Preliminary and Incomplete

Private Information, Wage Bargaining and Employment Fluctuations

John Kennan[1]
University of Wisconsin-Madison and NBER

May 2005

[1]Department of Economics, University of Wisconsin, 1180 Observatory Drive, Madison, WI 53706; jkennan@ssc.wisc.edu. I thank Rob Shimer and Bob Hall for useful comments. I am particularly grateful to Rob Shimer for pointing out a serious mistake in previous versions of the paper. The National Science Foundation provided research support.

1. Introduction

Shimer (2003) pointed out that the basic Mortensen-Pissarides (1994) model does not generate nearly enough volatility in unemployment and vacancies, for plausible parameter values. Hall (2005) argued that this problem can be fixed if the Nash bargaining component of the model is dropped: Hall assumed that wages are sticky in the sense that the wage level in a previous contract establishes a "social norm" that largely determines the wage in the next contract. In the absence of a theory of social norms, this solution effectively requires the introduction of a free parameter. The question in this paper is whether an extension of the Mortensen-Pissarides model to allow for informational rents can explain the volatility of unemployment in a more parsimonious way. A much more elaborate treatment of private information in this context is given by Menzio (2004). Nagypál (2004) has shown that heterogeneity in workers' (private) evaluations of nonpecuniary job characteristics can substantially increase the volatility of unemployment.

2. A Model of Sticky Wages with Private Information and Aggregate Shocks

The model is a simplified version of the model analyzed in Kennan (2003). A successful job match generates a surplus to be divided between the worker and the employer. The value of the worker's output is modeled as a binary random variable whose realization ("L" for low or "H" for high) is observed privately by the employer when the match is made. The probability of drawing a high surplus is a publicly observed Markov pure jump process with two states ("b" for bad and "g" for good), and exit hazards λ_b and λ_g. The probability of the high surplus is assumed to be higher in the good state; for simplicity, the probability of the high surplus is assumed to be zero in the bad state.[2]

Job and worker flows are modeled in the standard way, following Mortensen and Pissarides (1994). When the joint continuation value from a match falls below the joint opportunity cost, the match is destroyed. The job destruction hazard rate is a constant, δ, and there is a constant returns matching function that generates a flow of new matches $M(N_U,N_V)$ from unemployment and vacancy stocks N_U and N_V. There is an infinitely elastic supply of potential vacancies, and the actual number of vacancies posted is such that the expected profit from a vacancy is zero.

The match surplus is divided in the following way. Either the employer or the worker is randomly selected to make an offer, and if this offer is rejected the match dissolves. Clearly, the employer's offer will just match the worker's reservation level, which is the value of searching for another match. The worker effectively has two choices: an offer that exhausts the low surplus, with a sure acceptance, or an

[2]Tawara (2005) considers the implications of allowing for informational rents in both aggregate states.

offer that exhausts the high surplus, with acceptance only if the high surplus has actually been realized. It is assumed that the parameters are such that the worker always finds it optimal to demand the low surplus.

The match surplus depends on whether the employer draws a high or low value from the output distribution, and it also depends on the aggregate state. Let y_L^b and S_L^b be the flow surplus and the continuation value of the match when the output value is low, and the aggregate state is bad, and similarly for the other configurations. For simplicity, it is assumed that the difference between the low and high output values does not depend on the aggregate state. That is, $y_H^g - y_L^g = y_H^b - y_L^b = \Delta y$.

