Labor market dynamics with searching friction and fair wage considerations[*]

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Abstract

We modify the Mortensen-Pissarides model (MP) by incorporating fair wage consideration instead of Nash Bargaining to study the cyclical behavior of equilibrium unemployment and vacancies. In addition to vacancy posting and employment level, employers also set wage taking into account workers' effort. Employing the effort function of Danthine and Kurmann (2004) in which worker's effort depends on individual wage, aggregate real wage, aggregate employment and aggregate past wage, we find that the volatility of labor market tightness depends critically on the sensitivity of effort to individual wage. Moreover, an increase in the sensitivity of effort to aggregate wage increase the real wage volatility and hence decreases the volatility of labor market tightness. We show the model could generate plausible statistical moments of aggregate wage, labor market flows as well as unemployment.

Keywords: Fair wage, Real wage rigidity, Labor market tightness, Unemployment volatility
JEL Classification: E24, E32, J64.

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1   Introduction

Recently the Mortensen-Pissarides (MP) search and matching model becomes standard theory of equilibrium unemployment. However, this model produces much smaller variation in unemployment and vacancy, which are two of its central elements. As illustrated in Shimer (2005), suppose there is a positive labor productivity shock which makes unemployment relatively expensive and vacancies relative cheap. The substitution toward vacancies pulls down the unemployment rate. With Nash bargaining assumption of wage determination, this raises the workers' threat point and therefore expected present value of wages in new jobs. The rising wages reduce the incentive of firm posting vacancies. Hence the labor productivity shock cannot generate sufficient fluctuations of unemployment, vacancy and job-finding rate as in the data. The determinants of real wage are considered as the key for better understanding both labor market and inflation dynamics. Wage rigidity is proposed as one solution based on the observation of weak cyclicality of aggregate wage data.

Along this way several modifications are developed to remedy the deficiency of the MP model. Hall (2005) imposes exogenous wage rigidity therefore allows the model to produce much larger volatility in unemployment. Hagedorn and Manovskii (2008) argued that the high observed volatility of unemployment is an indication that workers are relatively indifferent with respect to unemployment. They recalibrate two key parameters of the MP model– the worker's value of nonmarket activity and the worker's bargaining power, and find that the model is consistent with the data. Another proposal is due to Hall and Milgrom (2008), who argued that the relevant threat point of a worker is not his or her outside option, but the value of continuing negotiation. The possibility of delaying negotiation gives the worker bargaining power. The consequence is that labor market condition does not explicitly enter the wage, at least does no affect it much cyclically. Rudanko (2009) extends the MP model including directed search and emphasizing the role of contracting frictions in long term wage contract under incomplete market assumption where the worker could not save. The equilibrium contract is featured wage smoothing, limited by the inability of parties to commit to contracts. The model with two-sided limited commitment could produce wage and labor market tightness volatility comparable to the data. This model could generate a range of degree of wage rigidity given the volatility of labor market tightness, depending on the contracting environment.

In this paper, we provide another modification of the MP model to study

the cyclical behavior of equilbrium unemployment and vacancies. We emphasize the role of effort consideration when the firm set wage. In the gift exchange model of Akerlof(1982), the workers dislike effort. The effort of an individual worker depends on a comparison between the current wage and a reference compensation level which includes the salary perceived by other workers, the level of unemployment and unemployment benefits, and the actual wage of the individual in previous periods. The optimal response of firms to this behavior is to offer a wage above the market-clearing level in exchange for which worker would provide a higher level of effort. Large change of wages has important effect on worker morale and consequently on the level of effort provided. The efficiency wage is supported by many micro, psychological and experimental studies.[1] For example, Bewley(1998) interviewed business people, labor leaders, and unemployment counselors in the United states to understand why wages almost never declined. He finds that employers are reluctant to cut pay because they believe doing so would hurt employee morale, leading to lower productivity and current and future difficulties with hiring and retention. A key point of his survey is that morale depends not only on the level of wages, but most importantly on wage changes.

Some earlier studies, for instance, Danthine and Donaldson(1990), incorporating fair wage into general equilibrium models fail to generate wage sluggishness and large volatility of unemployment, which could mainly be attributed to their specification of the wage reference of the worker. It is negatively related to contemporaneous outside earning opportunities and the latter is sensitive to aggregate shocks. For example, in response to a negative labor demand shift, the firms reduce employment. Meanwhile, there is general equilibrium fall of the wage reference, permitting individual firms to lower their wage and leading to a further decrease in the reference wage. Therefore, it is possible for firm to reduce wage without severe consequence on effort.

Recent studies emphasize the role of lagged aggregate (or individual) past wage in determining worker's effort and generating real wage rigidity and unemployment. In the models of Collard and de la Croix(2000), they include also the past wage of the worker or society. They show the latter model reproduces the high variability of employment, the low variability of wages and the low wage-employment correlation. Danthine and Kurmann (2004) build a new Keynesian model of the business cycle with sticky prices and real

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[1]For example, Goodman (1974), Lord and Hohenfeld (1979), Wadhwani, S. and Wall (1991), Clark(1996)

wage rigidities induced by fair wage consideration. Workers' effort depends on their current wage, aggregate employment, wage and past wage. Firms find it optimal to set wages so as to elicit a constant level of effort (the Solow condition). In equilibrium, wage depends on aggregate employment and past wage (the fair wage function). Comparing with the standard NNS model, real wage rigidity makes real wage and real marginal cost less sensitive to aggregate output, thereby there is smaller price and bigger quantity adjustment in response to aggregate demand shocks. In addition, their model with fair wage generates more plausible labor market characteristics.[2]

We modify the MP model by replacing the Nash bargaining wage determination assumption with fair wage consideration. We are interested in whether success of fair wage considerations in explaining labor market dynamics could carry to study of equilibrium unemployment and vacancy.

