\varepsilon}} di \right]^{\frac{\varepsilon}{\varepsilon-1}}, \tag{32}$$

where ε, which is assumed to be greater than one, is the elasticity of substitution across the differentiated retail goods. Then, the demand curve facing each retailer is given by:

$$y_{it} = \left(\frac{p_{it}}{p_t} \right)^{-\varepsilon} y_t, \tag{33}$$

where p_t is the aggregate price index:

$$p_t = \left[\int_0^1 p_{it}^{1-\varepsilon} di \right]^{\frac{1}{1-\varepsilon}}. \tag{34}$$

As in Calvo (1983), I assume that in any given period each retailer can reset its price with a fixed probability $1-\varphi$ that is independent of the time elapsed since the last price adjustment. This assumption implies that prices are fixed on average for $\frac{1}{1-\varphi}$ periods. Retailers, then, choose their price to maximize expected future discounted profits given the demand for the good they produce and under the hypothesis that the price they set at date t applies at date $t+s$ with probability φ^s. The solution to this problem gives:

$$p_{it} = \mu E_t \sum_{s=0}^{\infty} \omega_{t,t+s} x_{t+s}^n, \tag{35}$$

where $\mu = \frac{\varepsilon}{\varepsilon-1}$ is the flexible-price markup and $x_t^n = p_t x_t$ is the nominal marginal cost at date t. The weights $\omega_{t,t+s}$ are given by:

$$\omega_{t,t+s} = \frac{\varphi^s \beta_{t,t+s} R_{it,t+s}}{E_t \sum_{k=0}^{\infty} \varphi^k \beta_{t,t+k} R_{it,t+k}}, \tag{36}$$

where $R_{it,t+s}$ denotes revenues from good i at time $t+s$ conditional on the price set at date t. Thus, retailers set their price equal to a markup μ over a weighted average of expected future marginal costs, where the weights represent the relative proportion of expected discounted revenues at each future date.[16]

Finally, the model is closed by imposing the economy-wide resource constraint

$$y_t = c_t, \tag{37}$$

and the market clearing condition in the intermediate good sector

$$y_t = n_t (1-\rho) f(h_t), \tag{38}$$

where y_t is aggregate demand, $n_t(1-\rho)$ is the number of firms actually producing in t and $f(h_t)$ is each firm's production.

[16] In the limiting case in which retailers are allowed to reset their price every period ($\varphi = 0$), equation (35) reduces to the standard condition that the price is a constant markup over the nominal marginal cost.

2.5 Monetary authority

The monetary authority conducts monetary policy using the short-term nominal interest rate as the policy instrument and lets the nominal amount of money adjusting accordingly. The gross nominal interest rate r_t^n follows a Taylor-type rule of the following type:

$$r_t^n = \beta^{-(1-\rho_m)} \left(r_{t-1}^n\right)^{\rho_m} E_t \left(\pi_{t+1}\right)^{\gamma_\pi (1-\rho_m)} \left(y_t^z\right)^{\gamma_y (1-\rho_m)} e^{\varepsilon_t^m}. \tag{39}$$

The parameter ρ_m measures the degree of interest rate smoothing and is included following the empirical evidence presented in Clarida, Galí and Gertler (2000). The parameters γ_π and γ_y are the response coefficients of expected inflation and the output gap y_t^z. Finally, ε_t^m is an i.i.d. monetary policy shock.

3 Real marginal cost under EB and RTM

Inflation dynamics in the model are determined by the behavior of real marginal costs, according to a conventional NK Phillips curve, which can be obtained by log-linearizing the price setting conditions. What changes relative to the baseline NK model with a neoclassical labor market is the behavior of real marginal costs. The presence of search and matching frictions together with wage bargaining changes the nature of real marginal costs because it affects both the way the labor input is used to produce output and the way its price is determined.

First, recall that the relative price of intermediate goods x_t coincides with the real marginal cost faced by retailers. Then, note that final goods output is produced according to equation (38):

$$y_t = (1-\rho)\, n_t f\left(h_t\right),$$

which says that output can be changed either by changing the number of hours that each employed worker supplies, h_t, or by changing the number of employed workers producing in t, $(1-\rho)\, n_t$. Since it takes time to hire a new worker through vacancy posting and matching, i.e., the stock of currently employed workers n_t is predetermined, this implies that only the hours of work h_t can be freely adjusted to enable firms to meet demand. Thus, the marginal costs equals the cost of producing one additional unit of output by increasing hours worked. This is given by the optimal condition for the determination of hours, which differs depending on which bargaining model we consider.

Under EB, the marginal cost equals the marginal rate of substitution, normalized by the marginal product of hours:

$$x_t = \frac{mrs_t}{mpl_t}.$$

It is important to note that while this condition turns out to have exactly the same form as in a neoclassical labor market, there are two important differences. First, in a neoclassical labor market, the wage adjusts to equate the value of the marginal product of hours to the marginal rate of substitution. In contrast, under EB the wage plays no allocational role for hours, meaning that a firm and a worker determine hours by equating costs and benefits of additional hours for the match as a whole. The wage only represents a transfer between the worker and the firm and needs not to be equal to neither the value of the marginal product nor to the marginal rate of substitution. Second, the condition above determines hours per worker, the intensive margin, as opposed to total hours in the neoclassical framework. Thus as long as part of the adjustment of the labor input occurs at the extensive margin, this has the important implication that, other things being equal, the marginal cost will change less than in the baseline NK model where all variation in total hours occurs at the intensive margin. That is, allowing for variation of the labor input at both the extensive and the intensive margin reduces the elasticity of marginal costs with respect to output. I will refer to this channel as the extensive margin channel.

Under right to manage, the marginal cost equals the bargained real wage, normalized by the marginal product of hours:

$$x_t = \frac{w_t}{mpl_t}.$$

As argued earlier, because firms choose hours of work unilaterally, taking as given the bargained wage, the wage is the measure of the labor costs to the firms and plays an allocational role for hours. Thus, any factor that may potentially affect the outcome of the wage bargaining process will have a direct influence on marginal costs and inflation. Moreover, if the bargained wage turns out to be less responsive to economic conditions than the wage in a neoclassical labor market, marginal costs will be less responsive as well. That is, under RTM wage rigidities lead directly to a lower elasticity of marginal costs with respect to output. I will refer to this channel as the wage channel.

4 Model dynamics

The dynamics of the model are obtained by taking a log-linear approximation around a deterministic steady state, with zero inflation. The complete log-linearized model is described below, where variables with a "hat" denote log-deviations from their steady state value, while variables without a time subscript denote steady state values.

Taylor-type interest rate rule

$$\widehat{r}_t^{\,n} = \rho_m \widehat{r}_{t-1}^{\,n} + (1-\rho_m)\,\gamma_\pi E_t \widehat{\pi}_{t+1} + (1-\rho_m)\,\gamma_y \widehat{y}_t + \varepsilon_t^m \tag{40}$$

Euler equation

$$\widehat{\lambda}_t = E_t \widehat{\lambda}_{t+1} + \widehat{r}_t \tag{41}$$

Marginal utility of consumption

$$\widehat{\lambda}_t = -\widehat{c}_t$$

Real interest rate

$$\widehat{r}_t = \widehat{r}_t^{\,n} - E_t \pi_{t+1} \tag{42}$$

Resource constraint

$$\widehat{y}_t = \widehat{c}_t \tag{43}$$

Phillips curve

$$\widehat{\pi}_t = \gamma \widehat{x}_t + \beta E_t \widehat{\pi}_{t+1} \tag{44}$$

where $\gamma = \frac{(1-\beta\varphi)(1-\varphi)}{\varphi}$.

