Wage Determination and Employment Fluctuations

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Abstract:

Following a recession, the aggregate labor market is slack—employment remains below normal and recruiting efforts of employers, as measured by vacancies, are low. A model of matching frictions explains the qualitative responses of the labor market to adverse shocks, but requires implausibly large shocks to account for the magnitude of observed fluctuations. The incorporation of wage-setting frictions vastly increases the sensitivity of the model to driving forces. I develop a new model of wage friction. The friction arises in an economic equilibrium and satisfies the condition that no worker-employer pair has an unexploited opportunity for mutual improvement. The wage friction neither interferes with the efficient formation of employment matches nor causes inefficient job loss. Thus it provides an answer to the fundamental criticism previously directed at sticky-wage models of fluctuations.

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I. Introduction

Modern economies experience substantial fluctuations in aggregate output and employment. In recessions, employment falls and unemployment rises. In the years immediately after a recession, the labor market is slack—unemployment remains high and the vacancy rate and other measures of employer recruiting effort are abnormally low. Unemployment is determined by the rate at which workers lose jobs and the rate at which the unemployed find jobs. I develop a model of fluctuations embodying both matching and wage frictions. The incorporation of a wage friction makes employment realistically sensitive to driving forces. My characterization of the wage friction is rather different from earlier ideas of wage rigidity and more closely integrated with the matching process. The model with both wage and matching frictions describes an economic equilibrium and overcomes the arbitrary disequilibrium character of earlier sticky-wage models.

A line of research starting with Diamond [1982], Mortensen [1982], and Pissarides [1985]—nicely summarized in Pissarides's [2000] book and in Shimer [2003]—provides an account of unemployment as a productive use of time. I adopt many of the elements of their model—the DMP model—in this paper. The DMP model views the labor market in terms of an economic equilibrium where workers and employers interact purposefully. A friction in matching unemployed workers to recruiting employers accounts for the existence of unemployment. Variations in the economic environment lead to fluctuations in unemployment. The DMP model portrays wage determination as a Nash bargain, where employers receive a constant fraction of the match surplus. The payoff to recruiting activity—the employers' share of the surplus—is not very sensitive to driving forces. Hence the DMP model cannot explain the magnitude of movements in recruiting activity. In reality, the labor market slackens substantially in recessions and workers encounter difficulty in finding jobs, but the DMP model with Nash-bargain wage determination suggests stability in job-finding rates under plausible variations in the driving forces.

In a model with matching frictions, the bargaining set for wage determination is relatively wide, because the difficulty in locating matches creates match capital the moment a tentative match is made. The value of the match capital determines the gap between the minimum wage acceptable to the worker and the maximum wage acceptable to the employer. From the perspective of bilateral bargaining theory in general, *any* wage within the bargaining set could be an outcome of the bargain. The Nash bargain sets the wage at a weighted average of the limiting wages, with a fixed weight over time. The alternative I offer permits variations over time in the position of the wage within the bargaining set. When the wage is relatively high—closer to the employer's maximum—the employer anticipates less of the surplus from new matches and puts correspondingly less effort into recruiting workers. Jobs become hard to find, unemployment rises, and employment falls.

In the wage-friction model I develop, when changes in the economic environment shift the boundaries of the bargaining set, at first the wage remains close to constant. Then the wage adjusts over time because—thanks to heterogeneity in matches—the wage in some cases falls outside the bargaining set and is then moved to the boundary of the set. This mechanism guarantees that wage rigidity never results in an allocation of labor that is inefficient from the joint perspective of worker and employer. Consequently, the model provides a full answer to Barro's [1977] condemnation of sticky-wage models for invoking an inefficiency that intelligent actors could easily avoid. Unlike frictions portrayed as essentially arbitrary restrictions on the ability to set wages or prices—such as in Calvo's [1983] well-known model for prices—the friction considered here arises within an economic equilibrium. It satisfies the criterion that no employer-worker pair foregoes bilateral opportunities for mutual improvement.

Although wage rigidity has no effect on the formation of a job match once worker and employer meet and no effect on the continuation of the match, rigidity does have a profound influence on the search process. If wages are toward the upper end of the bargaining set, the incentives that employers face to look for additional workers are low. I start the paper with evidence about the remarkably strong procyclical movements of help-wanted advertising and vacancies. This evidence supports the mechanism proposed here.

I then turn to the model. I adopt the matching friction of the DMP model. But as Shimer [2003] and Veracierto [2002] have stressed, the DMP model and others with the same basic view of the labor market do not offer a plausible explanation of observed fluctuations in unemployment. The magnitude of changes in driving forces needed to account for the rise in unemployment and decline in recruiting effort during slumps is much too large to fit the facts about the U.S. economy. For this reason—and following Shimer's suggestion—I introduce the wage friction into the DMP setup. The resulting model makes recruiting effort, job-finding rates, and unemployment remarkably sensitive to changes in determinants. A small decline in the product price, productivity, or increase in input prices results in a slump in the labor market. With the wage friction, these changes depress employers' returns to recruiting substantially. The offsetting decline in the wage that occurs instantly in the DMP model is delayed by the wage friction. The immediate effect is a decline in recruiting efforts, a lower job-finding rate, and a slacker labor market with higher unemployment.

II. Variations in Recruiting Effort

The DMP model captures recruiting effort in the vacancy rate. Prior to the beginning of the Job Openings and Labor Turnover Survey (JOLTS) in December 2000, no direct measures of vacancies have been available for the U.S. labor market. Previous authors have suggested—reasonably persuasively—that data on help-wanted advertising provided good evidence about variations in vacancies over time. Figure 1 shows the Conference Board's index of help-wanted advertising since 1951. Recruiting effort as measured by advertising is remarkably volatile. It is not uncommon for advertising to fall by 50 percent from peak to trough, as it did from 2000 to 2003.

