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## Do Search Frictions Matter for Inflation Dynamics?

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**Do Search Frictions Matter for Inflation  
Dynamics?**

**by**

**Michael U. Krause, David J. Lopez-Salido and Thomas Lubik**

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# Do Search Frictions Matter for Inflation Dynamics?\*

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Preliminary and incomplete

## Abstract

We assess the empirical relevance for inflation dynamics of accounting for the presence of search frictions in the labor market. The New Keynesian Phillips curve explains inflation dynamics as being mainly driven by current and expected future marginal costs. Recent empirical research has emphasized different measures of real marginal costs to be consistent with observed inflation persistence. We argue that, allowing for search frictions in the labor market, real marginal cost should also incorporate the cost of generating and maintaining long-term employment relationships, along with conventional measures, such as real unit labor costs. In order to construct a synthetic measure of real marginal costs, we use newly available labor market data on worker finding and separation rates that reflect firing and hiring costs to the firm. We then estimate a New Keynesian Phillips curve using structural econometric techniques.

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# 1 Introduction

The New Keynesian Phillips curve is at the heart of modern macroeconomic models that are used in the discussion and formulation of monetary policy. It is theoretically appealing in that it can be derived from first principles in form of an individual, forward-looking firm's price setting decision. Yet, at the same time, it preserves some of the flavor of more traditional Phillips-curve modeling. Empirical investigation of the NKPC faces two difficulties, however. First, the assumption of forward-looking expectation formation and the endogeneity of inflation and marginal cost render standard regression techniques problematic. Second, marginal cost as the explanatory variable for inflation dynamics is not readily observable to the econometrician. While marginal costs can be linked to observables, such as output, via the production function, these attempts have not proven to be entirely successful (Fuhrer and Moore, 1995, Roberts 1995, 1997).

In their seminal paper, Galí and Gertler (1999) address these issues by estimating the structural parameters of the NKPC using methods of moments techniques. Using unit labor costs as a proxy for marginal costs they show that it outperforms output and other activity measures in explaining inflation. Moreover, they find that any lagged inflation terms that capture persistence are small, yet significant, but quantitatively unimportant. The key to this result is that marginal costs are sluggish enough to explain the persistence in inflation and exhibit the 'right' degree of comovement. In this single-equation setting, however, the determinants of marginal costs are left unexplained.

We assess the empirical relevance for inflation dynamics of accounting for the presence of search frictions in the labor market. To this end we use the benchmark new Keynesian model with search frictions as in Krause and Lubik (2007).<sup>1</sup> We obtain an expression for real marginal costs that depends on the labor share plus terms that reflect hiring and firing costs. We then use newly available labor market data on worker job finding and separation rates, which are directly related to hiring and firing. This allows us to generate a synthetic time series for real marginal costs, which we then use to estimate the parameters of the new Keynesian Phillips curve. We argue that this measure is preferable to the labor share because it explicitly takes labor market conditions into account. By virtue of vacancies posted, it also incorporates forward looking considerations of firms into the relevant cost measure of

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<sup>1</sup>The model is closely related to Trigari (2006).

firms. These would be missing from measures that only incorporated wages and/or the unemployment rate.

We find that search frictions do indeed matter for inflation dynamics, in that they tend to reduce the role of backward-looking price setting for generating persistence, and by changing the sensitivity of inflation to real marginal costs. But it turns out that the synthetic measure of real marginal costs is fairly closely related to the labor share. We also assess alternative formulations of the labor market, including the variations of Blanchard and Gali (2006) and Rotemberg (2006), who change the timing assumption of the benchmark model to avoid considering endogenous separations. While the estimates suggest similar effects on the role of backward- and forward-looking inflation, the sensitivity of inflation to real marginal costs depends on specific calibrations.

It may appear surprising that the incorporation of labor market information does not make a strong difference to the coefficients of the hybrid New Keynesian Phillips curve. However, it is well known that the benchmark search and matching model of Mortensen and Pissarides (1994) does not explain the dynamics of vacancies and unemployment very well. This is intricately linked with the way wages and labor market tightness, the vacancy-unemployment ratio, interact. Different behavior of wages or differences in how labor market tightness reflects hiring costs may substantially change the dynamics of the model, especially through their effect on real marginal costs. Examples are real wage rigidities in combination with different matching functions or hiring costs.<sup>2</sup> Thus our results do not prove labor market frictions to be irrelevant for inflation dynamics. But more is required than the simple search and matching model to improve our understanding of inflation dynamics. Also, our procedure does not make use of the cross-equation restrictions that arise in general equilibrium, which puts additional constraints on the joint dynamics of the marginal costs components.<sup>3</sup>

The next section derives the measure of real marginal costs that arises in the presence of search frictions. The basis is a new Keynesian model with a general description of a frictional labor market. We also show special cases which have recently been presented in the literature, such as Blanchard and Gali (2006) and Rotemberg (2006), which make particular assumption on the timing of decisions, the endogeneity

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<sup>2</sup>For example, see Krause and Lubik (2007), Christoffel and Linzert (2006), and Gertler and Trigari (2006) for the former, and Gertler and Trigari (2006), Rotemberg (2006) and Blanchard and Gali (2006) for the latter. Another factor that may labor adjustment is firing cost, as shown in Zanetti (2005).

<sup>3</sup>See Trigari (2005) for a model with habit formation where search frictions influence inflation dynamics.

of separations, and hiring costs. Then, in section 3, we construct a time series of real marginal costs, using the flows data on separations, hiring, and vacancies. Section 4 estimates a new Keynesian Phillips curve using the synthetic measure of real marginal costs. Section 5 concludes.

## 2 Marginal Costs with Search Frictions

We begin by deriving an expression for a firm's marginal cost in the presence of search frictions in the labor market. Our benchmark setup closely follows Krause and Lubik (2007), which includes large firms that simultaneously decide on pricing and employment subject to adjustment costs, and have both endogenous hiring and firing margins available for employment adjustment. A matching function governs the flows from unemployment to employment.

### 2.1 Employment and Pricing Decisions

We assume that there is a continuum of firms of measure one. Each firm is a monopolistic competitor and produces a differentiated good. Let  $P_{it}$  and  $Y_{it}$  denote nominal price and output for firm  $i$ , and  $P_t$  and  $Y_t$  be the corresponding aggregate values. A firm's output is sold in a monopolistically competitive market with demand, derived from consumer preferences, given by:

$$Y_{it} = \left( \frac{P_{it}}{P_t} \right)^{-\epsilon} Y_t, \quad (1)$$

where  $Y_t = \left( \int_0^1 Y_{it}^{(\epsilon-1)/\epsilon} di \right)^{\epsilon/(\epsilon-1)}$ . The parameter  $\epsilon > 1$  represents the elasticity of substitution between differentiated products. Accordingly,  $P_t = \left( \int_0^1 P_t(j)^{1-\epsilon} dj \right)^{\frac{1}{1-\epsilon}}$  is the consumption-based, aggregate price index. Finally, a firm produces its differentiated good using  $N_{it}$  workers according to the following technology:<sup>4</sup>

$$Y_{it} = A_t N_{it}^\alpha, \quad (2)$$

where  $A_t$  is an aggregate productivity shocks, and  $0 < \alpha < 1$ .