Market clearing

$$\widehat{y}_t = \alpha \widehat{h}_t + \widehat{n}_t \tag{45}$$

Matching function

$$\widehat{m}_t = \sigma \widehat{u}_t + (1-\sigma)\,\widehat{v}_t \tag{46}$$

Transition probabilities

$$\widehat{q}_t = \widehat{m}_t - \widehat{v}_t \tag{47}$$

$$\widehat{s}_t = \widehat{m}_t - \widehat{u}_t \tag{48}$$

Employment dynamics

$$\widehat{n}_t = (1-\rho)\widehat{n}_{t-1} + \rho \widehat{m}_{t-1} \tag{49}$$

Searchers

$$\widehat{u}_t = -\frac{n}{u}\,(1-\rho)\,\widehat{n}_t \tag{50}$$

Job creation

$$q_t = -\beta\,(1-\rho)\,\varsigma^{-1}\left(\alpha^{-1} x_{t+1} - w_{t+1}\right) + \beta\,(1-\rho)\,q_{t+1} - (1-\beta\,(1-\rho))\,\lambda_{t+1} \tag{51}$$

where $\varsigma = \frac{\kappa/q\lambda}{wh}$.

Hours

Efficient bargaining

$$\widehat{x}_t + m\widehat{p}l_t = m\widehat{r}s_t \tag{52}$$

Right to manage

$$\widehat{x}_t + m\widehat{p}l_t = \widehat{w}_t \tag{53}$$

Real wage

Efficient bargaining

$$\widehat{w}_t = \eta\alpha^{-1}\left(\widehat{x}_t + m\widehat{p}l_t\right) + \eta\varsigma s\left(\widehat{\theta}_t - \widehat{h}_t - \widehat{\lambda}_t\right) + (1-\eta)\,(1+\phi)^{-1}\,m\widehat{r}s_t - (1-\eta)\,\rho_u \widehat{h}_t \tag{54}$$

where $\rho_u = \frac{b}{wh}$

Right to manage

$$\widehat{w}_t = \eta\alpha^{-1}\left(\widehat{x}_t + m\widehat{pl}_t\right) + \eta\varsigma s\left(\widehat{\theta}_t - \widehat{h}_t - \widehat{\lambda}_t\right) + (1-\eta)(1+\phi)^{-1} m\widehat{rs}_t - (1-\eta)\rho_u\widehat{h}_t + \widehat{\Upsilon}_t \qquad (55)$$

where

$$\widehat{\Upsilon}_t = \varsigma_1\widehat{\chi}_t - \varsigma_2\widehat{\chi}_{t+1} \qquad (56)$$

and $\varsigma_1 = \frac{\eta}{1-\eta}\left(\frac{1-\alpha}{\alpha} + \varsigma\right)$, $\varsigma_2 = \frac{\eta}{1-\eta}(1-s)\varsigma$.

Below, I will compare the predictions of the model developed in this paper with those of a baseline NK model that does not have search and matching frictions but keeps all other features the same. The first way in which the model developed here differs from the NK model with a neoclassical labor market is of course the presence equilibrium unemployment. However, because of perfect income insurance the demand side of the model is unchanged. The pricing decision is also unaffected, leading to a standard NK Phillips curve where inflation depends on marginal costs and expected future inflation. The market clearing condition (45) shows that the labor input can vary at both the extensive and the intensive margin, while in the baseline model all changes in total hours will occur at the intensive margin. Equations (46) to (51) describe the dynamics of the labor market with search and matching frictions and are absent from the baseline NK model.

The second difference with the baseline NK model is the determination of real wages and hours. Under both specifications of the bargaining process, the hourly real wage can be expressed as a weighted average of the marginal product of labor, the market tightness per hour normalized by the marginal utility of consumption, the marginal rate of substitution, and the unemployment benefit per hour (plus an additional term capturing movements in the weight χ at time t and $t+1$ under RTM). The real marginal cost x_t, instead, depends on which bargaining model is assumed. While under RTM the marginal cost is the wage net of the marginal product of labor, with EB it is given by the the marginal rate of substitution net of the marginal product of labor. Thus, under EB the marginal cost is determined as in the baseline NK model. Only the wage is different. In contrast, under RTM the marginal cost depends on the bargained wage.

To sum up, the baseline NK model without search and matching frictions that I will use for comparison is described by equations (40) to (45), where in equation (45) $\widehat{n}_t$ is equal to zero, plus a labor demand and a labor supply equation equating the wage to the value of the marginal product of labor and the marginal rate of substitution, respectively.

5 Model calibration

In this section I discuss the calibration of the parameters of the model. I set the quarterly discount factor β to 0.99, which implies a quarterly real rate of interest of approximately 1 percent. The other parameters of the utility function that we need to calibrate are ϕ and κ_h. The elasticity of intertemporal substitution in the supply of hours is equal to $1/\phi$. The value of this elasticity has been a substantial source of controversy in the literature. Students of the business cycle tend to work with elasticities that are higher than microeconomic estimates, typically unity and above. Most microeconomic studies, however, estimate this elasticity to be much smaller, close to 0 and not higher than 0.5.[17] I accordingly set ϕ equal to 10, which implies a labor supply elasticity of 0.1. I then normalize the value of the time spent working in the steady state, h, to 1 and set κ_h accordingly.

I set the probability λ that a firm does not change its price in a given period equal to 0.85, implying that the average time between price adjustments is 6.5 quarters. I assume that the markup of prices on marginal costs is on average 10 percent. This amounts to setting ε equal to 11.

The empirical literature provides us with several measures of the U.S. worker separation rate. Davis, Haltiwanger and Schuh (1996) compute a quarterly worker separation rate of about 8 percent, while Hall (1995) reports this rate to be between 8 and 10 percent. I accordingly set the separation rate ρ to 0.08. I choose the elasticity of matches to unemployment, σ, to be equal to 0.5, the midpoint of values typically used in the literature. This choice is within the range of plausible values of 0.5 to 0.7 reported by Petrongolo and Pissarides (2001) in their survey of the literature on the estimation of the matching function. I set the steady state employment rate n to 0.8.[18] The probability s that a worker finds a job is calculated from the steady state relationships to be 0.25, implying that the average time until a worker finds a job is 4 quarters. Recall that in the model we have interpreted the pool of searching workers as both unemployed and partly out of the labor force. Then, I set the probability q that a firm fills a vacancy to 0.7, as in Cooley and Quadrini (1999) and den Haan, Ramey and Watson (2000).[19] Finally, I obtain the value of the parameter σ_m from the steady state calculation.

To maintain comparability with much of the existing literature, in the baseline calibration I set the bargaining power parameter η to be equal to 0.5.[20] Note that $\eta = 0.5$ in conjunction with $\sigma = 0.5$ ensures the efficiency of the equilibrium in the flexible version of the model (Hosios, 1990). In Section 6, however, I try different values for η and report the sensitivity of the results to this parameter. After normalizing the technology level in the intermediate goods sector to $z = 1$, I set the technology parameter α to be equal to 0.9. Under right to manage $1 - \alpha$ corresponds to the firms' steady state profit share, given by $(xh^{\alpha} - wh)/xh^{\alpha}$. I then set the value of the benefit from

[17] For a survey of the literature see Card (1994).

[18] Andolfatto (1996) sets n to 0.57, while den Haan, Ramey and Watson (2000) set it to 0.89. These values, which are obviously lower than in the data, can be justified by interpreting the unmatched workers in the model as being both unemployed and partly out of the labor force. This interpretation is consistent with the abstraction in the model from labor force participation decisions.

[19] This is actually only a normalization.

