Sequential bargaining in a new-Keynesian model with frictional unemployment and staggered wage negotiation

Gregory de Walque* Olivier Pierrard†

Henri Sneessens‡ Raf Wouters§

May 29, 2008

Abstract

We consider a model with frictional unemployment and staggered wage bargaining where hours worked are negotiated every period. The workers' bargaining power in the hours negotiation affects both unemployment volatility and inflation persistence. The closer to zero this parameter, (i) the more firms adjust on the intensive margin, reducing employment volatility, (ii) the lower the effective workers' bargaining power for wages and (iii) the more important the hourly wage in the marginal cost determination. This set-up produces realistic labor market statistics together with inflation persistence.

Keywords: DSGE, Search and Matching, Nominal Wage Rigidity, Monetary Policy.

JEL classification: E31, E32, E52, J64.

*National Bank of Belgium and Department of Economics, University of Namur, Belgium. E-mail: gregory.dewalque@nbb.be, tel: +32 2221 2244, fax: +32 2221 3162, address: Boulevard de Berlaimont 14, 1000 Brussels (Belgium).

†Banque Centrale du Luxembourg and Department of Economics, Université Catholique de Louvain, Belgium. E-mail: olivier.pierrard@bcl.lu, tel: +352 4774 4449, fax: +352 4774 4920, address: Boulevard Royal 2, 2983 Luxembourg (Luxembourg).

‡Department of Economics and IRES, Université Catholique de Louvain, Belgium. E-mail: henri.sneessens@uclouvain.be, tel: +32 1047 3962, fax: +32 1047 3945, address: Place Montesquieu 3, 1348 Louvain-la-Neuve (Belgium).

§National Bank of Belgium and Department of Economics, Université Catholique de Louvain, Belgium. E-mail: rafael.wouters@nbb.be, tel: +32 2221 5441, fax: +32 2221 31 62, address: Boulevard de Berlaimont 14, 1000 Brussels (Belgium).

1 Introduction

Real wage and labor market dynamics are crucial for understanding the inflation process. Standard new-Keynesian models contain only a highly abstract description of the labor market which does not allow for involuntary unemployment and real wage rigidity. These two issues are key when monetary policy faces complicated trade-off decisions. Search and matching models, on the other hand, provide a more realistic framework that can be used to analyze unemployment and wage bargaining situations.

This explains the recent efforts to integrate frictional unemployment in new-Keynesian models with price and wage nominal stickiness. The initial expectation is that the combination of real and nominal wage stickiness is able to produce endogenous inflation persistence, while at the same time the search and matching frictions can produce realistic labor market outcomes.

This research program faces two major difficulties. The first is related to labor market modelling: since the contributions of Hall (2005a) and Shimer (2004), it is known that the standard Diamond-Mortensen-Pissarides model is not able to produce the observed volatilities of employment and vacancies. However, these contributions also show that the introduction of wage rigidities for newly created jobs allows one to circumvent this difficulty. Following their insight, we adopt the Gertler and Trigari (2006) framework and model infrequent wage bargaining through a time dependent schedule à la Calvo. In addition, we allow nominal wage rigidity to be different for existing and newly created jobs. Indeed, these two types of rigidities have very different effects on the economy: the first is especially important to reduce the wage volatility and enhance inflation persistence while the second is crucial for the volatility of labor market variables.

A second difficulty arises from the combination of the search and matching setup with nominal price stickiness. In the standard search and matching model, both capital and labor are predetermined and prices are the only source of flexibility in the short run. Such a market clearing role for prices is difficult to reconcile with the observed price stickiness and inflation persistence. Several solutions to this problem have been imagined so far. For example, one could consider that employment can adjust instantaneously, with the inconvenient that it becomes a jump variable, contrasting with empirical observation.[1] Others (e.g. Trigari, 2004 and Walsh, 2005) consider endogenous job destruction with the drawback that most labor adjustment occurs through the firing channel, in contradiction with the new hiring statistics that show acyclical job destruction (Shimer, 2007 and Hall, 2005b).[2]

The present paper focuses on an alternative solution allowing labor to adjust at the intensive margin, that is allowing hours worked to be modified along the business cycle. Several

[1] Actually, the fact that employment is predetermined or not depends essentially of the time span represented by one period in the model. On a monthly basis, employment is probably predetermined, but on a quarterly basis it is rational to consider that it can adjust instantaneously (e.g. Blanchard and Gali, 2006 or Gertler, Sala and Trigari, 2007).

[2] This view is however still debated. Some elements of the controversy can be found in Fujita and Ramey (2007) and Elsby et al. (2008).

recent papers have worked on this idea[3] which actually adapts the labor union literature on employment bargaining to endogenize the working time decision. Indeed, in the search and matching literature, unions have no direct influence on the hiring or firing process: firms decide alone whether to post a vacancy and most models consider exogenous job destruction. In this sense, the Diamond-Mortensen-Pissarides framework is close to the idea of the 'right-to-manage' (Nickell, 1982). However, within the labor contract long-term relationship, it seems natural that any decision affecting working time should be discussed by the two parties to the contract.

An important part of the literature on the intensive margin is developed under the assumption that hours and wages are re-bargained every period. In the present paper we want to analyze the consequences of combining staggered wage bargaining with continuously re-negotiated hours worked. Indeed, observed collective wage bargaining is infrequent, at least for institutional reasons. Given the medium-to-long run agreement reached for the wage, the workforce can be adjusted along the business cycle. This adjustment can occur either on the extensive margin, which is a costly and time-consuming process, or on the intensive margin, but in this case it is likely to involve some negotiation. This setup is actually very close to the idea of sequential bargaining introduced by Manning (1987), the main differences being that (*i*) he considers employment instead of individual working time and (*ii*) his wage-employment sequential bargain happens every period. For the rest, we also allow bargaining power to be different in the wage and in the hours negotiations, following the intuition that the workers' influence over different aspects may vary widely.[4]

This paper is certainly not the first to combine flexible working time with time-dependent wage bargaining. For example, Christoffel, Linzert and Kuester (2006) assume that hours are unilaterally decided by the firm each period and Thomas (2008) considers that the infrequent non-cooperative nominal wage bargain is based on the anticipation that firms and workers somehow manage to reach a period-by-period privately efficient working time decision.[5] The Thomas (2008) model has the advantage to be immune to the Barro (1977) critique since wage is not allocational for working time within the long-run labor contract relationship. This feature turns out to be also a drawback as it implies that there is no longer direct link between wage and the marginal cost. Consequently, both real and nominal wage rigidities affect inflation persistence only through their effect on hours worked. On the other hand, leaving the working time decision entirely to the firm, as in CLK (2006), leads to a direct link between wage, working time and the marginal cost. While this provides good performance from the inflation persistence point of

[3] See for example Moyen and Sahuc (2004), Walsh (2005), Trigari (2004, 2006), Christoffel and Linzert (2005), Thomas (2008).

[4] This can be the case for institutional reasons. For example, in the United States, wages belong to the list of mandatory issues on which employers have to bargain with unions, while employment and working time are listed as permissive issues. As examplified by Manning (1987, page 125), the legal structure can play an important role in differentiating the bargaining power by issues: "*In the United States strikes at contract renegotiations about mandatory issues are legal, but strikes about permissive issues in the course of contracts are not*".

[5] In the remainder of the paper, we will consider for simplicity that this is the outcome of some cooperative behavior.

view, it leads to very unsatisfactory results regarding labor market statistics. Because of the huge flexibility given to firms, labor adjustments occur mainly on the intensive margin, inducing unrealistic responses in hours and strongly reducing employment volatility.

Compared with these two ways of modelling the working time decision, the sequential bargaining procedure discussed in this paper displays some interesting features. First, it is fully coherent with the rules of the non-cooperative game theory. Second, it offers a general set-up of which the two above mentioned hours setting assumptions are a special case. Indeed, the CLK (2006) model is obtained simply by setting to zero workers' bargaining power relative to the working time issue. We also display that there exists a value of this bargaining power such that the working time is independent of the wage and for this parametrization, the model is a fairly close approximation of Thomas (2008). Finally, for intermediate values of the hours bargaining power parameter, the sequential bargaining mechanism reduces strongly the incentive of the firm to adjust on the intensive margin compared to CLK (2006) without affecting the wage-inflation channel.

The paper proceeds as follows. Section 2 of the paper lays out the model, focusing on the labor market. Apart from the labor market representation, the model encompasses the same structure and the same set of nominal and real rigidities as the workhorse new-Keynesian model (e.g. Smets and Wouters (2003, 2007) or Christiano, Eichenbaum and Evans (2005)). Section 3 first discusses the calibration to US data and then simulates the models to study their dynamic behavior after a productivity and a monetary policy shock. In particular we assess the ability of the models to match US labor market statistics and to generate inflation persistence. The simulation exercise provides an opportunity to discuss the impact of several parameters such as the workers' bargaining power in the hours negotiation, the Calvo probabilities to bargain the wage of an existing or of a newly created job. Section 4 concludes.

