Flow Value of Unemployment, Stock Returns, and Unemployment Volatility

Dongweon Lee*
Seoul National University

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Abstract

This paper studies how the elasticity of intertemporal substitution (EIS) influences labor market fluctuations in the labor search and matching model with both extensive and intensive margins of labor supply. With the curvature of utility, the countercyclical marginal utility of consumption induces the flow value of unemployment to be procyclical, and the stock returns to be countercyclical. The former effect reduces unemployment volatility by weakening wage rigidity. In contrast, the latter effect magnifies unemployment volatility by discounting higher future payoffs at a lower discount rates, if wages do not absorb all of productivity shocks. The higher EIS reduces the procyclicality of the flow value of unemployment, and reinforces the countercyclicality of the stock returns. We quantitatively show that high values of the EIS are required to resolve the unemployment volatility puzzle.

KEY WORDS: Elasticity of Intertemporal Substitution; Unemployment Volatility

*Correspondence: 413, SK building (58), Business School, Seoul National University, 1 Gwanak-ro, Gwanak-gu, Seoul 151-916, Korea. Email: dongweonlee78@gmail.com.

1 Introduction

The labor search and matching model of Mortensen and Pissarides (1994) (MP model hereafter) has become the standard workhorse of equilibrium unemployment. However, Shimer (2005) argues that the standard calibration of the MP model is unable to reproduce the volatility of unemployment and vacancies observed in the postwar U.S. data. The quantitative failure of the MP model is attributed to the way wages are determined: the Nash-bargained wages respond strongly to variations in productivity. Therefore, the literature has proposed numerous modifications of the MP model that generate wage rigidity, among which the small surplus calibration of Hagedorn and Manovskii (2008) and the alternating-offer wage bargaining of Hall and Milgrom (2008) are the leading solutions to the unemployment volatility puzzle.

There are considerable debates about empirical plausibility of those alternative models. However, the literature has commonly adopted the strong assumption of the MP model: utility is linear. The absent of utility curvature has been regarded to be an appropriate approximation of the richer MP model, not only because productivity changes are relatively small and not permanent, but also because the log-linearization is typically used to quantify the cyclical properties of the MP model. The goal of this paper is to relax the assumption of linear utility and analyze the relationship between the elasticity of intertemporal substitution (EIS hereafter), which governs the willingness to trade-off consumption over time, and unemployment volatility in the MP model. Using the non-linear solutions, we suggest that the utility curvature plays a key role in determining the success of the MP model to account for labor market fluctuations.

We embed the MP model with the alternating-offer wage bargaining into a dynamic stochastic general equilibrium model with the preference of both extensive and intensive margins of labor supply used by Hall and Milgrom (2008). We find that the utility curvature influences unemployment fluctuation through two offsetting channels: the wage channel and the discount rate channel.

The wage channel represents that the utility curvature affects wage rigidity through the cyclicality of the flow value of unemployment. According to Hall and Milgrom (2008), the flow value of unemployment[1] is made up of unemployment benefits and the flow value of

[1] This terminology is from Hall (2014). Hall and Milgrom (2008) and Chodorow-Reich and Karabarbounis (2014) use "the flow value of nonwork" and "the opportunity costs of employment" instead, respectively.

non-working time in terms of consumption. The second measures the additional value that the household gains by shifting a worker from employment to unemployment, which equals the sum of the increase in flow utility and the decrease in consumption of the worker moving from work to nonwork. With the linear utility, the flow value of unemployment is constant, which plays an important role in generating wage rigidity in many models including the alternating-offer wage bargaining. With the utility curvature, the countercyclical marginal utility of consumption, however, induces the flow value of non-working time to rise in response to increase in productivity. In other words, the household appreciates the contribution of the unemployed relative that of the employed during booms, when the marginal utility of consumption is low due to larger consumption and more hours worked. If unemployment benefits are relatively small, the flow value of unemployment are procyclical, weakening wage rigidity generated by the alternating-offer wage bargaining. Therefore, the wage channel of the utility curvature reduces labor market volatility. This intuition is suggested by Pissarides (1985), and Hagedorn and Manovskii (2008). More recently, Chodorow-Reich and Karabarbounis (2014) empirically shows that the procyclical flow value of unemployment is able to dampen the ability of the MP model to replicate business cycle facts, which is against the common view of the search literature.