The rest of the paper is organized as following. The next section reviews basic elements and features of our benchmark new Keynesian model with searching friction and fair wage. We discuss the mechanism via which the model produces comparable statistical moments of labor market variables in section 3. Section 4 contains the parameterizations and numerical results of the benchmark model. Section 5 considers some sensitivity check. Based on the previous analysis, we draw some conclusions in section 6.

2   The Model

In this section, we present our benchmark new Keynesian model with both searching frictions and fair wage.

2.1   Families and individuals

2.1.1   Preferences and effort decisions

Our model economy is inhabited by a $[0-1]$ continuum of families each composed of a $[0-1]$ continuum of infinitely-lived individual family members. Each family maximizes lifetime utility over consumption sequence

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[2]Danthine and Kurmann (2006) argued that in efficiency wage models another way of modeling wage reference, which is made dependent on the firm's ability to pay, are also capable of generating strong wage rigidity. The wage setting curve is slightly negatively sloped. Suppose there is a positive labor productivity shock, the labor demand increases. Meanwhile, the wage setting curve shifts up and neutralizes some of the negative impact on wages, thereby produce rigid wage.

of a CES aggregate of differentiated products and work effort. Labor is supplied inelastically, with the labor force normalized to one. The composite consumption good is a CES aggregate of the differentiated products $C_t = (\int_0^1 C_{it}^{(\epsilon-1)/\epsilon} di)^{\epsilon/(\epsilon-1)}$, $\epsilon > 1$. The expected discounted lifetime utility of a typical family is assumed to be of the form

$$U = E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{c_t^{1-\sigma} - 1}{1 - \sigma} - n_t G(e_t) \right] \tag{1}$$

where c_t is the aggregate family consumption at date t, n_t is the fraction of family members working at date t and $G(e_t)$ is disutility of effort of the typical working family member.

Following Danthine and Kurmann (2004), the worker j's utility is negatively related to the distance between the effort provided by household j, denoted $e_t(j)$ and the effort judged by the family $e_t^*(j)$:

$$G(e_t(j)) = (e_t(j) - e_t^*(j))^2 \tag{2}$$

The effort is assumed to have following functional form

$$e_t(j) = \phi_0 + \phi_1 log w_t(j) + \phi_2 log n_t + \phi_3 log w_t + \phi_4 log w_{t-1} \tag{3}$$

where $e_t(j)$, $w_t(j)$ stand for individual j's effort and her current period's real wage level, respectively; n_t, w_t, and $w_{t-1}(j)$ stand for aggregate employment level, aggregate current and lagged real wage in the economy, respectively.

The budget constraint of the family is

$$\frac{B_t}{P_t R_t} - \frac{B_{t-1}}{P_{t-1}} = w_t n_t + \Lambda_t - c_t - T_t \tag{4}$$

where B_t, Λ_t, T_t stand for the asset holding of each family, aggregate profits of the firm, and lump sum tax. Bonds pays a gross interest rate R_t.

Since effort and consumption are separable in preference and effort does not show up in wealth, we could determine effort and consumption separately. Minimizing effort function yields

$$e_t(j) = \phi_0 + \phi_1 log w_t(j) + \phi_2 log n_t + \phi_3 log w_t + \phi_4 log w_{t-1} \tag{5}$$

and

$$G(e_t(j)) = 0 \tag{6}$$

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Note we assume that effort depends positive on the individual's current real wage, negatively on aggregate compensation level, the tightness of the labor market and aggregate lagged real wage, i.e., $\phi_1 > 0$, $\phi_2 < 0$, $\phi_3 < 0$, $\phi_4 < 0$, $\phi_1 + \phi_3 > 0$, where the last assumption implies that the positive incentive effect of a larger own wage is stronger than the negative effect of a higher comparison wage.

2.1.2 The consumption/savings decision

Intertemporal optimization by households implies the following first order conditions:

$$
\begin{aligned}
C_t^{-\sigma} &= \lambda_t \\
\lambda_t &= \beta E_t(R_t \lambda_{t+1} P_t / P_{t+1})
\end{aligned}
$$

2.2 Labor Market Frictions

Labor market frictions are represented by the a constant returns to scale matching function, $m(v_t, u_t)$,

$$ m_t = \bar{m} v_t^\nu u_t^{1-\nu}, $$

v_t is the total vacancies in the economy and u_t is the number of unemployed workers. Total work force is normalized to 1, $u_t + n_t = 1$. There is an exogenous job separating rate ρ.

Labor market tightness is defined as the ratio of vacancy to unemployment, $\theta_t = v_t / u_t$. The matching probabilities for vacancies is $q_t = m_t / v_t = q(\theta_t)$. The matching probabilities for unemployed worker is $s_t = m_t / u_t = \theta_t q(\theta_t)$. The former is decreasing in θ_t; firms are less likely to fill their vacancies in a tighter labor market. The latter is an increasing function of θ_t; job-seekers are more likely to find jobs in a tighter labor market. New matches become productive in the following period, so the law of motion of employment for firm i could be specified as

$$ n_{it} = (1 - \rho)n_{it-1} + v_{it-1}q(\theta_{t-1}). $$

2.3 Firms

We assume a producer-retailer structure. Firms in the intermediate sector operate in a competitive market, and they choose number of employed workers, vacancies, and wage to maximize their profits. In the standard search

and matching framework, wage is determined by Nash-Bargaining, in which firm and workers divide the surplus of a match. However, in our model, firms decide wage that is optimal to stimulate workers to supply their efforts. The final good sector transforms the intermediate goods into a differentiated final good and is subject to staggered price-setting.

