The Cyclical Behavior of Labor Markets*

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1 Introduction

A sequence of recent papers (Costain and Reiter 2003, Hall 2003a, Shimer 2003) has argued that the standard theory of equilibrium unemployment, the Mortensen-Pissarides search and matching model (Mortensen and Pissarides 1994, Pissarides 2000) cannot explain the magnitude of the cyclical fluctuations in two of its central elements, unemployment and vacancies. Firms create more vacancies in response to an increase in labor productivity. This reduces the duration of unemployment, putting upward pressure on wages. In a reasonably calibrated version of the economy, the wage increase absorbs virtually all of the productivity increase, and so the shock has little effect on unemployment and vacancies.

Hall (2003b) introduces an additional real wage rigidity, a backward-looking social norm, into the Mortensen-Pissarides model. The wage rigidity is socially inefficient: wages are too low in expansions, inducing excessive vacancy creation, and too high in recessions, discouraging most vacancy creation. Nevertheless, Hall (2003b) shows that there are no bilateral gains from renegotiating the wage; every employed worker always prefers to receive a higher wage and every employer always wants to pay a lower wage. The model thereby avoids Barro’s (1977) critique that in many implicit contract models, workers and firms do not exploit all

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the potential gains from trade. Despite this, Hall’s (2003b) model quantitatively matches
the behavior of unemployment and vacancies in the U.S..

This paper first reviews the argument in Shimer (2003) that the Mortensen-Pissarides
matching model cannot generate substantial fluctuations in unemployment and vacancies.
It then proves that this conclusion does not depend on the extent of wage flexibility in
existing employment relationships, but is dramatically altered if the wage for new hires is
independent of the current state of aggregate productivity. In the latter case, the model
easily generates large fluctuations in unemployment and vacancies. Finally, the paper asks
a variant of Lucas’s (1987) cost-of-business-cycle question. Suppose real wages are constant.
How much would a worker be willing to pay to eliminate the real wage rigidity, so wages
instead vary optimally over the business cycle? In a calibrated example, the cost of the real
wage rigidity is small, about 0.1 percent of lifetime consumption, even though the rigidity
amplifies fluctuations in unemployment and vacancies by more than a factor of ten. To the
extent that policies designed to make real wages more flexible\textsuperscript{1} are difficult to implement,
unevenly effective, and have unintended consequences, this analysis suggests that they are
unlikely to be desirable even in an economy in which real wages would otherwise be fixed.

2 Flexible Wage Model

The benchmark model extends Pissarides (1985) by making labor productivity $p$ stochastic.
Because the model has become fairly standard, I describe it only briefly.\textsuperscript{2}

Time is continuous. The economy consists of a measure 1 of risk-neutral,\textsuperscript{3} infinitely-lived
workers and a continuum of risk-neutral, infinitely-lived firms. Workers and firms discount
future payoffs at a common rate $r > 0$, but I focus on limiting results as $r \to 0$. Workers
can either be unemployed or employed. An unemployed worker gets flow utility $z$ from non-
market activity (‘leisure’) and searches for a job. An employed worker earns an endogenous
productivity-contingent wage $w_p$ but may not search.

Firms have a constant returns to scale production technology that uses only labor; each
worker yields profit equal to the difference between labor productivity and the wage, $p - w_p$.
Jobs end exogenously at rate $s > 0$, leaving the worker unemployed and the firm with a
vacancy. In order to hire a worker, a firm must maintain an open vacancy at flow cost $c$.