[20] In the literature η has been typically set either to satisfy the Hosios (1990) condition or to achieve symmetric Nash barganing (equally shared surplus). This has led most researchers to set values in the range 0.4 to 0.5.

unemployment, b, so that the profit rate under efficient bargaining is also equal to 10 percent.[21] The implied benefit from unemployment relative to what workers produce on the job, $\overline{b} = b/xh^{\alpha}$, is 0.47. This is close to the value of 0.4 typically assumed in the literature and consistent with the assumption that the value of non work activities is far below what worker produce on the job.[22] The parameter κ, then, is derived from the steady state relationships.

Finally, I follow the estimates presented in Clarida, Galí and Gertler (2000) and set the interest rate smoothing parameter ρ to 0.9, and the parameters γ_{π} and γ_{y} to 1.5 and 0.5.

6 Results

In this section I analyze the response of the model economy to a monetary policy shock under the two specifications of the bargaining process, EB and RTM. The monetary shock is a 25 basis point decrease in the nominal interest rate. I also compare the predictions of the model with those from a baseline NK model that does not have search and matching frictions but keeps all other features the same.

Figure 1 plots the impulse responses of the nominal interest rate, output, hours, real wages, marginal costs and inflation in the three models under the baseline calibration. The figure clearly shows that the behavior of all variables in the model with search, under both EB and RTM, is remarkably similar to the baseline NK model. Qualitatively, the fall in the nominal interest rate causes a decrease in the real interest rate because there are nominal price rigidities. As a consequence of the reduction in the real interest rate, aggregate demand, output of final goods and hours worked increase. The increase in output and hours worked can only occur at increased real wages and marginal costs. Then, because prices are set based on expected future real marginal costs, inflation raises. The responses are also very similar from a quantitative point of view. In the RTM model, the bargained wage is almost as volatile as the wage in the baseline NK model, implying that marginal costs and inflation also have similar volatilities. In the EB model, the real wage turns out to be less volatile than the competitive wage. However, because under EB the real wage is not allocational for hours, this does not cause the response of marginal costs and inflation to be lower than in the baseline model. Under EB, in fact, marginal costs are determined by the marginal disutility from supplying hours of work, and the response of hours is as volatile as in the NK model. Overall, under our baseline calibration, search and matching frictions do not seem to have any significant effect on the behavior of marginal costs and inflation.

Figure 2 presents the dynamics of the labor market under the two bargaining assumptions in the aftermath of the monetary shock. The figure plots the response of vacancies, the job creation rate, the probability that a vacancy is filled, the probability that a searching worker finds a job and, finally, the response of the labor input at both the extensive (number of workers employed) and

[21] That is, the efficient bargaining and the right to manage model are calibrated to have the same steady state.

[22] See Hall (2005b) for a discussion.

the intensive margin (hours per worker). The increase in current and future expected aggregate demand induces firms to raise their hiring activity. Thus, the number of vacancies posted and the job creation rate raise on impact, causing employment to raise from the following period. The increase in the number of vacancies relative to the number of searching workers, in turn, reduces the probability that a firm fills a vacancy and raises the probability that a worker finds a job. Finally, as the last two plots make clear, at first the hours of work increase significantly to enable firms to meet the higher demand. That is, on impact, output increases through a raise in hours worked, for a given level of employment. Then, as employment starts rising, the demand for intermediate goods per firm gradually decreases. As a consequence, the response of hours of work is reverted fairly quickly. Note that under EB the monetary shock causes a larger change in the firms' hiring activity, leading to a larger raise in employment as well. In both models, however, the response of employment is quite low relative to the response of hours of work.

6.1 The role of real wage rigidity

Under the baseline calibration, the model with search and matching frictions has similar implications for the cyclical behavior of real wages than the baseline NK model. However, the degree of wage rigidity delivered by the model is very sensitive to the calibration of two important parameters: the bargaining power η and the benefit from unemployment b. In the baseline calibration, the bargaining power parameter is set to 0.5 and the implied value of the benefit from unemployment, relative to what workers produce on the job, is 0.47. As noted earlier, these values are close to the values typically assumed in the literature. A recent paper by Hagedorn and Manovskii (HM, 2005), however, challenges the standard calibration and argues that a lower value of the bargaining power together with a larger value of the benefit from unemployment can be reasonably assumed to help the baseline search and matching model delivering rigid wages. Rigid wages, in turn, help the model to account for the high volatility in labor market activity that is observed in the data. Specifically, these authors set the bargaining power to 0.06 and the relative unemployment flow value to 0.94.[23]

With the only purpose of analyzing the effects of wage rigidity on the dynamic behavior of marginal costs and inflation, I then try setting η to a lower value. This implies, given the calibration strategy previously described, a larger value of the relative benefit from unemployment. Table 1 reports three alternative calibrations, where the last calibration comes near to the one proposed by HM.[24]

[23]The HM calibration has been criticized for relying on an implausibly high value of the flow benefit from unemployment. A number of alternative ways to generate rigid wages in the Mortensen and Pissarides model have been proposed in the literature (see Hall, 2005b, for a survey). Here, however, allowing for calibrations similar to HM allows me to illustrate in a simple, straightforward way the workings of the wage channel works under RTM.

[24]The third row in the table also corresponds to the values I assumed for the baseline calibration in a previous version of this paper (IGIER Working Paper No. 268).

Table 1: Alternative calibrations	
Bargaining power, η	Relative benefit, $\bar{b}$
0.5	0.47
0.1	0.78
0.01	0.81

Figure 3 plots the responses of real wages, marginal costs and inflation to the monetary shock under the three alternative calibrations, both in the EB and the RTM model. First of all, the figure shows that reducing the bargaining power, along with increasing the value of the benefit from unemployment, significantly reduces the response of real wages in both models of bargaining. This happens because the alternative calibrations increase the weight of the benefit from unemployment in the wage equation, relative to the other cyclical components (the marginal product of labor, the labor market tightness and the marginal disutility from supplying hours of work). This of course makes wages less sensitive to changes in aggregate economic conditions.

Wage stickiness, however, has a very different effect on marginal costs and inflation depending on which bargaining model is assumed. Under EB, marginal costs and inflation are almost unaffected by the wage rigidity. Because with EB marginal costs are determined by the marginal disutility of supplying hours of work, it must be the case that the wage rigidity only influences in a limited way the response of hours. In fact, because output is demand determined and employment cannot move on impact, hours of work must raise to enable firms to meet the higher demand. Under RTM, instead, the wage determines the marginal cost. Thus, wage stickiness directly translates into a lower elasticity of marginal costs with respect to output, implying that inflation is significantly less responsive to monetary shocks.

The main conclusion from this analysis is that under RTM any factor that may potentially influence the outcome of the wage bargaining process or affect the degree of wage rigidity will have a direct effect on marginal costs and inflation. This direct wage channel, instead, is absent from the EB model as the wage does not play an allocational role for hours. Along these lines, an interesting recent paper by Christoffel and Linzert (2005) augments the EB and RTM models developed here with an *ad hoc* wage rule, according to which the wage is assumed to be a weighted average of the bargained wage and last's period wage. They show that wage rigidity translates into less volatile and more persistent movements in inflation only in the RTM model.

6.2 The role of the extensive margin

In a recent paper, Trigari (2004) estimates the response of a set of labor market variables in the U.S. economy to a monetary shock and shows that the response of employment is significantly larger and more persistent than the response of hours worked. The model developed in this paper, in contrast, predicts that the labor input varies mostly at the intensive margin, while changes at the extensive margin are relatively small (see Figure 2). This happens for two reasons. First, only the hours of work can be freely and instantaneously adjusted to accommodate changes in demand-determined output. Second, because the model cannot generate a hump-shaped response in consumption, the largest change in aggregate demand and output occurs in the first period, when employment cannot adjust.[25] Thus, hours worked have to increase significantly to allow firms to meet the higher demand that results from the expansionary monetary shock.