2.3.1 Intermediate Sector

Firms in the intermediate sector hire workers in the frictional labor market, and produce a homogenous good using a production function $y_t = A_t(e_t n_t)^\alpha$. Output depends on aggregate productivity A_t, effort e_t, and the number of employed workers n_t. The cost of posting vacancies in real terms is $\kappa_t = \frac{\kappa}{\lambda_t}$, κ is utility cost and λ_t is household's marginal utility of wealth.

Firms choose $\{n_t(j), w_t(j), v_t(j)\}_{t=0}^\infty$ to maximize their profits, subject to the evolution of employment and effort funtion.

$$max E_0 \sum_{t=0}^\infty \beta^t \frac{\lambda_t}{\lambda_0}[x_t A_t(e_t(j)n_t(j))^\alpha - w_t(j)n_t(j) - \kappa_t v_t(j)]$$

$$s.t. n_{jt} = (1-\rho)n_{jt-1} + v_{jt-1}q(\theta_{t-1}) \tag{7}$$

$$e_t(j) = \phi_0 + \phi_1 log w_t(j) + \phi_2 log n_t + \phi_3 log w_t + \phi_4 log w_{t-1} \tag{8}$$

The first-order conditions are given by

$$n_t(j) : w_t(j) = x_t \alpha \frac{y_t}{n_t(j)} - \mu_t + (1-\rho)\beta \frac{\lambda_{t+1}}{\lambda_t}\mu_{t+1} \tag{9}$$

$$w_t(j) : n_t(j) = x_t \alpha \frac{y_t}{e_t}\frac{\phi_1}{w_t(j)} \tag{10}$$

$$v_t(j) : \kappa_t = \beta E_t \frac{\lambda_{t+1}}{\lambda_t}q(\theta_t)\mu_{t+1} \tag{11}$$

μ_t is the Lagrange multipliers with respect to constraint (7). Combining equation (9) and (11) to eliminate the Lagrange multiplier, we obtain the job creation condition:

$$\frac{\kappa_t}{q(\theta_t)} = E_t \beta_{t+1}[\alpha \frac{y_{t+1}}{n_{t+1}(j)}x_{t+1} - w_{t+1}(j) + (1-\rho)\frac{\kappa_{t+1}}{q(\theta_{t+1})}] \tag{12}$$

From (9) and (10), note that the usual Solow condition does not hold in the presence of hiring frictions.

2.3.2 The final good sector

Firms in the final good sector are monopolistic competitors; they buy intermediate goods and differentiate them. The Dixit-Stiglitz consumption basket is

$$C_t = (\int_0^1 C_{it}^{(\epsilon_t-1)/\epsilon_t} di)^{\epsilon_t/(\epsilon_t-1)}$$

$\epsilon_t > 1$ is the elasticity of substitution across differentiated goods. Demand for each good i is derived from the cost minimization for a given level of consumption,

$$c_t(i) = [\tfrac{p_t(i)}{P_t}]^{-\epsilon_t} C_t.$$

The corresponding price index is $P_t \equiv (\int_0^1 p_{it}^{\frac{\epsilon_t-1}{\epsilon_t}} di)^{\frac{\epsilon_t}{\epsilon_t-1}}$.

We use Calvo(1983) model of staggered price setting. Each period, a randomly selected γ fraction of firms cannot change their prices. The New Keynesian Phillips curve is

$$\pi_t = \beta E_t \pi_{t+1} + \frac{(1-\gamma\beta)(1-\gamma)}{\gamma} x_t + \mu_t \tag{13}$$

where μ_t is the markup shock and follows $AR(1)$ process $\mu_t = \rho_\mu \mu_{t-1} + z_t$.

2.4 The monetary policymaker

The monetary policy rule:

$$\frac{R_t}{R^*} = (\frac{R_{t-1}}{R^*})^{\rho_r} [(\frac{\pi_t}{\pi^*})^{r_\pi} (\frac{y_t}{Y^*})^{r_y}]^{1-\rho_r} \epsilon_t^R \tag{14}$$

where ϵ_t^R is an i.i.d process with zero mean and variance σ_R^2.

2.5 Market clearing and Equilibrium

The behavior of labor market is characterized by the evolution of employment,

$$n_t = (1-\rho)n_{t-1} + m_{t-1}.$$

Note that in equilibrium, $\rho n = m$, meaning that number of new matches is equal to the number of separated jobs.

Since all households are identical, market clearing on the financial market implies that total bond holding are zero, $B_t = 0$. There is no investment, production is consumed and used to post vacancies, $Y_t = C_t + \kappa_t v_t$.

In symmetric equilibrium, individual firm sets price, wage, vacancy and employment equal to the aggregate level,

$$
\begin{aligned}
p_t(j) &= P_t \\
w_t(j) &= W_t \\
v_t(j) &= v_t \\
n_t(j) &= n_t
\end{aligned}
$$

3 Some mechanisms

3.1 The role of sensitivity of effort with respect to individual wage

Recall the job creation condition is

$$
\frac{\kappa_t}{q(\theta_t)} = E_t \beta_{t+1} [\alpha \frac{y_{t+1}}{n_{t+1}(j)} x_{t+1} - w_{t+1}(j) + (1 - \rho) \frac{\kappa_{t+1}}{q(\theta_{t+1})}] \qquad (15)
$$

Suppose there is a technology shock, the right hand side starts to increase. The firm responds by increasing vacancy posting. Unemployment decreases and wage rises, thereby labor market becomes tighter and the probability of filling a vacancy decrease. Hence the left hand side also start to increase.