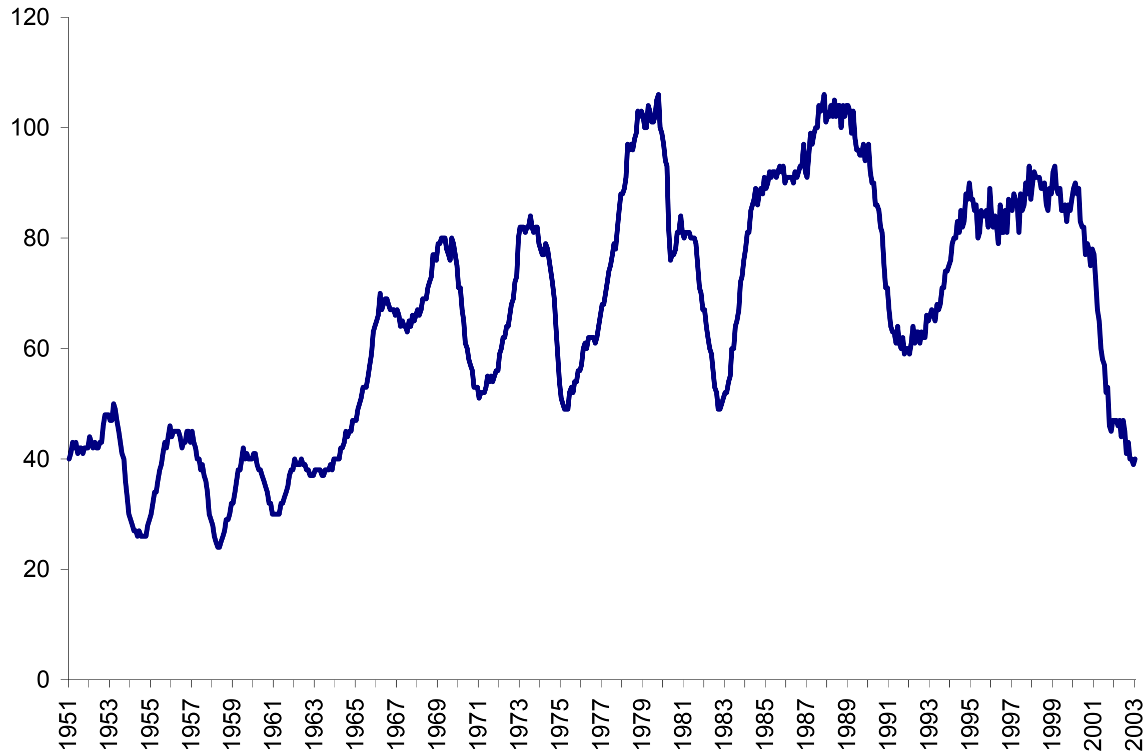

Figure 1. Index of Help-Wanted Advertising

Source: The Conference Board, http://www.globalindicators.org

Table 1 shows data from JOLTS on vacancies by industry for the period of slackening of the labor market since late 2000. The figures confirm the high volatility of vacancies suggested by the data on help-wanted advertising. The data show that vacancies have declined in almost all industries. Although the forces that caused the downturn in the economy disproportionately affected a few industries far more than others—notably computers, software, and telecommunications equipment—the softening of the labor market was economy-wide. The new data strongly confirm the position of Abraham and Katz [1986] that recessions are times when the labor markets of almost all industries slacken—not times when workers move from industries with slack markets to others with tight markets. I conclude that a realistic model of the labor market needs to invoke a market-wide force that has powerful effects on the recruiting efforts of employers.

Industry	*Ratio of vacancy rates in 12/02 and 12/00*
Mining	0.36
Construction	0.38
Durables	0.45
Nondurables	0.48
Transportation and utilities	0.80
Wholesale trade	0.52
Retail trade	0.60
Finance, insurance, and real estate	0.79
Services	0.68
Federal government	0.54
State and local government	0.70

Table 1. Change in Vacancy Rates by Industry in JOLTS, December 2000 to December 2002

III. Model of the Labor Market

A. The Matching Process and Recruiting Effort

I adopt the standard view of the matching friction in the labor market. The flow of candidate matches results from the application of a constant-returns matching technology to vacancies, v, and unemployment, u (both are expressed as ratios to the labor force). Let x be the ratio of vacancies to unemployment and let $\phi(x)$ be the per-period probability that a searching worker will find a job. Let $\rho(x)=\frac{\phi(x)}{x}$ be the per-period probability that an employer will fill a vacancy. ϕ is an increasing function and ρ is a decreasing function. Employers open vacancies and initiate the recruiting process whenever it is profitable to do so.

The vacancy/unemployment ratio, x, serves as the indicator of labor-market conditions in the model. In a tight market with a high ratio of vacancies to unemployment, the unemployed find it easy to locate new jobs, so the job-finding rate $\phi(x)$ is high. Employers find it difficult to locate new workers, so the job-filling rate $\rho(x)$ is low. The matching model gives a precise meaning to the notion of tight and slack markets.

A standard specification for the matching technology is

$$\phi(x)=\omega x^{\alpha} \tag{3.1}$$

The parameter ω controls the efficiency of matching and the parameter α splits the variation between changes in job-finding rates and changes in job-filling rates. The underlying matching function gives an elasticity of α to vacancies and $1-\alpha$ to unemployment.

B. Separations

For simplicity, I assume a fixed hazard, s, that a job will end. In the U.S. labor market, separations that result in unemployment appear to rise somewhat when unemployment rises, but separations involving direct re-employment in new jobs decline. JOLTS measures the sum of the two flows; the sum rose moderately from December 2000 through the most recently reported data. The situation is further complicated by the flows into unemployment of people who were previously out of the labor force and the flows of unemployed people back out of the labor force (see Blanchard and Diamond [1990]). My model in its present form does not claim to do justice to these aspects of labor-market dynamics.

It is straightforward to extend the model to make separations endogenous. The key properties considered here would not be altered by that extension. Because the U.S. has a well-defined Beveridge curve, nicely traced out by the data from JOLTS and the unemployment survey for the contraction that began in early 2001, separations cannot be too sensitive to driving forces, else the model would be unable to explain the high amplitude of variations in vacancies documented in Table 1. Higher separations in slack markets would require higher vacancies to maintain stochastic equilibrium in the market and this influence could flatten the Beveridge curve unrealistically (see Shimer [2003]).

In addition to ruling out endogenous movements of the separation rate, my assumption also rules out exogenous movements. That is, I do not take spontaneous fluctuations in the separation rate as a driving force in the model. A spontaneous burst of separations raises both unemployment and vacancies and shifts the Beveridge curve outward. The stability of the Beveridge curve argues against the importance of such a driving force (see Abraham and Katz [1986]).

