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Labor Market Search, Wage Bargaining and Inflation Dynamics*

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Abstract

This paper integrates a theory of equilibrium unemployment into a monetary model with nominal price rigidities. The model is used to study the dynamic response of the economy to a monetary policy shock. The labor market displays search and matching frictions and bargaining over real wages and hours of work. Search frictions generate unemployment in equilibrium. Wage bargaining introduces a microfounded real wage rigidity. First, I study a Nash bargaining model. Then, I develop an alternative bargaining model, which I refer to as right-to-manage bargaining. Both models have similar predictions in terms of real wage dynamics: bargaining significantly reduces the volatility of the real wage. But they have different implications for inflation dynamics: under right-to-manage, the real wage rigidity also results in smaller fluctuations of inflation. These findings are consistent with recent evidence suggesting that real wages and inflation only vary by a moderate amount in response to a monetary shock. Finally, the model can explain important features of labor-market fluctuations. In particular, a monetary expansion leads to a rise in job creation and to a hump-shaped decline in unemployment.

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

1 Introduction

In recent years, a considerable amount of research has been devoted to understand the links between money, inflation and business cycle fluctuations. The new keynesian literature, in particular, has focused on investigating the demand-side effects of monetary policy. This literature, which integrates

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imperfect competition and nominal rigidities into an optimizing general equilibrium framework, has gained consensus among both policymakers and macroeconomists and it is widely used to analyze the economy's response to monetary policy shocks.

However, the baseline new keynesian model explains in an unsatisfactory manner, or has not attempted to explain, a number of stylized facts that characterize the labor market. These include the existence of unemployed workers, fluctuations in the rate of unemployment and the observation that the cyclical adjustment of the labor input occurs at both the extensive margin (through changes in the number of employed people) and the intensive margin (through changes in the hours worked by each employed person). The baseline model has also been criticized for generating too large fluctuations in real wages when assuming an elasticity of intertemporal substitution that is consistent with microeconomic estimates. This is why students of the business cycle typically assume an implausibly high willingness of individuals to substitute leisure across different times. A subsequent drawback of the baseline model is the prediction that inflation is strongly procyclical, while evidence indicates that it is only mildly so.[1]

Specifically, in the baseline new keynesian model, the occurrence of unemployment in equilibrium is ruled out by the assumption of a frictionless perfectly competitive labor market. This makes the baseline model unable to account for the observed significant levels of unemployment as well as the large and persistent fluctuations in that variable. The absence of labor-market frictions also implies that the real wage is equalized to the marginal rate of substitution between consumption and leisure. With output being-demand determined, the baseline model predicts that the number of hours worked varies significantly as consequence of a monetary policy shock. Unless the elasticity of intertemporal substitution is assumed to be implausibly high, this leads to sizeable movements in the marginal rate of substitution and, consequently, sizeable movements in real wages and marginal costs. Because firms set prices based on marginal costs, the large adjustment in marginal costs causes also a substantial response of inflation.

This paper develops a general equilibrium model that integrates a monetary new keynesian framework with a theory of equilibrium unemployment, along the lines of the work by Pissarides (1990). The model is characterized by three main building blocks: nominal rigidities in price setting, search and matching frictions in the labor market and decentralized bargaining over wages and hours of work. Nominal rigidities introduce a demand-side channel for monetary policy. Search frictions generate unemployment in equilibrium. Wage bargaining introduces a microfounded real wage rigidity. First, I study an efficient Nash bargaining model, which is standard in the equilibrium unemployment literature. Then, I develop an alternative bargaining model, which I refer to as right-to-manage bargaining. While the new bargaining model delivers similar implications to the Nash bargaining in terms of the dynamics of the real wage, it has different and more appealing implications for the dynamics of inflation.

[1] A number of recent papers have provided some evidence that following a monetary policy shock inflation and real wages vary only by a moderate amount. See, for example, Bernanke and Gertler (1995), Christiano, Eichenbaum and Evans (1997), Bernanke and Mihov (1998).

In general, many authors have suggested that introducing labor-market imperfections in monetary business cycle models may reduce the elasticity of marginal costs with respect to aggregate activity.[2] This, in turn, would lead to smaller variations in marginal costs and inflation after a monetary policy shock. In this paper, I explore whether a lower elasticity of marginal costs to output can arise from search and matching frictions and wage bargaining. In principle, this can happen for two reasons. First, because search and matching frictions generate unemployment in equilibrium, the model allows for variations of the labor input along the extensive margin. Thus, demand-determined variations in output can now be accommodated through changes in both employment and hours per worker. This microfounded real flexibility increases the elasticity of the response of output to aggregate demand without increasing the marginal cost.[3] However, under a reasonable parametrization of the model, this channel does not turn out to be quantitatively important.[4] Second, the wage rate prevailing under bargaining does not equal the competitive wage and may therefore behave quite differently from it. In particular, the bargained wage depends on the marginal rate of substitution but also on the state of the labor market, as it is represented by the exit rate from unemployment and the benefit from being unemployed. I show that, under a reasonable parametrization of the model, wage bargaining introduces a microfounded real wage rigidity that significantly reduces the response of real wages to changes in output. If the marginal cost of labor is determined by the real wage, then the real wage rigidity also reduces the volatility of marginal costs and inflation. However, this is true only under right-to-manage bargaining, as I discuss in the paper.

To introduce nominal price rigidities, I assume that at least some firms are monopolistic competitive and face constraints on the frequency with which they can adjust the price of the good they produce, as in Calvo (1983). 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.[5,6] 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

[2]See, in particular, Christiano, Eichenbaum and Evans (1997), Dotsey and King (2001) and Gertler, Galí and Lopez-Salido (2001).

[3]The terminology "real flexibility" has first been used by Dotsey and King (2001).

[4]This happens because the model cannot account for the significantly larger variation of the labor input at the extensive margin than at the intensive one, as it is observed in the data. One reason why employment is not very volatile is that I assume *exogenous* job destruction. This implies that employment can vary only at the job creation margin. If job destruction were to be endogenous, however, the right-to-manage model of bargaining, which is central to this paper, would become highly untractable. In Trigari (2003), I develop a model that is similar in the spirit to the one developed in this paper but allows for endogenous job destruction and several other features that turn out to be important to match the data. There, I focus on the extensive margin channel to explain the dynamics of inflation.

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

[6]For simplicity, I will often refer to retail firms as retailers and to intermediate goods firms as simply firms.

sector.

The main results of the paper can be summarized as follows. First, under a reasonable parametrization of the model, the response of the real wage is significantly less volatile than in a baseline new keynesian model. This is true under both bargaining models: efficient Nash bargaining and right-to-manage. Second, under right-to-manage the real wage rigidity reduces the elasticity of marginal costs with respect to output and leads to a considerably smaller volatility of inflation than in the baseline model. Third, monetary policy shocks can explain important features of labor-market fluctuations: a monetary expansion leads to a rise in job creation and to a hump-shaped decline in unemployment.

Several recent papers have considered search and matching in a real business cycle model and showed that this new framework improves the empirical performance of the standard model in several directions (Merz, 1995, Andolfatto, 1996, and den Haan, Ramey and Watson, 1997). These non-monetary models, however, are not suitable to study how search and matching shape the response of the economy to monetary policy shocks. Cooley and Quadrini (1999) integrate a model of equilibrium unemployment with a limited participation model of money. Their model is consistent with evidence about the impact of monetary policy shocks on the economy and can produce labor-market dynamics that fit the data. However, their analysis focuses on the cost channel, or supply-side channel, of monetary transmission and ignore the demand-type channel due to nominal rigidities. Finally, a recent paper by Walsh (2003) also studies, independently from this paper, the interaction between price rigidities and labor-market search.

The remainder of the paper is organized as follows: Section 2 describes the model, Section 3 presents the dynamics of the model around the steady state, Section 4 describes the model calibration, Section 5 discusses the results from simulating the log-linearized version of the model and compare them to those obtained from the baseline new keynesian model. Finally, Section 6 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 retailers 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

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

and

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

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

The presence of equilibrium unemployment introduces heterogeneity in the model. In the absence of perfect income insurance, each individual's labor income differs based on his employment status. In this case, the individuals' saving decision would become dependent on their entire employment history. To the purpose of this paper, I avoid these distributional issues by assuming that family members pool their incomes and chose per capita consumption and asset holdings to maximize the expected lifetime utility of the representative household:[7]

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

where $\beta \in (0,1)$ is the intertemporal discount factor and c_t is per capita consumption of each family member at date t. 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. 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). The solution to this problem gives a standard Euler equation for consumption:

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

[7] The same result could be obtained with a more sophisticated variant of the income-pooling hypothesis if the individuals insure one another against the risk of being unemployed. See as an example Andolfatto (1996).

[8] This term is nevertheless important to derive the value of employment and unemployment 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 non-tradable output of final good produced at home by unemployed family members and the family share of aggregate profits from retailers and matched firms.

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

$$r_t = \frac{p_t}{p_{t+1}} r_t^n. \tag{7}$$

2.2 Firms and the labor market

Firms producing intermediate goods sell their output in competitive markets and use labor as their only input. They meet workers on a matching market. That is, firms cannot hire workers instantaneously. Rather, workers must be hired from the unemployment pool through a costly and time-consuming job creation process. Workers' wages and hours of work are determined through a decentralized bargaining process.

2.2.1 Matching market

In order to match with a worker, firms must actively search for workers in the unemployment pool. This idea is formalized 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.[10] Denote with v_t the number of vacancies posted by firms at date t and with u_t the number of workers seeking for a job at date t.

Vacancies are matched to searching workers at a rate that depends on the number of searchers on each side of the market, i.e., the number of workers seeking for a job and the number of posted vacancies. In particular, the flow of successful matches within period t, denoted with m_t, is given by the following matching function:

$$m_t = \sigma_m u_t^{\sigma} v_t^{1-\sigma}, \tag{8}$$

where $\sigma \in (0,1)$ and σ_m is a scale parameter reflecting the efficiency of the matching process. Notice that the matching function is increasing in its arguments and satisfies constant returns to scale. It is convenient to introduce the ratio v_t/u_t as a separate variable denoted with θ_t. This ratio is the relative number of searchers and measures the labor-market tightness.