The discount rate channel represents that the utility curvature influences discount rates through the stochastic discount factor. Whereas the linear utility implies constant discount rates, the utility curvature gives rise to countercyclical discount rates. If the equilibrium wage does not soak up all of the shock, the stock price rises in response to increase in productivity, discounting higher future payoffs at a lower discount rate. As the decline of the stock return raises the expected payoff from hiring a new worker, the firm tends to invest more resources in recruitment. Therefore, the discount rate channel of the utility curvature magnifies labor market volatility. Mukoyama (2009) also suggests that the labor market volatility is amplified by the exogenously procyclical discount factor, which can be interpreted by a cyclical stochastic discount factor.

The total effect of two offsetting channels on unemployment fluctuations crucially depends on the magnitude of the EIS. When the EIS is low, the household is more reluctant to change consumption over time. the household, therefore, tends more to depreciate the relative value of non-working time to consumption from wage incomes, strengthening the procyclicality of the flow value of unemployment. On the other hand, the strong wealth effect discourages the agents from taking advantage of the temporal increase in labor productivity by opening more vacancies. Furthermore, more flexible wages reduce variations in firm's profits and thus suppress fluctuations in the stock returns. Therefore, the larger curvature of utility declines labor market volatility. When the EIS is high, large changes in consumption is more acceptable. The marginal utility of consumption, therefore, becomes less countercyclical, inducing the flow value of unemployment to be less procyclical. Moreover, the more productivity-insulated wages reinforce the coutercyclicality of stock returns. Because the substitution effect dominates the income effect, the discount rate effect amplifies the incentive of agents to save more for the future and invest more in hiring. Therefore, the smaller curvature of utility widens labor market volatility.

In the quantitative analysis, the MP model with the alternating-offer wage bargaining is able to replicate the observed labor market moments under the EIS parameter of 2.0. At the same time, we obtain high volatility of stock returns and low volatility of risk-free rates comparable to the data, which represents the link between financial market volatility and labor market volatility. Meanwhile, the standard calibration and the small surplus calibration of Hagedorn and Manovskii (2008) in the MP model with the Nash wage bargaining also show the same relationship between the EIS and unemployment volatility, but present much weaker unemployment fluctuations. The alternating-offer-bargained wages are mainly determined by the disagreement payoff that is affected not only by the flow value of unemployment but also by the bargaining delay costs and the bargaining termination probability. In contrast, the Nash-bargained wages rely on the outside option that is influenced only by the flow value of unemployment. Thus, the procyclical flow value of unemployment causes the Nash-bargained wages even under the small surplus calibration to be still responsive to productivity.

There is little agreement in the macroeconomics and finance literature about the appropriate magnitude for the EIS. Hall (1988) and Campbell (1999) argue that the EIS to be close to zero. On the contrary, Attanasio and Vissing-Jorgensen (2003), Gruber (2006), and van Binsbergen, Fernández-Villaverde, Koijen, and Rubio-Ramírez (2012) argue that the EIS is well over one. Also, Bansal and Yaron (2004), Gourio (2012) and Nakamura, Steinsson, Barro, and Ursúa (2013) find that the low EIS entails counterfactual implications for busyness cycles and asset prices in their models. In our model, the EIS parameter of 2.0 generates the EIS estimate close to zero in the regression of Hall (1988), which confirms the downward bias of the estimation approach. In addition, the low EIS counterfactually involves the countercyclical hours worked and the negative autocorrelation of dividends, because of the strong wealth effect. Theses results motivate high values of the EIS in our model.

This paper is built on two strands of the literature. The first group tries to resolve the unemployment volatility puzzle of Shimer (2005) by improving the MP model and by verifying quantitative and empirical plausibility of the modifications. Chodorow-Reich and Karabarbounis (2014) structurally measure the flow value of unemployment derived by Hall and Milgrom (2008) using the microdata and the administrative data. They find that the flow value of unemployment is estimated to be so procyclical that an elasticity of the flow value of unemployment with respect to the marginal product of employment is close to one. As a consequence, they argue that the unemployment volatility puzzle cannot be solved by the wage rigidity that appeals to the flow value of unemployment, such as Hagedorn and Manovskii (2008) and Hall and Milgrom (2008). Our paper complements Chodorow-Reich and Karabarbounis (2014) in the following ways. First, we analyze how the EIS changes the procyclicality of the flow value of unemployment. For the purpose, we choose the preference suggested by Hall and Milgrom (2008), which allows us to choose values of the EIS parameter flexibly. On the contrary, the preference used by Chodorow-Reich and Karabarbounis (2014) requires only low values of the EIS parameter for obtaining the complementarity between consumption and hours at the same time. Second, we more rigorously analyze the effect of the procyclical flow value of unemployment on wage rigidity and unemployment fluctuations, using the non-linear solutions. Third, we argue that the the countercyclical marginal utility of consumption influences the labor market not only through the flow value of unemployment, but also through the discount rates. Meanwhile, Hall (2014) and Albertini and Poirier (2014) shows that countercyclical discount rates are able to drive up unemployment fluctuations. From the view point that labor productivity is not a good driving force in the MP model because of the observed low correlation between productivity and unemployment, they assume that discount rates moves exogenously independent of productivity . In contrast, the stochastic discount factor in our model endogenously fluctuates in response to changes in the marginal utility of consumption.

