The Unemployment Volatility Puzzle: Is Wage Stickiness the Answer?

Christopher A Pissarides*

Centre for Economic Performance, London School of Economics

IZA and CEPR

30 May 2007

Abstract

I study the cyclical behavior of an equilibrium search model with endogenous job creation and destruction and extract from it a wage equation that can be compared with the econometric evidence. Job creation in the model is influenced by wages in new matches. I summarize microeconometric evidence on wages in new matches and show that the key model elasticities are consistent with the evidence. Therefore sticky wages is not the answer to the unemployment volatility puzzle. I discuss some alternative mechanisms that can increase volatility, in particular extensions of the model and alternative driving mechanisms.

Employment relationships in the search and matching model command monopoly rents that are shared between the firm and the worker by a wage contract. The most common wage contract found in the literature is derived from Nash, and yields a wage rate that is a linear combination of the productivity of the match and the worker's returns from nonmarket activities and search. Because the imputed returns from nonmarket activities (leisure and home production) are less cyclical than labor productivity, this wage rate is also less cyclical than labor productivity - and consequently employment is more cyclical than in a competitive market-clearing model.[1]

*The Walras-Bowley lecture, North American Summer Meetings of the Econometric Society, Duke University, June 2007. I am grateful to Per Krusell, Rachel Ngai, Michael Reiter, Christian Haefke, Gary Solon for comments and to Pedro Gomes for his research assistance. Partial funding for this study was provided by the Centre for Economic Performance, a designated research centre of the ESRC.

[1]Pissarides (1985). In Pissarides (1987) the model was extended to show the consistency between the cyclical fluctuations in unemployment and the constant unemployment rate in growth equilibrium, in response to temporary and permanent productivity shocks.

The key control variable that delivers this result is the firm's job creation decision and the implied transition out of unemployment. Evidence by, among others, Davis and Haltiwanger (1992) and Darby, Haltiwanger and Plant (1986) showed that there is also substantial cyclical volatility in job destruction and the entry into unemployment. Mortensen and Pissarides (1994) extended the search and matching model to explain optimal job destruction and showed that the Nash wage equation combined with productivity shocks could also generate cyclical dynamics in job destruction and the entry into unemployment.

The question that I take up in this paper is about the quantitative power of this model. Shimer (2005a), in an influential paper, showed that under common parameter choices the model did not have enough power to generate the observed cyclical volatility in its key variable, the ratio of job vacancies to unemployment ("tightness").[2] The model's mechanism could be strengthened by choosing "unconventional" parameter values, in particular a very high value of nonmarket returns. Hagedorn and Manovskii (2006) have shown that if nonmarket returns are about 95% of market returns for the typical worker, the model has enough power to generate the observed cyclical volatility in tightness. But as Costain and Reiter (2005) note, in a paper that anticipated to some extent both the Shimer (2005a) critique and the Hagedorn and Manovskii (2006) response, if nonmarket returns are high the model runs into another difficulty. The response of unemployment to labor market policy, in particular unemployment insurance, is too large.[3]

I call the failure of the model to match the observed volatility of unemployment the unemployment volatility puzzle. It is important, in selecting the right model to study this puzzle, to be clear which unemployment (or employment) variable we are studying. Unemployment in this paper is the conventionally defined rate of unemployment, the ratio of unemployed workers to all labor force participants. I argue (in section 1) that to a good approximation one can study the volatility of this variable by ignoring the movements of workers in and out of the labor force and focus on the transitions between employment and unemployment. But I will also argue that it is important to endoge-

[2]The model was incorporated into the conventional real business cycle model with success, in the sense that it replicated the standard results obtained for the macro aggregates and in addition it improved the model's performance with respect to employment. See Langot (1995), Merz (1995), Andolfatto (1976) 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 the discussion by Hornstein, Krusell and Violante (2005) and Mortensen and Nagypal (2006), both of which also survey other contributions to this literature.

nize both transitions in and out of unemployment. There is ample evidence that both transitions contribute to its cyclical volatility, with the outflow roughly twice as important as the inflow. The literature has focused mainly on the cyclical volatility of job creation (which delivers the outflow), either ignoring variations in job destruction and separations or treating them as exogenous and subject to cyclical shocks.[4] I show that volatility in job separations translates directly into unemployment volatility whatever its source. But whether it influences job creation or not depends critically on whether it is endogenous or exogenous. Endogenous job destruction along the lines of Mortensen and Pissarides (1984) does not impact on job creation, whereas exogenous job separation shocks of the kind analyzed by Yashiv (2006) and Mortensen and Nagypal (2006) have a big negative impact on job creation. The reason for the difference is that in the case of optimal job destruction only jobs whose net productivity is close to zero are destroyed, whereas in the case of exogenous shocks all jobs, however far they are from the reservation productivity margin, have an equal probability of destruction. This difference turns out to be crucial in the dynamics of labor market tightness.

The main response of the literature to the unemployment volatility puzzle was to study more closely the type of wage contract used in the model. Because of the frictions that characterize search equilibrium, there are many "rational" wage outcomes that are consistent with the assumptions of the model. The Nash solution that is commonly adopted is only one of them. If Nash implied too much volatility in wages, an alternative may reduce the response of wages to the cyclical shocks and so increase the volatility of unemployment.

Hall (2005a) showed that fixing wages completely within the bounds of indeterminacy implied by the model's bilateral monopoly yields too much unemployment volatility. Therefore, it should be possible to find less sticky wage contracts that exactly match the observed volatility. Hall and Milgrom (2006) suggest one such contract. They adopt the sequential bargaining approach of Binmore, Rubinstein and Wolinski (1986) but instead of assuming that in the event of failure to agree on a wage offer the firm and worker abandon negotiations altogether and rejoin search, which is underlying the Nash solution, they assume that each party makes credible delaying threats. Other reasons for wage stickiness within the framework of the model include asymmetric information about key

[4]The motivation for the recent focus on job creation came from empirical papers on the relative significance of unemployment flows, especially Shimer (2005b) and Hall (2005b). For examples of papers that study the impact of exogenous job destruction shocks see Yashiv (2006) and Mortensen and Nagypal (2006).

parameters and the use of wages as signalling devices for the state of productivity.[5]

Wage stickiness is a traditional hunting ground for macroeconomists looking for a solution to the puzzle of excess employment volatility. Time series evidence, starting with the famous Keynes-Tarshis-Dunlop controversy, appeared to justify the interest in wage stickiness.[6] The search and matching model has one big advantage over the competitive market-clearing model when it comes to wage stickiness: it is immune of Barro's (1977) critique that in a rational equilibrium wage stickiness should not cause employment volatility. But ultimately, whether wage stickiness is the answer to excess volatility or not depends on the consistency between the model and the empirical evidence. There is now a large econometric literature that sheds light on the cyclical behavior of wages. I examine the findings of this literature in the context of the search and matching model.

In the search and matching model, the timing of wage payments during the job's tenure is not important for job creation. It is the expected productivity and cost of labor in new matches that drives job creation. I argue that the model's Nash wage equation should therefore be compared with wages in new matches, which are a good proxy for the expected cost of labor.[7] I summarize the 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.

I conclude that wage stickiness is not the answer to the unemployment volatility puzzle. The Nash wage equation implies too much cyclical volatility for the wages of ongoing employment relationships, but this cyclicality is irrelevant for job creation; getting rid of it will not increase the model's unemployment volatility. Some small extensions to the model, such as the introduction of endogenous search intensity and noncyclical hiring and firing costs, can increase unemployment volatility, but not enough. In order to match the observed volatility the model requires stronger incentives for job creation and I briefly discuss some alternatives. The introduction of demand shocks, by assuming for example monopolistic output markets, is a particularly promising avenue, because it can increase the incentives for job creation without having much impact on the relation between productivity and wages.

[5] See for example Kennan (2006), Menzio (2005), Brugemann and Moscarini (2007) and for related discussions Shimer (2004), Gertler and Trigari (2007), Mortensen and Nagypal (2006), Horstein, Krusell and Violante (2005) and Yashiv (2007).

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

[7] This point was also independently made by Haefke, Sonntag and van Rens (2007).

In the remainder to this paper I first study 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 canonical search and matching model with endogenous job finding and job separations (sections 2 and 3). I then survey the econometric evidence on wages and show that it does not lend support to wage stickiness as the cause of unemployment volatility (section 4). I finally discuss the implications of my findings for wage modeling and for the cyclical dynamics of unemployment (sections 5 and 6)

1 Employment, unemployment, inactivity and the dynamics of unemployment

I will argue that for the rate of unemployment it is reasonable to focus attention on the transitions between employment and unemployment, and ignore the transitions between the labor force and inactivity. For other variables, especially for the rate of employment out of the population of working age, ignoring inactivity may not be so reasonable (Veracierto, 2004, Fujita and Ramey, 2006).

Changes in the rate of inactivity do exhibit some cyclicality. Figure 1 shows the cyclical components of employment, unemployment and inactivity, all divided by the population 16 years and over. Employment and unemployment are more cyclical than inactivity is. The standard deviations of annual observations are 0.54 for employment, 0.44 for unemployment and 0.18 for inactivity. The correlation between the employment and unemployment cycles is -0.95, the one between inactivity and unemployment is 0.45, and the one between employment and inactivity -0.69. But the cyclicality of inactivity is not important if attention is focused on the unemployment rate. By definition the unemployment rate is $u = U/L$, where U and L are respectively the ratios of unemployment and the labor force (the sum of employment and unemployment) to the population over 16. Taking logs and re-writing the equation in deviations from means, squaring them and taking expected values, yields the following approximation in the variances:[8]

$$\sigma_u^2 = \sigma_U^2 - 2\rho_{UL}\sigma_U\sigma_L + \sigma_L^2. \tag{1}$$

[8]The variances and covariances shown are the ones for the cyclical component of the logs, quarterly data for 1948-2006, obtained by applying an HP filter to the original data with parameter 1600.

The three terms on the right-hand side are, respectively and in percentage terms, $1.94, -0.016$ and 0.0015. So if it is assumed that $\sigma_L = 0$ we are still capturing 98% of the variance of $\log u$, a simplification worth making.

