The Cyclicality of Marginal Cost and the Dynamics of the Labor Market and Inflation

Pierrick Clerc *
Banque de France

Abstract

Existing business-cycle models for which firms unilaterally adjust labor along both the intensive and extensive margins have difficulties in reproducing the dynamics of employment and hours per worker. Within a New-Keynesian framework with search frictions in the labor market, we show that a much higher pro-cyclicality for marginal labor cost than for average labor cost, in accordance with empirical observations, is a crucial mechanism for replicating labor-market fluctuations. At the same time, the large pro-cyclicality of marginal cost is consistent with inflation inertia since this pro-cyclicality induces strong strategic complementarities between price-setters.

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1 Introduction

There is now a wide literature which aims at replicating labor-market dynamics within the search-and-matching framework initiated by Mortensen and Pissarides[1]. Substantial improvements have been made since the seminal contribution of Shimer (2005). Existing models, however, still have difficulties in reproducing labor-market fluctuations once firms, realistically, can adjust labor along both the intensive (hours per worker) and extensive (employment) margins[2]. These models particularly fail to explain two salient facts of the US labor market. First, most adjustments in total hours of work appear as fluctuations in employment rather than in hours per worker. Secondly, employment fluctuations are large such that the unemployment rate is highly volatile[3]. In this paper, we argue that the inability to replicate these facts stems from a particular feature of available models, namely that they deliver roughly the same cyclical behavior for short-run *marginal* cost (the wage paid to hire an additional hour of work) and for short-run *average* cost (the wage paid for each of the hours already hired). This feature stands in sharp contrast with the empirical results of Bils (1987), who finds that marginal cost is strongly pro-cyclical whereas average cost is only moderately pro-cyclical.

The first contribution of the present paper is to show that a pro-cyclicality of marginal cost much higher than that of average cost, in accordance with the findings of Bils (1987), is a key mechanism to reproduce the two above-mentioned facts. A larger pro-cyclicality for marginal cost than for average cost means that the cost of additional hours per employee moves relatively more than the (flow) cost of an additional worker in response to shocks, which creates an incentive for firms to adjust labor mainly through the extensive margin. This also implies that the value of an additional worker is pro-cyclical, thus amplifying the incentive to adjust employment. One could object that a sharp pro-cyclicality of marginal cost would generate large variations in inflation, at odds with the small but persistent responses of this variable observed in the data. The second contribution of this paper is to stress that a high pro-cyclicality of marginal cost is consistent with the observed pattern of inflation: this high pro-cyclicality induces strong strategic complementarities between price setters, which produce inflation inertia through a flat New-Keynesian Phillips Curve (henceforth NKPC). We further point out that the larger the pro-cyclicality of marginal cost, the stronger the strategic complementarities and the flatter the NKPC.

To emphasize the role of marginal cost on labor-market and inflation dynamics, we use a New-Keynesian model with matching frictions in the labor market[4]. More precisely, we

[1]See Pissarides (2000) for an exposition of the standard search-and-matching model.

[2]This is notably the case for Sveen and Weinke (2008), Christoffel and Kuester (2008) and Thomas (2011).

[3]See Kydland (1995) and Ohanian and Raffo (2012) for evidence related to the adjustment along both labor margins. Shimer (2005) emphasizes the high unemployment volatility in the United States and the incapacity of the standard search-and-matching model to reproduce it.

[4]See Galí (2008) for a presentation of the canonical New-Keynesian framework.

consider a framework in which firms create jobs, determine hours per worker and set prices[5]. These firms bargain with each of their workers over the hourly wage, also called the *average* wage. Moreover, employment is predetermined, so that firms can only adjust hours per employee on impact in response to shocks[6]. This entails that marginal cost in the short run is defined by the wage paid to hire an additional hour of work, namely the *marginal* wage. Importantly, firms choose hours per worker *before* the wage negotiation occurs, taking rationally into account that a marginal change in hours per employee will imply a change in the bargained average wage. The marginal and average wages are therefore not equal and can display different cyclical patterns[7].

Within this framework, we compare various wage bargains that provide different degrees of cyclicality for the marginal and average wages. We show that the wage bargains which deliver a marginal wage much more pro-cyclical than the average wage enable this framework to replicate the relative adjustment between labor margins and the high volatility of unemployment. At the same time, these wage bargains produce inflation inertia through a large amount of strategic complementarities between firms. Conversely, the wage bargains which generate roughly the same pro-cyclicality for the marginal and average wages completely fail to reproduce labor-market dynamics.

To gain some intuition, take a firm that wishes to increase total working hours in response to a positive shock. If this firm raises hours of existing employees, each of these additional hours will come at a cost equal to the marginal wage. Alternatively, if total hours of work are increased by recruiting an additional worker, the cost of each hour will be the average wage. A marginal wage more pro-cyclical than the average wage means that the cost of raising total hours through additional hours for existing employees increases relatively more than the cost of raising total hours through an additional worker[8]. This creates an incentive for firms to adjust labor relatively more along the extensive margin. Moreover, in a context of predetermined employment, the contribution of a an additional worker to current profits is driven by the marginal wage, since this worker allows to save extra hours of already employed workers. A higher pro-cyclicality for the marginal wage than for the average wage therefore implies an increase in the value of a new worker for the firm, since this worker allows to save hours whose price increases more than the price of her own hours worked. This amplifies the incentive to hire an additional worker. In sum, a marginal wage

[5]Such framework is notably implemented in the recent literature by Sveen and Weinke (2009), Thomas (2011) and Dossche et al. (2014).

[6]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)).

[7]This stands in sharp contrast with the Right-To-Manage set-up initiated by Trigari (2006), where firms determine hours per worker *after* having negotiated over the average wage. The marginal and average wages are then equal, since each additional hour of work can be hired at the previously bargained average wage.

[8]Obviously, recruiting an additional worker involves other costs, like vacancy posting and training costs. The average wage is then the *flow* unit cost of adjusting total hours through the extensive margin.

more pro-cyclical than the average one entails not only that labor is adjusted relatively more along the extensive margin, but also that job creations, and then unemployment reduction, are substantial.