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

$$q_t = \frac{m_t}{v_t} = \sigma_m \theta_t^{-\sigma}. \tag{9}$$

This implies that firms with vacancies find workers more easily the lower is the market tightness, that is, the higher is the number of searching workers relative to the available jobs. 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:

$$s_t = \frac{m_t}{u_t} = \sigma_m \theta_t^{1-\sigma}. \tag{10}$$

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

Analogously, searching workers find jobs more easily the higher is the market tightness, that is, the higher is the number of vacant jobs relative to the number of available workers.

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.

Let us now characterize the employment dynamics. First, because job searching and matching is a time-consuming process, matches formed in $t-1$ only start producing in t. Second, employment relationships might be severed for exogenous reasons in any given period, so that the stock of active jobs is subject to continual depletion. Hence, employment n_t evolves according to the following dynamic equation:

$$n_t = (1-\rho)\, n_{t-1} + m_{t-1}, \tag{11}$$

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:

$$u_t = 1 - (1-\rho)\, n_t, \tag{12}$$

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

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:

$$J_t = x_t f(h_t) - w_t h_t + E_t \beta_{t+1} (1-\rho)\, J_{t+1}, \tag{13}$$

where x_t and w_t denote, respectively, the relative price of the intermediate good and the hourly wage rate at date t. The current value of the job is simply equal to the profits: $x_t f(h_t) - w_t h_t$. The future expected present value of the job, instead, can be explained as follows. Next period, with probability $1-\rho$ the match is not severed. In this event the firm obtains a future payoff 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 β_{t+1}, where $\beta_{t+s} = \frac{\beta^s \lambda_{t+s}}{\lambda_t}$.[11]

Denote with V_t the value of an open vacancy for a firm at time t expressed in terms of current consumption. With probability $q_t(1-\rho)$ the vacancy is filled in t and it is not discontinued in $t+1$. In this case the vacancy becomes a match with value J_{t+1}. With probability $1-q_t$ the vacancy remains open. Finally, with probability $q_t\rho$ the vacancy is filled in t but the new match is discontinued in $t+1$. In this case the future value is zero. Denoting with κ the utility cost of keeping a vacancy open, V_t can be written as:

$$V_t = -\frac{\kappa}{\lambda_t} + E_t\beta_{t+1}\left[q_t(1-\rho)J_{t+1} + (1-q_t)V_{t+1}\right]. \tag{14}$$

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.[12] Consider first the situation of an employed worker. The current value of employment is the labor income net of the labor disutility. Next period, with probability $1-\rho$ the match is not discontinued and the worker obtains a future payoff W_{t+1}. In contrast, with probability ρ the match is severed and the worker becomes unemployed with future payoff U_{t+1}. Therefore, W_t can be written as:

$$W_t = w_t h_t - \frac{g(h_t)}{\lambda_t} + E_t\beta_{t+1}\left[(1-\rho)(W_{t+1} - U_{t+1}) + U_{t+1}\right], \tag{15}$$

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

Finally, consider the situation of an unemployed worker. His current value is equal to the benefit b from being unemployed. I assume that each unemployed individual produces at home a non-tradable output b of the final good. Then, with probability $s_t(1-\rho)$ the unemployed worker is matched with a firm in period t and continues in the match in $t+1$. In this case he obtains a future payoff W_{t+1}. With probability $1-s_t+s_t\rho$, instead, the worker remains in the unemployment pool. Therefore, U_t is given by:

$$U_t = b + E_t\beta_{t+1}\left[s_t(1-\rho)(W_{t+1} - U_{t+1}) + U_{t+1}\right]. \tag{16}$$

2.2.3 Vacancy posting

In this section I study the opening of new vacancies. Note that opening a new vacancy is not job creation. Job creation takes place when a firm with a vacant job and an unemployed worker meet and agree to form a match.

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

[12]Because there is perfect income insurance it is not straightforward to define these values. In the Appendix W_t and U_t are derived from the family problem.

As long as the value of a vacancy V_t is greater than zero, firms will open new vacancies. In this case, however, as the number of vacancies increases, the probability q_t that any open vacancy finds a suitable worker decreases. A lower probability of filling a vacancy reduces the attractiveness of recruitment activities, thus decreasing the value of an open vacancy. In equilibrium, free entry ensures that $V_t = 0$ at any time t. Hence, from (14) the condition for the posting of new vacancies is:

$$\frac{\kappa}{\lambda_t q_t} = E_t \beta_{t+1} (1 - \rho) J_{t+1}. \tag{17}$$

Noting that $1/q_t$ is the expected duration of an open vacancy, equation (17) simply says that in equilibrium the expected cost of hiring a worker is equal to the expected value of a match.

Substituting recursively equation (13) into (17) and using the law of iterated expectations I obtain:

$$\frac{\kappa}{\lambda_t q_t} = E_t \sum_{s=1}^{\infty} \beta_{t+s} (1 - \rho)^s \widetilde{\pi}_{t+s}, \tag{18}$$

where the variable $\widetilde{\pi}_t$ denotes the profits of the firm at date t.

Equation (18) 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 (18) can be rearranged to a first-order difference equation in q_t:

$$\frac{\kappa}{\lambda_t q_t} = E_t \beta_{t+1} (1 - \rho) \widetilde{\pi}_{t+1} + E_t \beta_{t+1} (1 - \rho) \frac{\kappa}{\lambda_{t+1} q_{t+1}}. \tag{19}$$

2.3 Two models of bargaining

In equilibrium, matched firms and workers obtain from the match a total return that is strictly higher than the expected return of unmatched firms and workers. The reason is that if the firm and the worker separate, each will have to go through an expensive and time-consuming process of search before meeting another partner. Hence a realized job match needs to share this pure economic rent which is equal to the sum of expected search costs for the firm and the worker. The most natural way to do this is through bargaining.

Bargaining can take place along two dimensions, according to whether the firm retains the right to manage or determine hours. If it does, the firm and the worker bargain over the real wage, and the firm then chooses the hours of work to maximize its value from employment for a given bargained wage. The alternative assumption is that the firm and the worker bargain simultaneously over the wage and the hours of work.

I assume Nash bargaining: the outcome of the bargaining process maximizes the weighted product of the parties' surpluses from employment:

$$(W_t - U_t)^{\eta} (J_t - V_t)^{1-\eta}, \tag{20}$$

where the first term in brackets is the worker's surplus, the second is the firm's surplus, and η reflects the parties' relative bargaining power, other than the one implied by the "threat points" U_t and V_t.[13]

As I discuss below, if both the worker and the firm bargain simultaneously about wages and hours, the outcome is (privately) efficient and the wage plays only a distributive role. The model of efficient bargaining, in effect, is equivalent to one where hours are chosen to maximize the joint surplus of the match, while the wage is set to split that surplus according to the parameter η. I will refer to this bargaining model as "efficient Nash bargaining".[14] If instead the firm retains the right to determine hours, for a given bargained wage, the wage is allocative. In this case, the optimal pair (w_t, h_t) fails to maximize the joint surplus of the match. The allocation of resources within the match is then inefficient in that at least one of the two parties could be better off by bargaining over hours as well as wages. I will refer to this bargaining model as "right-to-manage bargaining".

Below I characterize the equilibrium wage and working hours under efficient Nash bargaining and right-to-manage bargaining.

2.3.1 Efficient Nash bargaining

Together the firm and the worker choose the real wage w_t and the hours of work h_t to maximize (20), taking as given the relative price x_t.

The wage w_t chosen by the match satisfies the optimality condition

$$\eta J_t = (1 - \eta)(W_t - U_t). \tag{21}$$

This condition implies that the total surplus that a job match creates is shared according to the parameter η, as mentioned above. To see why, let $S_t = W_t - U_t + J_t$ denote the total surplus from a match at date t. Finally, from (21) we obtain $W_t - U_t = \eta S_t$ and $J_t = (1 - \eta) S_t$.

[13] I will treat η as a constant parameter strictly between 0 and 1.

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

Substituting (13), (15) and (16) into (21), I obtain:

$$w_t h_t = \eta \left(x_t f(h_t) + f_t^F \right) + (1-\eta) \left(\frac{g(h_t)}{\lambda_t} + b - f_t^W \right), \tag{22}$$

where f_t^F and f_t^W are the future expected net present values from employment for the firm and the worker, respectively.[15] The above equation can be interpreted as follows. The wage shares costs and benefits from the activity of the match according to the parameter η. In particular, the first term on the right-hand side indicates that 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. The second term indicates that the worker is compensated for a fraction $1-\eta$ of the disutility he suffers from supplying hours of work, the foregone benefit from unemployment and the foregone future expected net present value from unemployment (which is simply equal to minus the future expected net present value from employment).

Finally, using also equations (9), (10), (17) and (21), I obtain the following wage equation:

$$w_t = \eta \left(\frac{x_t mpl_t}{\alpha} + \frac{\kappa}{\lambda_t} \frac{\theta_t}{h_t} \right) + (1-\eta) \left(\frac{mrs_t}{1+\phi} + \frac{b}{h_t} \right), \tag{23}$$

where $mpl_t = f_h(h_t)$ and $mrs_t = \dfrac{g_h(h_t)}{\lambda_t}$.

In a frictionless perfectly competitive labor market, the wage would adjust to equate the marginal rate of substitution between consumption and leisure and the marginal product of labor. With efficient Nash bargaining and equilibrium unemployment the wage does not equal (although is related to) the marginal rate of substitution or the marginal product of labor. In particular, from (23) the wage also depends on the state of the labor market as it is measured by the exit rate from unemployment - the labor market tightness - and the level of the benefit from being unemployed. In a tight labor market, knowing that finding another job is likely to be easy, workers will only accept a relatively high wage. Conversely, in a depressed labor market they will be willing to settle for a lower wage. The level of the benefit from unemployment affects the equilibrium wage through a similar channel: the higher the benefit, the lower the cost of being unemployed and the higher the bargained wage. The bargained wage, then, may potentially behave quite differently from the competitive wage.

Below, after deriving a log-linearized version of (23) that expresses the hourly real wage as a weighted sum of the marginal rate of substitution, the market tightness per hour (normalized by the marginal utility of consumption) and the benefit from unemployment per hour, I show that the response of the bargained wage to a monetary shock under efficient Nash bargaining is significantly smaller than the response of the competitive wage in the baseline new keynesian model. This occurs because while the marginal rate of substitution is strongly procyclical, the market tightness per hour is less procyclical and the benefit from unemployment per hour is countercyclical.

[15] From equations (13), (15) and (16): $f_t^F = E_t \beta_{t+1} (1-\rho) J_{t+1}$ and $f_t^W = E_t \beta_{t+1} (1-\rho)(1-s_t)(W_{t+1} - U_{t+1})$.