Next, I ask, how are the changes in the stock of unemployment related to the flows in and out of unemployment? Generally, the unemployment rate changes during some short time interval either because the inherited flows in and out of unemployment are not equal to each other, or because one or both flows change. Let f_i be the instantaneous rate at which a typical worker moves from employment to unemployment at some time t, and f_o the instantaneous rate at which a worker moves from unemployment to employment. Ignoring all other flows, in continuous time the unemployment rate evolves according to

$$\dot{u} = f_i(1-u) - f_o u. \tag{2}$$

If f_i and f_o remain constant for a sufficiently long time unemployment converges to the steady-state rate,

$$u = \frac{f_i}{f_i + f_o}. \tag{3}$$

With quarterly data on unemployment stocks and flows, constructed under the assumption that f_i and f_o are constant during the quarter, the unemployment rate obtained from (3) is virtually indistinguishable from the actual unemployment rate.[9] The computed instantaneous transition rates are sufficiently large that the unemployment rate practically converges to the underlying steady-state rate within the quarter. I therefore use (3) as my unemployment equation. I first use it to do some "unemployment accounting", to uncover the contribution of the inflow and outflow rates to the dynamic evolution of unemployment.

In principle, this exercise should be straightforward but it has attracted some controversy because of the non-linearity of (3) and the cyclical correlation between the inflow and outflow rates. In Pissarides (1986) I derived two unemployment rates for Great Britain from (3). The first was traced by holding the inflow rate constant to its value at the start of the sample and letting the outflow rate take its actual values, and the second was traced by holding the outflow constant at its initial value and letting the inflow take its actual values. The constant-inflow unemployment rate turned out to be very close to the actual unemployment rate, whereas the constant-outflow rate bore no

[9] See Shimer (2005b), where quarterly time series data are also available for downloading, http://robert.shimer.googlepages.com/flows.

relation to the actual series. I concluded that unemployment in Britain was driven by the outflow rate.[10]

Shimer's (2005b) calculations for post-war US flows followed a similar methodology and he reached a similar conclusion, although he also found some role for the employment-unemployment transition and the unemployment-inactivity transition. His findings contrast with earlier work by Darby, Haltiwanger and Plant (1986), which reached the exact opposite conclusion. Hall (2005b), comparing the volatility of the inflow and outflow rates, concluded that the volatility in unemployment is explained entirely by changes in the outflow rate. His explanation of the virtual stability of the inflow rate is that although the layoff rate increases in recessions, the quit rate decreases to offset its impact on the overall entry rate. But as Davis (2005) points out, this does not necessarily negate any contribution of the inflow rate to the dynamics of unemployment. Data on the composition of unemployment show that the share of short-duration unemployment increases in the first few months of recession but falls as the recession progresses. Another factor pointing to the cyclical importance of the employment-unemployment transition is that new unemployment insurance claims are strongly counter-cyclical. Despite such evidence, however, Hall's and Shimer's conclusions provided the motivation for the use of models with constant job destruction rate by the majority of recent researchers.

A simple decomposition of unemployment changes can shed some light on the relative contribution of the inflow and outflow rates to the unemployment cycle. Log-differentiation of (3) gives,

$$d \ln u = (1 - u)(d \ln f_i - d \ln f_o). \tag{4}$$

Figure 2 shows the two series for the log change in the flow rates. There is variability in both, although the outflow rate fluctuates more. As in (1), interpreting the differentials as deviations from means and taking expected values of their squares yields

$$\sigma_u^2 = (1 - u)^2(\sigma_i^2 - 2\rho_{io}\sigma_i\sigma_o + \sigma_o^2). \tag{5}$$

The three terms inside the brackets in (5) are, respectively, $0.0056, 0.01$ and 0.014, so the outflow rate contributes the most, the covariance term second, and the inflow third. Given the high correlation between the two rates ($\rho_{io} = -0.574$), there is clearly a

[10]There is some preliminary evidence that the dynamics of British unemployment flows have changed since the mid-1980s, with more volatility in the outflow rate experienced in more recent cycles.

need of a model that can explain both the variances and the covariance between the two rates. The variance of the inflow rate is about 40% of the variance of the outflow, so ignoring the covariance, the relative contribution of the two rates in (4) is about 30 : 70. This decomposition corresponds roughly to the one found by Braun, De Bock and DiCecio (2006) in structural VARs, in which they report that the dynamics in the unemployment rate are driven by "up to one third" by the inflow rate. Mortensen and Nagypal (2006) also claim that the contribution of the inflow rate is "about a third", whereas Elsby, Michaels and Solon (2007), who re-examined Shimer's claims about the relative importance of the inflow and outflow rates by making use of the decomposition in (4), concluded that the contribution of the inflow and outflow rates until very recent recessions was of the order of 35 : 65.[11]

The recent literature has either ignored the inflow rate when studying the dynamics of unemployment, or treated shocks to the inflow rate as one of the exogenous forces driving changes in the outflow rate. Thus, Mortensen and Nagypal (2006), in their preferred decomposition, assume that the outflow rate is driven by two shocks, common productivity and common separations shocks. They give them their sample variances and covariance to arrive at the conclusion that (in their version of the model) they jointly explain about two thirds of the standard deviation of the vacancy-unemployment ratio. Shimer (2005a) rejects shocks to the separation rate as an explanation for fluctuations in unemployment because they violate the Beveridge curve, a feature that is not present in Mortensen's and Nagypal's version of the model. As I pointed out in the Introduction, exogenous separation shocks have very different effects in the model from endogenous changes in separations, a point to which I will return after the description of the model.

2 The canonical model with endogenous job destruction

Agent decisions are made with full awareness of the future path of variables. Vacancy creation and reservation (acceptance) values are jump variables but employment and unemployment are state variables. Wages in the canonical model are also jump variables. The objective of the exercise is to compare the second moments of the endogenous

[11] In contrast to these claims, Fujita and Ramey (2006) find that the driving force of fluctuations in employment is the separations rate. This is in line with the job flows literature (e.g., Davis, Haltiwanger and Schuh, 1996). The important difference between their work and ours is that they are interested in employment volatility, not in unemployment-rate volatility.

variables, in particular unemployment, vacancies and wages, with the second moment of labor productivity, the canonical model's driving force. 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, there is no loss of generality if we set up the model in continuous time and compare steady states at different realizations of labor productivity.

Decisions take place as follows. At any time t the economy inherits employment $1-u$ and unemployment u. Each employed position is characterized by productivity px and a wage rate $w(x)$, with $p > 0$ a proportional economy-wide productivity parameter and $x \in [0,1]$ a match-specific parameter. A randomly-selected fraction $s \geq 0$ of jobs break up for exogenous reasons and another randomly-selected fraction $\lambda \geq 0$ receive a productivity shock that moves each job's idiosyncratic productivity to some other value $x' \in [0,1]$ according to the c.d.f. $G(x' \mid x) = G(x')$. All persistence in idiosyncratic productivities is in the arrival process λ, and at the individual level the process has no memory.

Each one of the matches that receives a productivity shock has the option of either continuing production at px' or closing down. If the firm and worker decide to continue, a new wage $w(x')$ is agreed and production takes place; otherwise the job is destroyed, the worker enters unemployment and the firm gets zero payoff. If on-the-job search is allowed the worker can search on the job whilst producing and if she finds another job she quits to form a new job.

The workers who are unemployed, the ones who lose their jobs either because of the exogenous process s or because they received an unacceptable productivity shock x', and the employed job seekers (if any) participate in matching with a measure of vacancies v, determined by firms' profit-maximizing decisions. The outcome is a measure m of new job matches which can produce with maximum productivity p. Matching takes place according to a concave constant returns aggregate matching function $m(u+e, v)$, where e are the employed job seekers. Once a new job is formed the vacancy is withdrawn and a wage $w(1)$ agreed with the worker before production takes place.

I derive first the flows in and out of unemployment, and re-write equation (3) for the canonical model. In this analysis I ignore on-the-job search, so the flow out of unemployment is the matching rate which, when divided by employment, is also the empirical job creation rate. The flow into unemployment is the sum of job destruction and exogenous breakups.

The matching rate is $m(u,v)$, which is written more conveniently in terms of the transition rate for an individual worker, $m(1,v/u)$. I define tightness $\theta \equiv v/u$ and $q(\theta)$ as the transition rate for a vacancy, with $q'(\theta) > 0, q''(\theta) \leq 0$, so $m(1,v/u) = \theta q(\theta)$. Job destruction is driven by a reservation productivity rule on the idiosyncratic productivity parameter. Let R be the reservation productivity, such that existing jobs remain active if and only if $x \geq R$. In the notation of equation (3), $f_i = s + \lambda G(R)$ and $f_o = \theta q(\theta)$, so the rate of unemployment that equates the matching rate with job separations is given by

$$u = \frac{s + \lambda G(R)}{s + \lambda G(R) + \theta q(\theta)}. \tag{6}$$

2.1 Job creation and job destruction

The utility function of both workers and firms is linear, but 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 he posts a vacancy, at a flow cost c for the duration of the vacancy. In contrast, the equilibrium reservation product, R, reflects the decisions of both parties to continue an existing employment relationship, if necessary through redistribution of the future surplus from the job. I assume that whatever the wage determination mechanism, no jobs that can survive through redistribution are destroyed, namely, that job destruction does not violate joint rationality. For a given wage determination mechanism, a *search equilibrium* is a pair (R, θ) that simultaneously solves the job creation and job destruction conditions.

For the moment I invoke the existence of a wage mechanism $w(x)$ for each job with idiosyncratic productivity x,with non-negative first derivative (I suppress for convenience the dependence on p and any other variable). A continuing match with productivity x has capital value $J(x)$ to an employer that solves the following asset pricing equation

$$rJ(x) = px - w(x) + \lambda \int_R^1 [J(n) - J(x)]dG(n) - [\lambda G(R) + s]\, J(x) \tag{7}$$

where r represents the risk free interest rate and the assumption is made that a destroyed job has zero value to the employer. The return on the capital value of an existing job-worker match to the employer is equal to current profit plus the expected capital gain or loss associated with the arrival of a productivity shock. Taking expected values of (7) and denoting in general $\bar{J} = E(J(x) \mid x \in [R, 1])$, we obtain the expected value of a successful match,

$$\bar{J} = \frac{p\bar{x} - \bar{w}}{r + s + \lambda G(R)}. \tag{8}$$

A new vacancy leads to a match at maximum idiosyncratic productivity so it satisfies the asset pricing equation

$$rV = -c + q(\theta)[J(1) - V]. \tag{9}$$

Vacancies are a jump variable and vacancy creation exhausts all available profits, so the *job creation condition* is

$$V = 0. \tag{10}$$

From (9) and (10) we write the job creation condition in the more convenient form

$$J(1) = \frac{c}{q(\theta)}. \tag{11}$$

From (7) and (8) we can write

$$J(1) = \frac{p - w(1) - (p\bar{x} - \bar{w})}{r + s + \lambda} + \bar{J}. \tag{12}$$

The first term on the right shows the excess profit made by the firm in the initial period of the match, when productivity is at its maximum. After the arrival of the first shock the job makes on average mean profit, $\bar{J}$.