During period  $t$ , the firm sets its nominal price  $P_{it}$ , subject to the requirement that it satisfy demand at that price. Following Rotemberg (1982), the firm faces a

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<sup>4</sup>For the purpose of this paper, we abstract from capital accumulation since it does not alter the expression of the marginal costs. See Rotemberg and Woodford (1999).

quadratic cost of adjusting its nominal price between periods, measured in terms of aggregate output and given by

$$\mathcal{P}_{it} = \frac{\psi}{2} \left( \frac{1}{\tilde{\pi}_{t-1}} \frac{P_{it}}{P_{it-1}} - 1 \right)^2 Y_t, \quad (3)$$

with  $\psi > 0$  controlling the importance of the price adjustment costs, and  $\tilde{\pi}_{t-1} = \pi_{t-1}^\gamma \pi^{1-\gamma}$ ; the parameter  $0 < \gamma < 1$  governs the degree of backward-lookingness of the price setting, and finally  $\pi$  represents steady-state inflation.<sup>5</sup> This cost function penalizes deviations of the firms price change from an average between past aggregate inflation  $\pi_{t-1}$  and steady-state inflation,  $\pi$ . When, in particular,  $\gamma = 0$ , then price setting is purely forward-looking, in the sense that it is costless for firms to increase their prices in line with steady-state inflation. When, on the other hand,  $\gamma = 1$ , price setting is purely backward-looking, in the sense that it is costless for firms to increase their prices in line with the previous period's actual rate of inflation. Interestingly, this formulation yields a Phillips curve analogous to the one deriving from Calvo-price setting with backward-looking firms, as in Galí and Gertler (1999); or with backward indexation, as in Christiano, Eichenbaum and Evans (2005).

The labor market is subject to search frictions. To form new employment relationships, workers must search and firms must post vacancies. In line with the literature, we assume that the total number of new matches  $M_t$  is produced by the aggregate matching function:

$$M_t = m U_t^\mu V_t^{1-\mu}, \quad (4)$$

which gives the number of new employment relationships available at the beginning of period  $t+1$ . In the previous expression,  $U_t$  represents the size of the unemployment pool (the measure of non-employed who search),  $V_t$  is the total number of vacancies posted (search activity of firms); the constant  $m > 0$  is match efficiency, and  $0 < \mu < 1$  is the elasticity of the matching function with respect to unemployment. This function is homogeneous of degree one, increasing in each of its arguments, concave, and continuously differentiable. Homogeneity implies that a vacancy gets filled with probability  $q(\theta) = \frac{M(U,V)}{V} = M(1, \frac{1}{\theta}) = m\theta^{-\mu}$ , which is decreasing in the degree of labor market *tightness*  $\theta \equiv V/U$ . Analogously, an unemployed worker finds a job with probability  $p(\theta) = \frac{M(U,V)}{U} \equiv \theta q(\theta)$ , which is increasing in  $\theta$ .<sup>6</sup> We assume that

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<sup>5</sup>See Ireland (2006). As Ireland shows, steady state inflation is identical to the monetary authority's inflation target.

<sup>6</sup>Instead of (4) we could have used:  $M_t = \frac{U_t V_t}{[(U_t)^\eta + (V_t)^\eta]^{\frac{1}{\eta}}}$ , as in den Haan et al. (2000). Although,



the new matches going to a firm are proportionate to the ratio of its vacancies to total vacancies,  $V_{it}/V_t$ , so that  $V_{it}M_t/V_t = V_{it}q(\theta)$  is hiring by firm  $i$ .

The evolution of employment at firm  $i$  can be written as:

$$N_{it} = (1 - \rho_{it}) [N_{it-1} + V_{it-1}q(\theta_{t-1})], \quad (5)$$

where  $\rho_{it}$  is the endogenous separation rate of existing employment relationships, which includes previous employees and the number of new hires.<sup>7</sup> Firms incur two types of (real) costs when adjusting employment. First, a fraction  $\rho$  of jobs is destroyed unless successfully upgraded at a convex cost  $g(a_{it})$ , where  $a_{it}$  is the chosen reduction in separations. The endogenous job destruction, or separation, rate is  $\rho_{it} = \rho(1 - a_{it})$ . This formulation is in the spirit of vintage models, where jobs can be upgraded to the newest available technology (see Michelacci and Lopez-Salido (2007)). In the aggregate,  $1 - U_t = N_t = \int_0^1 N_{it}di$ , and  $V_t = \int_0^1 V_{it}di$ .

Second, in order for a firm to post vacancies  $V_{it}$ , it has to pay a concave flow cost  $c(V_{it})$ . Allowing for  $c'' < 0$  follows Rotemberg (2006) and departs from the standard search and matching model where cost of recruiting are assumed to be linear (Pissarides, 2000). As emphasized by Rotemberg (2006), if this cost is interpreted as the cost of advertising openings in an information source it can easily be subject to economies of scale at the firm level.<sup>8</sup> Thus, total labor adjustment costs are given by the following expression:

$$\mathcal{N}_{it} = c(V_{it}) + g(a_{it})\rho [N_{it-1} + V_{it-1}q(\theta_{t-1})], \quad (6)$$

Finally, the total hirings in period  $t$  depend on last period's search in the labor market and the probability that the match survives, i.e.  $h_{it} = (1 - \rho(1 - a_{it}))\theta_{t-1}q(\theta_{t-1}) = (1 - \rho(1 - a_{it}))m\theta_{t-1}^{1-\mu}$ . Thus, as in Pissarides (2000) the finding rate depends positively on the ratio of vacancies posted by the firm to unemployment. However, with endogenous separations, the finding rate also depends on how many new matches actually turn into productive jobs.

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the main advantage of this matching function, relative to the Cobb-Douglas specification (4), is that guarantees matching probabilities between zero and one for all  $U$ , and  $V$ , both specifications have identical implications for the log-linearized version of the model considered in this paper.

<sup>7</sup>All separated workers are assumed to reenter the unemployment pool, thus we abstract from workers' labor force participation decisions.

<sup>8</sup>Note that in models where firms consist of only one worker, the assumption of returns to scale in vacancy posting would be immaterial.

Firms maximize the present value of discounted flow profits:

$$E_0 \sum_{t=0}^{\infty} \beta^t \lambda_t \left[ \left( \frac{P_{it}}{P_t} \right)^{1-\epsilon} Y_t - W_{it} N_{it} - \mathcal{N}_{it} - \mathcal{P}_{it} \right], \quad (7)$$

with respect to  $P_{it}$ ,  $N_{it}$ ,  $V_{it}$ , and  $a_{it}$ , subject to the employment constraint (5) and the constraint that demand (1) equals production (2). The discount factor  $\beta^t \lambda_t$  derives from consumer preferences in the presence of perfect capital market and is taken as exogenous by the firms.

