The Limited Influence of Unemployment on the Wage Bargain*

Robert E. Hall
Hoover Institution and Department of Economics
rehall@stanford.edu stanford.edu/∼rehall
Paul R. Milgrom
Department of Economics
milgrom@stanford.edu www.milgrom.net
Stanford University

October 20, 2007

Abstract

When a job-seeker and an employer meet, find a prospective joint surplus, and bargain over the wage, conditions in the outside labor market, including especially unemployment, may have limited influence. The job-seeker's only credible threat during bargaining is to hold out for a better deal, not to terminate bargaining and resume search at other employers. Similarly, the employer's threat is to delay bargaining, not to terminate it. Consequently, the outcome of the bargain depends on the relative costs of delays to the parties, rather than on the payoffs that result from exiting negotiations. Modelling bargaining in this way makes wages less responsive to unemployment. A stochastic model of the labor market with credible bargaining and reasonable parameter values yields larger employment fluctuations than does the standard Mortensen-Pissarides model.

*We are grateful to Daron Acemoglu, John Kennan, Dan Quint, Randy Wright, four referees, and the editor for comments. Hall's research is part of the program on Economic Fluctuations and Growth of the NBER. A file containing the calculations is available at Stanford.edu/∼rehall

1 Introduction

> Congratulations! You made it through the interview process. Both you and the hiring manager agree that you are the right person for the job. Now, however, you must negotiate the terms of the job offer.

So begins Wegerbauer (2000), a book offering advice to job-seekers about dealing with a prospective employer. If terms are indeed determined by negotiation after a match has been identified, then the nature of the negotiation has a role in determining the employer surplus. Anticipation of that surplus influences the employers' recruiting efforts, which affects the level of unemployment. We show that replacing the traditional model of bargaining with a more credible alternating offer bargaining model leads to weaker feedback from current unemployment levels to the current wage. Consequently, when the labor market is hit with productivity shocks, the credible bargaining model delivers greater variation in employer surplus, employer recruiting efforts, and employment than the ”Nash” bargaining model.

The model of the wage-setting process at the heart of our analysis is a non-cooperative alternating offer model and improves on two common conceptions of wage bargaining. According to one conception, employers set wages and other terms and hire the most qualified applicant willing to work on those terms. The terms are offered to applicants on a strict take-it-or-leave-it basis. We believe that this model fails in an important way to describe much of the labor market, though essentially no research has studied the question.

A second common conception, which forms the basis of a large literature whose canon is Mortensen and Pissarides (1994), has wages and other terms of employment set by a "Nash bargain." Models using this formulation assume that the threat point for bargaining is the payoff pair that results when the job-seeker returns to the market and the employer waits for another applicant. A consequence is that the bargained wage is a weighted average of the applicant's productivity in the job and the value of unemployment. That latter value, in turn, depends in large part on the wages offered in other jobs. If an adverse unit productivity shock reduces every employer's reservation wage by one unit, then both terms in the average fall by almost equal amounts. If both changed by exactly one unit, then the employer's recruiting effort would be unchanged and unemployment would not fluctuate. The actual equilibrium is similar to this approximate equilibrium and cannot explain realistic employment fluctuations. This is the point of an influential paper, Shimer (2005).

This flexible-wage conclusion, however, hinges on unrealistic assumptions about bargaining threats, which we challenge. Once a qualified worker meets an employer, a threat to walk away, permanently terminating the bargain, is not credible. The bargainers have a joint surplus, arising from search friction, that glues them together. We make use of bargaining theory from Binmore, Rubinstein and Wolinsky (1986) to invoke more realistic threats during bargaining. The threats are to extend bargaining rather than to terminate it. The result is to loosen the tight connection between wages and outside conditions of the Mortensen-Pissarides model. In our model, a job-seeker loses most of the connection with outside conditions the moment she encounters a suitable employer, but before she makes her wage bargain. The bargain is controlled by the job's productivity and by her patience as a bargainer relative to the employer's. The possibility that she will return to job search remains in the picture because the job opportunity may disappear during bargaining, but this factor has a secondary influence.

The model delivers substantial volatility of unemployment through a mechanism similar to the one in Hall (2005a)—unemployment is high in periods when the wage bargain is unfavorable to employers. In times of low productivity, the wage falls only partly in response, the burden of the rest of the decline falls on employers. Because they have less to gain by hiring a worker, employers put fewer resources into recruiting, and the labor market is slacker.

Wage negotiations between General Motors and the United Auto Workers illustrate the key change we make to the bargaining model (see Holden (1997) for an application of the BRW theory in the union setting). The wage agreement depends on the losses the bargainers suffer during a strike or lock-out. Each side is keenly aware of the costs of delay that fall on themselves and on the other side. The union accumulates strike funds and the company accumulates inventories to lower the costs of holding out for a better deal. The union never seriously considers permanent resignation of the workers as an option and GM does not consider discharging the workers permanently. Except in extreme circumstances, neither threat would be credible, because the workers would do better to accept a reduced wage than to quit, and GM would do better to pay a higher wage than to start over with new workers. This observation has important consequences for the comparative statics of the bargaining model. For example, if a new law were to make it costlier for GM to discharge its workforce during a work stoppage, that would be predicted to have no effect on the wage bargain.

Similarly, the non-cooperative bargaining model of Binmore et al. (1986) distinguishes between the *outside-option* payoff that the parties get by quitting the negotiation to seek other opportunities and the *disagreement payoff* that the parties get during the bargaining, during the disagreement period before the agreement is reached. Unless the outside option is especially favorable, it is the disagreement payoff—not the outside option—that determines the bargaining outcome.

In the alternating offer wage-bargaining environment, so long as reaching an agreement creates value, a bargainer who gets a poor offer continues to bargain, because that choice has a strictly higher payoff than taking the outside option. Threats to exercise the outside option simply are not credible. Since this is common knowledge, changes in the value of the outside option cannot affect the bargaining outcome. In the BRW equilibrium, the parties do not actually spend any time bargaining. They think through the consequences of a sequence of offers and counteroffers and then move immediately to an agreement at the unique subgame perfect equilibrium of the bargaining game. They do not waste time and resources haggling over the wage.

In the MP class of models, conclusions about the insensitivity of compensation to unemployment—and the resulting high sensitivity of unemployment to driving forces—depend on certain key parameters. One is the elasticity of labor supply. Hagedorn and Manovskii (2006) demonstrate that the standard MP model delivers high sensitivity of unemployment to driving forces when labor supply is highly elastic. In that case, workers are close to indifferent to working or searching (in a sense we explain later), so small changes in the incentive to work cause large changes in the volume of search. We review the evidence on labor supply and find that the elasticity needed to generate the observed volatility of unemployment is far higher than the findings from research on labor supply. Our bargaining model delivers a realistic unemployment response to productivity shifts with a labor-supply elasticity in line with that research

For our model, a second key parameter is the cost of recruitment. We take this cost from data on hiring cost reported by employers. If we use a higher figure, the sensitivity of unemployment to productivity is lower. The success of our explanation of unemployment volatility depends on the realism of our inputs.

We model shifts in labor demand as changes in productivity, defined as the ratio of output to labor input. This incorporates shifts in labor demand arising from changes in total factor productivity and in the prices of other inputs.

Although this paper is about the limited response of the wage to conditions in the labor market, we do not provide direct evidence on the flexibility or stickiness of wages. We are skeptical about recent attempts to measure wage flexibility. Our strategy is to measure the empirical relation between productivity fluctuations and unemployment, to confirm that the MP model with standard parameter values falls far short of replicating the observed volatility of unemployment induced by productivity fluctuations, and to compare two models that are successful, the one in Hagedorn and Manovskii's (2006) paper and the one developed here. Following Mortensen and Éva Nagypál (2007), our perspective differs substantially from Shimer's (2005), who considers not the part of unemployment volatility induced by productivity variation, but rather all of the volatility. We show that productivity can account for only a fraction of unemployment volatility, and use that amount as our benchmark of explanatory success.

2 Model

Mortensen and Pissarides (1994) introduced a model that provides the foundation for a large amount of recent research on labor-market fluctuations. Part of that research, including this paper, retains all the elements of the MP model except its Nash bargain for wages. We refer to the MP class of models as those like ours that change only the wage determination specification. Our discussion begins with the elements we take over without change from the MP model.

2.1 Elements common to the MP class of models

The driving force of the model is productivity, p_i, where i is a discrete stationary state variable $i \in [1, \ldots, N]$ with transition matrix $\pi_{i,i'}$. Workers and employers are risk-neutral. Their discount rate is equal to the interest rate, r.

