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OF UNEMPLOYMENT AND INFLATION**

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# Credible Wage Bargaining and the Joint Dynamics of Unemployment and Inflation

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*Abstract* : Empirically, unemployment is highly volatile while inflation displays inertia, even though marginal cost is pro-cyclical. It was argued that real wage rigidities would no longer help replicate these facts, once firms determine employment and hours per worker. In this paper, real wage stickiness stems from wage bargaining with credible threat points, that we embed into a New Keynesian framework in which firms adjust both labor margins. This model notably reproduces the large jump in unemployment in the Great Recession. Moreover, inflation inertia is made consistent with pro-cyclical marginal cost since the credible bargaining induces strategic complementarities between firms.

*JEL Classification* : E32, E50, J63, J64.

*Keywords* : New-Keynesian model, labor market frictions, unemployment, inflation, real wage rigidities.

*Extrait* : Empiriquement, le taux de chômage est fortement volatile aux Etats-Unis alors que l'inflation est inerte, bien que le coût marginal soit pro-cyclique. La littérature a montré que les rigidités de salaire réel ne permettaient plus de répliquer ces faits stylisés lorsque les entreprises ajustent l'emploi et les heures par travailleur. Dans ce papier, les rigidités de salaire réel proviennent de la négociation salariale crédible, introduite dans un modèle Néo-Keynésien avec frictions sur le marché du travail. Les entreprises ajustent l'emploi et les heures par travailleur. Ce modèle réplique en particulier la forte augmentation du taux de chômage liée à la Grande Récession. En outre, l'inertie de l'inflation est rendue compatible avec un coût marginal pro-cyclique dans la mesure où la négociation crédible implique des complémentarités stratégiques entre les entreprises.

*Codes JEL* : E32, E50, J63, J64.

*Mots-clés* : modèle Néo-Keynésien, frictions sur le marché du travail, chômage, inflation, rigidités de salaire réel.

## Non-technical summary

A large literature in macroeconomics and labor economics stresses the major role played by real wage rigidities in explaining the dynamics of both unemployment and inflation. On the labor-market side, those rigidities would be the main ingredient to solve the unemployment volatility puzzle raised by Shimer (2005), namely the inability of the standard search and matching model to replicate the high volatility of the unemployment rate in the US. On the nominal side, real wage rigidities would make the standard New Keynesian model consistent with inflation inertia, namely the small and persistent response of inflation to shocks.

This literature usually retains frameworks in which firms adjust labor demand only through employment. However, when firms, realistically, can adjust labor along both the extensive (employment) and the intensive (hours per worker) margins, real wage rigidities would no longer amplify unemployment fluctuations, nor explain inflation inertia consistently with the empirical pro-cyclicality of the marginal cost. On the labor-market ground, Sveen and Weinke (2008) stress that real wage stickiness would create an incentive for firms to overuse hours per worker, which would come at the expense of raising unemployment movements. On the nominal ground, Basu (2005) challenges explanations of inflation inertia based on real wage rigidities : those rigidities would imply a sluggish dynamics for the cost of a marginal hour - the relevant marginal cost when firms adjust both labor margins - at odds with the pro-cyclical behavior of this cost highlighted by Bilts (1987).

In this paper, we argue that those failures are not related to real wage rigidities per se, but instead to the way these rigidities are introduced. The literature traditionally integrates those rigidities through the lens of an ad-hoc wage norm. Here, real wage stickiness results from wage bargaining with credible threat points (Hall and Milgrom (2008)) which corresponds to the sequential bargaining game of Rubinstein (1982). We introduce this wage bargaining into a New Keynesian framework with matching frictions in the labor market. Firms adjust both labor margins and set prices.

We first show that this model replicates the high volatility of unemployment, as well as the small and persistent movements in inflation, that characterize US post-war data. Moreover, the model displays inflation inertia in a way consistent with the pro-cyclical behavior of marginal cost. We next use our framework to address the “missing deflation puzzle” raised by Hall (2011), namely the inability of New Keynesian models to reconstitute the small decline in inflation that followed the financial crisis of 2008. We show that the model reproduces the

impulse response functions for both unemployment and inflation after the financial shock, making the weak fall in inflation consistent with the deep economic slack. We finally stress that the model is able to provide a substantial trade-off between stabilizing unemployment and stabilizing inflation, in line with conventional wisdom. Instead, the wage norm fails along all of these dimensions.

Hall and Milgrom (2008) underline that on a frictional labor market, the only credible threat consists in delaying the moment the worker and the employer reach an agreement. The credible threat points are therefore the a-cyclical payments obtained by the parties during the wage negotiation and no longer the pro-cyclical outside options. The a-cyclical payoffs entail a real wage rigidity with respect to labor market conditions. However, the real wage does not display any stickiness with respect to the disutility of labor and then with respect to hours per worker. Conversely, the wage norm implies a mechanical wage rigidity with respect to both labor market conditions and hours per worker.

The credible bargaining and the wage norm both generate a wage rigidity with respect to labor market conditions, which creates an incentive for firms to adjust on employment. For the credible bargaining, the wage flexibility with respect to hours per worker amplifies the incentive to adjust on employment, explaining the high volatility of the unemployment rate. At the same time, the flexibility of the real wage with hours implies that a firm, when considering a reduction in its relative price, expects that its marginal cost will largely increase and finally chooses a smaller price reduction. Hence, there is a high degree of strategic complementarities between price setters that makes inflation inertia consistent with a pro-cyclical marginal cost. For the wage norm, instead, the wage stickiness with respect to hours per worker creates an incentive for firms to adjust on hours that partly offsets the incentive to adjust on employment. At the same time, the rigidity of the real wage with respect to hours implies inflation inertia through a sluggish marginal cost, at odds with the evidence in Bils (1987).

# 1 Introduction

Real wage rigidities are considered as a major source of amplification of business-cycle shocks on unemployment<sup>1</sup>. At the same time, real wage stickiness can be a source of inflation inertia, by which we mean small and persistent response of inflation to shocks.<sup>2</sup> Yet, existing theories have difficulties generating both of these effects once labor, realistically, can be adjusted along both the extensive (employment) and the intensive (hours per worker) margins<sup>3</sup>. Sveen and Weinke (2008), for instance, point out that real wage stickiness would no longer amplify unemployment movements, given the resulting incentive for firms to use more hours per worker. Basu (2005) challenges explanations of inflation inertia based on real wage rigidities : these rigidities would make the cost of a marginal hour sluggish, at odds with the empirical pro-cyclicality of this cost highlighted by Bils (1987).

This paper introduces credible wage bargaining (Hall and Milgrom (2008)) into a New Keynesian model with matching frictions in the labor market. We consider a large-firm framework in which firms create jobs, determine hours per worker and set prices<sup>4</sup>. The credible bargaining applies the sequential bargaining game of Rubinstein (1982) to the wage negotiation. Wage stickiness arises endogenously. The paper demonstrates that this setup is able to generate the right dynamics for unemployment, inflation and marginal cost, even when firms determine both labor margins. A main implication of this paper is that the way to introduce real wage rigidities is critical in explaining the joint dynamics of unemployment and inflation.

Hall and Milgrom (2008) underline that on a frictional labor market, the credible threat is

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<sup>1</sup>Shimer (2005) and Hall (2005) notably argue that those rigidities are the solution to the unemployment volatility puzzle raised by Shimer (2005), i.e. the inability of the standard search and matching model to replicate the high volatility of unemployment in the US. See Pissarides (2000) for an exposition of the search and matching model.

<sup>2</sup>Blanchard and Galí (2007), for example, stress that wage stickiness is the required ingredient to reconcile the standard New Keynesian model with such inflation dynamics. See Galí (2008) for a presentation of the canonical New Keynesian framework.

<sup>3</sup>Ohanian and Raffo (2012) and Daly et al. (2014) show the importance of accounting for both labor margins.

<sup>4</sup>We therefore follow the recent literature, notably Sveen and Weinke (2009), Barnichon (2010a), Kuester (2010) and Thomas (2011), by assuming that the same set of firms that post vacancies and engage in wage negotiation also set prices. This assumption is natural given our focus on the impact of wage bargaining and wage rigidities on inflation dynamics. Moreover, it was shown that the interaction between wage and price settings creates strategic behaviors between firms. Hence, this assumption allows to investigate how various wage bargains modify strategic behaviors between price setters.

no longer to leave the wage bargain, but instead to delay the moment a wage agreement is reached. The credible threat points are the a-cyclical payments obtained by the parties during the negotiation. The resulting real hourly wage is therefore partly insulated from labor market conditions, which creates an incentive for firms to adjust labor through employment. However, the wage outcome does not display any stickiness with respect to the disutility of labor, and then with respect to hours worked. This means that the real marginal wage - the wage paid for an additional hour - largely increases with hours worked. The incentive to adjust employment is thus magnified. At the same time, the credible bargaining induces strategic complementarities between firms that make inflation inertia consistent with pro-cyclical marginal cost. Indeed, employment is predetermined<sup>5</sup> in our model. When faced with a shock, firms can only expand hours per worker on impact. The relevant marginal cost is then the cost of an additional hour, which is given by the real marginal wage. A firm that considers a reduction in its relative price will have to raise hours per worker to adjust production to its higher demand. Anticipating the large increase in its marginal cost will lead this firm to finally keep its price in line with the overall price level. Existing New Keynesian models with matching frictions usually introduce real wage rigidities through ad-hoc wage rules. In these models, there is a mechanical stickiness of the real marginal wage with respect to hours worked. This creates an incentive to overuse hours per worker instead of employment. Moreover, the rigidity of the real marginal wage implies inflation inertia through a sluggish marginal cost, in contrast to the evidence in Bils (1987).

We first assess the capacity of the model to replicate business cycle moments for the US economy. The credible bargaining is shown to reconstitute both the high unemployment volatility and inflation inertia in the US post-war data. This model also replicates to a large extent the relative volatility of employment and hours per worker in the data.

Next, we assess the ability of different wage-setting protocols to reproduce the stylized facts. We allow for an ad-hoc wage norm, initiated by Hall (2005), which was the standard way retained by the search and matching literature to introduce real wage stickiness. The wage norm sets the current real wage as a weighted average of a flexible wage and a constant, or lagged, wage. We show that the wage norm generates only weak unemployment fluctuations, with too much volatility of hours per worker relative to employment. Both of these

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<sup>5</sup>This means that it takes one period for a newly hired worker to become productive. Predetermined employment appears as a reasonable assumption since VAR evidence suggests that, on impact, employment responds little (if at all) to shocks (see Monacelli et al. (2010), Brueckner and Pappa (2012)).



specifications, the credible bargaining and the wage norm, display a reasonable amount of inflation inertia. The advantage of the credible bargaining is that it generates inflation inertia in a way consistent with the cyclical behavior of marginal cost. Namely, the cost of an additional hour per worker is highly pro-cyclical and close to the evidence reported by Bils (1987). The wage norm instead produces inflation inertia through an excessive sluggishness of the marginal cost.

The paper next uses the credible-bargaining framework to address the “missing deflation puzzle”. Hall (2011) argues that DSGE models based on the New Keynesian Phillips Curve (NKPC) would generate a sharp deflationary response to the severe rise in unemployment that followed the financial crisis of 2008. This deflationary response would be at odds with the observed weak decline in inflation for the US. We show that the credible bargaining reproduces the impulse response functions for both unemployment and inflation after a financial shock<sup>6</sup>, making the small decline in inflation consistent with the deep economic slack. This is obtained without assuming an exogenous increase in the degree of nominal price stickiness, as in Del Negro, Giannoni and Schorfheide (2015).

Finally, we consider normative issues, and particularly the stabilization trade-off between unemployment and inflation. For the credible bargaining, the unemployment rate, in response to a productivity shock, is much more volatile under the zero inflation policy than under the optimal monetary policy. The real wage rigidities resulting from this wage bargaining thus produce a meaningful trade-off between stabilizing unemployment and stabilizing inflation. For the wage norm, instead, the fluctuations of the unemployment rate under the policy ensuring price stability are very close to the optimal fluctuations of this rate.

**Related literature.** Christiano, Eichenbaum and Trabandt (2015b) introduce the credible bargaining into a New Keynesian model with matching frictions. They estimate this framework and show that it better fits the data than the model with nominal wage rigidities. Christiano, Eichenbaum and Trabandt (2015a) confront their model to the Great Recession and find that it accounts for the right dynamics of inflation. However, there are two important differences with our framework. First, firms adjust labor demand only through employment. Secondly, the firms that set prices and those that bargain over the wage are not the same. Inflation in their model does not collapse given both an assumed

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<sup>6</sup>We follow Del Negro, Giannoni and Schorfheide (2015) by interpreting an exogenous wedge between the intertemporal ratio of the marginal utility of consumption and the riskless real return as a “financial” shock.

neutral technology shock and a risky working capital effect, which arise independently of the wage bargain. By investigating the trade-off between the intensive and extensive margins of labor, and focusing on the channel between the wage bargain and pricing decisions, we provide a complementary analysis of the credible bargaining. All those papers share the common implication that using micro-founded real wage rigidities matters not only for theoretical elegance, but above all improves quantitative results.