The first-order conditions are:

$$\begin{aligned} \psi \left( \frac{\pi_{it}}{\tilde{\pi}_{t-1}} - 1 \right) \frac{\pi_{it}}{\tilde{\pi}_{t-1}} &= E_t \beta_{t+1} \psi \left( \frac{\pi_{it+1}}{\tilde{\pi}_t} - 1 \right) \frac{\pi_{it+1}}{\tilde{\pi}_t} \frac{Y_{t+1}}{Y_t} + \dots \\ &\dots + \left[ (1-\epsilon) \frac{P_{it}}{P_t} + \epsilon m c_{it} \right] \left( \frac{P_{it}}{P_t} \right)^{-\epsilon}, \end{aligned} \quad (8)$$

$$W_t = m c_{it} \alpha \frac{Y_{it}}{N_{it}} - \mu_{it} + E_t \beta_{t+1} \mu_{it+1} (1 - \rho(1 - a_{it+1})) - E_t \beta_{t+1} g(a_{it+1}), \quad (9)$$

$$\frac{c'(V_{it})}{q(\theta_t)} = E_t \beta_{t+1} [\mu_{it+1} (1 - \rho(1 - a_{it+1})) - g(a_{it+1})], \quad (10)$$

$$\mu_{it} = g'(a_{it}). \quad (11)$$

where  $\beta_{t+1} = \beta \lambda_{t+1} / \lambda_t$  is a stochastic discount factor where  $\lambda_t$  corresponds to the marginal utility of consumption of the representative worker. Recall the definition  $\tilde{\pi}_{t-1} = \pi_{t-1}^\gamma \pi^{1-\gamma}$ . The Lagrange multiplier  $\mu_{it}$  on the employment constraint is the current-period value of workers. The multiplier  $m c_{it}$  on the constraint that demand equals production is the contribution of an additional unit of output to the firm's revenue and equal to the firm's real marginal cost.

The first condition (8) is standard for models with quadratic price adjustment. It determines the dynamics of inflation as a function of real marginal cost  $m c_t$ . Combining (10) and (11), we derive the job creation condition in symmetric equilibrium:

$$\frac{c'(V_t)}{q(\theta_t)} = E_t \beta_{t+1} [(1 - \rho(1 - a_{t+1})) g'(a_{t+1}) - \rho g(a_{t+1})], \quad (12)$$

and further use (9) to get the job destruction condition:

$$g'(a_t) = m c_t \alpha \frac{Y_t}{N_t} - W_t + \frac{c'(V_t)}{q(\theta_t)}, \quad (13)$$

The job destruction condition (13) relates the marginal cost of upgrading a job to the benefit of keeping that job active, which consists of the net flow profit per

worker ( $mc_t \alpha \frac{Y_t}{N_t} - W_t$ ) and a measure of the future value of the job. This measure is determined by the job creation condition (12), which relates the cost of posting a vacancy to the expected present value of the job. With probability  $(1 - \rho(1 - a_t))$ , the job yields  $mc_t \alpha \frac{Y_t}{N_t} - W_t$  plus the future value, minus the upgrading costs incurred for the job. The key difference between job creation and job destruction in the model is that vacancy posting is an intertemporal margin of employment adjustment, while separation is an intratemporal margin of adjustment.

Note that we assume a symmetric equilibrium throughout. This entails  $P_{it} = P_t$ ,  $a_{it} = a_t$  and  $V_{it} = V_t$ , for all  $t$  and  $i$ . Then all firms behave in a similar manner and face the same costs. When  $P_{it} = P_t$ , all firms produce the same amounts of output, employ equal amounts of labor, and face the same marginal costs  $mc_t$ . One can use (13) along with the evolution of employment, to show that this implies an  $a_{it}$  and  $V_{it}$  that fulfill both equations simultaneously.

We also assume that firms take wages as given when choosing employment. This allows us to ignore two further subtleties for the purposes of our study. One is that if (Nash) bargained wages depend on the marginal product of labor, large firms as in our model have an incentive to overhire, in order to weaken incumbent workers' bargaining position. This would imply a wage  $W_t$  that is at the margin endogenous to the firms's choice of employment.<sup>9</sup> Secondly, when vacancy costs are decreasing, the wage bargained between workers and the firm (under Nash bargaining) would also depend on future hiring costs. That is, by hiring more workers today, the firm faces higher marginal hiring costs in the future, which in turn feeds back into the wage today. This issue is irrelevant in the case of  $c'' = 0$ .

## 2.2 Real Marginal Costs: A Baseline Specification

The job destruction condition (13) can be used to obtain an expression of the real marginal cost as a function of firing and hiring costs:

$$mc_t = \frac{W_t}{\alpha Y_t / N_t} + \frac{g'(a_t) - c'(V_t)/q(\theta_t)}{\alpha Y_t / N_t}. \quad (14)$$

In the presence of search and matching frictions, a firm's real marginal cost has two components, unit labor costs (the wage over the marginal product of labor), and labor adjustment cost  $g'(a_t)$ , corrected for the present value of the job. Intuitively, the firm

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<sup>9</sup>See Stole and Zwiebel (1995) for a general discussion, and Krause and Lubik (2006), who show that this so-called intra-firm bargaining has most likely only weak effects on the dynamic behavior of matching models.

does not merely evaluate real marginal cost at the full marginal cost of paying workers and keeping jobs alive today. It also takes into account the present value of a job kept active, as reflected here in the current-period hiring cost  $c'(V_t)/q(\theta_t)$ .

In a more compact form, the previous expression can be written as

$$mc_t = s_t(1 + x_t), \quad (15)$$

where  $s_t = \frac{W_t N_t}{\alpha Y_t}$  represents real unit labor costs (the labor income share divided by  $\alpha$  –the elasticity of output to employment–), and

$$x_t = \frac{1}{W_t} [g'(a_t) - c'(V_t)/q(\theta_t)], \quad (16)$$

captures the effects of labor adjustment costs relative to the real wage. In the absence of labor market frictions  $mc_t = s_t$ . This is familiar from new Keynesian models with competitive labor markets: real marginal costs are proportional to the labor share,  $S_t = \alpha s_t$ . Interestingly, as we discuss later, this formulation implies that the extra-term,  $x_t$ , in (16) depends negatively on the separation rate,  $\rho_t$ , and the degree of labor market *tightness*,  $\theta_t$ , but as discussed below the sign on vacancies,  $V_t$  depends upon the sign of the elasticity  $\frac{c''}{c'} V$ .

In the steady state, expression (8) implies that real marginal cost,  $mc$ , is a constant that solely depends on the elasticity of demand,  $\epsilon$ . That is  $mc = (1 - 1/\epsilon)$ , which turn is the inverse of the steady-state markup. This is a standard implication of monopolistic competition. In addition, it then follows from (12) to (13) that:

$$\left(1 - \frac{1}{\epsilon}\right) MPL = W(1 + x). \quad (17)$$

where  $MPL = \alpha \frac{Y}{N}$  is the marginal product of labor. This equation shows that the benefit of hiring an additional employee – the marginal revenue product of labor – equals the the marginal cost of adjusting labor that include the hiring and firing decisions. Thus (17) is our analogous representation of the expression (19) in Rotemberg (2006).

### 2.3 Exogenous Separations

In the wake of Shimer (2005) many recent papers that focus on search frictions assume that the job separation rate is purely exogenous. In this section we compare a

modification of our baseline model with two other models that emphasized the importance of hiring for labor adjustment. Notwithstanding, none of the papers take an empirical approach like the one we follow in this paper.

