New Keynesian Perspectives on Labor Market Dynamics*

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October 29, 2007

Abstract

We find that search and matching frictions can generate an important part of the observed business-cycle fluctuations in unemployment and job vacancies in response to supply and demand shocks of a plausible magnitude. This is shown in the context of a model where firms with market power are assumed to post sticky prices taking as given a bargained wage schedule. We also show that the solution to the remaining labor market puzzle is not real wage rigidity à la Hall (2005). Finally, we argue that the features proposed by Rotemberg (2006), namely economies of scale in the technology of vacancy posting and exogenous markup shocks share essentially the same problems and promises as in his flexible price model.

*Prepared for the Carnegie-Rochester Conference Series on Public Policy "Labor Markets, Macroeconomic Fluctuations, and Monetary Policy" to be held at Carnegie Mellon University on November 9-10, 2007. We thank the seminar participants at Duke University, Norges Bank and Universitat Pompeu Fabra for useful comments on earlier versions of this paper. We are especially thankful to Stephanie Schmitt-Grohé, Jordi Galí, Michael Reiter, Martín Uribe and Thijs van Rens. The usual disclaimer applies. The views expressed in this paper are those of the authors and should not be attributed to Norges Bank.

1 Introduction

Can search and matching frictions generate the observed business-cycle fluctuations in unemployment and job vacancies in response to shocks of a plausible magnitude? To address this question we develop a New Keynesian sticky price model with search and matching frictions. Following the lead of Trigari (2004) we assume two sectors, a monopolistically competitive final goods sector and a perfectly competitive intermediate inputs sector. Firms in the former sector set prices in a staggered fashion and firms in the latter sector make hiring decisions. Conditional on being in a match with a worker intermediate input producers choose hours taking as given a bargained wage schedule. Our model therefore features fluctuations in labor input resulting from both changes in hours and changes in employment, as in the data. (See, e.g., Hansen and Sargent 1988.) It is shown in the context of the resulting framework that the standard deviation of the vacancy-unemployment ratio is about 11 times as large as the standard deviation of average labor productivity. Our results extend some recent work by Costain and Reiter (2003), Shimer (2005) and Hagedorn and Manowskii (2005). They show that search frictions *per se* cannot explain the cyclical behavior of unemployment and vacancies. In the data the standard deviation of the vacancy-unemployment ratio is about 20 times as large as the standard deviation of average labor productivity, while Shimer shows that the two variables have nearly the same volatility in a text-book Mortensen Pissarides model. Under our baseline calibration we are therefore at half-way.

Let us motivate our modeling choices somewhat more. Final goods firms in our model are demand-constrained. It is well understood that demand-constrained firms take advantage of a positive technology shock by using less factor input. (See, e.g., Galí 1999.) This is of crucial importance for our purposes. In fact, it is shown that this simple economic mechanism can be used to explain why technology shocks do not generate sufficiently large employment fluctuations (relative to labor productivity). Demand shocks, on the other hand, give a strong incentive to firms to adjust labor input and we find that this kind of shock helps explain the unemployment volatility puzzle.[1]

It is natural to ask whether the remedy proposed by Shimer (2005), namely real wage rigidity à la Hall (2005), can be used to explain the remaining part of the unemployment volatility puzzle. Interestingly, that feature generally *reduces* the variability of the vacancy-unemployment ratio (i.e., it implies that our model is less in line with the data). The reason is that real wage rigidity reduces the extent to which an increase in demand translates into a price increase for intermediate goods. This implies in turn a relatively small increase in the gain of hiring.

Finally, we assess the extent to which the features proposed by Rotemberg (2006), namely economies of scale in the technology of vacancy posting and exogenous markup shocks help explain the labor market puzzle. We find that both features are useful extensions of our model. However, only under extreme parameter choices do they imply a standard deviation of the vacancy-unemployment ratio that is about 20 times as large as the standard deviation of average labor productivity. In the context of our model Rotemberg's features therefore share essentially the same problems and promises as in his flexible price model.