Let us now turn to inflation dynamics. Since employment is predetermined, firms can only expand hours per employee in the short run. The relevant marginal cost at this period is then the cost of an additional hour per worker, which is given by the marginal wage. A sharply pro-cyclical marginal wage should thus directly imply large variations in inflation. But at the same time, a sharp pro-cyclicality of the marginal wage indirectly dampens the response of prices to shocks. To understand this indirect effect, take a firm which considers a reduction in its relative price after a positive productivity shock. This firm will have to raise hours per worker to adjust production to the resulting higher demand. Anticipating the large increase in its marginal cost that will ensue finally leads this firm to keep its price in line with the overall price level. Such a strategic complementarity, or real price rigidity, therefore dampens the response of firms that can reset their prices. This indirect effect in price-setting also flattens the NKPC. Crucially, the size of this effect increases with the pro-cyclicality of the marginal wage: the more pro-cyclical the marginal wage, the stronger the strategic complementarities and the flatter the NKPC. Consequently, a higher pro-cyclicality of the marginal wage implies larger movements (direct effect) along a flatter NKPC (indirect effect).

We first assess the role of the relative cyclicality of the marginal and average wages in the replication of US labor-market dynamics. We apply alternative wage bargains which deliver different cyclical patterns for these two wages. We consider the standard Nash bargaining (with symmetric and low worker's bargaining power), the credible bargaining (Hall and Milgrom (2008)) and the wage norm (Hall (2005)). The symmetric Nash bargaining displays flexibility for the marginal and average wages. Conversely, the wage norm generates rigidities for both wages. These two wage bargains, however, counterfactually produce more volatility for hours per worker than for employment, and small unemployment fluctuations. On the other hand, the Nash bargaining with low worker's bargaining power and the credible bargaining reproduce the relative adjustment between the extensive and intensive labor margins, as well as the high volatility of unemployment. These wage bargains provide a flexible marginal wage but a sticky average wage, with magnitudes close to the evidence in Bils (1987): for both wage bargains the marginal wage is the same as under symmetric Nash bargaining, but the average wage is stickier. Hence, when firms adjust labor along both margins, a marginal wage much more pro-cyclical than the average wage is a crucial mechanism in the reproduction of labor-market fluctuations[9]. A main conclusion of this

[9]It is worth mentioning that the papers referred to in footnote 2, which we discuss in greater detail below, have only considered the symmetric Nash bargaining and the wage norm. This explains why the models of these papers fail to reproduce labor-market dynamics. By contrast, the Nash bargaining with low worker's bargaining power and the credible bargaining have not been investigated in models where firms determine both margins of labor.

paper is that what matters for labor-market dynamics is not the cyclicality of wages per se, but the cyclicality of the marginal wage with respect to that of the average wage.

We next assess the implications of different cyclical patterns for the marginal wage in terms of inflation dynamics. Since the wage norm generates low fluctuations in the marginal wage, this wage bargain obviously reproduces the small but persistent reactions of inflation to shocks. Interestingly, even though producing sizable movements in the marginal wage, the Nash bargaining (whatever the worker's bargaining power) and the credible bargaining also replicate the inertial dynamics of inflation. For these wage bargains, inflation inertia stems from high strategic complementarities which flatten the NKPC. High strategic complementarities, in turn, result from the large movements in the marginal wage. Hence, the direct effect of large variations in the marginal wage on inflation is more than offset by the indirect effect induced by these variations.

Related literature. The four papers closest to our work are those of Sveen and Weinke (2008), Christoffel and Kuester (2008), Sveen and Weinke (2009) and Thomas (2011). All these contributions adopt a New-Keynesian model with labor-market frictions in which firms unilaterally adjust both labor margins. We do not consider frameworks in which firms and workers bargain over hours per workers since Rotemberg (2008) provides some evidence, related to the length of the workweek in the United States, against negotiations over hours per worker[10].

Sveen and Weinke (2008) show that sticky wages, implemented by the wage norm, do not bring more unemployment volatility than flexible wages, implemented by the symmetric Nash bargaining. In each case, almost all labor adjustments rest on hours per worker. One could conclude from their results that the cyclical behavior of wages has no impact on labor-market dynamics when firms adjust labor along both margins. In this paper, we argue that this conclusion would miss the point that what matters is the *relative* cyclicality of the marginal and average wages. We stress that the wage norm and the symmetric Nash bargaining fail to reproduce labor-market facts since these wage bargains display the same cyclical pattern for both the marginal and average wages. In contrast, the Nash bargaining with low worker's bargaining power and the credible bargaining replicate labor-market dynamics by providing more pro-cyclicality for the marginal wage than for the average one.

Christoffel and Kuester (2008) assume that hours per worker are determined through the Right-To-Manage set-up, for which the marginal and average wages are always equal, whatever the wage bargain. They argue that introducing some stickiness in the average wage turns into sluggish marginal cost, thus generating inflation inertia. They also find a calibration, including fixed costs associated with maintaining existing jobs, which enables this framework to reproduce the volatility of the unemployment and vacancy rates. Nevertheless, hours per worker are not only three times more volatile than they are in the data,

[10]Trigari (2006) also notices that hours per worker are rarely the object of negotiations but uses the efficient bargaining framework (Trigari (2009)) for simplicity.

but also counter-factually more volatile than employment. Moreover, the volatility of the unemployment rate collapses in the absence of the fixed costs. These results are consistent with our argument: in order to restitute labor-market facts, the marginal wage should be much more pro-cyclical than the average wage.

Sveen and Weinke (2009) emphasize that strategic complementarities in price-setting emerge when firms both bargain over the average wage and set prices. For a given dynamics of marginal cost, these complementarities imply a lower response of inflation to shocks. Here, we invoke strategic complementarities to show that large fluctuations in the marginal wage are consistent with inflation inertia. We further point out that the degree of strategic complementarities, and then the slope of the NKPC, depend on the cyclicality of the marginal wage: a more pro-cyclical marginal wage entails stronger strategic complementarities and a flatter NKPC. Hence, large variations in the marginal wage create an incentive for firms to dampen price movements which more than overcomes the direct impact of these large variations on inflation.

With the same framework as we use in this paper and the symmetric Nash bargaining, Thomas (2011) replicates the large volatility of the unemployment rate and the relative adjustment between labor margins. However, the responses of employment to shocks are amplified by an additional mechanism related to the introduction of money through a cash-in-advance constraint. Thomas next considers a more standard cashless economy associated with a Taylor rule and finds that the volatility of the unemployment rate declines substantially, while hours per worker become more volatile than employment. In this paper, we stress that this framework is able to reproduce labor-market dynamics even for a cashless economy, provided that the marginal wage is much more pro-cyclical than the average one.