We start by describing the mechanism by which employers and workers match. Matching results from non-contractible pre-match effort by employers—help-wanted advertising and other recruiting costs—reinforced by the search time of job-seekers. It is conventional to describe the mechanism in terms of vacancies, though this concept need be nothing more than a metaphor capturing recruiting effort of many kinds. The key variable is θ_i, the ratio of vacancies to unemployment. The job-finding rate depends on θ_i according to the increasing function $\phi(\theta_i)$ and the recruiting rate is the decreasing function $\frac{\phi(\theta_i)}{\theta_i}$. The separation rate—the per-period probability that a job will end—is an exogenous constant s (see Hall (2005b) for evidence supporting this proposition).

During a period, an individual may be seeking a job or working and an employer may have a number of vacancies open and a number of employees. At the end of the period, the job seeker finds a potential position with probability $\phi(\theta_i)$. The job-seeker and the employer bargain for a wage with present value W_i for the job to start at the beginning of the next period. Our model implies that bargaining always results in employment, so $\phi(\theta_i)$ is also the job-finding rate. A vacancy is filled with a new hire with probability $\frac{\phi(\theta_i)}{\theta_i}$. An employee departs the firm at the end of the period with probability s. Finally, at the beginning of the next period, the firm decides how many vacancies to hold open during the period.

Three values characterize the job-seeker's bargaining position. If unemployed, the job-seeker achieves a value U_i. Upon finding a job, she receives a wage contract with a present value of W_i and also enjoys a value V_i for the rest of her career, starting with the period of job search that follows the job. While searching, a job-seeker receives a flow value z per period. She has a probability $\phi(\theta_i)$, the job-finding rate, of finding and starting a new job. Hence U_i must satisfy

$$U_i = z + \frac{1}{1+r}\sum_{i'} \pi_{i,i'}\left[\phi(\theta_{i'})(W_{i'} + V_{i'}) + (1-\phi(\theta_{i'}))U_{i'}\right]. \tag{1}$$

Similarly, V_i must satisfy

$$V_i = \frac{1}{1+r}\sum_{i'} \pi_{i,i'}\left[sU_{i'} + (1-s)V_{i'}\right]. \tag{2}$$

The value of the outside option of the job-seeker when bargaining over the wage with a prospective employer is U_i.

Workers produce output with a flow value of p_i, the marginal product of labor. The present value, P_i, of the output produced over the course of a job is:

$$P_i = p_i + \frac{1}{1+r}\sum_{i'} \pi_{i,i'}(1-s)P_{i'}. \tag{3}$$

The model assumes free entry on the employer side, so that the expected profit from initiating the recruitment of a new worker by opening a vacancy is zero. In that case, employer pre-match cost equals the employer's expected share of the match surplus. Employers control the resources that govern the job-finding rate. The incentive to deploy the resources is the employer's net value from a match, $P_i - W_i$. Recruiting to fill a vacancy costs c per period, payable at the end of the period. The zero-profit condition is:

$$\frac{\phi(\theta_i)}{\theta_i}(P_i - W_i) = c. \tag{4}$$

Employers create vacancies, drive up the vacancy/unemployment ratio θ_i, and drive down the recruiting rate to the point that satisfies the zero-profit condition. Because of free entry, the employer's outside option while bargaining with a worker has value zero. Notice that we require that the zero-profit condition hold for each value of the driving force i; this is what makes recruiting effort vary with i.

Equation (4) has an implication of central importance in the rest of the paper. Given a wage W_i, the zero-profit condition determines θ_i and thus unemployment. If the wage is flexible in the sense that employer surplus $P_i - W_i$ is nearly independent of the state, then unemployment has low volatility. In contrast, if the wage is sticky, so that the gap between productivity and the wage rises quickly with productivity, then unemployment will fall sharply when productivity rises, so the volatility of unemployment will be much higher. In the class of models considered here, which differ only in their wage-determination specifications, *wage stickiness is the sole determinant of unemployment volatility*. We need not investigate wage stickiness and unemployment volatility separately. We stress that this conclusion applies only in the class of models we are considering. Pissarides (2007) describes models with elements such as on-the-job search where stickiness and unemployment volatility are not locked together.

2.2 The wage bargain in the original MP model

In the set-up just described, the worker and employer have a prospective joint surplus of $P_i+V_i-U_i$, the difference between the value created by this job and the worker's subsequent career, $P_i + V_i$, and the worker's non-match value, U_i. The original MP model posits that the worker and employer receive given fractions β and $1 - \beta$ of that surplus. The job-seeker's threat point is the value achieved during the prospective employment period by disclaiming the current job opportunity and continuing to search, that is, the unemployment value, U_i. The worker's value, $W_i + V_i$, is this threat value plus the fraction β of the surplus:

$$W_i + V_i = U_i + \beta(P_i + V_i - U_i), \tag{5}$$

so the worker's wage is:

$$W_i = \beta P_i + (1 - \beta)(U_i - V_i). \tag{6}$$

The developers of this model often rationalized this wage rule as a Nash bargain.

The model has $5N$ endogenous variables, the worker's value of being unemployed, U_i, her value of employment after the prospective job, V_i, the vacancy/unemployment ratio, θ_i, the present value of productivity, P_i, and the present value of wage payments, W_i. It has $5N$ equations, (1), (2), (3), (4), and (6).

From the solution, we can calculate other variables, including the unemployment rate, u. In stochastic equilibrium while in state i, the flow rate of workers into unemployment is $s(1-u_i)$ equals the flow rate out of unemployment, $\phi(\theta_i)u_i$. Although in principle u is a separate state variable, it moves so much faster than i that we can use the stochastic equilibrium value as a close approximation to the actual value of unemployment:

$$u_i = \frac{s}{s+\phi(\theta_i)}. \tag{7}$$

In this model, the wage is the weighted average of productivity P_i and the worker's opportunity cost, $U_i - V_i$. In the usual calibration with β around 0.5, the wage is highly responsive to changes in productivity because P_i and $U_i - V_i$ move together—the worker's opportunity cost $U_i - V_i$ depends sensitively on the wages of other jobs. Indeed, in the calibration we attribute to Mortensen and Pissarides, W_i changes by 93 percent of the change in P_i. Thus, a transition from one level of P_i to a lower one results in correspondingly large changes in W_i but only tiny changes in unemployment. This flexible-wage property of the standard model is the point of Shimer (2005).

2.3 The alternating-offer wage bargain

In our bargaining model, adapted from Binmore et al. (1986), bargaining takes place over time. The parties alternate in making proposals. After a proposer makes an offer, the responding party has three options: accept the current proposal, reject it and make a counter-proposal, or abandon the bargaining and take the outside option. The abandonment of bargaining by either party results in lump-sum payoffs of zero for the employer and U_i for the worker. If the responding party makes a counter-proposal, both parties receive the disagreement payoff for that period and the game continues. The employer incurs a cost $\gamma > 0$ each time it formulates a counteroffer to the worker. The worker receives the flow benefit z while bargaining. Notice that our sign convention is the opposite for workers and employers—workers have a benefit z from waiting and firms incur a cost γ.

In this bargaining game, when the joint payoff from matching, $V_i + P_i$, exceeds both the unemployment payoff U_i and the capitalized flow $\frac{1+r}{r}(z-\gamma)$, the parties agree on a wage $W_i < P_i$. If $V_i + P_i$ falls short of either of the other two values, no agreement is reached. If $V_i + P_i = U_i$, the wage could be P_i but then employment will not occur because there is no incentive for recruiting effort by employers. The same is true if $V_i + P_i = \frac{1+r}{r}(z-\gamma)$. Our exposition emphasizes the first possibility for every state i, because it is the only one that can justify positive search by employers and positive equilibrium employment in every state.

We temporarily assume that the subgame perfect equilibrium of the bargaining models beginning with a proposal by the employer (or the worker) is unique; we return to prove this uniqueness the next subsection below. The consequence is that the value of rejecting an offer and continuing to bargain is uniquely defined, so the worker's equilibrium strategy is to accept the employer's offer if and only if it is better than both the continuation payoff and the payoff from exiting bargaining. Hence, there is some lowest wage offer W that the worker will accept. Symmetrically, there is a highest wage offer W' that the firm will accept.

Our calibration implies that, in equilibrium, the bargainers never abandon the negotiations. It is always strictly better for a worker or employer to make a counteroffer than to accept the outside options of U_i for the worker and zero for the employer. Consequently, it is optimal for each side in the bargaining always to make a just acceptable offer to the other side. The employer always offers W and the worker always offers W'. Because the worker is just indifferent about accepting W, it must be that her payoff from accepting, which is $W + V$, is just equal to her payoff from rejecting the offer and countering with the acceptable offer of W' at the next round.

Our treatment of wage determination takes full account of Coles and Wright's (1998) observation that alternating-offer bargaining in a dynamic setting requires that the bargainers be aware of the changes in the environment that will occur if they delay acceptance of an offer. To account for the dynamics, we subscript the relevant variables with the state variable i.