Let U and V denote the state-dependent continuation values of an unmatched worker and an unmatched employer, and let G denote the joint continuation value of a matched worker-employer pair. It is assumed that there is free entry of employers, so that V is zero in all states. In the low-output state, the joint continuation values are determined by the following asset pricing equations

$$\begin{aligned} rG_L^b &= y_L^b - \delta G_L^b + \delta U^b + \lambda_b\left(G_L^g - G_L^b\right) \\ rG_L^g &= y_L^g - \delta G_L^g + \delta U^g - \lambda_g\left(G_L^g - G_L^b\right) \end{aligned} \tag{1}$$

The (state-dependent) match surplus is the difference between the gross continuation value G and the joint continuation value of an unmatched worker, U. Thus

$$\begin{aligned} (r+\delta)\left(S_L^b + U^b\right) &= y_L^b + \delta U^b + \lambda_b\left(S_L^g - S_L^b + \Delta U\right) \\ (r+\delta)\left(S_L^g + U^g\right) &= y_L^g + \delta U^g - \lambda_g\left(S_L^g - S_L^b + \Delta U\right) \end{aligned} \tag{2}$$

where $\Delta U = U^g - U^b$. This implies

$$S_L^g - S_L^b + \Delta U = \frac{y_L^g - y_L^b + \delta \Delta U}{r + \delta + \Lambda} \tag{3}$$

where $\Lambda = \lambda_b + \lambda_g$. Substituting this in (2) gives

$$(r+\delta)S_L^b = y_L^b - rU^b + \frac{\lambda_b\left(y_L^g - y_L^b + \delta\Delta U\right)}{r+\delta+\Lambda}$$
$$(r+\delta)S_L^g = y_L^g - rU^g - \frac{\lambda_g\left(y_L^g - y_L^b + \delta\Delta U\right)}{r+\delta+\Lambda} \tag{4}$$

Similarly, for a high-output match, the surplus values are given by

$$(r+\delta)S_H^b = y_H^b - rU^b + \frac{\lambda_b\left(y_L^g - y_L^b + \delta\Delta U\right)}{r+\delta+\Lambda}$$
$$(r+\delta)S_H^g = y_H^g - rU^g - \frac{\lambda_g\left(y_L^g - y_L^b + \delta\Delta U\right)}{r+\delta+\Lambda} \tag{5}$$

The effect of the aggregate state on the match surplus is given by

$$S_H^g - S_H^b = S_L^g - S_L^b = \frac{\Delta y - (r+\Lambda)\Delta U}{r+\delta+\Lambda} \tag{6}$$

Thus if an unmatched worker has better prospects when the aggregate state is good, the match surplus might be lower when the aggregate state is good, for a given output draw. On the other hand there is a higher probability of drawing a high output value in the good aggregate state.

The effect of the output draw on the match surplus is given by

$$S_H^g - S_L^g = S_H^b - S_L^b = \frac{\Delta y}{r+\delta} \tag{7}$$

The rate at which unemployed workers find new matches is $M(N_U,N_V)/N_U = m(\theta)$, where $\theta = N_V/N_U$ represents market tightness, and $m(\theta) = M(1,\theta)$. The function m is assumed to be strictly increasing, and concave. When a match is made, the worker is selected to make an offer with probability ν. In this case, the worker gets the low-output surplus, and the employer gets an informational rent if the realized match value is high. If the employer is selected to make an offer, the worker gets the reservation level U and the

employer gets the whole surplus. Thus an unmatched worker's continuation values are determined by the asset pricing equations

$$\begin{aligned} rU^b &= w_0 + m(\theta^b)\nu S_L^b + \lambda_b\left(U^g - U^b\right) \\ rU^g &= w_0 + m(\theta^g)\nu S_L^g - \lambda_g\left(U^g - U^b\right) \end{aligned} \tag{8}$$

where w_0 is the flow value of unemployment (including unemployment benefits and the value of leisure). Thus

$$\begin{aligned} rU^b &= w_0 + \frac{r+\lambda_g}{r+\Lambda} m(\theta^b)\nu S_L^b + \frac{\lambda_b}{r+\Lambda} m(\theta^g)\nu S_L^g \\ rU^g &= w_0 + \frac{r+\lambda_b}{r+\Lambda} m(\theta^g)\nu S_L^g + \frac{\lambda_g}{r+\Lambda} m(\theta^b)\nu S_L^b \end{aligned} \tag{9}$$

Employers post new vacancies to the point where the net profit from doing so is zero. When a match is made, the employer gets an informational rent if the match value is high, and also gets a fraction 1-ν of the low-output surplus (in expectation). Thus the zero-profit conditions implied by free entry are

$$\begin{aligned} 0 &= rV^b = -c + \frac{m(\theta^b)}{\theta^b}(1-\nu)S_L^b \\ 0 &= rV^g = -c + \frac{m(\theta^g)}{\theta^g}\left((1-\nu)S_L^g + p\frac{\Delta y}{r+\delta}\right) \end{aligned} \tag{10}$$

where c is the flow cost of maintaining a vacancy.

