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THE UNEMPLOYMENT VOLATILITY PUZZLE: IS WAGE STICKINESS THE ANSWER?

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I discuss the failure of the canonical search and matching model to match the cyclical volatility in the job finding rate. I show that job creation in the model is influenced by wages in new matches. I summarize microeconometric evidence and find that wages in new matches are volatile and consistent with the model's key predictions. Therefore, explanations of the unemployment volatility puzzle have to preserve the cyclical volatility of wages. I discuss a modification of the model, based on fixed matching costs, that can increase cyclical unemployment volatility and is consistent with wage flexibility in new matches.

KEYWORDS: Unemployment volatility puzzle, wage stickiness, search and matching, Nash wage equation.

JOBS IN THE SEARCH AND MATCHING MODEL are characterized by monopoly rents, due to the matching frictions that give rise to search costs and unemployment. Despite notable recent exceptions, most of the literature assumes that the rents are shared through continuous recontracting between the firm and the worker, and uses the Nash solution to the wage bargain to derive the wage rate. The outcome is the "Nash wage equation," which gives the wage rate as a linear combination of the productivity of the match and the worker's returns from search and other nonmarket activities. Pissarides (1985) and Mortensen and Pissarides (1994) have shown that because the returns from nonmarket activities are less cyclical than the value of labor product, wages are less cyclical and employment is more cyclical in search and matching equilibrium than in a competitive market-clearing model.

Shimer (2005a), however, argued that under common parameter values, the Nash wage rate is close to being as cyclical as productivity, and so the model does not have enough power to generate the observed cyclical volatility in its key variable—the ratio of job vacancies to unemployment ("tightness"). The model can explain more volatility in employment and less in wages than the competitive model does, as shown in calibrated business cycles models, but the volatility in unemployment that it can explain is tiny compared with the data.[2]

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[2]See Hornstein, Krusell, and Violante (2005), Mortensen and Nagypal (2007), and Yashiv (2007) for a discussion of several issues related to this controversy. When matching frictions are

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I call the failure of the model to match the observed volatility of unemployment the unemployment volatility puzzle. I discuss this puzzle in a simple search and matching model, focusing on the role of wages. The model has only one driving force—the average product of labor (which in the canonical model is always equal to the marginal product). With this restriction, it is easy to show that the canonical model can deliver nontrivial volatility in unemployment only if there is at least some wage stickiness, defined as a wage rate that changes less than in proportion to the average product of labor over the cycle (see Hall and Milgrom (2008)). In the context of Shimer's claims, the search and matching model has one big advantage over the competitive model: it is immune to Barro's (1977) critique that in a rational equilibrium wage stickiness should not cause employment volatility. Moreover, as Hall (2005a) noted, there are rent division rules that stabilize the wage without violating either side's production participation constraints, and thus make the employer's profit from a new hire more cyclical than implied by the Nash wage rate. These rules imply a wide range of volatility of labor-market tightness, including the observed level of volatility. These findings, and the commonly held view that wages are sticky over the cycle, seemed to point to the conclusion that a solution to the unemployment volatility puzzle is an alternative to the Nash wage equation that delivers more wage stickiness.

Whether or not another wage equation is the answer to the unemployment volatility puzzle depends on the consistency between the model's wage equation and the empirical evidence. The commonly held view that wages are sticky over the cycle is derived mainly from time-series evidence, starting with the famous Keynes–Tarshis–Dunlop controversy, but this evidence is not relevant for the search and matching model.[3] I reexamine the evidence in the context of the search and matching model, and find that the answer is not as simple as implied by the argument of the preceding paragraph.

In the search and matching model, the timing of wage payments during the job's tenure is not important for job creation. Job creation is driven by the difference between the expected productivity and the expected cost of labor in new matches. I demonstrate that as long as the firm and the worker use the Nash wage rule to split rents at the time of job creation, the job creation conditions are unaffected by the rule used to split rents in ongoing jobs. So wages in continuing jobs may be completely fixed, and yet, if wages in new matches satisfy the Nash wage equation, the volatility of job creation will be unaffected by their wage stickiness. The wage stickiness that matters in this model

incorporated into the conventional real business cycle model, the standard results are replicated and there is an improvement in the model's performance with respect to employment. See Langot (1995), Merz (1995), Andolfatto (1996), and den Haan, Ramey, and Watson (2000). See also Cole and Rogerson (1999). But none of these papers explicitly addressed the issue of unemployment volatility.

[3]See Brandolini (1995) and Abraham and Haltiwanger (1995) for surveys of the time-series evidence.

is therefore wage stickiness in new matches, and the model's Nash wage equation should be compared with the empirical evidence relating only to wages in new matches.[4]

I summarize the existing empirical evidence about the cyclicality of wages in new matches and find that the model's Nash wage equation gets it about right: there is as much cyclicality in the empirical wage equations for new jobs as in the simple wage equation derived in the canonical model. The Nash wage equation implies too much cyclical volatility for wages in ongoing jobs, but this cyclicality is irrelevant for job creation. Moreover, this is true both in the United States and, perhaps more surprisingly, in the main European economies for which there are relevant data.

I conclude that a good explanation of the unemployment volatility puzzle needs to be consistent with the observed proportionality (or near proportionality) between wages in new matches and labor productivity. Models that imply nontrivial departures from unit elasticity between wages in new matches and productivity go against a large body of evidence.

I show in this paper that a small modification to the model, that maintains the usual parameter values used in calibrations, can deliver more volatility in the job finding rate without departing from wage flexibility in new jobs. The modification is in the way in which matching costs are modeled. In the canonical model, matching costs (other than foregone output) are proportional to the duration of a vacancy. This is a very strong assumption, because if, following a positive productivity shock, the duration of vacancies increases, the firm's cost of meeting a worker increases in proportion to the increase in duration. This discourages firms from posting many more vacancies when positive shocks arrive. If instead costs rise less than in proportion to the duration of vacancies, the firm's incentives to post vacancies remain high. I show that a simple remodeling of the costs from proportional to partly fixed and partly proportional can increase the volatility of tightness and job finding, virtually matching the observed magnitudes, without violating wage flexibility. I argue that the assumption that there are fixed costs to job creation is in itself a realistic assumption. These costs include the costs of negotiating with the successful job applicant, putting her on the firm's payroll, and training her.[5]

Hagedorn and Manovskii (2008) have used a calibration technique different from Shimer's (2005a) to conclude that the typical worker's nonmarket

[4]A similar argument was independently put forward by Haefke, Sonntag, and van Rens (2007), who also reported empirical estimates motivated by the model. See also Shimer (2004) for a discussion of similar issues.

[5]Hall and Milgrom (2008) changed the wage bargain to one of strategic (sequential) bargaining with delay costs. They showed that the model delivers the required unemployment volatility and avoids unrealistic wage stickiness. The fixed costs that I introduce in the model with the Nash wage equation play a similar role to their negotiation costs, but in their model the negotiation costs are not paid in equilibrium. Mortensen and Nagypal (2007) also showed that training costs increase the volatility of job finding.

returns are high, about 95% of market returns, and the share of labor in the wage bargain is low. With these parameters, the model can calibrate the observed cyclical volatility in tightness with near proportional wages. The model (at least in its canonical form) is subject to two other criticisms, however, even if one accepts that the improvement in a person's welfare from job acceptance can be that small. Costain and Reiter (2008) noted, in a paper that anticipated to some extent both the Shimer (2005a) critique and the Hagedorn and Manovskii (2008) response, that if nonmarket returns are high, the response of unemployment to labor-market policy, in particular unemployment insurance, is too large.[6] Hall and Milgrom (2008) also noted that the Hagedorn and Manovskii calibrations imply too high a labor supply elasticity, given empirical estimates. This research has brought out a general point: if a calibration of the canonical model implies that, on average, equilibrium wages are closer to productivity, it also implies an amplification of the impact of productivity shocks on unemployment without violating the near proportionality of wages in new jobs. The reason for this is that the profit margin becomes small, so small productivity shocks cause large proportional changes in profits, even if wages are near proportional to productivity.

In the remainder of this paper, I first briefly discuss some issues in the dynamic evolution of unemployment, in particular, the role of movements in and out of the labor force, and flows between employment and unemployment (Section 1). Following this, I derive the key cyclical elasticities of tightness and wages from a simple search and matching model with endogenous job finding but exogenous job separations (Sections 2 and 3). I then survey the econometric evidence on wages and show that the estimated elasticities for new jobs match the model's calibrated elasticities (Section 4). I finally discuss the role of matching costs and nonmarket returns for the cyclical volatilities of the model (Section 5).