We assume a probability δ that the job opportunity will end in a given period during bargaining. In that event, the job-seeker gets the unemployment value U_i and the employer gets zero. Thus, the indifference condition for the worker, when contemplating an offer W_i from the employer, is

$$W_i + V_i = \delta U_i + (1-\delta)\left[z + \frac{1}{1+r}\sum_{i'}\pi_{i,i'}(W'_{i'} + V_{i'})\right]. \tag{8}$$

The similar condition for the employer contemplating a counteroffer from the worker, W'_i is

$$P_i - W'_i = (1-\delta)\left[-\gamma + \frac{1}{1+r}\sum_{i'}\pi_{i,i'}(P_{i'} - W_i)\right]. \tag{9}$$

W_i is the wage that the employer will propose and the worker accept, when it is the employer's turn, and W'_i is the worker's counterpart. We assume that the employer makes the first offer, so W_i is the wage in equilibrium. Although the employer makes the first offer and the worker always accepts it, the wage is higher than it would be if the employer had the power to make a take-it-or-leave-it offer that denied the worker any part of the surplus. The worker's right to respond to a low wage offer by counteroffering a higher wage—though never used in equilibrium—gives the worker part of the surplus. We assume the absence of any commitment technology that would enable the employer to ignore a counteroffer.

Equations (8) and (9) replace equation (6) and are alternative structural equations of the model. They differ only in the role of the threats. These are, for the worker, U in the Nash model and the more complicated expression in equation (8) in the credible-bargaining model, and, for the employer, zero in the Nash model and the more complicated expression in equation (9) in the credible-bargaining model. Note that the threats are the same in the new model as in the standard model if $\delta = 1$.

The solution to equations (8) and (9) for the wage W_i is somewhat complicated. The solution for the average $\frac{1}{2}(W_i + W_i')$, which is hardly different from W_i in our calibration, is helpful in explaining the substance of the credible bargain. In obvious matrix notation, subtracting (9) from (8) leads to

$$\frac{1}{2}(W + W') = \frac{1}{2}\left\{P + \left(I - \frac{1-\delta}{1+r}\pi\right)^{-1}[\delta U + (1-\delta)(z+\gamma)\iota] - V\right\}, \tag{10}$$

where ι is a vector of ones. The effect of multiplication by

$$\left(I - \frac{1-\delta}{1+r}\pi\right)^{-1} \tag{11}$$

is to form a present value of a stream at interest rate r, subject to rate of decline $1-\delta$, and obeying, in the case of the vector U, the transition matrix π.

Equation (10) for the credible bargain gives the same role to productivity P and the worker's subsequent career value, V as does equation (6) for the Nash bargain. It differs from the Nash bargain only by giving less weight to U and adding the present value of the bargaining bias, $z + \gamma$. Because U_i reflects current conditions in the labor market while the $z + \gamma$ does not vary with the state, the wage is less sensitive to conditions as measured by unemployment under the credible bargain compared to the Nash bargain used in the original MP model.

In the MP version of the Nash wage bargain, conditions in the labor market influence the agreed wage through $U - V$, which is the worker's opportunity cost or reservation wage. Better conditions in the market as represented by a higher value of U give the worker a higher wage. In the wage equation for credible bargaining model, U is scaled down by δ because the outside option is only relevant when the worker is forced to return to search because of the ending of the opportunity.

The subsequent career value V has the same effect under credible and Nash bargaining. It reflects the post-employment opportunities enjoyed by a worker who takes a job today. Prolonging bargaining postpones the receipt of V, which is received at the time a job actually begins. Stronger long-run job opportunities V *lower* the wage by raising the cost to the worker of prolonging bargaining.

Another difference, of secondary importance, is that unemployment enters as the present value of the future values of U. In the new model, the persistence of the state variable i has a role because it controls the relation between the current state of the labor market and the future states that enter the present value. Its persistence also influences V under both Nash and credible bargaining.

All the other equations of the model are the same as in the standard model. The credible-bargaining model has $6N$ unknowns, because the hypothetical counteroffers W' need to be calculated.

2.4 Uniqueness of the equilibrium

Equations (8) and (9) are linear in W and W'. Because δ and r are both positive, the linear system has full rank and the solution $(\hat{W}, \hat{W}')$ is unique. It remains to show that any equilibrium wages of the bargaining game must satisfy these two equations.

In an equilibrium, at any round, there is some lowest wage proposal by the firm at its first move above which the worker always accepts; we call that the *worker's reservation wage*. Similarly, the *employer's reservation wage* is the highest wage below which any worker proposal is always accepted. Let $\underline{W}$ and $\underline{W}'$ denote the vector infimum across equilibria of the worker's (respectively, the employer's) reservation wages. These correspond to the best possible equilibrium bargaining outcomes for the employer in the full game and in the subgame beginning with an offer by the worker.

One can show by standard methods that the sets of reservation wages are closed, so there is an equilibrium of the game in which the employer initially offers $\underline{W}$ and the worker accepts. Hence, we may construct an equilibrium of the subgame beginning with the worker offer by specifying that, if the worker offer is rejected, then the employer always proposes $\underline{W}$ and the worker always accepts. Equation (8) can be solved for W and written as $W = \Phi_1(W')$ and similarly equation (9) can be solved for W' and written as $W' = \Phi_2(W)$. In the constructed equilibrium, at the worker's first move, the employer's reservation wage is $\Phi_2(\underline{W})$, so $\underline{W}' \leq \Phi_2(\underline{W})$. In any equilibrium, the employer can never gain by rejecting a wage proposal less than $\Phi_2(\underline{W})$, so $\underline{W}' \geq \Phi_2(\underline{W})$. Combining the inequalities, $\underline{W}' = \Phi_2(\underline{W})$.

The preceding conclusion implies that there is an equilibrium of the subgame beginning with the worker's offer in which the worker offers $\underline{W}'$ and the employer accepts. So, we may construct an equilibrium of the full game in which this continuation equilibrium is played whenever the employer offer is rejected. In the constructed equilibrium, the worker's reservation wage is $\Phi_1(\underline{W}')$, so $\underline{W} \leq \Phi_1(\underline{W}')$. In any equilibrium, the worker never accepts a wage less than $\Phi_1(\underline{W}')$, because she can always do better by rejecting it and proposing $\underline{W}' = \Phi_2(\underline{W})$, which is always accepted. Hence, $\underline{W} \geq \Phi_1(\underline{W}')$. Combining the inequalities, $\underline{W} = \Phi_1(\underline{W}')$.

Thus, the lowest equilibrium wages satisfy $(\underline{W}, \underline{W}') = \Phi(\underline{W}, \underline{W}')$ and hence $(\underline{W}, \underline{W}') = (\hat{W}, \hat{W}')$. A symmetric argument shows that the highest equilibrium wages satisfy $(\bar{W}, \bar{W}') = (\hat{W}, \hat{W}') = (\underline{W}, \underline{W}')$, so these are the unique equilibrium wage vectors.

3 Evidence

In this section we review evidence that helps guide the choice of employment-wage model and its parameters. The most critical parameters are the ones that determine the wage bargain—these are the flow value of non-work, z, the employer's cost of delay, γ, and the probability of bargaining breakdown, δ—and the employer's cost of maintaining a vacancy, c. We also cite evidence about the values of the other model parameters, including the efficiency of matching, its elasticity with respect to the vacancy/unemployment ratio θ, the normal level of θ and of unemployment, and the exogenous separation rate s, as well as about the portion of unemployment volatility attributable to productivity fluctuations.

The Appendix provides tables of values and sources for values of endogenous variables used in our calibration and the values of parameters resulting from the calibration.

3.1 The flow value of non-work, z

The linear preferences of the MP model stand in for preferences with curvature. To calibrate z, we use evidence about the Frisch elasticities that capture the curvature.

We posit that individuals order consumption-hours pairs according to the period utility, $U(c, h)$. As in earlier discussions of this issue, we can think of a family with a unit measure of members, of whom a fraction u are unemployed and the remainder employed. The family's allocation of consumption between the employed and unemployed maximizes family utility $uU(c_u, 0) + (1 - u)U(c_e, h)$ subject to the budget constraint $u(b - c_u) + (1 - u)(w - c_e) = x$, where c_u and c_e are the consumption of the unemployed and employed, respectively, h is hours of work of the employed,

w and b are the wage and unemployment benefit, and x is saving. Note that $c_u < c_e$ if consumption and hours are Edgeworth complements, with $U_{ch} > 0$).