C. Equilibrium with Matching Friction

The following is derived fairly directly from Pissarides [2000] and Shimer [2003]. I use discrete time to facilitate computations. I let λ be the value a worker enjoys when searching (leisure value and unemployment compensation). The price of output is p_t. Other inputs needed to produce the unit of output cost c. And it costs k in recruiting costs to hold a vacancy open for one period. Workers and firms are risk-neutral and discount the future at rate β.

The model is conveniently specified in terms of Bellman value-transition equations. Let U_t be the value a worker associates with being unemployed and searching for a new job and let E_t be the value the worker associates with being in a job, after receiving that period's wage payment, w_t. Let J_t be the value the employer associates with a filled job after making the wage payment. I assume, as is standard in this literature, that employers expand recruiting effort to the point of zero profit, so the value associated with an unfilled vacancy is zero.

The value transition equations are:

$$U_t = \beta\left[\phi(x_t)(w_{t+1} + E_{t+1}) + (1-\phi(x_t))(U_{t+1} + \lambda_{t+1})\right] \tag{3.2}$$

$$E_t = \beta\left[(1-s)(E_{t+1} + w_{t+1}) + s(U_{t+1} + \lambda_{t+1})\right] \tag{3.3}$$

$$J_t = \beta(1-s)(J_{t+1} + p_{t+1} - c_t - w_{t+1}) \tag{3.4}$$

$$0 = \beta\rho(x_t)(J_{t+1} + p_{t+1} - c_t - w_{t+1}) - k \tag{3.5}$$

Conditional on the wage, w_t, and future values of other variables, the first three equations determine the current values of U_t, E_t, and J_t. Equation (3.5) captures a central aspect of the model: Given the anticipated payoff from making a match, $J_{t+1} + p_{t+1} - c_{t+1} - w_{t+1}$, firms create vacancies up to the point where the payoff is canceled by the recruiting cost, *k*. As they create more vacancies, x_t rises, recruiting success, $\rho(x_t)$ falls, and the point of zero net payoff is achieved. This pins down the key variable, x_t, the vacancy/unemployment ratio.

D. Wage Determination

Here I depart from the DMP model, which views wage determination as the outcome of a Nash bargain. In this model, a worker with a reservation wage $\underline{w} = U + \lambda - E$ is matched with an employer with a reservation wage $\overline{w} = J + p - c$. The symmetric Nash bargain would be the average of the two values. Instead, I characterize wage determination in terms of a Nash [1953] demand game or auction (see also Chatterjee and Samuelson [1983] and Myerson and Satterthwaite [1983]). In the auction, worker and employer know one another's reservation values. The worker proposes a wage, w_L, and the firm, without knowing the worker's proposal, makes its own proposal, w_H. If $w_L \le w_H$, the match is made or continues and the wage is agreed to be $w = \kappa w_L + (1-\kappa) w_H$ with $0 < \kappa < 1$. The auction has the property that *any* w in the bargaining set $[\underline{w}, \overline{w}]$ is a Nash equilibrium. Believing that the worker is bidding w_L, the firm will bid w_L as well, provided that $w_L \le \overline{w}$. Similarly, believing that the firm is bidding w_H, the worker will bid w_H as well, provided $\underline{w} \le w_H$. Thus any $w = w_L = w_H \in [\underline{w}, \overline{w}]$ is a Nash equilibrium. Nash proposed the celebrated equilibrium selection rule—the Nash bargain—adopted in the DMP model.

I specify a different equilibrium selection rule to pin down the wage within the bargaining set. The basic idea is that the previous period's wage sets the norm for this period's wage. Akerlof, Dickens, and Perry [1996] discuss this type of a wage norm and Bewley [1999] provides evidence about the operation of a modern labor market under such a norm. Those authors focus on the avoidance of downward wage adjustments, but many of their ideas point toward the absence of immediate upward wage adjustments as well. My specification is limited in a way not previously considered in the literature on wage rigidity—I do not permit the norm to lie outside the bargaining set. The earlier work implied inefficient outcomes, especially the loss of a job under conditions where both worker and employer could have been better off with a wage adjustment. The wage norm I consider interferes neither with the formation of efficient matches once the parties are in touch with one another nor with the preservation of jobs with positive surplus. Inefficient separations cannot occur. As a result, the model provides a full answer to Barro's [1977] indictment of sticky wage models for invoking unexplained inefficiencies in economic arrangements.

In the simplest application of the idea, the wage would remain at its previous level as long as that level remained within the bargaining set. From a starting point where the wage is in the middle of the bargaining set, and for moderate disturbances that do not move the boundaries of the bargaining set past that wage, the wage simply remains fixed.

Strict fixity of the wage is not a reasonable property for a dynamic model. To formulate a more realistic version with gradual wage adjustment, I introduce heterogeneity into the model. Suppose that each wage bargain contains an idiosyncratic random shift, η, in the boundaries of the bargaining set, so that the set becomes $\left[\underline{w}+\eta, \overline{w}+\eta\right]$. The equilibrium selection rule becomes

$$
\begin{aligned}
w_t(\eta) &= \underline{w}_t + \eta \text{ if } w_{t-1} < \underline{w}_t + \eta \\
&= \overline{w}_t + \eta \text{ if } w_{t-1} > \overline{w}_t + \eta \\
&= w_{t-1} \text{ otherwise}
\end{aligned}
\tag{3.6}
$$

I take the norm to be $w_{t-1} = E\left(w_{t-1}(\eta)\right)$, the previously determined average of wages. The selection rule moves the wage to the boundary of the bargaining set in cases where either changes in $\underline{w}_t$ or $\overline{w}_t$, or the draw of η imply that the norm would lie outside the bargaining set.[1] These adjustments move the norm over time toward the middle of the interval $\left[\underline{w}, \overline{w}\right]$.