Let us now turn to the determination of hours. Because firms and workers bargain over both hours and wages, hours are chosen in an efficient way. Efficiency in the context of this model is where marginal rates of substitution of real wages for hours, for both the worker and the firm, are equal:[16]

$$\frac{mrs_t - w_t}{h_t} = \frac{x_t mpl_t - w_t}{h_t}. \tag{24}$$

Simplifying further yields:

$$x_t mpl_t = mrs_t, \tag{25}$$

where the value of the marginal product of labor is equated to the marginal disutility of supplying hours of work (normalized by the marginal utility of consumption). Thus, the correct measure of labor costs to the firms is the marginal rate of substitution between consumption and leisure, rather than the wage. That is, the marginal cost is determined by the marginal rate of substitution (divided by the marginal product of labor). This also implies that the wage only plays a distributive role.

2.3.2 Right-to-manage bargaining

If firms can set the hours of work ex-post, for a given bargained wage, then they choose hours to maximize their match value (13) taking as given the relative price x_t. The hours chosen by the firm satisfy the optimality condition:

$$x_t mpl_t = w_t, \tag{26}$$

or, alternatively,

$$h_t = f_h^{-1}\left(\frac{w_t}{x_t}\right) \equiv h\left(w_t\right). \tag{27}$$

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 under right-to-manage the wage is allocative and the marginal cost is determined by the wage (divided by the marginal product of labor).

Before the firm sets the optimal hours as in (27), the firm and the worker choose the wage so as to maximize (20) taking as given x_t and (27). That is, they take into account the second-stage hours determination. The wage chosen by the match satisfies the optimality condition

$$\eta \delta_t^W J_t = (1-\eta)\, \delta_t^F \left(W_t - U_t\right), \tag{28}$$

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

[16]To obtain (24) take the first-order condition with respect to h_t. Then, simplify the expression using (21) and divide by h_t.

each party, weighted by each party's bargaining strength. The net marginal benefits to the worker and the firm are:

$$\delta_t^W = h_t + w_t h_w(w_t) - mrs_t h_w(w_t) = \frac{h_t}{\alpha}\left(\frac{mrs_t}{w_t} - \alpha\right) \tag{29}$$

and

$$\delta_t^F = -\left[x_t mpl_t h_w(w_t) - h_t - w_t h_w(w_t)\right] = h_t. \tag{30}$$

Following the same steps as above, yields a wage equation that is very similar to the one obtained under efficient Nash bargaining:

$$w_t h_t = \chi_t\left(x_t f(h_t) + f_t^F\right) + (1-\chi_t)\left(\frac{g(h_t)}{\lambda_t} + b - f_t^W\right), \tag{31}$$

where

$$\chi_t = \frac{\eta\delta_t^W}{\eta\delta_t^W + (1-\eta)\,\delta_t^F}. \tag{32}$$

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 benefit from unemployment, plus the foregone future expected net present value from unemployment. In equation (31), however, the weights not only depend on the relative bargaining power η but also on the wage relative allocative effect, as it is captured by δ_t^W and δ_t^F.

Then, using equations (9), (10), (17), (28) and rearranging, I obtain the following wage equation:

$$w_t = \chi_t\left(\frac{x_t mpl_t}{\alpha} + \frac{\kappa}{\lambda_t}\frac{\theta_t}{h_t}\right) + (1-\chi_t)\left(\frac{mrs_t}{1+\phi} + \frac{b}{h_t}\right) + \chi_t(1-s_t)\frac{k}{\lambda_t q_t}\left(1 - \frac{1-\chi_t}{\chi_t}\frac{\chi_{t+1}}{1-\chi_{t+1}}\right). \tag{33}$$

Below, I derive a log-linear version of (33) that expresses the hourly wage as a weighted sum of the marginal rate of substitution, the market tightness per hour (normalized by the marginal utility of consumption) and the benefit from unemployment per hour, plus an additional term capturing movements in the weight χ at time t and $t+1$. Although the response of the wage turns out to be different than under efficient bargaining, it is still true that the bargained wage is significantly less volatile than the competitive wage in the baseline new keynesian model.

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.

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:

$$y_t = \left[\int_0^1 y_{it}^{\frac{\varepsilon-1}{\varepsilon}}\,di\right]^{\frac{\varepsilon}{\varepsilon-1}}, \tag{34}$$

where ε, which is assumed to be greater than one, is the elasticity of substitution across the differentiated retail goods.

Given the index (34) that aggregates individual retail goods into final goods, the demand curve facing each retailer is given by:

$$y_{it} = \left(\frac{p_{it}}{p_t}\right)^{-\varepsilon} y_t. \tag{35}$$

The aggregate price index, which is defined as the minimum expenditure required to purchase retail goods resulting in one unit of the final good, is:

$$p_t = \left[\int_0^1 p_{it}^{1-\varepsilon} di\right]^{\frac{1}{1-\varepsilon}}. \tag{36}$$

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.[17]

Retailers 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. Retailers, then, maximize

$$E_t \sum_{s=0}^{\infty} \varphi^s \beta_{t+s} \left[\frac{p_{it}}{p_{t+s}} - x_{t+s}\right] y_{it,t+s}, \tag{37}$$

where $y_{it,t+s}$ denotes the demand for good i at date $t+s$ conditional on the price set at date t. Note that the relative price of intermediate goods, x_t, coincides with the real marginal cost faced by retailers. The solution to this problem gives the following expression for the optimal reset price, p_{it}:

$$p_{it} = \mu E_t \sum_{s=0}^{\infty} \omega_{t,t+s} x_{t+s}^n, \tag{38}$$

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:

$$\omega_{t,t+s} = \frac{\varphi^s \beta_{t+s} R_{it,t+s}}{E_t \sum_{k=0}^{\infty} \varphi^k \beta_{t+k} R_{it,t+k}}, \tag{39}$$

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.[18]

[17] The Calvo's model avoids keeping track of every agent's pricing decision when prices are fixed for a certain number of periods.

[18] In the limiting case in which retailers are allowed to reset their price every period ($\varphi = 0$), equation (38) reduces to the standard condition that the price is a constant markup over the nominal marginal cost.

The average price of the retailers that do not adjust their price can be shown to be simply p_{t-1}. Thus, given (36), the aggregate price level evolves according to the following equation:

$$p_t = \left[\varphi p_{t-1}^{1-\varepsilon} + (1-\varphi)\, p_{it}^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}}. \tag{40}$$

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

$$y_t = c_t, \tag{41}$$

and the market clearing condition in the intermediate good sector

$$y_t = n_t\,(1-\rho)\, f(h_t), \tag{42}$$

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.

2.5 Monetary authority

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

$$r_t^n = \left(r_{t-1}^n\right)^{\rho^m} E_t\,(p_{t+1}/p_t)^{\gamma_\pi(1-\rho^m)}\,(y_t)^{\gamma_y(1-\rho^m)}\, e^{\varepsilon_t^m}. \tag{43}$$

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 inflation and output. Finally, ε_t^m is an i.i.d. monetary policy shock.

3 Model dynamics

I obtain the dynamics of the model by taking a log-linear approximation of equations (6), (7), (8), (9), (10), (11), (12), (19), (23), (25), (26), (29), (30), (32), (33), (38), (39), (40), (41), (42) and (43) around a deterministic steady state, with zero inflation.[19] Before doing this, however, I briefly describe in the next Section a log-linearized version of a baseline new keynesian model, which I then compare to the model developed in this paper. In what follows variables with a "hat" denote log-deviations from their steady state value, while variables without a time subscript denote steady state values.

[19] Equations (23) and (25) are specific to the efficient bargaining model. Equations (26), (29), (30), (32) and (33) are specific to the right-to-manage model. All other equations are common to both models.

3.1 The baseline new keynesian model

In order to carry on the comparison, I maintain the same structure wherever is possible and simply assume away search frictions and wage bargaining. In particular I keep the distinction between monopolistic competitive retailers and intermediate goods firms. The equations that characterize the dynamics of the baseline new keynesian model follow.

Taylor-type interest rate rule

$$\widehat{r}_t^n = \rho^m \widehat{r}_{t-1}^n + (1-\rho^m)\,\gamma_\pi E_t \pi_{t+1} + (1-\rho^m)\,\gamma_y \widehat{y}_t + \varepsilon_t^m \tag{44}$$

Euler equation

$$\widehat{\lambda}_t = E_t \widehat{\lambda}_{t+1} + \widehat{r}_t \tag{45}$$

Resource constraint

$$\widehat{y}_t = \widehat{c}_t \tag{46}$$

Real interest rate

$$\widehat{r}_t = \widehat{r}_t^n - E_t \pi_{t+1} \tag{47}$$

Phillips curve

$$\pi_t = \varphi_x \widehat{x}_t + \beta E_t \pi_{t+1} \tag{48}$$

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

Market clearing

$$\widehat{y}_t = \alpha \widehat{h}_t \tag{49}$$

Labor demand

$$\widehat{x}_t + m\widehat{p}l_t = \widehat{w}_t \tag{50}$$

where $m\widehat{p}l_t = (\alpha - 1)\,\widehat{h}_t$

Labor supply

$$\widehat{w}_t = m\widehat{r}s_t \tag{51}$$

where $m\widehat{r}s_t = \phi \widehat{h}_t - \widehat{\lambda}_t$

Equation (44) describes the conduct of monetary policy. The Euler equation, the resource constraint and the expression for the real interest rate describe the demand side of the model.

The pricing decision of the retailers under the Calvo-type restriction delivers the forward-looking equation for inflation (48), which is the key ingredient of the baseline new keynesian model. It is the so-called new keynesian Phillips curve, which relates current inflation to expected future inflation and current real marginal costs, x_t. In setting their price at time t, retailers take into account the expected future path of real marginal costs, given the likelihood that their price may remain fixed for multiple periods.

As equation (49) shows, in the baseline new keynesian model, changes in the labor input only occur through changes in hours of work. Finally, the labor market is frictionless and competitive: the real wage adjusts to equate labor demand (the value of the marginal product of labor) and labor supply (the marginal rate of substitution).

3.2 The model with equilibrium unemployment and bargaining

In this Section I describe the dynamics of the model developed in this paper, under both specifications of the bargaining process: efficient Nash bargaining and right-to-manage.

