

# Inflation and Labor Market Dynamics Revisited\*

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## Abstract

Firms adjust labor both at the intensive and at the extensive margin (see, e.g., Hansen and Sargent 1988). Moreover, employment adjustment is not frictionless (see, e.g., Mortensen and Pissarides 1994). What does this imply for inflation dynamics? To address this question we develop a New Keynesian model featuring two margins of labor adjustment as well as a simultaneous price-setting and employment decision at the firm level. We find that the presence of an empirically plausible labor adjustment decision at the firm level rationalizes strategic complementarities in price-setting which help explain inflation dynamics.

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# 1 Introduction

Firms adjust labor both at the intensive and at the extensive margin (see, e.g., Hansen and Sargent 1988). Moreover, employment adjustment is not frictionless (see, e.g., Mortensen and Pissarides 1994). What does this imply for inflation dynamics? To address this question we develop a New Keynesian (NK for short) model featuring two margins of labor adjustment, as well as labor adjustment costs at the firm level. Specifically, our model features an employment adjustment cost à la Rotemberg and Woodford (1999) and a hiring cost, as in Blanchard and Galí (2006). The latter adjustment cost component serves two purposes. First, it gives rise to equilibrium unemployment. Second, that cost, combined with our assumption that wage bargaining takes place at the firm level, implies that each firm faces an upward sloping labor supply schedule. We can therefore use the employment adjustment cost to obtain an empirically plausible split between the two margins of labor adjustment.

Our motivation for allowing for two margins of labor adjustment in our model is twofold. First, we note that the standard NK model assumes changes at the intensive margin only (see, e.g., Galí 2003). On the other hand, the Mortensen and Pissarides (1994) model, as well as the monetary models proposed by Walsh (2005), Blanchard and Galí (2006) and Krause and Lubik (2007) feature only an employment margin. The fact that these extreme and polar assumptions have been adopted in most of the related existing literature<sup>1</sup> might be surprising, given that in the data the cyclical fluctuations in total hours result from both changes in employment and changes in hours. More importantly, labor adjustments at the two margins have different implications for the determination of the marginal cost, and hence for inflation dynamics: adjustments at the hours margin are current-looking, while

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<sup>1</sup>A notable exception is Trigari (2006). She allows for two margins of labor adjustment but abstracts from the simultaneity of price-setting and employment decisions. Another recent paper which introduces two margins of labor adjustment in a monetary model is Barnichon (2006). He considers a simultaneous price-setting and employment problem in a Calvo-style model, but the real wage in his model evolves independently of monetary policy.

employment adjustment introduces a forward-looking element in the determination of the marginal cost. Ignoring one margin could therefore imply misleading results, as far as inflation dynamics are concerned.

Our main focus is the role of labor market frictions *per se* for inflation dynamics.<sup>2</sup> Two sets of results emerge. First, the restrictions on employment adjustment rationalize strategic complementarities in price-setting which help explain inflation dynamics.<sup>3</sup> Interestingly, our model also implies a reasonably volatile marginal cost schedule. The latter feature is empirically plausible (see, e.g., Bils 1987) and hence an inconvenient fact for those models whose ability to generate persistent inflation dynamics relies on assumptions which guarantee a smooth marginal cost, as has been recently emphasized by Basu (2005). Trigari (2006) argues that labor market frictions *per se* do *not* have a quantitatively important effect on inflation dynamics.<sup>4</sup> We confirm her result if we change our baseline model in such a way that price-setting and employment takes place in different sectors. Our main result shows, however, that this simplification is not innocuous for in that case important strategic complementarities are assumed away. Strategic complementarities in price-setting resulting from labor market frictions are also not present in the models proposed by Chéron and Langot (2000), Christoffel and Linzert (2005), Galí and Blanchard (2006), and Krause and Lubik (2007). This motivates our revisiting of inflation and labor market dynamics. Second, we analyze the role of real wage rigidity for inflation dynamics. It is shown that the presence of this feature alters dramatically the inflation dynamics implied by our model. The last finding is in stark contrast with the recent

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<sup>2</sup>Monetary models typically combine labor market frictions with other real rigidities. See, e.g., Walsh (2005), Trigari (2006), Gertler et al. (2007) and Krause and Lubik (2007).

<sup>3</sup>Most of the related existing literature has made the assumption that price-setting and hiring decisions take place in different sectors. A notable exception is Krause and Lubik (2007) who propose a sticky price model à la Rotemberg with only an employment margin for labor adjustment. Kuester (2007) proposes a Calvo-style model featuring one-worker firms within which a simultaneous negotiation over product price and wage takes place.

<sup>4</sup>Interestingly, if only an employment margin is assumed then labor market frictions combined with consumption habit and policy inertia reduce the inflation impact and amplify the real impact of a nominal interest rate shock. This is shown in Walsh (2005). In the present paper we are mainly concerned, however, with isolating the role of labor market frictions for inflation dynamics.

irrelevance result in Krause and Lubik (2007). We argue that the latter result is driven by the assumption that firms adjust labor at the employment margin only. Taken together we find that the discipline imposed by the labor market facts is of crucial importance for understanding inflation dynamics.

The remainder of the paper is organized as follows. Section 2 outlines our model. In Section 3 the results are presented and interpreted. Section 4 concludes.