By now there exists a large and growing literature which seeks to address the unemployment volatility puzzle. Most of that literature studies the type of wage contract used in the model. (See, e.g., Hall 2005, Hornstein, Krusell and Violante 2005, Gertler and Trigari 2006, Hall and Milgrom 2006 and Yashiv 2007.[2]) Our focus is different. We point at the importance of demand factors and show that their role is enhanced by an empirically plausible degree of price stickiness. It is in that sense that we provide a New Keynesian perspective on labor market dynamics.

The remainder of the paper is organized as follows. Section 2 outlines the model. Section 3 presents the results and Section 4 concludes.

[1] The terminology "unemployment volatility puzzle" has been used by Pissarides (2007). He also rightly conjectures the importance of demad shocks for explaining labor market dynamics.

[2] For overview articles, see, e.g., Mortensen and Nagypál (2007) and Pissarides (2007).

2 The Model

Our model features labor market search and matching frictions as in Mortensen and Pissarides (1994) and sticky prices à la Calvo (1983). We assume three types of agents: households, firms and monetary authorities.

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

$$U\left(C_t, H_t\left(h\right)\right) = \ln C_t - \chi \frac{H_t\left(h\right)^{1+\eta}}{1+\eta}, \tag{1}$$

which is separable in its two arguments C_t and $H_t\left(h\right)$. 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. Our notation also reflects the fact that heterogeneity in hours worked does not translate into consumption heterogeneity because household members are assumed to insure each other. Parameter χ is a scaling parameter whose role will be discussed below and η can be interpreted as the inverse of the (aggregate) Frisch labor supply elasticity. The consumption aggregate reads

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

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

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

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 subject to a sequence of budget constraints which take the following form

$$P_t C_t + D_t \leq D_{t-1} R_t + P_t W_t H_t N_t + BU_t + T_t, \tag{4}$$

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, H_t for hours worked by those household members who are employed and T_t for transfers, i.e., lump sum taxes and dividends resulting from ownership of firms. The (constant) unemployment subsidy for unemployed household members is denoted by B, while N_t gives the fraction of employed household members and $U_t \equiv 1 - N_t$ is period unemployment. The consumer Euler equation implied by this structure takes the standard form

$$1 = \beta R_t E_t \left\{ \left(\frac{C_t}{C_{t+1}} \right) \left(\frac{P_t}{P_{t+1}} \right) \right\}, \tag{5}$$

where β is the subjective discount factor.

2.2 Firms

We follow Trigari (2004) in assuming two sectors. Perfectly competitive intermediate goods producers use labor as the only input. They face search frictions and choose hours taking as given a bargained wage schedule. Firms in the final goods sector are monopolitistically competitive. They use intermediate goods and capital to produce final goods and sell them to consumers. These firms set prices in a staggered fashion.

2.2.1 Intermediate Goods Producers

There is a perfectly competetive intermediate good producer. That representative firm has access to the following Cobb-Douglas production function

$$\overline{X}_t = Z_t {H_t}^{\zeta}, \tag{6}$$

where $\overline{X}_t$ denotes intermediate good production, Z_t is the level of technology and H_t denotes hours hired with ζ measuring decreasing returns. Total intermediate goods production, X_t, is given by

$$X_t \equiv N_t Z_t H_t^{\zeta} = N_t \overline{X}_t, \tag{7}$$

The law of motion of employment reads

$$N_{t+1} = (1-s)\left[N_t + \Phi\left(V_t/U_t\right) V_t\right], \tag{8}$$

where parameter s gives the separation rate and we have also used the definition $\Phi\left(V_t/U_t\right) \equiv \omega\left(V_t/U_t\right)^{\gamma-1}$ where V_t and U_t denote, respectively, aggregate vacancies and unemployment. Following Rotemberg (2006) we assume that the cost of posting a vacancy takes the form $\frac{\upsilon}{\epsilon_V} {V_t}^{\epsilon_V}$. That cost is measured in units of the final good. The optimality condition for vacancy posting is given by