Assuming a fixed job separation rate in our baseline model entails  $\rho_{it} = \rho$ , and dropping the term representing the upgrading cost, i.e.,  $g = 0$ . Then the first-order conditions for employment become

$$\mu_t = mc_t \alpha \frac{Y_t}{N_t} - W_t + \frac{c'(V_t)}{q(\theta_t)}$$

and

$$\frac{c'(V_t)}{q(\theta_t)} = (1 - \rho) E_t \beta_{t+1} \left[ mc_{t+1} \alpha \frac{Y_{t+1}}{N_{t+1}} - W_{t+1} + \frac{c'(V_{t+1})}{q(\theta_{t+1})} \right]$$

The crucial difference to the baseline is that the current value of the job  $\mu_t$  is no longer equal to a marginal cost of contemporaneous adjustment  $g'(a_t)$ . Thus, real marginal cost  $mc_t$  can no longer be directly linked to observables, but would require a structural model to be determined. In the models by Blanchard and Galí (2006) and Rotemberg (2006), this problem is circumvented by appropriate timing assumptions.

### 2.3.1 Blanchard-Galí and Rotemberg

Blanchard and Galí (2006) have analyzed a version of the New Keynesian model with search and matching frictions that differs from the baseline specification in that hiring is instantaneous and the separation rate constant. Vacancies are assumed to be filled immediately by paying the hiring cost, which is assumed to be a function of labor market tightness. Thus hiring takes the intra-temporal role that separations took in the baseline. Jobs are destroyed at the fixed rate  $\rho$  and employment evolves as:

$$N_{it} = (1 - \rho) N_{it-1} + H_{it}. \quad (18)$$

Current-period employment at the firm level depends on last period's employment that survives the separation shock, and current period hiring.<sup>10</sup> Hiring,  $H_{it}$ , is given by  $V_{it} q(\theta_t)$ , as before. Hiring costs per firm are  $H_{it} G_t$ , where  $G_t = B h_t^\delta$ , with  $h_t = H_t / U_t$  and  $\delta \geq 0$ .  $B$  is a positive constant satisfying  $\rho B < 1$ .  $G_t$  and  $q(\theta_t)$  are taken as given by firms as they are based on aggregate variables. Thus firm  $i$  labor adjustment costs are  $\mathcal{N}_{it} = V_{it} q(\theta_t) G_t$ .

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<sup>10</sup> Another difference to our baseline setup is that new jobs are not affected by job destruction shocks. This assumption is immaterial for constant job destruction rates, as it just changes the implied constant in the matching function.

From the first-order condition for employment it follows that

$$Bh_t^\delta = mc_t A_t \alpha N_t^{\alpha-1} - W_t + (1 - \rho) E_t \beta_{t+1} B h_{t+1}^\delta.$$

The previous expression can be used to write the marginal costs as in our general expression (15) where

$$x_t = \frac{1}{W_t} [Bh_t^\delta - (1 - \rho) E_t \beta_{t+1} B h_{t+1}^\delta] \quad (19)$$

As emphasized by Blanchard and Galí, the term in  $h_t$  captures the cost of hiring a marginal employed worker, while the second relates to the savings in hiring costs resulting from the reduced hiring needs in period  $t + 1$ .<sup>11</sup> In our setup,  $h_t = H_t/U_t = \theta_t q(\theta_t) = m\theta_t^{1-\mu}$ , so that  $h_t^\delta = (m\theta_t^{1-\mu})^\delta$ .

As mentioned above, Rotemberg (2006) uses the large firm assumption for the purpose of motivating increasing returns to vacancy posting at the firm level. To see the effects of this assumption, notice that the cost of posting  $V_{it}$  can be specified by the following, in principle, non-linear function:

$$c(V_{it}) = c V_{it}^{\epsilon_c}$$

where  $\epsilon_c \leq 1$ , and  $\epsilon_c = 1$  corresponds to the linear case discussed by Pissarides (2000). Crucially, Rotemberg assumes that the hiring costs are incurred one period later, and that aggregate conditions in  $t + 1$  are observed at the end of period  $t$ , *before* vacancies are chosen. Essentially, this amounts to hiring taking place contemporaneously, as in Blanchard and Galí above. Therefore, we write from the outset the following evolution of employment<sup>12</sup>

$$N_{it} = (1 - \rho) N_{it-1} + V_{it} q(\theta_t).$$

The first-order condition for this setup is therefore

$$\frac{\epsilon_c c V_t^{\epsilon_c-1}}{q(\theta_t)} = mc_t A_t \alpha N_t^{\alpha-1} - W_t + (1 - \rho) E_t \beta_{t+1} \frac{\epsilon_c c V_{t+1}^{\epsilon_c-1}}{q(\theta_{t+1})}$$

From the previous expressions follows that the only difference to Blanchard and Galí (2006) is due to the specification of the returns to scale in vacancy posting. This

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<sup>11</sup>To avoid potential confusion, note that our  $h_t$  corresponds to Blanchard and Galí's  $x_t = H_t/U_t$ .

<sup>12</sup>In Rotemberg (2006), vacancies and labor market tightness would be timed  $t - 1$ .

expression can be used to write the marginal costs as in our general expression (15) with

$$x_t = \frac{1}{W_t} [B\theta_t^\mu V_t^{\epsilon_c-1} - (1-\rho)E_t\beta_{t+1}B\theta_{t+1}^\mu V_{t+1}^{\epsilon_c-1}] \quad (20)$$

where  $B = \frac{\epsilon_c c}{m}$ . Note that Rotemberg assumes that the households' utility of consumption is linear, so that  $\beta_t = \beta$ , for all  $t$ . For  $\epsilon_c = 1$ , and  $h_t = \theta_t^{1-\mu} \Leftrightarrow \theta_t^\mu = h_t^{\mu/(1-\mu)}$ , with  $\delta = \mu/(1-\mu)$ , and this expression is equivalent to the formulation above, i.e. Blanchard and Galí (2006) is identical to Rotemberg (2006). The new element is the negative dependence of hiring costs on  $V_t$ , arising from returns to scale in vacancy posting when  $\epsilon_c < 1$ . It is worth mentioning that contrary to the expression (16), expressions (19) and (20) have two distinctive features. First, the extra-term depends positively on the current hiring, vacancies and labor market tightness and negatively upon the expected values. This implies that the cyclical behavior of the marginal is modified in different forms depending upon the form and timing of both firing and hiring costs. Second, the last two expressions requires the specification of a stochastic discount factor,  $\beta_{t+1}$ . Both issues are discussed in the next sections.

### 3 The Cyclical Behavior of Marginal Costs

Our empirical analysis of the New Keynesian Phillips Curve in the presence of search and matching frictions proceeds in two steps. We first study the properties of real marginal costs, the main driver of inflation dynamics, based on the derivations above. We calibrate the parameters of the model and use data on labor market variables to generate the implied marginal cost series. We then describe the statistical properties of this series, and, in particular, contrast this with marginal cost series and their proxies that have typically been used in empirical studies. In the second step, we pursue a more formal econometric approach in that we derive a NKPC which we estimate using a methods of moments approach.<sup>13</sup>

#### 3.1 Measuring Marginal Costs with Search Frictions

**Baseline Model** The expression for marginal costs can now be log-linearized around a steady state (the caret ‘ $\wedge$ ’ denotes log-deviation from the steady state,

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<sup>13</sup>The NKPC with frictions is more highly parameterized than the standard relationship under a competitive labor market. This is likely to lead to identification problems. In order to circumvent this issue a full information-approach seems more useful. We pursue this agenda in ongoing research.