We write the budget constraint as

$$c_u = b - w + c_e + \frac{w - c_e + x}{u}. \tag{12}$$

We consider the family's within-period maximization problem, conditional on a given x:

$$U^*(u) = \max_{c_e} uU(b - w + c_e + \frac{w - c_e + x}{u}, 0) + (1 - u)U(c_e, h). \tag{13}$$

By the envelope theorem,

$$\begin{aligned} \frac{d}{du}U^*(u) &= U(c_u, 0) - U(c_e, h) + \frac{w - c_e + x}{u} U_c(c_u, 0) \\ &= U(c_u, 0) - U(c_e, h) + U_c(c_u, 0)(c_e - c_u + b - w). \end{aligned} \tag{14}$$

In the MP class of models, the flow values are measured in consumption rather than utility units. Marginal utility $\lambda = U_c$ translates from one to the other. Treating λ as a constant is appropriate in the static MP model without an aggregate shock and is a reasonable approximation in a model, such as the one in this paper, where the aggregate driving force is stationary (for a discussion of the non-stationary case, see Hall (2007)). The flow value of employment is normalized to be earnings, w, and z is the flow value of unemployment, so $\lambda(w - z) = \frac{d}{du}U^*(u)$. Thus

$$z = b + c_e - c_u + \frac{1}{\lambda}\left(U(c_u, 0) - U(c_e, h)\right). \tag{15}$$

To evaluate z, we pick a convenient functional form that captures the key curvature properties of the utility function:

$$U(c, h) = \frac{c^{1-1/\sigma}}{1 - 1/\sigma} - \chi c^{1-1/\sigma} h^{1/(\psi+1)} - \frac{\alpha}{1 + 1/\psi} h^{1+1/\psi}. \tag{16}$$

The parameter χ controls the complementarity of hours and work, with $U_{c,h} > 0$ for $\chi > 0$ and $\sigma < 1$. Without complementarity ($\chi = 0$), the Frisch consumption demand elasticity is σ and labor supply elasticity is ψ. At the calibrated level of complementarity, the actual Frisch elasticities are somewhat above the values of these curvature parameters, though they are still a good guide.

We derive the curvature parameters from recent research on consumption and labor supply, as surveyed in Hall (2007). We take $\sigma = 0.4$, which implies a Frisch elasticity of –0.5, a value consistent with research on both intertemporal substitution in consumption and risk aversion (it corresponds to a coefficient of relative risk aversion of 2). We take $\psi = 0.8$, corresponding to a

Frisch elasticity of labor supply of 1. Research on labor supply finds Frisch elasticities around 0.7 for prime-age men and somewhat above one for women and younger and older men.

To determine the value of the complementarity parameter χ, we use the results of research on the reduction in consumption that occurs when hours of work drop to zero, both involuntarily upon job loss or voluntarily at retirement. The research surveyed in Hall (2007) shows a consumption reduction of about 15 percent upon either event. We interpret this as the result of substitution of time for purchased goods that occurs when time becomes more plentiful.

We calibrate at the point where hours h of the employed are 1 and we normalize the marginal product of labor at 1. Anticipating the finding of later calculations, we take the wage w to be 0.985 of the marginal product so that employers receive the surplus required in the MP class of models.

We also need to fix a value for unemployment benefits, b. In our normalization, b is essentially a replacement rate, the fraction of normal earnings paid as the typical unemployment benefit. Krueger and Meyer (2002) describe the state-administered UI programs of the U.S. Although some workers receive a substantial fraction of their earlier wages as benefits, many features of the system limit the effective rate. Hall (2005b) calculates the ratio of benefits paid to previous earnings, on the assumption that the unemployed have the same average wage as the unemployed. He finds the ratio to be about 12 percent, but this is a lower bound, because the unemployed come differentially from lower-wage workers. Anderson and Meyer (1997) calculate an after-tax replacement rate of 36 percent from statutory provisions of the UI system. But this is an upper bound because a significant fraction of the unemployed do not receive any benefit. We take $b = 0.25$ as a reasonable estimate between the two bounds.

All people in our economy have the same marginal utility of consumption, λ. Some have zero time at work and $c_u = 0.85c_e$ units of consumption and the others have c_e units of consumption and one unit of time at work. The consumption levels c_e and c_u balance the family budget

$$u \cdot (c_u - b) + (1 - u) \cdot (c_e - w) = 0 \tag{17}$$

at an unemployment rate of $u = 0.055$.

The consumption first-order condition for non-workers is:

$$c_u^{-1/\sigma} = \lambda \tag{18}$$

and the consumption and work first-order conditions for workers are:

$$c_e^{-1/\sigma} - \chi c_e^{-1/\sigma}(1 - 1/\sigma) = \lambda \tag{19}$$

and

$$\chi(1+1/\psi)c_e^{1-1/\sigma} + \alpha = \lambda. \tag{20}$$

We solve these three equations for $\chi = 0.334$, $\alpha = 0.887$, and $\lambda = 1.70$.

Finally, we insert these values into equation (15) to find

$$\begin{aligned} z &= b + c_e - c_u + \frac{1}{\lambda}\left(U(c_u, 0) - U(c_e, h)\right) \\ &= 0.25 + 0.95 - 0.81 + \frac{1}{1.7}(-0.92 - (-1.45)) \\ &= 0.71. \end{aligned} \tag{21}$$

These findings shed some light on Hagedorn and Manovskii's (2006) estimate of z obtained from a radically different calibration strategy. They require their version of the MP model to match the derivative of the wage with respect to productivity and they calibrate to an outside estimate of the cost of posting a vacancy. They show that the criteria imply that the flow value of non-work has the high value of $z = 0.955$ (in units of productivity). The corresponding Frisch elasticity of labor supply is 2.8, out of the range of any empirical finding. Our recalibration of their model to the more realistic goal of matching the part of unemployment volatility associated with productivity fluctuations corresponds to a Frisch elasticity of 2.6.

For workers, we impute the same benefit of not working while bargaining that they enjoy while searching. The net benefit is the benefit of leisure less the costs of searching. Our assumption is that the costs that a worker would incur from dealing with an employer for an extra day and formulating a counteroffer are comparable to the costs of searching rather than enjoying leisure at home.

3.2 The cost of maintaining a vacancy, c

We follow Silva and Toledo (2007) in measuring the flow cost of maintaining a vacancy. They report that recruiting costs are 14 percent of quarterly pay per hire, or 9.1 days of pay per hire, based on data collected by PriceWaterhouseCoopers. The days in our model are weekdays. As described below, we take the daily probability of filling a vacancy as 3.44 percent. The flow cost is the product,

$$c = (4.7 \text{ percent }) \times (9.1 \text{ days of pay }) = 0.43 \text{ days of pay }. \tag{22}$$

Hagedorn and Manovskii (2006) use a much lower figure for non-capital hiring cost of 0.11, based on data for management time alone. On the other hand, they include a cost of idle capital of

0.47, so their value for c is 0.58, somewhat above ours, but not enough to alter any of our conclusions. We are skeptical of capital costs for recruiting, which rest on two hypotheses: First, that a vacancy involves a shortfall in employment, and second that the shortfall causes the corresponding fraction of capital to be idle. An optimizing firm will generate a flow of hires so that the resulting level of employment is close to the optimum, not chronically below because of outflows, so vacancies should not be interpreted as shortfalls in employment. And even if there is a shortfall, the capital should be spread over the available workers as much as possible, rather than leaving it all idle.

3.3 The employer's cost of delay, γ

We choose γ in the stationary version of the credible-bargaining model so that it generates the observed average level of unemployment, 5.5 percent. The resulting value of γ is 0.23 days of worker productivity per day of delay. This value is about half of Hagedorn and Manovskii's estimate of the cost of idle capital, which is a more consistently used as cost of bargaining delay than as vacancy cost, for the following reason: In equilibrium no delay occurs. Hence the delay is not one for which a rational manager would prepare. Unless investment is observed by the applicant and influences bargaining, capital will be installed at the moment a qualified applicant appears, not held off until bargaining is completed.

We could, alternatively, interpret γ as the cost that the employer incurs in formulating a counteroffer. The employer avoids this cost by accepting the worker's offer. If the worker produces \$20 per hour or \$160 per day, then $\gamma = .23$ implies a cost of \$37 to produce the counteroffer. Notice that the value of γ only comes into play two steps off the equilibrium path. First, the worker makes a counteroffer to the employer's starting offer, which never happens on the equilibrium path. Second, the firm counters the counter offer, which also never happens, even one step off the equilibrium path. Nonetheless, the value of γ has an important role in determining the equilibrium bargain.

3.4 The probability, δ, that a job opportunity disappears during bargaining

Higher values of δ lead to lower volatility of unemployment in our model. Our knowledge of δ is limited to the view that the probability cannot be smaller than the probability s that a job itself loses its productivity. We believe that the situation during bargaining is more fragile, however. We choose δ to match the observed volatility of unemployment, just as Hagedorn and Manovskii choose z to matched unemployment volatility. That value is $\delta = 0.0055$ per day, or 4 times the probability that a job will end.

3.5 Turnover and values in the standard model

We calibrate to a separation rate of 3 percent per month or 0.14 percent per day and an unemployment rate of 5.5 percent. These imply a job-finding rate of 2.4 percent per day. We take the vacancy/unemployment ratio, θ, to be 0.5, the average from 2000 to 2007 in the vacancy and unemployment surveys. The calibration is in the stationary equilibrium of a version of the model with only one state ($N = 1$) with marginal product of labor, p, equal to one. We take the discount rate r to be 5 percent per year or 0.019 percent per day. We take labor's bargaining power or share of the surplus to generate a wage at the value, 0.54, needed to satisfy the zero-profit condition of equation (4).