## 2 The Model

### 2.1 Households

There is a continuum of households and we follow Merz (1995) and Andolfatto (1996) in assuming that each of them is a large family consisting of a continuum of members with names on the unit interval. In equilibrium some members are unemployed while others work for firms. Each member has the following period utility function

$$U(C_t, H_t) = \ln C_t - \chi \frac{H_t^{1+\eta}}{1+\eta}, \quad (1)$$

which is separable in its two arguments  $C_t$  and  $H_t$ . The former denotes a Dixit-Stiglitz consumption aggregate while the latter is meant to indicate hours worked. Throughout the analysis the subscript  $t$  is used to indicate that a variable is dated as of that period. Parameter  $\chi$  is a scaling parameter whose role will be discussed below and  $\eta$  can be interpreted as the inverse of the (aggregate) Frisch labor supply elasticity. The consumption aggregate reads

$$C_t \equiv \left( \int_0^1 C_t(i)^{\frac{\epsilon-1}{\epsilon}} di \right)^{\frac{\epsilon}{\epsilon-1}}, \quad (2)$$

where  $\epsilon$  is the elasticity of substitution between different varieties of goods  $C_t(i)$ . The associated price index is defined as follows

$$P_t \equiv \left( \int_0^1 P_t(i)^{1-\epsilon} di \right)^{\frac{1}{1-\epsilon}}, \quad (3)$$

where  $P_t(i)$  is the price of good  $i$ . Requiring optimal allocation of any spending on the available goods implies that consumption expenditure can be written as  $P_t C_t$ . Households are assumed to maximize expected discounted utility

$$E_t \sum_{k=0}^{\infty} \beta^k U(C_{t+k}, H_{t+k}), \quad (4)$$

where  $\beta$  is the subjective discount factor. The maximization is subject to a sequence of budget constraints which take the following form

$$P_t C_t + D_t \leq D_{t-1} R_t + P_t W_t H_t N_t + B U_t^M + T_t, \quad (5)$$

where  $R_t$  is the gross nominal interest rate on bond holdings  $D_{t-1}$ . We have also used the notation  $W_t$  for the real wage and  $T_t$  for lump-sum transfers including dividends resulting from ownership of firms as well as lump-sum taxes. The unemployment benefit for unemployed household members is denoted by  $B$ , while  $N_t$  gives the fraction of employed household members, and  $U_t^M \equiv 1 - N_t$  is period unemployment.

The consumer Euler equation implied by this structure takes the standard form

$$1 = \beta R_t E_t \left\{ \left( \frac{C_t}{C_{t+1}} \right) \left( \frac{P_t}{P_{t+1}} \right) \right\}. \quad (6)$$

## 2.2 Firms

There is a continuum of firms and each of them is the monopolistically competitive producer of a differentiated good. Each firm  $i$  is assumed to maximize its market value subject to constraints implied by the demand for its good, the production

technology it has access to, the law of motion of its employment and a Calvo-type restriction on price adjustment. Importantly, we assume that each firm takes the relationship between hours hired and its wage as given. Wages are determined as the outcome of a bargain between a firm and its workers which is assumed to take place after price setting and hiring. We will discuss the details of that bargain below. Since firms are assumed to satisfy demand at the posted price<sup>5</sup> hours hired by each firm are determined and the only object of the negotiation is therefore the wage. Let us now be more specific about a firm's constraints. Technology is assumed to take the following simple form

$$Y_t(i) = Z_t N_t(i) H_t(i), \quad (7)$$

where  $Z_t$  indicates total factor productivity,  $N_t(i)$  is the number of employed workers in firm  $i$  and  $H_t(i)$  denotes average hours worked. We assume that production is linear in total hours.

The law of motion of employment is given by

$$N_t(i) = (1 - s) N_{t-1}(i) + L_t(i), \quad (8)$$

where parameter  $s$  denotes the separation rate and  $L_t(i)$  is meant to indicate the newly hired workers of firm  $i$ .

We assume the following labor adjustment costs

$$G_t(i) \equiv G_A \left( \frac{L_t}{U_t} \right) L_t(i) + G_F \left( \frac{N_t(i)}{N_{t-1}(i)} \right) N_{t-1}(i), \quad (9)$$

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<sup>5</sup>This is rationalized by the assumption of monopolistic competition in the goods market.

where

$$\begin{aligned} G_A \left( \frac{L_t}{U_t} \right) &\equiv \Upsilon Z_t \left( \frac{L_t}{U_t} \right)^\vartheta, \\ G_F \left( \frac{N_t}{N_{t-1}} \right) &\equiv \frac{\epsilon_N}{2} \left( \frac{N_t}{N_{t-1}} \right)^2. \end{aligned}$$

The definition of function  $G_t(\cdot)$  reflects our assumption that there are two distinct types of adjustment costs. The first term is meant to capture the hiring cost strictly speaking. That cost depends on aggregate labor market conditions, as parametrized by  $\vartheta$  and  $\Upsilon$ . We have also used the definition  $U_t \equiv 1 - (1 - s) N_{t-1}$  to denote the fraction of the labor force that is searching for a job at the beginning of period  $t$ . The second term in the definition of function  $G_t(\cdot)$  measures the additional cost associated with integrating the newly hired worker into the existing workforce of the firm. Parameter  $\epsilon_N > 1$  measures that cost in the log-linear approximation to the equilibrium dynamics to which we will restrict attention. The role of employment adjustment costs has been emphasized in the literature on labor market dynamics.<sup>6</sup> In the context of our model that feature allows us to obtain a reasonable split of variations in total hours between the two margins of adjustment.