Because job destruction is a jointly rational decision we need to derive the value of the job to both employer and worker before we can write the optimality condition. Let $S(x)$ be the joint surplus of a match, and let U be the value of unemployment to the worker. The value of a vacancy to the firm is V but if the match is destroyed because of a negative shock it is lost (so, as in the case of the firm's payoffs, the shocks are interpreted as productivity shocks which cannot be reversed after separation). It follows that the total value of a match to the pair is $S(x) + U + V$ and satisfies the Bellman equation

$$r(S(x) + U + V) = px + \lambda \int_R^1 [S(n) - S(x)]dG(n) - (s + \lambda G(R))\,(S(x) + V). \tag{13}$$

The jointly-rational *job destruction condition* is

$$S(R) + V = 0. \tag{14}$$

The common practice in the literature is to use the Bellman equations in conjunction with (10) and (14) to arrive at two equations in θ and R, each of which has elements of both the job creation and job destruction rules. I take a different route here, which is better-suited to the argument that I want to make in the remainder of the paper. I derive an equation for θ from (10) and the Bellman equations, and one for R from (14) and the Bellman equations, and interpret them as the "structural" equations of the model for job creation and job destruction respectively.

From (9), (8) and (12) I obtain the explicit equation for V

$$[r + q(\theta)]\, V = \frac{q(\theta)}{r + s + \lambda} \left(p - w(1) + \frac{\lambda(1 - G(R))\,(p\bar{x} - \bar{w})}{r + s + \lambda G(R)} \right) - c. \tag{15}$$

The job creation condition is a solution for θ derived from (15) for $V = 0$:

$$\frac{c\,(r + s + \lambda)}{q(\theta)} = p - w(1) + \frac{\lambda(1 - G(R))\,(p\bar{x} - \bar{w})}{r + s + \lambda G(R)}. \tag{16}$$

In order to derive the job destruction condition we need the worker's payoffs. The expected value of unemployment satisfies

$$rU = z + \theta q(\theta)(W(1) - U), \tag{17}$$

where $W(1)$ is the value of a new job to the worker and satisfies a condition that parallels (7), with the only difference that once the job is destroyed the worker enters unemployment with value U. The explicit solution for U is

$$\frac{r + s + \lambda G(R) + \theta q(\theta)}{r + s + \lambda G(R)} rU = \frac{\theta q(\theta)}{r + s + \lambda} \left[w(1) + \frac{\lambda(1 - G(R))}{r + s + \lambda G(R)} \bar{w} \right] + z. \tag{18}$$

The surplus from a job with idiosyncratic productivity x satisfies, $S(x) = J(x) + W(x) - V - U$. We note that (13) and (14) imply

$$S(x) + V = \frac{p(x - R)}{r + s + \lambda} \qquad \forall x \in [R, 1], \tag{19}$$

so the job destruction condition becomes,

$$pR + \frac{\lambda p}{r + s + \lambda} \int_R^1 (x - R) dG(x) = rU, \tag{20}$$

with rU satisfying (18). Because of the assumption of joint rationality in job destruction, the wage determination mechanism influences job destruction only through the influence of expected mean wages on the worker's expected payoffs from search

2.2 Wage determination

The canonical model assumes that wages share the surplus from the job in fixed proportions at all times

$$W(x) - U = \beta S(x) \qquad \forall x \in [R, 1], \tag{21}$$

which can be derived as the solution to a generalized Nash bargaining problem

$$w(x) = \arg\max \left\{ [W(x) - U]^{\beta} \, [S(x) - (W(x) - U)]^{1-\beta} \right\}. \tag{22}$$

The wage equation derived from this rule is, in general,

$$w(x) = rU + \beta(px - rU - rV), \tag{23}$$

with the solutions for rU and rV given by (18) and (15). This equation makes clear that there are three separate mechanisms through which a shock to productivity is transmitted to wages. First, there is a direct effect that is due to the sharing assumptions, the px term in (23); and 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 centres 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.

The solution commonly found in the literature is derived from (23) by making use of the job creation and job destruction conditions:

$$w(x) = (1 - \beta)z + \beta(px + c\theta) \qquad \forall x \geq R. \tag{24}$$

The job creation and job destruction conditions with this wage rule can be respectively represented by a downward-sloping and an upward-sloping curve in (R, θ) space. The main criticism made of this wage equation is that it makes wages too responsive to the cycle. But this conclusion is not usually reached by examining the relation between the wage equation of the model and wage volatility over the cycle in the data, but by showing that a less responsive wage equation can reconcile the high volatility of vacancies and unemployment with the low volatility of productivity.

The question that primarily interest us here is whether the estimated wage equations in the literature shed light on the elasticities implicit in (23). I summarize the key points from the econometric estimates in the next section. An issue here is whether the estimated wage equations are of the unconstrained structural form in (23), or whether the estimated elasticities have implicit in them the restrictions in the other two equilibrium conditions, $V = 0$ and $S(R) = 0$. Given that the econometric estimates are obtained from real data, micro or macro, from economies that may temporarily be out of equilibrium, and more importantly that the regressions include several institutional and other variables, a comparison with the unconstrained elasticities of the model would seem more appropriate. I will derive the elasticities implied by the model after I solve the model numerically.

3 Solving the model

3.1 Parameters and steady-state solutions

The model has three equations in three unknowns, θ, R, w. The three equations for this solution are (16), (20) and (24). Note that under the Nash wage equation, (20) becomes,

$$pR + \frac{\lambda p}{r+s+\lambda}\int_R^1 (x-R)dG(x) = z + \frac{\beta}{1-\beta}c\theta. \tag{25}$$

I solve the model with quarterly data.

As in Mortensen and Pissarides (1994) I assume that the idiosyncratic productivity distribution is uniform in the range $[\gamma, 1]$:

$$G(x) = \frac{x-\gamma}{1-\gamma}. \tag{26}$$

It follows that

$$\int_R^1 x dG(x) = \frac{1-R^2}{2(1-\gamma)} \tag{27}$$

$$\bar{x} = \frac{1+R}{2} \tag{28}$$

The matching function is assumed to be Cobb-Douglas $m = m_0 u^\eta v^{1-\eta}$, with unemployment elasticity $\eta = 0.6$ (see Petrongolo and Pissarides, 2001). Following common practice, I also assume $\beta = 0.6$, which internalizes the search externalities. The job finding rate is $\theta q(\theta) = m_0\theta^{0.6}$. The sample mean for θ in 1960-2006 was 0.72, derived by making use of JOLTS data since December 2000 and the Help-Wanted Index adjusted to the JOLTS units of measurement before then. Shimer (2005a) reports a mean value of the job finding rate of 1.355. I make use of these two numbers to solve for m_0. The result is $m_0 = 1.545$.

Given now the mean value for the job finding rate and a sample mean for the unemployment rate of 0.06, I use (3) to derive a mean value for the job separation rate,

$$s + \lambda G(R) = 0.086, \tag{29}$$

which implies a plausible mean job duration of 2.9 years. I identify $\lambda G(R)$ with worker displacement and s with other separations that lead to entry into unemployment. Farber (1997) reports that over a three-year period about 12% of workers experience displacement, whereas the job destruction rate over a comparable period, as calculated by Davis and Haltiwanger (1999), is 20%. With a quarterly rate of job destruction of $8-9\%$ and my calculated rate of job separations of 8.6%, I use the 12/20 ratio of worker displacement to job destruction to arrive at $\lambda G(R) = 0.05$ and $s = 0.036$. With $r = 0.012$, the figure used by Shimer (2005a), I obtain $r + s = 0.048$ as one component of the discount rate. For λ I choose $\lambda = 0.15$, which implies that on average there is a productivity shock every 6.7 quarters. Of course, no direct evidence can be obtained on this frequency. What guided me in the choice of $\lambda = 0.15$ is the fact that the biggest impact that different values of λ have is on the elasticity of separations with respect to productivity, with lower values giving smaller elasticities. The value of λ also has an impact on wage inequality, which is not an issue at present, but it does not influence the elasticities of tightness and wages with respect to productivity. The number that I chose implies a separations elasticity that is close to the figure observed in the United States. With this assumption and (26) I obtain a value for γ

$$\gamma = 1.33R - 0.33. \tag{30}$$

The average level of productivity in this economy is $p\bar{x}$. I assume that $z/p\bar{x} = 0.73$, as in Hall (2006) and Mortensen and Nagypal (2006), which gives

$$\frac{z}{p} = 0.365(1 + R). \tag{31}$$

There is only one other parameter that needs to be specified, the cost of maintaining a vacancy, c. I choose the value that satisfies the zero-profit condition (16) at sample means:

$$\frac{c}{p} = 2.526(1 - R). \tag{32}$$

In order to apply these parameters and functional forms to solve the model I use the job creation condition (16), which holds in equilibrium with Nash wages, and the job

Table 1: Parameter values, quarterly data

Parameter	value	description	target
r	0.012	interest rate	data
$s+\lambda G(R)$	0.086	job separations prob.	mean unemployment 0.06
s	0.036	exog. separations	40% of job separations
λ	0.15	shock arrival	separations elasticity
γ	0.910	lower prod. support	60% of job separations
z/p	0.708	leisure	Hall (2006)
c/p	0.229	vacancy cost	mean θ
m_0	1.545	matching fn. scale	job finding probability
η	0.6	matching fn. elasticity	Petrongolo-Pissarides (2001)
β	0.6	share of labor	$\beta = \eta$ (efficiency)
		Data	
θ	0.72	mean v/u (tightness)	JOLTS, HWI
$m_0\theta^{1-\eta}$	1.355	job finding prob.	Shimer (2005a)

destruction condition (20) that holds in equilibrium also with Nash wages:

$$pR + \frac{\lambda p}{r+s+\lambda}\int_R^1 (n-R)dG(n) = z + \frac{\beta}{1-\beta}c\theta. \tag{33}$$

The solution for R is $R = 0.94$. This value and the expressions previously given yield the parameter values shown in Table 1. The vacancy cost flow is about three weeks of average output. However, the vacancy cost is paid for $1/q(\theta) = .53$ quarters on average, whereas the job lasts 11.6 quarters, so ignoring discounting the firm's recruitment cost is on average only 1% of total expected output.

Some of the model solutions at these parameter values are shown in Table 2. Wages at low productivity levels exceed the firm's return from production and they are below the worker's reservation wage,[12] but the job is not destroyed because of its option value. Wages appear "sticky" in relation to the job-specific productivity, with a range of $0.946-0.982$ compared with a productivity range of $.94-1$. The percentage gain in flow receipts when a worker accepts a job is substantial, $100(.982/.708-1) = 38.7\%$. 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.