The rest of the paper is organized as follows. In the next section, we present the model and lay a particular emphasis on the various wage bargains considered. In Section 3, we calibrate and assess its quantitative implications along the labor-market and inflation dimensions. Section 4 concludes.

2 The Model

The basic structure of the model stems from Thomas (2011). Household members supply labor services on a frictional labor market and consume differentiated goods produced by monopolistic firms. These firms set prices, determine hours per worker, post vacancies and bargain over the hourly wage with each worker. We depart from Thomas (2011) and other papers that use this framework by considering alternative wage bargains. Finally, the monetary authority sets the nominal interest rate.

2.1 Labor-market frictions

Searching for a worker to fill a vacancy involves a fixed cost χ. The number of new matches for 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 $f(\theta_t) \equiv \frac{m(u_t,v_t)}{u_t}$. This rate increases with market tightness θ_t, the ratio of vacancies to unemployment. The rate at which vacancies are filled is given by $q(\theta_t) \equiv \frac{m(u_t,v_t)}{v_t}$, which decreases with θ_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:

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

where c_t is a Dixit-Stiglitz aggregator of different varieties of goods, n_{it} the number of workers in firm $i \in [0,1]$, h_{it} the number of hours worked by a worker in firm i and x_h a positive scaling parameter of disutility of work.

The household faces the sequence of real budget constraints:

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

where w_{it} is the real hourly wage earned by a worker in firm i, b is the unemployment income (including notably unemployment benefits and home production) received by unemployed members, P_t is the price level, 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 Θ_t is a lump-sum component of income that may include dividends from the firm sector or lump-sum taxes. From now on, w_{it} will be called the real *average* wage.

The inter-temporal optimality condition is given by the standard Euler condition:

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

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

2.3 Firms

Firms are assumed to set prices, post vacancies and choose hours per worker, and then bargain over the real average wage with employees.

2.3.1 The firm's program

There is a measure-one continuum of firms. Each of them produces 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 χ and chooses h_{it} working hours for each worker at a real average wage w_{it}. We denote by Π_{it} the value of the firm i at period t:

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

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:

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

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:

$$y_{it}^s = A_t n_{it} h_{it}^{\alpha}$$

where A_t is a common labor productivity shock. The log of this shock, $a_t = lnA_t$ 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 itself to meeting demand at the chosen price. This implies that the following condition should hold in every period:

$$(\frac{P_{it}}{P_t})^{-\epsilon} y_t^d = A_t n_{it} h_{it}^{\alpha} \tag{3}$$

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

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

Finally, firms reset their price in a Calvo (1983) fashion. Each period, a firm has a $(1-\delta)$ probability of re-optimizing its price and a δ probability of keeping its price of the last period. Hence, we have:

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

We denote by mc_{it} and ϑ_{it} the Lagrange multipliers with respect to constraints (3) and (4), respectively. Hence, mc_{it} represents the real marginal cost of production. Note that mc_{it} is a *firm-wide* variable. The firm determines the state-contingent path $\{P_{it}, h_{it}, v_{it}, n_{it+1}\}$ that maximizes its value Π_{it} subject to constraints (3), (4) and (5).

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

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

$$\partial h_{it}: \quad mc_{it} \alpha A_t h_{it}^{\alpha-1} = w_{it} + w_{it}'(h_{it})h_{it} \tag{7}$$

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

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

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 $\frac{\epsilon}{\epsilon-1} \succ 1$ over real marginal costs for the expected duration of the price set in period t.

We denote by ω_{it} the real *marginal* wage for a given worker in firm i, i.e. $\omega_{it} = w_{it} + w'_{it}(h_{it})h_{it}$. Since firms determine hours per worker *before* negotiating over the real average wage, they take rationally into account that a marginal change in hours per employee will imply a change in the average wage. This is reflected by the term $w'_{it}(h_{it})h_{it}$ in the marginal wage schedule. From equation (7), the real marginal cost is given by:

$$mc_{it} = \frac{\omega_{it}}{\alpha A_t h_{it}^{\alpha-1}} \tag{10}$$

Hence, the real marginal cost is the ratio between the real marginal wage and the marginal product of hours. Since employment is predetermined, increasing production in period t requires raising hours per worker. The real marginal cost is therefore the cost of an additional hour per employee.

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

2.3.2 The wage bargaining

We denote by W_{it} the value of a match for a given worker in firm i at period t:

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

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

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

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

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

where V_{it} is the firm's value of a vacancy. Given equation (8), $V_{it} = 0$ in equilibrium. Hence, U_t and $V_{it} = 0$ are the values obtained by the worker and the firm, respectively, when the match is dissolved. These values are called the *outside options* of the wage bargaining.

In what follows, we consider three alternative types of negotiation over the real average wage: the Nash bargaining, the credible bargaining and the wage norm.

Nash bargaining

The Nash bargaining is traditionally applied by the search-and-matching literature to obtain the real wage. Here, the real average wage is determined by the Generalized Nash Solution (1953) with the outside options as threat points, i.e. U_t for the worker and $V_{it} = 0$ for the firm. The equilibrium wage satisfies the following surplus-sharing rule:

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

where ζ denotes the worker's bargaining power. Inserting for W_{it}, U_t and J_{it} and using equations (8) and (9) yields the following real average wage[11] in firm i:

$$w_{it}^{nb} = \zeta[mc_{it} A_t h_{it}^{\alpha-1} + \chi \frac{\theta_t}{h_{it}}] + (1-\zeta)[\frac{b}{h_{it}} + x_h \frac{h_{it}^{\eta}}{(1+\eta)u'(c_t)}] \tag{11}$$

The real marginal wage in this firm is:

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

Using equation (10), the real marginal wage can be rewritten as:

$$\omega_{it}^{nb} = x_h \frac{h_{it}^{\eta}}{u'(c_t)} \tag{12}$$

The real marginal wage of a given worker in firm i is thus equal to the worker's marginal rate of substitution between consumption and leisure. It is worth noting here that the marginal wage is independent from the worker's bargaining power. Instead, the average wage critically depends on ζ. Hence, modifying this parameter will have an impact on the relative cyclicality of the marginal and average wages.