1. WHAT DRIVES THE DYNAMICS OF UNEMPLOYMENT?

The approach that I follow in this paper is to derive the impact of cyclical shocks on unemployment by modeling the flows in and out of unemployment. Two questions immediately arise: First, do we lose essential generality if we ignore transitions between unemployment and out of the labor force?; second, should we model cyclicality in both the flows in and the flows out of unemployment? The answer to these questions for the conventional rate of unemployment is no to the first and yes to the second.

[6]Policy effects might be dampened if the production function is such that a policy-induced fall in employment increases the average and marginal product of labor. Hagedorn, Manovskii, and Stetsenko (2008) obtained such an effect from the assumption of labor heterogeneity with imperfect substitutability between skilled and unskilled workers, and from complementarity between capital and skilled labor.

The flow rates between activity and inactivity show some cyclicality, but several investigators have concluded that they do not contribute substantially to the cyclical volatility of unemployment (see Shimer (2005b), Hall (2005b), Braun, De Bock, and DiCecio (2006), Elsby, Michaels, and Solon (2009), and Fujita and Ramey (2009)). The rate of inactivity itself is nearly acyclical, and the correlation between the cyclical components of the rates of unemployment and employment is -0.95. I therefore focus on a simple two-state model, with workers moving between the states of unemployment and employment in response to shocks. This is also the focus of the canonical model that has recently come under scrutiny.

In a two-state model, I define the change in the unemployment rate,

$$\Delta u_t = s_t(1 - u_t) - f_t u_t,$$

where s_t is the flow rate between employment and unemployment during period t (the inflow, defined as the total number of workers who move from employment to unemployment divided by the number of employed workers) and f_t is the flow rate in the other direction (the outflow, defined as the number of workers who move from unemployment to employment divided by the number of unemployed workers). If the two flow rates remain constant at s and f for a sufficiently long time, unemployment converges to the steady-state rate

$$u = \frac{s}{s+f}. \tag{1}$$

With quarterly data on unemployment stocks and flows, constructed under the assumption that s and f are constant during the quarter, the unemployment rate obtained from (1) is virtually indistinguishable from the actual unemployment rate.[7] I therefore use (1) as my unemployment equation throughout this paper. Taking first differences of (1), I find that the change in the rate of unemployment from quarter $t-1$ to quarter t is given by

$$\Delta u_t = (1 - u_t)u_{t-1}\frac{\Delta s_t}{s_{t-1}} - u_t(1 - u_{t-1})\frac{\Delta f_t}{f_{t-1}}. \tag{2}$$

Figure 1 shows the contribution of each flow rate to the change in unemployment. The flow rates are derived from the quarterly job finding and job exit probabilities constructed by Shimer (2005b) and available online, and the two series shown in Figure 1 are for each of the terms on the right side of (2). Clearly, both rates contribute to the change in the unemployment rate. Their correlation coefficient is -0.5, so on average their contribution is in the same

[7]See Shimer (2005b), where constructed quarterly time-series data for the flows are also available for downloading (http://robert.shimer.googlepages.com/flows). The same appears true of economies with longer durations in each state, as in pre-1980s Britain. See Pissarides (1986).

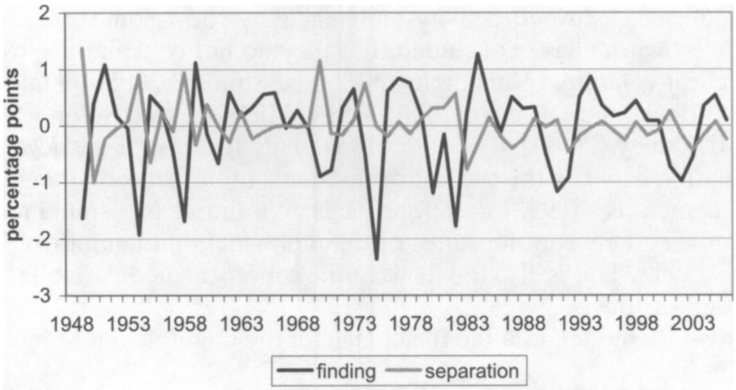

FIGURE 1.—Contribution of job finding and job separation rates to changes in unemployment.

direction. A consensus estimate in the literature for the contribution of the inflow rate lies between one-third and one-half of the total.[8]

2. THE CANONICAL MODEL

The recent literature has either ignored the inflow rate when studying the cyclical dynamics of unemployment or treated shocks to the inflow rate as one of the exogenous forces driving changes in the outflow rate. But because more low-productivity jobs are destroyed in recession (e.g., Solon, Barsky, and Parker (1994)), at least some part of job separations is driven by endogenous decisions in response to aggregate productivity shocks. If all job destruction were driven by exogenous separation shocks, the jobs destroyed in recession would be a random draw from the productivity distribution.

The model of Mortensen and Pissarides (1994) accounts for the volatility in the flow into unemployment through the endogenous job destruction decisions of firms. An important implication of the endogeneity of job destruction, related to the composition bias of the empirical literature, is the following. Compare the impact of exogenous and endogenous job destruction shocks on the expected profit from a new job position. Exogenous job destruction shocks are equivalent to shocks to the discount rate applied to the flow of output from all

[8]See the references cited earlier in this section. Of course, the question of the cyclicality of unemployment flows is quite distinct from the question of the cyclicality of job flows. Concerning especially the flow out of jobs, one can distinguish between the flow of workers from employment to unemployment (the focus of this paper), the flow of workers out of jobs (the *separation* rate), and the flow of jobs from activity to inactivity (the *job destruction* rate). See, for example, Davis, Haltiwanger, and Schuh (1996) and Hall (2005b). Because of the abstractions of the model, I often refer to the unemployment outflow rate as the job creation or job finding rate and refer to the unemployment inflow rate as the job destruction or job separation rate.

jobs, so they have an impact on the present discounted value of profits and on job creation. But endogenous job destruction due to productivity shocks does not have an impact on job creation in the neighborhood of equilibrium, essentially because of the envelope theorem. In the canonical model, both the entry of new vacancies and the choice of reservation productivity that governs job destruction maximize the value of a vacant job. The impact that small productivity shocks have on the entry of vacancies is unaffected by the response of the reservation productivity to the same productivity shocks. Intuitively, following a small negative shock to productivity, the productivity of the jobs destroyed is close to the reservation value and so their profit flow is zero. Their disappearance does not affect the present discounted value of the profit from the average job that governs job creation.[9]

The only types of shocks that I study in this paper are productivity shocks. By the argument of the preceding paragraph, I can derive their impact on job creation from a model with constant job destruction rate, which helps make my argument more transparent. Their impact on job destruction requires, in addition, the endogenous job destruction margin of the Mortensen–Pissarides model. To compute the quantitative impact of productivity shocks on job destruction in the Mortensen–Pissarides model, I require knowledge of the parameters of the process that brings idiosyncratic productivity shocks to active jobs. We do not yet know enough about the quantitative properties of this process to calibrate it independently of the observed job creation and job destruction rates. For this reason, I focus here on the unemployment outflow rate shown in Figure 1, for which the model makes strong quantitative predictions, and leave the quantitative evaluation of the model's inflow rate for future research.[10]

My objective is to compare the second moments of the endogenous variables, in particular unemployment, vacancies, and wages, with the second moment of labor productivity. But because the matching flows are large and there is a lot of persistence in productivity when compared with the speed at which unemployment approaches its steady state, I can approximate the cyclical results by comparative static results with a continuous-time model that compares steady states at different realizations of labor productivity (Shimer (2005a)).

[9]This claim is spelt out more fully and more formally in the longer version of this paper that circulated as Centre for Economic Performance (LSE) Discussion Paper 0839 (November 2007). It is also available on my web page, http://personal.lse.ac.uk/pissarid/.

[10]In the longer version of the paper cited in the preceding footnote, I calibrated a particular version of the model with endogenous job destruction and uniform idiosyncratic productivity shocks. The calibration results for the job creation rate are the same as in the shorter model in this paper. Recently, Menzio and Shi (2008) used the tenure distribution to "back out" the distribution of idiosyncratic productivities across active jobs. Although this is a promising avenue for calibrating the steady-state distribution, it still leaves open the question of shocks to the idiosyncratic productivity, their frequency, and their intensity. Menzio and Shi bypassed this difficulty by assuming that there are no idiosyncratic shocks.