\textsuperscript{1}Monetary policy may have such an effect if nominal wages are sticky.
\textsuperscript{3}Alternatively one can view this as a complete markets model in which labor income risk is insured.
There is a Cobb-Douglas, constant returns to scale matching technology, so that the rate at which unemployed workers find jobs and the rate at which vacancies are filled depends only on the endogenous productivity-contingent vacancy-unemployment ratio \( \theta_p \). More precisely, workers find jobs at rate \( \mu \theta_p^{1-\alpha} \) and vacancies are filled at rate \( \mu \theta_p^{-\alpha} \), where \( \alpha \in (0, 1) \) is the elasticity of the matching function with respect to the unemployment rate. The unemployment rate \( u(t) \) increases with job destruction and decreases when workers find jobs, and so evolves according to

\[
\dot{u}(t) = s(1 - u(t)) - \mu \theta_p^{1-\alpha} u(t),
\]

where \( p(t) \) is the level of labor productivity at time \( t \).

An aggregate shock hits the economy according to a Poisson process with arrival rate \( \lambda \), at which point a new productivity \( p' \) is drawn from a distribution that depends on the current productivity level \( p \). Assume that the support of the unconditional productivity distribution is compact. Let \( \mathbb{E}_p X_{p'} \) denote the expected value of an arbitrary variable \( X \) following the next aggregate shock, conditional on the current state \( p \). Current productivity and the stochastic process for productivity are common knowledge.

The model is most precisely described through four Bellman equations:

\[
\begin{align*}
ru_p & = z + \mu \theta_p^{1-\alpha} (E_p - U_p) + \lambda (\mathbb{E}_p U_{p'} - U_p) \\
re_p & = w_p + s (U_p - E_p) + \lambda (\mathbb{E}_p E_{p'} - E_p) \\
rV_p & = -c + \mu \theta_p^{-\alpha} (F_p - V_p) + \lambda (\mathbb{E}_p V_{p'} - V_p) \\
rF_p & = p_p - w_p + s (V_p - F_p) + \lambda (\mathbb{E}_p F_{p'} - F_p)
\end{align*}
\]

The first pair of equations describe the value of a worker when she is unemployed (\( U \)) and employed (\( E \)) as a function of the current productivity level \( p \). If she is unemployed, she gets current value from leisure \( z \) and finds a job at rate \( \mu \theta_p^{1-\alpha} \). There is also an aggregate shock at rate \( \lambda \), giving a capital gain \( \mathbb{E}_p U_{p'} - U_p \). When she is employed, she earns the endogenous wage \( w_p \), loses her job at rate \( s \), and realizes an aggregate shock at rate \( \lambda \). The

\[\text{Petrongolo and Pissarides (2001) argue that the matching function exhibits constant returns to scale. There has been less analysis of the Cobb-Douglas assumption, which is central to the interpretation of some of the results that follow. See Blanchard and Diamond (1989) for an estimate of a CES matching function; they cannot reject a unit elasticity of substitution, the Cobb-Douglas case.}\]

\[\text{These equations implicitly assume that the value functions are independent of the unemployment rate. It is straightforward to show that there is an equilibrium with such a property. In fact, there is no equilibrium in which the value functions depend on the unemployment rate or on any 'sunspot' variable.}\]

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second pair of equations similarly describe the value of a job that is vacant \( V \) or filled \( F \).

For each productivity level \( p \), there are six endogenous variables within the four equations (2)–(5), four Bellman values, the vacancy-unemployment ratio \( \theta_p \), and the wage \( w_p \). To close the model, we need two additional equations. One is a free entry condition for vacancies: firms create job openings until the value of a vacancy is zero,

\[ V_p = 0. \] (6)

The other assumption, dating back at least to Pissarides (1985), is that wages are set by asymmetric Nash bargaining. I assume here that wages are renegotiated following each aggregate shock, which ensures that at any point in time all workers are paid a common wage \( w_p \). Section 4 considers an extreme alternative, in which the wage in existing jobs is fixed following an aggregate shock. In the present context, with linear utility and no on-the-job search, the Nash bargaining assumption amounts to

\[ \frac{E_p - U_p}{\beta} = \frac{F_p - V_p}{1 - \beta}, \] (7)

where \( \beta \in (0, 1) \) represents workers’ bargaining power.