Taylor-type interest rate rule

$$\widehat{r}_t^n = \rho^m \widehat{r}_{t-1}^n + (1-\rho^m)\gamma_\pi E_t \pi_{t+1} + (1-\rho^m)\gamma_y \widehat{y}_t + \varepsilon_t^m \tag{52}$$

Euler equation

$$\widehat{\lambda}_t = E_t \widehat{\lambda}_{t+1} + \widehat{r}_t \tag{53}$$

Real interest rate

$$\widehat{r}_t = \widehat{r}_t^n - E_t \pi_{t+1} \tag{54}$$

Phillips curve

$$\pi_t = \varphi_x \widehat{x}_t + \beta E_t \pi_{t+1} \tag{55}$$

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

Resource constraint

$$\widehat{y}_t = \widehat{c}_t \tag{56}$$

Market clearing

$$\widehat{y}_t = \alpha \widehat{h}_t + \widehat{n}_t \tag{57}$$

Matching function

$$\widehat{m}_t = \sigma \widehat{u}_t + (1-\sigma)\widehat{v}_t \tag{58}$$

Transition probabilities

$$\widehat{q}_t = \widehat{m}_t - \widehat{v}_t \tag{59}$$

$$\widehat{s}_t = \widehat{m}_t - \widehat{u}_t \tag{60}$$

Employment dynamics

$$\widehat{n}_t = (1-\rho)\widehat{n}_{t-1} + \rho \widehat{m}_{t-1} \tag{61}$$

Searchers

$$\widehat{u}_t = -\frac{n}{u}(1-\rho)\widehat{n}_t \tag{62}$$

Job creation

$$\begin{aligned}\widehat{q}_t &= -(1-\rho)\,\beta\frac{\lambda q}{\kappa}E_t\left[xzh^{\alpha}\left(\widehat{x}_{t+1}+\alpha\widehat{h}_{t+1}\right)-wh\left(\widehat{w}_{t+1}+\widehat{h}_{t+1}\right)\right] \\ &\quad +(1-\rho)\,\beta E_t\widehat{q}_{t+1}-(1-(1-\rho)\,\beta)\,E_t\widehat{\lambda}_{t+1}\end{aligned} \tag{63}$$

Hours

Efficient bargaining

$$\widehat{x}_t + m\widehat{p}l_t = m\widehat{r}s_t \tag{64}$$

Right-to-manage

$$\widehat{x}_t + m\widehat{p}l_t = \widehat{w}_t \tag{65}$$

where $m\widehat{p}l_t = (\alpha-1)\,\widehat{h}_t$ and $m\widehat{r}s_t = \phi\widehat{h}_t - \widehat{\lambda}_t$

Real wage

Efficient bargaining

$$\widehat{w}_t = \lambda_1 m\widehat{r}s_t + \lambda_2\left(\widehat{\theta}_{ht}-\widehat{\lambda}_t\right)+\lambda_3\widehat{b}_{ht} \tag{66}$$

Right-to-manage

$$\widehat{w}_t = \gamma_1 m\widehat{r}s_t + \gamma_2\left(\widehat{\theta}_{ht}-\widehat{\lambda}_t\right)+\gamma_3\widehat{b}_{ht}+\varsigma_1\widehat{\chi}_t-\varsigma_2\widehat{\chi}_{t+1} \tag{67}$$

where $\widehat{\theta}_{ht} = \widehat{v}_t - \widehat{u}_t - \widehat{h}_t$, $\widehat{b}_{ht} = -h_t$ and $\sum_i \lambda_i = \sum_i \gamma_i = 1$[20]

The first way in which the model presented in this paper differs from the baseline new keynesian model is the occurrence of unemployment in equilibrium. However, with perfect income insurance the presence of equilibrium unemployment does not affect the households' saving decision. Consequently, the demand side of the model is the same as in the baseline model. The pricing problem of the retailers is also unchanged and inflation dynamics are characterized by a standard new keynesian Phillips curve.

Equations (58) to (63) describe the dynamics of employment and unemployment. Since the labor force is assumed to be constant, movements in unemployment are just the mirror of movements in

[20]In particular, $\lambda_1 = \frac{1-\eta}{1+\phi}+\frac{\eta}{\alpha}$, $\lambda_2 = \frac{\eta\kappa\theta}{w\lambda h}$, $\lambda_3 = \frac{(1-\eta)b}{wh}$, $\gamma_1 = \frac{\lambda_1}{\left(1-\frac{\eta}{\alpha}\right)}$, $\gamma_2 = \frac{\lambda_2}{\left(1-\frac{\eta}{\alpha}\right)}$, $\gamma_3 = \frac{\lambda_3}{\left(1-\frac{\eta}{\alpha}\right)}$, $\varsigma_1 = \frac{\frac{\eta}{1-\eta}\;\frac{1-\alpha}{\alpha}+\frac{\kappa}{qw\lambda h}}{\left(1-\frac{\eta}{\alpha}\right)}$ and $\varsigma_2 = \frac{\frac{\eta}{1-\eta}(1-s)\frac{\kappa}{qw\lambda h}}{\left(1-\frac{\eta}{\alpha}\right)}$.

employment. Employment is the outcome of forward-looking job creation decisions made by firms. When deciding whether to post new vacancies, firms take into account the future expected path of profits, given the likelihood that the match may be severed in the future. Then, the matching process between firms with vacancies and searching unemployed workers leads to the creation of new jobs and shapes the dynamics of employment.

With equilibrium unemployment, the labor input can vary at both the intensive and the extensive margin. As equation (57) shows, there are two inputs to the production of intermediate goods: the number of employed people and the hours that each individual works. This may potentially have important implications for the cyclical behavior of real marginal costs and inflation, as I discuss when I present the results.

The second difference with the baseline model comes from what determines the real wage and the hours of work. In the model with equilibrium unemployment, these are determined through a decentralized bargaining process between workers and firms. In contrast to the competitive wage, which is always equalized to the marginal rate of substitution, the bargained wages (66) and (67) also depend on the state of the labor market. In particular, the hourly real wage can be expressed as a weighted average of the marginal rate of substitution, the market tightness per hour (denoted with θ_h) normalized by λ and the benefit from unemployment per hour (denoted with b_h) (plus an additional term capturing movements in the weight χ at time t and $t+1$ under right-to-manage). This is true under both bargaining specifications: efficient bargaining and right-to-manage. The real marginal cost x_t, instead, depends on which bargaining model is assumed. While in the right-to-manage the marginal cost is the wage rate minus the marginal product of labor (equation (65)), in the efficient bargaining the marginal cost is given by the the marginal rate of substitution minus the marginal product of labor (equation (64)). Thus, as equations (50) and (51) show, with efficient bargaining the marginal cost is determined as in the baseline new keynesian model. Only the wage is different. In contrast, under right-to-manage the marginal cost depends on the bargained wage that, in turn, does not equal the marginal rate of substitution. Below, I will discuss the implications for the dynamic behavior of both real marginal costs and inflation.

4 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.[21] I accordingly set ϕ equal to 5, which implies a labor supply elasticity of 0.2. I then choose the value of the parameter κ_h so that the time spent working in the steady state, h, is equal to 1/3.

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, on average, the markup of prices on marginal costs is 10 percent. This amounts to setting ε equal to 11.

The empirical literature provides us with several measures of the US 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. Accordingly, I set the separation rate ρ to 0.08. I take the elasticity of new matches with respect to the number of searching workers to be $\sigma = 0.4$, which is consistent with the estimate of Blanchard and Diamond (1989). I set the steady state employment rate n to 0.8.[22] 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). The probability s that a worker finds a job is calculated from the steady state relationships to be equal to 0.25. These values imply that the average time a vacancy is filled and a worker finds a job are about 1.5 and 4 quarters, respectively. Finally, I obtain the value of the parameter σ_m from the steady state calculation.

As I discuss below, the lower is the value of the bargaining power η, the lower is the volatility of the bargained wage. Since wages are almost acyclical in the data, I take the bargaining power η to be low and equal to 0.01, as in Cooley and Quadrini (1999). However, I try different values for η and report the sensitivity of the results to this parameter.[23]

I normalize the technology level z in the intermediate goods sector to 1 and set the technology parameter α to be equal to 0.6667. Under right-to-manage α corresponds to the labor share. I then set the value of the benefit from unemployment so that the labor share under efficient bargaining is also equal to 0.6667. The parameter κ, then, is derived from the steady state relationships.

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

[22] Andolfatto (1996) sets n to 0.57, while den Haan, Ramey and Watson (2000) set it to 0.89. These values, which are obviously larger 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. Another way to rationalize a lower value for n is the following. It is assumed in order to capture labor force participation changes. When the steady state fraction of searchers is low, the model implies that a small percentage increase in the number of employed workers causes a large percentage decrease in the numbers of workers looking for a job. This, in turn, decreases significantly the probability of filling a vacancy. In reality, however, a higher probability of finding a job raises the labor force participation. In that case, a increase in the number of employed people does not necessarily translates in a one-to-one decrease in the number of people searching for a job. As a result, the probability of filling a vacancy may decrease by a lower amount. A possible way to take this labor force participation effect into account is to assume a higher steady state value for the fraction of searching workers.

[23] It should be noticed that the "effective" relative bargaining power is also determined by the parties' outside options (or threat points). Thus, a low value of η does not necessarily implies an equally low value of the worker's effective bargaining power.

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.

5 Results

In this section I analyze the response of a set of variables to a monetary policy shock under the two specifications of the bargaining process.