$$0 = -\Xi_t + E_t\left\{\beta\left(\frac{C_t}{C_{t+1}}\right)\left[P_{t+1}^x \overline{X}_{t+1} - W_{t+1}H_{t+1} + (1-s)\,\Xi_{t+1}\right]\right\}, \tag{9}$$

where $\Xi_t \equiv \frac{\upsilon {V_t}^{\epsilon_V - 1}}{(1-s)\Phi(V_t/U_t)}$ is the time t shadow value of filling a vacancy in period t+1. Free entry implies that the cost of posting a vacancy equals the shadow value times the probability that the vacancy is filled. The latter consists of two parts: the probability of a match, $\Phi\left(V_t/U_t\right)$, and the probability that the match survives the exogenous separation, which occurs at rate s.

2.2.2 Wage Negotiation

The value of a match for a household, $\widetilde{W}_t$, is given by

$$\widetilde{W}_t = W_t H_t - \chi C_t \frac{H_t^{1+\eta}}{1+\eta} + E_t \left\{ Q_{t,t+1} \left[(1-s) \left(\widetilde{W}_{t+1} - \widetilde{U}_{t+1} \right) + \widetilde{U}_{t+1} \right] \right\}. \qquad (10)$$

where $Q_{t,t+1} \equiv \beta \frac{C_t}{C_{t+1}}$ denotes the stochastic discount factor and $\widetilde{U}_t$ is the value of being unemployed. The last equation has an intuitive interpretation. From a household's perspective the value of a match depends on the resulting real wage income net of the associated disutility of supplying hours (measured in units of final good consumption), taking rationally into account the future values of working for a firm or being unemployed. The latter value is given by

$$\widetilde{U}_t = B + E_t \left\{ Q_{t,t+1} \left[(1-s) F_t \left(\widetilde{W}_{t+1} - \widetilde{U}_{t+1} \right) + \widetilde{U}_{t+1} \right] \right\}, \qquad (11)$$

where $F_t \equiv \frac{\Phi(V_t/U_t)V_t}{U_t}$ is the job-finding rate. The value of a match for an intermediate goods producer, $\widetilde{J}_t$, is given by

$$\widetilde{J}_t = P_t^x \overline{X}_t - W_t H_t + (1-s) E_t \left\{ Q_{t,t+1} \widetilde{J}_{t+1} \right\}, \qquad (12)$$

where the P_t^x denotes the relative intermediate goods price. We have also used the fact that $\Xi_t = E_t \left\{ Q_{t,t+1} \widetilde{J}_{t+1} \right\}$. Surplus splitting implies

$$(1-\phi) \widetilde{J}_t = \phi \left(\widetilde{W}_t - \widetilde{U}_t \right), \qquad (13)$$

where $(1-\phi)$ denotes the weight of workers in the bargain. Inserting for $\widetilde{J}_t$, $\widetilde{W}_t$ and $\widetilde{U}_t$ and using the optimality condition for vacancy posting (9) allow us to write the real wage income in the following way

$$W_t H_t = (1-\phi) \left(\frac{P_t^x X_t}{N_t} + \upsilon \frac{V_t^{\epsilon_V}}{U_t} \right) + \phi \left(\chi C_t \frac{H_t^{1+\eta}}{1+\eta} + B \right). \qquad (14)$$