[11] It is worth noting here that (11) is not a differential equation in the function $w_{it}(.)$. In order to have a differential equation, one would have to express $mc_{it} A_t h_{it}^{\alpha-1}$ in terms of $\omega_{it} = w_{it} + w'_{it}(h_{it})h_{it}$. However, the term $mc_{it} A_t h_{it}^{\alpha-1}$ reflects the fact that if a given worker z walked away from her job, the demand-constrained firm i 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 firm i, the first order condition $mc_{it} \alpha A_t h_{it}^{\alpha-1} = \omega_{it}$ for that worker would no longer apply. It would therefore be incorrect to replace $mc_{it} A_t h_{it}^{\alpha-1}$ by $\frac{\omega_{it}}{\alpha}$ in equation (11). 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 *no longer* depends on worker z's marginal wage, and then on her working hours. We would like to thank Carlos Thomas for showing us that mc_{it} is independent from h_{it} at the time of the wage bargaining, exactly as in Thomas (2011).

Credible bargaining

Hall and Milgrom (2008) and Christiano et al. (2016) argue that on a frictional labor market, the surplus of a match is such that both worker and firm get higher payoffs by going to the end of the wage bargaining rather than leaving the negotiation to search for another match. The threat to leave the wage bargaining is then not credible. This means that the outside options are not credible threat points. The only credible threat is to reject the other party's offer and continue negotiating in the following period.

In each period, worker and firm bargain over the real average wage to be paid in that period. If no wage agreement is reached, then no production takes place in that period. We assume that the worker enjoys the payoff b while the firm incurs the fixed cost γ. The wage bargaining resumes at the beginning of the next period. We follow Snower and Merkl (2006), Jimeno and Thomas (2013) and Balleer et al. (2015) by assuming that disagreement in the current period does not affect future returns. Those papers define the *disagreement value* for a given worker matched with firm i by:

$$\widetilde{W}_{it} = b + E_t\beta_{t,t+1}[(1-s)W_{it+1} + sU_{t+1}]$$

while the disagreement value for firm i matched with a given worker is defined by[12]:

$$\widetilde{J}_{it} = -\gamma + E_t\beta_{t,t+1}[(1-s)J_{it+1} + sV_{it+1}]$$

When the threat points are given by the disagreement values, the surplus of the worker is:

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

while the surplus of the firm is:

$$J_{it} - \widetilde{J}_{it} = mc_{it}A_t h_{it}^{\alpha} - w_{it}h_{it} + \gamma$$

We still assume that the real average wage is determined by the Generalized Nash Solution[13]. The equilibrium wage therefore satisfies the following surplus-sharing rule:

[12] Jung and Kuester (2011), Faia et al. (2014) and Kaplan and Menzio (2015) implicitly use the same definition for the disagreement values. In these papers, surpluses are directly expressed in flows. This means, for a negotiating party, that the value of a match and the threat point have the same continuation value terms that cancel each other out when writing the surplus. This happens when the threat points are the disagreement values defined by $\widetilde{W}_{it}$ and $\widetilde{J}_{it}$. In the words of Kaplan and Menzio (2015): "The assumption that, in case of disagreement, the firm and the worker do not lose contact with each other simplifies the analysis by making the wage only a function of current variables."

[13] Boitier and Lepetit (2016) provide an alternative, albeit more complicated, solution for the average wage under credible bargaining.

$$(1-\zeta)(W_{it}-\widetilde{W}_{it})=\zeta(J_{it}-\widetilde{J}_{it})$$

This yields the following real average wage in firm i:

$$w_{it}^{cb}=\zeta[mc_{it}A_t h_{it}^{\alpha-1}+\frac{\gamma}{h_{it}}]+(1-\zeta)[\frac{b}{h_{it}}+x_h\frac{h_{it}^{\eta}}{(1+\eta)u'(c_t)}] \tag{13}$$

The real marginal wage in this firm is:

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

Using equation (10), the real marginal wage can be rewritten as:

$$\omega_{it}^{cb}=x_h\frac{h_{it}^{\eta}}{u'(c_t)} \tag{14}$$

The real marginal wage for the credible bargaining is equal to the worker's marginal rate of substitution between consumption and leisure. Hence, the credible bargaining and the Nash bargaining share the same expression for the marginal wage. However, the average wage under credible bargaining is less pro-cyclical than the average wage under Nash bargaining. Indeed, the average wage for the credible bargaining is insulated from labor-market conditions: contrary to equation (11), neither unemployment nor vacancies appear in equation (13). The average wage resulting from the credible bargaining is therefore sticky with respect to labor-market fluctuations, which notably reflects that the disagreement values are independent from current period labor-market variables.

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"[14]. This norm can take many forms but the last period's average wage or a constant average wage are usually considered. Here we retain a constant wage (equal to the steady-state average wage) as a norm. The real average wage for a given worker in firm i is therefore:

$$\begin{aligned} w_{it}^{wn}&=\psi\bar{w}+(1-\psi)w_{it}^{nb}\\ &=\psi\bar{w}+(1-\psi)\left[\zeta[mc_{it}A_t h_{it}^{\alpha-1}+\chi\frac{\theta_t}{h_{it}}]+(1-\zeta)[\frac{b}{h_{it}}+x_h\frac{h_{it}^{\eta}}{(1+\eta)u'(c_t)}]\right] \end{aligned} \tag{15}$$

[14]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.

where $\psi \in [0,1]$ measures the degree of rigidity of the real average wage. The real marginal wage in this firm is:

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

Using equation (10), the real marginal wage can be rewritten as:

$$\omega_{it}^{wn} = \frac{\psi\bar{w} + (1-\psi)(1-\zeta)x_h \frac{h_{it}^{\eta}}{u'(c_t)}}{1-(1-\psi)\zeta} \tag{16}$$

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 $\psi = 0$, the marginal wage corresponds to the marginal wage under Nash bargaining and credible bargaining. With $\psi = 1$, the marginal wage is fixed and equal to the steady-state average wage. Moreover, an increase in ψ will reduce the cyclicality of both the marginal and average wages.