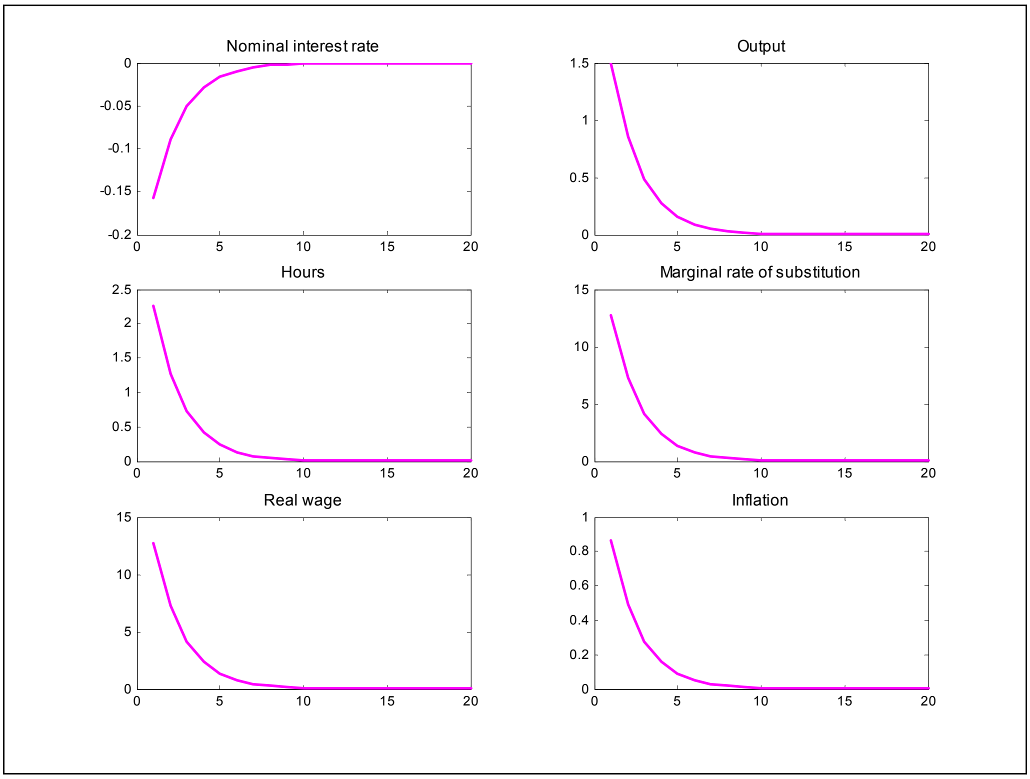

Figure 1: Responses to a monetary shock in the new keynesian model

The monetary shock is a 1 percent decrease in the nominal interest rate. I also compare the predictions of the model with those from the baseline new keynesian model.

Figure 1 plots the impulse responses of the nominal interest rate, output, hours, the marginal rate of substitution, the real wage and inflation in the baseline model. 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 response of the real wage equals the response of the marginal rate of substitution. Moreover, since I have assumed a low value for the elasticity of intertemporal substitution, the real wage and the marginal rate of substitution are highly volatile.

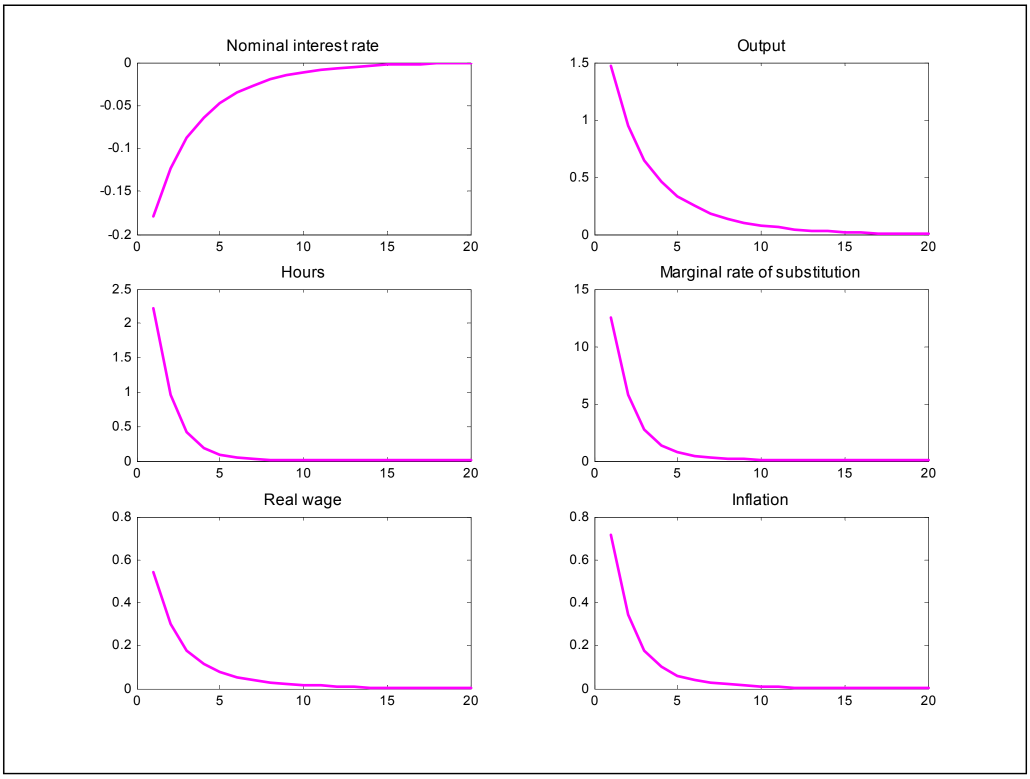

Figure 2: Responses to a monetary shock under efficient bargaining

Figures 2 and 3 plot the impulse responses of the same variables as in Figure 1 in the model with equilibrium unemployment and bargaining, under efficient bargaining and right-to-manage, respectively. Note that in order to facilitate the comparison with the baseline model I plot the hours per worker rather than the total hours. As can be seen from the figures, the qualitative response of all variables is similar to the baseline model. In other words, the models are observationally equivalent. From a quantitative point of view, however, the efficient bargaining and the right-to-manage models behave extremely differently from the baseline one. In particular, while the responses of the nominal interest rate, output, the hours worked and the marginal rate of substitution are similar also quantitatively, the responses of real wages and inflation are much lower than in the baseline model. I will interpret these differences in the following sections, after explaining labor-market dynamics.

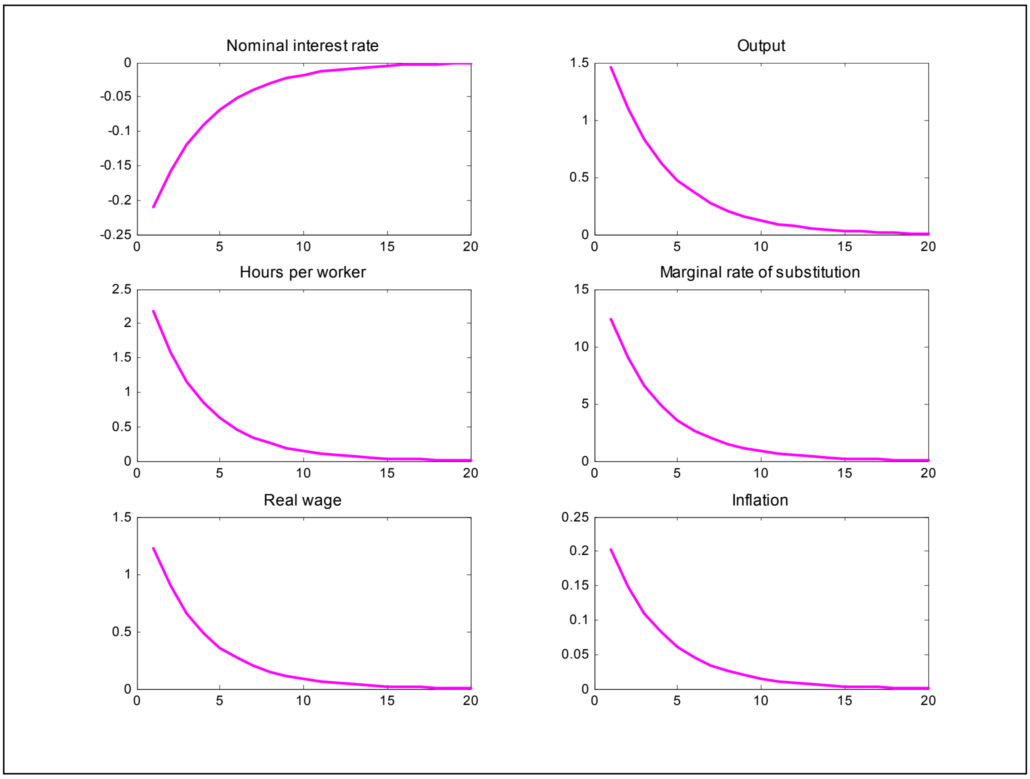

Figure 3: Responses to a monetary shock under right-to-manage

5.1 Labor-market dynamics

Figures 4 and 5 present the dynamics of the labor market under the two bargaining assumptions in the aftermath of the monetary shock. In particular, the figures plot the response of the number of vacancies, the probability that a vacancy is filled, the probability that a searching worker finds a job, the employment rate, the unemployment rate and the job creation rate.

The response of unemployment is explained by the dynamics of job creation (in this model, job destruction is exogenous). A fall in the nominal interest rate, which translates into a fall in the real rate because prices are sticky, increases current and expected future aggregate demand and firms' profits. This raises the value of opening a vacancy V_t and induces firms to post more vacancies. The increase in vacancies raises both the number of successful matches and the job creation rate, which equals the number of new matches over the existing ones. As a consequence, in the next period, employment increases and the unemployment decreases.

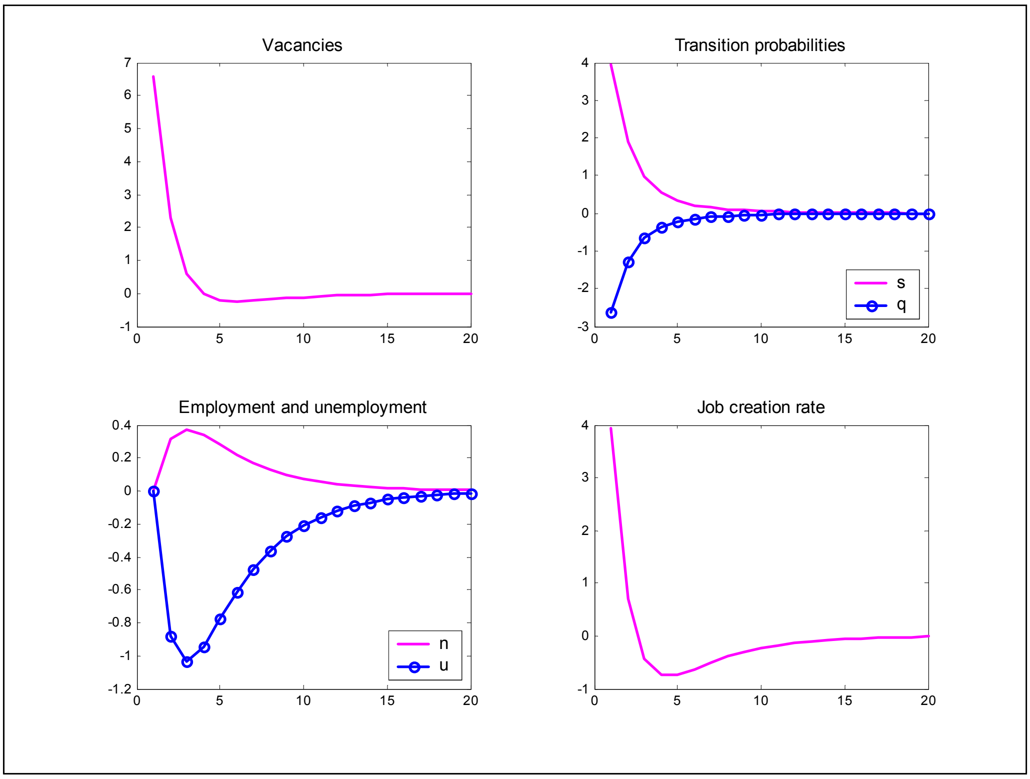

Figure 4: Labor-market dynamics under efficient bargaining

The raise in the number of vacancies posted by firms causes the relative number of vacancies looking for workers and workers looking for jobs to increase on impact. Thus, at the time of the monetary shock, the probability that a firm fills a vacancy (q_t) drops while the probability that a worker finds a job (s_t) raises.