Next we determine the price of intermediate goods P_t^x. To this end we start by invoking profit maximization on the part of intermediate goods firms. The implied first-order condition reads

$$P_t^x \overline{X}' (H_t) = W (H_t) + W' (H_t) H_t. \tag{15}$$

Implicit in the last equation is our assumption that an intermediate good producer chooses hours taking into account the bargained wage schedule. Taken together we obtain

$$P_t^x = \frac{\chi C_t H_t^\eta}{\zeta X_t / (H_t N_t)}. \tag{16}$$

2.2.3 Final Goods Producers

There is a continuum of final goods firms and each of them is the monopolistically competitive producer of a differentiated good. Each firm j is assumed to maximize its market value subject to constraints implied by the demand for its good, the production technology it has access to and a Calvo-type restriction on price adjustment. Let us now be more specific about a firm's constraints. Firm j's production, $Y_t (j)$, is given by

$$Y_t (j) = \left(K_t (j) \overline{K}\right)^\alpha X_t (j)^{1-\alpha} - \Theta, \tag{17}$$

where $K_t (j)$ denotes capital utilization, $\overline{K}$ is the (constant) level of capital and $X_t (j)$ is the amount of intermediate goods used in firm j's production. Last, parameter Θ measures the fixed cost of production. At this point we need to stress some important differences between our model and the framework proposed by Trigari (2004), which are motivated by our research question. Her model does not feature neither variable capital utilization nor a fixed cost of production. Given our focus in the present paper, the standard deviation of average labor productivity is at center stage. The assumption of a fixed capital stock at the firm-level combined with variable capital utilization implies that average labor productivity is a procyclical variable, as in the US data which are used to calibrate our model. We also impose that our model implies an empirically plausible labor share. This motivates the assumption of a fixed cost of production. Given our modeling choices the real marginal cost, $MC_t(j)$, reads

$$MC_t(j) = \frac{1}{1-\alpha} P_t^x \left(\frac{X_t(j)}{K_t(j)\,\overline{K}} \right)^{\alpha}. \tag{18}$$

Cost-minimization on the part of firms implies

$$Q'(K_t(j)) = \frac{\alpha}{1-\alpha} \frac{P_t^x X_t(j)}{K_t(j)}, \tag{19}$$

where function $Q(\cdot)$ is assumed to satisfy $Q(1) = 0$ and $\frac{Q''(1)}{Q'(1)} = \epsilon_B$. Let us also mention here that we have normalized the steady state level of capital utilization to unity. Finally, we obtain a standard first-order condition for price-setting

$$\sum_{k=0}^{\infty} \theta^k E_t \left\{ \beta^k \left(\frac{C_t}{C_{t+k}} \right) \frac{Y_{t+k}(j)}{P_{t+k}} \left[P_t^*(j) - \mu \; MC_{t+k}(j) \right] \right\} = 0, \tag{20}$$

where $P_t^*(j)$ is the optimally chosen price, θ gives the probability that a firm is not allowed to change its price in a given period and $\mu \equiv \frac{\varepsilon}{\varepsilon-1}$ is the frictionless markup.

2.3 Some Linearized Equilibrium Conditions

We restrict attention to 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

$$c_t = E_t\{c_{t+1}\} - (r_t - E_t \pi_{t+1} - \rho), \tag{21}$$

where parameter ρ denotes the household's time preference rate, $\pi_t \equiv \log\left(\frac{P_t}{P_{t-1}}\right)$ is inflation and r_t denotes the nominal interest rate. Up to the first order, aggregate final goods production is of the form

$$y_t = \frac{Y + \Theta}{Y} \left[\alpha k_t + (1 - \alpha) x_t \right],$$

where we have used the notation that a variable without a time subscript is meant to indicate the steady state value of that variable. Total production of intermediate goods is given by

$$x_t = z_t + n_t + \zeta h_t. \tag{22}$$

The final goods market clearing condition reads

$$y_t = \frac{C}{Y} c_t + \upsilon \frac{V^{\epsilon_V}}{Y} v_t + \frac{Q'(1)}{Y} k_t. \tag{23}$$

Aggregating the linearized first-order condition for capital utilization results in

$$k_t = \frac{1}{1 + \epsilon_B} \left(p_t^x + x_t \right). \tag{24}$$

The linearized law of motion of employment is given by

$$n_{t+1} = (1 - s) n_t + s \left[\gamma v_t + (1 - \gamma) u_t \right]. \tag{25}$$