Cost minimization on the part of households implies that demand for good  $i$  is given by

$$Y_t(i) = \left( \frac{P_t(i)}{P_t} \right)^{-\epsilon} Y_t, \quad (10)$$

where  $Y_t$  denotes aggregate output which is defined in the following way

$$Y_t \equiv \left( \int_0^1 Y_t(i)^{\frac{\epsilon-1}{\epsilon}} di \right)^{\frac{\epsilon}{\epsilon-1}}. \quad (11)$$

Finally, the Calvo restriction on price adjustment states that each period a lottery takes place and with probability  $(1 - \theta)$  a firm gets to re-optimize its price while with probability  $\theta$  the firm posts its last period's price. A firm's problem therefore

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<sup>6</sup>See, e.g., Nickell (1986), Hammermesh and Pfann (1996) and Cooper and Willis (2002).

reads

$$\max \sum_{k=0}^{\infty} E_t \left\{ \beta^k \left( \frac{C_t}{C_{t+k}} \right) \left( \frac{P_t}{P_{t+k}} \right) \left[ \begin{array}{c} Y_{t+k}(i) P_{t+k}(i) - \\ P_{t+k} [W_{t+k}(i) N_{t+k}(i) H_{t+k}(i) + G_{t+k}(i)] \end{array} \right] \right\}$$

s.t.

$$\begin{aligned} Y_{t+k}(i) &= \left( \frac{P_{t+k}(i)}{P_{t+k}} \right)^{-\epsilon} Y_{t+k}, \\ Y_{t+k}(i) &= Z_{t+k} N_{t+k}(i) H_{t+k}(i), \\ N_{t+k}(i) &= (1-s) N_{t+k-1}(i) + L_{t+k}(i), \\ P_{t+k+1}(i) &= \begin{cases} P_{t+k+1}^*(i) & \text{with prob. } (1-\theta) \\ P_{t+k}(i) & \text{with prob. } \theta \end{cases}. \end{aligned}$$

The firm's problem implies a standard first order condition for price-setting

$$\sum_{k=0}^{\infty} \theta^k E_t \left\{ \beta^k \left( \frac{C_t}{C_{t+k}} \right) \left( \frac{P_t}{P_{t+k}} \right) Y_{t+k}(i) [P_t^*(i) - \mu P_{t+k} MC_{t+k}(i)] \right\} = 0, \quad (12)$$

where  $\mu \equiv \frac{\epsilon}{\epsilon-1}$  denotes the frictionless markup and  $MC_t(i)$  is meant to indicate the real marginal cost at the firm level. Under the Calvo assumption prices are set in a forward-looking manner or, more precisely, a new price is chosen in such a way that over its expected lifetime the average markup is equal to its desired frictionless value. The real marginal cost is determined in the following way

$$MC_t(i) = \frac{W_t(i) + H_t(i) \frac{\partial W_t(i)}{\partial H_t(i)}}{\frac{Y_t(i)}{H_t(i) N_t(i)}}. \quad (13)$$

As usual, the shadow value of relaxing the technological constraint implied by the production function can be interpreted as the marginal cost. With wage bargaining the firm takes rationally into account that a marginal change in hours implies a change in its real wage. This is reflected in the  $H_t(i) \frac{\partial W_t(i)}{\partial H_t(i)}$  term in the marginal



cost equation.<sup>7</sup>

Combining the first order conditions for employment and for hiring allows us to write

$$W_t(i) H_t(i) + \frac{\partial G_t(i)}{\partial N_t(i)} = MC_t(i) Y_t(i) / N_t(i) + E_t \left\{ \beta \left( \frac{C_t}{C_{t+1}} \right) \frac{\partial G_{t+1}(i)}{\partial N_t(i)} \right\}. \quad (14)$$

The last equation has an intuitive interpretation. The left hand side gives the cost associated with hiring one additional worker. That cost includes both a wage payment and adjustment costs. The right hand side gives the benefit from hiring one additional worker, i.e., the marginal savings in the cost of using hours associated with having an additional worker in place, as well as expected reductions in future adjustment costs.

### 2.3 Wage Negotiation

The household's value of a match with firm  $i$  is given by

$$\begin{aligned} \widetilde{W}_t(i) = & W_t(i) H_t(i) - \chi C_t \frac{H_t(i)^{1+\eta}}{1+\eta} \\ & + E_t \left\{ \beta \left( \frac{C_t}{C_{t+1}} \right) \left[ (1-s) \widetilde{W}_{t+1}(i) + s \left( F_{t+1} \widetilde{W}_{t+1} + (1-F_{t+1}) \widetilde{U}_{t+1} \right) \right] \right\}. \end{aligned} \quad (15)$$

where  $\widetilde{W}_t \equiv \int_0^1 \widetilde{W}_t(i) \frac{L_t(i)}{L_t} di$  denotes the average value of a match and  $F_t \equiv \frac{L_t}{U_t}$  is the job-finding probability. The value of a match with firm  $i$  consists of three elements. First, the real wage income resulting from working  $H_t(i)$  hours at the wage  $W_t(i)$ . Second, the associated disutility of supplying labor (expressed in units of consumption). Third, the expected discounted value of continuing the match in the next period, or of searching for a job.

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<sup>7</sup>For an early discussion of the implications of hiring costs for the construction of marginal cost measures, see Rotemberg and Woodford (1999).

The value of being unemployed after hiring has taken place is given by

$$\tilde{U}_t = B + E_t \left\{ \beta \left( \frac{C_t}{C_{t+1}} \right) \left[ F_{t+1} \tilde{W}_{t+1} + (1 - F_{t+1}) \tilde{U}_{t+1} \right] \right\}, \quad (16)$$

which equals the unemployment benefit and the expected discounted value of looking for a job in the next period.

We follow Blanchard and Galí (2006) in assuming that newly hired workers become productive instantaneously. This implies that the value of a match for firm  $i$  corresponds to the cost of hiring a worker

$$\tilde{J}_t = G_A(F_t), \quad (17)$$

which is independent of the firm. The value of an open vacancy for firm  $i$  is zero, given our assumptions.