In the simple version of the model (Pissarides (2000, Chap. 1)), the flow of workers from employment to unemployment is the result of a negative shock that hits occupied jobs at constant rate s; I refer to this as the job separation rate. The flow of workers from unemployment to employment is derived from the rate at which unemployed workers are matched to vacant jobs; I refer to this as the job finding rate. Matching is pairwise and random, and is given by the aggregate matching function $m(u, v)$, which is concave in its arguments and homogenous of degree 1. The arguments are the measures of unemployment and vacancies, the first describing the state of the system at any point in time and the second resulting from the profit maximization decisions of firms. The transition rate for each vacant job is the average $m(u/v, 1) \equiv q(\theta)$, where $\theta \equiv v/u$ is the tightness of the market and $q'(\theta) < 0$. The transition rate for unemployed workers is $f(\theta) \equiv m(1, v/u) = \theta q(\theta)$ and $f'(\theta) > 0$. With knowledge of s and f, we get the unemployment rate from (1).

2.1. *Job Creation*

The utility function of both workers and firms is linear. Unemployed workers enjoy some imputed income z during unemployment, which has to be given up when they take a job. The job creation decision is initiated by an employer when she posts a vacancy, at a flow cost c for the duration of the vacancy. A *search equilibrium* is a pair (θ, w) that simultaneously solves the job creation condition and the wage rule.

To derive the job creation condition, let V be the value of a new vacancy to an employer. It satisfies the Bellman equation

$$rV = -c + q(\theta)(J - V). \tag{3}$$

J is the value of an occupied job and satisfies

$$rJ = p - w - sJ, \tag{4}$$

where r represents the risk-free interest rate, and the assumption is made that a destroyed job has zero value to the employer. Vacancy creation exhausts all available profits, so the *job creation condition* is

$$V = 0 \quad \Longleftrightarrow \quad \frac{p - w}{r + s} = \frac{c}{q(\theta)}. \tag{5}$$

2.2. *Wages*

The canonical model assumes that wages share the surplus from the job in fixed proportions at all times. If we let W be the worker's expected returns from holding a job and let U be the expected returns from unemployment, wages solve

$$W - U = \beta(J + W - V - U), \quad \beta \in [0, 1). \tag{6}$$

This sharing rule can be derived as the solution to a generalized Nash bargaining problem

$$w = \arg\max\{(W-U)^{\beta}(J-V)^{1-\beta}\}$$

and is referred to as the Nash sharing rule or simply as the Nash wage. Given (4) and the equivalent equation satisfied by W,

$$rW = w - s(W-U), \tag{7}$$

the wage equation also satisfies, in general,

$$w = rU + \beta(p - rU - (r+s)V). \tag{8}$$

This equation makes clear that there are three separate channels through which a shock to productivity is transmitted to wages. First, there is a direct effect from the own-job productivity that is due to the sharing assumptions, the p term in (8); second and third, there are indirect effects that transmit shocks to p through changes in the reservation values of the firm and the worker. The controversy surrounding wages centers on the role of the reservation values in wage determination, which in the Nash wage rule have maximum impact because they define the "threat points" of the firm and the worker.[11]

The solution commonly found in the literature is derived from (8) by using the expression for the value of unemployment and the job creation condition to substitute out the reservation values. We first note that because of (3), (5), and (6),

$$\begin{aligned} rU &= z + f(\theta)(W-U) \\ &= z + f(\theta)\frac{\beta}{1-\beta}(J-V) \\ &= z + \frac{\beta}{1-\beta}c\theta. \end{aligned} \tag{9}$$

The wage equation is

$$w = (1-\beta)z + \beta(p + c\theta). \tag{10}$$

The job creation condition (5) slopes down in (θ, w) space and the wage equation (10) slopes up, giving a unique equilibrium tightness–wage pair. Given tightness, equation (1) delivers the unemployment rate.

[11]Note that because the vacancy value is lost at rate s, whereas the value of unemployment is never lost, the value of a vacancy is discounted at rate $r+s$ whereas that of unemployment is discounted only at rate r.

2.3. *Wages in New and Continuing Jobs*

The Nash sharing rule in the canonical model holds at all times, irrespective of the tenure of the job. But this is not important for job creation in the model. If wages in new jobs are fixed by the Nash wage rule, the job creation condition is the same as that in the canonical model, irrespective of how wages are determined in subsequent job tenures. When I examine the empirical evidence on wages later in this paper, I find a sharp distinction between the wages in new matches and the wages in continuing jobs. In anticipation of the discussion of the empirical results that follows, I now demonstrate the equivalence of the job creation condition in the canonical model and in an alternative model where the Nash sharing rule holds only in new jobs.

A job is new when the firm and the worker first match, and remains "new" for an average period of length $1/\lambda$. At some constant rate λ it changes status to a continuing job. The event that changes the status of the job from new to continuing need not be specified. It might be connected with the arrival of aggregate or idiosyncratic shocks to productivity. To make the point more transparent, I first derive the wage equation and job creation condition under the assumption that the market is in stationary equilibrium at productivity p and tightness θ throughout the life of the job.[12]

The asset values of belonging to a new or continuing job are now, respectively, distinguished by superscript n or c. In continuing jobs, the asset values are as in (4) and (7), except that J, W, and w are distinguished by superscript c. In new jobs we now have

$$(11) \qquad (r+s)J^n = p - w^n + \lambda(J^c - J^n),$$

$$(12) \qquad (r+s)(W^n - U) = w^n + \lambda(W^c - W^n) - rU.$$

I define the surplus from new jobs as $S^n = J^n + W^n - U$. Making use of all asset-value equations for new and continuing jobs to calculate S^n, I obtain

$$(13) \qquad S^n = \frac{p - rU}{r+s}.$$

The duration of new jobs does not influence their net surplus.

I assume that the Nash sharing rule holds for new jobs but not necessarily for continuing jobs. The rule in (6) implies $J^n = (1-\beta)S^n$ and so job creation is given by

$$(14) \qquad (1-\beta)S^n = (1-\beta)\frac{p - rU}{r+s} = \frac{c}{q(\theta)}.$$

[12]Less strictly, the wage equation that I derive under this restriction is a good approximation to a wage equation for new jobs when the event that changes the status of the job arrives with much higher frequency than the event that changes productivity. But the main result holds in more general setups with appropriate modification of the Bellman equations.

From (9), which still holds for new jobs, I get the job creation condition for this model:

$$\frac{(1-\beta)(p-z)-\beta c\theta}{r+s}=\frac{c}{q(\theta)}. \tag{15}$$

The interesting property of (15) is that it is identical to the job creation condition of the canonical model, obtained when (10) is substituted into (5). Reversing this argument, we can define a "mean" wage $\bar{w}$ for a job by

$$\bar{w}=(1-\beta)z+\beta(p+c\theta), \tag{16}$$

use this as if it were the wage rate at every tenure, and derive the full solution for job creation. But this wage is identical to the Nash wage equation (10), although the Nash wage rule in this model holds only for new jobs with an arbitrary mean duration $1/\lambda$. Wages in continuing jobs can take on arbitrary values, since we derived (15) without imposing any restrictions on w^c.

Of course, wages in new and continuing jobs will not, in general, behave like the Nash wage if the Nash sharing rule is applied only to new jobs. Making use of the Nash sharing rule and the asset valuation equations to solve for wages in new jobs, I obtain

$$w^n=(1-\beta)z+\beta(p+c\theta)+\lambda(\beta J^c-(1-\beta)(W^c-U)). \tag{17}$$

This wage equation coincides with the Nash wage equation of the canonical model if wages in continuing jobs also satisfy the Nash sharing rule, because in this case $\beta J^c=(1-\beta)(W^c-U)$. But if the share of the firm in continuing jobs is bigger than required by Nash, the wage rate in new jobs is higher to compensate the worker, whereas if it is smaller, the opposite holds.

Now it is straightforward to show that if the change of job status coincides with a change in productivity and tightness (or any other variable), a wage equation like (17) still holds.[13] For the benefit of the analysis that follows, I therefore now assume that a match is formed in some state i but its status changes to a continuing match when a new state j arrives, which coincides with the arrival of a new productivity and tightness for all jobs. States alternate between i and j at the same constant rate λ. I can derive, with obvious notation,

$$w_i^n=(1-\beta)z+\beta(p_i+c\theta_i)+\lambda(\beta J_j^c-(1-\beta)(W_j^c-U_j)). \tag{18}$$

[13]The reason that I did not use this more general setup to make the previous point (that when wages in new jobs satisfy the Nash rule, job creation is the same as in the canonical model) is that in the more general setup, the mean wage equation in (16) is considerably more complicated. However, it still coincides with the equivalent equation when the Nash sharing rule applies to all jobs and there are productivity differences across jobs.