Sveen and Weinke (2008) emphasize that the ability of real wage rigidity to amplify unemployment fluctuations critically depends on the way hours are determined. They consider a standard New Keynesian model in which the real wage follows a wage norm. They argue that when hours are firms's decisions, real wage stickiness would lose the capacity to magnify labor market dynamics. Conversely, real wage rigidities would display the right dynamics for unemployment when it is assumed that workers and employers also bargain over hours per employee, since the cost of an additional hour is made independent from the bargained wage in this case. They nonetheless acknowledge that such a disconnection between the cost of a marginal hour and the wage is quite implausible. Moreover, Trigari (2006) notices that hours per worker are rarely the object of negotiation while Rotemberg (2008) provides some evidence, related to the length of the workweek in the U.S, against efficient bargaining for hours. In this paper, we point out that it is no longer required to make this strong assumption, once real wage rigidities stem from the credible bargaining. This also illustrates the gain of considering a micro-founded explanation of real wage stickiness.

Sveen and Weinke (2009), Barnichon (2010a), Kuester (2010) and Thomas (2011) assume that firms both bargain over the wage and set prices. Those papers find that the interaction between wage bargain and price setting produces strategic complementarities between firms, which reduce inflation variations. Here, we show that pricing decisions depend on the way real wage rigidities are introduced. We stress that even if the credible bargaining and the wage norm entail real wage stickiness, these wage bargainings imply different degrees of strategic complementarities between price setters, different slopes for the NKPC and then different explanations for inflation inertia.

According to Blanchard and Galí (2007, 2010), there would be no stabilization trade-off between unemployment and inflation in the standard New Keynesian model. Introducing real wage stickiness would then be the required ingredient to break this unrealistic *divine coincidence*. In their framework, firms adjust labor demand only through employment.

Again, we highlight that the way real wage rigidities are introduced is critical to generate a substantial trade-off, when firms also adjust labor demand through the intensive margin.

The rest of the paper is organized as follows. In the next section, we present the model. In Section 3, we calibrate and assess its quantitative implications along the labor market and inflation dimensions. In Section 4, we determine the optimal monetary policy and the stabilization trade-off between unemployment and inflation. Section 5 concludes.

## 2 The Model

### 2.1 Labor market frictions

Searching for a worker to fill a vacancy involves a fixed cost  $\chi$ . The number of new matches each period is given by a matching function  $m(u_t, v_t)$ , where  $u_t$  and  $v_t$  represent the number of unemployed workers and the number of open job vacancies, respectively, at period  $t$ . Since the labor force is normalized to one,  $u_t$  and  $v_t$  also represent the unemployment and vacancy rates.

The matching rate for unemployed workers, the job-finding rate, is given by :

$$\frac{m(u_t, v_t)}{u_t} = m(1, \theta_t) \equiv f(\theta_t)$$

which is increasing in market tightness  $\theta_t$ , the ratio of vacancies to unemployment. The rate at which vacancies are filled is given by :

$$\frac{m(u_t, v_t)}{v_t} = \frac{f(\theta_t)}{\theta_t} \equiv q(\theta_t)$$

and is decreasing in  $\theta_t$ .

Finally, matches are destroyed at the exogenous rate  $s$  at the end of each period.

## 2.2 Households

Following Merz (1995), we assume a large representative household in which a fraction  $n_t$  of members are employed in a measure-one continuum of firms. The remaining fraction  $u_t = 1 - n_t$  is unemployed and searching for a job. Equal consumption across members is ensured through the pooling of incomes. The welfare of the household is given by :

$$H_t = u(c_t) - \int_0^1 \left[ x_h \frac{\int_0^{n_{it}} h_{it}(z)^{1+\eta} dz}{1+\eta} \right] di + \beta E_t H_{t+1}$$

where  $n_{it}$  represents the number of workers in firm  $i \in [0, 1]$ ,  $h_{it}(z)$  the number of hours worked by employee  $z$  in firm  $i$  and  $x_h$  a positive scaling parameter of disutility of work.

$$c_t \equiv \left( \int_0^1 c_{it}^{\frac{\epsilon-1}{\epsilon}} di \right)^{\frac{\epsilon}{\epsilon-1}}$$

is a Dixit-Stiglitz aggregator of different varieties of goods, with  $\epsilon$  measuring the elasticity of substitution across differentiated goods. The associated price index is defined as follows:

$$P_t \equiv \left( \int_0^1 P_{it}^{1-\epsilon} di \right)^{\frac{1}{1-\epsilon}}$$

The household faces the sequence of real budget constraints :

$$\int_0^1 \left[ \int_0^{n_{it}} w_{it}(h_{it}(z)) h_{it}(z) dz \right] di + (1 - n_{it})b + \frac{\Theta_t}{P_t} + (1 + i_t) \frac{B_{t-1}}{P_t} \geq c_t + \frac{B_t}{P_t}$$

where  $w_{it}(h_{it}(z))$  is the real hourly wage earned by worker  $z$  in firm  $i$  (which depends on the number of hours worked by this worker),  $b$  is the unemployment income (including notably unemployment benefits and home production) received by unemployed members,  $B_{t-1}$  is the holdings of one-period nominal bonds which pay a gross nominal interest rate  $(1 + i_t)$  one period later and  $\Theta_t$  is a lump-sum component of income that may notably include dividends from the firm sector or lump-sum taxes. From now onwards,  $w_{it}(h_{it}(z))$  will be called the real *average* wage.

The intertemporal optimality condition is given by the standard Euler condition :

$$u'(c_t) = \beta(1 + i_t) E_t \left[ \frac{P_t}{P_{t+1}} u'(c_{t+1}) \right] \quad (1)$$

As usual, optimality also requires that a No-Ponzi condition is satisfied.

## 2.3 Firms

We follow Sveen and Weinke (2009) and Thomas (2011) by assuming that firms first set prices, post vacancies and choose hours per worker, and then bargain over the real average wage with employees<sup>7</sup>. While determining hours, firms take rationally into account that a marginal change in hours will imply a change in the real average wage.

### 2.3.1 The firm's program

There is a measure-one continuum of firms. Each of them produce a differentiated good which is sold monopolistically. Consider a firm  $i \in [0, 1]$  which starts period  $t$  with a continuum of workers of size  $n_{it}$ . This firm posts  $v_{it}$  vacancies at cost  $\chi$  and chooses  $h_{it}(z)$  working hours for *each* individual worker  $z \in [0, n_{it}]$  at a real average wage  $w_{it}(h_{it}(z))$ . We denote by  $\Pi_{it}$  the value of the firm  $i$  at period  $t$  :

$$\Pi_{it} = \frac{P_{it}}{P_t} y_{it}^d - \int_0^{n_{it}} w_{it}(h_{it}(z)) h_{it}(z) dz - \chi v_{it} + E_t \beta_{t,t+1} \Pi_{it+1}$$

where  $P_{it}$  is the firm's nominal price,  $y_{it}^d$  the demand for its good and  $\beta_{t,t+k} \equiv \beta^k u'(c_{t+k})/u'(c_t)$  the stochastic discount factor between periods  $t$  and  $t+k$ . Cost minimization by households implies that demand for each firm can be written as :

$$y_{it}^d = \left( \frac{P_{it}}{P_t} \right)^{-\epsilon} y_t^d \quad (2)$$

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<sup>7</sup>Note that this timing is different from the "right-to-manage" schedule of Trigari (2006), for which firms first create jobs, next bargain over the wage and finally set hours per worker. Here, we instead follow Sveen and Weinke (2008, 2009) and Thomas (2011) by assuming that firms create jobs and determine hours at the same time, for four reasons. First, with right-to-manage, the real marginal wage (i.e. the wage paid for an additional hour) corresponds to real average wage (i.e. the real hourly wage). The evidence in Bils (1987) instead shows that the real marginal wage is more pro-cyclical than the real average wage, which is the case with our timing. Secondly, as the trade-off between adjusting the intensive and extensive margins is critical in this paper, it is natural to consider that firms choose both margins at the same time. Thirdly, the inability of real wage rigidities to amplify unemployment fluctuations was shown within this timing by Sveen and Weinke (2008). Since we defend the opposite conclusion for the credible bargaining, we keep their timing so as to ensure that our results are not biased by a different timing assumption. Lastly, the equations, notably for wages, are much more simple and tractable.

where  $y_t^d$  denotes aggregate demand. We assume that vacancy posting costs take the form of the same CES function as the one defining the consumption index. Aggregate demand is therefore given by :

$$y_t^d = c_t + \chi v_t$$

Labor is transformed into output by means of the following production function :

$$y_{it}^s = A_t \int_0^{n_{it}} h_{it}(z) dz$$

where  $A_t$  is a common labor productivity shock. The log of this shock,  $a_t = \ln A_t$  follows an AR(1) process,  $a_t = \rho_a a_{t-1} + e_t^a$ , where  $e_t^a$  is an iid shock. The firm commits to satisfy demand at the chosen price. This implies that the following condition should hold in every period :

$$\left(\frac{P_{it}}{P_t}\right)^{-\epsilon} y_t^d = A_t \int_0^{n_{it}} h_{it}(z) dz \quad (3)$$

Given search frictions on the labor market, it is assumed that a new worker becomes productive in the following period. Employment at the firm level is thus given by :

$$n_{it+1} = (1 - s)n_{it} + q(\theta_t)v_{it} \quad (4)$$

Finally, firms reset their price in a Calvo (1983) fashion. Each period, a firm has a probability  $(1 - \delta)$  to re-optimize its price while with probability  $\delta$  the firm keeps its last period's price. Hence, we have :

$$P_{it} = \begin{cases} P_{it}^* & \text{with probability } 1 - \delta \\ P_{it-1} & \text{with probability } \delta \end{cases} \quad (5)$$

We denote by  $mc_{it}$  and  $\vartheta_{it}$  the Lagrange multipliers with respect to constraints (3) and (4), respectively. Hence,  $mc_{it}$  represents the real marginal cost of production. Notice that  $mc_{it}$  is a *firm-wide* variable. The firm determines the state-contingent path  $\{P_{it}, h_{it}(z), v_{it}, n_{it}\}$  that maximizes its value  $\Pi_{it}$  subject to constraints (3), (4) and (5).

First-order conditions for the above problem read as follows :

$$\partial P_{it} : \quad E_t \sum_{T=t}^{\infty} \delta^{T-t} \beta_{t,T} P_T^\epsilon y_T^d \left\{ \frac{P_{it}^*}{P_T} - \frac{\epsilon}{\epsilon - 1} mc_{iT|t} \right\} = 0 \quad (6)$$

$$\partial h_{it}(z) : \quad mc_{it}A_t = w'_{it}(h_{it}(z))h_{it}(z) + w_{it}(h_{it}(z)) \quad (7)$$

$$\partial v_{it} : \quad \frac{\chi}{q(\theta_t)} = \vartheta_{it} \quad (8)$$

$$\partial n_{it} : \quad \vartheta_{it} = E_t \beta_{t,t+1} [mc_{it+1}A_{t+1}h_{it+1}(z) - w_{it+1}(h_{it+1}(z))h_{it+1}(z) + (1-s)\vartheta_{it+1}] \quad (9)$$

where the subscript  $T|t$  denotes period  $T$  values conditional on the firm not having reset its price since period  $t$ .

According to equation (6), price-setters target a constant mark-up  $\frac{\epsilon}{\epsilon-1} > 1$  over real marginal costs for the expected duration of the price set in period  $t$ . We denote by  $\omega_{it}(h_{it}(z))$  the real *marginal* wage for worker  $z$ , i.e.  $\omega_{it}(h_{it}(z)) = w'_{it}(h_{it}(z))h_{it}(z) + w_{it}(h_{it}(z))$ . From equation (7), the real marginal cost is given by :

$$mc_{it} = \frac{\omega_{it}(h_{it}(z))}{A_t} \quad (10)$$

The real marginal cost is therefore the ratio between the real marginal wage and the marginal product of labor<sup>8</sup>. Since employment is predetermined, increasing production in period  $t$  requires to raise hours per worker. This comes at a cost  $\omega_{it}(h_{it}(z))$  per employee<sup>9</sup>.

From equation (8), the firm posts vacancies until the expected value of an additional worker equates the marginal cost of posting a vacancy. Equation (9) gives the value of an additional worker  $z$ . In a context of monopolistic competition and infrequent price adjustment, the contribution of the marginal worker to firm's flow profit is given by the marginal reduction in the wage bill,  $mc_{it}A_t h_{it}(z)$ . If the worker walked away from the job, and given the impossibility of hiring a replacement immediately, the firm would have to make up for the lost production,  $A_t h_{it}(z)$ , by raising working hours for all other employees. This comes at a cost  $mc_{it}A_t h_{it}(z)$  for the firm.

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<sup>8</sup>Equation (10) corresponds to equation (3) in Bilts (1987).

<sup>9</sup>For the right-to-manage set up, the cost of a marginal hour is given by the real average wage  $w_{it}(h_{it}(z))$  instead of the real marginal wage  $\omega_{it}(h_{it}(z))$ . This is the first reason, advocated in footnote 7, for which we prefer our timing.