The lower probability of hiring a worker reduces the attractiveness of hiring activities and the value of an open vacancy. Therefore, after the initial impact, the number of vacancies goes down and so does the job creation rate. Under right-to-manage, for example, the job creation rate drops under its steady state value in the fourth period and starts to be dominated by the job destruction rate (which is constant at its steady state value). Because the job creation rate is smaller than the job destruction rate, from the fifth period employment begins to decline and unemployment to raise.

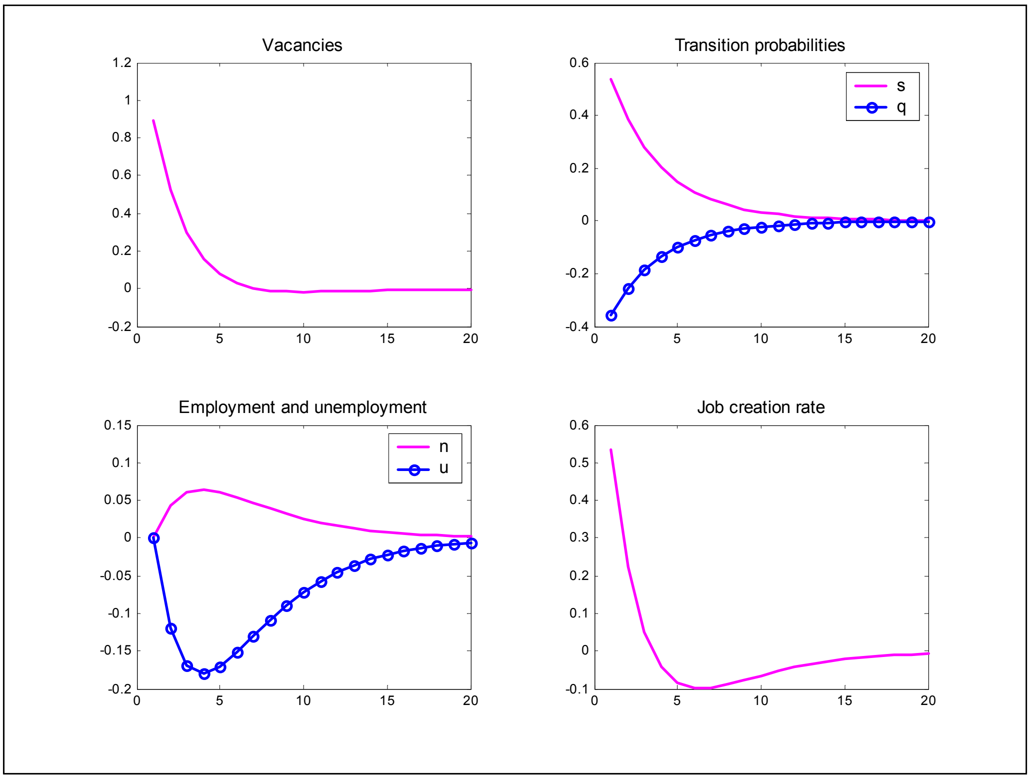

Figure 5: Labor-market dynamics under right-to-manage

5.2 Real wage rigidity

I say that the real wage is rigid when it is not very sensitive to economic conditions. To the purpose of this paper, I take as a benchmark the competitive wage, which would arise in the baseline new keynesian model. Then, the real wage is rigid when its response is lower than the response of the competitive wage.

Figure 6 compares the response of the competitive wage to the monetary shock with that of the bargained wage under efficient bargaining and right-to-manage. The figure shows that, under the parametrization described above, the response of the bargained wage is significantly smaller than the response of the competitive wage, whichever bargaining assumption I make. That is, search and matching frictions, together with decentralized wage bargaining, do generate a real wage rigidity. The new model, then, can help to account for the relatively small fluctuations of real wages that are observed in the data.

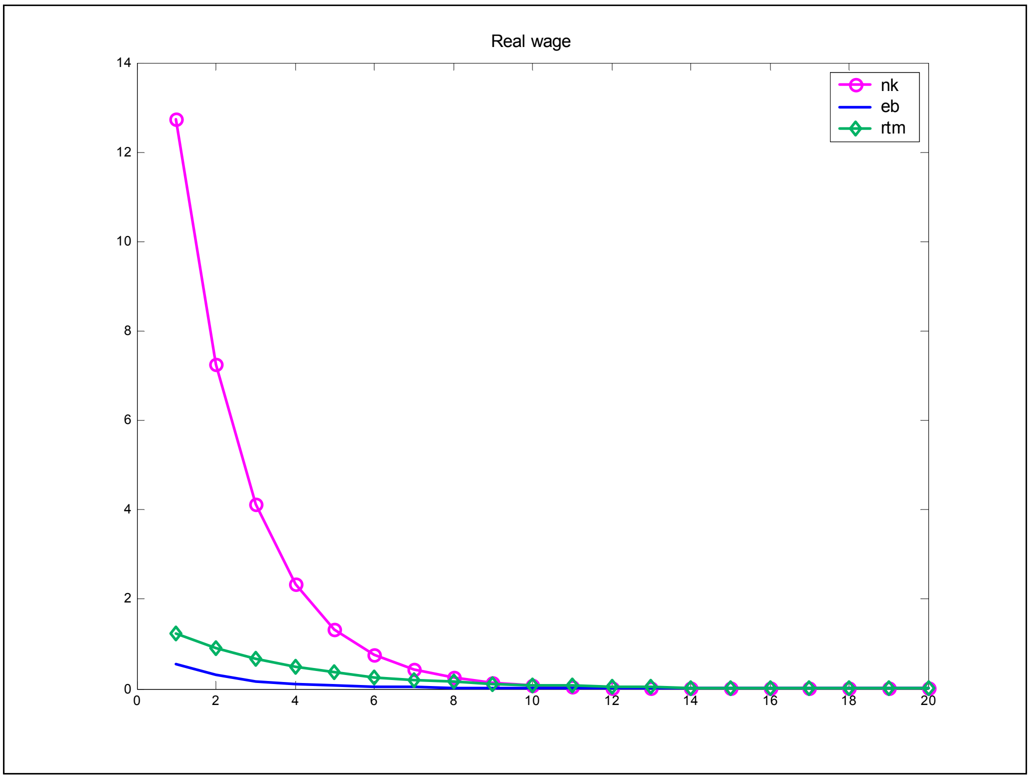

Figure 6: Real wage rigidity

In order to gain some understanding on why the real wage rigidity arises, I decompose the response of the bargained wage into its components. Figures 7 refers to the efficient bargaining model, while Figure 8 to the right-to-manage.

Let me first comment the efficient bargaining model. Recall, from equation (66), that under efficient bargaining the hourly wage is a weighted average of three elements: the marginal rate of substitution, the labor market tightness per hour (normalized by the marginal utility of consumption) and the benefit from unemployment per hour.

As you can see from Figure 7, while the marginal rate of substitution is highly procyclical, the market tightness per hour is less procyclical and the benefit from unemployment per hour is countercyclical. Moreover, under the calibration described in Section 4, the weights in equation (66) turn out to be $\lambda_1 = 0.18$, $\lambda_2 = 0.012$ and $\lambda_3 = 0.808$. As a consequence, the bargained wage responds by much less than does the marginal rate of substitution, which in turn equals the wage in the baseline new keynesian model.