Linearized unemployment reads

$$u_t = -\frac{N}{1 - N} n_t. \tag{26}$$

The linearized optimality condition for vacancy posting is of the form

$$\begin{aligned} \xi_t \;\; = \;\; & -E_t \left\{ (r_t - \pi_{t+1} - \rho) - \beta (1 - s) \xi_{t+1} \right\} \\ & + \frac{\beta}{\Xi} E_t \left\{ \frac{P^x X}{N} \left(p_{t+1}^x + x_{t+1} - n_{t+1} \right) - WH \left(w_{t+1} + h_{t+1} \right) \right\}. \end{aligned} \tag{27}$$

We also have

$$v_t = \frac{1}{\epsilon_V - \gamma}\left[\xi_t + (1-\gamma)\, u_t\right]. \tag{28}$$

The real wage is given by

$$\begin{aligned} w_t \;&=\; \frac{\phi\chi C}{WH}\frac{H^{1+\eta}}{1+\eta}c_t + \left(\frac{\phi\chi C H^{1+\eta}}{WH} - 1\right) h_t \\ &\quad + \frac{(1-\phi)}{WH}\frac{\upsilon V^{\epsilon_V}}{U}\left(\epsilon_V v_t - u_t\right) + (1-\phi)\,\frac{P^x Y}{WNH}\left(p_t^x + x_t\right). \end{aligned} \tag{29}$$

The real marginal cost reads

$$mc_t = p_t^x + \alpha\left(x_t - k_t\right), \tag{30}$$

with

$$p_t^x = c_t + \eta h_t - \left(x_t - h_t - n_t\right). \tag{31}$$

The inflation equation is given by

$$\pi_t = \beta E_t \pi_{t+1} + \kappa\; mc_t, \tag{32}$$

with $\kappa \equiv \frac{(1-\beta)(1-\beta\theta)}{\theta}\frac{1+\epsilon_B(1-\alpha)}{1+\epsilon_B[1+\alpha(\epsilon-1)]}$. Finally, let us state the exogenous driving forces. Technology is assumed to follow a stationary $AR(1)$ process

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

and monetary policy is assumed to take the form as in Galí and Rabanal (2004)

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

where e_{rt} denotes an *iid* shock to monetary policy. Parameter ρ_r measures interest rate smoothing, while τ_π and τ_y are, respectively, the policy reactions to inflation and output growth.

3 Results

Our goal is to analyze whether search and matching frictions can generate the observed business-cycle fluctuations in unemployment and job vacancies in response to shocks of a plausible magnitude. We use the theoretical framework developed above to explain the role of price rigidity in that context. Before turning to the results we briefly discuss how the parameter values are chosen.

3.1 Baseline Calibration

The period length is one month and the discount rate, ρ, is chosen to imply a steady state annual real interest rate of 4 per cent. We set the labor supply elasticity $\frac{1}{\eta} = 0.25$, which is well within the empirically plausible range. (See, e.g., MaCurdy 1981 and Blundell and MaCurdy 1999.) Parameter χ it is set to imply that those household members who are employed spend one-third of their available time working. We choose B such that unemployed people receive 80 per cent of the following: the wage income plus the consumption equivalent of the disutiliy of hours. There is no agreement in the literature regarding the empirically plausible value of the unemployment benefit. Our choice of the benefit is larger than 0.7, which is the value used by Mortensen and Nagypál (2007), and smaller than 0.9, which is justified in Rotemberg (2006).[3] As in Golosov and Lucas (2007) we choose $\epsilon = 7$, which implies a steady state mark-up of about 17 per cent. Moreover, choosing $\theta = 1 - 1/12$ implies that the frequency of price changes is about one year. (See, e.g., Galí 2003.) For the decreasing returns in hours we follow Khan and Thomas (2007) and set $\zeta = 0.86$. The capital share, α, and the fixed cost of production are chosen to imply, respectively, a labor's share and a capital-to-output ratio of about 0.64 and 2.35, as in the U.S. data. (See Khan and Thomas 2007.) We also choose $\gamma = \phi = \frac{1}{2}$. The former value is within the range of empirically plausible parameter values, as esti-