McCallum and Nelson (1999), Fuhrer (2000) and Christiano, Eichenbaum and Evans (2005) show that habit formation in consumption preferences is important to understand the transmission mechanism of monetary shocks. In particular, it permits to account for the hump-shaped increase in consumption together with the fall in the real interest rate after a monetary shock.[26] Along these lines, I introduce habit persistence in consumption and show that when output responds gradually to the monetary shock a larger part of the response in total hours takes the form of changes at the employment margin. In fact, the progressive increase in output makes it possible for firms to plan ahead their job creation decisions and adjust the labor input at the extensive margin. Changes at the extensive margin, in turn, introduce an additional channel through which search frictions affect the dynamic behavior of marginal costs and inflation.

To introduce habit formation in consumption preferences, I assume that the utility from consumption in equation (1) is now given by $u(c_t, c_{t-1}) = \log(c_t - ec_{t-1})$, where $e > 0$ measures the degree of habit persistence. After setting e to the value of 0.6, I study the response of the model economy under EB and RTM and compare it to the baseline NK model.[27] Figure 4 plots the results. As in the baseline specification without habit persistence, the three models generate a similar qualitative response of all variables. From a quantitative point of view, however, the EB and the RTM models behave differently from the baseline NK model. First, they generate a lower volatility of inflation relatively to the volatility of output. This is particularly true in the EB model. The ratio of the peak response of inflation to the peak response of output is 1.63 in the NK model, 1.11 in the RTM model and 0.81 in the EB model. Second, they generate a more persistent response of output. In the baseline NK model output goes back to its steady state after 12 quarters, while it takes around 17 and 20 quarters in the RTM and the EB model, respectively. The lower volatility of inflation relative to output and the larger persistence of output are caused by the lower elasticity of marginal costs with respect to output. The figure shows that a given increase in output is associated with a lower increase in the level of marginal costs than in the baseline NK model. In turn, smaller variations in marginal costs induce firms setting prices to make smaller adjustments in prices. This increases the sluggishness of the aggregate price level to changes in aggregate demand and reduces the volatility of inflation. Finally, the lower sensitivity of the price level to variations in aggregate demand raises the persistence of aggregate demand and output to the monetary shock.

In the EB model, the elasticity of marginal costs with respect to output is lower because hours

[25] Output is solely determined by consumption demand, as I abstract from capital and government spending.

[26] A model with standard, time-separable preferences cannot reproduce this fact.

[27] The value of 0.6 is very close to the values estimated by Christiano, Eichenbaum and Evans (2005) and Trigari (2004).

worked are considerably less volatile than in the baseline NK model. This happens because unless an implausibly high labor supply elasticity is assumed the cost of producing one additional unit of output by changing hours worked, i.e., the marginal disutility from supplying hours of work, is relatively high. This induces firms to adjust the labor input mostly at the extensive margin. Figure 5 plots labor market dynamics when the model allows for habit formation in consumption preferences and shows that under EB the raise in employment is significantly larger and more persistent than the increase in hours per worker.

In the RTM model, the response of hours worked is also smaller than in the baseline NK model, though less than under EB. Figure 5 shows that while introducing habit persistence increases the share of fluctuations in total hours at the extensive margin, it remains true that hours fluctuate relatively more than employment. Under RTM, in fact, marginal costs are determined by real wages. These in turn, are only indirectly affected by the disutility from supplying hours worked. Therefore, in the RTM model, allowing firms to change the labor input at both margins has a smaller effect on the hours-employment trade off. For this reason, the response of real wages, marginal costs and inflation is only slightly smaller than in the baseline NK model.

The main results from this analysis can be summarized as follows. In the model with search and matching frictions the labor input can vary at both the intensive and the extensive margin. However, in the baseline specification, the largest increase in output occurs on impact when employment cannot adjust. This implies that firms are forced to rely on adjusting hours of work to meet the higher demand. When habit persistence is introduced, leading to a more gradual response of output, firms are effectively allowed to adjust the labor input at the extensive margin and choose to do so. This reduces the elasticity of marginal costs with respect to output, especially in the EB model where changes at the extensive margin affect marginal costs directly.[28]

I next analyze whether the ability of the model to allow for potentially large fluctuations in employment modifies the links between wage rigidity and the dynamic behavior of marginal costs and inflation. A number of recent papers, beginning with Shimer (2005) and Hall (2005a), considers the role of real wage rigidity in explaining labor market dynamics within a baseline Mortensen and Pissarides model.[29] By enhancing the cyclicality of firms' profits and incentives to hire, wage stickiness helps to account for the volatility of employment and labor market activity that is observed in the data. These analyses differ from the one conducted in this paper in several aspects: they study non monetary models, only consider the extensive margin and, finally, take technology shocks as the exogenous force driving fluctuations. Nevertheless, they suggest that in the current model wage rigidities might affect marginal costs indirectly by enhancing fluctuations of the labor input at the extensive margin. Figure 6 plots the responses of real wages, marginal costs and inflation to the monetary shock under the three alternative calibrations presented in the previous section, with the

[28] In Trigari (2004) I develop and estimate an EB model to the one presented here that also features endogenous job destruction. I show that in this case the extensive margin channel has an even stronger effect on the elasticity of marginal costs with respect to output.

[29] See Hall (2005b) for a survey. See also Hagedorn and Manovskii (2005).

alternative calibrations leading to different degrees of wage rigidity. It shows that, differently from the baseline specification without habit persistence, wage rigidity reduces the elasticity of marginal costs to output and the response of inflation under the EB specification as well. However, while under RTM marginal costs are determined by real wages, so that the wage rigidity directly affects their dynamic behavior, under EB the wage rigidity affects marginal costs because it enhances the cyclicality of firms' hiring incentives, leading to larger fluctuations at the employment margin relatively to the intensive margin.

7 Conclusions

This paper develops a dynamic general equilibrium model that integrates labor market search and matching into an otherwise standard NK model. I allow for changes of the labor input at both the extensive and the intensive margin and develop two alternative specifications of the bargaining process. Under efficient bargaining (EB) hours are determined jointly by the firm and the worker as a part of the same Nash bargain that determines wages. With right to manage (RTM), instead, firms retain the right to set hours of work unilaterally.

The main contribution of the paper is to shed light on how search and matching frictions change the nature of real marginal costs. This depends on the way firms and worker bargain about wages and hours of work. In the RTM model, the marginal cost is determined by the bargained wage, so that any factor that may influence the outcome of the bargaining process will have a direct influence on marginal costs and inflation dynamics. In particular, I show that labor market institutions such as the workers' bargaining power and benefit from unemployment directly affect the cyclical behavior of marginal costs and inflation. Moreover, if these institutions increase the degree of wage rigidity delivered by the model, this leads *directly* to a lower elasticity of marginal costs to output. This is not true in the EB model, where marginal costs are determined by the worker's marginal disutility from supplying hours of work. Under EB, in fact, the wage only represents a transfer between the worker and the firm and does not play an allocational role for hours. However, in the EB model marginal costs are affected by the simple fact that the labor input is allowed to change at both the extensive and the intensive margin. In particular, I show that as long as part of the variation in total hours occurs at the extensive margin, the elasticity of marginal costs will be lower than in a baseline NK model where all variation occurs at the intensive margin. Finally, I also clarify that in the EB model wage rigidity further reduces the volatility of marginal costs because it enhances the relative fluctuation at the extensive margin.