### 2.3.2 The wage bargaining

We denote by  $W_{it}(z)$  the worker  $z$ 's value of a match in firm  $i$  at period  $t$  :

$$W_{it}(z) = w_{it}(h_{it}(z))h_{it}(z) - x_h \frac{h_{it}(z)^{1+\eta}}{(1+\eta)u'(c_t)} + E_t \beta_{t,t+1} [(1-s)W_{it+1}(z) + sU_{t+1}]$$

where the marginal disutility of labor is expressed in consumption units and  $U_t$  is the unemployment value given by :

$$U_t = b + E_t \beta_{t,t+1} [f(\theta_t)W_{it+1}(z) + sU_{t+1}]$$

We denote by  $J_{it}(z)$  the firm's value of a filled match with employee  $z$  at period  $t$  :

$$J_{it}(z) = mc_{it}A_t h_{it}(z) - w_{it}(h_{it}(z))h_{it}(z) + E_t \beta_{t,t+1} [(1-s)J_{it+1}(z) + sV_{it+1}]$$

where  $V_{it}$  is the firm's value of a vacancy. Given equation (8),  $V_{it} = 0$  in equilibrium.

**Credible bargaining.** We follow Hall and Milgrom (2008) by assuming that the worker and the employer alternate in making wage proposals, in a Rubinstein (1982) fashion. After a proposer makes an offer, the responding party has three options :

- (i) accept the current proposal;
- (ii) reject this proposal and make a counter-offer next period. During the period, the worker receives  $b$  while it is assumed that the employer incurs a fixed cost  $\gamma$ . The payoffs  $b$  and  $-\gamma$  are called the *disagreement payoffs*;
- (iii) abandon the negotiation and take her outside option.

Hall and Milgrom (2008) also assume that the wage bargain could break before reaching an agreement with probability  $\psi$ . Here, we leave aside this event for two reasons. First, this probability does not exist in the alternating offers game of Rubinstein (1982). Secondly, this case is purely exogenous and has no empirical value to be compared to<sup>10</sup>. In the Appendix, we nevertheless introduce this probability of disruption by arbitrarily setting  $\psi = s$  and show that our results are hardly modified.

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<sup>10</sup>It is worth noticing that many papers considering the credible bargaining, notably Mortensen and Nagypál (2007), Jung and Kuester (2011), Jimeno and Thomas (2013) and Kaplan and Menzio (2015), also omit this case.



The point of Hall and Milgrom (2008) is to show that on a frictional labor market, the surplus of a match is such that both the worker and the employer get higher payoffs by going to the end of the bargaining than leaving the negotiation to get their outside options. Consequently, outside options are not credible threat points and the solution of this strategic bargaining is the same as in the alternating offers game without outside options<sup>11</sup>.

It is rather complicated to determine the real wage directly from the alternating offers game. Instead, we follow Mortensen and Nagypál (2007), Jung and Kuester (2011) and Kaplan and Menzio (2015) by implementing the main result of Binmore, Rubinstein and Wolinsky (1986) : whenever the time interval between successive offers is sufficiently small, the solution of the alternating offers model converges to the solution of the corresponding static game. The solution to this game is found by the Generalized Nash Solution (1953) with the credible threat points. The credible threat for a player consists in delaying the wage bargaining by one period. The credible threat points are therefore the disagreement payoffs - i.e.  $b$  for the worker and  $-\gamma$  for the employer. The surplus of worker  $z$ , matched with firm  $i$ , in the current period is then :

$$S_{it}^W(z) = w_{it}(h_{it}(z))h_{it}(z) - x_h \frac{h_{it}(z)^{1+\eta}}{(1+\eta)u'(c_t)} - b$$

while the surplus of firm  $i$ , matched with worker  $z$ , is :

$$S_{it}^F(z) = mc_{it}A_t h_{it}(z) - w_{it}(h_{it}(z))h_{it}(z) + \gamma$$

The Generalized Nash Solution in this environment is such that the equilibrium real average wage satisfies the following surplus-sharing rule :

$$(1 - \zeta)S_{it}^W(z) = \zeta S_{it}^F(z)$$

where  $\zeta$  denotes the worker's bargaining power. This yields the following real average wage for worker  $z$  :

$$w_{it}^{cb}(h_{it}(z)) = \zeta \left[ mc_{it}A_t + \frac{\gamma}{h_{it}(z)} \right] + (1 - \zeta) \left[ \frac{b}{h_{it}(z)} + x_h \frac{h_{it}(z)^\eta}{(1+\eta)u'(c_t)} \right] \quad (11)$$

Notice that this is not a differential equation in the function  $w_{it}(\cdot)$ . In order to have a differential equation, one would have to express  $mc_{it}A_t$  in terms of  $\omega_{it}(h_{it}(z)) = w'_{it}(h_{it}(z))h_{it}(z) +$

<sup>11</sup>See Osborne and Rubinstein (1990) for a demonstration.

$w_{it}(h_{it}(z))$ . However, the term  $mc_{it}A_t$  reflects the fact that if worker  $z$  walked away from her job, the demand-constrained firm would have to make up for the lost output by readjusting the hours of the other workers in the firm. Since worker  $z$  would no longer be in the firm, the first order condition  $mc_{it}A_t = \omega_{it}(h_{it}(z))$  for that worker would no longer apply. It would therefore be incorrect to replace  $mc_{it}A_t$  by  $\omega_{it}(h_{it}(z))$  in the wage equation. Hence, by the time the worker and the firm negotiate the wage at the end of period  $t$  (when pricing, hiring and production decisions have already been made), the marginal cost  $mc_{it}$  no longer depends on worker  $z$ 's marginal wage,  $\omega_{it}(h_{it}(z))$ , and then on her working hours,  $h_{it}(z)$ <sup>12</sup>.

The real wage income is therefore :

$$w_{it}^{cb}(h_{it}(z))h_{it}(z) = \zeta[mc_{it}A_t h_{it}(z) + \gamma] + (1 - \zeta)[b + x_h \frac{h_{it}(z)^{1+\eta}}{(1 + \eta)u'(c_t)}] \quad (12)$$

which is convex in  $h_{it}(z)$ . The real marginal wage for worker  $z$  is :

$$\omega_{it}^{cb}(h_{it}(z)) = w_{it}^{cb'}(h_{it}(z))h_{it}(z) + w_{it}^{cb}(h_{it}(z)) = \zeta mc_{it}A_t + (1 - \zeta)x_h \frac{h_{it}(z)^\eta}{u'(c_t)} \quad (13)$$

where we have used the fact that, by the time the wage negotiation takes place,  $mc_{it}$  does not depend on  $h_{it}(z)$ . From (7) and the convexity of equation (12), we have that the firm optimally chooses the same number of hours for all workers,

$$h_{it}(z) = h_{it}, \quad \forall z \in [0, n_{it}] \quad (14)$$

Combining equations (7), (13) and (14) gives the real marginal wage for any worker in firm  $i$ <sup>13</sup> :

$$\omega_{it}^{cb}(h_{it}) = x_h \frac{h_{it}^\eta}{u'(c_t)} \quad (15)$$

The real marginal wage for the credible bargaining is thus equal to the worker's marginal rate of substitution between consumption and leisure.

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<sup>12</sup>We thank Carlos Thomas for showing us that  $mc_{it}$  is independent from  $h_{it}(z)$  at the time of the wage bargaining, exactly as in Thomas (2011).

<sup>13</sup>As an intermediate step, one can first combine equations (13) and (14). In this case, the real marginal wage for any worker in firm  $i$  is :  $\omega_{it}^{cb}(h_{it}) = \zeta mc_{it}A_t + (1 - \zeta)x_h \frac{h_{it}^\eta}{u'(c_t)}$ . Hence, when any worker in the firm is asked to work one additional hour, her real marginal wage increases by two different effects. The first effect is direct : an additional hour worked implies a higher disutility of work that raises the real marginal wage with coefficient  $1 - \zeta$ . The second effect comes from the symmetry argument : given symmetry of hours worked, all workers in the firm are asked to work one additional hour. This raises the real marginal cost of the firm and then the real marginal wage of any worker with coefficient  $\zeta$ .

**Nash bargaining.** To understand how the wage rigidity works, we compare these real average and marginal wages to those resulting from the Nash bargaining and the wage norm specification. Before Shimer (2005), the Nash bargaining was traditionally applied by the search and matching literature to get the real wage. In this case, the real wage is determined by the Generalized Nash Solution with the outside options as threat points. The outside options are  $U_t$  for the worker and  $V_{it} = 0$  for the employer. The surplus-sharing rule implies :

$$(1 - \zeta)(W_{it}(z) - U_t) = \zeta J_{it}(z)$$

Inserting for  $W_{it}(z)$ ,  $U_t$  and  $J_{it}(z)$  and using equations (8) and (9) yields the following real average wage for worker  $z$  :

$$w_{it}^{nb}(h_{it}(z)) = \zeta[mc_{it}A_t + \chi \frac{\theta_t}{h_{it}(z)}] + (1 - \zeta)[\frac{b}{h_{it}(z)} + x_h \frac{h_{it}(z)^\eta}{(1 + \eta)u'(c_t)}] \quad (16)$$

By the same argument as the one that applies for equation (11), equation (16) is not a differential equation in  $w_{it}(\cdot)$ . The real wage income is therefore :

$$w_{it}^{nb}(h_{it}(z))h_{it}(z) = \zeta[mc_{it}A_t h_{it}(z) + \chi \theta_t] + (1 - \zeta)[b + x_h \frac{h_{it}(z)^{1+\eta}}{(1 + \eta)u'(c_t)}] \quad (17)$$

which is convex in  $h_{it}(z)$ . The real marginal wage for worker  $z$  is :

$$\omega_{it}^{nb}(h_{it}(z)) = w_{it}^{nb'}(h_{it}(z))h_{it}(z) + w_{it}^{nb}(h_{it}(z)) = \zeta mc_{it}A_t + (1 - \zeta)x_h \frac{h_{it}(z)^\eta}{u'(c_t)} \quad (18)$$

where again we have used the fact that  $mc_{it}$  does not depend on  $h_{it}(z)$  at the time of the wage bargaining. It is worth noting that equation (18) and (13) are identical : the credible bargaining and the Nash bargaining therefore share the same expression for the real marginal wage. From (7) and the convexity of equation (17), the firm optimally chooses the same number of hours for all workers. Hence, equation (14) also applies for the Nash bargaining. Combining equations (7), (14) and (18) gives the real marginal wage for any worker in firm  $i$  :

$$\omega_{it}^{nb}(h_{it}) = x_h \frac{h_{it}^\eta}{u'(c_t)} \quad (19)$$

As for the credible bargaining, the real marginal wage for the Nash bargaining is equal to the worker's marginal rate of substitution between consumption and leisure.

Comparing equations (11) and (16), the real average wage stemming from the credible bargaining is more rigid than the real average wage resulting from the Nash bargaining, since  $\theta_t$  does not enter equation (11). This stickiness with respect to labor market conditions reflects that the threat points are the a-cyclical disagreement payoffs rather than the pro-cyclical outside options. However, the alternative threat points for the credible bargaining do not imply any rigidity with respect to the disutility of labor. Hence, both wage specifications display the same real marginal wage, which is given by the worker's marginal rate of substitution between consumption and leisure.

**Wage norm.** In order to introduce real wage rigidities, most of the literature that merges New Keynesian and search and matching models assumes that the real average wage is set as a weighted average of the Nash bargaining real average wage and a real “wage norm”<sup>14</sup>. This norm can take many forms but last period's average wage or a constant average wage are usually considered. Here we retain a constant wage (equal to the steady state real average wage) as a norm. The real average wage for worker  $z$  is therefore :

$$\begin{aligned} w_{it}^{wn}(h_{it}(z)) &= \alpha\bar{w} + (1 - \alpha)w_{it}^{nb}(h_{it}(z)) \\ &= \alpha\bar{w} + (1 - \alpha) \left[ \zeta[mc_{it}A_t + \chi\frac{\theta_t}{h_{it}(z)}] + (1 - \zeta)\left[\frac{b}{h_{it}(z)} + x_h\frac{h_{it}(z)^\eta}{(1 + \eta)u'(c_t)}\right] \right] \end{aligned} \quad (20)$$

where  $\alpha \in [0, 1]$  measures the degree of real wage rigidity. Once again, this equation is not a differential equation in  $w_{it}(\cdot)$ . With such a wage rule, the real wage income is :

$$w_{it}^{wn}(h_{it}(z))h_{it}(z) = \alpha\bar{w}h_{it}(z) + (1 - \alpha) \left[ \zeta[mc_{it}A_t h_{it}(z) + \chi\theta_t] + (1 - \zeta)\left[b + x_h\frac{h_{it}(z)^{1+\eta}}{(1 + \eta)u'(c_t)}\right] \right] \quad (21)$$

which is convex in  $h_{it}(z)$ . The real marginal wage for worker  $z$  is :

$$\omega_{it}^{wn}(h_{it}(z)) = w_{it}^{wn'}(h_{it}(z))h_{it}(z) + w_{it}^{wn}(h_{it}(z)) = \alpha\bar{w} + (1 - \alpha)\left[\zeta mc_{it}A_t + (1 - \zeta)x_h\frac{h_{it}(z)^\eta}{u'(c_t)}\right] \quad (22)$$

where again  $mc_{it}$  does not depend on  $h_{it}(z)$  at the time of the wage bargaining. From (7) and the convexity of equation (21), the firm still optimally chooses the same number of

<sup>14</sup>The wage norm was initiated by Hall (2005) in the search and matching literature. Blanchard and Galí (2007, 2010), Krause and Lubik (2007), Faia (2008), Sveen and Weinke (2008), Christoffel and Linzert (2010), Ravenna and Walsh (2012), among others, take some form of this approach when they integrate real wage rigidities into the New Keynesian model.

hours for all workers. Hence, equation (14) still applies for the wage norm specification. Combining (7), (14) and (22) gives the real marginal wage for any worker in firm  $i$ <sup>15</sup> :

$$\omega_{it}^{wn}(h_{it}) = \frac{\alpha\bar{w} + (1 - \alpha)(1 - \zeta)x_h \frac{h_{it}^\eta}{u'(c_t)}}{1 - (1 - \alpha)\zeta} \quad (23)$$

The real marginal wage for this specification is a weighted average of the worker's marginal rate of substitution between consumption and leisure and the constant wage norm. With  $\alpha = 0$ , the real marginal wage corresponds to the real marginal wage for the Nash bargaining and the credible bargaining. With  $\alpha = 1$ , the real marginal wage is fixed and equal to the steady state real average wage.