[12] The reservation wage is conventionally defined as rU. However, given the model solutions it is a misnomer in this case.

Table 2: Model solutions, Nash wages

Variable	description	solution	Variable	description	solution
R	reservation prod.	0.940	rV	value vacancy	0
$\bar{x}$	mean prod.	0.970	$rJ(1)$	value new job	0.121
$w(1)$	max wage	0.982	$rJ(\bar{x})$	value mean job	0.061
$\bar{w}$	mean wage	0.964	$rJ(R)$	value res. job	0
$w(R)$	min wage	0.946	$W(1) - U$	gain, new job	0.182
$\lambda G(R)$	job destruction	0.050	$W(\bar{x}) - U$	gain, mean job	0.091
rU	value unempl.	0.955	$W(R) - U$	gain, res. job	0

3.2 Elasticities

In order to compute the impact of productivity shocks on the model's unknowns I calculate the model's solutions for a 1% higher common productivity p.[13] This has two effects, it reduces the reservation productivity and increases tightness. The former reduces the mean value of the idiosyncratic productivity of active jobs, so the observed rise in labor productivity is less than the 1% rise in p. This effect corresponds to a "composition" change, but because we have assumed a λ that does not imply much inequality, our estimates show that the mean productivity $p\bar{x}$ goes up by 0.96% in response to the 1% rise in p. The higher tightness increases job creation but it also increases wages. In Table 3 I give the solutions for $p = 1.01$ and the "elasticities" of each variable with respect to common productivity p and the (endogenous) mean labor productivity $p\bar{x}$. The elasticities are calculated as the log change in the variable in question divided by the log change in either p or $p\bar{x}$.

The change in the productivity parameter p is the only cyclical change that I consider in this section but of course the model is consistent with other cyclical shocks and the observed correlations in the data indicate that there are other shocks driving the changes in job finding and job separation rates. I compare the computed elasticities with respect to mean productivity to the regression coefficients that would be obtained from simple regressions of the endogenous variables on labor productivity.

The computed response of the job separation rate to productivity is close to the one observed in the data but this correspondence is largely due to our choice of the free parameter λ. In US data the ratio of the standard deviations of job separations and

[13] The computed elasticities are virtually identical for a 1% or a 2% change in p. The standard deviation of labor productivity in the sample is 2% but this is not the same as the standard deviation of p because of changes in the composition of jobs.

Table 3: Impact of 1 percent higher common productivity on equilibrium outcomes

Variable	description	solution	elasticity w.r.t. p	elasticity w.r.t. $p\bar{x}$
R	reservation prod.	0.939	-0.78	-0.82
θ	tightness	0.747	3.70	3.84
$\bar{x}$	mean prod.	0.970	-0.04	–
$w(1)$	max wage	0.992	0.99	1.03
$\bar{w}$	mean wage	0.973	0.96	1.00
$w(R)$	min wage	0.955	0.94	0.98
$\lambda G(R)$	job destruction	0.049	-2.48	-2.58
$s + \lambda G(R)$	separations	0.086	-1.44	-1.49
rU	value unempl.	0.964	0.97	1.01

labor productivity is $0.075/0.020 = 3.75$ and their correlation coefficient -0.524 (see Shimer, 2005a, Table 1), which gives a partial impact of productivity of -1.96. The model prediction of an elasticity of -1.49 with respect to mean productivity is of the right order of magnitude.[14]

The elasticity that has attracted most attention in the literature is the one of tightness, which drives the job creation rate and the exit from unemployment. In the canonical model this is 3.84. In his original critique of the search and matching model Shimer (2005a) finds an elasticity of 1.71. The target for this elasticity is 7.56 (and not 19.1, as originally claimed by Shimer, which would be the case if there were no other shocks in the model). Virtually the only reason for the difference in the two elasticities is that we have used a bigger value for z. The bigger z 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. When job destruction is held constant, the change of z from 0.4 (Shimer's number) to our 0.708 increases the elasticity in our version of the model from 1.74 to 3.53.

The results in Table 3 show that the equilibrium response of wages to productivity shocks is very close to proportionality. This encouraged the search of alternative wage determination mechanisms but whether it is reasonable or not depends on the data. It is clear, however, that (a) the model can accommodate sufficient wage stickiness without violating rationality, because of the local monopoly rents created by a job match (Hall's,

[14] In the data the job destruction rate has higher variance than the employment-unemployment transition, because quitting into unemployment is procyclical. In this paper we assumed that the job destruction rate (or more accurately, displacement) is the only cyclically-sensitive component of the employment-unemployment transition, so the differential in the model between the cyclicality of the job destruction rate and the overall transition is smaller than it is in the data.

2005a, point), and (b) even small amounts of wage stickiness can make a lot of difference to the response of job creation to productivity shocks.

Before taking a close look at the empirical evidence on wage cyclicality, I derive one final set of elasticities from the model. These are the partial elasticities that would appear in an estimated wage equation with p, θ and some other non-cyclical controls on the right-hand side. I derive here the elasticities with respect to p and θ at constant job-specific productivity $\bar{x}$, so they are ones that would be estimated in individual wage regressions. I use equation (23) for wages and (18)-(15) for the two reservation values and compute numerically the following partial wage elasticities:[15]

$$\frac{\partial \ln w}{\partial \ln p} = 0.6 \qquad \frac{\partial \ln w}{\partial \ln \theta} = 0.1. \tag{34}$$

Translating the latter elasticity into one with respect to unemployment yields -0.28. There is consistency between these elasticities and the "total" ones in Table 3, since

$$\frac{d \ln w}{d \ln p} = \frac{\partial \ln w}{\partial \ln p} + \frac{\partial \ln w}{\partial \ln \theta}\frac{d \ln \theta}{d \ln p} = 0.97, \tag{35}$$

which compares favorably with the 0.96 derived directly in Table 3. I also report the total elasticities with respect to unemployment, obtained from the model, which can be compared directly with the econometric evidence.[16]:

$$\frac{\partial \ln w}{\partial \ln u} = -0.36 \quad \text{or} \quad \frac{\partial \ln w}{\partial u} \times 100 = -2.15 \tag{36}$$

The latter number says that in the model, when cyclical unemployment is higher by a 1 percentage point cyclical wages are lower by 2.15%.

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 econ-

[15] Perhaps surprisingly, the computed elasticities turn out to be virtually identical to the ones that can be computed directly from (24). The computed partial effects on U and V are: $\partial rU/\partial p = 0.55$, $\partial rU/\partial \theta = 0.14$, $\partial rV/\partial p = 0.37$, $\partial rV/\partial \theta = -0.14$.

[16] In order to derive the numbers in (36) I made use of the equilibrium response of unemployment to productivity shocks, including the response due to job destruction. If instead I use the variances and covariances given by Shimer (2005a) to compute the implied elasticity of unemployment to productivity I obtain $d \ln u / d \ln p = -3.88$ (instead of the model's -2.74), which implies that the wage elasticity and semi-elasticity in (36) are -0.24 and -1.52 respectively.

omy.[17] 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. 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; i.e., wages are sticky, and may exhibit a limited degree of pro- or counter-cyclicality depending on time period, deflator used, coverage and other issues.

A second stimulus to the study of wage cyclicality came with the publication of Lucas and Rapping's (1960) paper on the intertemporal substitution hypothesis. Procyclical wages are crucial in driving employment fluctuations in their model. Again, the predominant regression used to test the model was one of time series data for the economy as a whole or for a big fraction of it (e.g., manufacturing). Results were similar to the earlier studies, that there is probably some, but not much cyclicality. Because these studies used more recent data they generally find more procyclical wages than the earlier studies did.

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. The search and matching model draws a sharp distinction between the cyclicality of the wages negotiated in new matches and the wages of ongoing relationships. The outcome that matters for job creation is the share of a new match claimed by the firm. given this share, the timing of wage payments is irrelevant (see also Shimer, 2004). But 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 counter-cyclical bias in wages in the aggregate studies, at least during the 1970s and 1980s.[18] 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

[17] 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). I focus on US evidence but there is also some comparable work for other countries, with similar results. See for example Hart (2006) for Britain, Peng and Siebert (2007) for Germany and Carneiro and Portugal (2007) for Portugal.

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

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.[19] 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. Table 4 summarizes the results of individual studies of wage behavior, focusing on studies that draw a distinction between continuing jobs and new matches. It gives 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 3 shows the estimated cyclical component for wages in new and continuing matches from Devereux's (2001) PSID study.[20]

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 that remain in the same job with the same employer (Devereux, 2001, Shin and Solon, 2006), are still mildly procyclical. The procyclicality of job stayers' wages appears to be mainly 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 coefficient in wage regressions for job changers is close to 3, i.e., for every percentage point rise in unemployment, the wages in new matches are lower by about 3%. Because no study distinguishes between the wage impact of own productivity, economy-wide productivity

[19] As Abraham and Haltiwanger (1995) emphasize, the procyclicality of wages may vary across cyclical episodes. 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, and earlier cycles may be different. Barnichon (2006) shows that the contemporaneous correlation between productivity shocks and unemployment changed in the early 1980s, which also points to heterogeneity over cyclical episodes.

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

Table 4: Estimates of the cyclicality of hourly wages

Author	Data	Coefficient on $-\Delta u \times 100$	
Bils (1985)	NLSY 1966-80	all (sep whites/nonwh.)	1.6/1.8
		stayers	0.6/0.4
		changers	3.0/4.0
Shin (1994)	NLSY 1966-81	all (sep whites/nonwh.)	1.7/1.4
		stayers	1.2/0.2
		changers	2.7/3.8
Barlevi (2001)	PSID, 1968-93	changers	2.59
	NLSY, 1979-93	changers	3.00
Beaudry and DiNardo (1991)	PSID 1976-84	all, cont. u^1	0.7
		all, initial u^2	0.6
		all, min u^3	2.9
Beaudry and DiNardo (1991)	CPS 1979, 1983	all, cont. u^1	0.0
		all, initial u^2	0.0
		all, min u^3	3.1
Grant (2003)	NLSY 1966-81	all, cont. u^1	2.37
		all, initial u^2	0.60
		all, min u^3	2.29
Solon, Barsky and Parker (1994)	PSID 1968-87	all men	1.40
		all women	0.53
		stayers, men	1.24
Devereux (2001)	PSID 1970-91	all	1.16
		stayers	0.81
		single job holders	0.54
Shin and Solon (2006)	NLSY 1979-93	all	1.37
		stayers	1.17
		single job holders	1.13

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, as follows: 1. contemporraneous unemployment, 2. unemployment at start of job, 3. lowest unemployment since start of job and labor-market tightness (even if measured only with unemployment), it is not possible to compare each one of the elasticities of the model with the empirical estimates. However, converting both the model prediction and the empirical estimates to an overall impact of the cyclical component of hourly productivity on wages gives very similar results.