To summarize, search and matching frictions may affect the cyclical behavior of real marginal costs by way of two different channels: a wage channel under RTM and an extensive margin channel under EB. In both cases, moreover, they may cause a lower elasticity of marginal costs to output and thus help to account for the observed inertia in inflation. The assessment of the empirical relevance of the wage channel relative to the extensive one is left for future research.

References

[1] Andolfatto, David (1996). "Business Cycles and Labor Market Search", *American Economic Review* 861, 112-132.

[2] Andrews, M. and S. J. Nickell (1983). "Unions, Real Wages and Employment in Britain 1951-79", *Oxford Economic Papers*, New Series, Vol. 35, Supplement: The Causes of Unemployment, 183-206.

[3] Bernanke, Ben, Mark Gertler and Simon Gilchrist (1999). "The Financial Accelerator in a Business Cycle Framework", *Handbook of Macroeconomics*, J. Taylor and M. Woodford, editors.

[4] Calvo, Guillermo (1983). "Staggered Prices in a Utility Maximizing Framework", *Journal of Monetary Economics* 12, 383-398.

[5] Card, David (1994). "Intertemporal Labor Supply: An Assessment", *Advances in Econometrics*, C. Sims, editor.

[6] Christiano, Lawrence , Martin Eichenbaum and Charles Evans (2000). "Monetary Policy Shocks: What Have We Learned and to What End?", *Handbook of Macroeconomics*, J. Taylor and M. Woodford, editors.

[7] Christiano, Lawrence, Martin Eichenbaum and Charles Evans (2005). "Nominal Rigidities and the Dynamics Effects of a Shock to Monetary Policy", *Journal of Political Economy* 113(1), 1-45.

[8] Christoffel, Kai and Tobias Linzert (2005). "The Role of Real Wage Rigidity and Labor Market Frictions for Unemployment and Inflation Dynamics", ECB Working Paper No. 556.

[9] Clarida, Richard, Jordi Galí and Mark Gertler (2000). "Monetary Policy Rules and Macroeconomic Stability: Evidence and Some Theory", *Quarterly Journal of Economics* 115(1), 147-180.

[10] Cooley, Thomas and Vincenzo Quadrini (1999). "A Neoclassical Model of the Phillips Curve", *Journal of Monetary Economics* 4, 165-193.

[11] Davis Steven, John Haltiwanger and Scott Schuh (1996). Job Creation and Destruction, The MIT Press.

[12] den Haan, Wouter , Gary Ramey and Joel Watson (2000), "Job Destruction and Propagation of Shocks", *American Economic Review* 90, 482-498.

[13] Fuhrer, Jeffrey (2000). "Habit Formation in Consumption and Its Implications for Monetary-Policy Models," *American Economic Review* 90, 367-390.

[14] Galí, Jordi (2003). "New Perspectives on Monetary Policy, Inflation and the Business Cycle", *Advances in Economic Theory*, Vol. III, M. Dewatripont, L. Hansen and S. Turnovsky, editors, Cambridge University Press.

[15] Galí, Jordi, Mark Gertler and David Lopez-Salido (2001). "European Inflation Dynamics", *European Economic Review* 45(7), 1237-1270.

[16] Gertler, Mark and Antonella Trigari (2005). "Unemployment Fluctuations with Staggered Nash Wage Bargaining", mimeo.

[17] Hairault, Jean-Olivier (2002). "Labor market Search and International Business Cycles", *Review of Economic Dynamics* 5(3), 535-558.

[18] Hagedorn, Marcus and Iourii Manovskii (2005). "The Cyclical Behavior of Equilibrium Unemployment and Vacancies Revisited", mimeo, University of Pennsylvania.

[19] Hall, Robert (2005a). "Employment Fluctuations with Equilibrium Wage Stickiness", *American Economic Review*, 95 (1), 50-65.

[20] Hall, Robert (2005b). "Job Loss, Job Finding, and Unemployment in the U.S. Economy over the Past Fifty Years", *NBER Macroeconomic Annual*, M. Gertler and K. Rogoff, editors, MIT Press.

[21] Holmlund, Bertil and John Pencavel (1988). "The Determination of Wages, Employment, and Work Hours in an Economy with Centralised Wage Setting: Sweden, 1950-83", *The Economic Journal* 98(393), 1105-1126.

[22] Hosios, Arthur (1990). "On the Efficiency of Matching and Related Models of Search and Unemployment", *Review of Economic Studies* 57(2), 279-298.

[23] Krause, Michael and Thomas Lubik (2005). "The (Ir)relevance of Real Wage Rigidity in the New Keynesian Model with Search Frictions", *Journal of Monetary Economics*, forthcoming.

[24] Levin, Andrew, Alexei Onatski, John Williams and Noah Williams (2005). "Monetary Policy under Uncertainty in Micro-Founded Macroeconometric Models", NBER Working Paper No. 11523.

[25] McCallum, Bennett and Edward Nelson, 1999, Nominal Income Targeting in an Open-Economy Optimizing Model, *Journal of Monetary Economics* 43, 553-578.

[26] Merz, Monika (1995). "Search in the Labor Market and the Real Business Cycle", *Journal of Monetary Economics* 36, 269-300.

[27] Mortensen, Dale and Christopher Pissarides (1994). "Job Creation and Job Destruction in the Theory of Unemployment", *Review of Economic Studies* 61, 397-415.

[28] Nason, James and George Slotsve (2004). "Along the New Keynesian Phillips Curve with Nominal and Real Rigidities", FRBA Working Paper No. 2004-09.

[29] Petrongolo, Barbara and Christopher Pissarides (2001). "Looking into the Black Box: A Survey of the Matching Function", *Journal of Economic Literature* 39(2), 390-431.

[30] Pissarides, Christopher (2000). Equilibrium Unemployment Theory, The MIT Press.

[31] Shimer, Robert (2005). "The Cyclical Behavior of Equilibrium Unemployment and Vacancies: Evidence and Theory", *American Economic Review* 95(1), 25-49.

[32] Smets, Frank and Raf Wouters (2003). "An Estimated Dynamic Stochastic General Equilibrium Model of the Euro Area", *Journal of The European Economic Association* 1(5), 527-549.

[33] Trigari, Antonella (2003). "Labor Market Search, Wage Bargaining and Inflation Dynamics", IGIER Working Paper No. 268.

[34] Trigari, Antonella (2004). "Equilibrium Unemployment, Job Flows and Inflation Dynamics", ECB Working Paper No. 304.

[35] Walsh, Carl (2005). "Labor Market Search, Sticky Prices and Interest Rate Rules", *Review of Economic Dynamics* 8, 829-849.

Appendix

Derivation of the surplus from employment for a worker

This Appendix shows how the surplus from employment for a worker - the difference between the employment and unemployment values - can be obtained from the family's problem. In this way, it is possible to rationalize the existence of bargaining between workers and firms when workers are perfectly insured against the risk of being unemployed, as it is assumed in the paper. The argument is based on the assumption that workers value their actions in terms of the contribution these actions give to the utility of the family to which they belong. This implies that the surplus from employment for a worker can be defined as the change in the family's utility from having one additional member employed.

Suppose that there is a continuum of identical families indexed on the unit interval. Each of these families has a continuum of members with names on the unit interval. At time t, a fraction $n_t^a = (1-\rho)\, n_t$ of these members is employed, while the remaining fraction $1 - n_t^a$ is unemployed. Note that n_t^a denotes the number of individuals producing in period t. This is different from n_t, the number of individuals that are employed at the beginning of period t, previously to the realization of the separation shock. The representative family's optimal value function, denoted with Ω_t, can be written as:

$$\Omega_t\left(n_t^a\right) = u(c_t) - n_t^a g\left(h_t\right) + \beta E_t \Omega_{t+1}\left(n_{t+1}^a\right). \tag{57}$$

Note that the family's disutility from having a fraction n_t^a of its members supplying hours of work, previously denoted with G_t, is made explicit in (57) and is equal to $n_t^a g\left(h_t\right)$.