Let w_j^c be the continuation wage in state j, that is, the wage offered to those hired in state i or in state j in earlier periods, and assume that it is exogenous. Then substituting out of (18) the continuation values from the Bellman equations, I obtain

$$w_i^n = w_i^N + \frac{\lambda}{r+s+\lambda}(w_j^n - w_j^c), \tag{19}$$

where w_i^N is the Nash wage in state i, that is, the wage that satisfies (10) with p and θ qualified by subscript i. Equation (19) is intuitive. If $w_j^c = w_j^n$, the Nash sharing rule is used for both continuing and new jobs, so the wage equation is the equation of the canonical model. If continuation wages are expected to be higher than wages in new matches, new wages offered now are lower to compensate. I will return to this equation when I study wage volatility in new and old jobs.

3. SOLVING THE MODEL

3.1. *Parameter Values and Steady-State Solutions*

Given our interest in the job finding rate only, we can ignore for now the Beveridge curve (1) and focus on the two-equation system (5) and (10) in the two unknowns θ and w. I solve the model for monthly data with the parameters shown in Table I. I will return to the model with two wages after I derive the canonical solutions.

The matching function is assumed to be Cobb–Douglas $m = m_0 u^\eta v^{1-\eta}$, with unemployment elasticity $\eta = 0.5$ (see Petrongolo and Pissarides (2001)). Following common practice, I also assume $\beta = 0.5$, which internalizes the search

TABLE I

PARAMETER VALUES, QUARTERLY DATA

Parameter	Value	Description	Source/Target
r	0.004	Interest rate	Data
s	0.036	Exog. separations	Shimer (2005b)
z	0.71	Leisure and UI comp.	Hall–Milgrom (2008)
c	0.356	Vacancy cost	Mean θ
m_0	0.7	Matching fn. scale	Job finding probability
η	0.5	Matching fn. elasticity	Petrongolo–Pissarides (2001)
β	0.5	Share of labor	$\beta = \eta$ (efficiency)
		Data, Mean Values	
θ	0.72	Mean v/u (tightness)	JOLTS, HWI
$m_0\theta^{1-\eta}$	0.594	Job finding prob.	Shimer (2005b)

externalities.[14] The job finding rate is $f(\theta) = m_0\theta^{0.5}$. The sample mean for θ in 1960–2006 was 0.72, derived by making use of Job Openings and Labor Turnover Survey (JOLTS) data since December 2000 and the Help-Wanted Index (HWI) adjusted to the JOLTS units of measurement before then. Shimer's (2005b) monthly transitions data (under the assumption that monthly transition rates are constant within the quarter) give a mean value for 1960–2004 of 0.594 for the job finding rate and 0.036 for the job separation rate. The implied unemployment rate is 5.7%, very close to the actual mean. I set $s = 0.036$ and make use of the mean job finding rate and mean tightness value to solve for m_0. The result is $m_0 = 0.7$.

All costs and returns are normalized by the value of output, which is set to 1 in the initial equilibrium. The income equivalent that the unemployed give up to take a job was recently calculated by Hall and Milgrom (2008) to be 0.71; it includes both unemployment insurance and the value of time. The cost of advertising vacancies and recruiting is obtained from the steady-state solutions of the model; it is the value that gives $\theta = 0.72$ when all the other parameter values are set as above. We can check how plausible it is by computing the expected recruitment costs, $c/q(\theta) = 0.43$, giving that the expected recruitment cost is 43% of a month's output.

The solution for wages obtained in the steady state is $w = 0.98$. The percentage gain in flow receipts when a worker accepts a job is substantial, $100(0.98/0.71 - 1) = 38.4\%$. But the "permanent income" of employed workers is only marginally above the "permanent income" of unemployed workers, a consequence of the assumption of infinite horizons, short unemployment durations, and uniform unemployment incidence.

3.2. *Elasticities*

To compute the impact of productivity shocks on the model's unknowns, I differentiate the job creation condition and wage equation, and compute the elasticities at the steady-state solutions. The computed θ elasticity is 3.67. In his original critique of the search and matching model, Shimer (2005a) found an elasticity of 1.71. The target for this elasticity is 7.56, which would be the regression coefficient in a simple regression with tightness as the dependent variable and productivity as the independent variable.[15] Virtually the only reason for the difference in the two elasticities is due to z. The bigger z in our

[14]See Hall and Milgrom (2008) for a different motivation for $\beta \cong 0.5$, and see Hagedorn and Manovskii (2008) for reasons to select a much smaller value for β. As with β, the elasticity η plays some role in the quantitative solutions of the model, but within the small range of 0.5–0.7, which conforms to the empirical estimates reported in Petrongolo and Pissarides (2001), the solutions are robust to it.

[15]Shimer (2005a) set the target at 19.1, which is the ratio of the standard deviations of tightness and productivity. But this should be the target if there were no measurement or other random errors in the two variables and if no other shocks influenced tightness. To get the 7.56 target, I multiply by their correlation coefficient. See Shimer's paper for the data used here.

calibration has an impact because it reduces the firm's steady-state profit and so implies that cyclical shocks have a bigger proportional impact on profits. The change of z from 0.4 (Shimer's number) to our 0.71 increases the elasticity in our version of the model from 1.74 to 3.67.

The response of wages to the change in productivity is very close to proportionality. The wage–productivity elasticity is 0.985 and in the version of the model with $z = 0.4$, it is 1. This implication of the Nash wage equation was used to criticize it, because time-series data show substantial wage stickiness (see Section 4).[16] Two features of the model encouraged research in modifications of the model that might yield a stickier wage equation. First, the model can accommodate substantial wage stickiness without violating rationality, because of the local monopoly rents created by a job match (Hall's (2005a) point); second, even small amounts of wage stickiness can make a lot of difference in the response of job creation to productivity shocks.

To illustrate how much wage stickiness is needed to match the response of tightness to productivity shocks, let the elasticity of θ with respect to p be ε_θ and let the elasticity of wages be ε_w. From (5),

$$\varepsilon_\theta = \frac{1}{\eta}\frac{p - \varepsilon_w w}{p - w}. \tag{20}$$

If $\varepsilon_w = 1$, then $\varepsilon_\theta = 1/\eta = 2$, essentially the Shimer critique. Obviously, reducing ε_w increases ε_θ. As we noted before, in this model $\varepsilon_\theta = 3.67$, achieved by a wage elasticity $\varepsilon_w = 0.985$ and a solution for $w = 0.983$. How much wage stickiness is needed to hit the required θ elasticity of 7.56?

As is clear from (20), the answer to this question depends critically on how close w is to p. I rearrange (20) to obtain

$$\varepsilon_w^* = \frac{p}{w} - \varepsilon_\theta \frac{\eta(p - w)}{w}. \tag{21}$$

Using the same solution for w as in the model with the Nash wage equation and setting $\varepsilon_\theta = 7.56$ gives $\varepsilon_w^* = 0.885$. For solutions that yield a w closer to p, the required wage elasticity is closer to 1. In this simple model the distance of w from p is dictated largely by z, so its role is crucial in computing the wage elasticity needed to deliver the required volatility in the job finding rate. For $z = 0.4$, the required wage stickiness is $\varepsilon_w^* = 0.758$, whereas for $z = 0.9$, the computed Nash wage elasticity of 0.955 delivers even more volatility in θ than the required elasticity, with $\varepsilon_\theta = 11.07$.[17]

[16]Wage stickiness in this debate is loosely defined as a wage–productivity elasticity that is less than 1. I follow this practice.

[17]The latter is the point made by Hagedorn and Manovskii (2008).

3.3. *Wages in New Jobs*

I have argued that the job creation condition of the canonical model also holds in a model where the Nash sharing rule applies only to new jobs. The wage equation, however, differs in this case, as shown by equation (19), so its cyclical properties are also likely to differ. To derive precise dynamic properties of the initial wage, we need to know the dynamic properties of the continuation wage. Different models of the determination of the continuation wage, which have no implications for the volatility of job creation, will imply different wage elasticities for new matches. I derive here the elasticity of wages in new jobs for a popular class of models.