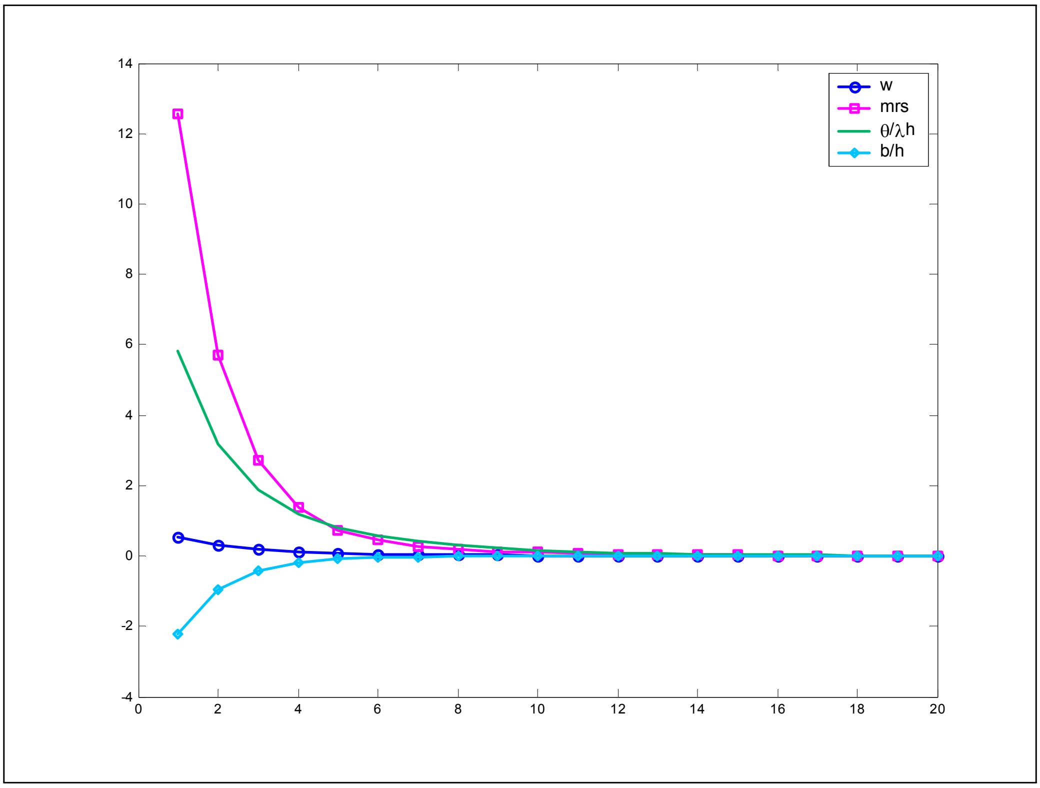

Figure 7: Wage components under efficient bargaining

As Figure 8 shows, under right-to-manage the marginal rate of substitution is highly procyclical, the labor market tightness per hour is only mildly procyclical and the benefit from unemployment per hour is countercyclical. Also, the weights in equation (67) are similar to the weights under efficient bargaining: $\gamma_1 = 0.167$, $\gamma_2 = 0.013$ and $\gamma_3 = 0.820$. Finally, the weight component χ is highly procyclical. However, since in equation (67) it is the case that $\gamma_1 = 0.057$ and $\gamma_2 = 0.040$, the contribution of the fluctuations in χ_t to the volatility of the wage is largely offset by the fluctuations in χ_{t+1}. Taking everything into account, the wage under right-to-manage turns out to be significantly less procyclical than both the marginal rate of substitution and the wage in the baseline new keynesian model.

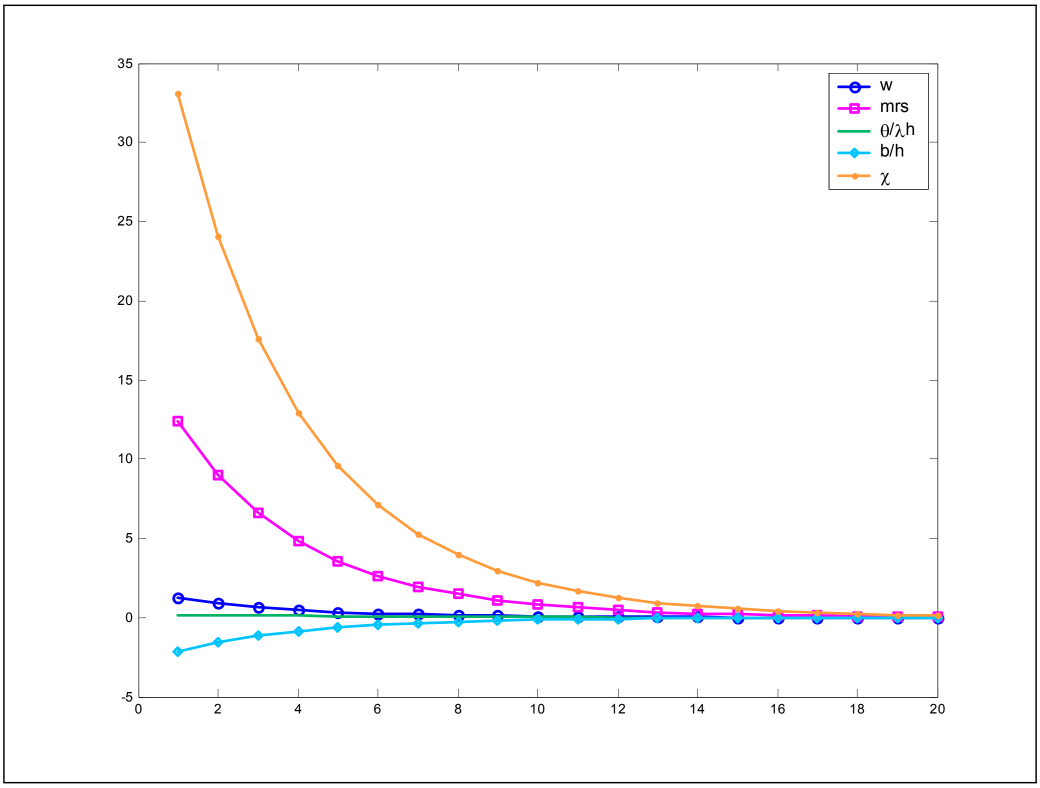

Figure 8: Wage components under right-to-manage

In principle, there is another reason why the bargained wage might be less volatile than the wage in the baseline model. In the model with equilibrium unemployment, a given change in output may be obtained with a change in both the number of employed people and the number of working hours. The existence of the extensive margin reduces the volatility of hours. Because the marginal disutility of supplying hours is increasing in the number of hours worked by each individual, this also reduces the volatility of the marginal rate of substitution, which is the most volatile component of the bargained wage. However, this effect is not quantitatively important. In fact, as Figures 1, 2 and 3 show, the marginal rate of substitution in the model with equilibrium unemployment, under both bargaining specifications, is nearly as volatile as in the baseline model.

5.3 Real marginal cost and inflation

Figure 9 shows the impulse responses of the real marginal cost and inflation under both bargaining assumptions and compare them to the predictions of the baseline new keynesian model. While real marginal costs and inflation are significantly less volatile under right-to-manage than in the baseline model, they are only slightly less volatile under efficient bargaining.

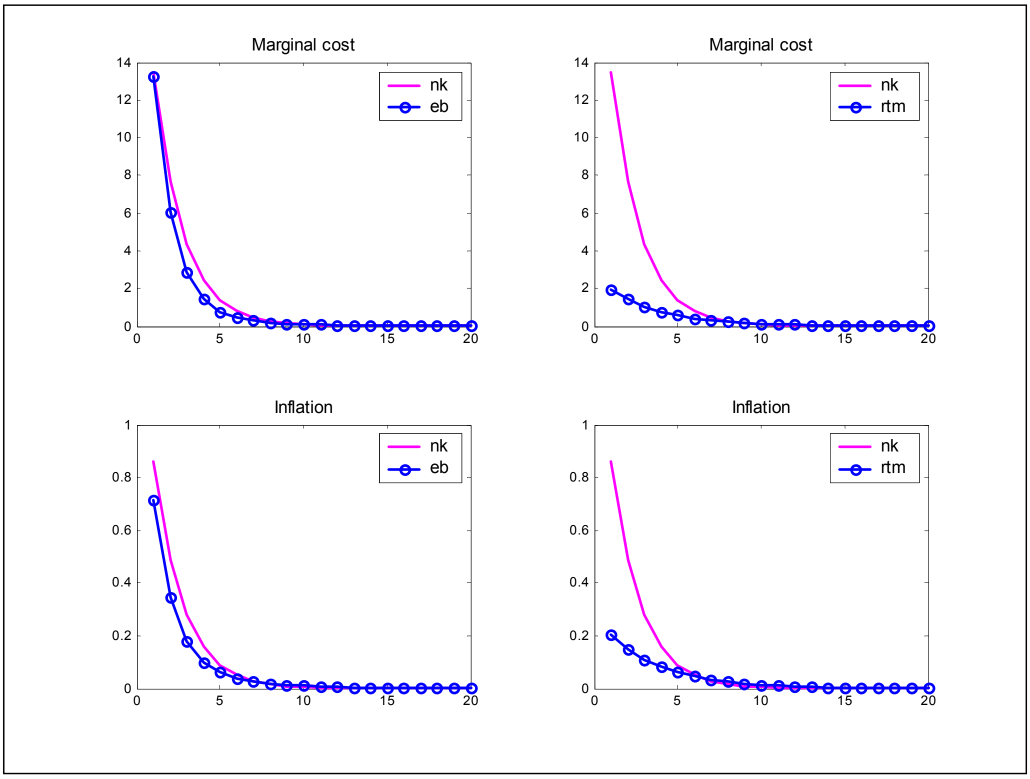

Figure 9: Real marginal cost and inflation

Since inflation is equal to the sum of expected future marginal costs, the lower volatility of inflation is explained by the lower volatility of marginal costs. The lower volatility of marginal costs, in turn, has two different sources: the extensive margin channel and the wage bargaining channel. The second channel, as I discuss below, is only active in the right-to-manage case. The first is active under both efficient bargaining and right-to-manage. However, the first channel is quantitatively very small.

The extensive margin channel works as follows. Changes in the labor input, which is used in the production of intermediate goods, can be obtained through variations in both the number of employed people and the number of working hours. The presence of the extensive margin, other things being equal, reduces the volatility of the hours that each individual works. In the efficient bargaining the marginal cost is equal to the marginal rate of substitution minus the marginal product of labor. In the right-to-manage the marginal cost is the wage minus the marginal product of labor. And the wage is a weighted average of the marginal rate of substitution, the market tightness per hour and the benefit from unemployment per hour. Since the marginal rate of substitution increases and the marginal product of labor decreases with the hours of work, the lower response of hours reduces the responses of marginal costs in both bargaining models. However, although the model predicts that the labor input varies at both margins, under the calibration previously described the extensive margin is not very volatile. This implies that the extensive channel margin has a negligible effect on marginal costs. In Trigari (2003), I develop a model where the extensive margin channel significantly reduces the response of marginal costs and inflation.

The bargaining channel, instead, has an important effect on marginal costs but is only active in the right-to-manage. As I have showed in the previous section, the bargained wage is less volatile than the marginal rate of substitution. Under right-to-manage the marginal cost is determined by the wage rather than by the marginal rate of substitution. Consequently, the marginal cost is also less volatile than the marginal rate of substitution. This does not happen in the efficient bargaining where the wage plays only a distributive role.

In the case of right-to-manage, then, the model developed in this paper is also more consistent than the baseline new keynesian model with evidence about the relative moderate response of inflation to a monetary shock.

Finally, because the real wage rigidity is microfounded, the model can be used to study the effect on wages and inflation of changes in the parameters that characterize the bargaining process. The most important among them is the relative bargaining power η.