2 The Model

The production side of the economy is very similar to Smets and Wouters (2003, 2007) or Christiano, Eichenbaum and Evans (2005). We therefore describe it only very briefly. The economy produces an homogenous final good and a continuum of intermediate goods. The final good serves for consumption and investment purposes. The final good sector is perfectly competitive. It produces an homogeneous good y_t by aggregating a continuum of intermediate goods indexed by ι on the unit interval using a CES Dixit-Stiglitz technology

$$y_t = \left[\int_0^1 \left[y_t(\iota)^{\lambda_p} d\iota \right] \right]^{1/\lambda_p} \quad . \tag{1}$$

Each intermediate good is produced by a single firm and sold in a market characterized by monopolistic competition. Intermediate producers rent capital services $\tilde{k}_t$ directly from the households and labor services l_t from labor firms and they combine these inputs using a Cobb-

Douglas technology

$$y_t(\iota) = \varepsilon_t^a \left[\tilde{k}_t(\iota)\right]^{\alpha} [l_t(\iota)]^{1-\alpha} \tag{2}$$

where ε_t^a represents total factor productivity modelled as an autoregressive process of order 1

$$\varepsilon_t^a = (\bar{\varepsilon}^a)^{1-\rho_a} \left(\varepsilon_{t-1}^a\right)^{\rho_a} \eta_t^a \quad \text{with } \eta_t^a \sim iidN \quad .$$

As we assume constant returns to scale and price-taking behavior on the input markets, the real marginal cost x_t is independent of the price and production levels:

$$x_t = \frac{1}{\varepsilon_t^a} \left(\frac{\mu_t}{1-\alpha}\right)^{1-\alpha} \left(\frac{r_t^k}{\alpha}\right)^{\alpha} \tag{3}$$

where μ_t and r_t^k represent the competitive price of labor services and capital services respectively.

We consider time-dependent price setting *à la* Calvo (1983). At each period, each intermediate good firm ι has a constant probability $(1-\xi_p)$ that it will have an opportunity to reset a new price. This price will prevail for j periods with probability ξ_p^j. All the intermediate goods producers who are allowed to reset their selling price at time t face exactly the same optimization problem and will therefore choose the same optimal price p_t^*. They fix it in order to maximize the expected flow of discounted profits. The producers who cannot change their price are able to index it on a weighted average of past and trend inflation. These assumptions lead to the following log-linearized new-Keynesian Phillips curve for inflation π_t:

$$\left(1+\beta\gamma_p\right) \cdot \hat{\pi}_t = \beta \cdot E_t\hat{\pi}_{t+1} + \gamma_p\hat{\pi}_{t-1} + \frac{(1-\beta\xi_p)(1-\xi_p)}{\xi_p}\hat{x}_t \tag{4}$$

where hats denote variables expressed in percentage deviation from steady state. Parameter β is the subjective discount factor and γ_p represents the weight given to past inflation in the indexation process.

The labor input of the intermediate goods firms is produced by a continuum of one-worker labor firms that will be carefully described in section 2.2 below. Let us simply say at this stage that the labor firms sell homogenous labor services on a competitive market to monopolistic intermediate producers. This model structure isolates the wage decision from the price decision. The rest of the section focuses on the household optimisation and the labor market representation.

2.1 Households

Households consist of a continuum of workers indexed by τ on the unit interval. Workers supply an homogeneous type of labor, but only a proportion n_t of them is employed. Furthermore, employed workers may receive different wages and differ in their worked hours due to labor market specificities that will be discussed in subsection 2.2.3 below. Because of our representative -or large- household interpretation, the unemployment rate u_t is identical at the household and aggregate level. As exemplified by Merz (1995), the representative household assumption amounts to consider state-contingent securities insuring workers against differences in their specific labor income. Family members share their labor income, i.e. wage and unemployment benefits, before choosing per capita consumption, investment, bond holdings and the degree of capacity utilization.

The representative household's total real income is therefore equal to aggregate income

$$\mathcal{Y}_t = \int_0^{n_t} w_t(\tau) \cdot h_t(\tau) \ d\tau + (1-n_t) \cdot b + \left(r_t^k z_t - \Psi(z_t) \right) \cdot k_{t-1} + \Pi_t \tag{5}$$

This is made up of labor income, the return on the real capital stock and profits Π_t generated by the monopolistic competitive intermediate producer firms and the hiring firms. Labor income is the sum of the average total wage (the product of hourly wage $w_t(\tau)$ by hours $h_t(\tau)$) and of the unemployment benefit b,[6] weighted by the employment-unemployment proportions. Households hold the capital stock k_{t-1}, a homogeneous production factor, and rent capital services to intermediate goods producers at the rental rate r_t^k. They can adjust the capital supply either by varying the capacity utilization rate z_t or by buying new capital goods which take one period to be installed. The steady state utilization rate is normalized to 1 and we assume that there is a cost $\Psi(z_t)$ associated with variations in the degree of capacity utilization

$$\Psi(z_t) = \frac{\omega}{1+\zeta} \left[z_t^{1+\zeta} - 1 \right] ,$$

so that $\Psi(1) = 0$ while parameter ζ represents the elasticity of the capital utilization cost function and ω is a scaling parameter. The capital accumulation process follows

$$k_t = (1-\delta) \cdot k_{t-1} + \left[1 - \frac{\varphi}{2} \left(\frac{\Delta i_t}{i_{t-1}} \right)^2 \right] \cdot i_t,$$

where i_t is gross investment and δ the depreciation rate. We assume quadratic adjustment costs associated with changes in investment.

Households hold their financial wealth in the form of bonds B_t. Bonds are one-period securities with price $1/R_t$. The budget constraint faced by the representative household may be written as

$$\frac{B_t}{R_t \cdot p_t} + c_t + i_t = \frac{B_{t-1}}{p_t} + \mathcal{Y}_t \tag{6}$$

where c_t represents aggregate consumption and p_t is the price index.

We assume separability between leisure and consumption in the instantaneous utility function. Therefore, all the members of the representative household share the same marginal utility of wealth and choose the same optimal consumption, even though they do not spend the same amount of time at work. Adding external consumption habits, the household utility function can be written

$$\mathcal{U}\left(c_t, c_{t-1}, h_t(\tau)\right) = \log\left(c_t - e\, c_{t-1}\right) \, - \, \kappa_h \frac{\int_0^{n_t} \left[h_t(\tau)\right]^{1+\phi} d\tau}{1+\phi} \quad , \tag{7}$$

[6]It could alternatively be interpreted as the income generated by the domestic activities of an unemployed worker.

with $0 < e < 1$ and $\phi \geq 0$. Let $\mathcal{H}_t$ be the value function of the representative household. If we momentarily leave aside the labor supply decision, its maximization program is

$$\mathcal{H}_t = \max_{c_t, i_t, B_t, z_t} \{\mathcal{U}(c_t, c_{t-1}) + \beta \cdot \mathrm{E}_t \mathcal{H}_{t+1}\} \tag{8}$$

The consumer's optimal decision results in the following equations for the marginal utility of consumption λ_t, capital utilization rate, investment and the real value of capital p_t^k:

$$\lambda_t = \mathrm{E}_t \left\{ \beta \; R_t \; \lambda_{t+1} \frac{p_t}{p_{t+1}} \right\} , \tag{9}$$

$$r_t^k = \omega \, z_t^{\zeta} , \tag{10}$$

$$1 = p_t^k \left[1 - \frac{\varphi}{2} \left(\frac{\Delta i_t}{i_{t-1}} \right)^2 \right] - \mathrm{E}_t \left\{ p_t^k \, \varphi \, \frac{\Delta i_t}{i_{t-1}} \frac{i_t}{i_{t-1}} - \beta \frac{\lambda_{t+1}}{\lambda_t} p_{t+1}^k \varphi \frac{\Delta i_{t+1}}{i_t} \left(\frac{i_{t+1}}{i_t} \right)^2 \right\} , \tag{11}$$

$$p_t^k = \mathrm{E}_t \left\{ \beta \frac{\lambda_{t+1}}{\lambda_t} \left[z_{t+1} \, r_{t+1}^k - \Psi(z_{t+1}) + (1 - \delta) \, p_{t+1}^k \right] \right\} . \tag{12}$$

2.2 Labor market

2.2.1 Labor market flows

We normalize the labor force to one, so that n_t represents both the total number of jobs and the employment rate. This leads to the following accounting identity:

$$n_t + u_t = 1 \quad , \tag{13}$$

where u_t denotes the number of unemployed job-seekers. Let m_t denote the number of new firm-worker matches. We assume that the number of matches is a function of the number of job vacancies v_t and effective job seekers u_t, and we consider the following linear homogeneous matching function:

$$m_t = \vartheta_m \, v_t^{\vartheta} \, u_t^{1-\vartheta} \quad . \tag{14}$$

For an unemployed worker, the probability of finding a job is given by

$$j_t = \frac{m_t}{u_t} \quad , \tag{15}$$

while the probability that a firm fills a vacancy is

$$q_t = \frac{m_t}{v_t} \quad . \tag{16}$$

An exogenous proportion s of firm-worker relationships terminates each period, which implies the following employment dynamics:

$$n_t = (1 - s) \cdot n_{t-1} + m_{t-1} \quad . \tag{17}$$

2.2.2 One-worker hiring firms

As described above, the labor-hiring firms are intermediaries renting labor services from households and selling these services to intermediate-goods producers at a hourly rate μ_t on a competitive market. In this sense, their role is very similar to that of the labor packers in the traditional new-Keynesian model with staggered wages and walrasian labor markets (see Erceg, Levin and Henderson (2000)). However, instead of aggregating differentiated types of labor, the role of the hiring firms is to find workers in the pool of unemployed. Keeping the Mortensen and Pissarides (1999) assumption that they can hire at most one worker, we consider a continuum of hiring firms indexed by l, with l distributed over the unit interval.