Since the six equations (2)–(7) are linear in five of the endogenous variables, \( U_p, E_p, V_p, F_p, \) and \( w_p \), we can eliminate these variables algebraically to get a forward-looking non-linear difference equation for the vacancy-unemployment ratio. First subtract equation (2) from the sum of equations (3) and (5), simplifying using the free-entry condition (6):

\[ (r + s + \lambda)S_p = p - z - \mu \theta_p^{1-\alpha}(E_p - U_p) + \lambda \bar{E}_p S_p', \]

where \( S_p = F_p + E_p - U_p \). Next observe that equation (7) implies \( E_p - U_p = \beta S_p \). Finally, we can eliminate current and future values of \( S_p \) using the final Bellman equation (4) and the Nash bargaining solution \( F_p = (1 - \beta)S_p \):

\[ \frac{r + s + \lambda}{\mu \theta_p^{-\alpha}} + \beta \theta_p = \left(1 - \beta \right) \frac{p - z}{c} + \lambda \bar{E} \frac{1}{\mu \theta_p^{-\alpha}}. \] (8)

Note that only the ratio of market productivity \( p \) minus non-market productivity \( z \) to the vacancy posting cost \( c \) enters this equation. A productivity shock therefore has exactly the same effect as a shock to any of these other variables.

It is also possible to express the wage as a function of the contemporaneous vacancy-
unemployment ratio and model parameters. Replace current and future values of \( F_p \) in (5) using (4) and the free entry condition:

\[
\frac{r + s + \lambda}{\mu \theta_p^{-\alpha}} = \frac{p - w_p}{c} + \lambda \frac{1}{\mu \theta_p^{-\alpha}}.
\]

Then simplify using (8) to get

\[
w_p = \beta (p + c \theta_p) + (1 - \beta)z.
\]

Equations (8) and (9) implicitly define the state-contingent vacancy-unemployment ratio and wage, and are easily solved numerically given particular parameter values.

## 3 Calibration

Table 1 shows summary statistics for productivity, wages, unemployment, and vacancies using quarterly data from the U.S. from 1951 to 2001.\(^6\) Productivity and wages are constructed by the Bureau of Labor Statistics (BLS) from the National Income and Product Accounts and the Current Employment Statistics. The former is measured as real average output per hour in the non-farm business sector; the latter is real hourly compensation in the same sector. It is a broad measure of compensation, including wages, salaries, tips, bonuses, and in-kind payments, as well as imputed compensation for proprietors and unpaid family workers. Unemployment is measured by the BLS using the Current Population Survey. Vacancies are crudely measured by the Conference Board help-wanted advertising index, but this variable closely tracks direct measures of vacancies when they are available (Abraham 1987, Shimer 2003). All data are detrended using a very low frequency Hodrick-Prescott filter with smoothing parameter 100,000.

I calibrate the model to match this data. The parameter choices are summarized in Table 2; the next three paragraphs provide a brief justification. I assume labor productivity \( p \) follows a first order autoregressive process. I normalize its mean to unity and then use data on real output per hour in the non-farm business sector, constructed by the Bureau of Labor Statistics as part of its Major Sector Productivity and Costs program, to quantify the instantaneous standard deviation and persistence of this key variable. This translates

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\(^6\)The U.S. economy is an interesting benchmark because, relative to most European economies, it is thought to have flexible wages. The finding that wages in the U.S. economy are significantly more rigid than in the benchmark model is therefore all-the-more-surprising.
into a three state Markov process for $p$, with values 0.976, 1 and 1.024. An aggregate shock hits according to a Poisson process with arrival rate 0.16 per quarter. When productivity is in an extreme state and a shock arrives, it moves to the intermediate state. From the intermediate state, productivity is equally likely to move to either of the extreme states.\footnote{The first and second moments are robust to a substantial increase in the number of productivity states. See Shimer (2003) for details.}

Next I set the discount rate to zero. Compared with a more standard number, say 0.010 or 0.015 per quarter, this choice scarcely affects the quantitative results; however, it simplifies the normative analysis because welfare only depends on the long-run behavior of the economy and in particular is independent of the current state. The separation rate $s$ is equal to 0.1, based on Abowd and Zellner’s (1985) corrected worker flow data. The value of leisure is set to 0.4, consistent with an unemployment benefit replacement ratio of 40 percent. I normalize the cost of a vacancy to 0.53. This essentially pins down the units of a vacancy; in particular, I target a mean vacancy-unemployment ratio of 1.