In a simplified version of standard MP model with Nash Bargaining, we could arrive an equation like

$$
\hat{\theta}_t = \frac{(1 - \rho)\beta}{\nu} E_t [\frac{q(\theta)}{\kappa} (1 - \eta) \hat{A}_{t+1} + [\nu - \eta s] \hat{\theta}_{t+1}] \qquad (16)
$$

Hagedorn and Manovskii (2008) show that increasing unemployment benefits and reducing the bargaining power of worker could increase $\frac{q}{\kappa}(1 - \eta)$, boosting the labor market tightness volatility and reconciling the MP model with Nash bargaining with data.

In comparison, we use a simplified model to illustrate the volatility of labor market tightness in our model. Discount rate and vacancy posting cost

are assumed to be constant; ie $\beta_t = \beta, \kappa_t = \kappa$. Combining job creation condition, wage setting equation and effort function

$$w_t = \alpha\phi_1 \frac{x_t y_t}{e_t n_t(j)} \tag{17}$$

and after log-linearization, we could arrive the following equation

$$\hat{\theta}_t = \frac{qZ}{k(1-\nu)} \{ \frac{1+\phi_3}{1+(1-\alpha)(\phi_1+\phi_3)}(\hat{x}_{t+1} + \hat{A}_{t+1}) + W[(\phi_2+1)\hat{n}_{t+1}$$

$$+\phi_4\hat{w}_t] + \phi_2\hat{n}_{t+1} + \phi_4\hat{w}_t + (\alpha-1)\hat{n}_{t+1}\} + \beta(1-\rho)\hat{\theta}_{t+1} \tag{18}$$

where

$$Z \equiv \alpha\beta x n^{\alpha-1} \tag{19}$$

and

$$W \equiv \frac{(\alpha-1)[(\phi_1+\phi_3)\alpha - \phi_1]}{1+(1-\alpha)(\phi_1+\phi_3)} \tag{20}$$

We could analyze the volatility of labor market tightness via the above equation. In contrast to standard MP model, at least two differences appear. The first is the coefficient on technology, of which the important component is $\frac{q}{k}\frac{1+\phi_3}{1+(1-\alpha)(\phi_1+\phi_3)}$, playing critical role in determining θ volatility. The term $\frac{1+\phi_3}{1+(1-\alpha)(\phi_1+\phi_3)}$, which is smaller than one, is a negative function of ϕ_1. Moreover, the parameter ϕ_1 affects $\frac{q}{k}$ more heavily. Remember at the steady state the real wage and vacancy posting cost are $w = \frac{\phi_1\alpha xy}{en}$ and $\kappa = \frac{\beta q}{1-\beta(1-\rho)}(\frac{\alpha xy}{n} - w)$, respectively. Here we could derive $\frac{q}{\kappa} = \frac{1-\beta(1-\rho)}{\beta\rho}\frac{1}{\frac{\alpha xy}{n}(1-\phi_1)}$, where ϕ_1 measures sensitivity of effort responds to worker's own wage. The volatility of labor market tightness will be large when the parameter ϕ_1 comes close to 1, and tends to infinity when $\phi_1 \to 1$. The intuition is following. A higher ϕ_1[3] implies that effort is more sensitive to the individual wage the firm set. As a result, firm is willing to set a higher wage, which reduces the marginal benefit of hiring an additional worker. In this model, the marginal vacancy posting cost is endogenously determined and equal to the marginal benefit. Hence the vacancy posting cost is low and the volatility of labor market tightness is high.[4].

The intuition in our model is similar to Hagedorn and Manovskii (2008). Larger ϕ_1 leads to larger steady state wage which comes closer to productivity. This boost the volatility of labor market tightness.

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[3]Note ϕ_1 must be smaller than 1, otherwise the firm will make negative profit.

[4]We normalize the steady state of effort is 1

3.2 The role of sensitivity of effort to aggregate wage

The steady state wage is $w = \frac{\phi_1 \alpha x y}{en}$ and the wage setting equation is

$$\hat{w}_t = \frac{1}{1+(1-\alpha)(\phi_1+\phi_3)}[(\hat{x}_t + \hat{A}_t) - (1-\alpha)(1+\phi_2)\hat{n}_t - (1-\alpha)\phi_4\hat{w}_{t-1}]$$

The volatility of real wage is critically determined by the term $\frac{1}{1+(1-\alpha)(\phi_1+\phi_3)}$, which is smaller than 1, assuming $\phi_1 + \phi_3 > 0$. It depends positively on the modulus of ϕ_3. A larger $|\phi_3|$ implies that the effort is sensitive to outside opportunities. Therefore individual worker's wage need to be adjusted substantially in response to aggregate wage changes due to aggregate shocks.

From the previous log-linearized equation for labor market tightness, the term $\frac{1+\phi_3}{1+(1-\alpha)(\phi_1+\phi_3)}$ is decreasing in the modulus of ϕ_3. Since the real wage volatility is increasing in $|\phi_3|$, a larger $|\phi_3|$ leads to less rigid wage, thereby decreases the labor market tightness volatility.