2.3.3 Vacancy posting

The standard job-creation condition is obtained by merging equations (8) and (9). Moreover, replacing mc_{it} by its expression given by equation (10), we have:

$$\frac{\chi}{q(\theta_t)} = E_t\beta_{t,t+1}[(\frac{\omega_{it+1}}{\alpha} - w_{it+1})h_{it+1} + (1-s)\frac{\chi}{q(\theta_{t+1})}] \tag{17}$$

Equation (17) can be rewritten as:

$$\frac{\chi}{q(\theta_t)} + E_t\beta_{t,t+1}[w_{it+1}h_{it+1}] = E_t\beta_{t,t+1}[\frac{\omega_{it+1}}{\alpha}h_{it+1} + (1-s)\frac{\chi}{q(\theta_{t+1})}] \tag{18}$$

The left-hand side of equation (18) gives the cost associated with hiring an additional worker, which includes both wage income and vacancy posting costs. The right-hand side gives the benefit of hiring an additional worker. This benefit includes the discounted savings in the future costs of using hours per employee associated with having one additional worker in place, and the discounted savings in the future vacancy posting costs. The contribution of an additional worker to the firm's flow profit is therefore given by the marginal reduction in the wage bill, which is equal to $\frac{\omega_{it+1}}{\alpha}h_{it+1}$.

2.3.4 Price setting and inflation dynamics

From equations (10), (12), (14) and (16), the real marginal cost for each wage specification is:

$$mc_{it}^{cb} = x_h \frac{h_{it}^{\eta}}{u'(c_t)A_t} \tag{19}$$

$$mc_{it}^{nb} = x_h \frac{h_{it}^{\eta}}{u'(c_t)A_t} \tag{20}$$

$$mc_{it}^{wn} = \frac{\psi\bar{w} + (1-\psi)(1-\zeta)x_h \frac{h_{it}^{\eta}}{u'(c_t)}}{(1-(1-\alpha)\zeta)A_t} \tag{21}$$

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 bargains. The real marginal cost is given by the ratio between the marginal rate of substitution between consumption and leisure and the marginal product of labour. Second, since $\psi \in [0,1]$, mc_{it}^{wn} is less pro-cyclical than mc_{it}^{cb} and mc_{it}^{nb}. This stems from ω_{it}^{wn} which is less flexible with respect to hours per worker than ω_{it}^{cb} and ω_{it}^{nb}.

In a technical appendix[15], we show that these different marginal cost schedules imply different slopes for the New-Keynesian Phillips Curve (NKPC). Since the Nash bargaining and the credible bargaining generate the same real marginal cost expression, we focus our attention on the Nash bargaining on the one hand, and the wage norm on the other. The results for the Nash bargaining[16], in this subsection, therefore convey to the credible bargaining. The NKPC for the Nash bargaining and the wage norm are given by:

$$\pi_t^{nb} = \beta E_t \pi_{t+1} + \kappa^{nb}\widehat{mc}_t^{nb} \tag{22}$$

$$\pi_t^{wn} = \beta E_t \pi_{t+1} + \kappa^{wn}\widehat{mc}_t^{wn} \tag{23}$$

where "hats" denote log-deviations of a variable around its steady-state value. κ^{nb} and κ^{wn} read as follows:

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

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

[15] Available upon request to the author

[16] The derivation of the NKPC for the Nash bargaining follows Thomas (2011), as does the discussion of how strategic complementarities affect its slope.

with ϕ^{nb} and ϕ^{wn} given by:

$$\phi^{nb} = \frac{1}{\alpha}[\eta\epsilon - \delta\beta\eta\tau^n_{nb}]$$

$$\phi^{wn} = \frac{1}{\alpha}[D\eta\epsilon - D\delta\beta\eta\tau^n_{wn}]$$

with ϵ the elasticity of substitution between differentiated goods. The expression and the derivation for τ^n_{nb} and τ^n_{wn} are provided in the technical appendix. The parameter D is given by:

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

The parameters ϕ^{nb} and ϕ^{wn} have two components each: $\eta\epsilon$ and $\delta\beta\eta\tau^{nb}$ for ϕ^{nb}; $D\eta\epsilon$ and $D\delta\beta\eta\tau^{wn}$ for ϕ^{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. These complementarities dampen the price level adjustment in response to real marginal cost movements. To understand this point, take a price-setter which 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 ϵ. 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 per employee, which is all the more important as η 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 these prices by a little amount.

Crucially, as $D \leq 1$, the degree of strategic complementarities is higher for the Nash bargaining than for the wage norm. Indeed, for the Nash bargaining, an additional hour per worker increases the real marginal cost by an elasticity η, 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. An additional hour per worker thus increases the real marginal cost only by an elasticity $D\eta$.

The terms $\delta\beta\eta\tau^{nb}$ 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[17]. Thomas

[17]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. Again, this effect is stronger for the Nash bargaining: since the real marginal cost is more flexible for the Nash

(2011) demonstrates that $\eta\epsilon > \delta\beta\eta\tau^{nb}$ while we show in the technical appendix that $D\eta\epsilon > D\delta\beta\eta\tau^{wn}$. This means that the latter effect is dominated by the strategic complementarities effect, for both the Nash bargaining and the wage norm. Both ϕ^{nb} and ϕ^{wn} are therefore positive. Furthermore, we also show that $\phi^{nb} \geq \phi^{wn}$. This implies that the NKPC resulting from the Nash bargaining is flatter than the NKPC resulting from the wage norm: for the Nash bargaining, fluctuations in real marginal costs are turned into inflation by a lower extent. 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:

$$y_t = c_t + \chi v_t \tag{24}$$

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

$$y_t = A_t n_t h_t^{\alpha} \tag{25}$$

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:

$$i_t = \rho_i i_{t-1} + (1 - \rho_i)(\rho + \varphi_\pi \pi_t + \varphi_y \Delta y_t) + e_t^m \tag{26}$$

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

bargaining, the anticipation of even lower real marginal costs in the future leads the firm to reduce its price even more.

3 The Joint Dynamics of the Labor Market and Inflation

3.1 Calibration

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

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

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

Technology, preferences and price rigidities. Time is measured in months. We set $\alpha = 0.99$, implying only mildly decreasing returns to hours worked per worker. We select standard values for the discount factor $\beta = 0.99^{1/3}$ (corresponding to an annual interest rate equal of 4%) as well as for the inter-temporal 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. We choose a standard average duration for a price contract of approximately a year, which entails $\delta = 1 - \frac{1}{12}$. The monopolistic markup is set to a conventional level of 20%, implying an elasticity of substitution between differentiated goods ϵ equal to 6. Given the values of α, β, η, ϵ and δ, we obtain $\phi^{nb} = 1.55$ and then $\kappa^{nb} = 0.0028$ for both the Nash bargaining and the credible bargaining. At the same time, we have $\phi^{wn} = 0.72$ and $\kappa^{wn} = 0.0042$ for the wage norm. Therefore, the slope of the NKPC for the Nash bargaining and the credible bargaining is flatter than the slope of the NKPC for the wage norm.