[3] Even more extreme values of the unemployment benefit have been advocated in the literature. Shimer (2005) uses a value of about 0.4, while Hagedorn and Manowskii (2005) report evidence in favour of choosing a value that is larger than 0.95.

mated by Petrongolo and Pissarides (2001), and the second one is simply a typical choice in the literature, given the lack of direct empirical evidence on that parameter. We follow Shimer (2005) and set the exogenous rate of separation, s, and the steady state job-finding rate, F, to 0.034 and 0.45, respectively. This implies a steady state rate of unemployment of about 7.25 per cent. Parameter ω is set such that the matching frequency is 2/3, based on the evidence in van Ours and Ridder (1992) that firms on average fill a vacancy within 45 days. Our baseline choice for parameter ϵ_V is one, i.e., we assume a linear cost of vacancy posting. Given the above choices, the optimality condition for vacancy posting and the wage equation pin down the vacancy cost υ. The variable capital utilization cost, ϵ_B, is set to $1,17$ based on the estimate reported by Smets and Wouters (2007).[4] In specifying the monetary policy rule we use the estimates in Galí and Rabanal (2004) and set $\tau_\pi = 1.35$, $\tau_y = 0.26$, and $\rho_r = 0.69^{1/3}$. The autocorrelation in the technology shock is set to $\rho_z = 0.95^{1/3}$. (See, e.g., Erceg, Henderson and Levin 2000 and Walsh 2005.) Finally, we choose the relative importance of the two stochastic disturbances in such a way that the ratio of standard deviations $\frac{std\{Y_t/(N_t H_t)\}}{std\{Y_t/N_t\}}$ is about 0.83, as in the data.[5] The last choice is motivated by the fact that our theoretical model features two margins of labor adjustment. We therefore need to impose empirical discipline in order to avoid that our results would be an artefact of the choice of our productivity measure.

[4]Smets and Wouters (2007) normalize the coefficient measuring the cost of variable capital utilization, ψ_{sw}, to be a number between zero and one. It is related to our parameter ϵ_B in the following way: $\epsilon_B = \frac{\psi_{sw}}{1-\psi_{sw}}$. Their mean estimate of ψ_{sw} is 0.54.

[5]Our measure of GDP is quarterly, seasonally adjusted annual rates of output in billions of chained 2000 Dollars in annual rates (St. Louise FED series ID: GDPC1). Hours are the quarterly average of a seasonally adjusted monthly series of average weekly hours of production workers (BLS series ID: CES0500000005). Last, employment is measured using seasonally adjusted quarterly averages of non-farm employees (BLS series ID: CES0000000081).

3.2 Demand and Supply Shocks

We assume that our model economy is driven by both technology shocks and monetary policy shocks. The results are shown in Table 1.

Table 1: Results from baseline calibration

Model	$\frac{std(V/U)}{std(Y/N)}$	$corr\,(U,V)$	$\frac{std(Y/NH)}{std(Y/N)}$
U.S. Data	20	-0.89	0.83
Baseline	11.4	-0.66	0.83
Only productivity shocks	4.1	-0.89	1.22
Flexible prices	5.8	-0.95	1.08
Flexible prices, fixed hours	6.4	-0.95	1

Under our baseline calibration the standard deviation of the vacancy-unemployment ratio relative to the standard deviation of average labor productivity is 11.4. Our model also implies a Beveridge curve (i.e., a negative correlation between vacancies and unemployment, even though that correlation is less strong than in the data). This is our first main result. An empirically plausible degree of price stickiness implies an important role for monetary policy shocks in explaining labor market dynamics. At the same time it is clear that we are only at half-way as far as explaining the value 20 which obtains in the data is concerned. Before we turn to the question of what economic features are useful extensions we use our model to disentangle the respective roles of the economic mechanisms underlying our first result.