The second group tries to account for the business cycles by introducing the search and matching frictions in the labor market into the real business cycle model, which is pioneered by Merz (1995) and Andolfatto (1996). Petrosky-Nadeau, Zhang, and Kuehn (2013) present that the labor market frictions replicate financial market moments, such as high equity premiums, high volatility of stock prices, and low and stable risk-free rates. They argue that the fixed component in the vacancy posting costs and the small surplus calibration similar to Hagedorn and Manovskii (2008) give rise to economic disasters inside the model. Although our paper focuses on the labor market moments, both papers emphasize the link between the labor market and the financial market in the context of the real business cycle model. Because the procyclical flow value of unemployment may hamper the endogenous disaster mechanism, the results of our paper also bears on Petrosky-Nadeau, Zhang, and Kuehn (2013).

The paper proceeds as follows. Section 2 presents the economy. Section 3 parameterizes the model. Section 4 studies the quantitative implications. Section 5 discusses some extensions and robustness. Section 6 concludes. The supplemental technical appendix provides the derivations of all equations, the data sources, and the computational algorithm.

2 Model

We embed the standard labor market search and matching frictions of Mortensen and Pissarides (1994) into a dynamic stochastic general equilibrium model with both extensive and intensive margins of labor supply. Time is discrete and infinite. Consumption is the numeraire good. The economy is populated by a representative firm and a representative household family. The firm is owned by the household, produces output with labor, and pays out profits as dividends. The household family is made up of a continuum of identical workers of mass one. And it perfectly insures its members against income variations, achieving equal marginal utility across all workers. The assumption of perfect consumption insurance is widely used for analytical simplicity in the literature.[2]

2.1 Search and Matching Frictions in the Labor Market

In each period t, a fraction n_t of workers are employed and producing output. A remaining fraction $u_t = 1 - n_t$ of workers are unemployed and searching for a job. For simplicity, we ignore small cyclical variations in labor force participation. At the beginning of period t, the firm posts job vacancies v_t to increase next-period employment n_{t+1}. Holding a vacancy open costs κ_t per unit of time. We assume that κ_t is constant at κ in the baseline model.

[2]Merz (1995), Hall (2009), Chodorow-Reich and Karabarbounis (2014), Petrosky-Nadeau, Zhang, and Kuehn (2013), etc. Without the assumption, we should track individual states of all employed and unemployed workers for aggregation. Blundell, Pistaferri, and Preston (2008) present that individual workers are substantially insured against transitory income risks.

The flow of successful matches m_t is determined by a constant-return-to-scale matching function $m(u_t, v_t)$, which is increasing and strictly concave in u_t and v_t. The matching function represents labor market frictions, such as lack of coordination, imperfect information, and heterogeneity of vacancies and workers. Even though all family members are allocated to working, only a fraction of them become employed and the remainder are searching for a job. For the matching function, we adopt the functional form introduced by den Haan, Ramey, and Watson (2000).[3]

$$m(u_t, v_t) = \frac{u_t v_t}{(u_t^\iota + v_t^\iota)^{1/\iota}}, \quad \iota > 0 \tag{1}$$

Let θ_t denote the vacancies/unemployment ratio (v_t/u_t), which represents labor market tightness from firm's perspective. From the matching function (1), the vacancy-filling rate q_t of the firm and the job-finding rate f_t of workers are given by

$$q_t = q(\theta_t) = \frac{m_t}{v_t} = \frac{1}{(1 + \theta_t^\iota)^{1/\iota}} \tag{2}$$

$$f_t = f(\theta_t) = \frac{m_t}{u_t} = \frac{1}{(1 + \theta_t^{-\iota})^{1/\iota}} = \theta_t q_t \tag{3}$$

As the labor market becomes tighter, it is more difficult for the firm to recruit a worker ($q'(\theta_t) < 0$), but it is easier for job-seekers to become employed ($f'(\theta_t) > 0$). q_t and f_t are outcomes from an interaction of all workers and the firm in the labor market. However, the household and the firm take them as a given feature of the labor market.