Labor-market. From Shimer (2005), we set the separation rate s at 0.03. We target a steady-state unemployment rate of 0.06 (which is the average rate of our sample) and a probability of finding a worker of 0.33 (which corresponds to the quarterly probability of 0.70 found by Den Haan and al. (2000)). The efficiency parameter of the matching function m_0 is set to match these 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). In accordance with the figure found by Silva and Toledo (2009), the value of the vacancy posting cost χ is chosen so as to represents 10% of the monthly real wage income at the steady state, which entails $\chi = 0.082$. We let b adjusts to solve the job-creation condition at the steady state. We obtain $b = 0.425$, which is very close to the value of 0.4 often used in the literature. The worker's bargaining power ζ is chosen at 0.5, a common practice that implies a symmetric bargaining. The value of the fixed cost incurred by employers under credible bargaining, $\gamma = 0.117$, is chosen so as to induce the

same steady-state average wage as we get for the Nash bargaining[18]. Finally, the partial adjustment coefficient ψ of the wage norm is set to 0.4, the value that allows to reproduce the empirical volatility of the real average wage. Note that at the steady state, the average wage for the wage norm is always equal to the average wage for the Nash bargaining, whatever the value of ψ. Overall, our calibration strategy implies the same steady-state values for all the wage bargains considered.
For the Nash bargaining, we will also consider a lower value for ζ, namely $\zeta = 0.12$, which enables this wage bargain to replicate the empirical volatility of the real average wage. As we did for the symmetric bargaining case, we let b adjusts to solve the job-creation condition at the steady state, which entails $b = 0.532$. Note that the sum of the flow value of unemployment and the marginal disutility of working, $b + x_h \frac{h^{1+\eta}}{(1+\eta)u'(c)}$, equals 0.80 at the steady state. This is just above the value of 0.73 found by Mortensen and Nagypál (2007). Most importantly, this alternative calibration for ζ and b leaves the steady state unchanged. Hence, the results obtained are by no means related to a modified surplus for firms. Therefore, even if this calibration is close in spirit to the one retained by Hagedorn and Manovskii (2008), it does not involve a small steady-state profit.

Monetary policy and shocks. We set standard values for the parameters of the Taylor rule: $\varphi_\pi = 1.5$, $\varphi_y = 0.5/12$ and $\rho_i = 0.7^{1/3}$. We select the standard deviation of the interest rate shock, $\sigma_m = 0.058\%$, from Walsh (2005)[19]. 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 auto-correlation coefficient ρ_a set at the usual value of $0.95^{1/3}$. The standard deviation of the productivity shock, for each wage bargain, is chosen to replicate the standard deviation of real output in the data.

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

[18] This value for γ is in fact equal to $\chi\theta$, since at the steady state the average wage for the credible bargaining is equal to the average wage for the Nash bargaining only if $\gamma = \chi\theta$.

[19] Walsh (2005) finds a quarterly standard deviation for this shock equal to 0.2%. Given $\rho_i = 0.7^{1/3}$, the corresponding monthly value is 0.058%.

Table 1: Parameters

Parameter	Definition	Value
β	Discount factor	$0.99^{1/3}$
σ	Inter-temporal elasticity of substitution	1
η	Convexity of labor disutility	2
x_h	Scaling factor to disutility of work	0.884
δ	Fraction of unchanged prices	0.92
ϵ	Elasticity of demand curves	6
κ^{nb}	Slope NKPC, Nash bargaining	0.0028
κ^{wn}	Slope NKPC, wage norm	0.0042
s	Separation rate	0.03
ς	Elasticity matching fct wrt vacancies	0.6
m_o	Efficiency parameter of the matching fct	0.38
χ	Vacancy posting cost	0.082
ζ	Worker's bargaining power	0.5
b	Flow value of unemployment	0.425
γ	Fixed cost for employers, credible bargaining	0.117
ψ	Partial adjustment coefficient, wage norm	0.4
ρ_a	AC of productivity shock	$0.95^{1/3}$
φ_π	Response to inflation in the Taylor rule	1.5
φ_y	Response to output gap in the Taylor rule	0.5/12
ρ_i	Interest rate smoothing	$0.7^{1/3}$

Table 2: Steady state

Variable	Definition	Value
y	Real output	0.94
c	Consumption	0.933
h	Hours per worker	1
n	Employment	0.94
u	Unemployment rate	0.06
v	Vacancy rate	0.085
w	Real average wage	0.825
ω	Real marginal wage	1/1.2
mc	Real marginal cost	1/1.2

3.2 Quantitative analysis

Table 3: Labor-market volatility and inflation inertia

	Data	**Nash**	**Nash**	**Credible**	**Wage Norm**
		$\zeta = 0.5$	$\zeta = 0.12$		
$\sigma(y_t), \%$	1.56	1.56	1.57	1.55	1.56
$\sigma(u_t)/\sigma(y_t)$	8.48	2.61	7.04	8.83	3.46
$\sigma(v_t)/\sigma(y_t)$	9.11	3.05	7.85	9.43	3.69
$\sigma(\theta_t)/\sigma(y_t)$	17.22	4.97	13.28	16.50	6.47
$\sigma(h_t)/\sigma(y_t)$	0.34	0.38	0.33	0.36	0.36
$\sigma(h_t)/\sigma(n_t)$	0.49	2.27	0.72	0.64	1.63
$\sigma(w_t)/\sigma(y_t)$	0.60	1.21	0.61	0.65	0.58
$\epsilon(\omega_t)$	[1.84 - 3.24]	3.21	2.87	3.27	1.84
$\epsilon(\frac{\omega_t}{w_t})$	1.40	0.32	1.14	1.63	0.40
$\sigma(\pi_t)/\sigma(y_t)$	0.18	0.10	0.08	0.08	0.09
$\rho(\pi_t, \pi_{t-1})$	0.42	0.67	0.70	0.71	0.70

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[20]. On the labor-market side, two stylized facts are summarized. First, the unemployment rate (second row) is highly volatile, as compared to real output. Second, the volatility of hours per worker is less than half the volatility of employment (sixth row), which means that firms adjust labor mainly through the extensive margin. On the inflation side, the fluctuations of the inflation rate are weakly volatile but persistent: there is some inflation inertia[21].