For newly hired workers, the process works in the following way: A value of η is drawn. If the norm, w_{t-1}, is inside the bargaining set $\left[\underline{w}_t + \eta, \overline{w}_t + \eta\right]$, the worker starts the job at wage w_{t-1}; otherwise, the wage is $\underline{w}_t + \eta$, if η is so high that w_{t-1} is below the

[1] Thomas and Worrall [1988] develop a similar wage-setting rule. In their model, a worker and a firm generate a potential surplus if the firm can insure the worker against wage fluctuations. But the worker and firm cannot commit to continue the relationship. Hence the wage is confined to the interval defined by the current bargaining set. The optimal rule is to change the wage only when it would otherwise fall outside the bargaining set, in order to shield the worker from wage fluctuations. The paper does not include a resolution of the initial indeterminacy of the wage—the subject of my work—nor does it include volatility of unemployment, which does not exist in the model.

lower boundary of the bargaining set, or $\overline{w}_t + \eta$, if η is so low that w_{t-1} is above the upper boundary of the bargaining set. In subsequent periods, new draws of η occur and the wage is the current norm w_{t-1} if it lies inside the bargaining set or is adjusted to the boundary of the bargaining set.

I assume that η is normally distributed with mean zero and standard deviation σ. Let F be its cumulative distribution and f its density and note that

$$\int_{-\infty}^{x} \eta f(\eta) d\eta = \sigma^2 f(x). \tag{3.7}$$

The average wage evolves according to

$$\begin{aligned} w_t = &\left(1 - F\left(w_{t-1} - \underline{w}_t\right)\right)\overline{w}_t + \sigma^2 f\left(w_{t-1} - \underline{w}_t\right) + \\ &\left(F\left(w_{t-1} - \underline{w}_t\right) - F\left(w_{t-1} - \overline{w}_t\right)\right) w_{t-1} \\ &+ F\left(w_{t-1} - \overline{w}_t\right)\overline{w}_t - \sigma^2 f\left(w_{t-1} - \overline{w}_t\right) \end{aligned}. \tag{3.8}$$

Figure 2 shows the relation of the new wage w_t to the earlier w_{t-1}. I have exaggerated the standard deviation of the idiosyncratic element and thus overstated the rate of adjustment. At the calibrated rate of adjustment, the two lines would lie almost atop one another.

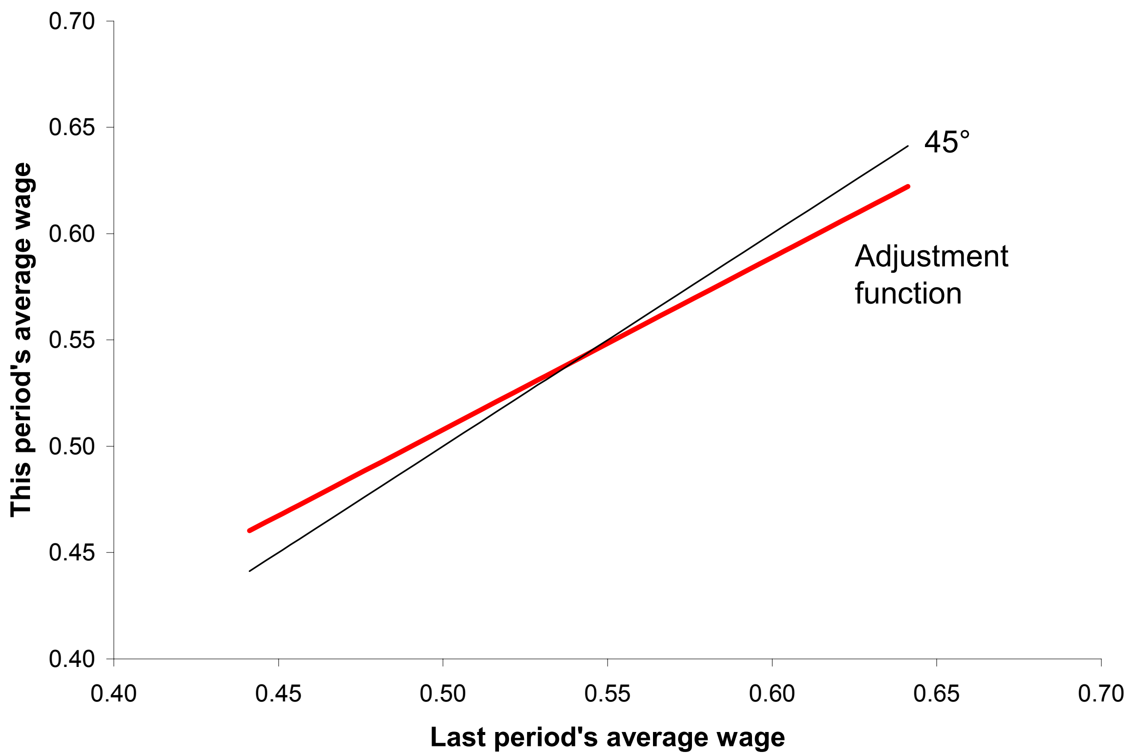

Figure 2. Wage Adjustment Function

The wage-adjustment function can be expressed in the form

$$w' = \left(1 - \chi\left(w, \underline{w}, \overline{w}\right)\right) w + \chi\left(w, \underline{w}, \overline{w}\right) w^* . \tag{3.9}$$

where $\chi\left(w, \underline{w}, \overline{w}\right)$ is the adjustment rate and

$$w^* = \frac{\underline{w} + \overline{w}}{2} \tag{3.10}$$

is the symmetric Nash bargain wage rate. In a standard partial-adjustment model, the rate would be a constant. Here, adjustment is more rapid near the boundaries of the bargaining set than in the middle and more rapid if the boundaries are closer together.

E. Equilibrium

The model is a difference equation in reverse time. From values of U_{t+1}, E_{t+1}, J_{t+1}, w_{t+1}, and x_t, equations (3.2), (3.3), and (3.4) give U_t, E_t, and J_t. These are present discounted values formed recursively. Then the zero-profit condition for time *t,* equation (3.5) can be solved for the new value of the vacancy/unemployment ratio, x_{t-1}. Finally the wage adjustment equation, (3.8), can be solved for w_t given w_{t+1}, $\underline{w}_{t+1}$, and $\overline{w}_{t+1}$. The wage is a state variable that starts at an historical value which I take as the stationary (symmetric Nash bargain) wage for $p=1$. With an infinite horizon, the values of U_{t+1}, E_{t+1}, J_{t+1}, and w_{t+1} would satisfy a transversality condition. To approximate the infinite-horizon case over a finite period of 10 years, I find the terminal wage and associated stationary-state values of U_T, E_T, and J_T that satisfy the initial condition for the wage. At realistic adjustment rates, this "shooting" problem can be solved easily by trial and error.