A first comparison can be made between the model elasticities in (36) and the estimates in Table 4. The model prediction of -2.15 for the semi-elasticity is a little below the consensus estimate in the literature. The estimate in the literature is obtained by regressing the coefficients on the time dummies on the change in national unemployment and a linear time trend. However, examination of the data shows that a linear time trend is not necessarily the best approximation to the trend change. The model is more about cyclical changes in wages and unemployment. In Figure 3 I HP-filtered the PSID-derived data and re-ran the regression, obtaining, for job changers,

$$\begin{aligned} \Delta \log w_t &= 0.00 \quad \underset{(0.65)}{-2.92}\Delta u \qquad R^2 = 0.51 \end{aligned} \tag{37}$$

The coefficient estimate is very similar to the ones obtained in the literature and still slightly above the model prediction.

The same conclusion emerges when we compare the elasticities with respect to the model's driving force, productivity. In the model the total elasticity of wages with respect to productivity is about 0.96. In order to convert the estimated unemployment elasticities to productivity elasticities, 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 regression which yields, $\Delta u_t/\Delta \ln p_{t-1} = -0.32$. This result is remarkably robust to small changes in specification, such as using the log-change in labor productivity instead of its deviation from HP trend. When the sample is restricted to 1970-1993, as in the panel studies, the coefficient goes up to -0.45. 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 we find elasticities exceeding 0.9 in the most conservative estimates, and for the estimates over the 1970-93 period elasticities exceeding 1, in the range 1.2 to 1.4.

Running a regression with the data in Figure 3, with dependent variable the cyclical component of the change in log wages and independent the cyclical component of the change in log productivity gives an elasticity of 1.7, well above the one predicted by the model but not significantly different from it. More interestingly, we can now estimate

$$\begin{array}{llllll} \Delta \log w_t & = & 0.00 & +0.08\Delta \log \theta & +0.77\Delta \log p & \\ & & & (0.036) & (0.66) & R^2 = 0.47 \end{array} \tag{38}$$

The estimated elasticities compare favorably with the model prediction of 0.1 and 0.6 respectively.[21]

Of course, the initial wage is not the only one that matters in the job creation decisions of firms, although it is the main influence. But other evidence also supports the claim that the cost of labor to the firm is procyclical.[22] The wages of continually employed workers also increase in cyclical peaks, with an estimated unemployment coefficient of $1-1.5$. This implies a wage-productivity elasticity of $0.3-0.5$.[23] Let us suppose that workers hired in recession expect their wages in the future to respond to changes in the state of the economy with the same elasticities as wages in current ongoing matches. The fact that the elasticities in continuing jobs are about half of what they are in new jobs implies that the losses suffered in recession are not immediately reversed. However, this is only indirect evidence for this important property. More direct evidence on this issue was provided by Beaudry and DiNardo (1991).

They 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 kinds of 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. When they ran regressions with each unemployment variable introduced separately in the wage regressions, their results were consistent with earlier studies. But when they nested the regressions, they found that the dominant influence 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

[21] More recently, and too late to fully discuss in this version of the paper, Haefke, Sonntag, and van Rens (2007) computed a quarterly wage series from the CPS, for matches that originate from non-employment. Although the results are still preliminary, they also show virtual proportionality between wages and productivity.

[22] 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 another reason for procyclicality in labor costs.

[23] Blank (1990) who unlike 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.

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.[24]

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 form quitting.

Yet more evidence supporting the strong procyclicality of wages was found by Blanchflower and Oswald (1994)[25] They estimated a "wage curve" for industry-aggregated wages across a panel of 19 US 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 interpret this finding as evidence in favor of the bargaining model for wage determination. It implies that there is co-movement 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 Lessons for the modeling of wages

The results of panel regressions contain one clear message: the wages of workers who change jobs during the year are about as cyclical as labor productivity but the wages of those in ongoing jobs are about half as cyclical (in terms of the wage-productivity

[24] 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.

[25] The main objective of Blanchflower and Oswald (1994) was to show that there is a "wage curve", a negative relation between real wages and local unemployment. Their main tests 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 4 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 David Card (1995) in his review of Blanchflower and Oswald points 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).

elasticity). Moreover, wages in ongoing jobs respond more to an improvement in labor market conditions than to a deterioration.

The Nash wage equation of search models does not quite match these facts but it matches the most important one: that in equilibrium the wages negotiated in new matches are about as cyclical as productivity. The evidence certainly does not support wage equations that imply so much cyclical stickiness for new matches as to provide the answer to the unemployment volatility puzzle. As an example I take the Hall and Milgrom (2006) wage equation, which has already been influential in this literature. In their equation workers and firms bargain over the wage making threats that increase the costs from prolonging the bargaining to the other side, but never threatening to quit. Outside labor market conditions do influence the outcome of the wage bargain but only because there is a positive probability that the productivity of the match may be lost if negotiations last long, and both sides be thrown back to the vacancy and unemployment pools. Given the small probability of an exogenous loss of the productive opportunity, the impact of the outside labor market on wages is small. In numerical illustrations the authors show that with the Nash wage equation and their choice of parameters the wage-productivity elasticity is equal to 0.94, and it is the sum of the elasticity with respect to own productivity, 0.5, and with respect to outside conditions, which adds the remaining 0.44. With their credible bargaining model, the internal elasticity is again 0.5[26] but the external one is 0. This implication is not supported by the panel wage regressions. Outside conditions matter, especially, as argued by Beaudry and DiNardo (1999), when there is an improvement.

Of course, outside conditions can play a role in strategic bargaining situations. Consider the following modification to the Hall and Milgrom (2006) model. Following Shaked and Sutton (1984) and Sutton (1989), assume that during negotiations and whilst each party is waiting for the other to make a counter offer, it is also looking for an alternative match. This threat is credible because neither party threatens to quit into unemployment and neither party need tell the other that they are actively searching for an alternative. If another offer is found the party that finds it can either switch, or engage in Bertrand competition with the existing partner. In the Shaked-Sutton (1984) model there is a fixed period T after which one party switches to another partner if no agreement is reached. More realistically, a party may switch to another partner with a probability that depends on market tightness. If θ is high the worker is more likely to find a partner

[26] They assume the share of labor to be 0.5 rather than our 0.6, which gives their internal producitivty elasticity, but this difference is immaterial in the Nash equilibrium.

and switch than the firm is, for similar reasons to the ones in the canonical model. The wage outcome in this game is one that depends on outside conditions not through the dependence of the reservation payoffs on outside conditions, as in the canonical model, but through the probability that an alternative match may be located during protracted negotiations. If it is assumed that the probability that the negotiating agents locate partners at the same frequency as the unemployed agents in the canonical model the outcomes should be similar, although the full solutions need to be worked out to make a statement of this kind with confidence.

In this environment, why would the wages of continuing workers not reflect outside conditions as much as the wages of new jobs? Most likely because unattached workers are more likely to search during negotiations to threaten the firm with abandoning negotiations than incumbents are. In a similar vein, incumbents are more likely to search for an alternative job when outside labor market conditions improve, whereas firms are less likely to search for an alternative worker altogether. So good conditions are more likely to be reflected in renegotiated wages than bad conditions are.[27]

Finally, I discuss a small modification of the canonical model that shifts the entire cyclical variation in wages to the starting wage and makes the wage in the rest of the job tenure flat, except for workers hired in recession. Suppose workers are risk averse but firms risk neutral, for the reasons given in the implicit contract models of Azariadis (1975) and Baily (1974).[28] As argued by the implicit contract literature, the risk-neutral firm absorbs all fluctuations in productivity as long as it is jointly rational to continue the job. I derive the wage equation under risk aversion and quitting threats, by making the assumption that all job destruction is exogenous. It turns out that if I focus on job creation and the job finding rate this assumption makes no difference to the results, when compared with the canonical model. I therefore write $\lambda = 0$ and $x = 1$ in the model of section 2, and so set $s = 0.083$, i.e., all job separations are exogenous. I study a market environment that fluctuates between two states, a high-productivity one and a low-productivity one. The output flow of each match in the high state is a constant p_h and in the low state another constant $p_l < p_h$. When the economy is in the high state the low state arrives at rate μ_h and when it is in the low state the high state arrives at rate μ_l. Therefore, the mean duration of the high state is $1/\mu_h$ and the mean duration

[27] See also Arozamena and Centero (2007) Building on the common argument that incumbents with long tenures accumulate job-specific capital, they show that the cyclicality of wages should fall with tenure.

[28] See also Rudanko (2006) for similar resuls.

of the low state $1/\mu_l$, and on average over long periods of time the economy spends a fraction of the time $\mu_l/(\mu_h+\mu_l)$ in the high state and a fraction $\mu_h/(\mu_h+\mu_l)$ in the low state. The ratio of vacancies to unemployment jumps between a high value θ_h and a low value θ_l according to the state of the economy, and we will focus on this variable rather than employment or unemployment, which change more slowly towards a high or low value when the economy makes transitions between the two states.

In the good state vacant jobs become occupied at rate $q(\theta_h)$, and unemployed workers find jobs at rate $\theta_h q(\theta_h)$. Similar expressions hold in the bad state. Since when the worker is employed there are no frictions and information about the state is complete and symmetric, we can ignore wage variations within each state as irrelevant regardless of attitudes to risk. There are therefore a maximum of four wage rates that we need to distinguish, (w_h, w_h'), respectively for a high-productivity and a low-productivity state, and applying to matches formed in the good state; and (w_l, w_l'), respectively for a bad and a good state, applying to matches formed in the bad state.

I make the extreme assumption that workers have no access to the capital market and so hold no assets. Their consumption is always equal to their income. When they are unemployed they receive income z from an outside agent, e.g., the government, which is not contingent on the state of the market. Consider first the equilibrium outcome when the firm and the worker fully commit to the job until it is destroyed by the exogenous process s. Then, if workers derive utility $u(w)$ from a wage w, with $u'(w) > 0$ and $u''(w) \leq 0$, it is easy to show that there are only two wages, w_h for jobs formed in the good state and $w_l < w_h$ for wages formed in the bad state. Once a job is formed, the wage is fixed for the tenure of the job. In this environment, the elasticity of wages in continuing jobs with respect to cyclical productivity is zero. But wages in new matches respond to cyclical change.