$\widehat{x}_t \equiv \ln x_t - \ln \bar{x}$ ):

$$\widehat{mc}_t = \widehat{s}_t + \frac{1-\phi}{1-\widetilde{\beta}} \left[ \epsilon_{g'} \widehat{a}_t - \widetilde{\beta}(\epsilon_c - 1) \widehat{v}_t - \widetilde{\beta} \mu \widehat{\theta}_t - (1 - \widetilde{\beta}) \widehat{w}_t \right], \quad (21)$$

where  $\phi = \frac{s}{mc} = \frac{1}{1+x}$ ,  $\widetilde{\beta} = \beta[1 - \rho(1 - \widetilde{a})]$ ,  $\widetilde{a} = a(1 - \epsilon_g^{-1})$ , and the elasticities,  $\epsilon_{g'} = \frac{g''}{g'} a$ ,  $\epsilon_g = \frac{g'}{g} a$ , and where we have used that  $\epsilon_{c'} = \frac{c''}{c'} V = \epsilon_c - 1 < 0$  if  $\epsilon_c < 1$ ; and  $\epsilon_q = \frac{q'}{q} \theta = -\mu$ . It is straightforward to see that in a Walrasian labor market, that is, when  $mc = s$ , then  $\phi = 1$  and hence  $\widehat{mc}_t = \widehat{s}_t$ . This corresponds to the baseline specification in Rotemberg and Woodford (1999) and Galí and Gertler (1999).

A firm's real marginal cost is thus directly affected by various labor market variables that serve as indicators of the cost of establishing and maintaining employment relationships. In the standard search and matching model, such as Mortensen and Pissarides (1994), hiring costs are assumed linear, so that  $c'' = 0$ , and expression above reduces to:

$$\widehat{mc}_t = \widehat{s}_t + \frac{1-\phi}{1-\widetilde{\beta}} \left[ \epsilon_{g'} \widehat{a}_t - \widetilde{\beta} \mu \widehat{\theta}_t - (1 - \widetilde{\beta}) \widehat{w}_t \right]. \quad (22)$$

Interestingly, the previous measure of real marginal cost can be written in terms of workers flows, in particular, the job separation and job finding rates. This provides a link to recent research focusing on job loss and job finding probabilities faced by individual workers as explaining the cyclical pattern of unemployment in the US economy (see, for instance, Shimer (2005), Hall (2005), Fujita and Ramey (2007), Elsby et al. (2007)).

In our baseline model, the separation rate corresponds to  $\rho_t = \rho(1 - a_t)$ , which implies that,  $\widehat{a}_t = -\frac{1-a}{a} \widehat{\rho}_t$ . Notice also that the total hirings in period  $t$  depend on the previous period's search activity in the labor market and the probability that a match survives, i.e.,  $h_t = (1 - \rho(1 - a_t))\theta_{t-1}q(\theta_{t-1}) = (1 - \rho(1 - a_t))m\theta_{t-1}^{1-\mu}$ . In log-linear terms around the steady state we get  $\widehat{h}_t = (1 - \mu)\widehat{\theta}_{t-1} + \rho a/(1 - \rho(1 - a))\widehat{a}_t$ . Using this expression one period ahead to solve for  $\widehat{\theta}_t$  and the log-linear approximation for separations, implies that the previous expression (21) becomes:

$$\widehat{mc}_t = \widehat{s}_t - \frac{1-\phi}{1-\widetilde{\beta}} \left[ \frac{\mu}{1-\mu} \widetilde{\beta} E_t \widehat{h}_{t+1} + \frac{\mu\rho(1-a)}{(1-\rho(1-a))} \widetilde{\beta} E_t \widehat{\rho}_{t+1} + \epsilon_{g'} \frac{1-a}{a} \widehat{\rho}_t + (1 - \widetilde{\beta}) \widehat{w}_t \right], \quad (23)$$

Next period's hirings are directly proportional to the current period's search activity, which firms take into account as part of real marginal costs. Hence higher



expected firing and higher current and expected hiring flows tend to reduce current marginal costs.

Equations (21), (22), and (23) give three alternative measures of the marginal costs corresponding to our baseline model. We now proceed to obtain similar log-linear approximations for the two extensions considered in this paper corresponding to the models by Blanchard and Galí (2006) and Rotemberg (2006), respectively.

**Blanchard-Galí and Rotemberg** A log-linear approximation around the steady state of the marginal costs (15) using expression (19) yields:

$$\widehat{mc}_t = \widehat{s}_t + \frac{1-\phi}{1-\widetilde{\beta}} \left[ \frac{\mu}{1-\mu} (\widehat{h}_t - \widetilde{\beta} E_t \widehat{h}_{t+1}) - \widetilde{\beta} E_t \widehat{\beta}_{t+1} - (1-\widetilde{\beta}) \widehat{w}_t \right] \quad (24)$$

where  $\widetilde{\beta} = \beta(1-\rho)$ , and we have used the steady state condition  $\delta = \frac{\mu}{1-\mu}$ . Finally, notice that  $E_t \widehat{\beta}_{t+1} = E_t \widehat{\lambda}_{t+1} - \widehat{\lambda}_t$ , where  $\widehat{\lambda}_t$  corresponds to the marginal utility of consumption. Notice that, from the viewpoint of the unemployed, the index  $h_t$  has two alternative interpretations. First, it may represent the probability of being hired in period  $t$ , or, in other words, the job-finding rate. Second, it could be an index of labor market tightness, i.e. defined as the ratio of aggregate hires to the unemployment rate.

In a similar way, using expression (20) we can easily obtain a log-linear approximation of the marginal costs in Rotemberg's model, i.e.:

$$\widehat{mc}_t = \widehat{s}_t + \frac{1-\phi}{1-\widetilde{\beta}} \left[ \frac{\mu}{1-\mu} (\widehat{h}_t - \widetilde{\beta} E_t \widehat{h}_{t+1}) + (\epsilon_c - 1)(\widehat{v}_t - \widetilde{\beta} E_t \widehat{v}_{t+1}) - (1-\widetilde{\beta}) \widehat{w}_t \right] \quad (25)$$

which is identical to expression (24) under  $\epsilon_c = 1$ .

Finally, we assume that infinitely-lived worker have an instantaneous utility function for consumption of the form:  $\frac{C_t^{1-\sigma}-1}{1-\sigma}$ , where  $C_t$  represents the level of consumption at period  $t$  and  $\sigma$  is the curvature parameter that control both risk aversion and intertemporal substitution attitudes of the representative worker. Given the previous functional form, a log-linear approximation to the stochastic discount factor is given takes the following familiar form:

$$E_t \widehat{\beta}_{t+1} = -\sigma(E_t \widehat{c}_{t+1} - \widehat{c}_t).$$

**Calibration** Each period is assumed to correspond to a quarter. Table 1 describes the values of the parameters we use for the construction of alternative measures

of marginal cost as well as the corresponding steady state. With regard to preference parameters, the benchmark value of the relative risk aversion parameter,  $\sigma$ , is set equal to 1 (as in Blanchard-Galí (2006)), although we also consider the case of linear preferences as in Shimer (2005) and Rotemberg (2006). We set the discount factor  $\beta = 1.03^{-\frac{1}{4}}$  which implies a 3 percent annual real interest rate. We keep the steady state labor income share,  $S$ , equal to 0.64 as in Cooley and Prescott (1995), and the (quarterly) steady-state rate of exogenous and endogenous separation  $\rho(1-a) = 0.11$ , a value consistent with Den Haan et al (2000) and that corresponds to a monthly rate of around 3.5% (Shimer (2005)). Finally, we follow Bentolila and Bertola (1990) and we set the firing costs as linear. Hence, we set  $\epsilon_g^{-1} = 0.2$  and  $\epsilon_{g'} = 0$ , which corresponds to the values used by those authors for the U.K.