To find the resulting paths of unemployment, employment, and vacancies, I iterate forward from the given initial unemployment rate. Suppose that the labor force is normalized at one. Then the law of motion for employment is:

$$n_t = \phi(x_{t-1})u_{t-1} + (1-s)n_{t-1} \tag{3.11}$$

and unemployment is:

$$u_t = 1 - n_t \ . \tag{3.12}$$

The vacancy rate is

$$v_t = x_t u_t \ . \tag{3.13}$$

IV. Parameters

To estimate the elasticity of the matching function, α, I use the aggregate data from JOLTS shown in Table 2. I calculate x as the ratio of vacancies to unemployment and the job-filling rate as the job-finding rate divided by x and estimate the elasticity as the change in the log of the job-finding rate divided by the change in the log of the vacancy/unemployment ratio, x. The resulting estimate is 0.765.

	December 2000	*December 2002*
New hires	4.070 million	3.187 million
Unemployed	5.264 million	8.209 million
Vacancies	4.036 million	2.558 million
Job-finding rate, ϕ	0.773 per month	0.388 per month
Job-filling rate, ρ	1.008 per month	1.246 per month
Unemployment rate, u	3.6 percent	5.7 percent
Vacancy rate, v	2.8 percent	1.8 percent
x	0.767 vacancies per unemployed worker	0.312 vacancies per unemployed worker
α, elasticity of job finding with respect to x	0.765	

Table 2. Calculations from JOLTS Data

The model operates at a weekly frequency, to avoid the danger that either the job-finding rate or the job-filling rate might exceed one. I calibrate to the data shown in Table 3.

Symbol	*Concept*	*Value*	*Source*
ϕ	Job-finding rate	0.62 per month = 0.14 per week	JOLTS and Household Survey
v	Vacancy rate	0.028	JOLTS
u	Unemployment rate	0.056	Household Survey historical average

Table 3. Data from U.S. Labor Market

Notice that the value of the vacancy/unemployment ratio, x, is 0.5. I calibrate or estimate the parameters as shown in Table 4.

Parameter	*Interpretation*	*Value*	*Source*
ω	Efficiency of matching	0.212	Calibration
s	Weekly separation rate	0.00815	Calibration
λ	Flow value while searching (leisure or unemployment compensation)	0.4	Corresponds to a flow value while searching that is about 75 percent of the flow wage
c	Flow cost of other inputs	0.45	Approximate labor share in revenue in typical industry
k	Flow cost of a vacancy	0.255	Calibration
β	Discount factor	0.999014	Corresponds to 5 percent annual rate
σ	Standard deviation of idiosyncratic shift of the boundaries of the wage bargaining set	0.23	Roughly matches persistence of unemployment, assuming a random walk for price

Table 4. Calibration and Estimation of Parameters

I normalize the stationary level of the price, p, to one. The calibration solves the 9 equations: (3.1) through (3.5) and (3.10) through (3.13). The solution gives the stationary values of four endogenous variables: U, E, J, and w and three calibrated parameters: ω, s, and k (I treat the separation rate, s, as a calibrated parameter even though it can be found in JOLTS in order to make the stochastic equilibrium condition, equation (3.11) without time subscripts, hold exactly).

The values of the variables are shown in Table 5.

Variable	*Interpretation*	*Value*
U	Value while searching	539.7
E	Value of future work while working	540.5
J	Value of worker to the firm	0.91
w	Wage	0.54

Table 5. Stationary Values of Endogenous Variables

V. Properties of the Model

A. The Stationary State

The model keeps wages essentially constant in the short run. Strict constancy of the wage would result in extreme sensitivity of the stationary-state unemployment and vacancies to changes in the product price, as shown in Figure 3.

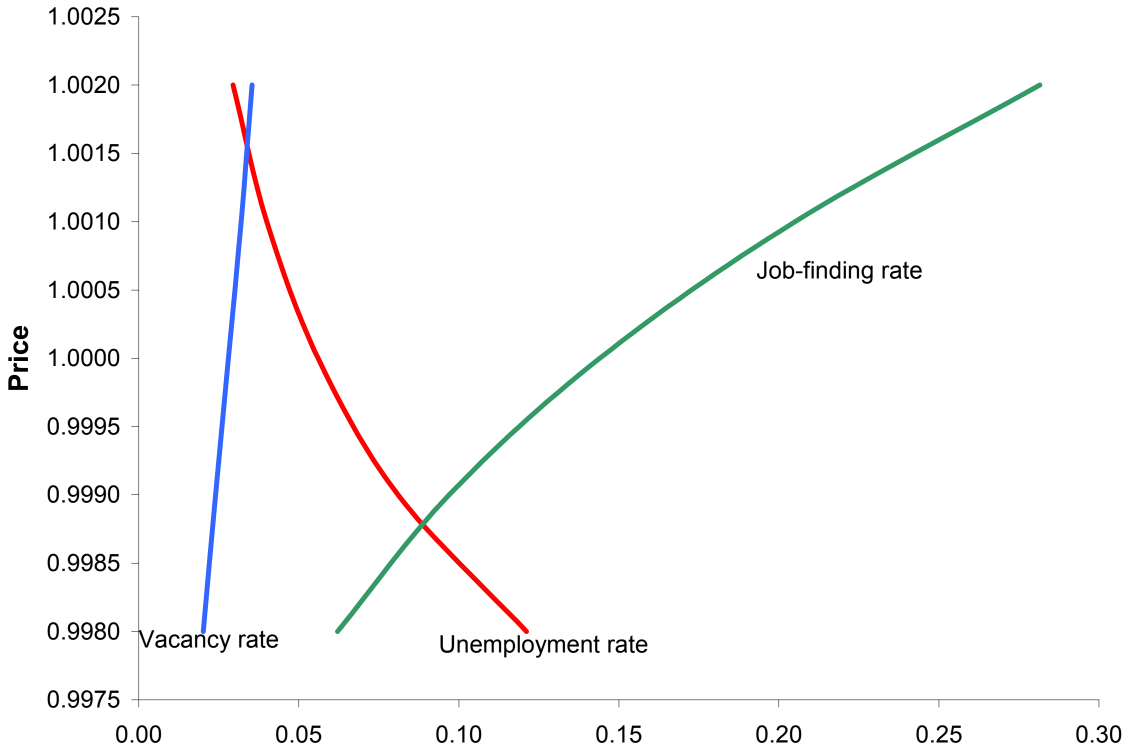

Figure 3. Stationary-State Relations among Price and Job Finding, Vacancy, and Unemployment Rates, Fixed Wage

The relations abstracts from transitory dynamics and from effects from changing driving forces. At a higher product price in relation to the fixed wage, employers put more resources into recruiting because they receive a higher fraction of the surplus. Consequently, the job-finding rate is higher and the unemployment rate is lower.