At the beginning of next period $t + 1$, matched workers and the firm haggle over hours worked h_{t+1} and a wage rate w_{t+1}. Both have some bargaining power, because the matching frictions prevent vacancies or workers from being replaced instantaneously. We will describes determination of hours worked and a wage rate in Section 2.4. Employed workers exogenously lose their job with a separation rate ϕ.[4] Therefore, employment evolves, as follows.

$$n_{t+1} = (1 - \phi)n_t + q_t v_t \tag{4}$$

[3]Unlike the standard Cobb-Douglas specification, the functional form ensures that the vacancy-filling rate and the job-finding rate lie between zero and one for all u_t and v_t. This feature is important because our calibration strategy targets at the observed value of θ.

[4]Shimer (2005) shows that most unemployment volatility in the United States is explained by fluctuations in job creation, rather than in job destruction.

2.2 Household's Decisions

Taking the labor market outcomes and the path of prices as given, the household family maximizes utility by choosing consumptions of employed and unemployed workers, $c_{n,t}$ and $c_{u,t}$.

$$J_t = \max_{c_{n,t}, c_{u,t}} n_t U_t(c_{n,t}, h_t) + u_t U_t(c_{u,t}, 0) + \beta \mathbb{E}_t [J_{t+1}] \tag{5}$$

where β is the discount factor, $\mathbb{E}_t$ is the mathematical expectation conditional on the information set at period t. $U_t(c_t, h_t)$ is a period utility that is assumed to be the additively separable specification of Hall and Milgrom (2008).[5]

$$U_t(c_t, h_t) = \frac{c_t^{1-1/\psi}}{1-1/\psi} - \tau c_t^{1-1/\psi} h_t^{1+1/\chi} - \varphi \frac{h_t^{1+1/\chi}}{1+1/\chi} + Q \tag{7}$$

where c_t is consumption and h_t is hours worked. ψ controls the elasticity of intertemporal substitution (EIS), and τ sets the complementarity between consumption and hours worked. ψ and τ should satisfy an inequality of $\tau(1-\psi) > 0$ to make the household assign a higher level of consumption to employed workers than to unemployed workers ($U_{ch} > 0$). χ determines the Frisch elasticity of labor supply, and φ governs the disutility of hours worked. Note eliminating the complementarity ($\tau = 0$) from the utility fixes the consumption demand elasticity and the labor supply elasticity at ψ and χ, respectively. Finally, Q is the additional utility from consuming non-marketed home production. Following Chodorow-Reich and Karabarbounis (2014), we add this parameter to target the level of the flow value of unemployment and thus the unemployment rate. We assume that Q is a positive constant for the unemployed and zero for the employed.

The budget constraint of the household is

$$n_t c_{n,t} + u_t c_{u,t} + T_t + \frac{b_{t+1}}{R_t^f} + a_{t+1} e_t = w_t h_t n_t + \eta u_t + b_t + a_t(d_t + e_t) \tag{8}$$

where η is unemployment benefits per the unemployed, b_t is holdings of risk-free assets, R_t^f is a risk-free rate, a_t is holdings of equity shares, e_t is an ex-dividend equity value, d_t is dividends, and $T_t = \eta u_t$ is lump-sum taxes to finance the public benefits. Let λ_t denote

[5] If ψ goes to one, it becomes

$$U_t(c_t, h_t) = \log c_t - \tau h_t^{1+1/\chi} \log c_t - \varphi \frac{h_t^{1+1/\chi}}{1+1/\chi} + Q \tag{6}$$

a Lagrange multiplier on the budget constraint. Then a stochastic discount factor M_{t+1} is given by

$$M_{t+1} = \beta \frac{\lambda_{t+1}}{\lambda_t} = \beta \left(\frac{c_{u,t+1}}{c_{u,t}} \right)^{-1/\psi} = \beta \left(\frac{c_{n,t+1}}{c_{n,t}} \right)^{-1/\psi} \left(\frac{1 - \tau(1 - 1/\psi) h_{t+1}^{1+1/\chi}}{1 - \tau(1 - 1/\psi) h_t^{1+1/\chi}} \right) \tag{9}$$