To this end we study first a situation in which technology shocks are assumed to be the only source of aggregate uncertainty. This implies that the standard deviation of the vacancy-unemployment ratio relative to the standard deviation of average labor productivity drops to a value of about 4. The intuition behind this result is simple. Demand-constrained firms take advantage of a positive technology shock by using less factor input. (See, e.g., Galí 1999.) In the context of our model this economic mechanism implies that intermediate goods producers use less hours, hence the price of intermediate goods goes down and this reduces the incentive to post vacancies. This explains why employment features too little variability in response to technology shocks. Consistent with that intuition we also find that the value of the relative standard deviation increases to 5.8 if we assume fully flexible prices. Under the couterfactual assumption that labor adjustment takes place at the extensive margin only that number increases to 6.4. This is also consistent with our intuition. Next we conduct some additional sensitivity analysis. The results are shown in Table 2.

Table 2: Sensitivity analysis

Model	$\frac{std(V/U)}{std(Y/N)}$	$corr\,(U,V)$	$\frac{std(Y/NH)}{std(Y/N)}$
U.S. Data	20	-0.89	0.83
$\gamma = \phi = 0.28$	11.9	-0.78	0.83
The above and flexible prices	5.6	-0.97	1.06
Unemployment Benefit = 0.7	7.9	-0.66	0.83
The above and flexible prices	3.9	-0.95	1.07

Choosing values for the elasticity of the matching function, γ, and the bargaining power of firms, ϕ, as in Shimer (2005) improves the ability of our model to explain labor market dynamics slightly. Mortensen and Nagypál (2007) note, however, that $\gamma = 0.28$ is somewhat outside the empirically plausible range. Again, assuming flexible prices results in a large drop in the relative standard deviation of the vacancy-unemployment ratio. Finally, we show that the comparsion between our model and its flexible price counterpart gives qualitatively the same result if we conduct it at a lower value of the unemployment benefit. In that case the respective relative standard deviations of the vacancy-unemployment ratio are 7.9 and 3.9. The fact that these numbers are smaller than under our baseline calibration should not be surprising given that Hagedorn and Manowskii (2005) have found an important role of the unemployment benefit parameter for the results obtained. The same effect is also at work in our sticky price model. We conclude that there remains some puzzle because the labor market fluctuations generated by our model are generally still too small compared with the data. It is therefore natural to ask which economic features are useful extensions.

3.3 Extensions

In the following we discuss three extensions of our baseline model: real wage rigidity à la Hall (2005) and two features proposed by Rotemberg (2006), namely economies of scale in the technology of vacancy posting and exogenous markup shocks. We assess the extent to which these features play out in ways that are different from the economic mechanisms that have been identified in the context of flexible price models.

3.3.1 Real Wage Rigidity

Shimer (2005) proposes real wage rigidity à la Hall (2005) as a candidate explanation for the labor market puzzle. It is straightforward to add that feature to our model. We assume a wage norm, $\overline{W}$ (equal to the steady state real wage) and a parameter δ measuring its weight in the determination of the real wage. We therefore have

$$W_t = \delta \overline{W} + (1-\delta) W_t^b, \tag{35}$$

where W_t^b is the bargained real wage, as given by equation (14). The implied expression for the price of intermediate goods reads

$$P_t^x = \frac{\delta \overline{W} + (1-\delta)\, \phi \chi C_t H_t^{\eta}}{\left[1-(1-\delta)(1-\phi)\right] \zeta X_t / H_t}.$$

This extension allows us to analyze the extent to which real wage rigidity helps explain the labor market facts. The results are shown in Table 3.