In order to compare the wage equations derived from this model with the wages of the canonical model I compute the wages of this model in the limit, as risk aversion vanishes. The full wage equations obtained from the model evaluated at $u''(w) = 0$

are:[29]

$$w_h = (1-\beta)z + \beta(p_h + c\theta_h) - \frac{\beta\mu_h}{r+s+\mu_h+\mu_l}[p_h - p_l + c(\theta_h - \theta_l)] \quad (39)$$

$$w_l = (1-\beta)z + \beta(p_l + c\theta_l) + \frac{\beta\mu_l}{r+s+\mu_h+\mu_l}[p_h - p_l + c(\theta_h - \theta_l)] \quad (40)$$

If each cyclical state has sufficiently long duration, these wage equations become identical to the wage equation of the canonical model. As the economy fluctuates between the high and the low state, wages in new matches change in the same proportion as the change in productivity, but wages in continuing jobs do not change at all. Giving realistic values to the transition rates μ_h and μ_l reduces the response of both wages and tightness to the cyclical productivity change. According to the NBER's dating of business cycles, the mean peacetime duration of a contraction between 1960 and 2001 was 10.7 months and the mean peacetime duration of an expansion was 57 months.[30] Given my quarterly calculations, I set $\mu_h = 3/57 = 0.053$ and $\mu_l = 3/10.7 = 0.28$ and compute the following elasticities:, defined by and similarly for θ :

$$\frac{\log(w_h/w_l)}{\log(p_h/p_l)} = 0.21 \qquad \frac{\log(\theta_h/\theta_l)}{\log(p_h/p_l)} = 2.87. \quad (41)$$

The wage elasticity in particular is sensitive to the length of the cycle, because it reflects average conditions across the two cyclical states.

Suppose now we allow workers to search on the job. The workers hired in the good state are still paid w_h throughout their tenure, as in (39), so they will never have an incentive to quit their firm. But workers hired in the bad state will have an incentive to quit when the good state arrives if $w_h > w_l'$. If the worker quits, the firm will re-advertise the vacancy and when a new worker arrives it will offer w_h, because the worker will have been hired in the good state. But then the firm is worse off than if it made a counter-offer of w_h to the worker hired in the bad state to avoid the quit: the productivity flow of the two workers is the same but in the case when the firm allows the worker to quit it suffers a period of negative return, when the job is vacant and re-advertised.

[29] The derivation follows the steps of the derivations in the canonical model except that now the economy may change state according to μ_h and μ_l. The full derivation is available on the author's website (to be supplied).

[30] The excluded "wartime" cycle is the one for December 69 to November 1973. Including it does not alter the mean duration of recessions but lengthens the mean duration of expansions to 64 months. The mean duration of expansions is influenced by the one very long expansion between March 1991 to November 2001. If both this and the Vietnam expansions are excluded the mean duration of expansions is 44.4 months.

It follows that when the worker hired in the bad state makes a credible threat to quit in the good state it will be to the firm's advantage to increase her wage rate to w_h. If the firm has full information on the worker's search activities and job contacts, the threat to quit becomes credible when the worker finds another job, an event that arrives at rate $\theta_h q(\theta_h)$. I solve the model under the simplifying assumption that the firm offers the w_h as soon as the good state arrives. The solution derived is simpler and more transparent than the one derived under the more realistic assumption of a counter-offer in the event of a credible threat, with similar implications for volatility.[31] The solution obtained for the wages of those hired in the good state is as in (39) but the solution obtained for those hired in the bad state is as in the canonical model:

$$w_l = (1-\beta)z + \beta(p_h + c\theta_h). \tag{42}$$

This wage, however, is paid only for as long as the bad state lasts, and revised to w_h when the good state arrives.

With these wage equations the relevant cyclical elasticities are

$$\frac{\log(w_h/w_l)}{\log(p_h/p_l)} = 0.81 \qquad \frac{\log(\theta_h/\theta_l)}{\log(p_h/p_l)} = 2.85. \tag{43}$$

Moreover, wages in ongoing jobs now respond to an improvement in cyclical conditions with the same elasticity if the worker was hired in the bad state, but do not respond to the cycle if the worker was hired in the good state. These results are consistent with the evidence on the cyclicality of wages in new matches and with the evidence of Beaudry and DiNardo (1991) and Grant (2003). The wages of all workers reflect the best labor market conditions in the tenure of the job, with an elasticity close to 1. The workers for whom initial conditions still matter are the ones for whom the initial conditions are still the best they have experienced. Initial wages are very responsive to outside conditions, but wages in continuing jobs are on average less responsive, because only those who are paid below the best outside offers get pay raises in the event of an improvement in conditions.

6 What might drive fluctuations in job creation?

It follows from the preceding analysis that wage stickiness is not the answer to the unemployment volatility puzzle, not because it cannot deliver it, but because it does

[31] The reason for this is that the duration of search, $1/\theta_h q(\theta_h)$ is much shorter than the duration of the good state, $1/\mu_l$, so the wage is adjusted fast in the credible threat case too.

not receive support from the econometric findings. Yet, even with endogenous job destruction, the model fails to account for about half to two thirds of the volatility in unemployment. Where might the answer be?

A number of avenues unrelated to wage stickiness, some of which have been explored in the literature, can deliver more volatility in unemployment. First, within the framework of the canonical model, variable search intensity, noncyclical hiring and firing costs and nonlinear costs of posting a vacancy contribute to more volatility. Variable search intensity intensifies the complementarities inherent in search models. When firms open more vacancies workers search with more intensity and firms in turn open up more vacancies.[32] Hiring and firing costs reduce the profit of the firm and so increase the percentage change in profit caused by a given percentage change in labor productivity (Mortensen and Nagypal, 2006).

Nonlinear vacancy costs do something similar, although the empirical issue of exactly what are these costs has not yet been tackled. In the canonical model the unit vacancy cost is linear in the firm's choice variables but increases with aggregate tightness because of the congestion effect of search. Yashiv (2006) and Rotemberg (2006) give plausible reasons for nonlinearity and show that it contributes to unemployment volatility. But Yashiv advocates convex costs whereas Rotemberg assumes concave costs. If vacancy costs are interpreted as advertising and interviewing costs the assumption of concave costs is plausible. The fixed cost of placing newspaper ads or of convening interviewing panels justify it. But convex costs through congestion are also plausible; newspapers may offer discounts for multiple job ads but put up their mean advertising rates when there is more demand.

The unemployment volatility that the model delivers can also be increased with some bigger departures from the canonical model. Two of these is the introduction of on-the-job search and the study of different types of driving forces for the cycle.

On-the-job search is empirically important but the question is, does it make much difference to the unemployment model, or can it be neglected for the same reasons that transitions out of the labor force are neglected, that it does not change the results much. The latter appears to be the view taken by most theorists, with claims that the cyclical implications for unemployment go the other way: because of congestion caused by the entry of employed job seekers in the recovery phase, the transition out of unemployment

[32] This complementarity was the original motivation for Peter Diamond's famous "coconut" model. See Diamond (1982). For explicit applications to labor markets and business cycles see Pissarides (2000 chapter 5), Merz (1995) and Nagypal (2006)

slows down (Pissarides, 1994). But recently Krause and Lubik (2004) and Nagypal (2006) have shown that on-the-job search can increase the volatility of unemployment, even with Nash wages. Krause and Lubik derive their results through the interaction of job quality and search intensity. As in Pissarides (1994), in cyclical recoveries more employed job seekers enter the market and the composition of jobs shifts in favor of more productive jobs. But they also assume increased search intensity and show within the context of a business cycle model that the response of unemployment and tightness to cyclical shocks increases, whereas the response of wages is muted because the hiring options of the firm increase. Put in terms of the language of the model, the tightness measure that influences wages is the ratio of vacancies to all job seekers, and this measure is not very responsive to the cycle.

Nagypal (2006) also argues that on-the-job search activity increases unemployment volatility, because of heterogeneities between employed and unemployed job seekers. The key difference between employed and unemployed job seekers in her model is that employed job seekers have a current situation that is better than the one that unemployed job seekers have. So if an employed job seeker is prepared to give up her current job to accept another it must mean that she likes the new job a lot, and so is likely to have a longer tenure in it than an unemployed job seeker is. Unemployed job seekers are more likely to accept an offer, and this is good for job creation, but employed job seekers are more likely to stay longer when they do accept, which is also good for job creation. Nagypal shows that if there are job creation shocks firms prefer the employed job seekers because they have longer time periods over which to recover the job creation costs. So, given that in the recovery phase of the cycle more employed workers search for jobs, the response of job vacancies to the recovery is bigger than in the canonical model.

With regard to the driving force of the cycle, the canonical model assumes that it is a uniformly-distributed productivity shock. Mortensen and Nagypal (2006) argue that job destruction shocks can also increase the volatility of job creation, a property not satisfied by the canonical model. The key difference between the role of separation shocks in Mortensen and Nagypal's model and in the model of this paper is that in their model the shocks are exogenous, whereas in the model of this paper they are endogenous responses to the productivity shocks. In terms of our notation, their shocks are exogenous changes in s, whereas ours are endogenous changes in $G(R)$. Now, looking at the unemployment equation (6), it is clear that as far as the volatility in unemployment is concerned, it should not matter if the shocks are in s or in $G(R)$. They both have the same impact on u. But looking at the job creation condition $V = 0$, the exogenous changes in s have a large impact on V at given tightness, because they influence the rate at which future profits are discounted. See for example (12) or (16). Mortensen and Nagypal emphasize this channel, which has also been found important by previous investigators, most notably Yashiv (2006). A rise in s within the plausible range has a large impact on the discount rate because it is a big component of it. But V satisfies the envelope property with respect to R, so endogenous changes in $G(R)$ should have no impact on V at given tightness, provided they are small enough. In our model this is the case. Although the endogenous changes in the separation rate are of the same order of magnitude as the exogenous ones used by Mortensen and Nagypal, the impact on the elasticity of θ with respect to p in our model is minimal, and due to the fact that the 1% discrete change in p that we modeled is not "small enough".[33]

The intuition behind the envelope property satisfied by endogenous job destruction is this. Changes in endogenous job destruction have two effects on expected profits that work in opposite directions. They change both the discount rate and the conditional mean of expected future output. A rise in endogenous job destruction raises the discount rate, which reduces the present-discounted value of future profits at give profit flow, but also raises the expected profit flow because the jobs that are destroyed are in the left tail of the productivity distribution. At the optimum point the two effects exactly cancel each other out. Exogenous separation shocks have only the discounting effect, because they are assumed to influence all jobs with the same probability. The additional jobs destroyed by an increase in exogenous job destruction are a random selection from the productivity distribution.