It is convenient to define $\eta = \theta/m(\theta)$ as the expected duration of a vacancy. Then the free-entry conditions can be written as

$$
\begin{aligned}
c\eta^b &= (1-\nu)S_L^b \\
c\eta^g &= (1-\nu)S_L^g + p\left(S_H^g - S_L^g\right)
\end{aligned}
\tag{11}
$$

The model can be solved as follows. For given values of η^b and η^g, the free entry conditions determine S_L^b and S_L^g:

$$
\begin{aligned}
S_L^b &= \frac{c\eta^b}{1-\nu} \\
S_L^g &= \frac{c\eta^g}{1-\nu} - \frac{p\Delta y}{(1-\nu)(r+\delta)}
\end{aligned}
\tag{12}
$$

Equations (2) and (3) can be rearranged to give U^b and U^g as linear functions of S_L^b and S_L^g, and U^b and U^g can then be expressed in terms of η^b and η^g as

$$
\begin{aligned}
rU^b &= y_L^b - (\delta + r)\frac{c\eta^b}{1-\nu} + \frac{\lambda^b\left(y_L^g - y_L^b\right)}{\Lambda + r} - \frac{\lambda^b\delta}{\Lambda + r}\left(\frac{c\eta^g}{1-\nu} - \frac{p\Delta y}{(1-\nu)(r+\delta)} - \frac{c\eta^b}{1-\nu}\right) \\
rU^g &= y_L^g - (\delta + r)\left(\frac{c\eta^g}{1-\nu} - \frac{p\Delta y}{(1-\nu)(r+\delta)}\right) - \frac{\lambda^g\left(y_L^g - y_L^b\right)}{\Lambda + r} + \frac{\lambda^g\delta}{\Lambda + r}\left(\frac{c\eta^g}{1-\nu} - \frac{p\Delta y}{(1-\nu)(r+\delta)} - \frac{c\eta^b}{1-\nu}\right)
\end{aligned}
\tag{13}
$$

Next (12) can be substituted in (9), giving

$$
\begin{aligned}
rU^b &= w_0 + \frac{r+\lambda_g}{r+\Lambda}\frac{\nu c\eta^b h(\eta^b)}{1-\nu} + \frac{\lambda_b}{r+\Lambda}\frac{\nu h(\eta^g)}{1-\nu}\left(c\eta^g - \frac{p\Delta y}{r+\delta}\right) \\
rU^g &= w_0 + \frac{r+\lambda_b}{r+\Lambda}\frac{\nu h(\eta^g)}{1-\nu}\left(c\eta^g - \frac{p\Delta y}{r+\delta}\right) + \frac{\lambda_g}{r+\Lambda}\frac{\nu c\eta^b h(\eta^b)}{1-\nu}
\end{aligned}
\tag{14}
$$

After eliminating U^b and U^g and rearranging, this gives the following equations determining η^b and η^g

$$\left(r+\delta+\lambda^{\mathrm{b}}\right)\eta^{b} = \frac{(1-\nu)\left(y_L^b - w_0\right)}{c} - \frac{\lambda^{\mathrm{b}}\mathrm{p}\Delta y}{\mathrm{c}(\mathrm{r}+\delta)} - \nu H\left(\eta^{\mathrm{b}}\right) + \lambda^{\mathrm{b}}\eta^{g}$$