### 2.3.3 Vacancy posting

The standard job creation condition is obtained by merging equations (8) and (9) :

$$\frac{\chi}{q(\theta_t)} = E_t\beta_{t,t+1}[mc_{it+1}A_{t+1}h_{it+1} - w_{it+1}(h_{it+1})h_{it+1} + (1 - s)\frac{\chi}{q(\theta_{t+1})}] \quad (24)$$

Equation (24) can be rewritten as :

$$\frac{\chi}{q(\theta_t)} + E_t\beta_{t,t+1}[w_{it+1}(h_{it+1})h_{it+1}] = E_t\beta_{t,t+1}[mc_{it+1}A_{t+1}h_{it+1} + (1 - s)\frac{\chi}{q(\theta_{t+1})}] \quad (25)$$

The left hand side of equation (25) gives the cost associated with hiring an additional worker. That cost includes both wage payment and vacancy posting costs. The right hand side gives the benefit from hiring an additional worker, which includes the discounted savings in the future cost of using hours associated with having one additional worker in place and the discounted savings in the future vacancy posting costs.

From equation (25), the cost of an additional worker depends on the real average wage. The incentive to post vacancies is then enhanced when the real average wage is sticky with

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<sup>15</sup>As an intermediate step, one can first combine equations (14) and (22). In this case, the real marginal wage for any worker in firm  $i$  is :  $\omega_{it}^{wn}(h_{it}) = \alpha\bar{w} + (1 - \alpha)[\zeta mc_{it}A_t + (1 - \zeta)x_h \frac{h_{it}^\eta}{u'(c_t)}]$ . Hence, when any worker in firm  $i$  is asked to work one additional hour, her real marginal wage increases directly by a coefficient  $(1 - \alpha)(1 - \zeta)$ , and given symmetry of hours worked by a coefficient  $(1 - \alpha)\zeta$ . Since  $\alpha \in [0, 1]$ , the real marginal wage for the wage norm less increases with hours per worker than the real marginal wage for the credible bargaining and the Nash bargaining.

respect to labor market conditions. From equation (7), the cost of an additional hour is given by the real marginal wage. The incentive to raise hours per worker is then enhanced when the real marginal wage is sticky with respect to hours. The relative adjustment between the two margins will thus be determined by the relative behavior of  $w_{it}$  and  $\omega_{it}$ .

### 2.3.4 Price setting and inflation dynamics

From equations (10), (15), (19) and (23), the real marginal cost for each wage specification is :

$$mc_{it}^{cb} = x_h \frac{h_{it}^\eta}{u'(c_t)A_t} \quad (26)$$

$$mc_{it}^{nb} = x_h \frac{h_{it}^\eta}{u'(c_t)A_t} \quad (27)$$

$$mc_{it}^{wn} = \frac{\alpha\bar{w} + (1-\alpha)(1-\zeta)x_h \frac{h_{it}^\eta}{u'(c_t)}}{(1-(1-\alpha)\zeta)A_t} \quad (28)$$

Two results are worth noting. First, the credible bargaining and the Nash bargaining generate the same real marginal cost. This stems from the same real marginal wage displayed by both wage bargainings. The real marginal cost is given by the ratio between the marginal rate of substitution between consumption and leisure and the marginal product of labor. Secondly, since  $\alpha \in [0, 1]$ ,  $mc_{it}^{wn}$  is less flexible with respect to hours than  $mc_{it}^{cb}$  and  $mc_{it}^{nb}$ . This stems from  $\omega_{it}^{wn}(h_{it})$  which is less flexible with respect to hours than  $\omega_{it}^{cb}(h_{it})$  and  $\omega_{it}^{nb}(h_{it})$ .

In an online technical appendix<sup>16</sup>, we show that those different marginal cost schedules imply different slopes for the New-Keynesian Phillips Curve (NKPC). Since the credible bargaining and the Nash bargaining generate the same real marginal cost expression, we restrict attention to the credible bargaining on one side, and the wage norm on the other side. The results for the credible bargaining, in this subsection, naturally convey to Nash bargaining. The NKPC for the credible bargaining and the wage norm are given by :

$$\pi_t^{cb} = \beta E_t \pi_{t+1} + \kappa^{cb} \widehat{mc}_t^{cb} \quad (29)$$

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<sup>16</sup>Available on the author's website : <https://sites.google.com/site/pierrickclerc/>

$$\pi_t^{wn} = \beta E_t \pi_{t+1} + \kappa^{wn} \widehat{m} c_t^{wn} \quad (30)$$

where  $\kappa^{cb}$  and  $\kappa^{wn}$  read :

$$\kappa^{cb} = \frac{(1 - \delta\beta)(1 - \delta)}{\delta} \frac{1}{1 + \phi^{cb}}$$

$$\kappa^{wn} = \frac{(1 - \delta\beta)(1 - \delta)}{\delta} \frac{1}{1 + \phi^{wn}}$$

with  $\phi^{cb}$  and  $\phi^{wn}$  given by :

$$\phi^{cb} = \eta\epsilon - \delta\beta\eta\tau_{cb}^n$$

$$\phi^{wn} = D\eta\epsilon - D\delta\beta\eta\tau_{wn}^n$$

The expression and the derivation of  $\tau_{cb}^n$  and  $\tau_{wn}^n$  are provided in the online appendix. The parameter  $D$  is given by :

$$D = \frac{(1 - \alpha)(1 - \zeta)x_h \frac{h^\eta}{u'(c)}}{\alpha\bar{w} + (1 - \alpha)(1 - \zeta)x_h \frac{h^\eta}{u'(c)}} \leq 1$$

The parameters  $\phi^{cb}$  and  $\phi^{wn}$  have two components each :  $\eta\epsilon$  and  $\delta\beta\eta\tau^{cb}$  for  $\phi^{cb}$ ;  $D\eta\epsilon$  and  $D\delta\beta\eta\tau^{wn}$  for  $\phi^{wn}$ . The terms  $\eta\epsilon$  and  $D\eta\epsilon$  embody the existence of strategic complementarities in price setting, or real price rigidities in Ball and Romer (1990) terminology. Those complementarities dampen the price level adjustment in response to real marginal cost movements. To understand this point, take a price-setter who is considering a reduction in its nominal price. Given the prices of other firms, such a reduction implies a reduction in its real price. This increases its sales by an elasticity  $\epsilon$ . Since employment is predetermined, the firm has to increase hours per worker in the initial period so as to accommodate the higher demand for its good. The rise in hours entails an increase in the real marginal cost, i.e. the cost of a marginal hour, which is all the more important as  $\eta$  is large. This anticipated increase in real marginal costs leads the firm to choose a smaller price reduction than the one initially considered. This results in strategic complementarities : given that some prices are kept unchanged (due to Calvo price-setting), the firms that have the ability to adjust theirs change those prices by little.

Crucially, as  $D \leq 1$ , the degree of strategic complementarities is higher for the credible bargaining than for the wage norm. Indeed, for the credible bargaining, an additional hour per worker increases the real marginal cost by an elasticity  $\eta$ , through the increase in workers' marginal disutility of labor. However, for the wage norm, only a fraction  $D$  of the real marginal cost is flexible. A marginal hour thus increases the real marginal cost only by an elasticity  $D\eta$ .

The terms  $\delta\beta\eta\tau^{cb}$  and  $D\delta\beta\eta\tau^{wn}$  reflect that real marginal costs, for a given amount of output, decrease with the firms' employment stock. Contrary to strategic complementarities, this accelerates price adjustment to real marginal cost fluctuations. To make things clear, take the same firm considering a reduction in its nominal price. With such a reduction, the firm expects a larger employment stock, and therefore lower real marginal costs in the future. This effect leads the firm to choose a larger price reduction than the one initially considered. Once again, this effect is stronger for the credible bargaining : since the real marginal cost is more flexible for the credible bargaining, the anticipation of even lower real marginal costs in the future leads the firm to reduce its price even more.

In the online appendix, we show that  $\eta\epsilon > \delta\beta\eta\tau^{cb}$  and  $D\eta\epsilon > D\delta\beta\eta\tau^{wn}$ . This means that the latter effect is dominated by the strategic complementarities effect, for both the credible bargaining and the wage norm. Both  $\phi^{cb}$  and  $\phi^{wn}$  are therefore positive. Furthermore, we show that  $\phi^{cb} \geq \phi^{wn}$ . This implies that the NKPC resulting from the credible bargaining is flatter than the NKPC resulting from the wage norm: fluctuations in real marginal costs are turned into inflation by less for the credible bargaining. This is due to the higher degree of strategic complementarities in price setting stemming from this wage bargain.

## 2.4 Aggregate output and market clearing

Aggregate output  $y_t$  is obtained by aggregating the goods produced by each firm :

$$y_t \equiv \left( \int_0^1 y_{it}^{\frac{\epsilon-1}{\epsilon}} di \right)^{\frac{\epsilon}{\epsilon-1}}$$

The goods market clearing condition is :

$$y_t = y_t^d$$



which implies :

$$y_t = c_t + \chi v_t \quad (31)$$

From the firm's production function, we obtain the aggregate production function:

$$y_t = A_t n_t h_t \quad (32)$$

## 2.5 Monetary policy

We follow much of the New Keynesian literature by assuming that monetary policy is described by a Taylor-type interest rate rule :

$$i_t = \rho_i i_{t-1} + (1 - \rho_i)(\rho + \varphi_\pi \pi_t + \varphi_y \Delta y_t) + e_t^m \quad (33)$$

where  $\rho \equiv -\log \beta$  denotes the household's discount rate,  $\rho_i$  captures the degree of interest rate smoothing,  $\varphi_\pi$  and  $\varphi_y$  the responses to inflation and output growth, respectively, and  $e_t^m$  is an iid shock to monetary policy.

# 3 The Joint Dynamics of Inflation and Unemployment

## 3.1 Calibration

From now onwards, we assume the following functional forms for the preferences over consumption and the matching technology:

$$u(c_t) = \frac{c_t^{1-\sigma}}{1-\sigma}$$

$$m(u_t, v_t) = m_0 u_t^{1-\varsigma} v_t^\varsigma$$

Our model is composed by 9 equations: the Euler equation which describes the evolution of consumption equation (1), the employment law of motion (4), the real average wage (11), the job creation condition (24), the real marginal cost (26), the NKPC (29), the goods market clearing condition (31), the aggregate production function (32) and the Taylor rule (33). The log-linear equations are listed in the online appendix.

**Preferences and price rigidities.** Time is measured in quarters. We set standard values for the discount factor  $\beta = 0.99$  (corresponding to an annual interest rate equal to 4%) as well as for the intertemporal elasticity of substitution  $\sigma = 1$ . Hours per worker are normalized to one at the steady state and the scaling parameter  $x_h$  is adjusted accordingly. We set  $\eta = 2$ , corresponding to a Frisch labor supply elasticity ( $1/\eta$ ) of 0.5. This parameter is critical, since it determines how the real marginal wage, and then the real marginal cost, respond to variations in hours worked. For a long time, the empirical value of the labor supply elasticity has been a matter of debate. On one side, the macroeconomic literature has often retained a value of 1 (or even above) for this elasticity, on the basis of balanced growth considerations (see e.g. Cooley and Prescott (1995)). On the other side, Card (1994) reports microeconomic estimates of the labor supply elasticity which are between 0 and 0.5, and most of the time around 0.2. It is therefore customary to find in the labor market literature a value for this elasticity at 0.5, i.e. the midpoint of macro and micro findings<sup>17</sup>. Nevertheless, Domeij and Flodén (2006) argue that previous micro studies have been biased downwards since liquidity constraints have been ignored. They find an average bias of 50%. This implies that most micro estimates would be actually close to 0.5. Hence, we set  $\eta = 2$  from both the usual practice and the evidence of Domeij and Flodén (2006).

We choose a standard average duration for a price contract of approximately a year, which entails  $\delta = 0.75$ . The monopolistic markup is chosen to a conventional level of 20%, implying an elasticity of substitution between differentiated goods  $\epsilon$  equal to 6. From the values for  $\beta$ ,  $\eta$ ,  $\epsilon$  and  $\delta$ , we obtain  $\phi^{cb} = 4.14$  and then  $\kappa^{cb} = 0.017$ . With steady state values for  $h$ ,  $w$  and  $c$  given by Table 2, we have  $D = 0.48$ , which implies  $\phi^{wn} = 2.12$  and then  $\kappa^{wn} = 0.028$ . Therefore, the NKPC for the wage norm is steeper than the NKPC for the credible bargaining<sup>18</sup>. As previously stated,  $\phi^{cb}$  and  $\kappa^{cb}$  also apply to the Nash bargaining.