Following a substantial literature, we take the job-finding function to be constant-elastic. Petrongolo and Pissarides (2001) find that the range of plausible estimates of the elasticity of the function is 0.3 to 0.5. Most of their estimates come from countries other than the United States. Hall (2005a) estimates a value of 0.77 based on the large movements of the vacancy/unemployment ratio and the job-finding rate in the U.S. recession of 2001, using data from the new vacancy and turnover survey that began in 2000. We take the value to be 0.5, so our job-finding function is

$$\phi(\theta) = \phi_0 \theta^{0.5} \tag{23}$$

and the recruiting rate function is

$$q(\theta) = \phi_0 \theta^{-0.5}. \tag{24}$$

We calibrate the efficiency parameter $\phi_0 = 0.024$ to the job-finding rate and vacancy/unemployment ratio.

At the calibrated stationary equilibrium, the wage is $W = 627$. The lower limit of the bargaining set for W is $U - V = 616$ and the upper limit is $P = 636$.

3.6 The driving force

We take output per hour of labor input as the productivity driving force—see Hall (2007) for an explanation of why this is the appropriate concept of the driving force, as opposed, for example, to total factor productivity. Our data are from the same source as Shimer (2005) and Hagedorn and Manovskii, the quarterly series on output per hour in the business sector, series PRS84006093 from the Bureau of Labor Statistics. We compute the driving force as deviations of log productivity from a fourth-order polynomial in time.

We create a discrete version of the productivity deviations, with $N = 5$ values, as shown in Table 1. The stationary probabilities of the five categories are equal at 0.2.

Category	*Productivity deviation, percent*	*Daily transition probability to new category*				
		1	2	3	4	5
1	-2.69	0.9944	0.0046	0.0005	0.0000	0.0005
2	-0.95	0.0057	0.9859	0.0073	0.0005	0.0005
3	0.07	0.0000	0.0083	0.9849	0.0063	0.0005
4	1.21	0.0000	0.0010	0.0068	0.9854	0.0068
5	2.43	0.0000	0.0000	0.0005	0.0077	0.9918

Table 1. Time-series Process for Productivity

Figure 1 shows the dynamic response of productivity to a one-time disturbance. The figure shows productivity starting at category 2 with a deviation of -0.95 percent and plots the mean value of each day thereafter as it follows the path determined by the transition matrix, π, in Table 1.

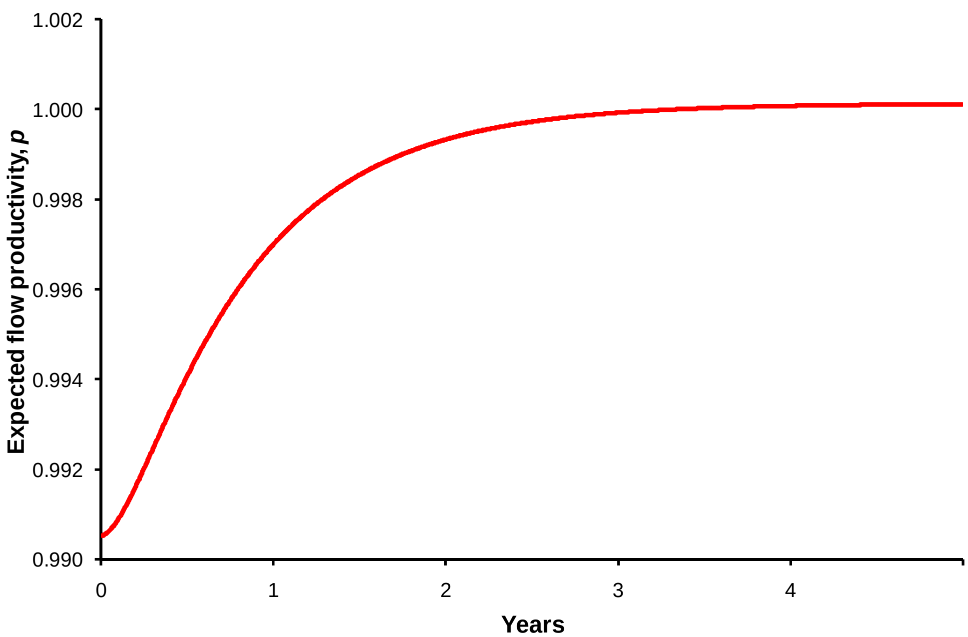

Figure 1. Impulse Response Function for Productivity

3.7 Unemployment volatility attributable to productivity fluctuations

Shimer (2005) focused on the question of whether the MP model could explain the observed volatility of unemployment as solely the result of fluctuations in productivity. Much of the research his paper triggered has remained in this framework. But, as Mortensen and Éva Nagypál (2007) point out, simple econometrics shows that no reasonable model similar to the MP model could explain all of unemployment volatility. A good deal of unemployment fluctuation is uncorrelated with productivity.

We have explored a variety of regressions of quarterly unemployment on the productivity measure just discussed. The standard deviation of the residuals from these regressions is a measure of the component that presumptively defies explanation by productivity fluctuations. We find that lagged productivity adds to the explanatory power. We will use a simple example that lies midway between the specification with lowest assignment to productivity (only a single right-hand variable, the contemporaneous productivity deviation) and the one with the highest (many lagged deviations included as well with separate coefficients). This specification relates current unemployment to the productivity deviation three quarters earlier.

The regression delivers the following decomposition of unemployment volatility: The standard deviation of unemployment over the sample period, 1948 Q4 through 2007 Q1, is 1.50 percentage points. The standard error of the residuals is 1.34 percentage points; this is the component beyond the reach of a productivity explanation. The implied standard deviation of the component driven by productivity is 0.68 percentage points. We will consider models that deliver this amount of volatility when driven only by the productivity process just derived.

4 Comparison of Models

We consider three models in the generalized MP class. These are the canonical model of Mortensen and Pissarides (1994), Hagedorn and Manovskii's (2006) variant of the MP model with "Nash bargaining," and the credible-bargaining model of this paper. To facilitate the comparison, we will standardize the non-wage parts of the model involving the matching function and the separation rate. We will require the three models to have the same average unemployment rate of 5.5 percent. For the MP model, we use our estimate of the flow value of non-work, z, which is higher than Shimer and others have used. For Hagedorn and Manovskii's model, we adopt their strategy of choosing the value of z from macro data. They choose it to match a measure of wage flexibility. We choose it to match our measure of unemployment volatility induced by productivity fluctuations. Later we will discuss the implications for wage flexibility.

4.1 Comparison of basic properties

Table 2 describes the inputs and results of solving the three models. In the upper part of each cell, "Input" means that we used the measure from the previous section to calibrate the model and "Output" means that the value came from the solution to the model.

		Model		
Measure	*Our estimate*	*Mortensen-Pissarides*	*Hagedorn-Manovskii*	*Credible bargaining*
Flow value of non-work, *z*	0.71	Input 0.71	Output 0.93	Input 0.71
Share of surplus		Output 0.54	Output 0.19	Output 0.54
Productivity component of unemployment volatility, standard deviation in percentage points	0.68	Output 0.17	Input 0.68	Input 0.68
Labor supply elasticity	1.0	Input 1.0	Output 2.6	Input 1.0

Table 2. Comparison of Three Models

The Mortensen-Pissarides column replicates earlier findings that it produces too little volatility of unemployment from realistic fluctuations in productivity. Even with the higher value of z, the implied standard deviation of unemployment fluctuations is only 0.16 percentage points, less than a quarter of the estimated level of 0.68 percentage points. Shimer's critique survives two major changes—a higher value of z and a much lower target for the amount of unemployment that the model should be able to explain.

The Hagedorn-Manovskii column shows that the Nash-bargaining model can replicate the observed amount of unemployment volatility induced by productivity fluctuations, but with a high value of the flow value of non-work, z, and a Frisch elasticity of labor supply of 2.6, far above the values found in research on this topic. Further, their version of the model implies a low bargaining weight of 0.17 for the worker, with the employer taking 83 percent of the joint surplus of the match.

The credible-bargaining column shows that our model can replicate the observed volatility of unemployment with reasonable values of z and of the elasticity of labor supply ψ. Also, the worker's share of the joint surplus implied by our calibration is 0.54, which is the same as in the MP model. Besides depending on z and γ, this share depends also on the parameter δ, the daily probability that a job opportunity would vanish during bargaining, which we took to be 4 times the probability that a job becomes unproductive once it starts.

4.2 Responses to Changes in Productivity

With Nash bargaining, the wage responds directly to P with a derivative equal to the bargaining weight β in equation (6). It responds indirectly through the presence of the opportunity cost term $(1-\beta)(U-V)$ in the same equation. U falls by more than V, so the opportunity cost falls and the wage falls on that account as well.