$$\left(r+\delta+\lambda^{\mathrm{g}}\right)\eta^{g} = \frac{(1-\nu)\left(y_L^g - w_0\right)}{c} + \frac{\left(r+\delta+\nu h(\eta^{g})+\lambda^{\mathrm{g}}\right)\mathrm{p}\Delta y}{\mathrm{c}(\mathrm{r}+\delta)} - \nu H\left(\eta^{\mathrm{g}}\right) + \lambda^{\mathrm{g}}\eta^{b} \tag{15}$$

where $H(\eta) = \theta$, and $h(\eta) = m(\theta)$. It is assumed that the function $\eta = \theta/m(\theta)$ is invertible, and that the inverse function H is convex, and that the function $m(\theta)$ is concave. Then (15) defines a mapping

$$\left(\eta^{b},\eta^{g}\right) = F\left(\eta^{b},\eta^{g}\right) \tag{16}$$

where F is a function which is concave, and quasi-increasing (meaning that the component functions F_1 and F_2 are both concave functions, with F_1 increasing in η^g, and F_2 increasing in η^b). Thus, by the uniqueness theorem in Kennan (2001), there is at most one positive solution. For example, if $m(\theta) = a\sqrt{\theta}$, with $a > 0$, then $\eta = (1/a)\sqrt{\theta}$, so $H(\eta) = a^2\eta^2$, and $h(\eta) = a^2\eta$, so F is concave and quasi-increasing.

Optimality of Pooling Offers

It is assumed that when a match is made in the good aggregate state, and the worker is selected to make an offer, it is optimal to demand the low surplus, rather than demand the high surplus at the risk of destroying the match. Thus the equilibrium surplus values must satisfy the following no-screening condition

$$S_L^g \geq pS_H^g = p\left(S_L^g + \frac{\Delta y}{r+\delta}\right) \tag{17}$$

which can be written as

$$S_L^g \geq \frac{p}{1-p}\frac{\Delta y}{r+\delta} \tag{18}$$

The low surplus in the good aggregate state is

$$S_L^g = \frac{1}{1-\nu}\left(c\eta^g - \frac{p\Delta y}{r+\delta}\right) \tag{19}$$

So the no-screening condition is

$$c\eta^g - \frac{p\Delta y}{r+\delta} \geq \frac{(1-\nu)p\Delta y}{(1-p)(r+\delta)} \tag{20}$$

This reduces to

$$\eta^g c \geq \left(1+\frac{1-\nu}{1-p}\right)\frac{p\Delta y}{r+\delta} \tag{21}$$

Although this condition does not say explicitly which parameter values are consistent with a pooling equilibrium, it is straightforward to check whether the condition is satisfied in any proposed equilibrium. It is clear from (15) that the equilibrium depends only on the product $p\Delta y$, but not on the components of this product (given the values of all of the other parameters). Thus if the no-screening condition holds for $p = p_0$, then it also holds for all values of $p \leq p_0$, with Δy adjusted to keep the product $p\Delta y$ constant.

Unemployment Volatility

Standard parameter values are used as far as possible, following Shimer (2003) and Hall (2003). The simplest choice for the matching function is a constant-returns Cobb-Douglas function that is symmetric in unemployment and vacancies. This implies $m(\theta) = a\sqrt{\theta}$, and a is set at 6.8, per annum (Shimer uses a = 1.7 for quarterly data). The job destruction rate δ is set at .42 per annum, so that the quarterly rate is $\exp(-.25\delta) = 0.1$. In the NBER postwar data, the average duration of a recession is 10 months, and the average duration of an expansion is 57 months. This implies that the exit hazards are $\lambda_g = 12/57$ and $\lambda_b = 12/10$.