**Labor market flows.** We set the separation rate  $s$  to 0.06, corresponding to the monthly

<sup>17</sup>This is notably the case for Christoffel and Kuester (2008), Barnichon (2010a) and Thomas (2011).

<sup>18</sup>The values found for  $\tau^*$  and  $\tau^n$  are  $\tau_{cb}^* = 0.10$  and  $\tau_{cb}^n = 5.29$  for the credible bargaining and  $\tau_{wn}^* = 0.08$  and  $\tau_{wn}^n = 5.11$  for the wage norm.

rate of 0.02 found by Fujita and Ramey (2006). We target a steady state unemployment rate at 0.06, which is the average rate of our sample, and a probability of finding a worker of 0.70, from Den Haan and al. (2000). The efficiency parameter of the matching function  $m_0$  is set to match those two targets. For the elasticity of the matching function with respect to vacancies, we select  $\varsigma = 0.6$ , from the evidence reported in Blanchard and Diamond (1989).

**Monetary policy and shocks.** The monetary policy is described by a Taylor-type rule with interest rate smoothing. We follow Sveen and Weinke (2008) by setting standard values for the parameters  $\varphi_\pi = 1.5$ ,  $\varphi_y = 0.5/4$  and  $\rho_i = 0.7$ . The standard deviation of the interest rate shock,  $\sigma_m = 0.002$ , is selected from Walsh (2005). The aggregate productivity shock  $A_t$  is normalized to one at the steady state. The log of this shock follows an AR(1) process with an autocorrelation coefficient  $\rho_a$  set to 0.95. The standard deviation of the productivity shock,  $\sigma_a = 0.0097$ , is chosen to roughly replicate the standard deviation of real output in the data<sup>19</sup>. While this is not a robust procedure<sup>20</sup>, this is not essential here since the model is not evaluated along this dimension.

**Wage bargaining parameters and vacancy posting costs.** The worker's bargaining power  $\zeta$  is chosen at 0.5, a common practice that implies a symmetric bargaining. We follow Shimer (2005) by setting  $b = 0.4$ . This means that the flow value of unemployment (that may include unemployment benefits and home production) represents 40% of the steady state worker output<sup>21</sup>,  $\frac{y}{n}$ . The partial adjustment coefficient  $\alpha$  of the wage norm is set to 0.35, the value that makes this wage specification roughly replicate the volatility of the real average wage  $w$  in the data. In the Appendix, we choose alternative values for  $\alpha$  and find that our results are insensitive to these changes.

Two parameters remain to calibrate : the cost borne by the employer during the wage bargaining  $\gamma$  and the vacancy posting cost  $\chi$ . Since  $\gamma$  is specific to the credible bargaining,  $\chi$  is the last parameter to calibrate for the Nash and wage norm specifications. There are no standard empirical counterparts for these costs. In order to assign values to those parameters, we proceed in two steps. We begin by determining the value of  $\chi$  that solves the job creation condition at the steady state for the Nash bargaining<sup>22</sup>. We next replace

<sup>19</sup>Walsh (2005) obtains roughly the same value for  $\sigma_a$ . The corresponding values for the Nash bargaining and the wage norm are  $\sigma_a = 0.0136$  and  $\sigma_a = 0.0096$ , respectively.

<sup>20</sup>This strategy is notably used by Walsh (2005) and Krause and Lubik (2007).

<sup>21</sup>Note that the sum of the flow value of unemployment and the marginal disutility of working,  $b + x_h \frac{h_{it}^{1+\eta}}{(1+\eta)u'(c_t)}$ , equals 0.68 at the steady state, just below the value 0.71 used by Hall and Milgrom (2008) and Pissarides (2009).

<sup>22</sup>The resulting value for  $\chi$  is also the value that solves the job creation condition under the wage norm,

$\chi$  by this value and find the value of  $\gamma$  that closes the job creation condition at the steady state for the credible bargaining.

This strategy has two advantages. First, there is a single value for the parameters that are common to the three wage specifications. Secondly, the real average wages at the steady state under the three specifications are identical<sup>23</sup>. This last point is critical for the labor market volatility: as Hagedorn and Manovskii (2008) stress, the labor market is all the more volatile as the steady state profit is low (and therefore as the steady state real average wage is high). By implying identical real average wages at the steady state, our calibration does not favour any particular wage specification.

The value of  $\chi$  that solves the job creation condition at the steady state for the Nash bargaining is 0.10. This value implies that the steady-state ratio of vacancy posting costs to GDP,  $\frac{\chi v}{y}$ , equals 0.009. This is just below the value targeted by Andolfatto (1996) and Blanchard and Galí (2010) for this ratio, at 0.01. Given  $\chi = 0.10$ , the job creation condition at the steady state under the credible bargaining is solved for  $\gamma = 0.13$ . This represents 13% of steady-state worker output. This value is below the one retained by Hall and Milgrom (2008), representing 27% of steady-state worker output.

All the parameters are summarized in Table 1 while the steady state for some of the model variables is reported in Table 2.

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since at the steady state the real average wages for the Nash bargaining and the wage norm are identical.

<sup>23</sup>Since the resulting value for  $\gamma$  equals  $\chi\theta$ .

**Table 1 : Parameters**

Parameter	Definition	Value
$\beta$	Discount factor	0.99
$\sigma$	Intertemporal elasticity of substitution	1
$\eta$	Convexity of labor disutility	2
$x_h$	Scaling factor to disutility of work	0.89
$\delta$	Fraction of unchanged prices	0.75
$\epsilon$	Elasticity of demand curves	6
$\kappa^{cb}$	Slope of the NKPC for the CB	0.017
$\kappa^{wn}$	Slope of the NKPC for the WN	0.028
$s$	Separation rate	0.06
$\varsigma$	Elasticity matching fct wrt vacancies	0.6
$m_o$	Efficiency parameter of the matching fct	0.79
$\sigma_a$	SD of productivity shock	0.0097
$\rho_a$	AC of productivity shock	0.95
$\sigma_m$	SD of policy shock	0.002
$\varphi_\pi$	Response to inflation in the Taylor rule	1.5
$\varphi_y$	Response to output gap in the Taylor rule	0.5/4
$\rho_i$	Interest rate smoothing	0.7
$\zeta$	Worker's bargaining power	0.5
$b$	Flow value of unemployment	0.4
$\chi$	Vacancy posting cost	0.10
$\gamma$	Employer's cost of delay	0.13

**Table 2 : Steady State**

Variable	Definition	Value
$y$	Real output	0.94
$c$	Consumption	0.93
$h$	Hours per worker	1
$n$	Employment	0.94
$u$	Unemployment rate	0.06
$v$	Vacancy rate	0.08
$w$	Real average wage	0.82
$\omega$	Real marginal wage	1/1.2
$mc$	Real marginal cost	1/1.2
$\frac{\chi v}{y}$	Share of output lost to vacancy posting	0.009
$J$	Value of a firm	0.14
$W - U$	Surplus of the worker from working	0.14

It is worth noticing that our calibration departs from the one retained by Hagedorn and Manovskii (2008) on two grounds. First, the steady state value of a firm,  $J$ , amounting to 15% of quarterly output, is far from zero. The volatility of unemployment in our simulations is therefore not driven by a small initial surplus of the firm. Secondly, the surplus of the worker from working,  $W - U$ , amounting to 17% of the quarterly real average wage per employee, is also far from zero. Our calibration thus implies that the value of a job for a worker is clearly higher than the value of unemployment.

## 3.2 Quantitative analysis

In this section, we proceed in two steps. We first compare the second moments of the model with their empirical counterparts, from 1953 to 2013. Next, we focus on the 2009-2012 period to assess the ability of the model to replicate the large jump in the unemployment rate, as well as the low decrease in inflation, that occurred just after the financial crisis. We therefore address the “missing deflation puzzle”, notably raised by Hall (2011).

### 3.2.1 Labor market volatility and inflation inertia

The second column of Table 3 displays the standard deviations and autocorrelations of the main labor market variables and inflation. We consider US data from 1953:q1 to 2013:q2<sup>24</sup>. Two well-known stylized facts are summarized. First, the unemployment and vacancy rates are highly volatile, as compared to real output, while the volatility of hours per worker is low. This means that firms mainly adjust labor demand through employment. Secondly, the fluctuations of the inflation rate are weakly volatile but persistent: there is some inflation inertia.

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<sup>24</sup>All data are taken from the Federal Reserve Bank of St. Louis database, except the vacancy rate which comes from the index built by Barnichon (2010b)<sup>25</sup>. We use quarterly, seasonally adjusted data on real GDP (in billions of chained 2009 Dollars), civilian unemployment rate, civilian employment, composite Help-Wanted Index, hours per employee in the non-farm business sector, real hourly compensation in the non-farm business sector and quarter-on-quarter inflation of the GDP deflator. All data, except inflation, are logged and HP-filtered with a conventional smoothing parameter (1,600).

Table 3: Labor market volatility and inflation inertia<sup>a</sup>

Data	Credible Bargaining			Nash Bargaining			Wage Norm		
	Prod.	Mon.	Both	Prod.	Mon.	Both	Prod.	Mon.	Both
$\sigma(y_t), \%$	1.40	0.66	1.55	1.44	0.60	1.56	1.43	0.63	1.56
$\sigma(u_t)/\sigma(y_t)$	7.19	8.12	7.35	1.18	4.38	2.01	2.46	4.05	2.79
$\sigma(v_t)/\sigma(y_t)$	8.02	12.27	8.93	1.09	6.73	2.78	2.60	6.16	3.45
$\sigma(\theta_t)/\sigma(y_t)$	12.74	14.41	13.05	2.09	7.77	3.56	4.37	7.16	4.94
$\sigma(h_t)/\sigma(y_t)$	0.29	0.88	0.46	0.31	0.90	0.45	0.09	0.89	0.37
$\sigma(h_t)/\sigma(n_t)$	0.64	1.70	0.97	4.09	3.18	3.50	0.79	3.50	2.07
$\sigma(w_t)/\sigma(y_t)$	0.43	1.47	0.74	0.63	2.20	1.03	0.50	0.92	0.60
$\sigma(\pi_t)/\sigma(y_t)$	0.09	0.09	0.08	0.10	0.10	0.10	0.09	0.10	0.09
$\rho(\pi_t, \pi_{t-1})$	0.70	0.35	0.64	0.62	0.43	0.59	0.65	0.45	0.62

<sup>a</sup>The model-simulated moments are provided when the source of the fluctuations are productivity shocks (“Prod.”), monetary policy shocks (“Mon.”) and both types of shocks together.

The first result emerging from Table 3 is the good replication of labor market dynamics by the credible bargaining, particularly for unemployment and vacancy rates. At the opposite, the wage norm produces only small fluctuations for those variables, even though this wage specification generates the same wage stickiness as in the data. Consistently with Sveen and Weinke (2008), the volatility of the unemployment and vacancy rates stemming from the wage norm is even lower than what we obtain under the Nash bargaining, in response to monetary policy shocks. The behavior of the real average wage -  $w$  - on one side, and the real marginal wage -  $\omega$  - on the other, is critical to understand these results. Let us assume that the economy is hit by a positive productivity shock. A firm increases production by raising hours per worker and vacancy creations. The relative adjustment between the two margins depends on their relative costs. From the job creation condition, the cost of an additional worker depends on  $w$ . For both the credible bargaining and the wage norm,  $w$  is sticky with respect to labor market conditions. The incentive to post vacancies is therefore enhanced. At the same time, the cost of an additional hour is determined by  $\omega$ . For the credible bargaining,  $\omega$  is equal to the worker's marginal rate of substitution between consumption and leisure, which is increasing and convex in the number of hours worked. The large increase in the cost of an additional hour magnifies the incentive to adjust labor demand through employment. On the contrary,  $\omega$  is sticky for the wage norm. The cost of an additional hour thus increases moderately with hours worked, which creates an incentive to adjust on hours that partly offsets the incentive to adjust on employment. This clearly appears in the sixth row of Table 3 : the volatility of hours per worker relative to that of employment is much higher than in the data.

The three wage specifications display inflation inertia. However, the channels through which the dynamics of inflation is replicated are different. For the credible bargaining and the Nash bargaining, inflation inertia is explained by strong strategic complementarities in price setting. Those strong complementarities come from the large increase in  $\omega$  with hours per worker : after a positive productivity shock, firms reduce their prices to a lower extent in order to avoid a large increase in the demand for their goods and then in hours. Recall that the real marginal cost is determined by  $\omega$ . Small movements in inflation are therefore consistent with large fluctuations in the real marginal cost, through a flatter NKPC. Conversely, strategic complementarities are lower for the wage norm, given the stickiness of  $\omega$  with respect to hours. The wage norm thus implies a steeper NKPC but replicates the low inflation dynamics through a sticky real marginal cost.