Labor-market dynamics. Table 3 makes clear that the Nash bargaining with low worker's bargaining power ($\zeta = 0.12$) and the credible bargaining replicate the high unemployment volatility, as well as the relative adjustment between the intensive and extensive

[20]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 (2010) (available on Barnichon's website). We use quarterly, seasonally adjusted data on real GDP (in billions of chained 2009 dollars), civilian unemployment rates, civilian employment, the 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).

[21]In order to calculate model moments, we follow Thomas (2011). We simulate 816 months of artificial data and take quarterly averages. We discard the first 30 observations so as to eliminate the effects of initial conditions. We are therefore left with 242 observations, which corresponds to the sample size. We next calculate the relevant second moments. We repeat this operation 200 times and finally take averages for each vector of moments.

labor margins. Conversely, the symmetric Nash bargaining ($\zeta = 0.5$) and the wage norm produce only small fluctuations for the unemployment rate, with a higher volatility for hours per worker than for employment.

The *relative* cyclicality of the marginal and average wages is critical to understand these results. We can observe from the seventh row of table 3 that the average wage is weakly pro-cyclical for both the Nash bargaining with low ζ and the credible bargaining: in each case, the average wage is made insulated from labor-market fluctuations. However, the marginal wage is sharply pro-cyclical for these two wage bargains. This sharp pro-cyclical pattern for the marginal wage is illustrated by the eight row of Table 3, which displays the elasticity of ω_t with respect to hours per employee, $\epsilon(\omega_t)$[22]. This elasticity is high for both wage bargains, which share the same expression for the marginal wage schedule (given by the marginal rate of substitution between consumption and leisure). Hence, the cyclical behavior of the marginal and average wages implies that the ratio of these two wages - $\frac{\omega_t}{w_t}$ - is strongly pro-cyclical for the Nash bargaining with low ζ and for the credible bargaining. This is reflected in the ninth row of Table 3, where the elasticity[23] of this ratio with respect to hours per worker - $\epsilon(\frac{\omega_t}{w_t})$ - is high and close to the one found by Rotemberg and Woodford (1999) from the figures in Bils (1987).

In order to stress the importance of a marginal wage much more pro-cyclical than the average wage, let us assume that the economy is hit by a positive productivity shock. Firms increase production by raising total working hours. Hiring an additional worker that will work h_t hours in period t comes at a flow cost equal to $w_t h_t$ for a firm[24]. On the other hand, hiring h_t additional hours of existing employees in this firm comes at a cost $\omega_t h_t$. The relative adjustment between the two margins therefore depends on the ratio $\frac{\omega_t}{w_t}$. At the same time, the contribution of an additional worker to current profits is equal to $\frac{\omega_t}{\alpha} h_t$. The value of this worker for the firm thus increases with $\frac{\omega_t}{w_t}$. The high increase in $\frac{\omega_t}{w_t}$ generated by the Nash bargaining with low ζ and by the credible bargaining implies that the cost of hiring additional hours of existing employees increases relatively more than the cost of raising total hours by hiring an additional worker. This leads firms to adjust labor mainly through employment. Moreover, the large increase in $\frac{\omega_t}{w_t}$ means that the value of an additional worker surges since this worker allows to save extra hours whose price, ω_t, increases more than the price of her own hours of work, w_t. This amplifies the incentive to

[22]For the simulated model, we approximate this elasticity by $\frac{\sigma(\omega_t)}{\sigma(h_t)}$. The empirical value for this elasticity comes from Bils (1987). 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 ω_t by 4.6%. This implies $\epsilon(\omega_t) = 1.84$. 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 ω_t by 6.6%, which implies $\epsilon(\omega_t) = 2.64$. Using instrumental variables, the increase in ω_t is 8.1%, which implies $\epsilon(\omega_t) = 3.24$.

[23]For the simulated model, this elasticity is approximated by $\frac{\sigma(\frac{\omega_t}{w_t})}{\sigma(h_t)}$.

[24]Of course, hiring an additional worker also involves to pay vacancy posting costs, χ. The real wage income $w_t h_t$ is then the *flow* cost of adjusting total hours through the extensive margin.

create jobs and then produces a substantial fall in unemployment.

Conversely, the symmetric Nash bargaining and the wage norm display only a weakly pro-cyclical $\frac{\omega_t}{w_t}$, with an elasticity of this ratio far below the empirical one. This stems from the fact that both the marginal and average wages are highly pro-cyclical for the symmetric Nash bargaining, while both of these wages are moderately pro-cyclical for the wage norm. The weak pro-cyclical pattern of $\frac{\omega_t}{w_t}$ explains why these wage bargains fail to reproduce labor-market dynamics. Furthermore, it is interesting to compare the wage norm with the Nash bargaining with low ζ. Indeed, both wage bargains are calibrated so as to replicate the empirical volatility of the average wage, $\frac{\sigma(w_t)}{\sigma(y_t)}$. The Nash bargaining with low ζ nevertheless replicates labor-market facts, in sharp contrast with the wage norm. The only difference between the two wage bargains lies in the cyclical behavior of the marginal wage: the eight row of Table 3 makes clear that the marginal wage resulting from the Nash bargaining with low ζ is much more pro-cyclical than the marginal wage resulting from the wage norm.

In the Appendix, we consider an alternative framework, namely the Right-To-Manage. In this latter, the marginal wage is by construction always equal to the average wage. Therefore, $\frac{\omega_t}{w_t}$ is a-cyclical and its elasticity with respect to hours per employee is nil. We show that the dynamics of the labor market resulting from the Right-To-Manage is completely at odds with the data, whatever the wage bargain. This stems from the a-cyclical behavior of $\frac{\omega_t}{w_t}$.

Hence, models for which firms unilaterally adjust both margins of labor are able to replicate the dynamics of employment and hours per worker, once they embed a wage bargain generating a much higher pro-cyclicality for the marginal wage than for the average wage. A main conclusion that can be drawn from this sub-section is that what matters for labor-market dynamics is not the cyclicality of wages *per se*, but the cyclicality of the marginal wage *with respect to* that of the average wage.