Suppose that when workers are hired in some state i, the wage rate is chosen to satisfy the Nash division rule, but then it is not varied again. So the continuation wage in a job created in state i is w_i^n and so in (19), $w_j^c = w_i^n$. This wage rule is inspired by the implicit contract models of Azariadis (1975) and Baily (1974). In their model workers are risk averse but firms are risk neutral, and there are stochastic productivity shocks. Once a worker is hired, it is to the advantage of the firm to hold the wage rate constant when a productivity shock arrives. The risk averse worker is made better off by the absence of income fluctuations and the risk neutral firm is not made worse off, as long as the mean value of profits is not affected by the productivity shocks over long periods of time.

The solution for wages when $w_j^c = w_i^n$ is substituted into (19) is

$$(22) \qquad w_i^n = \frac{r+s+\lambda}{r+s+2\lambda} w_i^N + \frac{\lambda}{r+s+2\lambda} w_j^n.$$

What is the response of new wages to changes in productivity p_i with this equation? We can answer this question in two ways. One, in keeping with the approach of the previous analysis, obtains the effect by log differentiating (22) with respect to p_i and p_j, that is, displaces productivities throughout the job tenure by the same proportion. A second approach, however, is more appropriate to this particular example. Since w_i^n are wages in new jobs when productivity is p_i and w_j^n are wages in new jobs when productivity is p_j, the cyclicality of new wages can be approximated by the ratio of the log difference between w_j^n and w_i^n to the log difference between p_j and p_i.

For the first approach, I assume that the elasticity of new wages with respect to same-state productivity is common across states and denoted by ε_n, and that the Nash wage elasticity is, as before, ε_w. Differentiating (22), I derive

$$(23) \qquad \varepsilon_n = \varepsilon_w \frac{(r+s+\lambda) w_i^N / w_i^n}{r+s+\lambda+\lambda(1-w_j^n/w_i^n)}.$$

Calibrating this wage elasticity precisely requires parameters for which we do not have information, but we can argue that it is likely to be very close to the Nash wage elasticity. First, suppose we evaluate it, as an approximation, at the point where new wages are equal (in level) to the Nash wage equation. Then the elasticity is precisely equal to the Nash wage elasticity. Next, suppose $p_i > p_j$, and so $w_i^n > w_j^n$ and $w_i^n < w_i^N$. Then both the numerator of (23) and λ in the denominator are multiplied by numbers bigger than 1, which have an offsetting impact on the ratio $\varepsilon_n/\varepsilon_w$. The same happens if $p_i < p_j$, as can easily be checked.

To calculate the cyclical response of new wages by making use of the log difference between w_i^n and w_j^n, I note that the ratio of the elasticities $\varepsilon_n/\varepsilon_w$ is to a good approximation equal to the ratio of the proportional changes in wages in new jobs and the Nash wage:

$$\text{(24)} \qquad \frac{\varepsilon_n}{\varepsilon_w} = \left(\frac{w_j^n - w_i^n}{w_j^n + w_i^n}\right) \Big/ \left(\frac{w_j^N - w_i^N}{w_j^N + w_i^N}\right).$$

To compute this ratio, I substitute w_i^n from (22) and w_j^n from the equivalent equation for it into (24), and noting that the economy alternates periodically between the two states, I obtain

$$\text{(25)} \qquad \frac{\varepsilon_n}{\varepsilon_w} = \frac{r+s+\lambda}{r+s+3\lambda}.$$

Under this formulation the ratio of the elasticities is constant and less than 1. If we assume that the periodic productivity shocks have typical cyclical durations, about four years, then a reasonable assumption for monthly data is $\lambda = 0.02$ The elasticity ratio in (25) is then 0.6, so if the model predicts a Nash elasticity of about 1, the predicted elasticity of wages in new jobs in this particular example is about 0.6.

Of course, wages in ongoing jobs do show some cyclicality. A modification to the implicit contract model by Beaudry and DiNardo (1991) to take into account quitting behavior by workers employed in continuing jobs implies the following. When workers are hired in a good state, for example, when $p_i > p_j$, wage behavior is described well by the assumptions underlying (22). Firms insure these workers against negative shocks. But when workers are hired in a low state, the outside wage offers when the good state arrives are higher than their own continuation wage, so they have an incentive to quit. Quitting is suboptimal in this model for both the individual agents and the social planner, because all jobs have the same productivity, and there are costs to recruiting and (possibly) job changing. The firm responds optimally to raise the wage and match outside wage offers. It follows that the Nash division rule holds also for the continuation state when workers are hired in the poor state. Therefore, wages in new jobs in this case satisfy the Nash wage equation precisely and so does their elasticity (see equation (18)).

More generally, if wages in continuing jobs respond to productivity shocks at some fraction k of the response of wages in new jobs, that is, if $w_j^c - w_i^n = k(w_j^n - w_i^n)$, the elasticity ratio in (25) becomes

$$\frac{\varepsilon_n}{\varepsilon_w} = \frac{r+s+\lambda}{r+s+\lambda+2\lambda(1-k)}. \tag{26}$$

So the bigger is the response of the continuation wage to productivity shocks, the closer the elasticity of wages in new matches gets to the Nash wage elasticity of the model, with an upper limit of 1.[18]

4. WHAT DO WAGE EQUATIONS SHOW?

The first and most influential studies of cyclical wage stickiness were based on time-series regressions derived either from single-equation or small aggregate models of the economy.[19] These studies were stimulated by the controversy between Keynes, his followers, and his critics (in particular Dunlop and Tarshis) about the role of wage stickiness in the business cycle. They continued well into the 1980s. Their findings are mixed. Results are sensitive to the specification used and to the sample period. Time-series data before 1960 show less wage cyclicality than data since 1970. A robust finding of these studies is that whichever way the cyclicality of wages goes, it is not very much; that is, wages are sticky, and may exhibit a limited degree of pro- or countercyclicality depending on time period, deflator used, coverage, and other issues.

These time-series studies have been extremely influential in shaping the opinions of macroeconomists about wage stickiness, giving rise to a consensus that made it into most textbooks. But their findings are not relevant to the search and matching model. As we argued, the profit measure that matters for job creation in the search and matching model is the share of a new match claimed by the firm. Given this share, the timing of wage payments is irrelevant and it is in this spirit that we were able to show that once wages in new matches satisfy the Nash wage rule, job creation also satisfies the formulas of the canonical model, irrespective of what happens to wages in ongoing jobs. Moreover,

[18]There are other explanations in the literature that draw a distinction between starting and continuation wages. Shaked and Sutton (1984), Thomas and Worral (1988), MacCleod and Malcomson (1993), and others argued that once a job is formed, wages change only when a shock makes the participation constraints of either side binding. The cyclicality of wages should fall with tenure because many jobs do not hit the participation constraints in response to cyclical shocks. Arozamena and Centero (2006) built on the common argument that incumbents with long tenures accumulate job-specific capital to give another reason why the cyclicality of wages should fall with tenure.

[19]This is not a comprehensive survey of the empirical literature, but a selective discussion of results that bear directly on the model. For good surveys of the main issues and the main empirical findings, see Brandolini (1995) and Abraham and Haltiwanger (1995).

even if the distinction between new and old matches is overlooked, the search and matching model is concerned with the cyclicality of wages in individual matches, not the average in the economy as a whole. In this connection there appears to be a strong countercyclical bias in the mean wages analyzed in the aggregate studies, at least during the 1970s and 1980s.[20] The bias is due mainly to the fact that low-wage, low-skill workers bear the brunt of cyclical adjustments and so their weight in aggregate data is bigger in cyclical peaks than in troughs.

In view of this, the results of panel regressions of individual workers, or matches, are more relevant to the search and matching model than the results of aggregate studies. These results favor strong procyclicality of wages in new matches.[21] Panel studies typically run a wage log change regression for the individuals in their panel on a set of personal characteristics, such as tenure, experience and education, regional or industry dummies, and time dummies. The coefficients on the time dummies are then used in a second regression as the dependent variable with a time trend and a cyclical indicator variable as regressors. Tables II and III summarize the results of individual studies of wage behavior, focusing on studies that draw a distinction between continuing jobs and new matches. The tables give the coefficient estimated in the second regression for the cyclical indicator, which is the change in national unemployment. The numbers given are the annual percentage change in wages when national unemployment falls by 1 percentage point from one year to the next. Figure 2 shows the estimated cyclical component for wages in new and continuing matches from Devereux's (2001) Panel Study of Income Dynamics (PSID) study.[22]

Some facts readily emerge. First, the wages of job changers are always substantially more procyclical than the wages of job stayers. The same fact is reflected in studies that draw a distinction between the wages of stayers and the wages of all workers. The wages of all workers are always more procyclical than the wages of job stayers. Second, the wages of job stayers, and even of those who remain in the same job with the same employer (Devereux (2001), Shin and Solon (2006)), are still mildly procyclical. Perhaps surprisingly, there is more procyclicality in the wages of stayers in Europe than in the United States. The procyclicality of job stayers' wages is sometimes due to bonuses, overtime pay, and the like, but it still reflects a rise in the hourly cost of labor to the firm in cyclical peaks.