Consequently, there are two competing explanations for inflation inertia : a flatter NKPC associated with large variations in the real marginal cost for the credible bargaining and the Nash bargaining; a steeper NKPC associated with small movements in the real marginal cost for the wage norm. Which one is the more plausible ? Basu (2005) and Sveen and Weinke (2009), from the evidence in Bils (1987), argue that the second story would be rejected by the data. Indeed, Bils (1987) provides estimations of the sensitivity of the real marginal wage with respect to hours per worker. In a first approach, Bils estimates the effect of hours on overtime hours directly, assuming an overtime premium of 50%. He finds that an increase in hours per week from 40 to 41 in manufacturing raises  $\omega$  by 4.6%. This represents an elasticity of  $\omega$  with respect to hours, denoted by  $\epsilon_\omega$ , equals to 1.84. In a second approach, the marginal wage schedule is estimated indirectly from observing the cost-minimizing choices made by firms for employment and hours. Using OLS, Bils finds that going from 40 to 41 hours per week raises  $\omega$  by 6.6%, which implies  $\epsilon_\omega = 2.64$ . Using instrumental variables, the increase in  $\omega$  is 8.1%, which implies  $\epsilon_\omega = 3.24$ . For the credible and Nash bargainings,  $\epsilon_\omega = \eta$ , which is set at 2 in our calibration. The sensitivity of the  $\omega$  with respect to hours therefore falls within the range of values estimated by Bils (1987). Alternatively, for the wage norm,  $\epsilon_\omega$  is given by :

$$\epsilon_\omega = \frac{\eta(1 - \alpha)(1 - \zeta)x_h \frac{h_t^\eta}{u'(c_t)}}{\alpha \bar{w} + (1 - \alpha)(1 - \zeta)x_h \frac{h_t^\eta}{u'(c_t)}}$$

Evaluated at the steady state,  $\epsilon_\omega = D\eta$ . With  $D = 0.48$ ,  $\epsilon_\omega = 0.96$ , which is much lower than Bils evidence. Since the real marginal cost is given by  $\omega$ , those results suggest that the behavior of the real marginal cost displayed by the credible bargaining and the Nash bargaining is much closer to the data than the real marginal cost displayed by the wage norm. The explanation of inflation inertia provided by the credible and Nash bargaining is thus more plausible than the one brought by the wage norm.

Why does real wage stickiness induced by the credible bargaining succeed in both magnifying labor market volatility and providing the right explanation for inflation inertia, while real wage stickiness induced by the wage norm fails ? On the one hand, the wage norm specification sets the real average wage as a weighted average of the Nash bargaining wage and the steady state wage. This rule implies a mechanical wage rigidity with respect to both labor market conditions and the disutility of work. Then,  $w$  hardly increases with additional workers hired and  $\omega$  hardly increases with hours worked. The rigidity of  $\omega$  with respect to hours not only creates an incentive to adjust labor demand through hours, but

also dampens the strategic complementarities between price setters. On the other hand, the solution of the credible bargaining corresponds to the Nash solution with credible threat points. On a frictional labor market, those threat points are no longer the outside options, which depend on labor market conditions, but rather the a-cyclical disagreement payoffs. Thus,  $w$  resulting from the credible bargaining also hardly increases with additional workers hired. Nevertheless, the a-cyclical disagreement payoffs do not deliver any wage stickiness with respect to the disutility of work. Hence,  $\omega$  displayed by the credible bargaining is as flexible with respect to hours as  $\omega$  displayed by the Nash bargaining. The credible bargaining therefore associates a sticky  $w$  with a flexible  $\omega$ , explaining why firms have a strong incentive to adjust on employment. Furthermore, the flexibility of  $\omega$  with respect to hours implies a high degree of strategic complementarities between price setters.

By considering real wage rigidities only through the lens of the wage norm, Sveen and Weinke (2008) conclude that the only way for those rigidities to solve the puzzle raised by Shimer (2005) and generate significant cyclicity of the real marginal cost, would be to make the strong assumption that workers and firms also bargain over hours. Indeed, the joint determination of hours implies that the cost of an additional hour is given by the worker's marginal rate of substitution between consumption and leisure, whatever the wage specification<sup>26</sup>. The results of this section show that real wage rigidities, when stemming from the credible bargaining, are the required ingredient to replicate the joint dynamics of unemployment, inflation, and real marginal cost, without having to assume a bargaining over hours per worker.

### 3.2.2 The Great Recession and the missing deflation puzzle

We now turn to the Great Recession. Precisely, we focus on the period from 2009:q2 to 2011:q4. The second quarter of 2009 was the date for which the US real GDP hit its low point while the last quarter of 2011 was the date for which it went back to trend. During this period, the unemployment rate considerably jumped but, surprisingly, the inflation rate hardly fell. According to Hall (2011) and Ball and Mazumder (2011), standard DSGE frameworks based on New Keynesian Phillips Curves would not be able to replicate this weak decline in inflation, associated to the large increase in unemployment as a

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<sup>26</sup>For the credible bargaining and the Nash bargaining, the cost of an additional hour is then given by the marginal rate of substitution, whatever the determination of hours per worker.

measure of slack : there would be some “missing deflation puzzle”. Del Negro, Giannoni and Schorfheide (2015) suggest that DSGE models are made consistent with the observed evolution of those variables once nominal price rigidities are increased. At the same time, Christiano, Eichenbaum and Trabandt (2015a) find that a NK model with credible bargaining accounts for the weak fall in inflation, once are assumed neutral technology shocks and a risky working capital effect. In this section, we argue that the credible bargaining, by producing real price and wage stickiness, is able to bring a solution to the puzzle without increasing exogenously nominal price rigidities nor assuming additional shocks and channels independent from the wage bargain.

To address this puzzle, we have to slightly modify the model so as to consider the financial shock that triggered the Great Recession. Our objective is not to provide an exhaustive comprehension of the channels through which the financial crisis transmitted to real economy. We instead aim at showing that given the large collapse in output resulting from a negative financial shock, the credible bargaining generates the right dynamics of unemployment and inflation. Hence, we follow Del Negro, Giannoni and Schorfheide (2015) by introducing financial shocks through a simple modification of the Euler equation for consumption. Equation (1) is replaced by (in log-linear form) :

$$\widehat{c}_t = E_t \widehat{c}_{t+1} - (\widehat{i}_t - E_t \pi_{t+1} + z_t) \quad (34)$$

The exogenous process  $z_t$ <sup>27</sup> drives a wedge between the intertemporal ratio of the marginal utility of consumption and the riskless real return  $i_t - E_t \pi_{t+1}$ . This shock follows an AR(1) process, with autoregressive coefficient  $\rho_z$  and standard deviation  $\sigma_z$ . Those parameters are calibrated such that the model, for the three wage specifications, replicates as much as possible the dynamics of the real GDP from 2009:q2 to 2011:q4<sup>28</sup>. More precisely, the values of  $\sigma_z$  and  $\rho_z$  are chosen with two targets: 1) reproducing the same initial fall in output; 2) minimizing the sum of least squares between effective GDP and output resulting from the model<sup>29</sup>.

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<sup>27</sup> $z_t$  corresponds to  $b_t$  in equation (3) of Del Negro, Giannoni and Schorfheide (2015).

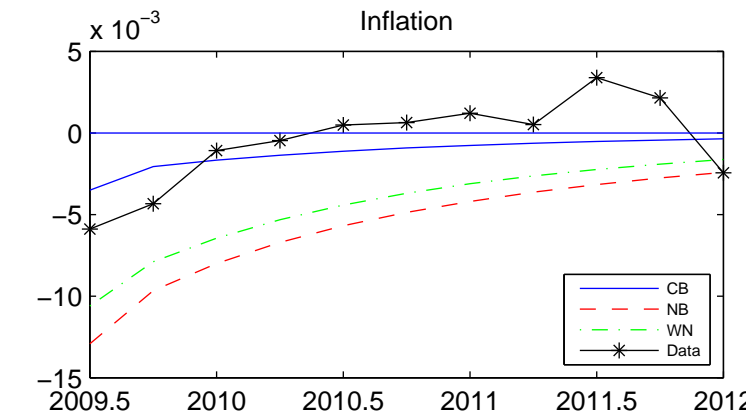
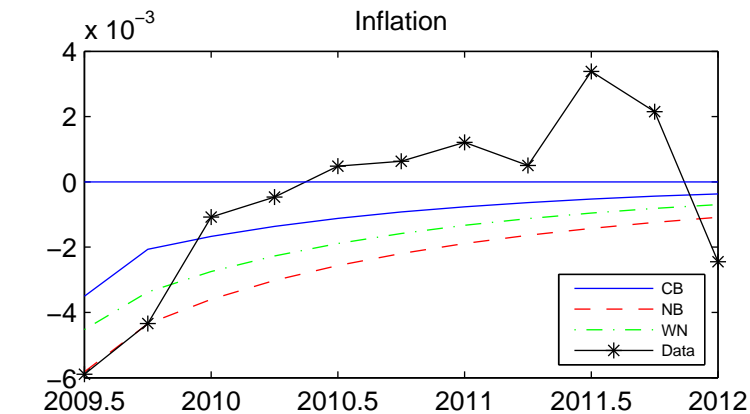
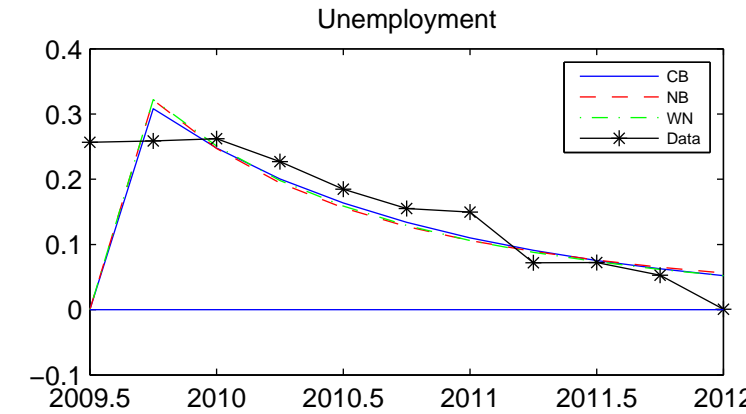
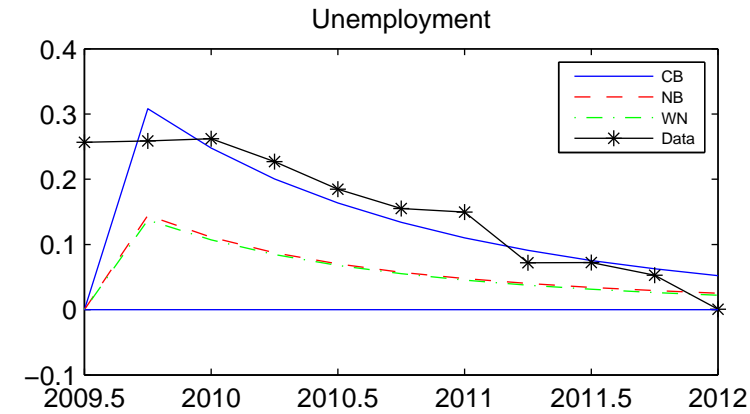
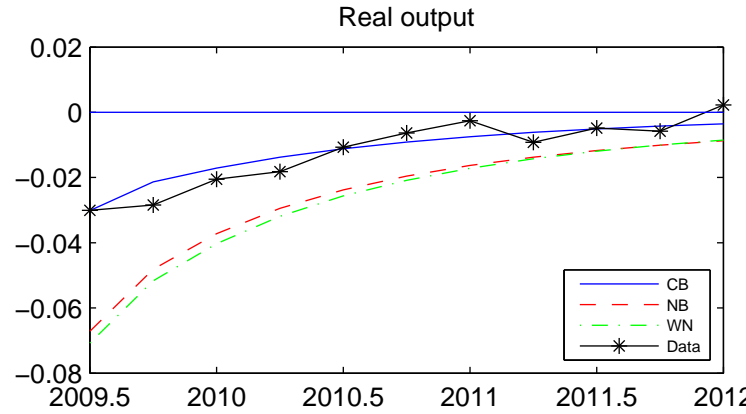
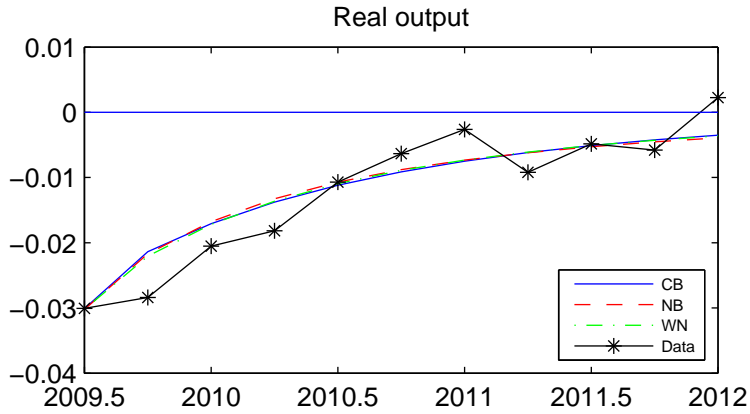
<sup>28</sup>Productivity and monetary shocks are accordingly muted.

<sup>29</sup>The values that achieve these targets are  $\sigma_z = 0.0059$  and  $\rho_z = 0.84$  for the credible bargaining,  $\sigma_z = 0.0063$  and  $\rho_z = 0.88$  for the Nash bargaining, and  $\sigma_z = 0.0064$  and  $\rho_z = 0.86$  for the wage norm.

Figure 1 : impulse response functions to a negative financial shock

Target : Real output

Target : Unemployment



CB = Credible bargaining; WN = Wage norm; NB = Nash bargaining

The left panel of Figure 1 plots the data and model-based impulse response functions of real output, unemployment and inflation. The credible bargaining displays unemployment and inflation responses very close to the actual ones. Therefore, the credible bargaining makes the weak fall in inflation consistent with the large jump in unemployment, i.e. with a deep slack. The mechanisms at work are the same as in the previous section: the combination of a sticky average wage and a flexible marginal wage creates a strong motive to reduce labor demand through employment; the large decline in the real marginal cost produces high strategic complementarities leading price setters to reduce their prices by less<sup>30</sup>.