Labor efficiency is decreasing with hours, so that h hours supplied by one worker produce only h^θ units of effective labor, with $\theta < 1$.[7] Consequently, hiring firm l produces either 0 or $[h_t(l)]^\theta$ units of effective labor and aggregate effective labor can be computed as

$$\mathbf{l}_t = \int_0^1 [h_t(l)]^\theta \ dl = \int_0^1 l_t(\iota) \ d\iota \quad . \tag{18}$$

2.2.3 Time-dependent staggered wage setting and flexible hours

The hourly wage is assumed to be bargained between the hiring firm and its employee. However, the wage is not bargained in every period since such negotiations are observed to be infrequent. According to this, we assume a time-dependent setting à la Calvo wherein each period only a fraction $(1-\xi_w^o)$ of all existing wage contracts is renegotiated. All other nominal wages are simply adjusted for trend inflation $\bar{\pi}$.

Newly created jobs are paid either the previous-period contract wage or the currently bargained wage with respective probabilities ξ_w^n and $(1-\xi_w^n)$. The 'previous-period contract wage' is a roundabout way to say that the actual wage is drawn out of the wage distribution prevailing in the previous period and indexed to trend inflation. As long as the draw is not realized, the expected real wage of such a firm is equal to the indexed past average wage $w_{t-1}\frac{\bar{\pi}\, p_{t-1}}{p_t}$, with $\frac{p_t}{p_{t-1}} = \pi_t$. Note that for $\xi_w^o = \xi_w^n$, this assumption is very close to considering a continuum of large firms, each firm paying the same wage to all its workers, as in Gertler and Trigari (2006).[8] However, allowing $\xi_w^o \neq \xi_w^n$ gives somewhat more flexibility. In particular it will prove useful when assessing the different roles played by nominal wage rigidity: ξ_w^n is particularly important to induce vacancies volatility while ξ_w^o helps to increase inflation persistence.[9] Finally, there is a growing body of empirical evidence that the wage rigidity for new jobs could be smaller than this of existing jobs (e.g. Haefke *et al.* (2007), or Pissarides (2007)).

[7] This decreasing returns to scale assumption is particularly important for the determination of working time in the case where firms decide it unilaterally.

[8] Actually the only difference would come from the 'horizon effect', i.e. the fact that with a continuum of large firms, the horizon of the labor contract of the worker is smaller than that of the firm since the latter continues its activity forever. In our one-job-per-firm set-up, firm and worker share the same horizon.

[9] As illustrated by Bodart and al. (2005), there is a deep interaction between ξ_w^o and ξ_w^n : the larger is ξ_w^o, the lower ξ_w^n has to be to induce the same volatility of vacancies.

Even though the wage bargaining will be discussed in detail below, it is important at this stage to stress that all the 'hiring firm-worker' pairs that are given the opportunity to (re)-negotiate their wage contract face the same problem and therefore set the same wage. Because of the time-dependent aspect of wage negotiation, workers may be paid different wages, even though they share the same productivity. Furthermore, given the bargained hourly wage, we allow the firm-worker pair some flexibility to react to unexpected shocks by adjusting working time every period. The exact connection between hours and wages will be described in section 2.2.5 below. At this stage, let us simply assume that hours worked are a function of the real wage. Formally, $w_{t-i}^* \frac{\bar{\pi}^i p_{t-i}}{p_t}$ denotes the real value at time t of the nominal hourly wage negotiated i periods earlier while $h_t(w_{t-i}^*)$ represents the corresponding hours worked. From the employment dynamics equation (17), we may express the real value of the average total wage as

$$\begin{aligned} h_t(w_t) \cdot w_t &= \frac{n_{t-1}}{n_t}(1-s) \cdot \left[(1-\xi_w^o) \cdot h_t(w_t^*) \cdot w_t^* + \xi_w^o \cdot h_t(w_{t-1}) \cdot w_{t-1} \cdot \frac{\bar{\pi} p_{t-1}}{p_t} \right] \\ &\quad + \frac{m_{t-1}}{n_t} \cdot \left[(1-\xi_w^n) \cdot h_t(w_t^*) \cdot w_t^* + \xi_w^n \cdot h_t(w_{t-1}) \cdot w_{t-1} \cdot \frac{\bar{\pi} p_{t-1}}{p_t} \right] \end{aligned} \tag{19}$$

Note that in the particular case $\xi_w^n = \xi_w^o = \xi_w$, i.e. if new hires have the same probability of bargaining their wage as existing jobs, expression (19) simplifies to

$$h_t(w_t) \cdot w_t = (1-\xi_w) \cdot h_t(w_t^*) \cdot w_t^* + \xi_w \cdot h_t(w_{t-1}) \cdot w_{t-1} \cdot \frac{\bar{\pi}}{\pi_t} \quad ,$$

so that we have a microfounded wage equation similar to the wage rigidities equation proposed in Blanchard and Gali (2006).

Recursively developing expression (19), we obtain the weight $\mathcal{W}_{t-i}$ associated with each wage w_{t-i}^* bargained in the past and its corresponding hours worked:

$$\mathcal{W}_{t-i} = \left[\frac{n_{t-1-i}(1-s)}{n_{t-i}}(1-\xi_w^o) + \frac{m_{t-1-i}}{n_{t-i}}(1-\xi_w^n) \right] \prod_{j=0}^{i-1} \left[\frac{n_{t-1-j}(1-s)}{n_{t-j}} \xi_w^o + \frac{m_{t-1-j}}{n_{t-j}} \xi_w^n \right]$$

Average hours worked $\mathbf{h}_t(w_t)$ is then simply computed as:

$$\mathbf{h}_t(w_t) = \int_0^{n_t} h_t(l)\, dl = \sum_{i=0}^{\infty} h_t(w_{t-i}^*) \cdot \mathcal{W}_{t-i} \tag{20}$$

2.2.4 Asset values of a job

Let us first adopt the viewpoint of a labor-hiring firm. We denote $A_t^f(w_{t-j}^*)$ the asset value in period t of a job with a wage that was bargained j periods earlier. It will prove convenient to recast this value in marginal utility terms, multiplying it by λ_t:

$$\mathcal{A}_t^f(w_{t-j}^*) = \lambda_t \, A_t^f(w_{t-j}^*) \quad .$$

The value of a job expressed in marginal utility of consumption may then be written as

$$
\begin{aligned}
\mathcal{A}_t^f(w_{t-j}^*) &= \lambda_t \left\{ \left[h_t(w_{t-j}^*)\right]^\theta \mu_t - h_t(w_{t-j}^*) \cdot w_{t-j}^* \cdot \frac{\bar{\pi}^j p_{t-j}}{p_t} \right\} \\
&+\beta(1-s)\,\mathrm{E}_t \left[(1-\xi_w^o)\,\mathcal{A}_{t+1}^f\left(w_{t+1}^*\right) + \xi_w^o\,\mathcal{A}_{t+1}^f\left(w_{t-j}^*\right) \right]. \qquad (21)
\end{aligned}
$$

where μ_t is the competitive price at which the hiring firm sells labor services to the intermediate goods firms.

If we now adopt the household viewpoint, the value of a job with a wage bargained j periods earlier is given by

$$
\begin{aligned}
\mathcal{V}_t^n(w_{t-j}^*) &= h_t(w_{t-j}^*)\; w_{t-j}^*\, \frac{\bar{\pi}^j p_{t-j}}{p_t} - \frac{\kappa_h}{\lambda_t} \frac{\left[h_t(w_{t-j}^*)\right]^{1+\phi}}{1+\phi} \\
&+\beta(1-s)\,\mathrm{E}_t \left\{ \frac{\lambda_{t+1}}{\lambda_t} \left[(1-\xi_w^o)\,\mathcal{V}_{t+1}^n(w_{t+1}^*) + \xi_w^o\,\mathcal{V}_{t+1}^n(w_{t-j}^*) \right] \right\} \\
&+\beta s\,\mathrm{E}_t \left\{ \frac{\lambda_{t+1}}{\lambda_t}\,\mathcal{V}_{t+1}^u \right\}
\end{aligned}
$$

where $\mathcal{V}_t^u$ represents the present value of being unemployed at period t. Formally,

$$
\begin{aligned}
\mathcal{V}_t^u &= b + \beta\,\mathrm{E}_t \left\{ \frac{\lambda_{t+1}}{\lambda_t}\,(1-j_t)\,\mathcal{V}_{t+1}^u \right\} \\
&+\beta\,\mathrm{E}_t \left\{ \frac{\lambda_{t+1}}{\lambda_t}\, j_t \left[(1-\xi_w^n)\,\mathcal{V}_{t+1}^n(w_{t+1}^*) + \xi_w^n\,\mathcal{V}_{t+1}^n(w_t) \right] \right\}
\end{aligned}
$$

and $\mathrm{E}_t \mathcal{V}_{t+1}^n(w_t)$ is simply the expected value of a new job in the next period if the wage of the latter is not bargained but drawn out of the previous-period wage distribution. Defining $\mathcal{A}_t^h(w_{t-j}^*)$ as the household surplus in t (expressed in marginal utility terms) for a job whose wage is bargained at time t, i.e. $\mathcal{A}_t^h(w_{t-j}^*) = \lambda_t \cdot \left(\mathcal{V}_t^n(w_{t-j}^*) - \mathcal{V}_t^u\right)$, we can write

$$
\begin{aligned}
\mathcal{A}_t^h(w_{t-j}^*) &= \lambda_t\, h_t\left(w_{t-j}^*\right)\; w_{t-j}^*\, \frac{\bar{\pi}^j p_{t-j}}{p_t} - \kappa_h \frac{\left[h_t\left(w_{t-j}^*\right)\right]^{1+\phi}}{1+\phi} - \lambda_t b \\
&+\beta\,(1-s)\,\mathrm{E}_t \left[(1-\xi_w^o)\,\mathcal{A}_{t+1}^h(w_{t+1}^*) + \xi_w^o\,\mathcal{A}_{t+1}^h(w_{t-j}^*) \right] \\
&-\beta \cdot j_t \cdot \mathrm{E}_t \left[(1-\xi_w^n)\,\mathcal{A}_{t+1}^h(w_{t+1}^*) + \xi_w^n\,\mathcal{A}_{t+1}^h(w_{t+j}) \right]. \qquad (22)
\end{aligned}
$$