The cyclical indicator variable used in the panel studies is usually national unemployment, following the lead of Bils (1985). A consensus estimate of the

[20]See Solon, Barsky, and Parker (1994) and the discussion in Abraham and Haltiwanger (1995, Section V).

[21]The panel studies cover data from 1970 onward and the recession of the 1970s appears to be a particularly procyclical wage episode. The discussion that follows is entirely about wages since the late 1960s; earlier cycles may be different.

[22]I am grateful to Paul Devereux for making these data available.

TABLE II

ESTIMATES OF THE CYCLICALITY OF HOURLY WAGES, UNITED STATES[a]

Author	Data	Coefficient on $-\Delta u \times 100$	
Bils (1985)	NLSY	All (whites/nonwh.)	1.6/1.8
	1966–1980	Stayers	0.6/0.4
		Changers	3.0/4.0
Shin (1994)	NLSY	All (whites/nonwh.)	1.7/1.4
	1966–1981	Stayers	1.2/0.2
		Changers	2.7/3.8
Barlevi (2001)	PSID, 1968–1993	Changers	2.59
	NLSY, 1979–1993	Changers	3.00
Beaudry and DiNardo (1991)	PSID	All, cont. u	0.7
	1976–1984	All, initial u	0.6
		All, min. u	2.9
	CPS	All, cont. u	0.0
	1979, 1983	All, initial u	0.0
		All, min. u	3.1
Grant (2003)	NLSY	All, cont. u	2.37
	1966–1981	All, initial u	0.60
		All, min. u	2.29
Solon, Barsky, and Parker (1994)	PSID	All men	1.40
	1968–1987	All women	0.53
		Stayers, men	1.24
Devereux (2001)	PSID	All	1.16
	1970–1991	Stayers	0.81
		Single job holders	0.54
Shin and Solon (2006)	NLSY	All	1.37
	1979–1993	Stayers	1.17
		Single job holders	1.13

[a]The dependent variable is the annual change in the log of hourly earnings, obtained from the estimated coefficients on annual time dummies in individual wage regressions. Results are for men, unless otherwise stated. Unemployment is national unemployment in percent, except for Barlevi's study, which uses state unemployment. In Beaudry and DiNardo's and Grant's studies the results shown are from regressions with three independent unemployment variables: (i) contemporaneous unemployment; (ii) unemployment at start of job; (iii) lowest unemployment since start of job. Acronyms used: National Longitudinal Surveys of Youths (NLSY); Current Population Survey (CPS).

coefficient in wage regressions for job changers is close to 3, that is, for every percentage point rise in unemployment, the wages in new matches are lower by about 3%. Converting the empirical estimates to an overall impact of the cyclical component of hourly productivity on wages gives results that are very close to the model's predictions.

In the model, the total elasticity of wages with respect to mean productivity is in the range 0.98–1. If wages in ongoing jobs do not satisfy the Nash

TABLE III

ESTIMATES OF THE CYCLICALITY OF HOURLY WAGES, EUROPE[a]

Author	Data[b]	Coefficient on $-\Delta u \times 100$	
Devereux and Hart (2006)	U.K. NESPD (admin.) 1975–2001	Stayers (men/women)	1.93/1.93
		Movers within co.	2.28/2.31
		Movers between co.	2.96/2.84
Peng and Siebert (2007)	U.K. BHPS 1991–2004	Stayers	2.19
		Movers within co.	2.27
		Movers between co.	2.89
	W. Germany GSOEP 1984–2002	Stayers	1.61
		Movers within co.	3.43
		Movers between co.	3.44
Peng and Siebert (2006)	N. Italy ECHP 1994–2001	Stayers	3.60
		Movers within co.	6.63
		Movers between co.	5.61
Carneiro and Portugal (2007)	Portugal QP (admin.) 1986–1998	Stayers (men/women)	1.20/0.85
		New hires (no panel)	2.08/1.78

[a]The dependent variable is the annual change in the log of hourly earnings, obtained from the estimated coefficients on annual time dummies in individual wage regressions. Results are for men, except for the studies of Devereux and Hart and Carneiro and Portugal, which report results separately for men and women. The data sets described as admin. are based on employer data; the others are from household surveys. Acronyms used: New Earnings Survey Panel Data (NESPD); British Household Panel Survey (BHPS); German Socio-Economic Panel (GSOEP); European Community Household Panel (ECHP); Quadros de Pessoal (QP).

[b]Results for East Germany and South/Central Italy not significant.

sharing rule, this elasticity is approximately the elasticily for initial wages when continuation wages are not too sticky. Given the empirical estimates of an un-

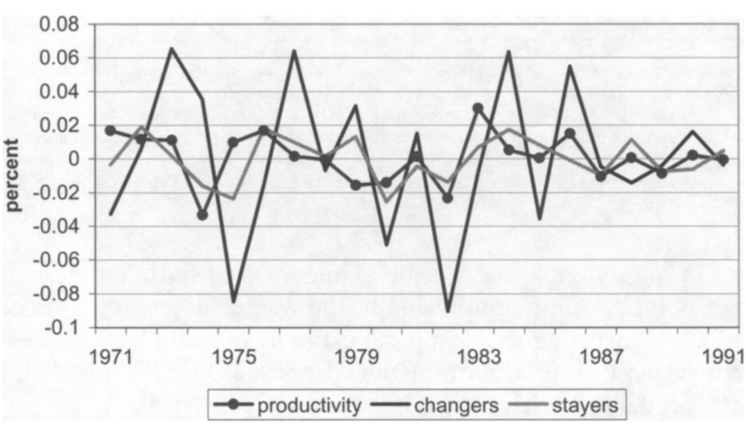

FIGURE 2.—Cyclical wage and productivity changes.

employment semielasticity, one could argue that to compare the model's prediction with the data, one should calculate the unemployment semielasticity implied by the model and compare it with the estimate. This, however, would not be the correct comparison, for two reasons. First, we deliberately focused on testing the model's performance with respect to the job creation rate, although we argued that the job destruction rate is also important in an overall explanation of the volatility of unemployment. Our quantitative model does not have a complete model of unemployment volatility, so its predictions cannot be expected to match those in the data. Second, even if the model had a complete model of unemployment volatility, the fact that unemployment is one of the model unknowns implies that its prediction of the wage–unemployment semielasticity is a composite of more than one model predictions. In particular, since the driving force is p, we can write

$$\text{(27)} \qquad \frac{d\log w}{du} = \frac{d\log w}{d\log p}\left(\frac{du}{d\log p}\right)^{-1}.$$

If the model underpredicts $du/d\log p$, then it will overpredict $d\log w/du$, even if it made an accurate prediction of the wage elasticity.

For these reasons I evaluate the model's wage predictions by converting the estimated unemployment elasticities to productivity elasticities using actual time-series data.[23] I use annual observations for 1948–2006 for the same unemployment variable as in the panel regressions and annual observations for the deviation of productivity from trend to run a simple ordinary least squares regression which yields $\Delta u_t/\Delta \ln p_{t-1} = -0.34$. This result is remarkably robust to small changes in specification, such as using the log change in labor productivity instead of its deviation from Hodrick–Prescott (HP) trend. When the sample is restricted to 1970–1993, as in the panel studies, the coefficient goes up to -0.49. These estimates appear to confirm a stable "Okun law" of hourly productivity on unemployment, although usually Okun's law is between aggregate GDP, which includes the change in hours, and unemployment. Applying the estimated Okun coefficients to convert the estimated cyclical impact on the wages of job changers to a wage–productivity elasticity, I find that for the estimated semielasticity of 3, the productivity elasticity of wages is $3 \times 0.34 = 1.02$, and for the estimates over the 1970–1993 period, it is 1.47. These numbers are very close to the predictions of the model for the cyclicality of Nash wages, and if anything they exceed the model's elasticities by a small (but statistically insignificant) margin.

[23]In the discussion of results in the empirical literature there is reference to "low" or "high" wage cyclicality through an implicit reference to an Okun-type relation that converts the cyclicality of unemployment to the cyclicality of gross domestic product (GDP). The correctness of this indirect approach is not questioned and standard errors are not reported. I follow a similar approach here, but I also obtain a direct measure of cyclicality for the series in Figure 2 further down in this section.