The Nash bargaining and the wage norm, instead, display a weak response of unemployment. Note that the wage norm again produces less unemployment variations than the Nash bargaining. For those wage specifications, there is some trade-off between reproducing the dynamics of output, unemployment and inflation. To illustrate this, we keep (for simplicity) the same persistence for the financial shock but increase  $\sigma_z$  so as to minimize the least squares between the effective unemployment rate and the unemployment rate resulting from the model<sup>31</sup>. The right panel of Figure 1 makes clear that replicating unemployment fluctuations comes at a cost of an excessive fall in both output and inflation for the Nash bargaining and the wage norm, while the credible bargaining reproduces output and inflation variations very well.

## 4 Optimal monetary policy and the inflation/unemployment trade-off

Blanchard and Galí (2007, 2010) argue that for the canonical NK model, in which firms adjust labor demand only through employment and the real wage is flexible, strict inflation

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<sup>30</sup>We check in the simulations that the nominal interest rate never crosses the zero lower bound. This is the case given the high persistence and the weak response to output growth of this rate with our calibration of the Taylor rule.

<sup>31</sup>For the credible bargaining, the value of  $\sigma_z$  which allows the model to match unemployment movements is the same as the one which makes the model match output fluctuations. For the Nash bargaining and the wage norm, those values are  $\sigma_z = 0.014$  and  $\sigma_z = 0.015$ , respectively.

targeting is the optimal monetary policy. Indeed, they demonstrate that the fluctuations of the unemployment rate resulting from the full stabilization of the inflation rate mimic those that result from the optimal policy. This absence of a stabilization trade-off between inflation and unemployment, at odds with conventional wisdom, is what Blanchard and Galí call the *divine coincidence*. Nevertheless, when real wage rigidities are introduced, the unemployment fluctuations stemming from the zero inflation policy are much more volatile than the fluctuations coming from the optimal policy : with real wage stickiness, strict inflation targeting entails sub-optimal fluctuations of the unemployment rate and the central bank faces a substantial stabilization trade-off.

In this section, we point that when firms determine both labor margins, the capacity of real wage rigidities to provide a meaningful policy trade-off critically depends on the way those rigidities are introduced. For the credible bargaining, price stability produces unemployment movements which are much larger than those resulting from the optimal policy. A significant inflation/unemployment trade-off therefore emerges. For the wage norm, the unemployment fluctuations under the zero inflation and optimal policies are very close and the monetary authority faces only a weak trade-off.

To determine the optimal monetary policy, we follow the Linear Quadratic approach pioneered by Rotemberg and Woodford (1997). This approach requires obtaining a second-order approximation of the representative household's welfare criterion, as well as a first-order approximation of the equilibrium conditions. We assume an efficient steady state, for two reasons. First, Benigno and Woodford (2005) stress that in the more general case of a distorted steady state, the LQ approach requires to get a complicated second-order approximation of the equilibrium conditions in order to substitute for the linear terms in the welfare criterion. Secondly, they argue, as Faia (2009), that steady-state distortions imply a sub-optimality of strict inflation targeting policies, independently of wage rigidities. Assuming an efficient steady state enables us to clearly assess the role of real wage rigidities in producing a case against price stability.

The second-order approximation of the welfare criterion and the three conditions ensuring an efficient steady state are provided by the online technical appendix<sup>32</sup>.

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<sup>32</sup>The three conditions ensuring the efficiency of the steady state imply the following changes in the calibration :  $\zeta = 0.4$ ,  $\chi = 0.25$ ,  $\gamma = 0.33$ ,  $x_h = 1.09$  and  $\kappa^{wn} = 0.026$ .

Figure 2 : impulse response functions to a 1% negative productivity shock

Credible Bargaining

Wage Norm

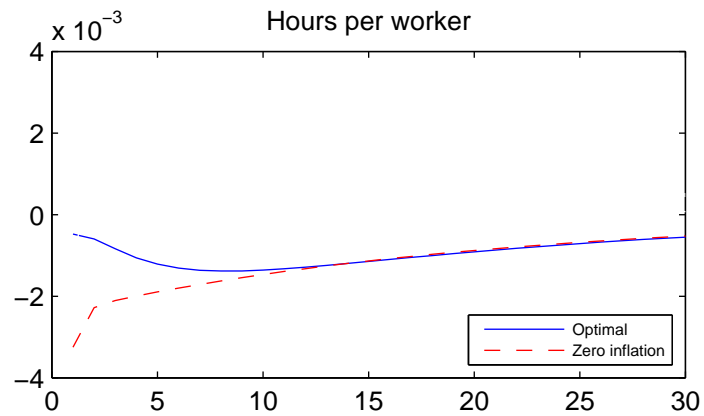
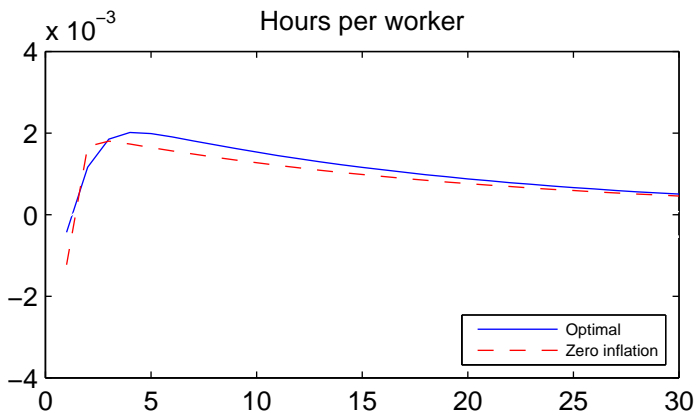
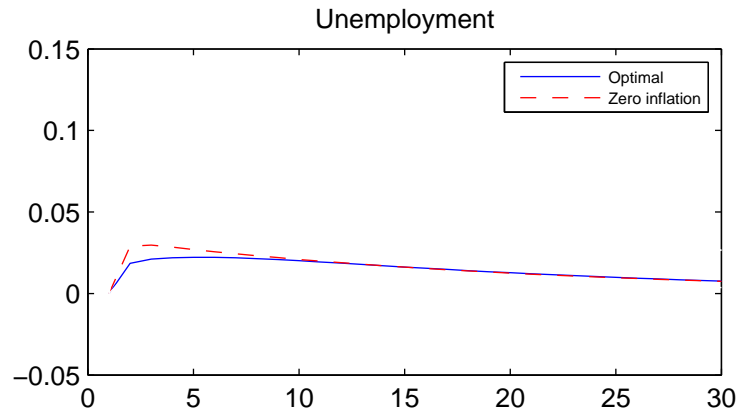
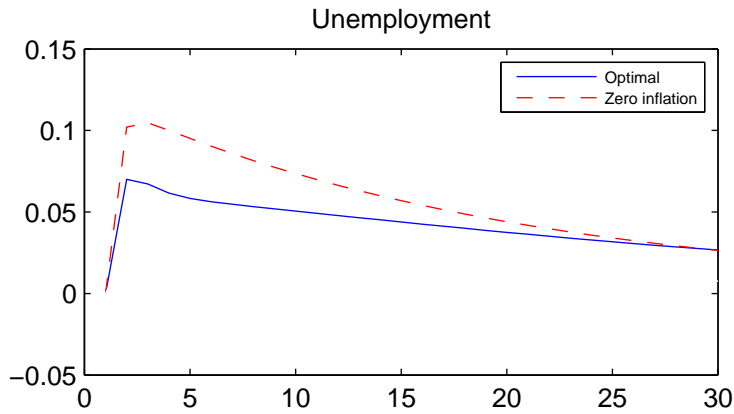
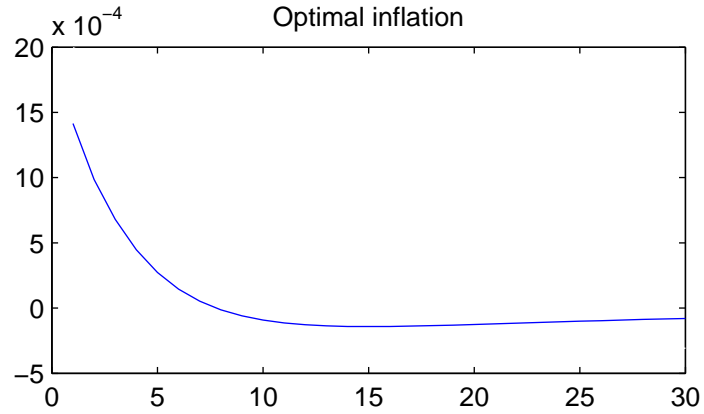
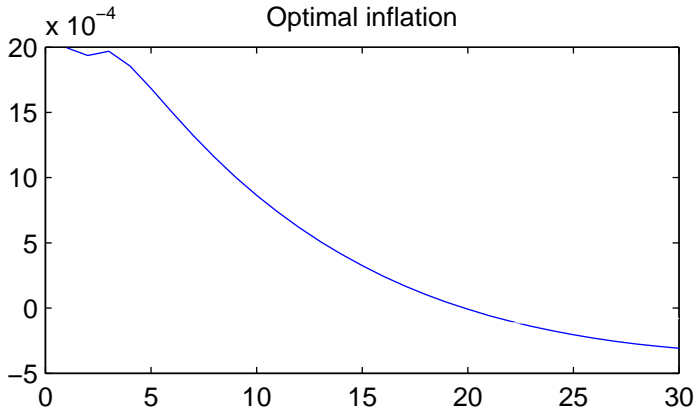


Figure 2 displays the responses of inflation, unemployment and hours per worker to a 1% negative productivity shock under the optimal and strict inflation targeting policies. This latter keeps the price level constant in every period. This policy is implemented by fully stabilizing the real marginal cost each period. Inflation responses are shown in annual terms.

For the credible bargaining, the inflation rate under the optimal policy deviates from zero, in order to reduce the large unemployment fluctuations resulting from the real wage rigidities. Moreover, the unemployment rate under strict inflation targeting is much more volatile than the optimal rate : the real wage stickiness resulting from the credible bargaining therefore creates a meaningful stabilization trade-off between inflation and unemployment. At the same time, the optimal inflation rate also departs from zero for the wage norm. However, the monetary authority uses inflation not to reduce unemployment fluctuations, but instead to stabilize hours per worker. Indeed, the unemployment movements under zero inflation and optimal policies are very close, while zero inflation and optimal hours per worker highly differ. In this case, the real wage rigidities implied by the wage norm generate a large trade-off between inflation and hours per worker, but a negligible one between inflation and unemployment.

Why does the real wage rigidity provided by the credible bargaining deliver a significant inflation/unemployment trade-off while the wage stickiness resulting from the wage norm does not ? As stressed by Ravenna and Walsh (2012), the gap between zero inflation and optimal policies is positively related to the amount of unemployment volatility. In the previous sections, we have shown that the wage norm produces only small unemployment fluctuations, since the real wage stickiness in this case implies a strong incentive for firms to adjust on hours. Hence, the gap between zero inflation and optimal unemployment movements is weak and so is the inflation/unemployment trade-off. Conversely, we have emphasized that the real wage rigidities stemming from the credible bargaining generate high unemployment volatility. The gap between zero inflation and optimal unemployment variations is therefore large and produces a substantial inflation/unemployment trade-off.

The failure of the wage norm to bring a meaningful inflation/unemployment stabilization trade-off when firms determine both hours and employment could challenge the role of real wage rigidities in generating such a trade-off. We again argue that the way of introducing wage rigidities is critical. Since for the credible bargaining zero inflation policies produce large and sub-optimal unemployment fluctuations, real wage rigidities are the required ingredient to create a significant policy trade-off.



## 5 Conclusion

In this paper, we have replaced the traditional wage norm by the credible bargaining into a New Keynesian model with matching frictions on the labor market. Firms set employment, hours per worker and prices. We have shown that the real wage rigidities stemming from the credible bargaining replicate the joint dynamics of unemployment, inflation and marginal cost of post-war US data. The muted response of inflation and the large jump in unemployment that followed the recent financial crisis are also reproduced. On the normative side, a significant stabilization trade-off between unemployment and inflation emerges.

The real wage resulting from the credible bargaining is sticky with respect to labor market conditions but flexible with respect to the disutility of labor. The rigidity in the cost of an additional worker associated with the flexibility in the cost of an additional hour therefore explain the large adjustment of labor demand through employment. At the same time, the flexibility of the wage with respect to hours generates strong strategic complementarities between price setters, which make inflation inertia consistent with the observed cyclicity of the marginal cost through a flatter NKPC.