To save on notations, define $U_t^n = U_t(c_{n,t}, h_t)$ and $U_t^u = U_t(c_{u,t}, 0)$. From the household's problem, a marginal value of an unemployed worker to the household $J_{u,t}$ is given in terms of consumption by

$$\frac{J_{u,t}}{\lambda_t} = \frac{U_t^u}{\lambda_t} - c_{u,t} + \eta + \mathbb{E}_t \left[M_{t+1} \left\{ \frac{J_{n,t+1}}{\lambda_{t+1}} f_t + \frac{J_{u,t+1}}{\lambda_{t+1}} (1 - f_t) \right\} \right] \tag{10}$$

An additional unemployed worker provides the household with the sum of period utility, unemployment benefits net of consumption, and an expected discounted marginal value in next period, in which she finds a job with a probability f_t or stays unemployed with a probability $1 - f_t$. $J_{u,t}$ plays a role of an outside option of the matched worker in wage negotiation. Note tighter labor market raises $J_{u,t}/\lambda_t$ through the job-finding rate. Because the MP model counter-factually shows high correlation between productivity and tightness, $J_{u,t}/\lambda_t$ is also vulnerable to productivity changes. Similarly, a marginal value of an employed worker to the household $J_{n,t}$ is given in terms of consumption by

$$\frac{J_{n,t}}{\lambda_t} = \frac{U_t^n}{\lambda_t} - c_{n,t} + w_t h_t + \mathbb{E}_t \left[M_{t+1} \left\{ \frac{J_{n,t+1}}{\lambda_{t+1}} (1 - \phi) + \frac{J_{u,t+1}}{\lambda_{t+1}} \phi \right\} \right] \tag{11}$$

An additional employed worker contributes period utility, wages net of consumption, and an expected discounted marginal value in next period, in which she remains employed with a probability ϕ, or loses a job with a probability $1 - \phi$. In sum, the household gets the following surplus, when an additional unemployed member becomes employed.

$$\begin{aligned} \frac{J_{n,t} - J_{u,t}}{\lambda_t} = w_t h_t - \left[\eta - (c_{u,t} - c_{n,t}) + \left(\frac{U_t^u - U_t^n}{\lambda_t} \right) \right] \\ + (1 - \phi - f_t) \mathbb{E}_t \left[M_{t+1} \left\{ \frac{J_{n,t+1} - J_{u,t+1}}{\lambda_{t+1}} \right\} \right] \end{aligned} \tag{12}$$

The second bracketed term of (12) represents the flow value of unemployment in unit of a person denoted by z_t.

$$z_t = \eta + \frac{[U_{u,t} - \lambda_t c_{u,t}] - [U_{n,t} - \lambda_t c_{n,t}]}{\lambda_t} = \eta + \varrho_t \tag{13}$$

Note the flow value of unemployment in unit of a hour z_t/h_t is more relevant to our model with the intensive margin of labor supply, because w_t is in unit of a hour. In contrast, the flow value of unemployment in unit of a person z_t is more related to the model without the intensive margin of labor supply, where w_t is in unit of a person.

z_t contains not only the foregone unemployment benefits η, but also the foregone flow value of non-working time in units of consumption ϱ_t. ϱ_t measures the additional utility that the household gains when a worker quits a job and enjoys non-working time. Chodorow-Reich and Karabarbounis (2014) show that (a) η is countercyclical but takes up only a small portion, and (b) ϱ_t is highly procyclical. Therefore, the flow value of unemployment in the lump is procyclical and volatile over the business cycle. When productivity increases, consumption grows and hours worked rises (if the substitution effect is greater than the wealth effect from the high wage rate). Therefore, the value of consumption from wage incomes becomes lower and the value of non-working time becomes higher, which is manifested by the diminished marginal utility of consumption.[6] In other words, the household appraises the contribution of an unemployed worker more than that of an employed worker during booms, which causes the flow value of unemployment to be procyclial. Chodorow-Reich and Karabarbounis (2014) also show that cyclical movements in ϱ_t is mainly determined by procyclicality of λ_t.[7] Therefore, the cyclicality of the flow value of non-work crucially relies on the EIS parameter. If ψ increases, λ_t becomes less volatile, and thus ϱ_t and z_t becomes less procyclical.