Much of the sensitivity analysis below focuses on the calibration of the elasticity of the matching function with respect to the vacancies ( $1 - \mu$ ), the concavity of the hiring costs ( $\epsilon_c$ ), and the steady state markup ( $\frac{\epsilon}{\epsilon-1}$ ). We set the elasticity of the matching function with respect to vacancies,  $1 - \mu$ , equal to 0.5 as our benchmark value. This value is in line with the upper bound of the range reported by Petrongolo and Pissarides (2001) in their review of the literature on the matching function, and it has been recently used by Blanchard and Galí (2006) and Mortensen and Nagypal (2006). Nevertheless we also consider the alternative value 0.3 in line with the estimates by Shimer (2005) and that constitutes a lower bound upon the available estimates. This parameter, which is an important determinant of how job-finding rate, responds to changes in its driving forces, is relevant also because it determines the sensitivity of marginal costs to the tightness ratio, the finding, and the separation hazards. Thus, the lower  $1 - \mu$  the higher is the sensitivity of marginal costs variations to the previous labor market variables (see expressions (21)-(25)).

Table 1. Parameter Values and Steady State

Parameter	Definition	Benchmark	Alternative
$\beta$	Discount factor	$1.03^{\frac{1}{4}}$	$1.03^{\frac{1}{4}}$
$\sigma$	Relative risk aversion	1.0	0.0
$\epsilon_{g'}$	Firing Costs –Non linear	0.0	0.0
$\epsilon_g^{-1}$	Firing Costs –Linear	0.2	0.2
$\epsilon_c$	Elasticity of recruiting costs	0.2	1
$\mu$	Elast. of matching to unemp.	0.5	0.3
$\epsilon$	Elasticity of demand	21	21
Steady State			
$\rho(1 - a)$	Separation rate	0.12	0.12
$S$	Labor income share	0.64	0.64
$1/mc$	Inverse of price over marg. cost	1.05	1.20
$\phi \equiv (1+x)^{-1}$	Marginal recruiting over marg. product	0.68	0.68

We follow Rotemberg (2006) and consider two values for the elasticity of recruiting costs  $\epsilon_c$ . The baseline corresponds to the one advocated by the previous author, i.e. 0.2. As an alternative calibration we follow Pissarides (2000) and assuming that the recruiting costs are linear in the vacancies posted, i.e.  $\epsilon_c = 1$ .

Notice that the  $mc$  is obtained by calibrating the steady state markup, measure as  $\frac{\epsilon}{\epsilon-1}$ . This requires a value for the elasticity of substitution across intermediate goods,  $\epsilon$ . We set  $\epsilon = 21$  as our benchmark value, that it is consistent with a steady state markup 5 percent which is consistent with the evidence presented by Basu and Fernald (1997). As follows from the steady state expression (17) for a given steady state marginal cost over price –inverse of the steady state markup– and the steady state labor share it follows a steady state value for the marginal recruiting costs over the marginal product, i.e.  $\phi = 0.68$ , a value in line with the recent calibration considered by Blanchard and Galí (2006) and Rotemberg (2006).

It is worth mentioning that if instead we set  $\epsilon$  equals to 6, which imply a high gross steady state markup equals to 20 per cent, then the value of  $\phi = 0.975$  and so the contribution of the labor market variables to the fluctuations of the real marginal costs becomes negligible, i.e.  $\frac{1-\phi}{1-\beta} = 0.02$ .<sup>14</sup>

<sup>14</sup>Given a labor share equal to 0.64, in order to satisfy that  $x > 0$ , and given the range of variation

## 3.2 Data Description

We take the series for the job separation and the job finding rate from Shimer (2005). They are quarterly averages of monthly rates. Shimer calculates two different series for the job separation and job finding rate. The first two are available from 1948 up to 2004. He uses available data from the Bureau of Labor Statistics for employment, unemployment, and unemployment duration to calculate the *instantaneous* rate at which workers move from employment to unemployment and vice versa. The two rates are computed under the assumption that workers move between employment to unemployment, and therefore abstracts from workers' labor force participation decisions. Hence, they are an approximation to the true underlying labor market rates. Starting from 1967:2, Shimer also uses the monthly Current Population Survey public microdata to directly calculate the flow of workers that move in and out of the three possible labor market states (employment, unemployment, and out of the labor force). With this information he calculates the instantaneous rates at which workers move in and out each state. This yields an exact instantaneous rate at which workers move from employment to unemployment and from unemployment to employment.

We also compare the results by using two data sets of two recent studies that have modified and extended Shimer's original calculation. We first use the hazard rates series from Fujita and Ramey (2006). The series are available at monthly frequency and cover the period of January 1976 through December 2005. We compute the quarterly averages of monthly rates. These authors correct by potential margin error – inconsistency in the stock-flow identities – in the CPS. In addition, these authors correct for time aggregation problems. Elsby et al. (2007) also propose some refinements of the correction methods used by Shimer's analysis based on publicly available data from the CPS, and as Fujita and Ramey redesign the analysis and correct for time aggregation bias. Interestingly, Elsby et al. (2007) also distinguish employment-to-unemployment flows stemming from job loss and from job leaving, and they show that these two flows have very different cyclical properties. Thus, we use their disaggregated analysis of unemployment where we distinguish three categories: job losers, job leavers, and labor force entrants.

We use the index of help-wanted advertisements released by the Conference Board as an approximation for vacancies (HW). We also use the stock of unemployed –16 years

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of steady state markup, this implies that  $\alpha$  –the short run elasticity of output to employment varies between 0.8 and 1, inside the range considered by the literature once variable capital utilization and/or variable effort are incorporated to the neoclassical production function (King and Rebelo (1999)).

and over— from the BLS, and the Unemployment Index equals to  $\frac{U(t)}{U(\text{June}87)}$ , which is consistent with HW Index. We construct the quarterly averages of monthly rates that are available starting at January 1951.

Finally, our measure of marginal costs corresponds to the Nonfarm Business Sector. The data are drawn from FRED<sup>®</sup>II database and the variables correspond to: real output (OUTNFB), the output deflator (IPDNBS), the aggregate number of hours worked (HOANBS), and the compensation per hour (COMPNFB), respectively. Real consumption corresponds to the sum of real non-durable (PCNDGC96) and services (PCESVC96), respectively. Finally, CNP160V is the civilian non-institutional population.

### 3.3 Results

The results of our calibration exercise are reported in Figures xx-xx, where real unit labor costs are compared with our alternative, synthetic, measures of real marginal costs. We first show an alternative calibration that makes vacancy creation more elastic. Then we compare the baseline version with the slightly modified models suggested by Blanchard and Galí (2006) and Rotemberg (2006) that use hiring as a contemporaneous margin of adjustment.

Figure 1 depicts our inclusive measure of marginal cost and real unit labor cost  $s_t$ . The latter is the typical marginal cost proxy in the New Keynesian Phillips-curve literature. As the figure shows, the two series are very similar. At first glance, it appears that the influence of search and matching frictions on inflation dynamics is negligible. The two series comove closely, with similar turning points, and exhibit similar persistence and volatility. From the 1980s, though, the new series is somewhat less volatile and smoother. This impression is not substantially altered when recruitment costs have unit elasticity, or when the representation of the real marginal cost equation (23) uses job-finding and separation rates. The figure also shows the deviations from mean of vacancies, and the inverses of labor market tightness and the real wage.