The curves in Figure 3 display properties that are central to the view of the labor market embodied in the model. Although the full model takes account of the aspects of the labor market not considered in the figure—matching dynamics and the effects of expected future changes in driving forces—the curves tell the main story of the model. If product demand is weak, unemployment rises. The rise occurs because the rate of flow out of unemployment falls.

The high sensitivity of labor-market conditions to the product price when the wage is fixed arises for the following reason: The gross value that an employer achieves from a success in recruiting is

$$V = J + p - c - w \tag{3.14}$$

Recruiting cost exhausts this value in equilibrium. The response of recruiting effort—and therefore of conditions in the labor market—depends on the change in V induced by a change in p. $J + p - c$ is the present value of the profit margin earned by a worker in the course of the job and, with exogenous separation, does not depend on any other variables in the model. In the calibration, $\frac{dJ}{dp} + 1 = 104.92$. With the wage held constant, there is no offset from a wage change and $\frac{dV}{dp} = 104.92$, resulting in large changes in recruiting effort. The elasticity of V with respect to p is well over 50, as the level of V is 0.9. By contrast, with a symmetric Nash wage bargain, as in the DMP model, almost all of this increased profit goes into wages, because a higher p raises both $\underline{w}$ and $\overline{w}$, so $\frac{dw}{dp} = 0.99$ and $\frac{dV}{dp} = 1.6$. The price change has little effect on the employer's gross value and thus little effect on recruiting effort.

The sensitivity of recruiting effort to the product price depends on the distribution of rents between workers and employers. If every employer makes take-it-or-leave-it offers to its workers and captures all the rent, workers are indifferent between unemployment and employment and their wage is the present value of λ for the duration of the job. Employers have large incentives to recruit workers at all times, but the elasticity of the gross value is unity and the response of recruiting effort to price changes is not very elastic. Thus the high amplification of price or productivity shocks that occurs in the model depends on the assumption that the typical workers shares a significant fraction of the joint surplus from the employment relationship.

B. Dynamic Response to Permanent Price Shock

I calculate the responses to a permanent price shock. The price jumps from 1 to $1+\Delta$ in the first period and remains at the new level. I start the calculations at the stationary distribution of the labor force between employment and unemployment (94.4 percent and 5.6 percent). Figure 4 shows the response of the unemployment and job-finding rates to a tiny price reduction of 0.1 percent. A standard deviation of the idiosyncratic element of wage setting of $\sigma = 0.23$ reproduces the persistence of U.S. unemployment, in the sense that unemployment declines to half its maximum level after 30 months. The thin line that tracks unemployment except at the outset is the stochastic equilibrium unemployment rate, $\dfrac{s}{\phi_t + s}$ —the unemployment rate that would prevail if the job-finding rate remained constant at its current value and the labor market reached stochastic equilibrium. The two curves differ materially only for the first few months. Except for the period just after a shock, it is safe to interpret the labor market as in stochastic equilibrium.

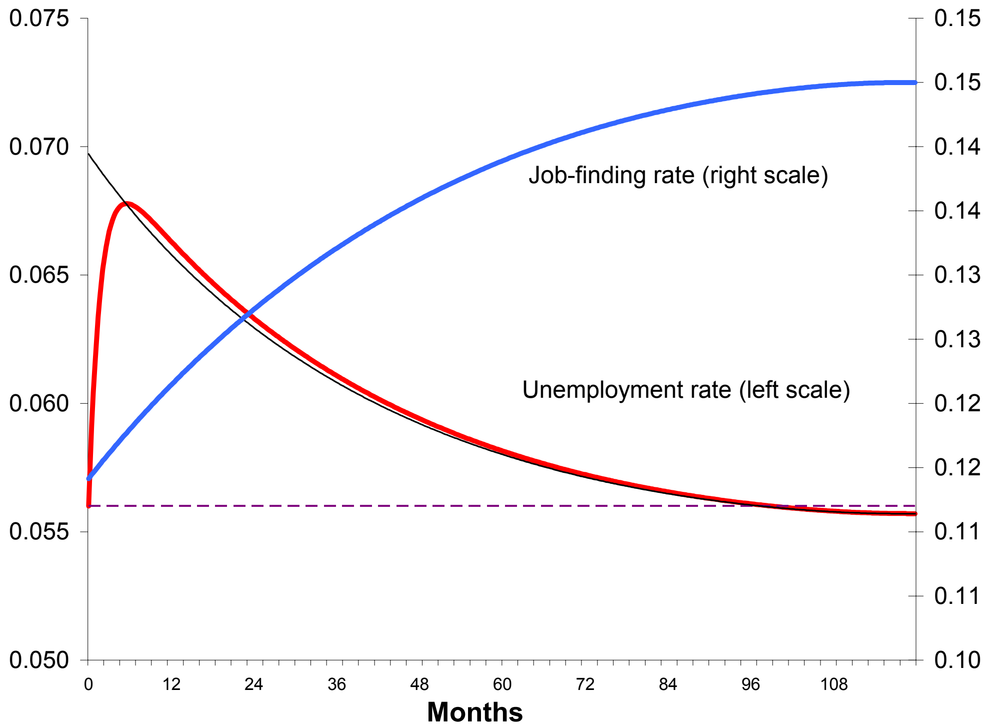

Figure 4. Response to Permanent Price Change in the Model with Wage and Matching Friction

As soon as the price drops, the labor market slackens—the job-finding rate falls from its normal level just above 14 percent per week to about 12 percent per week. With a constant inflow to unemployment and a diminished outflow, unemployment builds rapidly to a maximum of about 6.7 percent. The wage moves downward from the start, so the job-finding rate rises continuously. At about 7 months, improved job finding and higher unemployment combine to equate the outflow from unemployment to the exogenous inflow and unemployment reaches its maximum. From that point forward, further improvements in job finding bring the unemployment rate back down to its new stationary value slightly above the old stationary value of 5.6 percent (because the product price is permanently 0.1 percent lower). Notice that the overall dynamics of the model are second order and unemployment overshoots later in the adjustment process, though only slightly. At the 10-year cutoff in the figure, unemployment is still a bit below the old stationary level of 5.6 percent.