In view of the big difference that the modeling of separation shocks makes to optimal job creation, it is important to have more evidence on the nature of the cyclical changes in separation. Given their high correlation with productivity shocks it is unlikely that they are exogenous to the changes in productivity. Given also the long-established finding in the literature about the changing composition of jobs during the cycle, it is unlike that the majority of job destruction changes involve random draws from the productivity distribution. One would expect more destruction of less productive jobs when negative cyclical shocks arrive. But a fuller decomposition of separation shocks, namely, what fraction is due to endogenous changes in $G(R)$ or exogenous changes in s requires more

[33] The endogenous job destruction in our model raises the elasticity of θ with respect to mean productivity from 3.53 to 3.70.

data than we have at present.[34]

Other types of shocks are plausible and can deliver more volatility. First, new jobs may be subject to bigger shocks than existing jobs (see Costain and Reiter, 2005, Reiter, 2006, De Bock, 2006, Eyigungor, 2006). Of course, if all new vacancies reflect the higher productivity, the threat point of workers in new matches adjusts to it too. But two factors can increase the volatility of profits when new technology is embodied. First, the size of productivity shocks hitting new jobs is bigger than appears to be from looking at the variance of the average hourly product of labor, because existing jobs get smaller productivity shocks. Second, as noted by Reiter (2006), the worker's outside option varies with the productivity of new jobs, so it is more cyclical than in the canonical model, whereas the outside option of the firm is zero in both models. When a job is being created the worker anticipates a cyclical threat point whereas the firm anticipates acyclical productivity and threat point, and this increases the share of the firm in the peak and reduces it in the trough.

Unemployment also responds more to cyclical shocks when they are not uniformly distributed across industries. The industries that get the large positive shocks create more jobs, but the industries that get the small positive shocks do not destroy more jobs. The reason for the asymmetry is the monopoly rent associated with job matches. Industries that receive smaller positive shocks in the recovery phase can afford to pay higher wages in response to the bigger improvement of conditions elsewhere without shutting the jobs down. The econometric evidence shows that wages in existing matches do not rise by as much as wages in new jobs in the peak, which creates the asymmetry between job creation in the industries that receive the large positive shocks and job destruction in the industries that receive the small shocks.

Finally, and empirically perhaps most importantly, the cycle may be partly driven by demand shocks. With this driving force productivity can be mildly procyclical, wages proportional to it and profits higher by a bigger proportion. Normally demand shocks make wages anticyclical, which would go against the evidence. However, in the search and matching model, because wages depend also on market tightness which is procyclical, the equilibrium wage could be procyclical. Rotemberg (2006) shows that if the cycle is driven by shocks to the elasticity of demand the model can deliver low procyclicality in productivity and large unemployment volatility, consistent with both

[34] As in Mortensen and Nagypal, the endogenous separation in our model preserves the downward-sloping Beveridge curve, but the slope is very flat because of the small response of θ to the cycle in the canonical version of the model.

volatile and sticky wages. Firms in his model are large and monopolistic competitors, and in the boom competition intensifies so output and employment expand. Braun, De Bock and DiCerio (2006) find that there are both technology and demand shocks driving unemployment in their VARs, and Barnichon (2006) shows that the correlations between productivity shocks and unemployment also vary across cycles, which is consistent with the coexistence of productivity and demand shocks. Abraham and Haltiwanger (1995) also note that the cyclical properties of wages vary across samples, with some cycles exhibiting more demand-side shocks and some others more supply-side shocks.[35]

7 Conclusions

The following conclusions can be drawn from this paper.

1. Both the inflow and outflow rates drive the dynamics of unemployment, the inflow rate contributing about a third to unemployment volatility and the outflow rate the remaining two thirds.

2. If the only driving force for the cycle is a uniform productivity shock, endogenous job destruction contributes to the volatility of unemployment. But it does not have an impact on the job creation decisions of firms, which more or less mimic the decisions in a model with constant job destruction. But if job destruction is also driven by independent shocks that hit all jobs with the same probability, job creation falls when there are more job destruction shocks.

3. Wages in the model respond to productivity shocks by an elasticity close to 0.95. This is also more or less the elasticity estimated with panel data for new job matches. The wage-productivity elasticity estimated for continuing jobs is lower, in the range $0.3 - 0.5$, but it is irrelevant for job creation or job destruction.

4. Small modifications to the model can give the elasticities that are estimated with panel data, with no impact on unemployment volatility. So the answer to the unemployment volatility puzzle is not in wage stickiness.

[35] There is a large recent literature on price stickiness in search models that addresses itself mainly to monetary policy and the Phillips curve which has similar implications for unemployment volatility. Andres, Domenech and Ferri (2006) explore a SDGE version of the search and matching model with a number of different mechanisms for the cycle and conclude that price stickiness is the most potent cause of volatility.

5. Although small modifications to the model can deliver more volatility with the canonical Nash wage equation, the most promising avenues for a full explanation are likely to be in the modeling of alternative driving forces. Demand shocks in particular can deliver more volatility without the need to assume wage stickiness.

References

[1] Abraham, K. G. and J. C. Haltiwanger (1995). "Real Wages and the Business Cycle." *Journal of Economic Literature* 33: 1215-1264.

[2] Andres, J., R. Domenech, and J. Ferri (2006). "Price Rigidity and the Volatility of Vacancies and Unemployment." University of Valencia mimeo.

[3] Andolfatto, D. (1996). "Business Cycles and Labor Market Search." *American Economic Review* 86: 112-132.

[4] Arozamena, L. and M. Centeno (2007). "Tenure, Business Cycle and the Wage Setting Process." *European Economic Review* forthcoming.

[5] Azariadis, C. (1975). "Implicit Contracts and Underemployment Equilibria." *Journal of Political Economy* 83: 1183-1201.

[6] Baily, N. (1974). "Wages and Employment under Uncertain Demand." *Review of Economic Studies* 42: 37-50.

[7] Barlevy, G. (2001). "Why are the wages of job clangers so procyclical?" *Journal of Labor Economics*, 19: 837–78.

[8] Barnichon, R. (2007). "Productivity, Aggregate Demand and Unemployment Fluctuations." LSE mimeo.

[9] Barro, R. J. (1977). "Long-Term Contracting, Sticky Prices, and Monetary Policy." *Journal of Monetary Economics* 3: 305-316.

[10] Beaudry, P. and J. DiNardo (1991). "The effect of implicit contracts on the movement of wages over the business cycle: Evidence from micro data." *Journal of Political Economy*, 99: 665–88.

[11] Bell B., S. Nickell and G. Quadrini. (2002). "Wage Equations, Wage Curves and All That." *Labour Economics* 9: 341-360.

[12] Bils, M. J. (1985). "Real wages over the business cycle: Evidence from panel data." *Journal of Political Economy*, 93: 666–89.

[13] Binmore, K. G., A. Rubinstein, and A. Wolinski (1986). "The Nash Bargaining Solution in Economic Modelling." *Rand Journal of Economics* 17: 176-188.

[14] Blank, R. M. (1990). "Why Are Wages Cyclical in the 1970s?" *Journal of Labor Economics* 8: 16-47.

[15] Blanchflower, D. G. and A. J. Oswald (1994). *The Wage Curve*. Cambridge, MA, MIT Press.

[16] Brandolini, A. (1995). "In Search of a Stylised Fact: Do Real Wages Exhibit a Consistent Pattern of Cyclical Variability?" *Journal of Economic Surveys* 9: 103-163.

[17] Braun, H., R. De Bock, and R. DiCecio. (2006). "Aggregate Shocks and Labor Market Fluctuations." Federal Reserve bank of St. Louis Working Paper no. 2006-004A.

[18] Brugemann, B. and G. Moscarini (2007). "Rent Rigidity, Asymmetric Information and Volatility Bounds in Labor Markets." Yale University mimeo.

[19] Card, D. (1995). "The *Wage Curve*: A Review." *Journal of Economic Literature* 33: 785-799.

[20] Carneiro, A. and P. Portugal (2007). "Workers' flows and real wage cyclicality." Institute for the Study of Labor (IZA), Bonn, Discussion Paper 2604.

[21] Costain, J. S. and M. Reiter (2006). "Business Cycles, Unemployment Insurance, and the Calibration of Matching Models." University of Pompeu Fabra mimeo.

[22] Cole, H. and R. Rogerson (1999). "Can the Mortensen-Pissarides Matching Model Match the Business Cycle Facts?" *International Economic Review* 40: 933-959.

[23] Darby, M. R., J. C. Haltiwanger, and M. W. Plant (1986). "The Ins and Outs of Unemployment: The Ins Win." NBER Working Paper 1977.

[24] Davis, S. J. (2005). "Job Loss, Job Finding, and Unemployment in the U.S. Economy over the Past Fifty Years: Comment." *NBER Macroeconomics Annual*, 139-157.

[25] Davis, S. J. and J. C. Haltiwanger (1992). "Gross Job Creation, Gross Job Destruction, and Employment Reallocation." *Quarterly Journal of Economics* 107: 819-863.

[26] Davis, S. J. and J. C. Haltiwanger (1999). "Gross Job Flows". In *Handbook of Labor Economics vol. 3*. O. Ashenfelter and D. Card, eds. Amsterdam: North-Holland, 2711-2805.

[27] Davis, S. J., J. C. Haltiwanger, and S. Schuh (1996). *Job Creation and Destruction.* Cambridge, MA, MIT Press.

[28] De Bock, R. (2006). "Investment-Specific Technology Shocks and Labor Market Frictions." Northwestern University mimeo.

[29] den Haan, W., G. Ramey and J. Watson (2000). "Job Destruction and the Propagation of Shocks." *American Economic Review* 90: 482-498.

[30] Devereux, P. J. (2001). "The Cyclicality of Real Wages Within Employer-Employee Matches." *Industrial and Labor Relations Review*, 54: 835–850.

[31] Diamond, P. A. (1982). "Aggregate Demand Management in Search Equilibrium." *Journal of Political Economy* 90: 881-894.

[32] Elsby, M. W., R. Michaels, and G. Solon (2007). "The Ins and Outs of Cyclical Unemployment." NBER Working Paper 12853.

[33] Eyigungor, B. (2006). "Specific Capital and Vintage Effects on the Dynamics of Unemployment and Vacancies." UCLA mimeo.

[34] Farber, H. (1997). "The Changing Face of Job Loss in the United States." *Brookings Papers on Economic Activity: Microeconomics*: 161-166.