Each family faces the following budget constraint:

$$c_t + \frac{B_t}{p_t r_t^n} = n_t^a w_t h_t + \left(1 - n_t^a\right) b + \delta_t + \frac{B_{t-1}}{p_t}, \tag{58}$$

where the per capita family's income, previously denoted with d_t, is the sum of the first three terms on the right-hand side of the budget constraint. More precisely, the family obtains income from having a fraction n_t^a of its members working at the hourly wage w_t and a fraction $1 - n_t^a$ obtaining unemployment benefits b. Finally, δ_t denotes the family's per capita share of aggregate profits from retailers and intermediate goods firms, net of lump-sum government taxes.

The fraction of employed members evolves accordingly to the following dynamic equation:

$$n_{t+1}^a = (1-\rho)\, n_t^a + s_t (1-\rho)\left(1 - n_t^a\right), \tag{59}$$

where the representative family takes as given the probability s_t at which the search activity by the unemployed members leads to a job match.

Denote now with $\widetilde{S}_t^W$ the surplus from employment for a worker. As previously said, this is defined as the change in the family's optimal utility from having an additional member employed, that is,

$$\widetilde{S}_t^W \equiv \frac{\partial \Omega_t\left(n_t^a\right)}{\partial n_t^a}. \tag{60}$$

Taking the derivative of Ω_t in (57) with respect to n_t^a subject to equations (58) and (59) gives:

$$\frac{\partial \Omega_t}{\partial n_t^a} = \lambda_t w_t h_t - \lambda_t b - g\left(h_t\right) + \beta E_t \left[\left(1 - s_t\right)\left(1 - \rho\right) \frac{\partial \Omega_{t+1}\left(n_{t+1}^a\right)}{\partial n_{t+1}^a}\right]. \tag{61}$$

The surplus from employment, then, is given by the following expression:

$$\widetilde{S}_t^W = \lambda_t w_t h_t - \lambda_t b - g\left(h_t\right) + \beta E_t \left[\left(1 - s_t\right)\left(1 - \rho\right) \widetilde{S}_{t+1}^W\right]. \tag{62}$$

Finally, denote with S_t^W the value of the surplus from employment in terms of current consumption of final goods, i.e.,

$$S_t^W \equiv \frac{\widetilde{S}_t^W}{\lambda_t}. \tag{63}$$

After substituting into the above identity the expression for $\widetilde{S}_t^W$ and rearranging, the value of the surplus in terms of current consumption can be written as:

$$S_t^W = w_t h_t - b - \frac{g\left(h_t\right)}{\lambda_t} + E_t \beta_{t,t+1} \left[\left(1 - s_t\right)\left(1 - \rho\right) S_{t+1}^W\right]. \tag{64}$$

This equation corresponds to the difference between the value of employment (14) and the value of unemployment (15) that are reported in the paper.