As we note earlier, we add the value of home production Q to target the level of z_t, because η is estimated to be small. However, Q affects z_t in a different way from η. Q is measured in terms of utility, whereas η is in terms of consumption. As z_t contains Q/λ_t in exchange of η in the model, the procyclicality of z_t depends much less on the level of z_t. Chodorow-Reich and Karabarbounis (2014) also show that an elasticity of the flow value of unemployment with respect to the marginal production of employment does not vary much by increase in Q.

[6] From the first order conditions for $c_{n,t}$ and $c_{u,t}$, and the optimal conditions for h_t (25), we can express z_t as a function of λ_t, which is the same across employed and unemployed workers. The marginal utility of consumption λ_t is decreasing in consumption and hours worked.

[7] In recessions, c_n declines further than c_u, increasing $U_t^u - U_t^n$. On the other hand, h_t, which is a complement of c_n, is reduced, decreasing $U_t^u - U_t^n$. Meanwhile, c_u/c_n is quite smooth in the solutions. These are why variations in $[U_{u,t} - \lambda_t c_{u,t}] - [U_{n,t} - \lambda_t c_{n,t}]$ are relatively small.

2.3 Production and Firm's Decisions

The firm produces output y_t using labor as its only input according to the following linear production function.

$$y_t = p_t n_t = x_t h_t n_t \tag{14}$$

where p_t is a marginal product of employment, and x_t is labor productivity that follows a AR(1) process with a persistence ρ and a normal disturbance ε_t.

$$\log x_t = \rho \log x_{t-1} + \varepsilon_t, \quad \varepsilon_t \sim iid\ N(0, \sigma^2) \tag{15}$$

To focus on the labor market and gain computational simplicity, we abstracts from physical capital in the production, following the literature.[8] Physical capital shows smooth cyclical variations, and thus has little impact on the marginal product of employment that is considered to be the main driving force for unemployment fluctuations. However, we believe that adding curvature into the production will be a productive research to generate more realistic payoffs of the firm.

If the firm employs n_t workers and posts v_t vacancies, it receives profits in period t equal to revenues net of wages and vacancy-posting costs.

$$d_t = y_t - w_t h_t n_t - \kappa_t v_t \tag{16}$$

The firm is risk-neutral and discounts future payoffs with the same stochastic discount factor as does the household. Taking the labor market outcomes and the path of prices as given, the firm maximizes its cum-dividend value by posting vacancies v_t, subject to the employment evolution condition and the nonnegative vacancy condition.

$$S_t = \max_{v_t} \left\{ d_t + \mathbb{E}_t \Big[M_{t+1} S_{t+1} \Big] \right\} \tag{17}$$

$$s.t.$$

$$n_{t+1} = (1 - \phi) n_t + q_t v_t \tag{18}$$

$$v_t \geq 0 \tag{19}$$

As in Petrosky-Nadeau, Zhang, and Kuehn (2013), we impose the nonnegative vacancy condition (19), because it is occasionally binding under some calibrations with the Nash-bargained wages. It also facilitates obtaining numerical solutions to the model by preventing

[8] Shimer (2005), Pissarides (2009), Petrosky-Nadeau, Zhang, and Kuehn (2013), etc.

the vacancy-filling rate larger than one. However, this constraint is not essential in the model, as it does not bind in simulations based on the calibrations with the Nash-bargained wages used by this paper. Also, vacancies are always positive with the alternating-offer-bargained wages.

Let π_t and $\lambda_t q_t$ denote Lagrangian multipliers on the employment evolution condition and the nonnegative vacancy condition, respectively. Then the first order condition for v_t yields the intertemporal job creation condition.

$$\frac{\kappa_t}{q_t} - \zeta_t = \mathbb{E}_t\left[M_{t+1}\left\{x_{t+1}h_{t+1} - w_{t+1}h_{t+1} + \left(\frac{\kappa_{t+1}}{q_{t+1}} - \zeta_{t+1}\right)(1-\phi)\right\}\right] \tag{20}$$

In the equilibrium, a marginal cost of hiring an additional employee (or filling an additional vacancy) equals a expected discounted profits from the recruitment that equal the sum of a marginal product of employment and savings in the next-period marginal cost of hiring net of wages. The Kuhn-Tucker condition from the nonnegative vacancy condition is given by

$$\begin{aligned} &v_t = 0,\ \zeta_t q_t > 0 \quad \text{if binding} \\ &v_t > 0,\ \zeta_t q_t = 0 \quad \text{otherwise} \end{aligned} \tag{21}$$

From the firm's problem, a marginal value of an employed worker to the firm $S_{n,t}$ is given by

$$S_{n,t} = x_t h_t - w_t h_t + \mathbb{E}_t[M_{t+1}S_{n,t+1}(1-\phi)] \tag{22}$$