The wage is chosen in such a way that the Nash product is maximized, which implies the following first order condition

$$(1 - \phi) \tilde{J}_t = \phi \left( \tilde{W}_t(i) - \tilde{U}_t \right), \quad (18)$$

where  $(1 - \phi)$  denotes the weight of workers in the bargain. Next, we substitute for  $\tilde{J}_t$ ,  $\tilde{U}_t$  and  $\tilde{W}_t(i)$  in the last equation. Noting that  $\tilde{W}_t(i)$  is equal across firms allows us to find the wage resulting from the bargain in the following way

$$W_t(i) = \frac{\chi C_t \frac{H_t(i)^{1+\eta}}{1+\eta} + \Psi_t}{H_t(i)}, \quad (19)$$

where

$$\Psi_t \equiv B + \frac{1 - \phi}{\phi} G_A(F_t) - \frac{1 - \phi}{\phi} E_t \left\{ \beta \left( \frac{C_t}{C_{t+1}} \right) [(1 - s)(1 - F_{t+1}) G_A(F_{t+1})] \right\}. \quad (20)$$

For future reference let us rewrite the marginal cost in the following way

$$MC_t(i) = \frac{\chi C_t H_t(i)^\eta N_t(i)}{Y_t(i)/H_t(i)} = \frac{MRS_t(i)}{Y_t(i)/H_t(i) N_t(i)}, \quad (21)$$

where  $MRS_t(i)$  denotes the marginal rate of substitution of consumption for leisure, which is common to all workers hired by firm  $i$ . Finally, it is assumed that all markets clear.

## 2.4 Some Linearized Equilibrium Conditions

In what follows we consider a log-linear approximation to the equilibrium dynamics around a zero inflation steady state. Unless stated otherwise lower case letters denote the log-deviation of the original variable from its steady state value. The consumption Euler equation reads

$$c_t = E_t \{c_{t+1}\} - (r_t - E_t \pi_{t+1} - \rho), \quad (22)$$

where parameter  $\rho$  denotes the household's time preference rate. Up to the first order aggregate production is given by

$$y_t = z_t + n_t + h_t. \quad (23)$$

Aggregating the linearized law of motion of firm-level employment results in

$$n_t = (1 - s) n_{t-1} + s l_t. \quad (24)$$

Linearized unemployment reads

$$u_t = - (1 - s) \frac{N}{U} n_{t-1}, \quad (25)$$

where we have used the notation that a variable without a time subscript denotes the steady state value of that variable. Period unemployment is given by

$$u_t^M = -\frac{N}{U^M}n_t. \quad (26)$$

Aggregating and linearizing the first order condition for firm-level employment implies

$$\begin{aligned} \Delta n_t = & \beta E_t \{ \Delta n_{t+1} \} + \frac{1}{\epsilon_N} \left\{ \frac{Y}{\mu N} [mc_t + y_t - n_t] - WH (w_t + h_t) \right. \\ & \left. - \Upsilon (F)^\vartheta [\vartheta f_t + z_t - (1-s) \beta E_t \{ (r_t - \pi_{t+1} - \rho) - \vartheta f_{t+1} - z_{t+1} \}] \right\}. \end{aligned} \quad (27)$$

The following relationships holds true

$$f_t = l_t - u_t. \quad (28)$$

The real wage is given by

$$w_t = \frac{\chi C^{\frac{H^{1+\eta}}{1+\eta}}}{WH} c_t + \left( \frac{\chi CH^{1+\eta}}{WH} - 1 \right) h_t + \frac{\Psi}{WH} \psi_t, \quad (29)$$

where

$$\begin{aligned} \psi_t = & \frac{(1-\phi) \Upsilon (F)^\vartheta}{\phi \Psi} [\vartheta f_t + z_t + (1-s) \beta E_t \{ (1-F) (r_t - \pi_{t+1} - \rho) \\ & - ((1-F) \vartheta - F) f_{t+1} - (1-F) z_{t+1} \}]. \end{aligned} \quad (30)$$

The real marginal cost reads

$$mc_t = c_t + (1+\eta) h_t - y_t + n_t. \quad (31)$$

In the Appendix the following inflation equation is derived

$$\pi_t = \beta E_t \pi_{t+1} + \kappa mc_t, \quad (32)$$

where parameter  $\kappa$  is computed numerically using the method outlined in Woodford (2005). Finally, let us state the exogenous driving forces. Technology is assumed to follow a stationary  $AR(1)$  process

$$z_t = \rho_z z_{t-1} + e_{zt}, \quad (33)$$

and monetary policy is assumed to take the form of a Taylor rule

$$r_t = \rho_r r_{t-1} + (1 - \rho_r) [\rho + \tau_\pi \pi_t + \tau_y y_t] + e_{rt}, \quad (34)$$

where  $e_{rt}$  denotes an *iid* shock to monetary policy.

## 2.5 Calibration

Let us now discuss the values which we assign to the model parameters in most of the quantitative analysis that we are going to conduct. The period length is one quarter. We let  $\beta$  be 0.99, which implies an annual steady state real interest rate of about 4 per cent.

We follow Golosov and Lucas (2007) and set the elasticity of substitution between goods,  $\epsilon$ , to 7. This implies a steady-state mark-up of about 20 per cent. Our baseline value for the Calvo parameter for price setting,  $\theta$ , is  $2/3$ , which is consistent with the recent empirical finding of Nakamura and Steinsson (2006) that firms change their prices on average every third quarter.

As far as monetary policy is concerned we set  $\tau_y$  and  $\tau_\pi$  to 0.5 and 1.5, respectively, as originally suggested by Taylor (1993) and the parameter measuring interest rate smoothing,  $\rho_r$ , is set to 0.90. These parameter values are reasonable given the

empirical results in, e.g., Clarida et al. (2000).