4 Calibration and numerical results

4.1 Calibration of the model parameters

Table 1
Calibration

Parameter		Value	
labor market			
u	unemployment rate		0.09
ρ	job destruction rate		0.07
q	vacancy filling rate		0.7
ν	elasticity of match w.r.t. vacancy		0.4
effort function			
ϕ_1	coeff. w.r.t. current individual wage		0.99
ϕ_2	coeff. w.r.t.employment		-0.15
ϕ_3	coeff. w.r.t. current aggregate wage		-0.35
ϕ_4	coeff. w.r.t. lagged aggregate wage		-0.20
Production function			
α	elasticity		2/3
other parameters			
β	discount factor		0.992
μ	markup		0.1
$1 - \gamma$	fraction of sticky price		0.75
policy			
ρ_r	Interest rate smoothing		0.7
γ_π	Interest rate response to inflation		1.5
γ_y	Interest rate response to output		0.25
shocks			
ρ_a	AC of technology shock		0.95
ρ_μ	AC of markup shock		0.95
σ_a	standard deviation of technology shock		0.01
σ_μ	standard deviation of markup shock		0.01
σ_r	standard deviation of policy shock		0.01

Table 1 displays the benchmark calibration of parameter of our model. We consider three shocks, technology shock, markup shock and monetary policy shock. The former two are $AR(1)$ process with standard deviation and persistence as in the above table; monetary policy shock is an i.i.d. process with standard deviation specified in the above table.

4.2   Impulse response functions

4.2.1   Impulse response function with respect to a technology shock

[Insert figure 1 2 about here]

Figure 1 and 2 displays IRFs of the key variables over 40 quarter with respect to 1% technology shock in our model. Following a positive technology shock,

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output and consumption increase. Firms post more vacancies because the expected future value of a match increases. The number of new matches increases, therefore unemployment decreases and bring the downward sloping Beveridge curve. Labor market tightness increases and the probability of a vacancy to be filled decreases as it is decreasing in tightness. Effort level is higher as wage increases. Consistently with empirical evidence, we have pro-cyclical labor market tightness and persistent unemployment.

4.2.2 Impulse response function with respect to a markup shock

[Insert figure 3 4 about here]

Figure 3 and 4 show the impulse responses to a positive markup shock. An increase in the markup makes firms want to raise their price, therefore moving up their demand curves. The resulting fall in production depresses demand for the intermediate input. Firms post less vacancies and unemployment increases as it is more difficult to find a job. Effort declines as wage levels decrease, which is procyclical.

4.3 Relative volatility and persistence of labor market variables

[Insert table 2 about here]

Table 2 presents the relative volatility of some main labor market variables generated from our model and contrast it to the U.S. data as well at the Mortensen-Pissarides searching and matching model. The MP model fail to generate comparable volatility of labor market variables. In contrast, as we could see from table 2, our model with fair wage considerations could reproduce better the relative volatility of all the main labor market variables. In addition, our model also generates negative correlation of unemployment and vacancies. The correlation coefficient is -0.798, which is more closer to that in the data, -0.894.

[Insert table 3 about here]

Table 3 reports the quarterly autocorrelations of selected labor market variables in the U.S. data and those generated by this model. Our model is able to generate considerably persistent unemployment, vacancy, and labor market tightness comparable to the empirical evidence.

5   Further check

[Insert table 4 about here]

In this section, we are going to analyze the role of parameterization of effort function affecting labor market dynamics in our model. Some sensitive analysis are done to achieve this goal. Firstly, we are concerned at how the sensitivity of effort to individual wage affecting the volatility of labor market flows and wage. From table 4, the volatility of these variables are increasing in the value of ϕ_1, which confirms our previous analysis.

[Insert table 5 about here]

Secondly, we are interested in how sensitivity of effort to aggregate wage affect the volatility of labor market tightness. Table 5 presents the relative volatility of labor market variables[5] when we vary the value of ϕ_3, i.e., the sensitivity of effort to aggregate wage, while keeping other coefficients in effort function the same as in the benchmark model. The volatility of real wage is increasing in the absolute value of ϕ_3, and the volatility of unemployment, vacancies, and tightness decreasing in the absolute value of ϕ_3. As we previously analyzed, the higher $|\phi_3|$, the effort is more sensitive to outside wage. Hence individual worker's wage need to be adjusted substantially in response to aggregate wage changes due to aggregate shocks. The less rigid wage absorbs more the effects of productivity change and leads to less volatility of labor market variables.

6   Conclusions

We modify the Mortensen-Pissarides model (MP) by incorporating fair wage consideration to study the cyclical behavior of equilibrium unemployment and vacancies. In addition to vacancy posting and employment level, the employer also decides on wage subject to workers' effort function. Employing the effort function of Danthine and Kurmann (2004) in which worker's effort depends on individual wage, aggregate real wage, aggregate employment and aggregate past wage, we find that the volatility of labor market tightness depends critical on the sensitivity of effort to individual wage. Moreover, an increase in the sensitivity of effort to aggregate wage increase the real wage volatility and hence decreases the volatility of labor market tightness.While real wage rigidity arises endogenously, we show the model could replicate the negative correlation between unemployment and vacancies, i.e., the Beveridge

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[5]The volatility of labor productivity is normalized to 1.

curve; moreover, the model could generate plausible statistical moments of aggregate wage, labor market flows as well as unemployment. However, the volatility of labor market tightness is sensitive to the impact of individual wage on effort. For future research it is worth investigating the impact of fair wage consideration on inflation dynamics.