I set the constant in the matching function to $\mu = 1.65$, so as to match the mean unemployment rate in the data, 5.7 percent. I set the elasticity of the matching function with respect to unemployment at $\alpha = 0.5$. This is consistent with the evidence summarized by Petrongolo and Pissarides (2001). It also ensures that fluctuations in unemployment and vacancies are of approximately equal magnitude. Finally, I set workers’ bargaining power at $\beta = 0.5$. Shimer (2003) proves that if $\beta = \alpha$, the equilibrium in the economy with Nash bargaining maximizes the expected present value of output net of vacancy costs, even in the presence of productivity shocks, a generalization of the Hosios (1990) condition. Again, this restriction facilitates the welfare analysis.

Table 3 summarizes the model generated data. Although it is a continuous time model, I sample the model-generated data at discrete points in time corresponding to the end of each quarter so as to make it comparable with actual data. I chose parameters to match the mean unemployment rate and the standard deviation and first-order autocorrelation of labor productivity. The model-generated data can be compared with U.S. data along the remaining dimensions. In some cases, the model performs very well. For example, the correlation between unemployment and vacancies in this data set is $-0.90$, while in the model it is $-0.87$, so the model can produce a downward sloping ‘Beveridge curve’ or vacancy-unemployment relationship. On others, the model performs less well. In the data, vacancies are slightly more persistent than unemployment, while in the model vacancies are much less persistent. Introducing planning lags would presumably correct this shortcoming.
But the real problem lies in the absence of volatility. The unemployment rate 15.2 times as volatile in the data as in the model, the vacancy rate 11.4 times, and the vacancy-unemployment ratio 12.5 times. The Mortensen-Pissarides model generates only a tiny fraction of the volatility of its two central elements, unemployment and vacancies.

4 Rigid Wages in Old Matches

Section 5 shows that if wages in new matches are rigid in the presence of productivity shocks, the model can generate realistic fluctuations in unemployment and vacancies. Before getting to that result, it is worth observing that the rigidity of wages in old matches has absolutely no effect on the results discussed in the previous section. More precisely, suppose that the wage in new matches is determined by Nash bargaining, but it never changes following subsequent shocks. Let \( w^{p_0} \) denote the wage in match formed when productivity was equal to \( p_0 \). The model is otherwise unchanged. We may express the Bellman equations as

\[ rU_p = z + \mu \theta^{1-\alpha}_p (E^p_p - U_p) + \lambda (E_p U_{p'} - U_p) \]  
\[ rE^{p_0}_p = w^{p_0} + s (U_p - E^{p_0}_p) + \lambda (E_p E^{p_0}_{p'} - E^{p_0}_p) \]  
\[ rV_p = -c + \mu \theta^{-\alpha}_p (F^p_p - V_p) + \lambda (E_p V_{p'} - V_p) \]  
\[ rF^{p_0}_p = p - w^{p_0} + s (V_p - F^{p_0}_p) + \lambda (E_p F^{p_0}_{p'} - F^{p_0}_p) \],

where superscripts denote initial productivity and subscripts denote current productivity. The free entry condition (6) is unchanged, while the Nash bargaining solution need only obtain in new matches:

\[ \frac{E^p_p - U_p}{\beta} = \frac{F^p_p - V_p}{1-\beta}, \]  