The estimates reported by MaCurdy (1981) on the labor supply elasticity center around 0.15, which is our baseline value for  $1/\eta$ . We follow Shimer (2005) in setting steady state period unemployment to 0.057 and the quarterly job-finding rate to 0.71.<sup>8</sup> Given our model this implies a separation rate of about 0.15<sup>9</sup> and steady-state search unemployment of about 0.20. Following Hall (2005) the unemployment benefit,  $B$ , is set to 40% of steady state labor income. The employment adjustment cost parameter,  $\epsilon_N$ , is set to 2 which is in line with the estimates reported in Cooper and Willis (2002). In order to calibrate the elasticity in the hiring cost function,  $\vartheta$ , we follow Blanchard and Galí (2006) and use a simple relationship between the hiring cost model and the Mortensen and Pissarides (1994) model. In the latter, the matching function is given by  $L = \omega V^\gamma U^{1-\gamma}$ , where  $V$  denotes vacancies,  $\gamma$  is the elasticity of the matching function and  $\omega$  is a constant. In that framework the cost of hiring an additional worker is proportional to  $V/L = \omega^{-\frac{1}{\gamma}} F^{\frac{1-\gamma}{\gamma}}$ . Hall (2005) estimates  $\gamma$  to be 0.765 and we correspondingly set  $\vartheta = \frac{1-\gamma}{\gamma} = 0.307$ . In order to satisfy the Hosios (1990) condition we choose  $\phi$  equal to 0.765. Given the elasticity of the matching function, the first-order condition for employment and the wage equation, both evaluated in steady state, imply two conditions to pin down the steady state wage income  $WH$  and parameter  $\Upsilon$ . Last, we use  $\chi$  to pin down hours in steady state to 1/3 of available time.

We set the standard deviation of the monetary policy shock to 0.002. Walsh (2005) argues that this value is consistent with estimated Federal Reserve reaction functions. Moreover, the coefficient of autocorrelation in the process of technology,  $\rho_z$ , is assumed to take the value 0.95, as in Erceg et al. (2000) and Walsh (2005). The standard deviation of the productivity shock is set to 0.008382, in which case the baseline model matches the standard deviation of GDP of 1.69% in the data.

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<sup>8</sup>We compute the quarterly rate as  $0.34 * \sum_{j=1}^3 (1 - 0.34)^{j-1}$ , where 0.34 is the corresponding monthly rate reported by Shimer.

<sup>9</sup>The values used in the literature range from 0.07 (Merz 1995) to 0.15 (Andolfatto 1996).

### 3 Results

We start by analyzing the labor market dynamics implied by our model. The results are shown in Table 1.

Table 1: Data<sup>10</sup> and Model Statistics

Variable	U.S. Data		Model	
	Std	Std. Rel. to Empl.	Std	Std. Rel. to Empl.
GDP	1.69%	1.182	1.69%	1.2109
Hours	0.42/0.51%	0.294/0.357	0.5966%	0.3575
Employment	1.43%	1	1.6687%	1

The variability of employment and hours is reasonably well in line with the data. In order to illustrate how labor market frictions help explain inflation dynamics we analyze next the dynamic consequences of a 25 basis point increase in the nominal interest rate. The results are shown in Figure 1.

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<sup>10</sup>See, Bachmann (2006). The second numbers in the second row include unpaid hours.

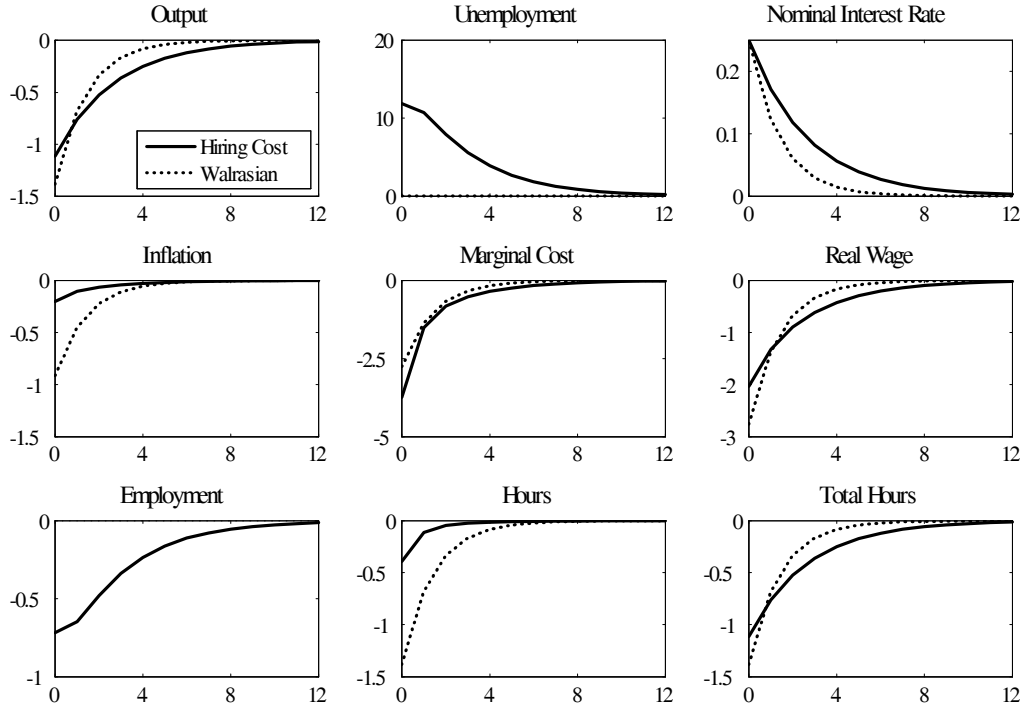


Figure I: Baseline Model: Shock to the Monetary Policy Rule

Specifically, we compare our baseline model to an alternative specification featuring a Walrasian labor market, i.e., in the latter model it is assumed that there exists only an hours margin for labor adjustment coupled with flexible wages and perfect competition in the labor market. This is a common modeling choice in the New Keynesian literature. To make the comparison meaningful we assume that the labor supply elasticity,  $\eta$ , is set to one in the Walrasian model, as in Galí (2003). Four aspects of that comparison are worth highlighting. First, wage bargaining implies a muted response of the average real wage. The reason is the wedge between the marginal rate of substitution of consumption for leisure and the real wage which is implied by the surplus sharing between firms and their workers. Interestingly, the corresponding average real marginal cost schedules display the opposite pattern: the average real marginal cost moves more in our baseline model than it is the case in the Walrasian benchmark economy. Intuitively, the marginal cost is linked to