An additional employed worker supplies the sum of flow profits plus an expected marginal value in next period, in which she remains matched with a probability $1-\phi$. Similarly, a marginal value of a posted vacancy to the firm $S_{v,t}$ is

$$S_{v,t} = -\kappa_t + \zeta_t q_t + \mathbb{E}_t[M_{t+1}S_{n,t+1}q_t] = 0 \tag{23}$$

An additional vacancy incurs posting costs, but provides a chance to hire a worker with a probability q_t in next period. The assumption on free entry yields $S_{v,t} = 0$, which is equivalent to (20). In sum, the firm gets the surplus of $S_{n,t} - S_{v,t} = S_{n,t}$, when it recruits an additional worker by filling a vacancy.

2.4 Bargaining on Hours Worked and Wage

A bargaining between the matched worker and the firm determines contract terms on hours worked and a wage rate. Let Λ_t denote the joint surplus from an additional match in terms of consumption.

$$\Lambda_t = \frac{J_{n,t} - J_{u,t}}{\lambda_t} + S_{n,t} - S_{v,t} \tag{24}$$

Hours worked are efficiently selected to maximize the surplus: the first-order condition for h_t is

$$x_t + \frac{1}{\lambda_t}\frac{\partial U_t^n}{\partial h_t} = 0 \tag{25}$$

A wage rate is selected by the alternating-offer wage bargaining proposed by Hall and Milgrom (2008).[9] The matched worker and the firm alternate in making wage proposals. The firm makes the first offer w_t^f. The worker responds to it by exercising one of three options: (a) accept the firm's offer, (b) reject it, prolong the bargain, and make a counter-offer w_{t+1}^h in next period, and (c) abandon the negotiation and exercise the outside option $J_{u,t}$. When the bargaining is delayed in the case of (b), the worker takes unemployment benefits η in current period, while the firm incurs bargaining delay costs ξ. And then the firm becomes a responding party with the same options in next period. When the bargaining is abandoned in the case of (c), the worker becomes unemployed and contributes $J_{u,t}/\lambda_t$ to the household, while the firm obtains $S_{v,t}$ that equals zero. The outside options are, however, assumed to be less favorable for both parties than an agreement, which will be accomplished by the calibration.[10] Therefore, taking the outside options is not a credible threat, and matters only when the negotiation breaks down exogenously with a probability δ. Because both parties think through the whole outcomes from a sequence of alternating offers, the firm proposes the just acceptable offer to the worker. Consequently, they do not waste time and resources for the haggling and arrive at an agreement immediately. Therefore, the firm's initial offer becomes the equilibrium wage: $w_t = w_t^f$.

Let $J_{n,t}^f$ and $J_{n,t}^h$ denote a marginal value of an employed worker that the household gets from a wage offer proposed by the firm and by the worker, respectively. From (11), they are

[9] We will discuss the results from the Nash wage bargaining under the standard calibration and the small surplus calibration of Hagedorn and Manovskii (2008) in Section 5.1.

[10] To make the bargainers never abandon, the joint value from an agreement should be larger than the joint value from the outside options. Also, it should outweigh the present value from prolonging the negotiation infinitely. Because the joint value from the outside options is bigger than the present value from delaying infinitely, we check whether the numerical solutions satisfy the following inequality.

$$\frac{J_{n,t}^f}{\lambda_t} + \left\{ x_t h_t - w_t^f h_t + \left(\frac{\kappa_t}{q_t} - \zeta_t\right)(1-\phi) \right\} > \frac{J_{u,t}}{\lambda_t} \tag{26}$$

given by

$$\frac{J^f_{n,t}}{\lambda_t} = \frac{U^n_t}{\lambda_t} - c_{n,t} + w^f_t h_t + \mathbb{E}_t\left[M_{t+1}\left\{\frac{J^f_{n,t+1}}{\lambda_{t+1}}(1-\phi) + \frac{J_{u,t+1}}{\lambda_{t+1}}\phi\right\}\right] \tag{27}$$

$$\frac{J^h_{n,t}}{\lambda_t} = \frac{U^n_t}{\lambda_t} - c_{n,t} + w^h_t h_t + \mathbb{E}_t\left[M_{t+1}\left\{\frac{J^h_{n,t+1}}{\lambda_{t+1}}(1-\phi) + \frac{J_{u,t+1}}{\lambda_{t+1}}\phi\right\}\right] \tag{28}$$