2.2.5 Wage and hours bargaining

As already noted, all the renegotiating 'hiring firm-worker' pairs face the same problem and therefore choose the same wage w_t^*. We assume that this wage is decided through a Nash bargaining procedure, i.e. it solves the following problem

$$
\max_{w_t^*} \; \left[\mathcal{A}_t^h(w_t^*)\right]^{\eta_w} \; \left[\mathcal{A}_t^f(w_t^*)\right]^{1-\eta_w} \qquad (23)
$$

where parameter $\eta_w \in (0,1)$ represents the household's bargaining power in the wage negotiation. The first-order condition implies the sharing rule:

$$\eta_w \cdot \mathcal{A}_t^f(w_t^*) \frac{d\mathcal{A}_t^h(w_t^*)}{dw_t^*} = (-1) \cdot (1-\eta_w) \cdot \mathcal{A}_t^h(w_t^*) \frac{d\mathcal{A}_t^f(w_t^*)}{dw_t^*} \quad , \tag{24}$$

with

$$\frac{d\mathcal{A}_t^h(w_t^*)}{dw_t^*} = \frac{\partial \mathcal{A}_t^h(w_t^*)}{\partial w_t^*} + \mathrm{E}_t \sum_{i=0}^{\infty} \frac{\partial \mathcal{A}_t^h(w_t^*)}{\partial h_{t+i}(w_t^*)} \cdot \frac{\partial h_{t+i}(w_t^*)}{\partial w_t^*} \tag{25}$$

$$\frac{d\mathcal{A}_t^f(w_t^*)}{dw_t^*} = \frac{\partial \mathcal{A}_t^f(w_t^*)}{\partial w_t^*} + \mathrm{E}_t \sum_{i=0}^{\infty} \frac{\partial \mathcal{A}_t^f(w_t^*)}{\partial h_{t+i}(w_t^*)} \cdot \frac{\partial h_{t+i}(w_t^*)}{\partial w_t^*} \tag{26}$$

The total derivatives with respect to wage depend on the sequence of expected hours worked because of the assumption that working time is allowed to adjust every period.

Cooperative hours determination If firms and workers decide to cooperatively set hours in order to maximize the period joint surplus as in Thomas (2008), working time is

$$h_t = \left(\frac{\theta}{\kappa_h} \mu_t \lambda_t \right)^{\frac{1}{1+\phi-\theta}} \tag{27}$$

so that working time depends only on macroeconomic variables and the wage is not allocational for hours, as in a traditional efficient bargaining model with flexible wage. Consequently, the two total derivatives (25) and (26) are identical except for the sign and the optimality condition for the wage bargain simply states that the ratio of household/firm intertemporal surpluses is equal to their relative bargaining power. From this expression, it is clear that the competitive price of labor μ_t only depends on hours worked and the marginal utility of consumption. It is absolutely not influenced by the average hourly wage and consequently, the nominal wage rigidity of existing jobs does not help to increase inflation persistence by smoothing the marginal cost.

Non-cooperative hours determination Let us now assume that, given the wage bargained j periods ago, the two parties to the contract seek to maximize their individual period surplus through a period-by-period hours negotiation. We allow the worker bargaining power $\eta_h \in (0,1)$ in this particular negotiation to be different from the one on wages (η_w):

$$\max_{h_t} \quad \left(h_t w_{t-j}^* \frac{\bar{\pi}^j p_{t-j}}{p_t} - b - \frac{\kappa_h}{\lambda_t} \frac{h_t^{1+\phi}}{1+\phi} \right)^{\eta_h} \cdot \left(h_t^\theta \mu_t - h_t w_{t-j}^* \frac{\bar{\pi}^j p_{t-j}}{p_t} \right)^{1-\eta_h} \tag{28}$$

Defining

$$\begin{aligned} F_t(w_{t-j}^*) &= (1-\eta_h) \cdot \left(h_t w_{t-j}^* \frac{\bar{\pi}^j p_{t-j}}{p_t} - b - \frac{\kappa_h}{\lambda_t} \frac{h_t^{1+\phi}}{1+\phi} \right) \cdot \left(\mu_t \theta h_t^{\theta-1} - w_{t-j}^* \frac{\bar{\pi}^j p_{t-j}}{p_t} \right) \\ &+ \eta_h \cdot \left(\mu_t h_t^{\theta-1} - w_{t-j}^* \frac{\bar{\pi}^j p_{t-j}}{p_t} \right) \cdot \left(h_t w_{t-j}^* \frac{\bar{\pi}^j p_{t-j}}{p_t} - \frac{\kappa_h}{\lambda_t} h_t^{1+\phi} \right) \quad , \end{aligned} \tag{29}$$

the first order condition is obtained for $F_t(w^*_{t-j}) = 0$.

In the particular case $\eta_h = 0$, the firm retains the right to manage working time and it equalizes the marginal cost of one unit of time with its marginal revenue. At the other extreme, if $\eta_h = 1$, the worker supplies labor until the revenue of the marginal hour is equal to its disutility. The first derivative of hours with respect to wage is negative for $\eta_h = 0$ and positive for $\eta_h = 1$. In between, it is monotonically increasing with η_h, implying that there exists a value of η_h such that the wage is not allocational for hours. For this particular value the positive effect of a wage increase on labor supply is exactly compensated by the negative effect on labor demand. This can be seen by loglinearizing the first order condition $F_t(w^*_{t-j}) = 0$ around the steady state :

$$\hat{h}_t(w^*_{t-j}) = \left(\hat{w}^*_{t-j} + \hat{p}_{t-j} - \hat{p}_t\right) \cdot H_w + \hat{\mu}_t \cdot H_\mu + \hat{\lambda}_{t+j} \cdot H_\lambda \qquad (30)$$

$$\text{with} \quad H_w = \frac{\bar{w}\bar{F}_w}{\bar{h}\bar{F}_h} \;,\; H_\mu = \frac{\bar{\mu}\bar{F}_\mu}{\bar{h}\bar{F}_h} \quad \text{and} \quad H_\lambda = \frac{\bar{\lambda}\bar{F}_\lambda}{\bar{h}\bar{F}_h} \qquad (31)$$

where variables with a hat denote percentage deviation from steady state, the bar above a variable indicates its steady state value and $\bar{F}_x$ is the derivative of F with respect to x $(x = w, \mu, \lambda)$ considered at steady state. We can derive

$$\bar{F}_{\bar{w}} = 0 \Leftrightarrow \eta_h = \frac{2\bar{h}\bar{w} - \bar{\mu}\theta\bar{h}^\theta - \frac{\kappa_h}{\bar{\lambda}}\frac{\bar{h}^{1+\phi}}{1+\phi} - b}{\frac{\kappa_h}{\bar{\lambda}}\bar{h}^{1+\phi} + \bar{\mu}\bar{h}^\theta(1-\theta) - \frac{\kappa_h}{\bar{\lambda}}\frac{\bar{h}^{1+\phi}}{1+\phi} - b} \;.$$

As long as η_h is different from this particular value, the competitive price of labor services μ_t is directly linked to the hourly wage, a feature some authors call the 'wage channel' (Trigari, 2006, Christoffel and Linzert, 2005). Since equation (30) holds for any wage, it is also valid for the aggregate hourly wage w_t with the consequence that nominal and real wage rigidities will directly affect inflation persistence.

In the case $\eta_h = 0$ studied by Christoffel, Kuester and Linzert (2006), we obtain

$$(-1)H_w = H_\mu = \frac{1}{1-\theta} \quad \text{and } H_\lambda = 0$$

so that the link between wage and the competitive price of labor is one-for-one. However, this assumption that the firm is given the right to manage working time implies that the distribution of individual hours worked is $(1-\theta)^{-2}$ times higher than the variance of the distribution of wage. This is especially large when θ is close to unity.

This serious problem can be solved by increasing the household bargaining power in the working time negotiation. In order to show this, Figure 1 plots the coefficients in the log-linearized hours equation as a function of workers' bargaining power on hours, η_h. Since a change in parameter η_h implies a modification of the steady state, this graph has been drawn numerically, using the same calibration as described in section 3.1 below.

[insert Figure 1]

The first observation we can draw from Figure 1 is that the absolute values of the wage and competitive labor price coefficients decrease rapidly and remain very close to each other as η_h increases away from zero. Therefore, an increase of the parameter η_h helps to reduce strongly the impact of a change in the bargained wage on the variation (and distribution) of hours while at the same time, for a fairly wide range of values, it only weakly alters the wage channel. Second, note that H_λ and H_μ are both equal to $\frac{1}{1+\phi+\theta}$ when H_w is equal to zero, which is a property of the model with cooperatively chosen hours.[10] From this we infer that the model with sequential bargaining and infrequently bargained wages offers a general set-up able to encompass both the right-to-manage model and a close approximation of the cooperatively chosen hours model as particular cases.