[35] Fujita, S. and G. Ramey (2006). "The Cyclicality of Job Loss and Hiring." University of California San Diego mimeo.

[36] Gertler, M. and A. Trigari (2006). "Unemployment Fluctuations with Staggered Nash Wage Bargaining." New York University mimeo.

[37] Grant, D. (2003). "The Effect of Implicit Contracts on the Movement of Wages over the Business Cycle: Evidence from the National Longitudinal Surveys." *Industrial and Labor Relations Review*, 56: .

[38] Haefke, C., M. Sonntag, and T. van Rens. (2007). "Wage Creation and Job Creation." Unpublished manuscript.

[39] Hagedorn, M. and I. Manovskii (2006). "The Cyclical Behavior of Equilibrium Unemployment and Vacancies Revisited." University of Pennsylvania mimeo.

[40] Hall, R. E. (2005a). "Employment Fluctuations with Equilibrium Wage Stickiness." *American Economic Review* 95: 50-65.

[41] Hall, R. E. (2005b). "Job Loss, Job Finding, and Unemployment in the U.S. Economy over the Past Fifty Years." *NBER Macroeconomics Annual*: 101-137.

[42] Hall, R. E. (2006). "Sources and Mechanisms of Cyclical Fluctuations in the Labor market." Stanford University mimeo.

[43] Hall, R. E. and P. Milgrom (2005). "The Limited Influence of Unemployment on the Wage Bargain." Stanford University mimeo.

[44] Hart, R. A. (2006). "Worker-Job Matches, Job Mobility and Real Wage Cyclicality." *Economica*, 73: 287-298

[45] Hornstein, A., P. Krusell, and G. L. Violante. (2005). "Unemployment and Vacancy Fluctuations in the Matching Model: Inspecting the Mechanisms." Federal Reserve Bank of Richmond *Economic Quarterly* 91(3): 19-51.

[46] Kennan, J. (2005). "Private Information, Wage Bargaining, and Employment Fluctuations." University of Wisconsin-Madison mimeo.

[47] Krause, M. and T. Lubik (2004). "On-the-Job Search and the Cyclical Dynamics of the Labor Market." Johns Hopkins University mimeo.

[48] Langot, F. (1995). "Unemployment and Business Cycle: A General Equilibrium Matching Model." In *Advances in Business Cycle Research*, ed., P.-Y. Henin. Berlin: Springer, 287-322.

[49] Lucas, R. E. and L. A. Rapping (1969). "Real Wages, Employment and Inflation." *Journal of Political Economy* 77: 721-754.

[50] McDonald, J. T. and Worswick, C. (1999). "Wages, Implicit Contracts, and the Business Cycle: Evidence from Canadian Micro Data." *Journal of Political Economy* 197: 884-892

[51] Menzio, G. (2005). "High Frequency Wage Rigidity." University of Pennsylvania mimeo.

[52] Merz, M. (1995). "Search in the Labor Market and the Real Business Cycle." *Journal of Monetary Economics* 36: 269-300.

[53] Mortensen, D. T. and E. Nagypal (2006). "More on Unemployment and Vacancy Fluctuations." Northwestern University mimeo.

[54] Mortensen, D. T. and C. A. Pissarides (1994). "Job Creation and Job Destruction in the Theory of Unemployment." *Review of Economic Studies* 61: 397-415.

[55] Nagypal, E. (2005). "Labor-Market Fluctuations, On-the-job Search, and the Acceptance Curse." Northwestern University mimeo.

[56] Peng, F. and W. S. Siebert (2007). "Real Wage Cyclicality in Germany and the UK: New results Using Panel Data." IZA Discussion Paper no. 2688.

[57] Petrongolo, B. and C. A. Pissarides (2001). "Looking into the Black Box: A Survey of the Matching Function." *Journal of Economic Literature* 39: 390-431.

[58] Pissarides, C. A. (1985). "Short-Run Equilibrium Dynamics of Unemployment, Vacancies, and Real Wages." *American Economic Review* 75: 676-690.

[59] Pissarides, C. A. (1986). "Unemployment and Vacancies in Britain." *Economic Policy* 3: 499-559.

[60] Pissarides, C. A. (1987). "Search, Wage Bargains and Cycles." *Review of Economic Studies* 54: 473-484.

[61] Pissarides, C. A. (1994). "Search Unemployment with On-the-job Search." *Review of Economic Studies* 61: 457-475.

[62] Pissarides, C. A. (2000). *Equilibrium Unemployment Theory.* 2nd ed., Cambridge, MA, MIT Press.

[63] Reiter, M. (2006). "Embodied Technical Change and the Fluctuations of Wages and Unemployment." University of Pompeu Fabra Working Paper no. 980.

[64] Rotemberg, J. (2006). "Cyclical Wages in a Search-and-Bargaining Model with Large Firms." CEPR Discussion Paper 5791. London.

[65] Rudanko, L. (2006). "Labor Market Dynamics under Long Term Wage Contracting and Incomplete Markets." University of Chicago mimeo.

[66] Shaked, A. and J. Sutton (1984). "Involuntary Unemployment as a Perfect Equilibrium in a Bargaining Model." *Econometrica* 52: 1351-1364.

[67] Shimer, R. (2004). "The Consequences of Rigid Wages in Search Models." *Journal of the European Economic Association (Papers and Proceedings)*, 2: 469-479.

[68] Shimer, R. (2005a). "The Cyclical Behavior of Equilibrium Unemployment and Vacancies." *American Economic Review* 95: 25-49.

[69] Shimer, R. (2005b). "Reassessing the Ins and Outs of Unemployment." University of Chicago mimeo.

[70] Shin, D. (1994). "Cyclicality of Real Wages Among Young Men." *Economics Letters*, 46: 137–142.

[71] Shin, D. and G. Solon. (2006). "New Evidence on Real Wage Cyclicality Within Employer-Employee Matches." National Bureau of Economic Research Working Paper no. 12262.

[72] Solon, G., R. Barsky, and J. A. Parker. (1994). "Measuring the Cyclicality of Real Wages: How Important is Composition Bias?" *Quarterly Journal of Economics*, 109: 1–25.

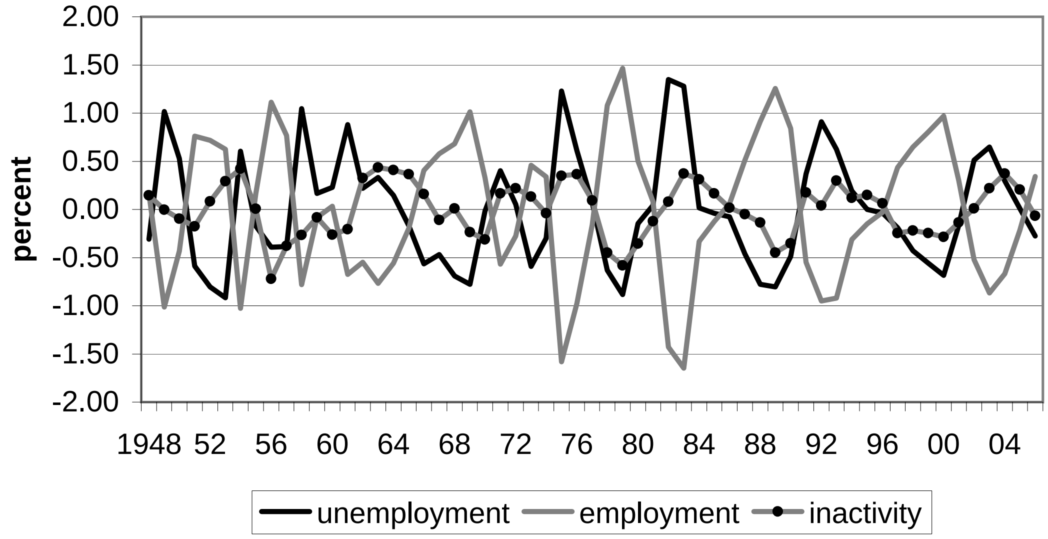
[73] Sutton, J. (1986). "Non-Cooperative Bargaining Theory: An Introduction." *Review of Economic Studies* 53: 709-724.

[74] Veracierto, M. (2004). "On the Cyclical Behavior of Employment, Unemployment and Labor Force Participation." Federal Reserve bank of Chicago Working Paper WP2002-12.

[75] Yashiv, E. (2006). "Evaluating the Performance of the Search and Matching Model." *European Economic Review* 50: 909-936.

[76] Yashiv, E. (2007). "Labor Search and Matching in Macroeconomics." IZA Discussion Paper. Bonn.

Figure 1
Ratios of employment, unemployment and inactivity to population over 16, cyclical components



-

Figure 2
Percent changes in unemployment inflow and outflow rates

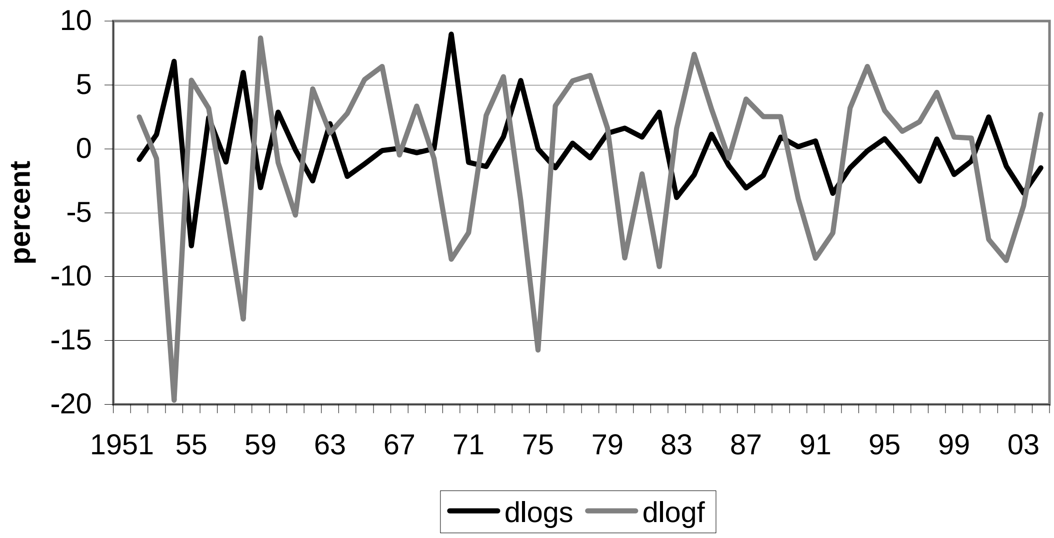


Figure 3

Cyclical wage and producitivty changes