More support for the volatility of wages in new jobs can be obtained from more direct estimates. I HP-filtered Devereux's PSID data shown in Figure 2 and reran his second-stage regression, obtaining, for job changers,

$$\Delta \log w_t = 0.00 - \underset{(0.65)}{2.67}\Delta u_t, \quad R^2 = 0.47.$$

The coefficient estimate is very similar to those obtained in the literature (the literature uses a time trend instead of HP filtering). Running a second regression with the data in Figure 2 to obtain a more direct estimate of the productivity elasticity of job changers, I obtain

$$\Delta \log w_t = 0.00 + \underset{(0.56)}{1.70}\Delta \log p_{t-1}, \quad R^2 = 0.33.$$

Both variables are deviations from HP trend. The estimated elasticity is above those computed indirectly from the unemployment estimates, but not significantly different. However, the point estimate obtained here is above the predictions of the model for wages in new matches when wages in continuing jobs are not as volatile as in new jobs.

More recently, Haefke, Sonntag, and van Rens (2007) computed a quarterly wage series from the CPS for matches that originate from nonemployment. They used the outgoing rotation group for 1979–2006 and defined new matches as those that involve a worker who declared himself or herself unemployed in one of the preceding three months. This contrasts with the samples in the two tables above, which cover all new matches, including job-to-job transitions. They found that the variance of the wage series for new hires is significantly higher than the variance of wages in ongoing jobs, in contrast to persistence, which is less. More importantly for the model, they found near proportionality between the wages of new hires and productivity. Their point estimates for the elasticity of wages with respect to productivity in a variety of specifications are about 0.9 or above for new hires and about 0.3 for all workers.[24] Their 3 to 1 ratio implies an approximate estimate for $k = 0.33$ in (26), although given the results of panel studies and the data sources that they used, $k = 0.5$ is a more plausible figure. With $k = 0.33$ we get that the model's prediction of the elasticity of wages in new matches is about 0.7, whereas $k = 0.5$ gives 0.75 for this elasticity. This is below the estimated elasticity of 0.9 but well within the 1 standard deviation interval.

[24]They also argue for strong composition effects, which biases downward any estimate of the coefficient of log wage on unemployment, as is done in the panel regressions. Their estimates are based on a mean or median constructed hourly wage series, which behaves very similarly to the Bureau of Labor Statistics (BLS) measure of mean wages.

The evidence shown in Tables II and III, and also the more direct estimates of Haefke, Sonntag, and van Rens (2007), show much less cyclicality in the wages of continuing jobs.[25] The wages of continually employed workers increase in cyclical peaks, with an estimated unemployment coefficient of 1 to 1.5. This implies a wage–productivity elasticity of 0.3–0.5.[26] The fact that the elasticities in continuing jobs are about half of what they are in new jobs implies that the losses suffered by workers who form new matches in recession are not immediately reversed. However, this is only indirect evidence for this important property. The work of Beaudry and DiNardo (1991) yields more direct evidence on this issue.

Beaudry and DiNardo ran the usual set of panel regressions with the PSID and the 1979 and 1982 Pension Supplements of the May CPS, but tried three different unemployment rates as cyclical indicators: contemporaneous unemployment, as in the other studies, unemployment at the time of hire, and the lowest unemployment rate during the tenure of the job. They found that the dominant influence on wages was exerted by the lowest unemployment rate during the job's tenure. The estimated coefficient on this variable implied a unit wage–productivity elasticity. Grant (2003) replicated their results with a different data set—the various cohorts of the NLS—and also found the strongest influence coming from the lowest unemployment rate since the formation of the match, although contemporaneous unemployment was also significant in his estimates.[27]

This evidence is strongly supportive of the argument that outside labor-market conditions exert a strong and asymmetric influence on wage negotiations, because incumbents' wages respond to the most favorable outside labor-market conditions, but do not reverse those gains when labor-market conditions deteriorate. The authors interpret this as evidence in favor of long-term implicit contracts, with the firm shielding wages from adverse outside conditions, and low mobility costs. When outside conditions improve, the firm raises wages to stop the workers from quitting.

Yet more evidence supporting the strong procyclicality of wages was found by Blanchflower and Oswald (1994).[28] They estimated a "wage curve" for

[25]An issue I did not address at all is taxation. If a firm can get more tax breaks in recession or if overall company taxation is progressive, this gives a reason for more procyclicality in labor costs than estimated in wage equations.

[26]Blank (1990), who, unlike in much of the literature, used the percent change in GDP as her cyclical indicator, estimated elasticities of that order of magnitude for repeated cross sections of the PSID or panels derived from it.

[27]Similar results regarding the lowest past unemployment were obtained by McDonald and Worswick (1999) for Canada and Bell, Nickell, and Quintini (2002) for the United Kingdom. Devereux and Hart (2007), using the superior New Earnings Survey Panel Data Set for Britain, found some supportive evidence, but they also found that the spot market is more important than in the original Beaudry and DiNardo study.

[28]The main objective of Blanchflower and Oswald's (1994) study was to show that there is a "wage curve," a negative relation between real wages and local unemployment. Their main tests

industry-aggregated wages across a panel of 19 U.S. manufacturing industries and found that industry profits per employee exert a strong positive influence on total compensation per employee when controlling for industry and time effects. They interpreted this finding as evidence in favor of the bargaining model for wage determination. Their result implies that there is comovement between the cyclicality of profits and the cyclicality of wages, as in the search and matching model, with the cyclicality in profits driving job creation.

5. THE ROLE OF MATCHING COSTS

The results of panel regressions contain one clear message: the wages of workers who change jobs during the year are at least as cyclical as labor productivity, but the wages of those in ongoing jobs are one-third to one-half as cyclical (in terms of the wage–productivity elasticity). The Nash wage equation of search models does not quite match these facts, but we have shown that extensions that distinguish between wages in new and continuing jobs yield results that are a good match, at least for wages in new jobs. The evidence certainly does not support explanations of the unemployment volatility puzzle that imply substantially less volatility in wages in new jobs than in productivity.

I conclude with a discussion of the role of matching costs in the cyclical volatility of tightness. Given that the timing of wage payments is not relevant to the firm's job creation and job destruction decisions, I simplify the modeling by applying the Nash solution to the wage bargain to all workers. However, the wage volatility results obtained from the model should be compared with the estimated wage volatility in new matches only.

Matching costs in the model are of two kinds: the worker's foregone leisure and unemployment income, and the vacancy posting costs of the firm. The worker's foregone costs have been discussed extensively in the context of Hagedorn and Manovskii's (2008) work, and I will refer to them briefly. But the nature of the firm's matching costs have received a lot less attention, although as I show here they play a critical role in the volatility results.

Tightness does two things in the canonical job creation model: it drives job creation through the matching function and influences the expected cost of hiring a worker. These properties are important and interconnected; one could argue that they are the identifying features of the model. Whereas the matching

use repeated cross sections. Although a wage curve is certainly consistent with the wage equation of the search and matching model, I did not include their study in Table II because their evidence is not about hourly wages, but about annual earnings, it does not distinguish between stayers and job changers, and it does not focus on the cyclical dimension of wages. However, as Card (1995) in his review of Blanchflower and Oswald pointed out, their point estimates are consistent with the estimates of the cyclicality literature and provide further support for cyclicality. In estimates by Card (1995, Table 3), hourly wages in the Blanchflower and Oswald samples also exhibit cyclicality for a variety of worker types and, importantly, the unemployment elasticity of wages doubles for workers who had more than one employer during the previous year (when compared with the wages of workers who had the same employer throughout the year).

function has been the topic of extensive research, the relation between tightness and mean recruitment costs has been much less researched, yet the precise relation between these two plays an important role in the cyclical volatility of tightness.

To see why, suppose there is a positive shock to productivity. Firms post more vacancies at cost c each, and through the search externalities, the entry of more vacancies increases the average duration of vacancies $1/q(\theta)$. The model's assumptions imply that the expected cost of hiring a worker increases in proportion to the increase in the mean duration of vacancies, since it is $c/q(\theta)$. The increase in average hiring costs checks the growth in vacancies and so reduces the response of tightness to the productivity shock.

Of course, the original motivation for making the vacancy cost depend on tightness is the realism of the assumption—a firm that expects a vacant job position to remain vacant longer should also expect the total cost of filling that position to be higher (in present-discounted value terms). However, the proportionality relation was more a matter of convenience in the absence of more information about the precise relation between costs and tightness. Other matching costs, such as training, negotiation, and one-off administrative costs of adding a worker on the payroll, are neglected by the model. I show that if fixed costs of this type are taken into account, the tightness volatility results can change substantially.