The low output value is normalized to 1. Since all matches produce low output in the bad aggregate state, the aggregate output level in the bad state is also 1. The difference between high and low output then determines the variability of output. Let Y_b and Y_g denote aggregate state-contingent productivity levels. The invariant distribution has mass λ^g/Λ on the bad state, and λ^b/Λ on the good state. Expected productivity is

$$\mu_Y = Y_b + \frac{\lambda_b}{\Lambda}\Delta Y$$

where $\Delta Y = Y_g - Y_b = p\Delta y$. The variance is given by

$$\begin{aligned}\sigma_Y^2 &= \frac{\lambda_b}{\Lambda}\left(Y_g - \mu_Y\right)^2 + \frac{\lambda_g}{\Lambda}\left(Y_b - \mu_Y\right)^2 \\ &= \frac{\lambda_b \lambda_g}{\Lambda^2}\Delta Y^2\end{aligned}$$

This implies

$$\frac{\Delta Y}{\sigma_Y} = \sqrt{\frac{\lambda_b}{\lambda_g}} + \sqrt{\frac{\lambda_g}{\lambda_b}}$$

If the process is symmetric, the standard deviation is half of the difference between Y_b and Y_g. Otherwise, the standard deviation is less than half of the difference. If the ratio of the transition rates is far from 1, the standard deviation can be made arbitrarily small, for any fixed difference (because the process spends virtually all of its time in one state). Setting $\Delta Y = .042$, with $\lambda_g = 12/57$ and $\lambda_b = 12/10$ and $Y_b = 1$ gives $\sigma_Y/\mu_Y = .014$. According to Shimer (2003), the coefficient of variation of U.S. aggregate labor productivity is .018. Since the basic question is whether informational rents can explain why unemployment is much more volatile than the underlying shocks, a process that understates the volatility of productivity errs on the side of caution.

The parameter values are summarized in Table 1.

Table 1: Parameter Values			
Parameter	**Notation**	**Value**	**Comments**
matching function	$m(\theta)$	$6.8\sqrt{\theta}$	Shimer
recession exit hazard	λ_b	12/10	recession duration (10 months)
expansion exit hazard	λ_g	12/57	expansion duration (57 months)
unmatched flow payoff	w_0	0.4	Shimer
low output	y_L	1	normalization
informational rent	$p\Delta y$	0.042	volatility of labor productivity
vacancy flow cost	c	.54	Shimer
separation rate	δ	.42	Shimer (see text)
interest rate	r	.05	

The steady-state unemployment levels are determined in the usual way as

$$u_b^* = \frac{1}{1+\frac{m(\theta^b)}{\delta}}, \quad u_g^* = \frac{1}{1+\frac{m(\theta^g)}{\delta}}$$

The equilibrium values of θ^b and θ^g for the parameters in Table 1 can be obtained from the following equations:

$$\sqrt{\theta^b} = \frac{102680}{70641} - \frac{340}{167}\theta^b + \frac{120}{167}\sqrt{\theta^g}$$
$$\theta^g = \frac{53701}{40185} + \frac{20}{323}\sqrt{\theta^b} + \frac{2528021}{2732580}\sqrt{\theta^g}$$

This is an equation system of the form x = f(x), where x = ($\sqrt{\theta^b}$,θ^g), and where f is concave, and quasi-increasing. Thus, by the uniqueness theorem in Kennan (2001), there is at most one positive solution. And there is a positive solution, at ($\sqrt{\theta^b}$ = .9313030242, θ^g = 2.995088793).
The no-screening condition for this example is evaluated as

$$\frac{27}{340}\sqrt{\theta^g} \geq \left(1+\frac{1}{2(1-p)}\right)\frac{21}{235} \tag{25}$$

This condition is satisfied at the equilibrium value of θ^g if $p \leq 0.0705$.

Table 2 shows that these parameter values can generate realistic variations in the unemployment rate. To illustrate the importance of informational rents in generating this result, the table includes the steady state unemployment rates for a baseline parameter set that matches the variance of aggregate productivity by letting the match surplus depend on the aggregate state, with no idiosyncratic variation. The parameter values are as in Table 1, but with $y_L^b = 1$, $y_L^g = 1.042$, and $p\Delta y = 0$. In this case, the unemployment rate is virtually constant.