C. The Adjustment Rate

When the standard deviation of the idiosyncratic shift of the boundaries of the bargaining set is 0.23, the weekly adjustment rate $\chi(w, \underline{w}, \overline{w})$ defined in equation (3.9) is only 0.00006. The corresponding annual adjustment rate is 0.3 percent. Recessions would last almost forever if this rate actually controlled the movement of the wage to its new stationary value after a price or productivity shock. But the effective adjustment rate is fast enough to generate the response shown in Figure 4. The reason is the extreme sensitivity of $\underline{w}$ and $\overline{w}$ to the difference between the price and the wage paid. A small decrease in the price lowers the job-finding rate and thus lowers the unemployment value, U, that determines $\underline{w}$. As discussed earlier, the lower price also lowers the value of the worker to the firm, J, and thus lowers the firm's reservation wage $\overline{w}$. The derivative of $\frac{\underline{w}+\overline{w}}{2}$ with respect to p in the stationary state is 255. The response shown in Figure 4 combines a large initial downward movement of $\underline{w}$ and $\overline{w}$ resulting from the price decline and the tiny adjustment rate $\chi(w, \underline{w}, \overline{w})$ to generate a realistic movement of the wage and the unemployment. Each small adjustment in the wage moves $\underline{w}$ and $\overline{w}$ closer by a factor of 500 toward their new stationary values.

D. Comparison to the Same Model with Nash Wage Bargain

A model in the DMP family can be created by replacing the wage determination process developed above with a symmetric Nash wage bargain,

$$w_t = \frac{\underline{w}_t + \overline{w}_t}{2} \tag{3.15}$$

Figure 5 shows the relations between the product price, *p*, and the job finding, and unemployment rates in the stationary state.

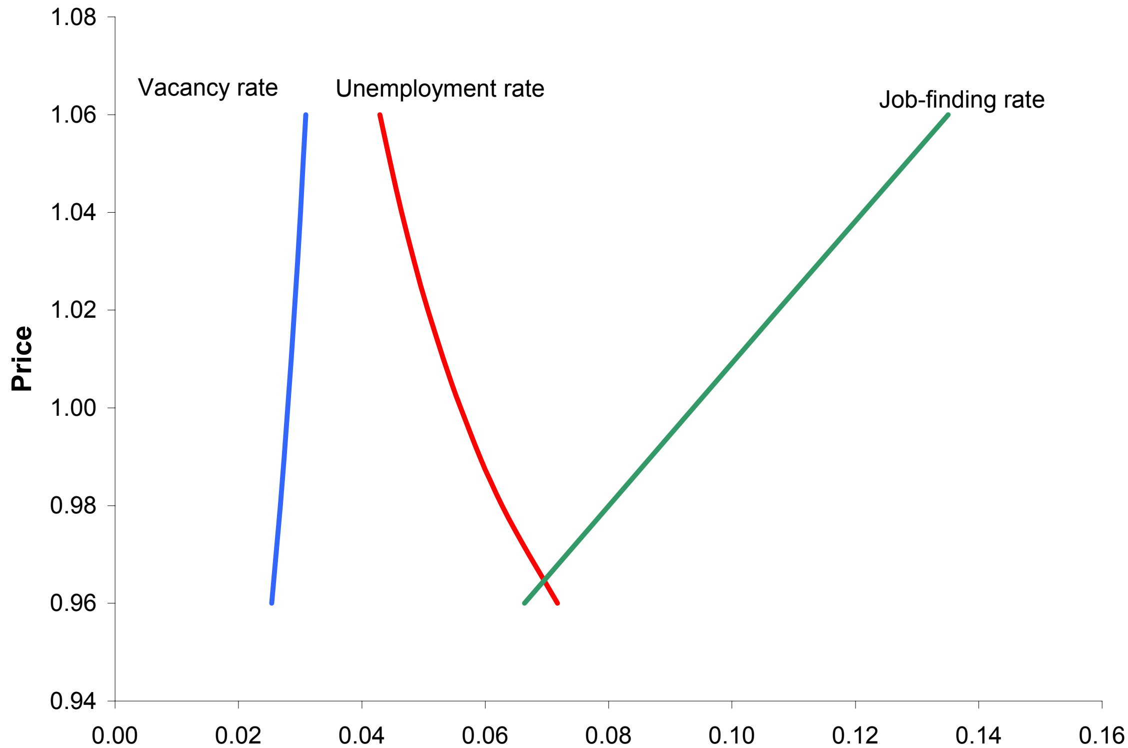

Figure 5. Stationary-State Relations among Price and Job Finding, Vacancy, and Unemployment Rates

Figure 5 displays the property of the DMP model stressed by Shimer [2003] and Veracierto [2002]—large movements in the driving forces are needed to explain observed movements in unemployment. In their models, the driving force is productivity. The variable *p* in this model could be interpreted as productivity instead of the product price. In addition, responses to changes in input prices would be essentially the same as for product prices. A change of several percent in *p* is required to change unemployment by one percentage point. Observed movements in productivity or in price-cost margins are typically nowhere near that large.

Figure 6 shows the dynamic responses to a permanent downward price shock of 4 percent. Unemployment rises rapidly to its new permanently higher level. The job-finding rate drops immediately to its new permanent level. The vacancy rate (not shown) moves in the same way as the job-finding rate. Except for the transitory dynamics from matching, the DMP model lacks the dynamics of the wage-friction model—conditions in the labor market, as measured by the job-finding rate, the job-filling rate, or the vacancy rate, move immediately to their new stationary levels. In order to generate realistic impulse responses, resembling those in Figure 4 for the wage-friction model, the DMP model must invoke persistent but non-permanent movements of the driving force.