It is straightforward to prove that the state-contingent vacancy-unemployment ratio, given in equation (8), is unaffected by this modification of the model, since match surplus \( S_p \equiv F^{p_0}_p + E^{p_0}_p - U_p \) is independent of the the initial productivity level. The wage equation, however, is altered by this modification. Subtract (10) from (11) and rewrite as

\[ (r + s + \lambda \mu \theta^{1-\alpha}_p)(E^p_p - U_p) = w^p - z + \lambda E_p (E^p_{p'} - U_{p'}) \]  
\[ = w^p - z + \lambda E_p \left( E^p_{p'} - U_{p'} + \frac{w^p - w^{p'}}{r + s} \right), \]
where the second equality uses the linearity of the Bellman equation (11) in the wage. Similarly subtract \( \theta_p \) times (12) from (13), eliminating \( V \) using (6), to get

\[
(r + s + \lambda + \mu \theta_p^{1-\alpha}) F_p = p - w^p + c\theta_p + \lambda \mathbb{E}_p F_{p'}^p
\]

\[
= p - w^p + c\theta_p + \lambda \mathbb{E}_p \left( F_{p'} - \frac{w^p - w^{p'}}{r + s} \right).
\]

Combine these equations using (14) to obtain the desired difference equation:

\[
w^p = \beta(p + c\theta_p) + (1 - \beta)z + \frac{\lambda}{r + s} \mathbb{E}_p(w^{p'} - w^p).
\]

One can easily confirm that the expected present value of wages as a function of initial productivity is the same if wages are continually renegotiated and hence depend only on current productivity, as in equation (9), or if they are fixed for the duration of the match and hence depend only on initial productivity, as in equation (15).

Since the equation for the vacancy-unemployment ratio is unaffected by whether wages are renegotiated, it follows that the response of unemployment and vacancies to a labor productivity shock is the same in this model as in the flexible wage model; the model still generates almost no volatility in these two variables. The behavior of wages, however, is significantly different. The coefficient of variation on the cross-sectional average wage declines from 0.016 to 0.004, the first order autocorrelation jumps up from 0.85 to 0.99, and the correlation between the average wage and labor productivity drops from 1.00 to 0.62. This suggests that looking at the volatility of wages is not a useful way to evaluate the success of a search model with long term employment relationships.

5 Rigid Wages in All Matches

Following the analysis in Hall (2003b), this section demonstrates the improved performance of the model if the expected present value of wages in new matches is rigid. I make an extreme assumption here and replace the Nash bargaining solution (7) with a fixed wage, \( w^p = \bar{w} \). It is simplest to view this assumption as a social norm. All workers expect to be

\[8\]

A shortcoming of this assumption is that long-run productivity growth will counterfactually induce a long-run decline in the unemployment rate. Hall (2003b) makes a more complicated assumption on wage setting that ensures a similar behavior of the model in the short-run but a more satisfactory response to long-run trends.
paid $\bar{w}$ when employed, and all firms expect to have to pay $\bar{w}$ to any employee. Crucially, a matched worker and firm have no incentive to renegotiate the wage. An employed worker always prefers a higher wage, so long as this does not induce the firm to lay her off (i.e. as long as $F_p > 0$), and an employer always prefers to pay a lower wage, so long as this does not induce the worker to quit (i.e. as long as $E_p > U_p$). I focus throughout on a range of parameter values for which these conditions hold.\footnote{With a constant wage $w^p$ that exceeds the value of leisure, the latter condition always holds. The former condition is equivalent to requiring $\theta_p > 0$; in my numerical example, this is true in all three states as long as $\bar{w} \leq 0.99$.}

An equilibrium is a solution to equations (2)–(6), with a constant and exogenous wage. The vacancy-unemployment ratio satisfies a forward-looking differential equation,

$$ \frac{r + s + \lambda}{\mu \theta_p^{-\alpha}} \frac{1}{c} + \lambda E_p \frac{1}{\mu \theta_p^{-\alpha}}, \tag{16} $$

with $\theta_p$ truncated at zero. Note that the vacancy-unemployment ratio $\theta_p$ may be positive even if the wage exceeds current productivity, $\bar{w} > p$, because of the option value from future productivity shocks.