Table 2: Unemployment Volatility

		Baseline	Informational Rent
Productivity Variation	y_L^g	1.042	1.0
	$p\Delta y$	0	.042
Steady State Unemployment Rates	u_b^*	5.86%	**6.22%**
	u_g^*	5.7%	**3.45%**

Table 3 shows results for some alternative values of the vacancy cost, the separation rate, and the flow value of unemployment. Large changes in these parameters have virtually no effect on volatility. Thus the ability of the model to explain unemployment volatility is based almost entirely on the presence of informational rents. The key point is that the informational rent can be large enough to amplify the underlying productivity shocks, without being too large to sustain a pooling equilibrium.

Table 3: **Unemployment Volatility** (no informational rent)					
		Baseline	Low c	Low δ	Low w_0
Baseline			0.54	.42	.40
Variant			0.27	.21	.20
Steady State Unemployment Rates	u_b^*	**5.86%**	4.14%	2.934%	2.54%
	u_g^*	**5.70%**	4.02%	2.852%	2.49%

Recently, Hagedorn and Manovskii (2005) have argued that the Mortensten-Pissarides model can generate realistic unemployment fluctuations if the value of the worker's outside option is close to the value of production. In the model considered here, this means setting w_0 near 1. Hagedorn and Manovskii calibrated w_0 as .943, with ν = .061. Table 4 explores the implications of these parameter values, in the model with no informational rents.

Table 4: Unemployment Volatility (no informational rent)						
		Baseline	High w_0	Low ν	High w_0 low ν	Higher w_0 low ν
Baseline					w_0 =.40 ν = .5	w_0 =.40 ν = .5
Variant			w_0 =.943 ν = .5	ν = .061	w_0 =.943 ν = .061	$w_0 = y_L^b = 1$ ν = .061
Steady State Unemployment Rates	u_b^*	**6.22%**	17.28%	1.67%	5.80%	33.9%
	u_g^*	**3.45%**	14.65%	1.62%	4.97%	22.9%

When the workers' outside opportunities are almost as good as their market production opportunities, it makes sense to reduce the number of vacancies. Moving workers into jobs raises the value of their output, but not by much, and in order to move workers into jobs, it is necessary to expend resources on vacancy costs. Reducing the number of vacancies economizes on the vacancy costs (because it reduces congestion); workers spend more time out of employment, but that is not very costly. Even if the value of the outside opportunity is the same as the value of production in the bad aggregate state, it still makes sense to move workers into jobs. This is because there may be a transition to the good aggregate state,

and when that happens, employed workers are more productive than unemployed workers. If this transition is unlikely, the unemployment rate in the bad state will be high. But in the data, recessions are relatively short-lived, so although the Hagedorn and Manovskii calibration yields high unemployment rates, there is not much difference between the level of unemployment in different states.

References

Hagedorn, Marcus and Iourii Manovskii, "The Cyclical Behavior of Equilibrium Unemployment and Vacancies Revisited," University of Pennsylvania, April 2005.

Hall, Robert E., "Employment Fluctuations with Equilibrium Wage Stickiness," *American Economic Review*, March 2005.

Kennan, John, "Informational Conflict and Employment Fluctuations," unpublished, November 2003; http://www.ssc.wisc.edu/~jkennan/research.

Kennan, John, "Uniqueness of Positive Fixed Points for Increasing Concave Functions on R^n: An Elementary Result," *Review of Economic Dynamics*, 4, October 2001, 893-899 (http://dx.doi.org/doi:10.1006/redy.2001.0133).

Menzio, Guido, "High Frequency Wage Rigidity," Northwestern University, December 2004.

Mortensen, Dale T., and Christopher A. Pissarides, "Job Creation and Job Destruction in the Theory of Unemployment," *Review of Economic Studies*, **61**, July 1994, 397-415.

Nagypál, Éva, "Amplification of Productivity Shocks: Why Vacancies Don't Like to Hire the Unemployed?", Northwestern University, August 2004.

Shimer, Robert E., "The Cyclical Behavior of Equilibrium Unemployment and Vacancies (2005) *American Economic Review*, 95(1): 25-49.

Tawara, Norikazu, "Search and Matching with Wage Bargaining under Asymmetric Information," University of Chicago, May 2005.