Figure 1. Impulse responses to a monetary shock: baseline specification

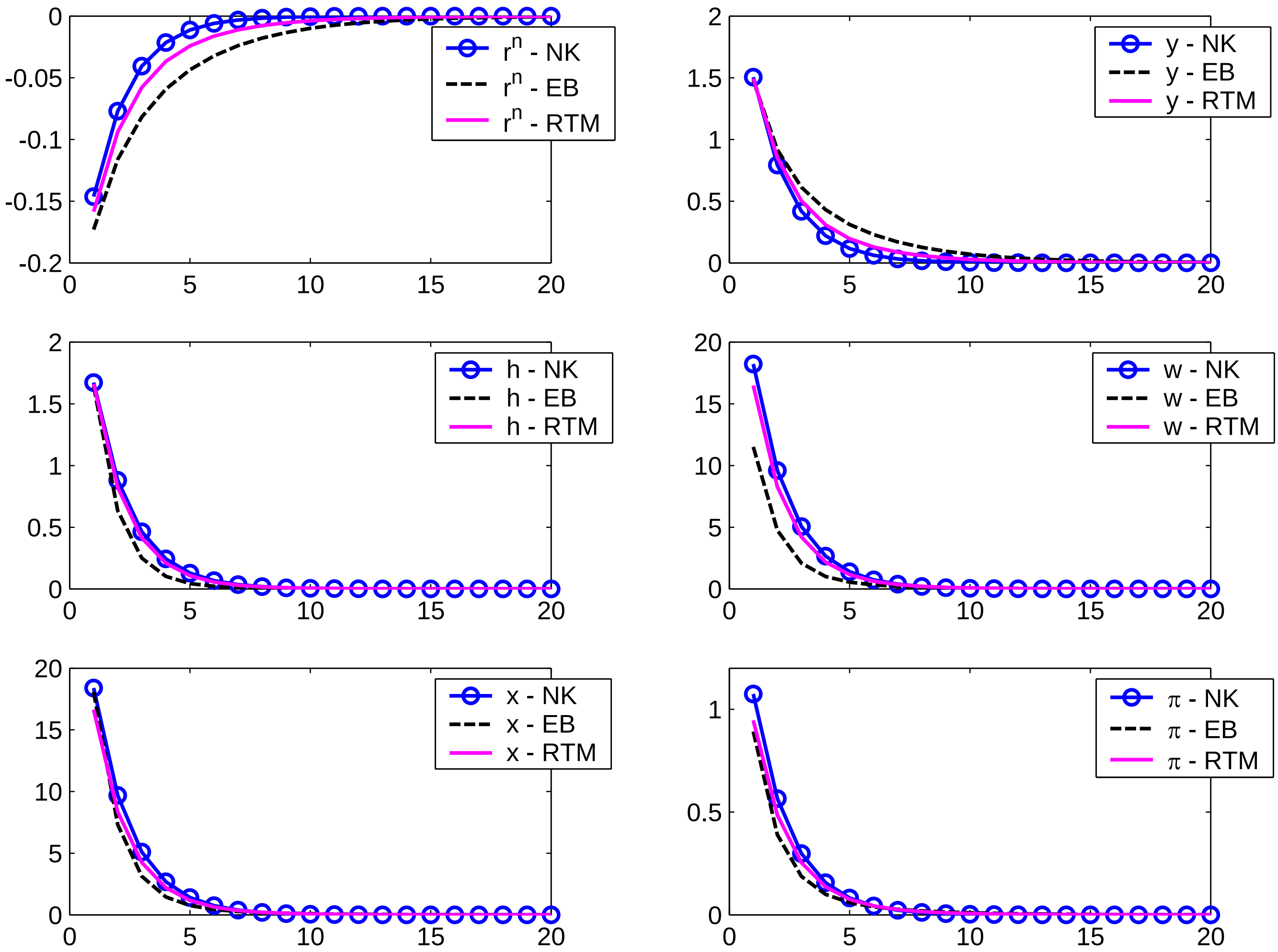

Figure 2. Labor market dynamics under EB and RTM: baseline specification

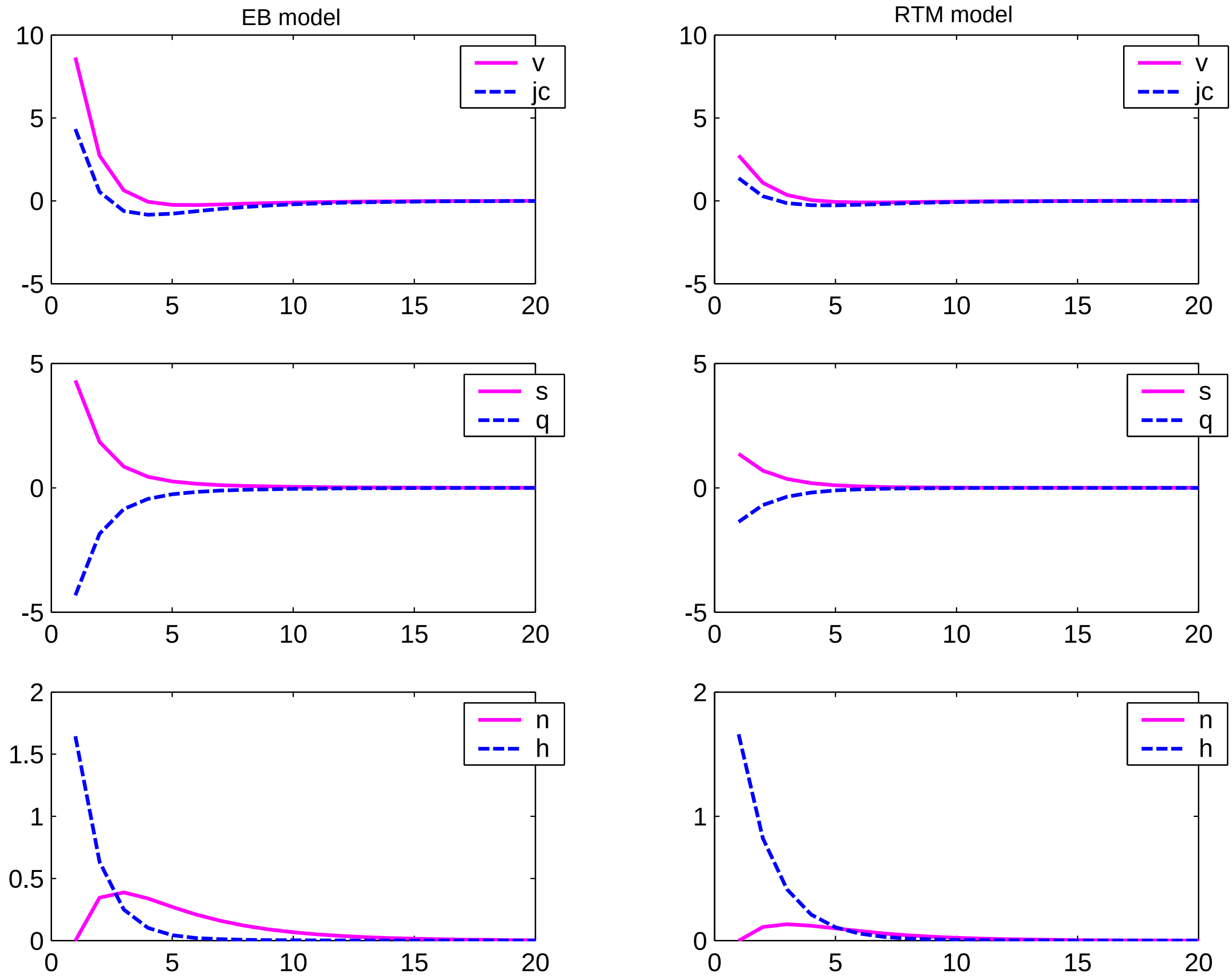

Figure 3. The effect of wage rigidity under EB and RTM: baseline specification

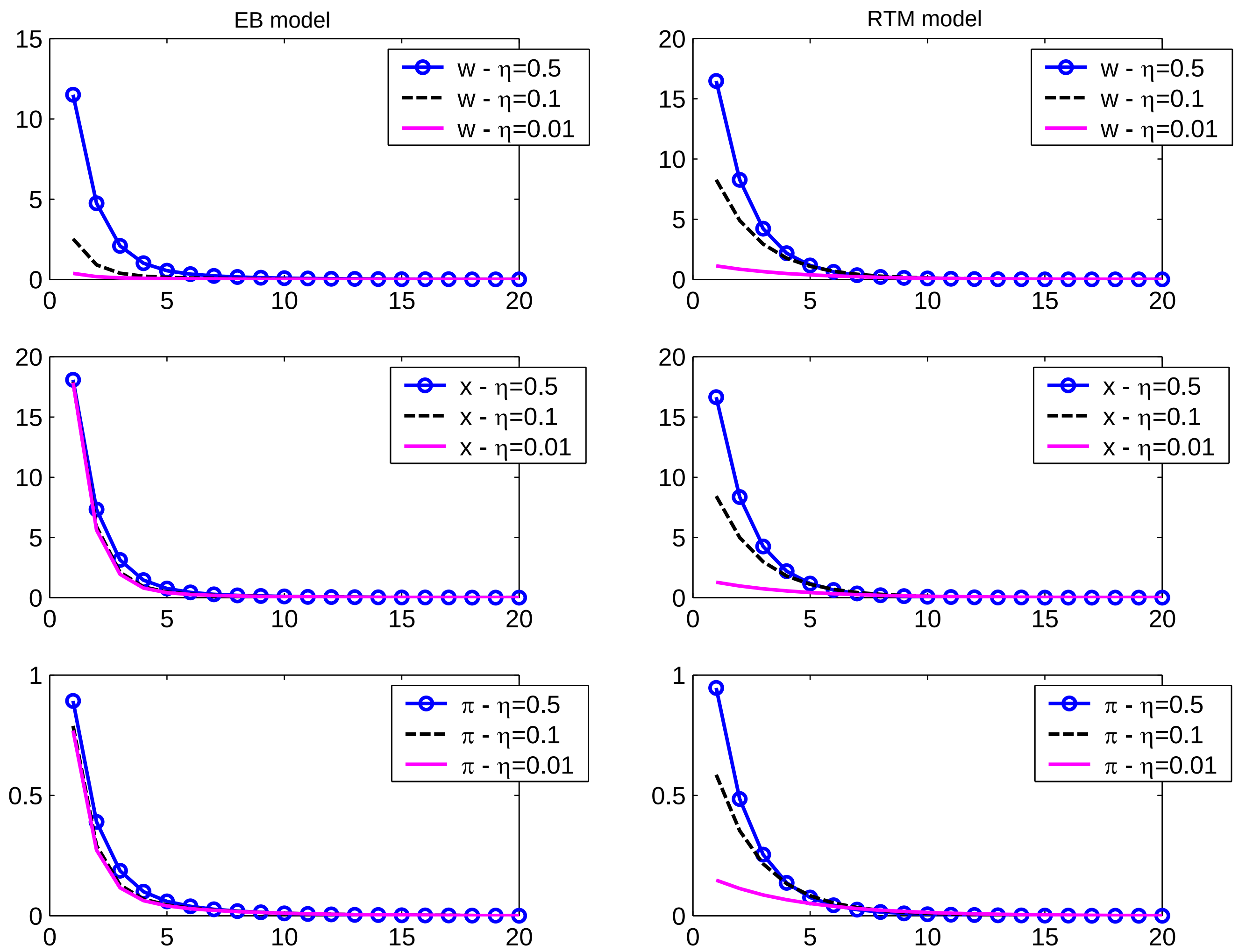

Figure 4. Impulse responses to a monetary shock: specification with habit persistence