2.2.6 Job creation and hiring costs

Let A_t^n represent the asset value of a new job for the firm, which can be written as follows:

$$A_t^n = (1 - \xi_w^n)\ A_t^f(w_t^*) + \xi_w^n\ A_t^f(w_{t-1})\,. \tag{32}$$

The asset value of a vacant job A_t^v is then given by:

$$A_t^v = -c_t^v + \beta\,\frac{\lambda_{t+1}}{\lambda_t}\left[\, q_t\ A_{t+1}^n + (1-q_t)\ A_{t+1}^v \right]\,, \tag{33}$$

where c_t^v is the recurrent cost of opening a vacancy. In order to make our results comparable with Gertler and Trigari (2006), we follow them and assume that the average cost per hire[11] is a linear function of the hiring rate m_t/n_t:

$$\frac{c_t^v}{q_t} = \kappa\,\frac{m_t}{n_t} \tag{34}$$

As Yashiv (2006) explains, this assumption emphasizes the cost of incorporating the newly hired workers into the labor force (e.g. training costs) while the usual constant vacancy posting cost focuses on the search cost. Considering the free entry condition $A_t^v = 0$, equation (33) can be recast in:

$$\kappa\frac{m_t}{n_t} = \mathrm{E}_t\left\{\beta\,\frac{\lambda_{t+1}}{\lambda_t}\ A_{t+1}^n\right\}\,. \tag{35}$$

The latter expression makes clear that the dynamics of job creation is leaded by the hiring rate while with more traditional constant recurrent vacancy posting posting costs, this role is played by the labor market tightness.

2.3 Market equilibrium and monetary authority behavior

The final goods market is in equilibrium if production equals demand augmented by the various adjustment costs. Households consume, invest and incur adjustment costs when adjusting the

[10] This can be easily verified by loglinearizing equation (27).

[11] In other words, the cost of adjusting the workforce along the extensive margin.

rate of capital utilization while hiring firms face vacancy posting costs

$$y_t = c_t + i_t + \Psi(z_t) \cdot k_{t-1} + c_t^v \cdot v_t$$

The capital market is in equilibrium when the supply of capital services by households satisfies the demand for capital of the intermediate goods producers.

The interest rate is determined by a reaction function that describes monetary policy decisions:

$$R_t = \varepsilon_t^r \ {R_{t-1}}^{0.9} \ \left[\frac{\bar{\pi}}{\beta} \left(\frac{\pi_t}{\bar{\pi}} \right)^{1.5} \right]^{0.1} , \tag{36}$$

where ε_t^r is an exogenous monetary policy shock specified as an i.i.d. normal process. In this simplified Taylor rule, monetary authorities respond to deviations of inflation from its objective $\bar{\pi}$. The chosen calibration is standard.

3 Simulations and model comparison

We divide our simulation exercise in two different parts. First, we examine the ability of the models described in the paper to reproduce second moments of the US labor market data after a productivity shock. In a second step, we compare the corresponding impulse response functions obtained after a monetary policy shock and focus on their ability to produce inflation persistence.

3.1 Calibration

Table 1 displays the value of the parameters that are kept unchanged through the various model variants in the simulation exercise. In order to properly assess the high rate of job finding that characterizes the US labor market, we opt for a monthly calibration. The key parameters of the business cycle literature are calibrated at conventional values: the chosen discount factor implies an annual steady state real interest rate of 4 percent, capital depreciates by 10% on an annual basis, the capital share is equal to 0.33 and the autocorrelation of the productivity shock is set at $0.95^{1/3}$. Parameters related to the search and matching setup, are mainly calibrated as in Gertler and Trigari (2006). Since there is no strong evidence on the degree of bargaining power, we assign equal power to workers and firms ($\eta = 0.5$). As usual, the worker bargaining power on wage is equal to the match elasticity to unemployment ($\eta_w = 1 - \vartheta$).[12] The separation rate $s = 0.035$ is standard and supported by strong empirical evidence. The unemployment benefit b is supposed constant and we assume that the replacement ratio (between unemployment benefits and the average wage) is 40 percent: $b = 0.4 \ \bar{w}$. We also impose that the job-finding rate and vacancy-filling rate are equal to 0.45 at the steady state ($\bar{j} = \bar{q} = 0.45$). These restrictions yield the values of ϑ_m (matching efficiency) and κ (fixed part of the vacancy-opening cost). Parameter

[12] In a flexible model, this condition would guarantee an efficient equilibrium (Hosios (1990) condition).

θ is adjusted so that the steady state cost of adjusting the workforce is one percent of GDP.[13] Since we consider the role of the intensive margin, we also have to specify some individual parameters. The disutility parameter κ_h is fixed to normalize steady state working time to 1 ($\bar{h} = 1$). The labor supply elasticity is fixed at 0.5, implying that parameter ϕ is 2, following the prior set on this parameter by Smets and Wouters (2005, 2007).

The parameters representing the real and nominal rigidities that are at the core of the new generation of monetary models are calibrated following the priors considered by Smets and Wouters (2005, 2007).[14] We set the habit formation parameter $e = 0.70$. We suppose a quadratic capital utilization cost ($\zeta = 1$) and we choose $\omega = 1/\beta - 1 + \delta$ to normalize steady state capital utilization rate to 1. We assume an annual inflation of 2 percent, implying $\bar{\pi} = 1 + 0.02/12$. The elasticity of substitution between intermediate goods is assumed to be 10, and the Calvo parameter for prices is $\xi_p = 0.87^{1/3}$ in order to reproduce the estimated elasticity of inflation with respect to the real marginal cost. Prices that are not reset may be indexed to past inflation or to trend inflation. We assume that the weight γ_p of past inflation is 0.5. We follow Gertler and Trigari (2006) and set the probability of bargaining the wage for an existing job at $\xi_w^o = 0.7^{1/3}$, implying that the average age of a wage contract is less than one year.

Finally, two parameters are set to match US data. The probability of bargaining the wage of a newly created job, ξ_w^n, is fixed in order to fit the volatility of the US unemployment series (see Table 2 below). The investment adjustment cost parameter, φ, is set to match the relative volatility of investment with respect to output for the data described in the next section.

[insert Table 1]

3.2 Productivity shock

For the productivity shock, we mainly compare the ability of the various variants of our model to match second moments of US statistics. The US data we use for this exercise are the following: output, real hourly compensation, labor share, employment, unemployment, vacancies, hours, output per hour and output per person. All the series are quarterly data in the non-farm business sector from the BLS, except for 'unemployment',[15] which is a monthly series transformed into a quarterly one, and 'vacancies', which is the seasonally help wanted advertising index from the Conference Board, available at a monthly frequency and also transformed to quarterly frequency. Our sample runs from 1966Q1 to 2005Q4. In order to fix the investment adjustment

[13]Imposing that the same proportion of GDP is devoted to the same employment adjustment cost in the steady state for all the variants of the model implies that we impose the same steady state wage. However, equation (24) clearly illustrates that the wage bargain will be very different from one variant to another and should imply differences in the steady state wage. In order to avoid this, we adjust the parameter θ accordingly.

[14]Quarterly parameters are transformed in monthly values.

[15]Seasonally adjusted unemployment level (16 year and over).

cost parameter, we use the investment series from the US Department of Commerce - Bureau of Economic Analysis.

All series are logged and HP-filtered with a 1600 smoothing weight. Their second moments are reported in the second column of Table 2. The other columns contain statistics computed from the data generated after a productivity shock respectively by (i) a model with monopolistic labor and nominal wage stickiness, denoted MC, (ii) the model with sequential bargaining (SB), simulated for various values of workers' bargaining power in the hours negotiation and (iii) the model with cooperatively chosen hours (CH).

The first row of Table 2 presents the calibrated values of workers' bargaining power η_h for the models with bargained hours. The second row displays the corresponding elasticity of the competitive price of labor with respect to wage. As was already clear from Figure 1, the larger η_h, the lower the influence of wages on the competitive price of labor. In particular, for $\eta_h = 0.97$, this elasticity becomes zero, as in the model where hours are cooperatively chosen to maximize the joint period surplus. The third row is interesting as it presents ξ_w^n, the wage rigidity on newly created jobs required to reproduce the observed standard deviation of unemployment relative to output. As we know since Shimer (2004) and Hall (2005b), the more rigid the wage of new jobs, the more vacancies and (un)employment are volatile. Note that the higher η_h the less we need this type of rigidity to reproduce the relative volatility of US labor statistics. This is good news since many have claimed that the wage of the new jobs is actually more flexible than that of existing jobs (cf. for example Haefke et al. (2007) and Pissarides (2007)). Interestingly, in the case $\eta_h = 0$, i.e. the 'right-to-manage' case, we are never able to produce realistic unemployment relative volatility. This can be easily understood. When the firms are left free to optimize the working time, they will demand lots of hours from the workers with a relatively low wage and the other way round. In some sense, the adjustment along the intensive margin is so cheap and unconstrained that they have few incentives to adjust along the extensive margin. As η_h increases, firms progressively lose this flexibility and eventually, once wage does not affect hours (that is if $\eta_h = 0.97$ or if hours are cooperatively decided), all the workers provide the same working time, whatever their wage.