Table 3 shows the slopes of the responses of the relevant variables in the three models, measured by comparing the values in state 2 with those in state 4. For the MP Nash calibration, the unemployment value U rises by a bit more than P rises—this reflects the direct effect of a higher P on the wage and thus on U plus the added benefit from the small tightening of the labor market, which raises U by shortening the time until the next job begins to pay. The value of the worker's subsequent career, V, rises by less than P, because the increase in P is transitory, as shown in Figure 1. Thus $U-V$ rises 84% as fast as P. The response of the wage is 0.93 times the increase in P. Because the wage W responds almost one-for-one to changes in P, the profit contribution of a new worker, $P-W$, hardly increases. Finally, according to equation (4), the vacancy/unemployment ratio θ rises only a little, so unemployment falls only slightly. The elasticity of unemployment with respect to P is -4.7, which is not nearly large enough to account for the volatility of unemployment.

With Nash bargaining and the Hagedorn-Manovskii calibration, the responses are different, as shown in the second line of Table 3. The direct contribution of P to W is smaller because the worker's bargaining power is so much less—again see equation (6). The response of the opportunity cost $U-V$ is also smaller because wages in alternative jobs respond less. The wage responds by only 71 percent of the change in productivity. The surplus accruing to the employer, $P-W$ changes by the remaining 29 percent and induces sharp changes in conditions in the labor market. The elasticity of unemployment with respect to productivity is -19, enough to account for the observed covariation of productivity and unemployment. Recall that this calibration achieves the

	Slope with respect to P			*Elasticity*
	U	*V*	*W*	*Unemploy-ment rate*
Nash bargaining, Mortensen-Pissarides calibration	1.14	0.30	0.93	-4.7
Nash bargaining, Hagedorn-Manovskii calibration	0.87	0.23	0.71	-19.1
Credible bargaining	1.20	0.32	0.69	-20.0

Table 3. Responses to Changes in Productivity

realistic elasticity by making the elasticity of labor supply unrealistically high and the bargaining power of labor low.

The credible bargaining model arrives at a similarly realistic elasticity by quite a different route. Equation (10) is a close approximation that helps explain the responses. The wage responds directly to a productivity change with a coefficient of 0.5. V responds by slightly more than it does in the MP case. The increase in U is somewhat larger than in the MP case, because the labor market tightens much more with credible bargaining. Because of the limited response to $U - V$, the wage response is only 0.69, in contrast to 0.93 in the MP-Nash case. The profit contribution, $P - W$, rises substantially, stimulating recruiting effort and lowering unemployment. The elasticity of unemployment with respect to P is -20, replicating the observed covariation of unemployment and productivity.

Table 4 presents the same information in a different format. The far right column shows the same wage responses as in Table 3. The three columns to the left decompose the responses into the three channels corresponding to P, U, and V. The direct effects from P in the left column are the two values of the bargaining weight, β for the Nash models and 0.5 for credible bargaining. The effects operating through dV/dP are multiplied by $1 - \beta$ for the Nash models and 0.5 for credible bargaining. We calculate the positive effect operating through unemployment value U as the residual from the total effect and the other two effects. They are considerably larger in the two Nash cases than in the credible-bargaining case—this is the point of our analysis.

Table 4 shows clearly the differences in the explanation of the strong response of unemployment to productivity in the Hagedorn-Manovskii Nash model and in the credible-bargaining model. Hagedorn and Manovskii limit the direct effect of productivity by choosing a low bargaining weight for workers. The direct influence of productivity on the wage is correspondingly low.

	Slope of P's contribution to W via			Slope of W with respect to P
	P	*U*	*V*	
Nash bargaining, Mortensen-Pissarides calibration	0.54	0.52	-0.14	0.93
Nash bargaining, Hagedorn-Manovskii calibration	0.19	0.70	-0.18	0.71
Credible bargaining	0.50	0.35	-0.16	0.69

Table 4. Decomposition of Effects of Productivity on the Wage

Their account of the influence of productivity operating though U and V is essentially the same as in the MP calibration. The credible-bargaining model, by contrast, has about the same direct effect of productivity on the wage as does the MP model but limits the role of the unemployment value U.

5 Wage Flexibility

5.1 Measuring wage flexibility in the three models

Our results have immediate and simple implications for wage flexibility. All the models we have discussed share the same zero-profit condition with the same parameter values. Let $\hat{u} = u/(1-u)$, the unemployment/employment ratio. The zero-profit condition can be written,

$$\hat{u}(P_i - W_i) = \frac{cs}{\phi_0^2}. \tag{25}$$

Then the flexibility of wages is

$$\frac{dW}{dP} = 1 + \frac{cs}{\phi_0^2 \hat{u}^2} \frac{d\hat{u}}{dP}. \tag{26}$$

The response of the wage to productivity—the measure of wage flexibility—is directly related to the response of unemployment to productivity. No other response appears in the derivative. Table 4 shows that the flexibility needed to rationalize the joint movements of productivity and unemployment is a derivative of about 0.7.

Hagedorn and Manovskii (2006) measure wage flexibility from wage and productivity data and find a derivative of about 0.5. Although the Hagedorn-Manovskii estimate of flexibility is not too much lower than the value implicit in our model, we are skeptical that econometric studies of wage data can shed much light on the issue of unemployment volatility. The wage variable W in the MP class of models is the employer's expectation of the present value of wage payments over the duration of a job, for workers about to be hired. Teasing this value out of data on wages paid to all workers, including those hired decades ago, is a daunting exercise.

Pissarides (2007) has recently argued that wage stickiness cannot explain observed unemployment volatility. A partial solution to the challenge of measuring the present value of compensation for new workers is to study the earnings of newly hired workers, an approach Pissarides considers at length. He surveys research on the regression coefficient for log wage change on the change in unemployment and finds a reasonably strong consensus that the coefficient (the semi-elasticity) is about -3. He presents a model in the MP tradition with endogenous separations and shows that it can match this coefficient. One important ingredient is the value of z from this paper.

To calculate the implications of the models considered here for Pissarides's regression coefficient, we need to translate the capital value of wages, W, to its underlying flow. Because the model determines only W, there are many ways to do this. An especially easy and plausible way is to presume a wage contract that sets the wage at any time to the hiring wage multiplied by any growth in productivity. With this specification, $w/W = p/P$, so we can calculate $w = \frac{p}{P}W$ from the data underlying Tables 3 and 4. Pissarides considers the semi-elasticity, $d \log w/du$. The values of the semi-elasticities are -11 for the MP Nash calibration and -2.5 for the Hagedorn-Manovskii and credible-bargaining models.

We conclude that two models with limited wage flexibility—ours and Hagedorn and Manovskii's—can come close to matching the observed semi-elasticity of about 3. Wages in the canonical MP model are far more flexible than found in the data. We have no disagreement with Pissarides's conclusion that other models can also match observed flexibility, only with his conclusion, "Therefore sticky wages is not the answer to the unemployment volatility puzzle."[1]

5.2 Implications of matching the observed average unemployment rate and observed vacancy cost

Along with virtually all researchers in the MP and related traditions, we require that the models we consider replicate the average unemployment rate $\bar{u}$, which we take to be its average over the past 60 years of 5.5 percent. According to the zero-profit condition, equation (4), common to all the models we consider, the surplus accruing to the employer $P - W$, is a known quantity equal

[1] In private correspondence, Pissarides has indicated that he may reformulate the conclusion in the paper.

to about 13 days of worker productivity. The recruiting rate is the ratio of the known job-finding rate and the known vacancy/unemployment ratio; the flow cost c is known from the sources we discussed earlier. The amount of the employer surplus, and the counterpart surplus accruing to workers, controls important features of the calibration of the rest of the model. We do not think it would be appropriate to adopt a calibration that failed to match the observed value of $P - W$.

Among Nash-bargaining models, fixing the known value of $P - W$, matching $\bar{u}$ creates a tradeoff between the two parameters controlling unemployment, the flow value z and bargaining power β. Our MP calibration with $z = 0.71$ and $\beta = 0.54$ is one point on that tradeoff and our Hagedorn-Manovskii calibration with $z = 0.93$ and $\beta = 0.19$ is another. In the credible-bargaining model, the corresponding tradeoff is between z and the employer's delay cost γ. Given our belief that $z = 0.71$ is known from research on labor supply and consumption, the implied value of γ is 0.27 days of worker compensation per day of delay. The reasonableness of this cost provides some confirmation of the model itself.

The sum of z and γ is 0.98, not very different from the value of z by itself in our version of Hagedorn and Manovskii's calibration, namely 0.93. One might conclude that the credible bargaining model is really the same as their model, with a different rationalization for the same value of $z + \gamma$. It is true, as we noted above, that $z + \gamma$ controls the unemployment rate, so if we believed in a higher z, we would need to believe in a lower γ, but this sum alone does not determine unemployment volatility. In the credible-bargaining model, volatility is also controlled by the frequency of bargaining interruptions, δ. The fact that the Hagedorn-Manovskii value of z corresponds to a γ of zero in our model is essentially unrelated to the fact that our model and theirs imply equal values of unemployment volatility. For example, the credible-bargaining model with $\delta = 0$ implies much higher unemployment volatility, but still has $z + \gamma$ close to Hagedorn and Manovskii's z.