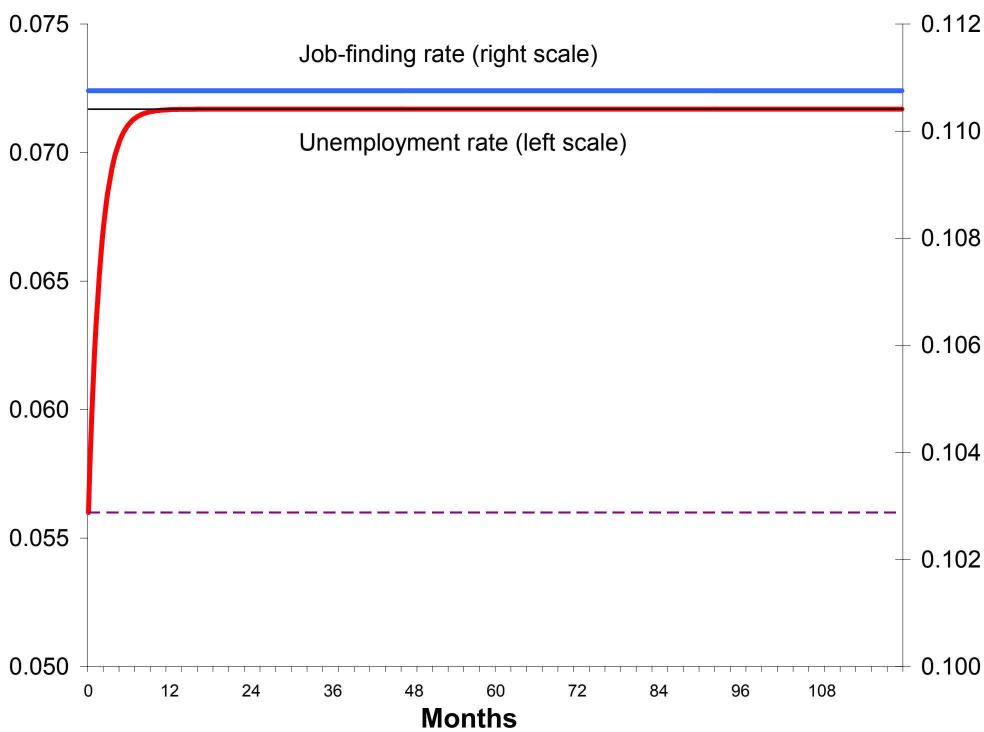

Figure 6. Responses in the DMP model to Four-Percent Price Decrease

Figure 6 confirms that the response functions are unrealistic in an important respect—a relatively large impulse is needed to account for the movements of the job-finding and unemployment rates that occur in a typical recession. The reason is that changes in the product price have modest effects on the match surplus, which is 1.84 at p = 1 and 1.77 at p = 0.96. Employers recruit workers on the expectation of receiving half the surplus. Their recruiting efforts do not fall very much with p, so the job-finding rate does not fall much either. Unemployment rises relatively little unless the decline in p is large.

VI. More Elaborate Wage Norms

Friedman [1968] and Phelps [1967] launched a rich literature on inertia in wage and price determination. They pointed out that the wage determination process would probably adapt to persistent inflation and thereby offset the tightening of the labor market that a simple model of inertia would predict. Experience in many countries in the ensuing three decades generally confirmed this proposition. The wage-adjustment process summarized in equation (3.9) could be augmented with a term that raised the wage norm by enough each period to incorporate adaptation to persistent inflation.

This is also an appropriate point to note that the wage-adjustment process is sensitive to the units in which wages are set. Equation (3.9) implies quite different outcomes if the wage is measured in money terms rather than in real terms. Both interpretations are consistent with the underlying idea that wage determination is an equilibrium selection issue within the bargaining set implied by the matching model.

One important branch of the literature following Friedman and Phelps—notably Lucas [1972]—associated the inertial element of wage determination with expectations. In Lucas's model, lags in the availability of information resulted in inertia in the sense of reliance in part on older information to solve a problem of inference about the current state of the economy. Subsequently many practical economists equated the inertial term with expected inflation. This view has proven to be something of a straitjacket. The amount of inertia implies long lags in the formation of expectations, as if participants in wage determination were forced to use truly stale information despite the ready availability of recent information. The notion that a wage norm adapts gradually to past experience seems a more promising way to understand inertia.

The wage norm also may help understand episodes in wage determination that do not fit the expectation view at all. Episodes of discrete, sudden regime change—such as those documented by Sargent [1982]—seem to break the connection of wage and price determination to history. These episodes do not fit econometric models based on expectation formation. The notion of a wage norm is sufficiently flexible to include rapid change in times of clear breaks in policy.

The wage-friction model developed in this paper, based on a wage norm as an equilibrium selection mechanism, achieves a strict standard of predictive power in one respect—that the wage never falls outside the bargaining set—but is permissive with respect to wage-determination mechanisms that keep the wage inside the bargaining set. Application of the model in practice needs to be guided by evidence about actual wage determination, because theory is unrestrictive apart from the role of the bargaining set.

VII. Concluding Remarks

Strong evidence supports the following view of fluctuations in employment and unemployment: When the labor market is tight and unemployment is low, employers devote substantial resources to recruiting workers. Job-finding rates for the unemployed are high. By contrast, when the market is slack and unemployment is high, employers recruit less aggressively and job-finding rates are low. Data on help-wanted advertising, vacancies, and unemployment confirm these relations. Further, transitions from strong markets with low unemployment and high vacancies to weak markets with high unemployment and low vacancies seem to occur without large measurable changes in driving forces. Rather, small shocks stimulate large responses of unemployment.

I have offered a model of fluctuations in the labor market that mimics all of these properties. In the model, the labor market becomes slack when recent events have lowered the benefit to the employer from hiring. These events, such as a small decline in productivity or a small rise in input prices, substantially reduce the payoff to hiring during the time when wage friction inhibits the offsetting movement of the wage. The friction is plausible, because it occurs only within the range where the wage does not block efficient bargains from being struck and maintained. The outcome of the bargain between worker and employer is fundamentally indeterminate and the wage friction is an equilibrium selection mechanism. The friction can be interpreted in terms of a wage norm that provides the equilibrium selection function.

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