In this particular case, the model is exactly similar to Gertler and Trigari (2006), but for the inclusion of hours.[16] The presence of hours explains that the observed unemployment relative standard deviation can be matched with ξ_w^n, the degree of wage rigidity for the newly hired workers much lower than ξ_w^o, the wage rigidity of the existing matches. This is simply because the procyclical behavior of hours increases the expected profitability of a new hire, reducing the need for a high ξ_w^n.

Note also that workers' bargaining power concerning their working time directly affects their effective bargaining power in the wage negotiation. For example, in the extreme case $\eta_h = 0$, workers internalize the fact that high wage requirements will imply very low working time and this reduces wage pressure. This mechanism is illustrated by the relative standard deviation

[16] And as said above, the horizon effect. However, Gertler and Trigari (2006) shows that the latter only plays a minor role.

of the hourly wage: the more wage is allocational for hours, the lower the volatility of the real hourly wage. While our models are rather good at matching the unemployment volatility, they have a harder job to produce enough volatility of total hours. From this viewpoint the best calibration of the sequential bargaining model is $\eta_h = 0.40$ as it matches both relative standard deviations. For higher values of the hours bargaining power -and for the model with cooperatively chosen hours-, individual hours reverse too quickly to the steady state as displayed by the serial correlation statistics. As already discussed, in the model with $\eta_h = 0$, it is the contrary that happens: individual hours are too volatile since the model is able to match the data relative standard deviation for this variable while it fails to reproduce observed employment relative volatility.

Finally, the model with sequential bargaining and the model with cooperatively chosen hours perform quite well with respect to the relative volatility of hourly productivity and especially of worker productivity. However, these series are too highly correlated with output while their serial correlation is more in line with data. The sequential bargaining model also seems particularly good at reproducing the co-movement between output and the labor share, total hours or vacancies. Note that for the model with $\eta_h = 0.40$, this is also true of unemployment.

[insert Table 2]

We conclude that the models with sequential bargaing or cooperatively chosen hours do not only provide a more complete picture of the labor market than the usual macroeconomic model with monopolistic labor: for the subset of concepts that are common with the latter model, they are most often at least as good in reproducing stylized facts.

3.3 Monetary policy shock

In the previous sub-section we focused on labor market variables. Let us now consider the ability of the various model variants to produce inflation persistence. In this exercise we use the MC model as the benchmark since it has already proved to perform well on this aspect. We run our comparative analysis on the basis of impulse response functions after an unanticipated drop of 1 percentage point in the (annual) nominal interest rate.

Figure 2 focuses on the role of the η_h parameter in the sequential bargaining model and illustrates the discussion of the 'wage channel'. For this purpose we plot the reactions of several variables after a monetary policy shock for three values of η_h (0, 0.4 and 0.97). Let us remember the aggregate variant of equation (30)

$$\hat{\mu}_t = \frac{h_t}{H_\mu} - \hat{w}_t \frac{H_w}{H_\mu} - \hat{\lambda}_t \frac{H_\lambda}{H_\mu} \tag{37}$$

together with Figure 1 that graphs the values of H_w, H_μ and H_λ for the chosen calibration. From this, it is obvious that for the $\eta_h = 0$, the wage channel is important since $H_w/H_\mu = -1$. The value of the elasticity of the competitive price of labor with respect to wage is respectively 0.95

and 0 for the two other values of η_h. We observe that when $\eta_h = 0$, the model produces huge inflation persistence. Indeed, marginal cost is the leading variable for inflation dynamics in the new-Keynesian Phillips curve (4) and the competitive price of labor μ_t is the major component of the the marginal cost. For $\eta_h = 0$, the third term on the RHS of (37) vanishes. As mentioned earlier, the labor force adjustment occurs mainly on the intensive margin but the movement in hours is counterbalanced by the weakness of its associated parameter in (37). Therefore wages are the main explanatory variable of μ_t and of marginal cost. Furthermore, as explained above, if firms retain the right-to-manage working hours when wage negotiations are infrequent, this strongly reduces workers' bargaining power in the wage negotiation, implying very sticky wages. As η_h increases, (*i*) the workers' bargaining power in the wage negotiation is enhanced, leading progressively to a less sticky wage, (*ii*) the aggregate wage coefficient in equation (37) gets smaller but at a very slow pace, (*iii*) aggregate individual hours react less strongly since more adjustment occurs along the intensive margin but the coefficient of this variable increases rapidly with η_h and (*iv*) the role of the marginal utility of consumption increases even though it remains moderate because of the weakness of the associated parameter. These four elements go in the same direction and contribute together to generate more volatility in the competitive price of labor, and consequently in inflation.

[insert Figure 2]

It is also interesting to illustrate how the Calvo parameter ξ_w^o setting the probability of re-bargaining the wage of existing jobs, interacts with parameter η_h to produce inflation persistence. This is the goal of Figure 3 which compares the effect of a drop from $\xi_w^o = 0.7^{1/3}$ to $\xi_w^o = 0.2^{1/3}$ in the cases $\eta_h = 0.4$ and $\eta_h = 0.97$. As already stated, parameter η_h controls the importance of the so-called 'wage channel' while parameter ξ_w^o helps to determine the wage stickiness. Obviously, if the wage channel is is completely closed, i.e. if $\eta_h = 0.97$ (or if the wage is cooperatively chosen), the competitive price of labor and the marginal cost are only marginally affected by a reduction in the probability of re-bargaining the wage even though it leads to a much higher wage volatility. This feature is clearly an argument against models without any wage channel since it is difficult to accept that variations in wage have no impact on price setting. On the contrary, once the wage channel is open (for example $\eta_h = 0.4$), any element that affects wage behavior modifies inflation patterns in the same direction. Of course, this is especially the case for parameter ξ_w^o. It is also interesting to note from this Figure that there is a strong interaction between parameters ξ_w^o and ξ_w^n. Indeed, the higher is ξ_w^o, the smoother are the dynamics of the expected wage for a newly created job. This provides an incentive for vacancy posting and job creation. At lower values of ξ_w^o, the volatility of employment falls and individual hours have to vary much more to compensate. This higher volatility of aggregate individual hours is the main source of the small increase in inflation we observe when the wage is not allocational for hours and the Calvo probability of re-bargaining an existing job increases.[17]

[insert Figure 3]

Finally, Table 1 and Figure 4 illustrate very similar dynamics for the models characterized by a wage that is not allocational for hours. From this, we conclude that our variant of the sequential bargaining model with a workers' bargaining power on individual hours worked strong enough for all workers to share the same working time is a good approximation of the Thomas (2008) model where hours are chosen in a privately efficient way to maximize the period surplus.

[insert Figure 4]

4 Conclusion

The present paper extends the literature on monetary models with search and matching frictions on the labor market. It builds upon the seminal work of Trigari (2006) and Christoffel and Linzert (2005) on the direct link that opens in these models between wage and marginal cost when firms are left free to manage hours worked. As exemplified by Christoffel, Kuester and Linzert (2006), this 'wage channel' produces inflation persistence once stickiness is introduced in the wage-setting process. These authors explored the path opened by Shimer (2004) and Hall (2005b) by introducing staggered wage bargaining. A priori, this should improve the performance of the model in reproducing labor market dynamics and also generate inflation persistence.

We establish that when firms retain the right-to-manage the hours worked in a framework with staggered wage bargaining, the result is an unrealistic volatility of the individual hours and too little volatility of employment. The reason is simply that firms can adjust easily along the intensive margin by asking the workers in the bottom of the wage distribution to work a lot. This generates an unrealistic distribution of individual hours and strongly reduces the effective bargaining power of the workers in the wage negotiation.

In order to counteract these pernicious effects, we amend the model to give workers the possibility to affect hours. For this we introduce a bargain on working time that is activated every period unlike the wage bargain. We show that reducing the firms' prerogatives this way reduces their incentive to adjust along the extensive margin and helps to produce realistic labor market statistics. In this sense, it plays a role similar to the fixed cost introduced by Christoffel and Kuester (2008) at the hiring firm level. Furthermore, for a wide range of values of the workers bargaining power in the hours negotiation, the wage channel remains relatively strong which allows to obtain inflation persistence. Interestingly, our model with sequential bargaining

[17] This point makes clear that in the absence of a wage channel, wage only affect the marginal cost indirectly through the employment dynamics and the implied behaviour of hours. About this, see Trigari (2006).

wage-hours encompasses as particular cases the right-to-manage model as well as a fairly close approximation of the model where hours are cooperatively fixed in an efficient way .

Finally, contrarily to Gertler and Trigari (2006) or Christoffel, Kuester and Linzert (2006), we allow the wage of new entrants on the labor market to be more flexible than those of the existing jobs, following both intuition and recent literature (Haefke *et al.*, 2007 and Pissarides, 2007). We show that this distinction is essential if we want to fine tune a model able to generate at the same time a realistic labor market and inflation persistence. Indeed, wage rigidity for the new entrants is important to generate a realistic amplitude of employment dynamics while wage rigidity for the existing jobs transmits into inflation persistence through the wage channel.

References

[1] **Barro, R. (1977)**, 'Long-term contracting, sticky prices, and monetary policy', *Journal of Monetary Economics*, Vol. 3(3), pages 305-316.

[2] **Blanchard, O. , and J. Gali (2006)**, 'A New Keynesian model with unemployment', National Bank of Belgium *Working Paper* No. 92.

[3] **Blanchard, O. , and J. Gali (2007)**, 'Real wage rigidities and the New Keynesian model', *Journal of Money, Credit and Banking*, Vol. 39(1), pages 35-65.