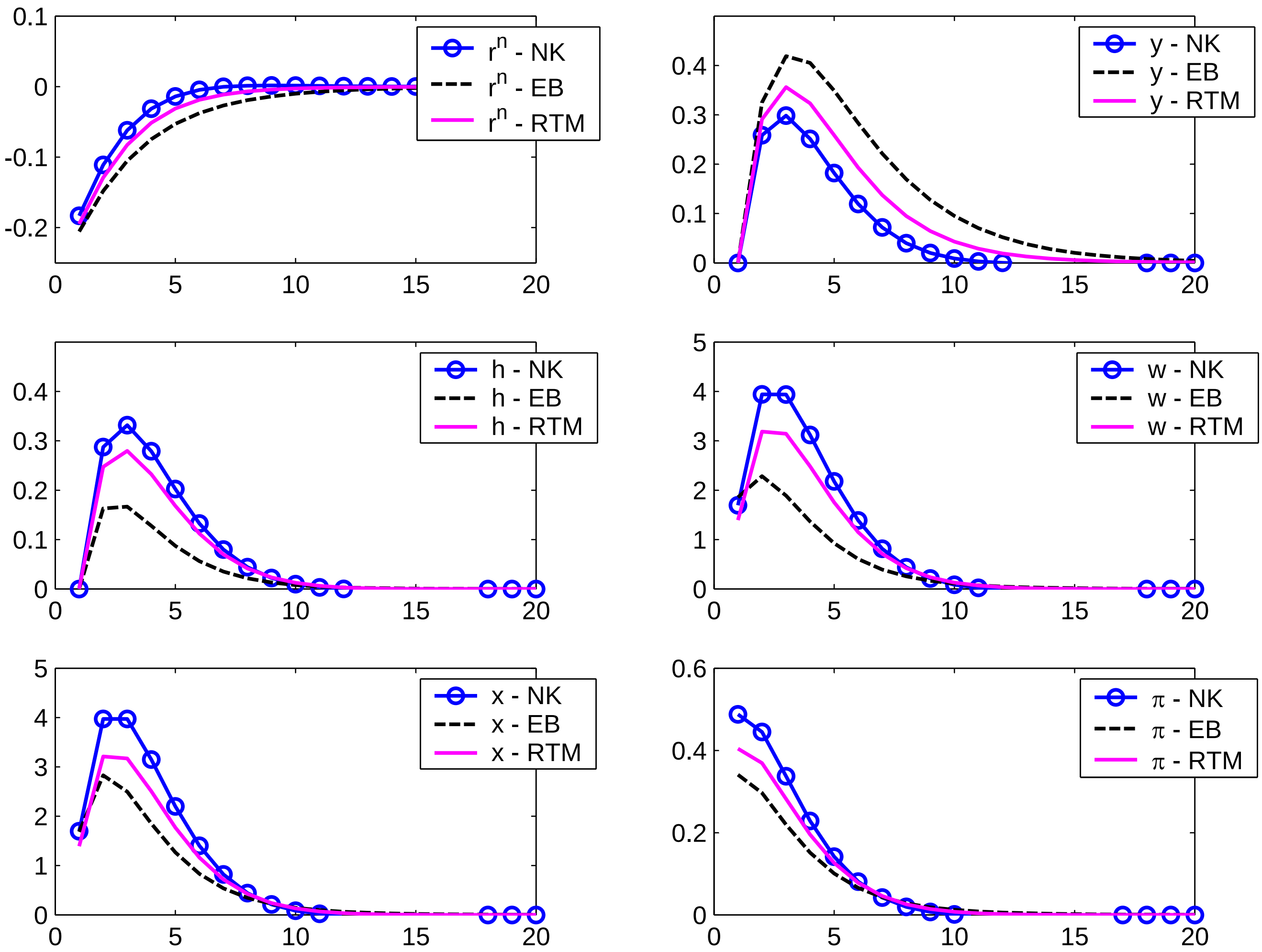

Figure 5. Labor market dynamics under EB and RTM: specification with habit persistence

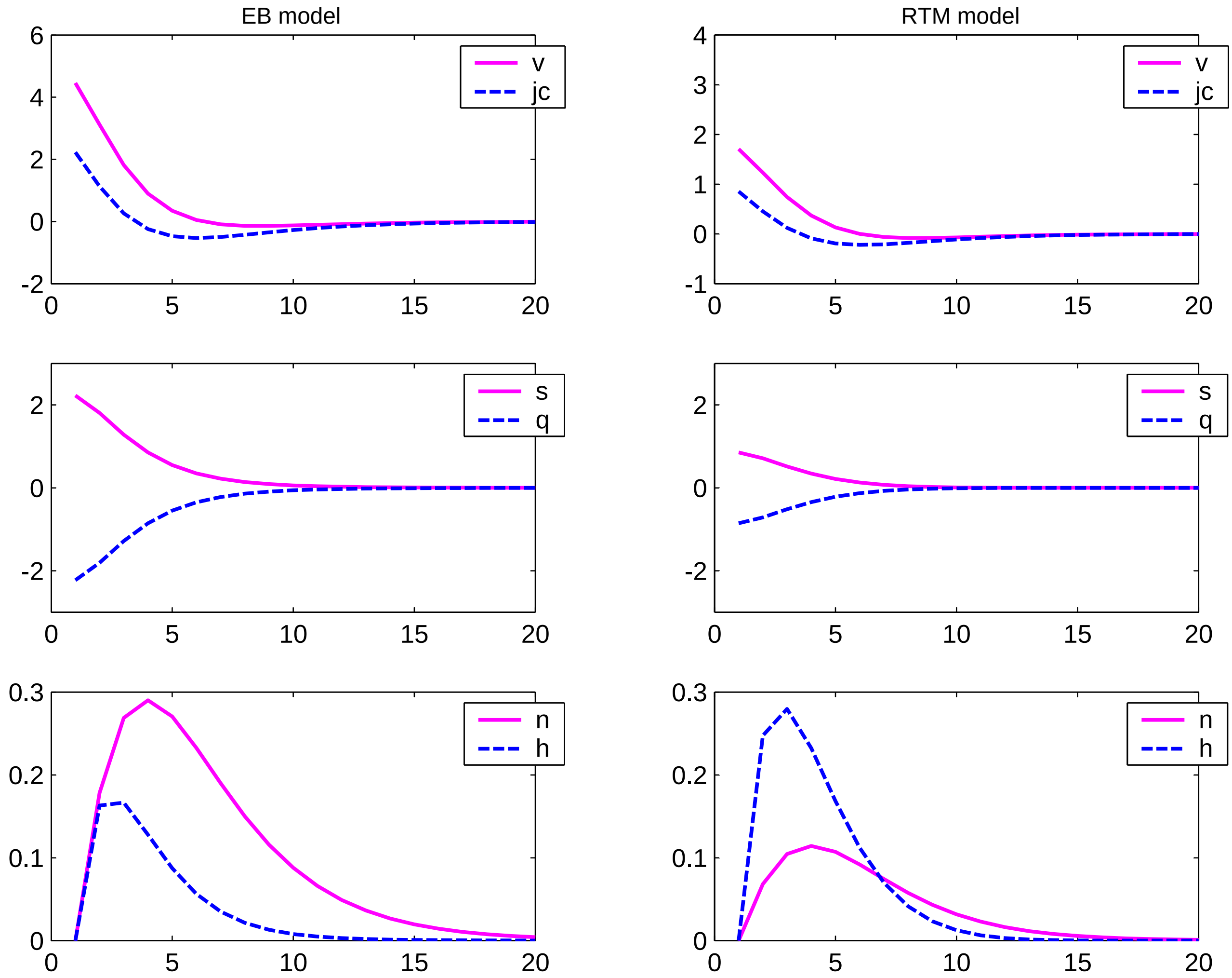

Figure 6. The effect of wage rigidity under EB and RTM: specification with habit persistence