I fix all the parameters (except workers’ bargaining power $\beta$) at their values in Table 2 and then characterize the equilibrium with the wage $\bar{w}$ chosen to replicate the appropriate average unemployment rate, 5.7 percent. Table 4 records the results. The autocorrelations and correlation matrix are almost unchanged. For example, the correlation between unemployment and vacancies becomes slightly less negative, $-0.85$ rather than $-0.87$, while the lack of persistence in vacancies remains a problem. But the variability of unemployment and vacancies rises dramatically. Unemployment is almost exactly as variable in the model as in the U.S. data, while vacancies are somewhat more variable in the model than in the data. This reflects the much greater variability in the vacancy-unemployment ratio when wages do not absorb any of the impact of a shock. From a positive perspective, the naïve assumption that wages are constant significantly improves the performance of the model.\footnote{I have also calibrated the model allowing productivity and wages to follow the joint stochastic process observed in U.S. data. This enriches the model by adding a ‘wage shock’; however, since the vacancy-unemployment ratio is determined by the (current and expected future) difference between productivity and wages — see equation (16) — it is possible to reduce the driving force to a single variable, net profit. I set the mean value of net profit at 0.032, as in the flexible wage model. U.S. data then imply that the coefficient of variation and first order autocorrelation of net profit are 0.522 and 0.858, respectively. In response to these productivity and wage shocks, the calibrated model delivers fluctuations in unemployment and vacancies similar to those in the fixed wage model: a coefficient of variation for unemployment of 0.183 and for vacancies of 0.242, with a correlation between these two key variables equal to $-0.861$.}
These results are sensitive to the choice of the mean wage. Figure 1 shows the mean unemployment and vacancy rates and the coefficient of variation of these two rates as functions of the fixed wage $\bar{w}$. A higher wage discourages vacancy creation, raising the mean unemployment rate. It also makes the ratio $\frac{p - \bar{w}}{c}$ more volatile, which implies that both vacancies and unemployment are more variable when $\bar{w}$ is larger. Nevertheless, with the wage fixed at approximately the average level in the economy with Nash bargaining, the Mortensen-Pissarides model is capable of matching the cyclical behavior of the key labor market variables.

6 The Cost of Rigid Wages

If rigid wages have a large effect on the equilibrium unemployment and vacancy rates, it seems natural that they would also have a large effect on welfare. During good times, wages are too low and so the vacancy-unemployment ratio $\theta$ is too high, while in bad times the opposite is true. This section analyzes the welfare cost of rigid wages in the presence of productivity fluctuations. The cost is very small, as low 0.1 percent of net output if the level of wages is approximately correct.

There are several modelling questions to address before demonstrating this result. First, what is the correct benchmark for measuring the cost of rigid wages? It is well-known that the equilibrium of the economy with Nash bargaining does not maximize welfare for generic values of workers’ bargaining power $\beta$. However, Shimer (2003), extending the results in Hosios (1990), proves that if the matching function is Cobb-Douglas and workers’ bargaining power is equal to the elasticity of the matching function with respect to the unemployment rate, $\alpha$, then the decentralized equilibrium is welfare-maximizing even in the presence of productivity shocks. That is, the state-contingent vacancy-unemployment ratio $\theta_p$ is socially optimal. I constructed the calibrated example to have this property, and so the benchmark economy is the social optimum.

Second, the cost of rigid wages might depend on the current state of the economy; it is less costly to have a high rigid wage when productivity is high than when it is low. But the assumption that the interest is zero, $r = 0$, allows us to avoid this complexity, since transitional dynamics do not affect undiscounted average lifetime utility.