To demonstrate this claim, suppose that in addition to the vacancy posting cost of the canonical model, there is a fixed matching cost. For example, it may be a cost of interviewing or negotiating with the worker after she arrives but before she is hired or it may be a fixed cost of training her after she is hired. The important property that needs to be satisfied by this component of costs is that it is independent of the duration of vacancies.[29]

I consider here, within the Nash framework of the canonical model, the implications of adding fixed matching costs to the proportional posting cost of the canonical model. For the purposes of the modeling, I interpret these costs as costs that are paid after the worker who is eventually hired arrives but before the wage bargain takes place; for example, they may be the costs of finding out

[29]The argument that follows does not go through if the fixed cost is paid when the vacancy is first created, independently of a worker's arrival. If there is a fixed posting cost K, the Bellman equations and the Nash sharing rule are all the same as in the canonical case, but the zero-profit condition on vacancies is replaced by $V = K$. This is not enough to give more volatility in tightness. The argument requires that the fixed costs are matching costs but it is irrelevant whether they are paid before or after the wage bargain takes place. Thus, waiting and negotiation costs before wage agreement play an important role in enhancing cyclicality in the strategic bargaining model of Hall and Milgrom (2008), although in their model the costs need not be paid. Mortensen and Nagypal (2007) emphasized training costs that are paid after the wage bargain takes place as a source of volatility. Rotemberg (2006) assumed that the average cost of posting a vacancy falls in the number of vacancies posted by the firm, which has the same qualitative implications for volatility as fixed costs.

about the qualities of the particular worker, of interviewing, and of negotiating with her. They are sunk before the wage bargain is concluded and the worker takes up the position, but this property is not important for volatility, because training costs that are not sunk play a similar role. The attractive feature of making them sunk, however, is that they can be interpreted as a component of the cost of frictions that characterize search models, so they are an alternative way of calibrating frictions to the conventional proportional cost.

Suppose that when the worker arrives, the firm pays a fixed fee H before the Nash wage is agreed. Because the cost is sunk at the time of the bargain, it is ignored in the Nash bargain equations; its only impact on the formal structure of the model is to introduce a cost of taking up the worker in the vacancy equation. The vacancy equation now becomes[30]

$$rV = -c + q(\theta)(J - H - V).$$

The important property of this reformulation is that the constant posting cost c is now effectively replaced by the cost $c + q(\theta)H$, which falls in tightness. The job creation and wage equations with this vacancy equation become

$$\frac{p - w}{r + s} = \frac{c}{q(\theta)} + H, \tag{28}$$

$$w = (1 - \beta)z + \beta(p + c\theta + f(\theta)H). \tag{29}$$

The intuition for the first condition is obvious. Job creation entails two costs: the proportional cost c and the fixed cost H. The fixed cost increases wages with coefficient $\beta f(\theta)$ because if the negotiation fails, the firm has to pay H when it meets another worker—an event that takes place at rate $f(\theta)$. So by staying in the match, the worker saves the firm an expected cost $f(\theta)H$ and wages increase by a fraction β of that saving by the Nash assumptions. Equations (28) and (29) are solved for the two endogenous variables θ and w.

Table IV gives a sample of results for different combinations of the two hiring costs, c and H, constructed such that the solutions for θ and w are in all cases the same as in the model with $H = 0$. As before, the notation is ε_θ for the elasticity of θ with respect to p, calculated from

$$\varepsilon_\theta = \frac{1}{\eta}\frac{p - \varepsilon_w w}{p - w - (r + s)H},$$

[30]Given that the costs are interpreted as costs needed to find out more about the worker and to negotiate with her, it may be argued that the underlying assumption in this equation is that once the cost is paid, the worker is always recruited. However, it would make no difference to the argument if we introduced a probability $\phi < 1$ that the match is successful after the firm pays the H cost. The vacancy equation would then be $rV = -c - q(\theta)H + q(\theta)\phi(J - V)$, with only a trivial modification to the job creation condition (28).

TABLE IV

MODEL RESULTS AT DIFFERENT COMBINATIONS OF JOB CREATION COSTS

H	c	ε_θ	ε_w	ε_w^*
0	0.36	3.67	0.98	0.88
0.1	0.27	4.18	0.99	0.97
0.2	0.20	4.87	0.99	0.98
0.3	0.11	5.82	1.00	1.00
0.4	0.02	7.25	1.01	1.01

and ε_w^* is the wage elasticity required to raise the θ elasticity to the data point 7.56, calculated from

$$\varepsilon_w^* = \frac{p}{w} - \varepsilon_\theta \frac{\eta[p - w - (r+s)H]}{w}.$$

It is clear from the table that as the hiring costs are shifted from the proportional to the fixed component, the volatility of job creation increases, whereas the wage elasticity hardly changes. At very small values of the proportional component, the observed elasticities are consistent with the data. Since we do not have information about how the job creation costs are split between the costs that depend on the duration of vacancies and the costs that do not, we cannot choose one combination over another on the basis of independent evidence. Hall and Milgrom (2008) derived a combination of job creation costs consistent with their strategic bargaining approach that produces results that are very similar to those shown in the bottom two rows of Table IV.

What role do the second type of matching costs—the foregone nonmarket value of the unemployed—play in this model? As noted by Hagedorn and Manovskii (2008), a higher leisure value z can also increase the cyclicality of wages, but as Costain and Reiter (2008) emphasized, this also increases to unreasonable levels the responsiveness of unemployment to changes in unemployment compensation. How unreasonable? At $H = 0$, the value of z required to match the θ elasticity in the data is about 0.85. I compare the unemployment outcome for two unemployment compensation levels, 0.2 and 0.3. If the value of leisure is 0.45 (i.e., centering it on the plausible overall value of $z = 0.7$), equilibrium unemployment at 0.2 compensation is 5.2% and at 0.3 it is 6.2%. But if the value of leisure is 0.6 and I recalibrate the model to give the sample unemployment mean at $z = 0.85$, unemployment at compensation level 0.2 is 4.9% and at 0.3 it is 7.0%. In other words, the impact of unemployment compensation on unemployment doubles. Nickell, Nunziata, and Ochel (2005) summarized cross-country econometric evidence and found that a 10 percentage point difference in unemployment compensation is associated with a 1.1 percentage point difference in unemployment. So the canonical model with

$z = 0.71$ gets this response about right, whereas in the case of $z = 0.85$, the unemployment response is too high.[31]

Does the model with $H > 0$ also suffer from this criticism? The case that matches the θ elasticity in the data with $z = 0.71$ is shown in the bottom row of Table IV. In this case, unemployment at compensation level 0.2 is 4.75% and at 0.3 it is 6.6%. The impact is nearly 1.9 percentage points, compared with the Nickell, Nunziata, and Ochel estimate of 1.1. It is closer to the data than the 2.1 response at $z = 0.85$, but still above the data estimate.

6. CONCLUSIONS

The main aim of this paper was to examine the cyclical volatility of wages and its implications for unemployment volatility in the search and matching model. I have shown that the job creation condition that drives the volatility of the job finding rate depends on the wage bargain in new jobs. Even if wages in new jobs only are fixed by the Nash bargaining solution, the volatility of the job finding rate is still the same as in the canonical model, where all wages are fixed by the Nash bargaining solution. Time-series or panel studies on the cyclical volatility of wages show considerable stickiness, but this evidence is dominated by wages in ongoing jobs and is not relevant for job creation in the search and matching model. An examination of panel data evidence on the volatility of wages in new jobs shows that volatility is about the same as in the Nash wage equation of the canonical model.

It follows that the explanation for the unemployment volatility puzzle—the observation that the response of unemployment to cyclical productivity shocks is bigger than implied by the canonical model—has to be one that preserves the wage elasticities implied by the model. A simple modification of the model can deliver this result: breaking up the proportional vacancy costs of the model into a proportional vacancy cost and a fixed matching component delivers more volatility in the job finding rate for the same volatility in wages. The fixed component is justified by the existence of one-off negotiating, administrative costs, or training costs, whereas the proportional component is justified by the advertising cost and capital idleness costs associated with a vacancy.

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[31]As we noted in the Introduction, a way to break the tight link between policy effects and cyclical volatilities is to explore nonlinearities in the production function (Hagedorn, Manovskii, and Stetsenko (2008)).

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