## Components of the Marginal Costs

*Endogenous Separation I (Baseline Calibration)*

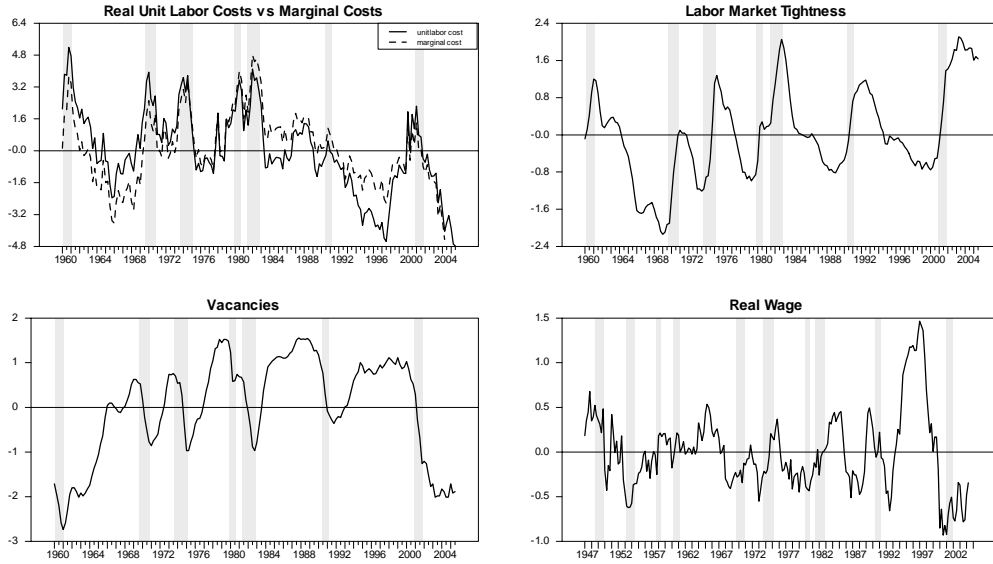


Figure 1

Figure 2 depicts the marginal cost series implied by the specification in Blanchard and Galí (2006) and Rotemberg (2006). Remember that hiring is contemporaneous in this case. This series exhibits much higher volatility than unit labor costs across all different parameterizations. It is striking that a mere change in the timing of job flows translates into such difference in volatility. The reason is that when there is only one margin of adjustment, the forward looking nature of employment adjustment is not captured any longer by the proxies of hiring and firing. Instead, the stochastic discount factor appears, which is highly volatile. Furthermore, the role of job separations as a means to smooth hiring is eliminated.<sup>15</sup> Thus the volatility of hiring is no longer offset by movements in separations, which are now removed from the model, but which generate the data.

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<sup>15</sup>See Krause and Lubik (2007).

## Components of the Marginal Costs

*Blanchard-Gali Baseline Calibration I*

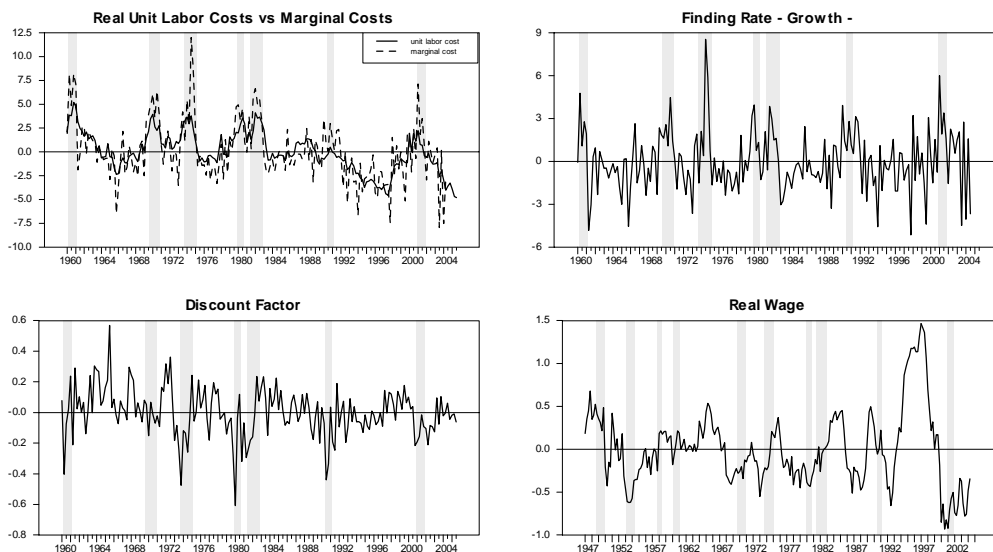


Figure 2

To summarize, we find that adding search and matching frictions in the labor market does not appear to materially affect the cyclical behavior of marginal costs in terms of comovement, persistence and volatility. A typical proxy measure for real marginal costs, such as unit labor costs, behaves similarly. This does not, however, allow us to conclude that these measures have no substantial effects on inflation dynamics. This we investigate now.

## 4 The New Keynesian Phillips Curve

We showed in the previous section that our marginal cost measure inclusive of labor market frictions behaves similarly to unit labor costs. This analysis was based, however, on a calibration analysis that used information from a variety of often conflicting sources, and that did not take into account possible parametric restrictions among coefficients. We therefore turn to a formal econometric analysis. We begin by introducing a New Keynesian Phillips curve which we then estimate using generalized method of moments (GMM).

In a symmetric equilibrium, a log-linear approximation of the price setting condition (8) reduces to the following familiar New Keynesian Phillips curve:

$$\hat{\pi}_t = \gamma_f E_t \hat{\pi}_{t+1} + \gamma_b \hat{\pi}_{t-1} + \kappa \widehat{mc}_t, \quad (26)$$

where inflation depends on past and expected future inflation and the forcing variable is real marginal costs. In the particular price setting model we use, the parameter on expected inflation is  $\gamma_f = \beta/(1 + \beta\gamma)$ , and the parameter on past inflation is  $\gamma_b = \gamma/(1 + \beta\gamma)$ , and finally the slope coefficient on real marginal costs is  $\kappa = (\epsilon - 1)/[\psi(1 + \beta\gamma)]$ .

As in the original model of Galí and Gertler (1999), expression (26) is a hybrid New Keynesian Phillips curve. First, when  $\gamma = 0$ , the model corresponds to Rotemberg’s (1982) original contribution, so that the model reduces to the purely forward looking New Keynesian Phillips curve. Second, when  $\beta = 1$  then  $\gamma_f + \gamma_b = 1$ . Finally, the pass-through from marginal costs to inflation,  $\kappa$ , is a function of the degree of inertia,  $\gamma$ , the discount factor  $\beta$ , the elasticity of demand,  $\epsilon$ , and the price adjustment cost parameter  $\psi$ . Notice that a higher elasticity of demand  $\epsilon$  implies a higher sensitivity of inflation to marginal costs; conversely, the higher price adjustment cost parameter and/or the degree of indexation, the lower is the pass-through from marginal costs to inflation.