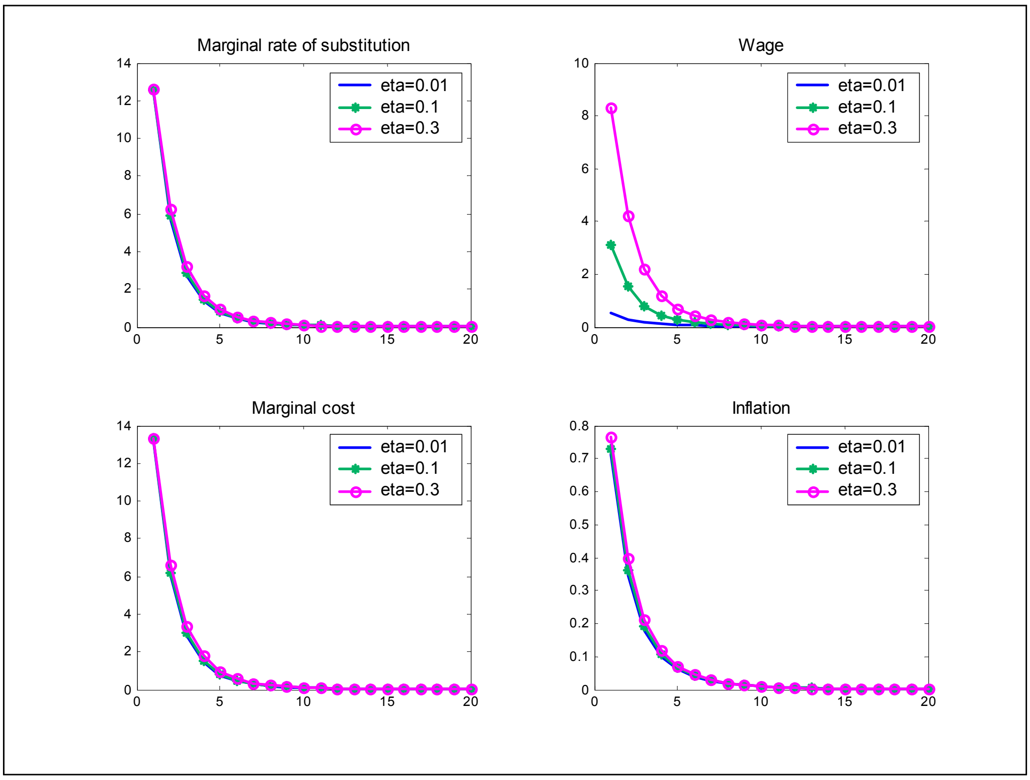

Figure 10: Effect of bargaining power under efficient bargaining

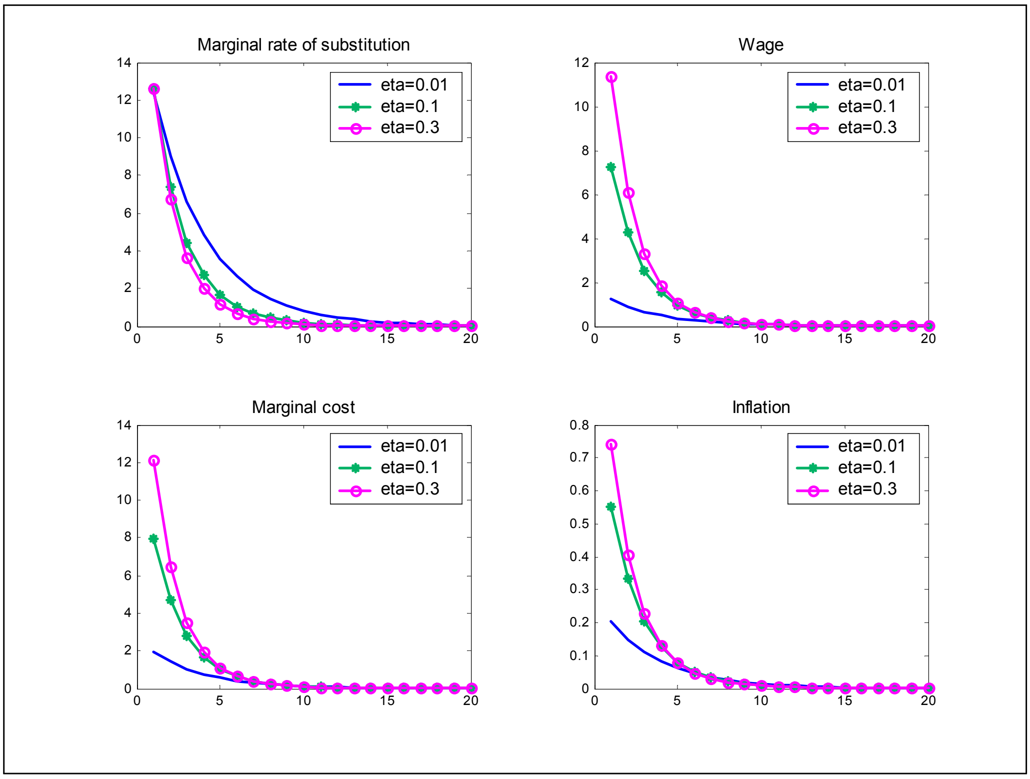

Figure 11: Effect of bargaining power under right-to-manage

Figure 10 and 11 report the responses of the marginal rate of substitution, the real wage, the marginal cost and inflation for different values of η, assuming first efficient bargaining and then right-to-manage.[24]

While a reduction in the bargaining power significantly decreases the real wage response under both specifications of the bargaining process, the marginal rate of substitution is only mildly affected by changes in η. The sensitivity of the marginal cost and inflation to variations in η, instead, depends on which bargaining model is assumed. Under efficient bargaining, the wage has only a distributive role and the marginal rate of substitution turns out to determine the firms' marginal cost. Marginal cost and inflation, then, are almost unaffected by movements in the bargaining power. Under right-to-manage, the wage is allocative and determines the firms' marginal cost. Thus, as Figure 11 shows, a reduction in η, which causes a smaller response of wages, also decreases the amplitude of the response of the marginal cost and inflation.

[24]From the steady state calculation, values for η higher than 0.3 imply a negative value of the benefit from unemployment.

6 Conclusions

In this paper I develop a general equilibrium model that combines a monetary new keynesian framework with a theory of equilibrium unemployment. I the use the new model to analyze the impact of demand-side transmitted monetary shocks on the economy. The labor market is characterized by search and matching frictions and decentralized bargaining over wages. Search frictions generate unemployment in equilibrium. Wage bargaining introduces a microfounded real wage rigidity. First, I study an efficient Nash bargaining model. Then, I develop an alternative bargaining model, which I refer to as right-to-manage bargaining. Both models have similar predictions for real wage dynamics, but they differ in terms of their implications for inflation dynamics.

The main results of the paper can be summarized as follows. First, the response of the real wage is significantly less volatile than in a baseline new keynesian model. This is true under both bargaining models: efficient Nash bargaining and right-to-manage. Second, under right-to-manage the real wage rigidity reduces the elasticity of marginal costs with respect to output and leads to a considerably smaller volatility of inflation than in the baseline model. These findings are consistent with recent evidence suggesting that real wages and inflation only vary by a moderate amount in response to a monetary shock. Third, monetary policy shocks can explain important features of labor-market fluctuations. In particular, a monetary expansion leads to a rise in job creation and to a hump-shaped decline in unemployment. Moreover, by taking into account the existence of unemployed in equilibrium, I can explain fluctuations in total hours at both the extensive and the intensive margin. However, the model cannot account for the relative magnitudes of the two margins that are observed in the data.

One reason why employment is not very volatile is that, for tractability reasons in the right-to-manage case, I have assumed that job destruction is exogenous. In this case, the dynamics of employment are only explained by the dynamics of job creation. However, empirical evidence shows that the job destruction flow is not constant, especially over the business cycle (Davis, Haltiwanger and Schuh, 1996). In Trigari (2003) I introduce endogenous job destruction and find that a large part of the variation in employment is due to the response of job destruction, which turns out to be greater and more persistent than the response of job creation. Then, allowing for endogenous job destruction increases the relative variation of the extensive margin with respect to the intensive margin. This allows me to focus on the extensive margin channel to explain the dynamic of inflation.

7 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. A fraction n_t^a of these members is employed, while the remaining fraction $1-n_t^a$ is unemployed. Recall that n_t^a denotes the number of individuals that are actually working 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 idiosyncratic shock. The representative family's optimal value function, denoted with Ω_t, can be written as:

$$\Omega_t\left(n_t^a\right) = u(c_t, c_{t-1}) - n_t^a g\left(h_t\right) + \beta E_t \Omega_{t+1}\left(n_{t+1}^a\right). \tag{68}$$

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 (68) and is equal to $n_t^a g\left(h_t\right)$.

Each family faces the following budget constraint:

$$c_t + \frac{B_t}{p_t r_t^n} = n_t^a w_t h_t + \left(1-n_t^a\right) b + \delta_t + \frac{B_{t-1}}{p_t}, \tag{69}$$

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 $1-n_t^a$ producing at home a non-tradable output b of final goods. Finally, δ_t denotes the family's per capita share of aggregate profits from retailers and intermediate goods firms.

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

$$n_{t+1}^a = (1-\rho)\, n_t^a + s_t (1-\rho)\left(1-n_t^a\right), \tag{70}$$

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,

$$\widetilde{S}_t^W \equiv \frac{\partial \Omega_t \left(n_t^a\right)}{\partial n_t^a}. \tag{71}$$

Taking the derivative of Ω_t in (68) with respect to n_t^a subject to equations (69) and (70) gives:

$$\frac{\partial \Omega_t}{\partial n_t^a} = \lambda_t w_t h_t - \lambda_t b - g\left(h_t\right) + \beta E_t \left[\left(1 - s_t\right)\left(1 - \rho\right) \frac{\partial \Omega_{t+1}\left(n_{t+1}^a\right)}{\partial n_{t+1}^a}\right]. \tag{72}$$

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

$$\widetilde{S}_t^W = \lambda_t w_t h_t - \lambda_t b - g\left(h_t\right) + \beta E_t \left[\left(1 - s_t\right)\left(1 - \rho\right) \widetilde{S}_{t+1}^W\right]. \tag{73}$$

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

$$S_t^W \equiv \frac{\widetilde{S}_t^W}{\lambda_t}. \tag{74}$$

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:

$$S_t^W = w_t h_t - b - \frac{g\left(h_t\right)}{\lambda_t} + E_t \beta_{t+1} \left[\left(1 - s_t\right)\left(1 - \rho\right) S_{t+1}^W\right]. \tag{75}$$

This equation corresponds to the difference between the value of employment (15) and the value of unemployment (16) that are reported in the paper.

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