[4] **Bodart, V., O. Pierrard and H. Sneessens (2005)**, 'Calvo wages in a search unemployment model', DNB Working Paper.

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

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

[7] **Christoffel, K., K. Kuester and T. Linzert (2006)**, 'The impact of labor markets on the transmission of monetary policy in an estimated DSGE model', ECB Working Paper 635.

[8] **Christoffel, K., and T. Linzert (2005)**, 'The role of real wage rigidity and labor markets frictions for unemployment and inflation dynamics', ECB Working Paper 556.

[9] **Christoffel, K. and K. Kuester (2008)**, 'Resuscitating the wage channel in models with unemployment fluctuations', *Journal of Monetary Economics*, forthcoming.

[10] **Elsby, M., R. Michaels and G. Solon (2008)**, 'The ins and outs of cyclical unemployment', *American Economic Journal: Macroeconomics*, forthcoming.

[11] **Erceg, C., D. Henderson and A. Levin (2000)**, 'Optimal monetary policy with staggered wage and price contracts', *Journal of Monetary Economics*, Vol. 46(2), pages 281-313.

[12] **Fujita, S. and G. Ramey (2007)**, 'Reassessing the Shimer facts', Working Papers 07-2, Federal Reserve Bank of Philadelphia.

[13] **Gertler, M., L. Sala and A. Trigari (2007)**, 'An estimated monetary DSGE model with unemployment and staggered nominal wage bargaining', mimeo.

[14] **Gertler, M. and A. Trigari (2006)**, 'Unemployment fluctuations with staggered Nash wage bargaining', Proceedings FRB San Francisco.

[15] **Haefke, C., M Sonntag and T. van Rens (2007)**, 'Wage rigidity and job creation', mimeo.

[16] **Hall (2005a)**, 'Employment fluctuations with equilibrium wage stickiness', *American Economic Review*, Vol. 95(1), pages 50-65.

[17] **Hall (2005b)**, 'Job loss, job finding and unemployment in the U.S. economy over the past fifty years', prepared for the NBER Macro Annual Conference, April 2005.

[18] **Hosios, A. (1990)**, 'On the efficiency of matching and related models of search and unemployment', *Review of Economic Studies*, Vol. 57, pages 279-298.

[19] **Krause, M., and T. Lubik (2006)**, 'The cyclical upgrading of labor and on-the-job search', *Labour Economics*, Vol. 13, pages 459-77.

[20] **Krause, M., and T. Lubik (2005)**, 'The (ir)relevance of real wage rigidity in the New Keynesian model with search frictions', *Journal of Monetary Economics*, Vol. 54, pages 706-27.

[21] **Manning, A. (1987)**, 'An integration of trade unions models in a sequential bargaining framework', Economic Journal, Vol. 97, pages 121-139.

[22] **Merz, M. (1995)**, 'Search in the labor market and the real business cycle', *Journal of Monetary Economics*, Vol. 36, pages 269-300.

[23] **Mortensen, D., and C. Pissarides (1994)**, 'Job creation and job destruction in the theory of unemployment', *Review of Economic Studies*, Vol. 61, No.3, pages 397-415.

[24] **Mortensen, D. and C. Pissarides (1999)**, 'Job reallocation, employment fluctuations and unemployment', in *Handbook of Macroeconomics*, ed. by J. Taylor and M. Woodford, Vol. 1, chap. 18, pages 1171-12228. Amsterdam: North-Holland.

[25] **Moyen, S. and J.-G. Sahuc (2005)**, 'Incorporating labor market frictions into an optimising-based monetary policy model', *Economic Modelling*, Vol. 22, pages 159-186.

[26] **Nickell, S. (1982)**, 'A bargaining model of the Phillips curve', Discussion Paper 105, London School of Economics.

[27] **Pissarides, C. (2007)**, 'The unemployment volatility puzzle: is wage stickiness the answer?', CEP Discussion Paper N°839, (LSE).

[28] **Shimer, R. (2004)**, 'The consequences of rigid wages in search models', *Journal of the European Economic Association*, Vol. 2, pages 469-479.

[29] **Shimer, R. (2005)**, 'The cyclical behaviour of equilibrium unemployment and vacancies', *American Economic Review*, Vol. 95, pages 25-49.

[30] **Shimer, R. (2007)**, 'Reassessing the ins and outs of unemployment', NBER Working Papers 13421.

[31] **Smets, F. and R. Wouters (2003),** 'An Estimated Dynamic Stochastic General Equilibrium Model of the Euro Area', *Journal of the European Economic Association*, Vol. 1(5), pages 1123-1175.

[32] **Smets, F. and R. Wouters (2005)**, 'Comparing shocks and frictions in US and euro area business cycles: a Bayesian DSGE Approach', *Journal of Applied Econometrics*, Vol. 20(2), pages 161-183.

[33] **Smets, F. and R. Wouters (2007)**, 'Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach', *American Economic Review*, Vol. 97(3), pages 586-606.

[34] **Thomas, C. (2008)**, 'Search and matching frictions and optimal monetary policy', *Journal of Monetary Economics*, forthcoming.

[35] **Trigari, A. (2004)**, 'Equilibrium unemployment, job flows and inflation dynamics', ECB Working Paper No. 304.

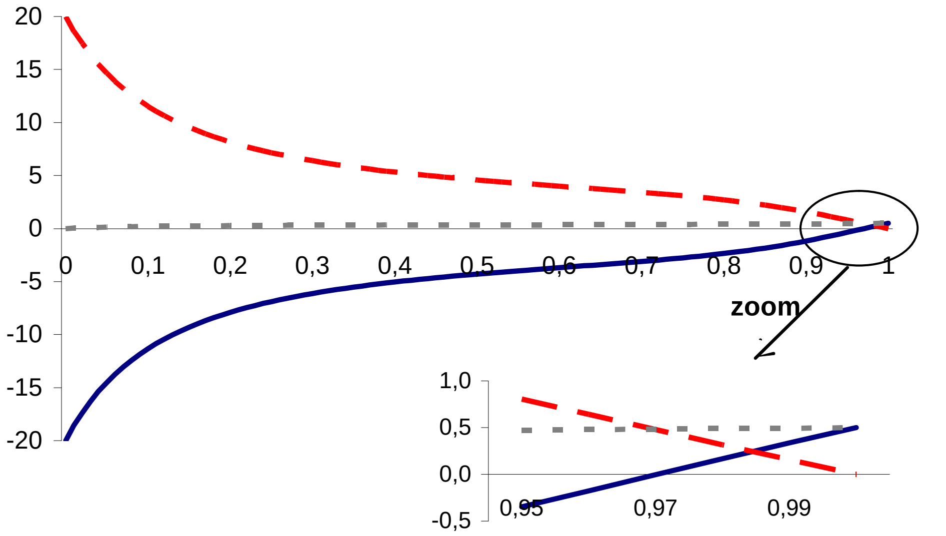
[36] **Trigari, A. (2006)**, 'The role of search frictions and bargaining for inflation dynamics', IGIER Working Paper No. 304.

[37] **Yashiv, E. (2006)**, 'Evaluating the performance of the search and matching model', European Economic Review, Vol. 50, pages 909-936.

[38] **Walsh, C. (2005)**, 'Labor marker search, sticky prices, and interest rate policies', *Review of Economic Dynamics*, Vol. 8, 829-849.

Appendix A: Figures and Tables

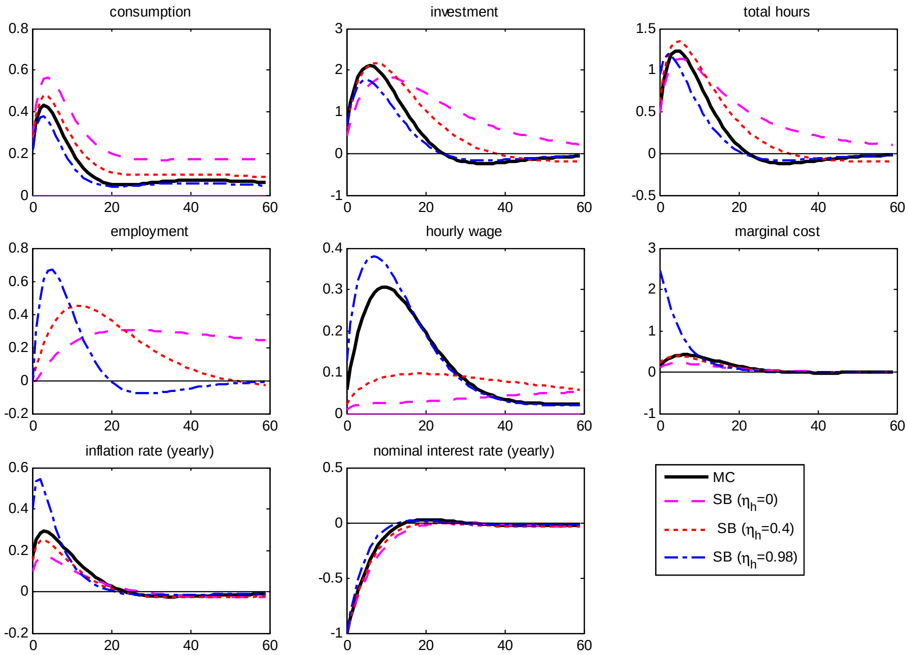
Figure 1: coefficients H_w, H_μ and H_λ (equ. 30) as a function of η_h