the marginal rate of substitution of consumption for leisure in both models, but the total effect of the relatively smaller hours adjustment in the presence of a relatively smaller labor supply elasticity in the baseline model implies a difference in the respective marginal cost schedules. This is our second finding. Third, and most importantly, the inflation response is muted in our baseline model with respect to its counterpart in the Walrasian economy.<sup>11</sup> A price setting firm internalizes the consequences of that decision for the marginal cost it faces over the expected lifetime of the chosen price. This economic incentive makes the price setter relatively reluctant to change its price in response to a change in the current (or future expected) average real marginal cost. Taken together the last two results suggest that our modeling of the labor market helps explain persistent inflation dynamics in the presence of substantial volatility in the marginal cost. The empirical evidence on marginal cost dynamics in Bils (1987) suggests that this is a desirable property of our model, and one that is not shared by alternative explanations of inflation persistence which assume a smooth marginal cost schedule. We also note that it is exactly on these grounds that Basu (2005) criticizes those alternative explanations. Our fourth observation regards the fact that variation in total hours (and hence, given our production function, output) is similar in our baseline model and in the Walrasian benchmark economy, but, by construction, only in our baseline model the labor market variables display the empirically plausible use of the two margins.

Our main result in the above comparison is that the strategic complementarities in price-setting implied by the restrictions on employment adjustment are quantitatively important.<sup>12</sup> To emphasize that point somewhat more we show next how

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<sup>11</sup>Moreover, the extent to which the inflation response is muted is empirically plausible. In fact, the Walrasian model would predict very similar inflation dynamics, if it was assumed in that model that the expected lifetime of a price is about 7 quarters, i.e., substantially more than the micro data on price adjustment suggest. On the other hand, it is well understood that an upward biased estimate of the price stickiness parameter obtains, if the macro data are analyzed through the lens of a model which does not feature any endogenous price stickiness. See, e.g., Smets and Wouters (2003).

<sup>12</sup>Given the prominent role of strategic complementarities for inflation dynamics one could ask how the comparison with the Walrasian model would change if decreasing returns to scale were added to both models. Maybe not surprisingly, the difference in inflation dynamics does indeed

the picture changes if these strategic complementarities are taken away by assuming that price-setting and employment takes place in different sectors. The results are shown in Figure 2.

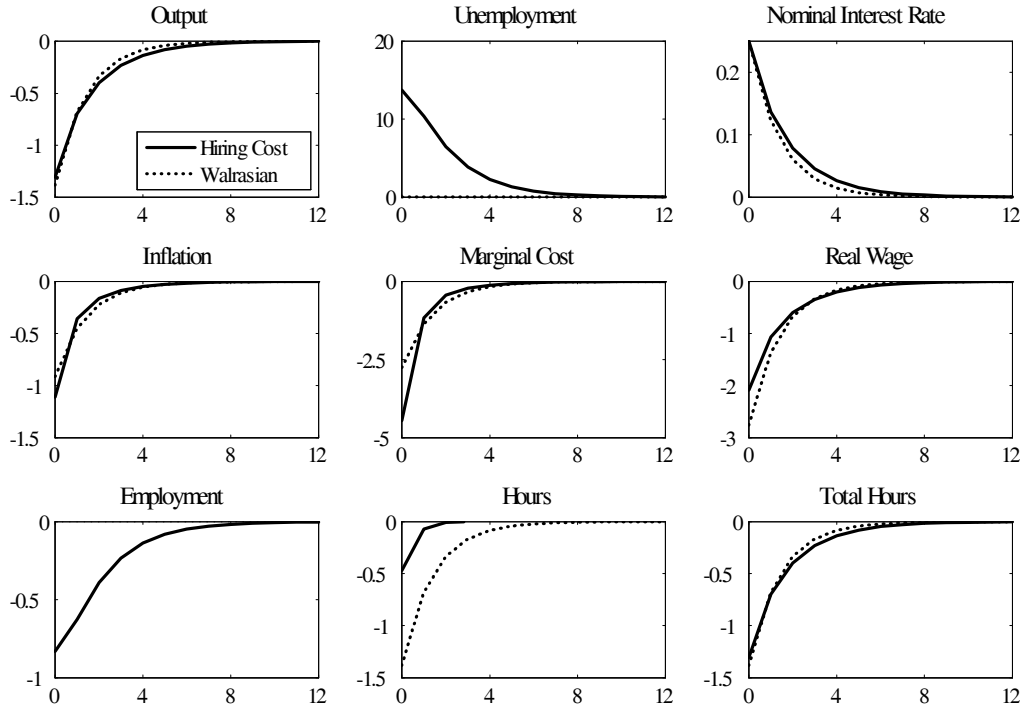


Figure II: Two Sector Model: Shock to the Monetary Policy Rule

In that case the two models imply similar dynamics. This confirms the result in Trigari (2006) according to which labor market frictions per se do not matter for inflation dynamics. Our point is that the simplifying assumption of separating price-setting and employment decisions is not inconsequential for the results obtained.