Finally, how should welfare be measured? Since workers are risk-neutral, they only care about their average consumption, which is equal to the average output in the economy net of vacancy posting costs. When productivity is $p$ and the unemployment rate is $u$, net output
is \((1 - u)p + uz - c\theta_p u\), the sum of income from the \(1 - u\) employed workers and from the \(u\) unemployed workers minus the cost of the \(v = \theta_p u\) vacancies.

Figure 2 reports the percentage loss in average net income in the economy with fixed wages as a function of the wage \(\bar{w}\). If \(\bar{w} \approx 0.967\), about 0.12 percent of average income is lost due to fixed wages, a negligible amount. While a fixed real wage dramatically alters the behavior of unemployment and vacancies, it scarcely has any effect on welfare.

There are two important caveats to this result. First, since workers in this economy are risk-neutral, this calculation is based on the cost that rigid wages impose on the mean level of consumption. The variance in consumption also matters if workers are risk-averse and capital markets are incomplete; however, calculations by Lucas (1987) and others indicate that the cost of consumption variability is small even in non-representative agent economies (Imrohoroglu 1989, Atkeson and Phelan 1994, Obstfeld 1994) or in economies with non-standard preferences (Alvarez and Jermann 2000).

Second, if the wage level is fixed at a different level, \(\bar{w} \neq 0.967\), the welfare costs may be much more significant. But this is not really a statement about wage rigidity in the presence of productivity fluctuations; it is similarly true that if wages are flexible but workers’ bargaining power \(\beta\) is not equal to the elasticity \(\alpha\), welfare may be reduced substantially. I therefore ignore this possibility and leave for future research the question of why a rigid real wage might tend towards the efficient level in the long-run.

7 Conclusion

I have extended the Mortensen-Pissarides search and matching model with the simplest possible model of rigid wages, a constant wage. With wages determined by Nash bargaining, unemployment and vacancies are much less variable in the model than in the U.S. economy. A fixed wage generates approximately the correct variance for these two key variables. At the same time, a fixed real wage need not have any significant welfare cost. This suggests that, to the extent that government policies distort the economy along other dimensions, policies designed to make real wages more flexible are likely to be counterproductive, even if they succeed in moderating employment and vacancy fluctuations.
References


Table 1: Summary Statistics, quarterly U.S. data, 1951 to 2001

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Correlation Matrix

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Notes: Average labor productivity $p$ is real average output per hour in the non-farm business sector, constructed by the Bureau of Labor Statistics (BLS) from the National Income and Product Accounts and the Current Employment Statistics. The unemployment rate $u$ is constructed by the BLS from the Current Population Survey. The help-wanted advertising index $v$ is constructed by the Conference Board. The wage $w$ is real hourly compensation in the non-farm business sector, constructed by the Bureau of Labor Statistics (BLS) from the National Income and Product Accounts and the Current Employment Statistics. Both $u$ and $v$ are quarterly averages of seasonally adjusted monthly series. Productivity, unemployment, vacancies, and wages are expressed as ratios to an HP filter with smoothing parameter $10^5$. The coefficient of variation is the ratio of the standard deviation to the mean.
<table>
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<td>discount rate</td>
<td>0</td>
<td>Simplify welfare analysis</td>
</tr>
<tr>
<td>$s$</td>
<td>separation rate</td>
<td>0.1</td>
<td>Abowd and Zellner (1985)</td>
</tr>
<tr>
<td>$z$</td>
<td>value of leisure</td>
<td>0.4</td>
<td>Benefit replacement ratio 40%</td>
</tr>
<tr>
<td>$c$</td>
<td>vacancy cost</td>
<td>0.53</td>
<td>Normalization $\theta \approx 1$</td>
</tr>
<tr>
<td>$\mu$</td>
<td>matching function constant</td>
<td>1.65</td>
<td>Unemployment rate 5.7%</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>matching function elasticity</td>
<td>0.5</td>
<td>Petrongolo and Pissarides (2001)</td>
</tr>
<tr>
<td>$\beta$</td>
<td>worker’s bargaining power</td>
<td>0.5</td>
<td>Decentralized equilibrium is optimal</td>
</tr>
</tbody>
</table>