The properties of the models depend on the vacancy cost c. We compare the estimated value of c to a value twice as high. According to equation (26), this cuts the relation between the response of unemployment, $\frac{d\hat{u}}{dP}$, and the stickiness of the wage, $1 - \frac{dW}{dP}$, in half. Table 5 compares the changes in the three models upon the doubling of c.

For both Nash-bargaining calibrations, the higher recruiting cost roughly doubles wage stickiness. This effect largely offsets the halving of the multiplier relating wage stickiness to the employment response, so the latter declines only a little. The reason that the Nash calibration has less flexible wages with higher recruiting cost is that the worker's bargaining share is lower for higher

	Estimated value of c		*Twice the estimated value of c*	
	1-*dW/dP*	*Elasticity*	1-*dW/dP*	*Elasticity*
Nash bargaining, Mortensen-Pissarides calibration	0.07	-4.7	0.14	-4.7
Nash bargaining, Hagedorn-Manovskii calibration	0.29	-19.1	0.53	-17.4
Credible bargaining	0.31	-20.0	0.34	-11.5

Table 5. Effects in Three Models from Doubling Recruiting Cost

cost. The direct effect of productivity on the wage is smaller.

For credible bargaining, wage stickiness hardly budges from 0.3 when recruiting cost doubles. Consequently, the elasticity of unemployment with respect to productivity falls almost in half.

6 Further discussion of the credible-bargaining model

6.1 Values during hypothetical bargaining

In the middle state, $i = 3$, the value of the job-seeker's hypothetical counteroffer is $W' = 619.756$, while the employer's original offer, and the governing wage, is $W = 619.435$. The job-seeker is indifferent between accepting W and counteroffering W' with a one-day delay in the onset of employment. The elements of the indifference condition in equation (8) are:

1. Lose W and gain $\frac{1-\delta}{1+r}W'$ for a net loss of 3.17
2. Lose V and gain $\frac{1-\delta}{1+r}V$ for a net loss of 25.04
3. Gain $\delta U = 27.78$
4. Gain $(1-\delta)z = 0.71$.

6.2 Applicability

Do workers have the theoretical opportunity to make a counteroffer to an employer? Or do employers generally have predetermined wages and somehow commit not to consider counteroffers?

We have been unable to find *any* academic empirical literature on the process by which employers and job-seekers arrive at the terms of employment. Because our model makes the unambiguous prediction that counteroffers do not occur in equilibrium, there is no use in asking if workers make counteroffers in reality. We believe that a commitment not to consider counteroffers is difficult to achieve.

Our impression of the process of wage determination—not founded on any extensive body of systematic empirical evidence—is that job-seekers gather information from friends and help-wanted ads, and they post resumes on websites to find jobs for which they are well matched. An employer reviews information about applicants and searches databases for good matches. The employer calls in the more promising prospects for interviews. Having found what appears to be a good match, the employer makes a comprehensive job offer, including pay, benefits, and duties. We believe that employers almost always make the initial offer. Many job-seekers accept the initial offer, but others make counteroffers. The probability that the job-seeker and employer will make an acceptable deal is high, once the employer has decided to make the initial offer.

Our model is a stylized representation of this process. We do not try to model the directed nature of the search—in our model, job-seekers know nothing about a job. And there is nothing to know because all jobs are alike. We concentrate on one realistic aspect—one party starts the process by making an offer and the other can then accept or respond with a counteroffer. The unique equilibrium in our model is for acceptance of the initial offer. Thus the model is successful in explaining why few job-seekers make counteroffers (if that is true) but not successful in explaining why some job-seekers do make counteroffers. Models with information asymmetries might be able to explain the latter.

7 Other Research Relevant to the Wage Bargain

7.1 The alternating offer bargaining model

Infinite horizon, alternating offer bargaining models were introduced into economics by Rubinstein (1982) and have spurred a very large literature. Rubinstein and Wolinsky (1985) incorporate search and bargaining in a non-stochastic model and find that market outcomes may be far from the competitive equilibrium even when search costs and search times are vanishingly small. Gale (1986) introduces the possibility that the arrival of other parties may interrupt bargaining and create an auction; he shows that this structure reverses the Rubinstein-Wolinsky conclusion. Osborne and Rubinstein (1990) give an integrated review of the early literature.

Binmore et al. (1986) first developed the distinction between a threat point and an outside option in their alternating offer bargaining model. Binmore, Shaked and Sutton (1989) report laboratory experiments that affirm the importance of this distinction. Malcomson (1999) argues for its importance in analyzing labor contracts, while a number of others have applied the BRW theory to individual wage determination. These include Rosen (1997), Shimer (2005), Menzio (2005), and Delacroix (2004). None of these papers deals with our topic, the way that alternating-offer bargaining delivers substantial employment fluctuations. Delacroix investigates sticky wages and employment fluctuations, but in a setting without unemployment or pre-match non-contractible recruiting effort by employers. In his model, wages are sticky during the course of employment. Employment fluctuations arise from bilaterally efficient endogenous separations, not from variations in recruiting effort, as in our model and others in the MP tradition based on sticky wages as of the time the employment match is formed.

7.2 Mortensen and Nagypál's version of the model

Mortensen and Éva Nagypál (2007) and Mortensen (2007) cite this paper in support of a simple wage bargain where the wage is the equally weighted average of the flow value of non-work, z, and productivity p. Their conclusion follows from our equation (10) in a static setting with the cost of bargaining to the employer, γ, set to zero. They observe, as our model implies, that the response of the wage to productivity delivers reasonably substantial unemployment volatility.

As we explained earlier in section 4.1, we believe it is inappropriate to adopt a calibration that does not match the observed average unemployment rate. The Mortensen-Nagypál calibration either fails to match the data we cite on the cost of maintaining a vacancy or it fails to match the average unemployment rate. But their calibration does not miss these targets by much and we find it congenial to the main point of this paper.

8 Competing Opportunities During Bargaining

So far, we have assumed that as the worker and employer negotiate, they are never interrupted by another competitor—a worker or employer. How might allowing new arrivals during negotiations alter our analysis?

Rubinstein and Wolinsky (1985) found negotiated prices far from competitive equilibrium even when search frictions are small in an alternating offer bargaining model. Gale (1986) modified their model to allow arrivals of additional players during bargaining and assumed that new arrivals trigger an auction. In the labor market context, if the newly arriving bargainer were a worker and the two workers bid in an auction for the single job, then the losing bidder would return to unemployment, which pays U. Then, Bertrand competition would also limit the winning bidder to a payoff of U, tying the equilibrium wage tied tightly to the unemployment payoff. If the new arrival were another employer, Bertrand competition between the two employers would give the worker the entire surplus.

We study the two cases separately. In the case of two workers bidding for the same job, the basic structure of the Mortensen-Pissarides model permits a simple argument that the auction will have the same equilibrium wage as bilateral bargaining. Employers create jobs costlessly, apart from a recruiting cost. An employer cannot commit not to bargain with the loser of the auction, because the bargain will yield a positive value to the employer, as in our earlier analysis. The bids in the auction will reflect the knowledge that the loser gets the bargained wage. Hence the equilibrium of the auction is the bargained wage, and the auction possibility has no effect on our earlier conclusions.

The case of two employers bidding for the same worker is quite different. The losing employer returns to recruiting—there is no alternate worker standing in the wings, comparable to the alternate job in the previous case. The lucky worker receives a wage equal to productivity and the winning employer receives no part of the surplus. The result is to connect the wage to productivity, not to make the unemployment value U a direct determinant of the wage. However, labor-market conditions have a larger role in wage determination because they control the probability that a second employer will appear during bargaining.

It should not be taken for granted that a job-seeker can run an auction where two employers make competing bids. We have found no empirical literature studying how bargaining takes place in labor markets, but casual empiricism suggests that for many types of jobs, auctions among employers for a worker are not common.

One practical reason that auctions for a worker do not occur is that an employer cannot verify the bid of another employer. The worker's representation about a competing opportunity is cheap talk and it is hardly in the employer's interest to confirm the worker's claim. If no auction is available, the best the worker can do is to pick the employer where the bilateral bargain is most favorable and make that bargain.

Even when wage offers are common knowledge among the parties, the equilibrium depends on the bargaining protocol. Consider the following bargaining game, which we believe may govern important parts of the labor market. When it is the worker's turn to make an offer, she can abandon bargaining with the first-to-arrive employer and instead make an offer to the second employer, leaving the first employer to return to recruiting.