Finally, we argue that restricting attention to an employment margin only is another simplification which is not innocuous for the results obtained. To show this

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become less pronounced in that case. The economic insight from that exercise is, however, relatively limited, we believe, for in that case important real world facts like variable factor utilization, which would tend to reduce the strategic complementarities in price-setting implied by decreasing returns to scale are not taken into account.

we analyze how real wage rigidity affects inflation dynamics. We follow Krause and Lubik (2007) in illustrating the effects of real wage rigidity by assuming that the real wage is constant over the cycle. This is shown in Figure 3, which compares the effect of real wage rigidity in our baseline model to its counterpart to a model featuring an employment margin only.

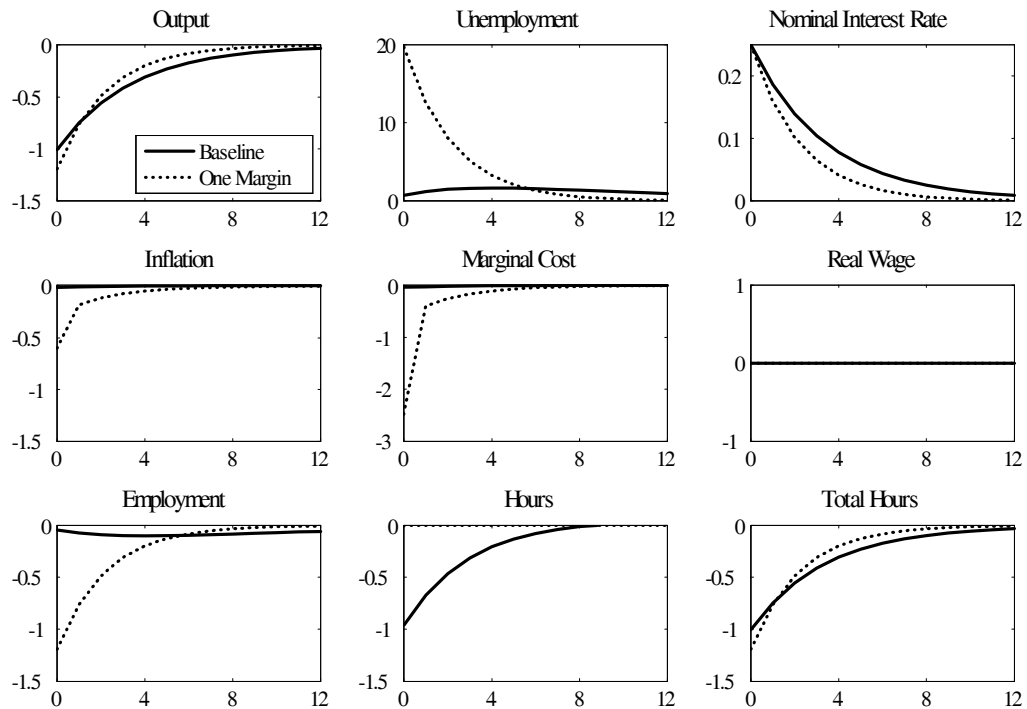


Figure III: Real Wage Rigidity: Shock to the Monetary Policy Rule

In the baseline model the real marginal cost and inflation remain unchanged in response to the monetary policy shock! This finding is in stark contrast with the irrelevance result in Krause and Lubik (2007). They argue that the reason for their finding is that, in the context of their model, the marginal cost depends only partly on the real wage. They stress that the presence of labor market frictions implies a forward-looking element in the determination of the marginal cost, which is in turn conjectured to explain the interesting and surprising irrelevance result they obtain.

We note, however, that a firm’s marginal cost, as implied by our baseline model, can be written in a way which is analogous to the corresponding expression in Krause and Lubik (2007). Specifically, we have

$$MC_t(i) = \frac{W_t(i) + \frac{1}{H_t(i)} \left[ \frac{\partial G_t(i)}{\partial N_t(i)} - E_t \left\{ \beta \left( \frac{C_t}{C_{t+1}} \right) \frac{\partial G_{t+1}(i)}{\partial N_t(i)} \right\} \right]}{Y_t(i) / (N_t(i) H_t(i))}.$$

The last equation is derived by solving equation (14) with respect to the real marginal cost. Formally, it is a consequence of cost-minimization on the part of firms, as noted by Rotemberg and Woodford (1999). The marginal cost can be seen to depend on two elements. The first one is the real wage divided by labor productivity, while the second reflects that labor market frictions imply a long-term relationship between a firm and its workers. This shows that Krause and Lubik’s irrelevance result is not so much a consequence of entertaining a real marginal cost that “contains a present value component that varies independently of the real wage”, as they claim, but rather an artefact of not considering any labor adjustment at the hours margin.

## 4 Conclusion

We try to understand the role of labor market frictions for inflation dynamics. To this end we develop a monetary model featuring two margins of labor adjustment as well as a simultaneous price-setting and employment decision at the firm level. Our work revisits the conventional wisdom on inflation and labor market dynamics in two ways. First, we show that earlier results according to which labor market frictions per se are irrelevant for inflation dynamics are an artefact of the commonly used simplification that employment and price-setting take place in different sectors. In fact, we argue that the discipline imposed by the labor market facts helps explain inflation dynamics. Second, we find that real wage rigidity alters the predictions of our model regarding inflation dynamics. This is in stark contrast with the conclusion

that obtains if labor adjustment takes place at the employment margin only.