Inflation inertia. From the two last rows of Table 3, we can see that every wage bargain generates inflation inertia. The wage norm through small variations in the marginal wage. The other wage bargains through strong strategic complementarities, themselves resulting from large movements in the marginal wage.

The impact of marginal wage variations on the dynamics of inflation operates through two different effects. The first effect is direct: for a given slope of the NKPC, fluctuations in the marginal wage implies fluctuations in marginal cost and therefore inflation movements. Moreover, the magnitude of this effect is positively related to the size of the variations in the marginal wage: the higher these variations, the larger the responses of inflation. At the same time, there is an indirect effect operating through the slope of the NKPC. This second effect is related to the presence of strategic complementarities. After a positive productivity shock, a firm which considers a fall in its price will have to raise hours per employee to satisfy the resulting additional demand. The increase in the marginal wage that will ensue finally leads this firm to choose a smaller price reduction, which flattens the NKPC. Furthermore, the amount of strategic complementarities positively depends on the size of the marginal wage fluctuations: in our example, the larger the increase in the marginal wage in response to the rise in hours per worker, the smaller the price reduction finally chosen and the flatter the NKPC.

The eight row of Table 3 shows that the marginal wage is sharply pro-cyclical for the Nash bargaining (with symmetric and low ζ) and for the credible bargaining, which entails a large direct effect on inflation dynamics. At the same time, strong strategic complementarities, and then a very flat NKPC, result from this cyclical pattern of the marginal wage. The ability of these wage bargains to produce inflation inertia therefore means that the indirect effect dominates the direct one: the sharp pro-cyclicality of the marginal wage results in large movements along a very flat NKPC. Alternatively, the marginal wage is less pro-cyclical for the wage norm, which implies a lower direct effect on inflation dynamics. But this also implies a lower amount of strategic complementarities, and then a steeper NKPC. Here, inflation inertia is produced by smaller movements of the marginal wage along a steeper NKPC.

4 Conclusion

We have argued that the relative cyclicality of short-run marginal and average costs is a key mechanism to allow models where firms adjust labor along both margins to reproduce labor-market dynamics. We have considered a New-Keynesian model with labor-market matching frictions in which firms set employment, hours per worker and prices. Within this framework, we have shown that the wage bargains which generate a pro-cyclicality of marginal cost much higher than that of average cost, in accordance with the empirical evidence, replicate the large fluctuations in the unemployment rate, as well as the relative adjustment between the intensive and extensive labor margins of post-war US data. Moreover, in spite of the large pro-cyclicality of marginal cost, these wage bargains deliver inflation inertia.

A larger pro-cyclicality for marginal cost than for average cost implies that the cost of additional hours per employee fluctuates relatively more than the flow cost of an additional worker in response to shocks, which leads firms to adjust labor mainly through employment. This also implies that the value of an additional worker is sharply pro-cyclical, thus magnifying the incentive to adjust employment. At the same time, the high pro-cyclicality of marginal cost induces strong strategic complementarities between price setters, which provide inflation inertia through a flat NKPC.

Appendix

Recall that in the framework we have exposed in Section 2 and assessed in Section 3, firms are assumed to choose hours per worker *before* the wage negotiation occurs, taking rationally into account that a marginal change in hours per employee will imply a change in the bargained average wage. Hence, the marginal and average wages are not equal and can display different cyclical pattern. In the Right-To-Manage framework, initially developed by Trigari (2006), firms are instead assumed to choose hours per worker *after* the average wage was negotiated. Firms can therefore hire each additional hour per employee at the current average wage. The first-order condition with respect to hours per worker for firm i becomes:

$$mc_{it}\alpha A_t h_{it}^{\alpha-1} = w_{it} \tag{27}$$

instead of equation (7). Thus, we have $\omega_{it} = w_{it}\ \ \forall t$, which means that the marginal wage, and then marginal cost, is driven by the average wage. Within this set-up, we implement the three wage bargains described in Section 2. So as to ease this implementation, we assume that the expression of the average wage for each of these wage bargains is the same as in Section 2[25]. The real average wage, and then the real marginal wage, is consequently given by equation (11) for the Nash bargaining, by equation (13) for the credible bargaining and by equation (15) for the wage norm.

Table 4: Labor-market volatility and inflation inertia / Right-To-Manage

	Data	**Nash**	**Nash**	**Credible**	**Wage Norm**
		$\zeta = 0.5$	$\zeta = 0.12$		
$\sigma(y_t), \%$	1.56	1.56	1.56	1.54	1.58
$\sigma(u_t)/\sigma(y_t)$	8.48	1.24	1.24	1.24	1.21
$\sigma(v_t)/\sigma(y_t)$	9.11	1.27	1.27	1.28	1.25
$\sigma(\theta_t)/\sigma(y_t)$	17.22	2.31	2.30	2.30	2.25
$\sigma(h_t)/\sigma(y_t)$	0.34	0.40	0.57	0.60	0.62
$\sigma(h_t)/\sigma(n_t)$	0.49	5.30	7.20	7.61	8.01
$\sigma(w_t)/\sigma(y_t)$	0.60	0.98	0.38	0.34	0.28
$\epsilon(\omega_t)$	[1.84 - 3.24]	2.45	0.67	0.57	0.46
$\epsilon(\frac{\omega_t}{w_t})$	1.40	0	0	0	0
$\sigma(\pi_t)/\sigma(y_t)$	0.18	0.09	0.08	0.08	0.08
$\rho(\pi_t, \pi_{t-1})$	0.42	0.73	0.72	0.72	0.75

[25]For the Right-To-Manage, this assumption means that firms and workers bargain over the average wage taking as given subsequent hiring decisions. Such an assumption is notably made by Moene and Wallerstein (1997) and Jimeno and Thomas (2013) when the wage bargaining takes place at the sector level. Note that this simplifying assumption has no significant impact on our results.

The Right-To-Manage fails to reproduce labor-market dynamics, whatever the wage bargain. Even for the Nash bargaining with low ζ and the credible bargaining (which, within the framework exposed in Section 2, replicate very well labor-market fluctuations) the results are at odds with the data. This is consistent with the argument advanced throughout this paper: when firms determine both employment and hours per worker, it is required that the marginal wage be much more pro-cyclical than the average wage. The fact that these two wages display exactly the same pro-cyclicality explains why the results obtained with the Right-to-Manage are poor.

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