Table 3: Real wage rigidity (RWR with $\delta = 0.5$)			
Model	$\frac{std(V/U)}{std(Y/N)}$	$corr\,(U,V)$	$\frac{std(Y/NH)}{std(Y/N)}$
Baseline with RWR	10.3	-0.87	0.83
Flexible prices and RWR	11.9	-0.95	0.60
Flex price, fixed hours, RWR	18.2	-0.95	1

Real wage rigidity implies a stronger Beveridge curve which brings the model closer to the data along that dimension. On the other hand, the feature of real wage rigidity implies a standard deviation of the vacancy-unemployment ratio relative to the standard deviation of average labor productivity which is smaller and hence less in line with the data than it is the case under our baseline calibration. This is our second main result. The intuition is as follows. Real wage rigidity reduces the extent to which an increase in the use of hours associated with an increase in demand translates into a price increase for intermediate goods. Conditional on a demand shock the incentive to post vacancies is therefore reduced with respect to our baseline case. Of course, there is a second effect which turns out to be less important than the first one under our baseline calibration: Conditional on a technology shock the presence of real wage rigidity implies that the associated reduction in hours results in a relatively small drop in the price for intermediate goods. The incentive to post vacancies is therefore reduced by less than it is the case in the absence of real wage rigidity. Consistent with that intuition we find that the feature of real wage rigidity increases the relative standard deviation of the vacancy-unemployment ratio if prices are assumed to be fully flexible. This is shown in the third row of Table 3. Finally, and also consistent with our intuition, we observe that the ability of real wage rigidity to imply a large relative standard deviation of the vacancy-unemployment ratio seems to rely on the assumption, which is often made, that labor adjustment takes place at the extensive margin only. That is counterfactual and not innocuous for the results obtained, as the last row of Table 3 shows.

3.3.2 Markup Shocks and Economies of Scale in the Technology of Vacancy Posting

Rotemberg (2006) notes that reductions in market power that lead firms to hire additional workers do not necessarily lead to large increases in labor productivity. In addition, Rotemberg argues convincingly that economies of scale in the technology of vacancy posting are a natural assumption. Rotemberg (2006) and Trigari (2006) in her comment emphasize that these two features help explain the unemployment volatility puzzle. In what follows we add the two Rotemberg features to our model, one at a time. The results are shown in Table 4.

Table 4: Rotemberg's remedies

Model	$\frac{std(V/U)}{std(Y/N)}$	$corr\ (U,V)$	$\frac{std(Y/NH)}{std(Y/N)}$
Baseline with $\epsilon_V = 0.645$	20.0	-0.58	0.83
Baseline with $\frac{std(\epsilon)}{std(y)} = 12.8$	20.0	-0.93	0.83

We find that both features are useful extensions of our model. Nevertheless, only under extreme parametrizations of the Rotemberg features does our model imply that the standard deviation of the vacancy-unemployment ratio is about 20 times as large as the standard deviation of average labor productivity, as in the data. It should also be noted that economies of scale in the technology of vacancy posting imply that our model features only a small Beveridge curve correlation. On the other hand, shocks to the elasticity of substitution between goods, ε, help explain both the relative standard deviation of the vacancy-unemployment ratio and the Beveridge curve.

4 Conclusion

We show that search and matching frictions can generate an important part of the observed business-cycle fluctuations in unemployment and job vacancies in response to shocks of a plausible magnitude. The main mechanism behind that result is simple: Demand shocks give a strong incentive to demand-constrained firms to adjust labor input. We also show that the prominent feature of real wage rigidity does not help explain the remaining part of the labor market puzzle. Finally, the features advocated by Rotemberg (2006), namely economies of scale in the technology of vacancy posting and exogenous markup shocks are found to be useful extensions of our model. Finally, our New Keynesian perspective on labor market dynamics leads us to think that economic mechanisms which imply additional volatility in the average marginal cost will be needed to make further progress in understanding the labor market dynamics. Clearly, structural model estimation will be needed to conduct the counter-factual simulations that will allow to tell which features will ultimately be regarded as the solution to the unemployment volatility puzzle. The recent paper by Gertler et al. (2007) is a step in that direction.

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