## Appendix: Price Setting and Employment

We posit rules for price setting and for employment. Since our model features a convex employment adjustment cost we have

$$\widehat{n}_t(i) = \xi_1 \widehat{p}_t(i) + \xi_2 \widehat{n}_{t-1}(i),$$

and

$$\widehat{p}_t^*(i) = \widehat{p}_t^* + \kappa_1 \widehat{n}_{t-1}(i).$$

Our goal is to find conditions for the unknown coefficients in the rules. To this end we first consider the linearized equation for the relative to average employment at the firm level

$$\Delta \widehat{n}_t(i) = \beta E_t \{ \Delta \widehat{n}_{t+1}(i) \} + \frac{1}{\zeta} \widehat{h}_t(i),$$

where  $\zeta \equiv \frac{\mu N \epsilon_N}{Y} \frac{1}{\eta}$ . Combining the last equation with the firm's demand constraint and with its production function results in

$$\left[ 1 + \beta + \frac{1}{\zeta} \right] \widehat{n}_t(i) = \beta E_t \{ \widehat{n}_{t+1}(i) \} + \widehat{n}_{t-1}(i) - \frac{\epsilon}{\zeta} \widehat{p}_t(i)$$

Our next goal is to find a condition on the unknown coefficients in the employment rule. Using the above rules as well as the Calvo assumption allows us to write

$$\widehat{n}_t(i) = \frac{1}{1 + \beta + \frac{1}{\zeta} - \beta \xi_2 - \beta \xi_1 (1 - \theta) \kappa_1} \left[ \left( \xi_1 \beta \theta - \frac{\epsilon}{\zeta} \right) \widehat{p}_t(i) + \widehat{n}_{t-1}(i) \right],$$

which imposes the following two constraints on the undetermined coefficients  $\xi_1$  and  $\xi_2$  in the employment rule

$$\xi_2 = \frac{1}{1 + \beta + \frac{1}{\zeta} - \beta \xi_2 - \beta \xi_1 (1 - \theta) \kappa_1},$$

and

$$\xi_1 = \xi_2 \left( \xi_1 \beta \theta - \frac{\epsilon}{\zeta} \right).$$

Clearly, the last two conditions depend on the unknown parameter  $\kappa_1$  from the pricing rule. Next we turn to the linearized price setting equation to find a condition for this parameter.

We can write the newly set price chosen by firm  $i$  as follows

$$\begin{aligned} \widehat{p}_t^*(i) &= \sum_{j=1}^{\infty} (\beta\theta)^j E_t \pi_{t+j} + \frac{(1-\beta\theta)}{1+\epsilon\eta} \sum_{j=0}^{\infty} (\beta\theta)^k mc_{t+j} \\ &\quad - \frac{(1-\beta\theta)\eta}{1+\epsilon\eta} \sum_{j=0}^{\infty} (\beta\theta)^k E_t \widehat{n}_{t+j}(i). \end{aligned}$$

Using the employment rule as well as the Calvo assumption we find after some algebra

$$\begin{aligned} \sum_{j=0}^{\infty} (\beta\theta)^k E_t \widehat{n}_{t+j}(i) &= \frac{\xi_2}{1-\xi_2\beta\theta} \widehat{n}_{t-1}(i) + \frac{\xi_1}{(1-\beta\theta)(1-\xi_2\beta\theta)} \widehat{p}_t^*(i) \\ &\quad - \frac{\xi_1}{(1-\beta\theta)(1-\xi_2\beta\theta)} \sum_{j=1}^{\infty} (\beta\theta)^j E_t \pi_{t+j}. \end{aligned}$$

Combining the last two equations and invoking the Calvo assumption, i.e. noting that the average value of  $\widehat{n}_{t-1}(i)$  is zero in the group of time  $t$  price setters we can impose the following condition on the unknown parameter in the pricing rule

$$\kappa_1 = - \frac{(1-\beta\theta)\eta}{1+\epsilon\eta} \frac{\xi_2}{1-\xi_2\beta\theta} \frac{1}{1 + \frac{(1-\beta\theta)\eta}{1+\epsilon\eta} \frac{\xi_1}{(1-\beta\theta)(1-\xi_2\beta\theta)}}.$$

The average newly set price reads

$$\widehat{p}_t^* = \sum_{j=1}^{\infty} (\beta\theta)^j E_t \pi_{t+j} + \frac{1-\beta\theta}{\omega} \sum_{j=0}^{\infty} (\beta\theta)^k mc_{t+j},$$

where

$$\omega \equiv \frac{[1 + \epsilon\eta](1 - \xi_2\beta\theta) + \eta\xi_1}{(1 - \xi_2\beta\theta)}.$$

Solving the last equation forward and invoking the linearized price index gives

$$\pi_t = \beta E_t \{\pi_{t+1}\} + \kappa mc_t,$$

where

$$\kappa \equiv \frac{(1 - \beta\theta)(1 - \theta)}{\theta} \frac{1}{\omega}.$$

Next we impose stability. Invoking once more the pricing and employment rules, as well as the definition of the price index we obtain

$$\begin{bmatrix} E_t \widehat{p}_{t+1}(i) \\ E_t \widehat{n}_{t+1}(i) \end{bmatrix} = A \begin{bmatrix} \widehat{p}_t(i) \\ \widehat{n}_t(i) \end{bmatrix},$$

where  $A \equiv \begin{bmatrix} \theta & (1 - \theta)\kappa_1 \\ \xi_1\theta & \xi_1\kappa_1(1 - \theta) + \xi_2 \end{bmatrix}$ . Stability requires that both roots of matrix  $A$  are inside the unit circle. For candidate parameter values which satisfy the stability requirement we therefore solve the following system

$$\begin{aligned} \kappa_1(\xi_1, \xi_2) &= \frac{\xi_2(1 - \beta\theta)\eta}{(\xi_2\beta\theta - 1)(1 + \epsilon\eta) - \xi_1\eta}, \\ \xi_1 &= \frac{\frac{\epsilon}{\zeta}\xi_2}{\xi_2\beta\theta - 1}, \\ 0 &= 1 - (1 + \beta)\xi_2 - \frac{\xi_2}{\zeta} + \beta\xi_2^2 + \beta\xi_1\xi_2(1 - \theta)\kappa_1. \end{aligned}$$

This pins down the coefficients  $(\xi_1, \xi_2, \kappa_1)$ .



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