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Appendix

A Steady state values of the model

1.Employment

$$n = 1 - u$$

2. Number of matched workers

$$n_t = (1 - \rho)n_{t-1} + m_{t-1}$$
$$m = \rho n$$

3. Vacancy

$$v = \frac{m}{q}$$

4.Labor market tightness

$$\theta = \frac{v}{u}$$

5.Interest rate

$$r = \frac{1}{\beta}$$

6. Real price of intermediate good

$$x = \frac{1}{\mu}$$

7. Output

$$y = (en)^\alpha$$

8. Consumption

$$c = y - \kappa v$$

9.Real wage

$$w = \frac{\phi_1 \alpha x y}{en}$$

10. Vacancy posting cost

$$\kappa = \frac{\beta q}{1 - \beta(1 - \rho)}\left(\frac{\alpha x y}{n} - w\right)$$

B Linearized equation system

1. Number of matched workers:

$$m_t = \bar{m} v_t^{\nu} u_t^{1-\nu}$$
$$\hat{m}_t = \nu \hat{v}_t + (1 - \nu)\hat{u}_t$$

2. Labor market tightness

$$\theta_t = \frac{v_t}{u_t}$$
$$\hat{\theta}_t = \hat{v}_t - \hat{u}_t$$

3. Number of unemployed and searching workers

$$u_t = 1 - n_t$$
$$\hat{n}_t = -\frac{u}{1-u}\hat{u}_t$$

4. Employment

$$n_t = (1 - \rho)n_{t-1} + m_{t-1}$$
$$n\hat{n}_t = (1 - \rho)n\hat{n}_{t-1} + m\hat{m}_{t-1}$$

5. Vacancy cost

$$k_t = \kappa/\lambda_t$$
$$c_t^{-\sigma} = \lambda_t$$
$$\Rightarrow k_t = \kappa c_t^{\sigma}$$
$$\hat{k}_t = \sigma \hat{c}_t$$

6. The Euler equation

$$c_t^{-\sigma} = \beta R_t E_t c_{t+1}^{-\sigma} \frac{p_t}{p_{t+1}}$$
$$\sigma(\hat{c}_{t+1} - \hat{c}_t) = \hat{R}_t - \hat{\pi}_{t+1}$$

7. The Philips curve

$$\hat{\pi}_t = \beta E_t \hat{\pi}_{t+1} + \frac{(1-\gamma)(1-\gamma\beta)}{\gamma} - \mu_t$$

8. The effort function

$$e_t = \phi_0 + (\phi_1 + \phi_3)logw_t + \phi_2 logn_t + \phi_4 logw_{t-1}$$
$$e\hat{e}_t = (\phi_1 + \phi_3)\hat{w}_t + \phi_2\hat{n}_t + \phi_4\hat{w}_{t-1}$$

9. The production function

$$y_t = A_t(e_t n_t)^{\alpha}$$
$$\hat{y}_t = \hat{A}_t + \alpha(\hat{e}_t + \hat{n}_t)$$

10. The wage setting equation (social norm case)

$$n_t(j) = x_t \alpha \frac{y_t}{e_t} \frac{\phi_1}{w_t(j)}$$
$$\hat{n}_t = \hat{c}_t + \hat{x}_t - \hat{e}_t - \hat{w}_t)$$

11. The job creation condition

$$\frac{\kappa_t}{q(\theta_t)} = E_t \beta_{t+1} [\alpha \frac{y_{t+1}}{n_{t+1}(j)} x_{t+1} - w_{t+1}(j) + (1-\rho) \frac{\kappa_{t+1}}{q(\theta_{t+1})}]$$
$$\frac{k}{q}(\hat{k}_t - \hat{q}_t) =$$
$$-\frac{k}{q} \sigma(\hat{c}_{t+1} - \hat{c}_t) + \beta x \alpha \frac{y}{n}(\hat{y}_{t+1} - \hat{n}_{t+1} + \hat{x}_{t+1}) - \beta w \hat{w}_{t+1} + (1-\rho)\beta \frac{k}{q}(\hat{k}_{t+1} - \hat{q}_{t+1})$$

12. The good market clearing condition

$$y_t = c_t + \kappa_t v_t$$
$$\hat{y}_t = \frac{c}{y}\hat{c}_t + \frac{\kappa v}{y}(\hat{\kappa}_t + \hat{v}_t)$$

13. The technology shock

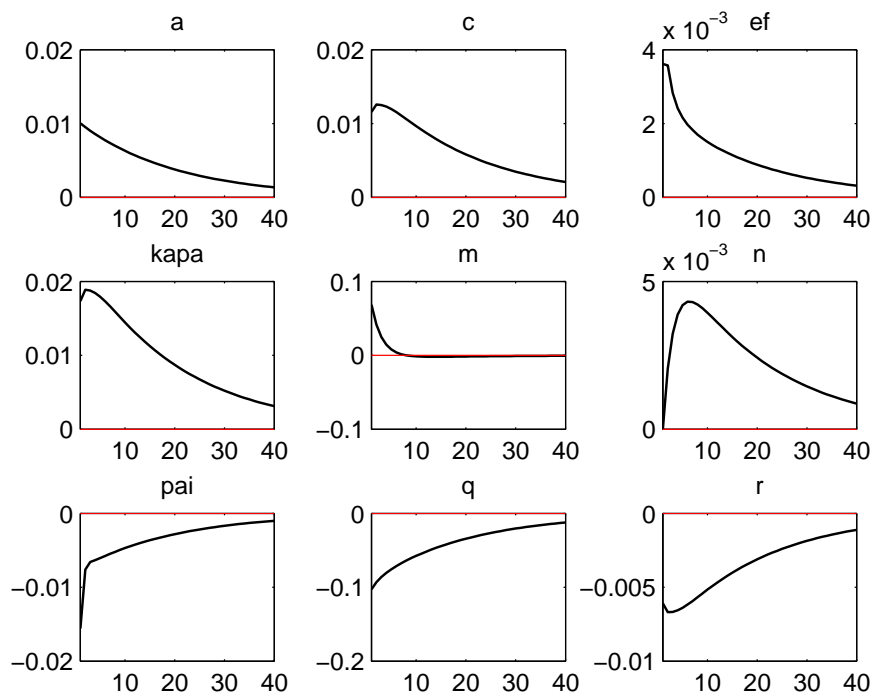$$\hat{A}_t = \rho_a \hat{A}_{t-1} + \epsilon_{a,t}$$