legend: H_w is the solid line, H_μ is the dashed line and H_λ the dotted line

Numerical computation based on the calibration described at section 3.1

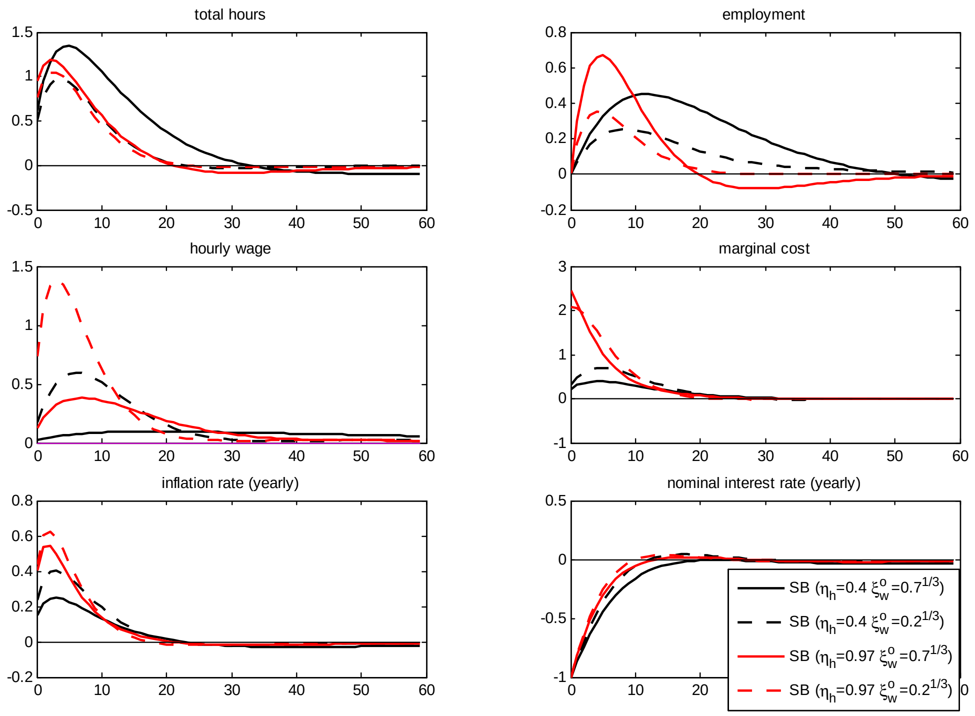
Figure 2: Monetary policy shock - the role of η_h



The monetary policy shock is an unexpected drop in the yearly nominal interest rate by 1 ppt.

one period = one month

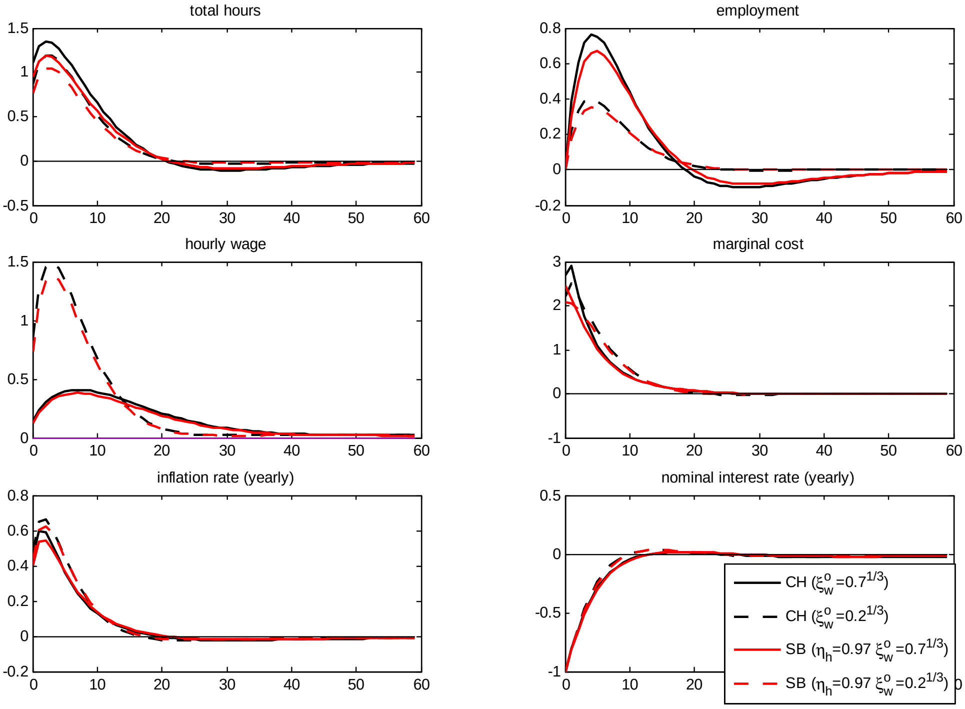
Figure 3: Monetary policy shock - the role of ξ_w^o



The monetary policy shock is an unexpected drop in the yearly nominal interest rate by 1 ppt.

one period = one month

Figure 4: Monetary policy shock - comparing CH and SB ($\eta_h = 0.97$)



The monetary policy shock is an unexpected drop in the yearly nominal interest rate by 1 ppt.

one period = one month

Table 1: Calibration common to all the variants (monthly)

Parameters	Description	Value
business cycle parameters		
β	discount factor	$0.99^{1/3}$
δ	capital depreciation rate	0.1/12
α	capital share	0.33
ρ_a	prod. shock AR1	$0.95^{1/3}$
search and matching		
s	job destruction rate	0.035
η_w	worker bargaining power (wage)	0.5
ϑ	vacancies elasticity	0.5
b	unemployment benefits	$\bar{w} \cdot 0.4$
$\bar{j}$	job finding probability	0.45
$\bar{q}$	vacancy filling probability	0.45
$\frac{c^v \bar{v}}{\bar{y}}$	vacancy cost as a share of GDP	0.01
hours		
ϕ	hours disutility elasticity	2
$\bar{h}$	hours	1
Real and nominal rigidities		
e	consumption habit	0.7
ζ	capital utilization cost elasticity	1
ω	capital utilization cost weight	0.012
$\bar{\pi}$	long run inflation	1.002
$\frac{1}{1-\lambda_p}$	CES production technology	10
ξ_p	price rigidity	$0.87^{1/3}$
ν	indexation parameter	0.5
ξ_w^o	prob. to bargain an existing job wage	$0.7^{1/3}$

Table 2: Productivity shock - summary of statistics

	US data	MC	SB					CH
η_h		-	0.00	0.40	0.80	0.90	0.97	-
$-(H_w/H_\mu)$		-	1.00	0.95	0.74	0.58	0.00	0.00
$(\xi_w^n)^3$		-	0.70	0.37	0.31	0.27	0.20	0.19
θ			0.98	0.98	0.97	0.97	0.93	0.96
Relative standard deviation (w.r.t. output)								
hourly wage	0.53	0.46	0.23	0.32	0.41	0.43	0.45	0.45
labor share	0.51	0.51	0.40	0.40	0.49	0.50	0.46	0.48
employment	0.61	-	0.27	0.41	0.40	0.40	0.41	0.40
total hours	0.84	0.71	0.84	0.82	0.70	0.67	0.64	0.64
unemployment	5.17	-	3.47	5.17	5.17	5.17	5.17	5.17
vacancies	6.57	-	4.07	6.30	6.47	6.53	6.65	6.26
tensions	11.99	-	7.43	11.30	11.36	11.40	11.45	11.00
prod./hour	0.49	0.58	0.41	0.44	0.53	0.55	0.55	0.56
prod./worker	0.62	-	0.91	0.67	0.62	0.62	0.62	0.63
Correlation with output								
hourly wage	0.56	0.86	0.88	0.78	0.79	0.81	0.83	0.83
labor share	-0.19	-0.05	-0.09	-0.17	-0.16	-0.15	-0.15	-0.49
employment	0.79	-	0.47	0.87	0.96	0.96	0.96	0.94
total hours	0.87	0.83	0.91	0.92	0.86	0.86	0.87	0.85
unemployment	-0.85	-	-0.47	-0.87	-0.96	-0.96	-0.96	-0.94
vacancies	0.89	-	0.72	0.98	0.94	0.91	0.87	0.88
tensions	0.88	-	0.61	0.95	0.97	0.96	0.94	0.95
prod./hour	0.54	0.72	0.57	0.61	0.75	0.77	0.81	0.80
prod./worker	0.71	-	0.97	0.95	0.98	0.98	0.98	0.98
Serial correlation								
output	0.87	0.92	0.93	0.93	0.92	0.91	0.89	0.90
hourly wage	0.92	0.95	0.95	0.95	0.95	0.95	0.95	0.95
labor share	0.71	0.65	0.67	0.67	0.68	0.69	0.69	0.77
employment	0.94	-	0.97	0.96	0.93	0.93	0.91	0.91
total hours	0.92	0.75	0.88	0.87	0.77	0.75	0.73	0.73
unemployment	0.92	-	0.97	0.96	0.93	0.93	0.91	0.91
vacancies	0.92	-	0.96	0.95	0.92	0.91	0.87	0.89
tensions	0.93	-	0.97	0.96	0.93	0.92	0.90	0.92
prod./hour	0.72	0.73	0.67	0.69	0.74	0.76	0.79	0.78
prod./worker	0.78	-	0.93	0.91	0.89	0.89	0.86	0.86