Notes: Additional details are provided in the text. Labor productivity takes on three possible values, 0.976474, 1, and 1.02449. A shock hits at rate $\lambda = 0.16$. If the old productivity level is not equal to 1, it adjusts there immediately. If it is equal to 1, it moves with equal probability to 0.976474 or 1.02449.
Table 3: Model-Generated Data, Nash-Bargaining

<table>
<thead>
<tr>
<th></th>
<th>$p$</th>
<th>$u$</th>
<th>$v$</th>
<th>$\theta$</th>
<th>$w$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>1.000</td>
<td>0.0569</td>
<td>0.0575</td>
<td>1.011</td>
<td>0.968</td>
</tr>
<tr>
<td>Coefficient of Variation</td>
<td>0.017</td>
<td>0.012</td>
<td>0.016</td>
<td>0.027</td>
<td>0.016</td>
</tr>
<tr>
<td>Autocorrelation (1 Quarter)</td>
<td>0.852</td>
<td>0.920</td>
<td>0.719</td>
<td>0.852</td>
<td>0.852</td>
</tr>
</tbody>
</table>

Correlation Matrix

<table>
<thead>
<tr>
<th></th>
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<th>$v$</th>
<th>$\theta$</th>
<th>$w$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$p$</td>
<td>1</td>
<td>-0.957</td>
<td>0.975</td>
<td>1.000</td>
<td>1.000</td>
</tr>
<tr>
<td>$u$</td>
<td>—</td>
<td>1</td>
<td>-0.868</td>
<td>-0.957</td>
<td>-0.957</td>
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<tr>
<td>$v$</td>
<td>—</td>
<td>—</td>
<td>1</td>
<td>0.975</td>
<td>0.975</td>
</tr>
<tr>
<td>$\theta$</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>1</td>
<td>0.000</td>
</tr>
<tr>
<td>$w$</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
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</tr>
</tbody>
</table>

Note: Parameterization given in Table 2.
Table 4: Model-Generated Data, Fixed Wage at $\bar{w} = 0.967$

<table>
<thead>
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<th>$w$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>1.000</td>
<td>0.0572</td>
<td>0.0595</td>
<td>1.112</td>
<td>0.967</td>
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<tr>
<td>Coefficient of Variation</td>
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<td>0.185</td>
<td>0.228</td>
<td>0.381</td>
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</tr>
<tr>
<td>Autocorrelation (1 Quarter)</td>
<td>0.852</td>
<td>0.920</td>
<td>0.715</td>
<td>0.851</td>
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</tbody>
</table>

Correlation Matrix

<table>
<thead>
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<th>$u$</th>
<th>$v$</th>
<th>$\theta$</th>
<th>$w$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$p$</td>
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<td>0.972</td>
<td>0.996</td>
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<td>$u$</td>
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<td>-0.852</td>
<td>-0.923</td>
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<tr>
<td>$v$</td>
<td>—</td>
<td>—</td>
<td>1</td>
<td>0.967</td>
<td>—</td>
</tr>
<tr>
<td>$\theta$</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>1</td>
<td>—</td>
</tr>
</tbody>
</table>

Note: Parameterization given in Table 2.
Figure 1: Vacancies and Unemployment as Functions of $\bar{w}$

Notes: The left panel shows the mean unemployment (solid line) and vacancy (dashed line) rates as a function of the fixed wage $\bar{w}$. The right panel shows the coefficient of variation of the unemployment and vacancy rates.
Figure 2: Utility Loss as a Function of $\bar{w}$

Note: The utility loss from a fixed wage $\bar{w}$, expressed as a percent of the socially optimal, flexible wage benchmark.