Our econometric procedure is relatively straightforward. Let  $\mathbf{z}_t$  denote a vector of variables observed at time  $t$ . Then, under rational expectations, equation (26) defines the set of orthogonality conditions for all  $t$ :

$$E_t\{(\pi_t - \gamma^b \pi_{t-1} - \gamma^f E_t\{\pi_{t+1}\} - \lambda \widehat{mc}_t) \mathbf{z}_t\} = 0$$

Given these orthogonality conditions, we can estimate the model using generalized method of moments (GMM).

**A simple baseline** As a first pass we estimate the NKPC (26) using our imputed marginal cost series, with  $\gamma_f + \gamma_b = 1$ . We impose this restriction to achieve identification with minimal assumptions and to avoid using additional moment conditions in the first step. We are interested in two questions: first, whether the inclusion of search and matching frictions affects the Phillips-curve coefficient  $\lambda$ ; and second, how much of the observed inflation persistence is due to the backward-looking component  $\gamma^b$ , as opposed to the extrinsic persistence in marginal costs. The results are reported in Table 1. We compare our estimates to those in Galí and Gertler (1999) who have proxied marginal costs by unit labor costs alone (“No Search Frictions”).



**Table 1**  
*GMM Restricted Estimates ( $\gamma_b + \gamma_f = 1$ )*

<i>Parameters</i>	Baseline GMM		Closed Form GMM	
	$\gamma_f$	$\lambda$	$\gamma_f$	$\lambda$
No Search Frictions	0.694 (0.052)	0.0048 (0.0043)	0.579 (0.021)	0.0021 (0.0012)
Endogenous Separation				
Baseline Calibration				
Tightness	0.716 (0.056)	0.0093 (0.0044)	0.648 (0.038)	0.0063 (0.0017)
Hazard Rates	0.738 (0.058)	0.0111 (0.0045)	0.651 (0.038)	0.0061 (0.0015)
Alternative Calibration				
Tightness	0.698 (0.052)	0.0066 (0.0048)	0.591 (0.021)	0.0022 (0.0011)
Hazard Rates	0.708 (0.053)	0.0080 (0.0050)	0.589 (0.022)	0.0024 (0.0012)
Exogenous Separation (BG)				
Baseline Calibration	0.701 (0.042)	0.0095 (0.0037)	0.580 (0.022)	0.0012 (0.0011)
Alternative Calibration	0.732 (0.046)	0.0125 (0.0048)	0.578 (0.0022)	0.0018 (0.0013)
Exogenous Separation (R)				
Baseline Calibration	0.722 (0.048)	0.0074 (0.0051)	0.583 (0.023)	0.0014 (0.0012)
Alternative Calibration	0.735 (0.047)	0.0124 (0.0047)	0.579 (0.022)	0.0020 (0.0013)

Note: Quarterly inflation is measured using GDP Deflator. Sample Period: 1960:I-2004:IV. Standard errors are below in brackets. The instrument set includes, two lags of detrended output, real marginal costs and wage inflation and four lags of price inflation. The hazard rates used are the one obtained by Shimer (2005). The results remains unchanged if we used alternative hazard rates.

In the standard NKPC-model we find a weight on the forward-looking component of inflation of  $\hat{\gamma}_f = 0.69$  and a Phillips-curve parameter of  $\hat{\lambda} = 0.0048$ . The numbers

are virtually identical to those found by Galí and Gertler (1999). When we estimate the NKPC using our imputed marginal costs series, two findings stand out. First, estimates of  $\lambda$  increase by a factor of 2-3 with the highest estimate being 0.0125 in case of the Blanchard-Gali specification. Second, the forward-looking coefficient  $\gamma^f$  increases across the board a small amount (the highest estimate being 0.738). This suggests that the persistence in the additional marginal cost determinants contributes by a small amount to inflation persistence and volatility. Although this result was pre-saged by the evidence from the calibration analysis it is nevertheless somewhat surprising. An added observation is that the specific way marginal costs are imputed matters. If we use separation and hiring, i.e. hazard rates, instead of the labor market tightness-based measure (22), estimates of both coefficients are systematically higher. However, the differences are not vast.

Closed form estimates confirm these findings. Starting from a lower coefficient on inflation expectations of  $\hat{\gamma}_f = 0.58$ , the coefficients rise when search frictions are included. The effect is most pronounced in the baseline calibration for the model with endogenous separations, for both tightness and hazard rates. Also, the coefficient on real marginal costs is about three times as large. In contrast, neither the alternative calibration of the baseline case nor the models with exogenous separations deliver any noticeable change in the forward looking component. The marginal cost coefficient even falls.

**Table 2**  
*GMM Unrestricted Estimates*

<i>Parameters</i>	Baseline GMM			Closed Form GMM		
	$\gamma_f$	$\gamma_b$	$\lambda$	$\gamma_f$	$\gamma_b$	$\lambda$
No Search Frictions	0.676 (0.051)	0.314 (0.051)	0.0064 (0.0051)	0.554 (0.024)	0.436 (0.019)	0.0060 (0.0039)
Endogenous Separation						
Baseline Calibration						
Tightness	0.690 (0.053)	0.293 (0.057)	0.012 (0.006)	0.655 (0.040)	0.340 (0.041)	0.0075 (0.0022)
Hazard Rates	0.698 (0.055)	0.276 (0.061)	0.015 (0.0066)	0.666 (0.043)	0.327 (0.045)	0.0084 (0.0026)
Alternative Calibration						
Tightness	0.684 (0.050)	0.308 (0.052)	0.0073 (0.0055)	0.589 (0.020)	0.404 (0.023)	0.0051 (0.00344)
Hazard Rates	0.689 (0.051)	0.299 (0.053)	0.0096 (0.0065)	0.583 (0.019)	0.408 (0.021)	0.0056 (0.0038)
Exogenous Separation (BG)						
Baseline Calibration	0.659 (0.044)	0.294 (0.041)	0.017 (0.0058)	0.555 (0.021)	0.439 (0.015)	0.0035 (0.0048)
Alternative Calibration	0.697 (0.047)	0.273 (0.046)	0.017 (0.0062)	0.556 (0.021)	0.435 (0.015)	0.0055 (0.0054)
Exogenous Separation (R)						
Baseline Calibration	0.705 (0.047)	0.278 (0.051)	0.011 (0.0077)	0.563 (0.020)	0.427 (0.017)	0.0055 (0.0012)
Alternative Calibration	0.694 (0.049)	0.270 (0.046)	0.019 (0.0064)	0.555 (0.021)	0.434 (0.015)	0.0065 (0.0055)

Note: See Table 1.

The unrestricted estimates yield a subtly different picture. The sum of the forward-looking and backward-looking inflation coefficients are slightly lower than one, although not statistically significant. Yet again, backward looking inflation appears less important with search frictions than without. For the closed form estimates, the baseline calibration of the model with endogenous separations shows the strongest effect of real marginal costs based on search frictions.

## 4.1 Robustness

[TBC]

## 5 Conclusions and Further Research

Accounting for search frictions per se does not necessarily deliver a measure of real marginal cost that differs from the labor share, or unit labor costs. The forward looking component in the hybrid New Keynesian Phillips curve become slightly more important, and the responsiveness of prices to marginal cost changes is larger. Interestingly, whether we use direct measures of hiring activity or infer them from vacancies and unemployment via a matching function, does not make much difference.

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