14. The markup shock

$$\hat{u}_t = \rho_u \hat{u}_{t-1} + \epsilon_{u,t}$$

15. Monetary policy rule

$$\frac{R_t}{R^*} = \left(\frac{R_{t-1}}{R^*}\right)^{\rho_r} \left[\left(\frac{\pi_t}{\pi^*}\right)^{r_\pi} \left(\frac{y_t}{Y^*}\right)^{r_y}\right]^{1-\rho_r} \epsilon_t^R$$
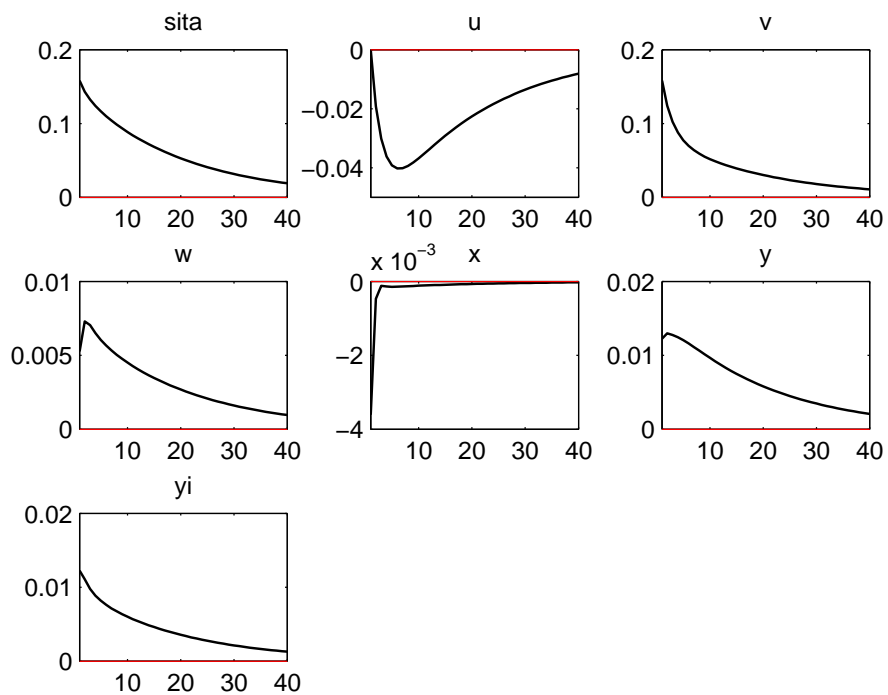$$\hat{R}_t = \rho_r \hat{R}_{t-1} + (1-\rho_r) r_\pi \hat{\pi}_t + (1-\rho_r) r_y \hat{y}_t + \epsilon_t^R$$

Figure 1: Impulse responses to 1% technology shock (The benchmark calibration)
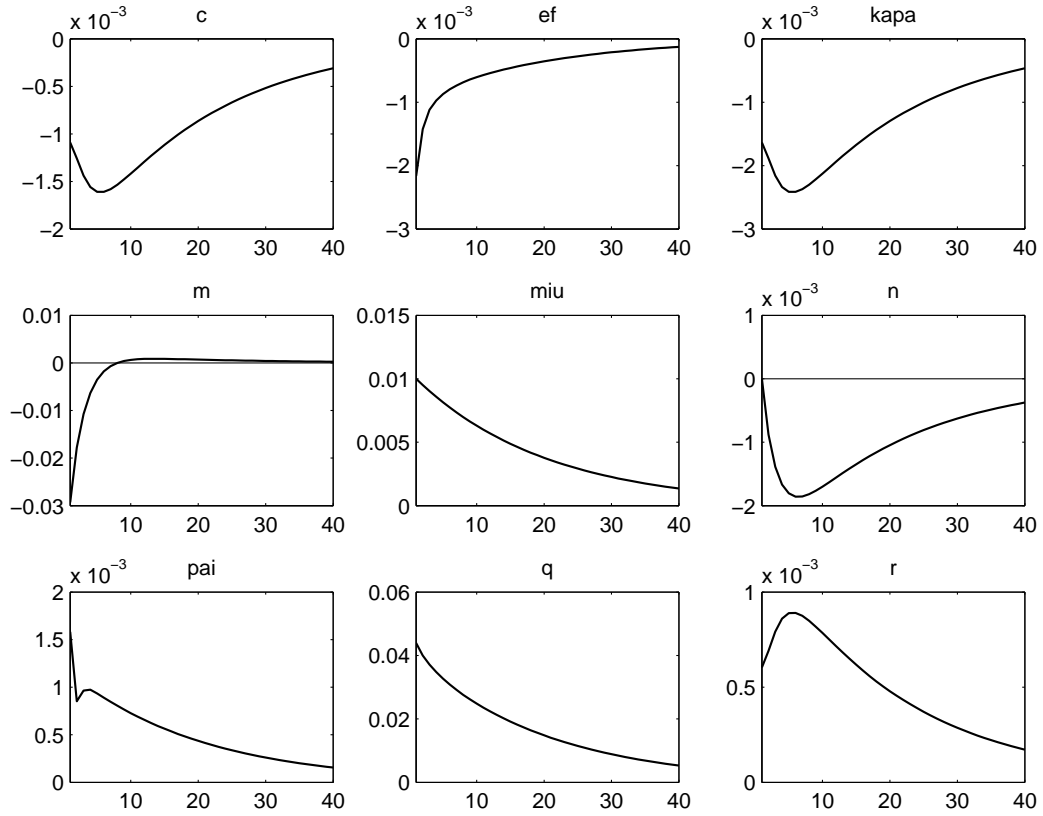

Notes: The variables are technology, consumption, effort, vacancy-post costs, matching, employment, inflation, probability of a vacancy to be filled, and interest rate.