In this game, when the worker abandons bargaining with the first employer, she enters a subgame that is identical to the bargaining game we have analyzed above, leading to a worker's payoff of $W + V$. So, we can analyze the subgame perfect equilibria of the new game by replacing the subgame with a terminal node at which the worker is assigned a payoff of $W + V$. That payoff functions as an outside option for the worker—an amount that she can claim if she stops bargaining with the first employer. By the BRW logic, this outside option does not affect the agreement with the first employer: the worker cannot credibly threaten to refuse a deal today paying $W + V$ and terminate negotiations today in favor of a deal paying the same amount tomorrow. Hence, in this model, the wage bargain is unaffected by the arrival of a new job applicant.

The same conclusion applies for any model in which the worker can switch back and forth a maximum of N times, where N is any positive integer. This follows by induction: Suppose that the worker's unique equilibrium payoff is $W + V$ in any game where it can switch $N - 1$ times. Then, just as above, $W + V$ is the employer's outside option in the initial negotiation with the first-to-arrive worker and the conclusion follows.

Binmore (1985) analyzed a similar "telephone bargaining" model, but with no limit N on the number of times the bargainer can switch back and forth between the employers. He found that the same offer policies emerge at one equilibrium. The uniqueness argument made above was written to apply to this game as well; it proves that the equilibrium wage offer W is unique. The equilibrium itself is not unique. Indeed, there are infinitely many subgame perfect equilibria, but they vary only in the way the worker chooses a bargaining partner whenever she faces that choice.

Of course, we do not believe that competition from other applicants for a job or other jobs available to a worker is actually as limited as the characterization in our model. Not every employer has a second job ready when two qualified applicants appear at the same time for one job. In some cases, competing offers to the same applicant can be verified, so a worker can run an auction. Perhaps in some cases workers can put competing employers in the same room and make them bid directly against each other. Our point is that there are good reasons to think that these situations are not the rule and that the rule is bilateral alternating-offer bargaining.

9 Concluding Remarks

The process by which workers and employers reach agreement on the terms of employment is a key determinant of real-wage rigidity and has first-order implications for the volatility of unemployment. If the parties believe that rejecting an offer results in an immediate return to unemployment, then the wage is naturally sensitive to conditions in the labor market. But the belief that the only alternative to accepting an offer is to return to unemployment is wrong; the parties can instead simply continue to bargain. When two well-matched parties recognize that one side cannot credibly refuse to consider a counteroffer, conditions in the outside labor market have much less influence on the wage bargain.

In the standard Mortensen-Pissarides model, if unemployment were to become high, the resulting fall in wages would stimulate labor demand and excess unemployment would vanish. With credible wage bargaining, however, the limited influence of unemployment on the wage results in large fluctuations in unemployment under plausible movements in the driving force.

References

Anderson, Patricia M. and Bruce D. Meyer, "Unemployment Insuracne Takeup Rates and the After-Tax Value of Benefits," *Quarterly Journal of Economics*, August 1997, *112* (3), 913–937.

Binmore, Ken, "Bargaining and Coalitions," in A. Roth, ed., *Game-Theoretic Models of Bargaining*, Cambridge: Cambridge University Press, 1985.

____ , Ariel Rubinstein, and Asher Wolinsky, "The Nash Bargaining Solution in Economic Modeling," *RAND Journal of Economics*, Summer 1986, *17* (2), pp. 176–188.

____ , Avner Shaked, and John Sutton, "An Outside Option Experiment," *Quarterly Journal of Economics*, 1989, *104* (4), pp. 753–770.

Coles, Melvyn G. and Randall Wright, "A Dynamic Equilibrium Model of Search, Bargaining, and Money," *Journal of Economic Theory*, 1998, *78*, pp. 32–54.

Delacroix, Alain, "Sticky Bargained Wages," *Journal of Macroeconomics*, 2004, *26*, 25–44.

Gale, Douglas, "Bargaining and Competition, Part I: Characterization," *Econometrica*, 1986, *54* (4), pp. 785–806.

Hagedorn, Marcus and Iourii Manovskii, "The Cyclical Behavior of Equilibrium Unemployment and Vacancies Revisited," April 2006. University of Frankfurt and University of Pennsylvania.

Hall, Robert E., "Employment Fluctuations with Equilibrium Wage Stickiness," *American Economic Review*, March 2005, *95* (1), 50–65.

____ , "Job Loss, Job Finding, and Unemployment in the U.S. Economy over the Past Fifty Years," *NBER Macroeconomics Annual*, 2005. Forthcoming.

____ , "Sources and Mechanisms of Cyclical Fluctuations in the Labor Market," July 2007. Hoover Institution, Stanford University, www.Stanford.edu/∼rehall.

Holden, Steinar, "Wage Bargaining, Holdout, and Inflation," *Oxford Economic Papers*, 1997, *49*, 235–255.

Krueger, Alan B. and Bruce D. Meyer, "Labor Supply Effects of Social Insurance," in Alan Auerbach and Martin Feldstein, eds., *Handbook of Public Economics, Volume 4*, Elsevier, 2002, pp. 2237–2392.

Malcomson, James M., "Individual Employment Contracts," in Orley Ashenfelter and David Card, eds., *Handbook of Labor Economics*, Vol. 3B, New York: North Holland, 1999, chapter 35, pp. 2291–2372.

Menzio, Guido, "A Cheap-Talk Theory of Random and Directed Search," September 2005. Department of Economics, University of Pennsylvania.

Mortensen, Dale T., "Island Matrching," June 2007. Northwestern University.

____ and Christopher Pissarides, "Job Creation and Job Destruction in the Theory of Unemployment," *Review of Economic Studies*, 1994, *61* (0), pp. 397–415.

____ and Éva Nagypál, "More on Unemplohyment and Vacancy Fluctuations," *Review of Economic Dynamics*, 2007, *10*, 327–347.

Osborne, Martin and Ariel Rubinstein, *Bargaining and Markets*, New York: Academic Press, 1990.

Petrongolo, Barbara and Christopher A. Pissarides, "Lookin into the Black Box: A Survey of the Matching Function," *Journal of Economic Literature*, June 2001, *39* (2), 390–431.

Pissarides, Christopher, "The Unemployment Volatility Puzzle: Is Wage Stickiness the Answer?," June 2007. Walras-Bowley Lecture, North American Summer Meetings of the Econometric Society.

Rosen, Asa, "An Equilibrium Search-Matching Model of Discrimination," *European Economic Review*, 1997, *41*, 1589–1613.

Rubinstein, Ariel, "Perfect Equilibrium in a Bargaining Model," *Econometrica*, 1982, *50* (1), pp. 97–110.

____ and Asher Wolinsky, "Equilibrium in a Market with Sequential Bargaining," *Econometrica*, 1985, *53* (5), pp. 1133–1150.

Shimer, Robert, "The Cyclical Behavior of Equilibrium Unemployment and Vacancies," *American Economic Review*, 2005, *95* (1), 24–49.

Silva, Jose A. and Manuel Toledo, "Labor Turnover Costs and the Cyclical Behavior of Vacancies and Unemployment," February 2007. Universitat Autonoma de Barcelona and Universidad Carlos III de Madrid.

Wegerbauer, Maryanne L., *Job Offer! A How-To Negotiation Guide*, Indianapolis: Jist Publishing, 2000.

Appendix

Variable	*Interpretation*	*Value*	*Source*
u	Unemployment rate, percent	5.5	Current Population Survey, long-run average
φ	Job-finding rate, percent per day	2.4	JOLTS hiring flow rate divided by unemployment rate
θ	Vacancy/unemployment ratio	0.5	Vacancy rate from JOLTS
	Standard deviation of unemployment related to productivity fluctuaitons, percent	0.68	See text, section 3.7

Values of endogenous variables for calibration

Parameter	*Interpretation*	*Model*	*Value*	*Calibration strategy*
\	Exogenous separation rate	All	0.0014	See Hall (2005). Rate of 3 percent per month from JOLTS.
	Elasticity of job-finding rate	All	0.5	Compromise between lower value found in earlier research and higher value found in JOLTS--see Hall (2005a)
φ	Coefficient of matching efficiency	All	0.034	Solve the job-finding function given θ and the job-finding rate from Table B
r	Daily interest rate	All	0.00019	Annual real rate of 5 percent
β	Worker's bargaining power	MP HM	0.54 0.19	Solve the zero-profit condition to match unemployment
δ	Daily probability that job opportunity disappears during bargaining	CB	0.0055	Match employment volatility
c	Cost of maintaining vacancy, in days of productivity per day	All	0.433	See Silva and Toledo (2007)
b	UI benefit replacement rate	MP and CB	0.25	See text, section 3.1
z	Flow value of non-work	MP and CB HM	0.71 0.932	See text, section 3.1 Match employment volatility
γ	Cost to employer of delaying bargaining by one day and formulating a counteroffer, in days of productivity	CB	0.27	Solve the zero-profit condition to match unemployment rate

Note: MP is Mortensen-Pissarides, HM is Hagedorn-Manovskii, and CB is credible bargaining

Values of calibrated parameters