## References

- [1] **Andolfatto D.** “Business Cycles and Labor-Market Search”, *American Economic Review*, Vol.86, No.1, 1996.
- [2] **Ball L, Mazumder S.** “Inflation Dynamics and the Great Recession”, NBER Working Papers 17044, 2011.
- [3] **Ball L, Romer D.** “Real Rigidities and the Non-neutrality of Money”, *Review of Economic Studies*, Vol.57, No.2, 1990.
- [4] **Barnichon R.** “Productivity and Unemployment over the Business Cycle”, *Journal of Monetary Economics*, Vol.57, No.8, 2010a.
- [5] **Barnichon R.** “Building a composite Help-Wanted Index”, *Economic Letters*, Vol.109, No.3, 2010b.
- [6] **Basu S.** “Comment on: Implications of state-dependent pricing for dynamic macroeconomic modeling”, *Journal of Monetary Economics*, Vol.52, No.1, 2005.
- [7] **Benigno P, Woodford M.** “Inflation Stabilization And Welfare: The Case Of A Distorted Steady State” *Journal of the European Economic Association*, MIT Press, vol.3, No.6, 2005.
- [8] **Bils M.** “The Cyclical Behavior of Marginal Cost and Price”, *American Economic Review*, Vol.77, No.5, 1987.
- [9] **Binmore K, Rubinstein A, Wolinsky A.** “The Nash Bargaining Solution in Economic Modelling”, *Rand Journal of Economics*, Vol.17, No.2, 1986.
- [10] **Blanchard O, Diamond P.** “The Beveridge Curve”, *Brookings Papers on Economic Activity* 1, 176, 1989.
- [11] **Blanchard O, Galí J.** “Real Wage Rigidities and the New Keynesian Model”, *Journal of Money, Credit and Banking*, supplement to Vol.39, No.1, 2007.
- [12] **Blanchard O, Galí J.** “Labor Markets and Monetary Policy: A New Keynesian Model with Unemployment”, *American Economic Journal: Macroeconomics*, Vol.2, No.2, 2010.
- [13] **Brueckner M, Pappa E.** “Fiscal Expansions, Unemployment and Labor Force Participation: Theory and Evidence”, *International Economic Review*, Vol.53, No.4, 2012.

- [14] **Calvo G.** “Staggered Prices in a Utility-Maximizing Framework”, *Journal of Monetary Economics*, Vol.12, No.3, 1983.
- [15] **Card D.** “Intertemporal Labor Supply: An Assessment”, in *Advances in Econometrics: Sixth World Congress*, Cambridge University Press, 1994.
- [16] **Christiano L, Eichenbaum M, Trabandt M.** “Understanding the Great Recession”, *American Economic Journal: Macroeconomics*, Vol.7, No.1, 2015a.
- [17] **Christiano L, Eichenbaum M, Trabandt M.** “Unemployment and Business Cycles”, *Econometrica*, Revise and Resubmit, 2015b.
- [18] **Christoffel K, Linzert T.** “The Role of Real Wage Rigidity and Labor Market Rigidities in Inflation Persistence”, *Journal of Money, Credit and Banking*, Vol.42, No.7, 2010.
- [19] **Cooley T, Prescott E.** “Economic Growth and Business Cycles”, in *Frontiers of Business Cycle Research*, Princeton University Press, 1995.
- [20] **Daly M, Fernald J, Jordà O, Nechio F.** “Output and Unemployment Dynamics”, Federal Reserve Bank of San Francisco, Working Paper Series 2013-32, 2014.
- [21] **Del Negro M, Giannoni M, Schorfheide F.** “Inflation in the Great Recession and New Keynesian Models”, *American Economic Review: Macroeconomics*, Vol.7, No.1, 2015.
- [22] **Den Haan W, Ramey G, Watson J.** “Job Destruction and Propagation of Shocks”, *American Economic Review*, Vol.90, No.3, 2000.
- [23] **Domeij D, Flodén M.** “The Labor-Supply Elasticity and Borrowing Constraints: Why Estimates are Biased”, *Review of Economic Dynamics*, Vol.9, No.2, 2006.
- [24] **Faia E.** “Ramsey Monetary Policy with Labour Market frictions”, *Journal of Monetary Economics*, Vol.56, No.4, 2009.
- [25] **Fujita S, Ramey G.** “The Cyclicity of Job Loss and Hiring”, Federal Reserve Bank of Philadelphia, Working Paper 06-17, 2006.
- [26] **Galí J.** *Monetary Policy, Inflation, and the Business Cycle*, Princeton University Press, 2008.
- [27] **Hagedorn M, Manovskii I.** “The Cyclical Behavior of Equilibrium Unemployment and Vacancies Revisited”, *American Economic Review*, Vol.98, No.4, 2008.

- [28] **Hall R.** “Employment Fluctuations with Equilibrium Wage Stickiness”, *American Economic Review*, Vol.95, No.1, 2005.
- [29] **Hall R.** “The Long Slump”, *American Economic Review*, Vol.101, No.2, 2011.
- [30] **Hall R, Milgrom P.** “The Limited Influence of Unemployment on the Wage Bargain”, *American Economic Review*, Vol.98, No.4, 2008.
- [31] **Jimeno J, Thomas C.** “Collective Bargaining, Firm Heterogeneity and Unemployment”, *European Economic Review*, Vol.59(C), 2013.
- [32] **Jung P, Kuester K.** “The (Un)Importance of Unemployment Fluctuations for the Welfare Cost of Business Cycles”, *Journal of Economic Dynamics and Control*, Vol.35, No.10, 2011.
- [33] **Kaplan G, Menzio G.** “Shopping Externalities and Self-Fulfilling Unemployment Fluctuations”, *Journal of Political Economy*, Forthcoming, June 2015.
- [34] **Krause M, Lubik T.** “The (Ir)Relevance of Real Wage Rigidities in the New Keynesian Model with Search Frictions”, *Journal of Monetary Economics*, Vol.54, No.3, 2007.
- [35] **Kuester K.** “Real Price and Wage Rigidities with Matching Frictions”, *Journal of Monetary Economics*, Vol.57, No.4, 2010.
- [36] **Merz M.** “Search in the Labor Market and the Real Business Cycle”, *Journal of Monetary Economics*, Vol.36, No.2, 1995.
- [37] **Monacelli T, Perotti R, Trigari A.** “Unemployment Fiscal Multipliers”, *Journal of Monetary Economics*, Vol.57, No.5, 2010.
- [38] **Mortensen D, Nagypál E.** “More on Unemployment and Vacancy Fluctuations”, *Review of Economic Dynamics*, Vol.10, No.3, 2007.
- [39] **Nash J.** “Two-Person Cooperative Games”, *Econometrica*, Vol.21, 1953.
- [40] **Ohanian L, Raffo A.** “Aggregate Hours Worked in OECD Countries: New Measurement and Implications for Business Cycles”, *Journal of Monetary Economics*, Vol.59, No.1, 2012.
- [41] **Osborne M, Rubinstein A.** *Bargaining and Markets*, Academic Press, 1990.
- [42] **Pissarides C.** *Equilibrium Unemployment Theory*, MIT Press, 2000.

- [43] **Pissarides C.** “The Unemployment Volatility Puzzle: Is Wage Stickiness the Answer?”, *Econometrica*, Vol.77, No.5, 2009.
- [44] **Ravenna F, Walsh C.** “Monetary policy and labor market frictions : A tax interpretation”, *Journal of Monetary Economics*, Vol.59, No.2, 2012.
- [45] **Rotemberg J, Woodford M.** “An optimization-based econometric model for the evaluation of monetary policy”, *NBER Macroeconomics Annual*, Vol.12, 1997.
- [46] **Rotemberg J.** “The Determination of Weekly Hours of Work : A Comment on Christoffel and Kuester’s “Resuscitating the Wage Channel in Models with Unemployment Fluctuations””, *Journal of Monetary Economics*, Vol.55, No.5, 2008.
- [47] **Rubinstein A.** “Perfect Equilibrium in a Bargaining Model”, *Econometrica*, Vol.50, No.1, 1982.
- [48] **Shimer R.** “The Cyclical Behavior of Equilibrium Unemployment and Vacancies”, *American Economic Review* Vol.95, No.1, 2005.
- [49] **Svein T, Weinke L.** “New Keynesian Perspectives on Labor Market Dynamics”, *Journal of Monetary Economics*, Vol.55, No.5, 2008.
- [50] **Svein T, Weinke L.** “Inflation and Labor Market Dynamics Revisited”, *Journal of Monetary Economics*, Vol.56, No.8, 2009.
- [51] **Thomas C.** “Search Frictions, Real Rigidities, and Inflation Dynamics”, *Journal of Money, Credit and Banking*, Vol.43, No.6, 2011.
- [52] **Trigari A.** “The Role of Search Frictions and Bargaining for Inflation Dynamics”, IGER Working Paper No.304, 2006.
- [53] **Walsh C.** “Labor Market Search, Sticky Prices, and Interest Rate Policies”, *Review of Economic Dynamics*, Vol.8, No.4, 2005.

## Appendix

Table 4 provides model-simulated moments under simultaneous productivity and monetary policy shocks<sup>33</sup>. To facilitate comparisons, we report the baseline results for the credible bargaining (i.e. with  $\psi = 0$ ), the wage norm (i.e. with  $\alpha = 0.35$ ) and the Nash bargaining of Table 3.

In the first column, we consider the case for which there is a probability  $\psi$  that the negotiation breaks before the end of the wage bargaining. When this event occurs, the worker and the employer get their outside options -  $U_t$  and  $V_{it} = 0$  - since they go back on the labor market to search for another match. The relevant threat points are therefore the outside options with probability  $\psi$  and the disagreement payoffs with probability  $1 - \psi$ . This implies that the surplus of a player is the Nash bargaining surplus with probability  $\psi$  and the credible bargaining surplus with probability  $1 - \psi$ . The worker's and firm's surpluses are respectively given by :

$$S_{it}^{W*}(z) = \psi(W_{it}(z) - U_t) + (1 - \psi)(w_{it}(h_{it}(z))h_{it}(z) - x_h \frac{h_{it}(z)^{1+\eta}}{(1 + \eta)u'(c_t)} - b)$$

$$S_{it}^{F*}(z) = \psi J_{it}(z) + (1 - \psi)(mc_{it}A_t h_{it}(z) - w_{it}(h_{it}(z))h_{it}(z) + \gamma)$$

Lacking evidence about the probability of bargaining disruption  $\psi$ , we assume that this probability equals the destruction rate  $s$ . The surplus-sharing rule -  $(1 - \zeta)S_{it}^{W*}(z) = \zeta S_{it}^{F*}(z)$  - yields the following expression for the real average wage :

$$w_{it}^{cb*}(h_{it}(z)) = \zeta[mc_{it}A_t + \frac{\gamma}{h_{it}(z)}] + (1 - \zeta)[\frac{b}{h_{it}(z)} + x_h \frac{h_{it}(z)^\eta}{(1 + \eta)u'(c_t)}] + \frac{s}{1 - s}[\zeta J_{it}(z) - (1 - \zeta)(W_{it}(z) - U_t)]$$

The other equations of the model, and particularly the real marginal wage, are not affected by introducing a potential breakdown during the wage bargaining.

The first column of Table 4 shows that introducing this exogenous event has a small impact on the quantitative results. As expected, the real average wage is more flexible since it now

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<sup>33</sup>Conditional results are available upon request.

Table 4 : Credible Bargaining with  $\psi = s$  / Wage Norm with alternative values for  $\alpha$

	CB	CB	WN	WN	WN	WN	NB
Data	$\psi = s$	$\psi = 0$	$\alpha = 0.20$	$\alpha = 0.35$	$\alpha = 0.95$		
$\sigma(y_t), \%$	1.56	1.55	1.56	1.62	1.60		1.56
$\sigma(u_t)/\sigma(y_t)$	5.99	7.35	2.38	2.76	3.23		2.01
$\sigma(v_t)/\sigma(y_t)$	7.33	8.93	3.04	3.38	3.94		2.78
$\sigma(\theta_t)/\sigma(y_t)$	10.62	13.05	4.22	4.89	5.73		3.56
$\sigma(h_t)/\sigma(y_t)$	0.44	0.46	0.38	0.38	0.75		0.45
$\sigma(h_t)/\sigma(n_t)$	1.13	0.97	2.50	2.00	3.64		3.50
$\sigma(w_t)/\sigma(y_t)$	0.77	0.74	0.75	0.59	0.03		1.03
$\sigma(\pi_t)/\sigma(y_t)$	0.09	0.08	0.10	0.09	0.07		0.10
$\rho(\pi_t, \pi_{t-1})$	0.62	0.64	0.61	0.62	0.70		0.59

depends on labor market conditions through  $U_t$ . However, this higher flexibility is marginal given that labor market conditions enter the wage equation only with the probability of negotiation breakdown. Since the real marginal wage is still highly pro-cyclical, firms still adjust labor demand mainly through employment. The volatility of unemployment and vacancy is then moderately lower than in the baseline case for which  $\psi = 0$ .

Columns three to five of Table 4 investigate alternative values for  $\alpha$  for the wage norm. In the third column,  $\alpha$  is set to 0.20, which implies that the volatility of the real average wage for the wage norm roughly matches that of the credible bargaining. In the fifth column,  $\alpha$  is set to 0.95, a value implying a very high wage stickiness. We observe that the results for the wage norm are relatively insensitive to changes in  $\alpha$ . With  $\alpha = 0.20$ , the volatility of the unemployment and vacancy rates is weak and close to that of the Nash bargaining. Hence, even though the wage norm and the credible bargaining display the same wage stickiness in this case, their implications in terms of labor market fluctuations are sharply different. With  $\alpha = 0.95$ , the wage norm generates slightly more volatility for the unemployment and vacancy rates, but is still far from the data. At the same time, inflation inertia is obtained through a very sluggish real marginal cost : with  $\alpha = 0.95$ ,  $\epsilon_\omega = 0.05$ , which is far lower than the range of values estimated by Bils (1987).



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