Figure 2: Impulse responses to 1% technology shock (cont'd) (The benchmark calibration)
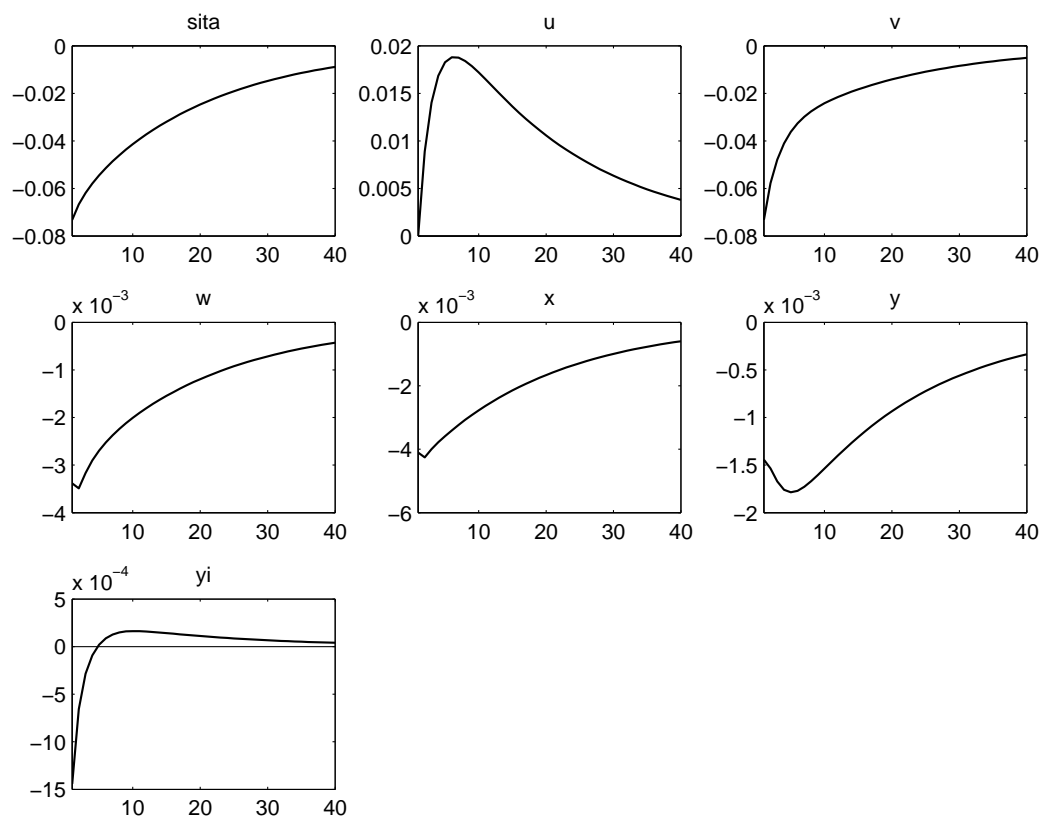

Notes: The variables are labor market tightness, unemployment, vacancy, wage, marginal cost, output, and output per worker.

Figure 3: Impulse responses to 1% markup shock (The benchmark calibration)

Notes: The variables are consumption, effort, vacancy-post costs, matching, markup, employment, inflation, probability of a vacancy to be filled, and interest rate.

Figure 4: Impulse responses to 1% markup shock (cont'd)(The benchmark calibration)

Notes: The variables are labor market tightness, unemployment, vacancy, wage, marginal cost, output, and output per worker.

Table 2
Relative Volatilities of Labor Market Variables

	y/n	u	v	θ	w	$corr(u,v)$
U.S. data	1	9.5	10.10	19.10	0.95	-0.894
Model with fair wage considerations	1	5.28	10.93	15.48	0.79	-0.798
Standard search and matching model	1	3.17	4.32	6.55	1.83	-0.427

Table 3
Quarterly autocorrelations of Selected Labor Market Variables

Quarterly autocorrelations	y/n	u	v	θ
U.S. data	0.908	0.936	0.940	0.941
Model with fair wage considerations	0.920	0.989	0.873	0.940

Table 4
Relative Volatilities of Labor Market Variables Under Different
Parameterizations of ϕ_1

	$\phi_1 = 0.989$	$\phi_1 = 0.990$	$\phi_1 = 0.991$
y/n	1	1	1
u	4.91	5.28	5.71
v	10.15	10.93	11.84
θ	14.38	15.48	16.75
w	0.784	0.787	0.790

Note: Other coefficients of the effort function are set as $\phi_2 = -0.15$, $\phi_3 = -0.35$, $\phi_4 = -0.2$.

Table 5

Relative Volatilities of Labor Market Variables Under Different
Parameterizations of ϕ_3

	$\phi_3 = -0.40$	$\phi_3 = -0.35$	$\phi_3 = -0.30$
y/n	1	1	1
u	4.83	5.28	5.70
v	9.99	10.93	11.81
θ	14.14	14.38	16.72
w	0.812	0.787	0.76

Note: Other coefficients of the effort function are set as $\phi_1 = 0.99$, $\phi_2 = -0.35$, $\phi_4 = -0.2$.