Similarly, define $S^f_{n,t}$ and $S^h_{n,t}$ as a marginal value of an employed worker that the firm gains from a wage offer proposed by the firm and by the worker, respectively. From (23), they are given by

$$S^f_{n,t} = x_t h_t - w^f_t h_t + \mathbb{E}_t[M_{t+1}S^f_{n,t+1}(1-\phi)] \tag{29}$$

$$S^h_{n,t} = x_t h_t - w^h_t h_t + \mathbb{E}_t[M_{t+1}S^h_{n,t+1}(1-\phi)] \tag{30}$$

Because the worker is indifferent to the firm's offer, the marginal value of an employed worker to the household from the firm's offer equals the flow value when the worker declines it.

$$\frac{J^f_{n,t}}{\lambda_t} = \delta\frac{J_{u,t}}{\lambda_t} + (1-\delta)\left\{\frac{U^u_t}{\lambda_t} - c_{u,t} + \eta + \mathbb{E}_t\left[M_{t+1}\frac{J^h_{n,t+1}}{\lambda_{t+1}}\right]\right\} \tag{31}$$

When the worker turns down w^f_t, the household obtains the marginal value of an unemployed worker with a probability δ, or the sum of the current-period flow value from an unemployed worker and the expected discounted marginal value of an employed worker from a counter offer w^h_{t+1} with a probability $1-\delta$. In the same manner, the marginal value of an employed worker to the firm from the household's offer equals the flow value when the firm rejects it.

$$S^h_{n,t} = \delta S_{v,t} + (1-\delta)\left(-\xi + \mathbb{E}_t\left[M_{t+1}S^f_{n,t+1}\right]\right) \tag{32}$$

When the firm refuses w^h_t, it obtains nothing with probability δ, or invests bargaining delay costs ξ in current period and gets the expected discounted marginal value of an employed worker from a counter offer w^f_{t+1} with probability $1-\delta$. From the indifference conditions (31) and (32), we can derive the wage offers from the parties.

$$\begin{aligned} w^f_t = \frac{1}{h_t}\Bigg\{ & z_t + (1-\delta)\mathbb{E}_t\left[M_{t+1}\left(\frac{J^h_{n,t+1}}{\lambda_{t+1}} - \frac{J_{u,t+1}}{\lambda_{t+1}}\right)\right] \\ & - (1-\phi-\delta f_t)\mathbb{E}_t\left[M_{t+1}\left(\frac{J^f_{n,t+1}}{\lambda_{t+1}} - \frac{J_{u,t+1}}{\lambda_{t+1}}\right)\right]\Bigg\} \end{aligned} \tag{33}$$

$$w_t^h = \frac{1}{h_t}\Bigg\{x_t h_t + (1-\phi)(1-\delta)\mathbb{E}_t\left[M_{t+1}\left\{-\xi + \left(\frac{\kappa_{t+1}}{q_{t+1}} - \zeta_{t+1}\right)\right\}\right] - (1-\delta)\left(-\xi + \left(\frac{\kappa_t}{q_t} - \zeta_t\right)\right)\Bigg\} \tag{34}$$

The key difference from the original wage equations of Hall and Milgrom (2008) is that the flow value of unemployment z_t in (33) is not constant but procyclical because of the extensive margin of labor supply. Therefore, the equilibrium wage moves to offset changes in productivity, which alleviates unemployment fluctuations. However, the bargaining termination probability δ and the bargaining delay costs ξ still help making the equilibrium wage partially inelastic to productivity. If δ is lower, the role of the outside option $J_{u,t}$ gets smaller in (31), and thus the equilibrium wage becomes more insulated from movements of tightness through the job-finding rate in (33). If δ is zero, the resulting wages are completely separated from the labor market.[11]

2.5 Asset prices

Using the stochastic discount factor (9), the risk-free rate R_t^f is computed by

$$R_t^f = \frac{1}{\mathbb{E}_t[M_{t+1}]} \tag{35}$$

Because the system of equilibrium conditions is homogenous of degree one, a return to holding a equity share equals a return to hiring a worker. From the intertemporal job creation condition (20), the stock return R_{t+1}^S is, therefore, given by

$$R_{t+1}^S = \frac{S_{t+1}}{S_t - d_t} = \frac{x_{t+1}h_{t+1} - w_{t+1}h_{t+1} + \left(\frac{\kappa_{t+1}}{q_{t+1}} - \zeta_{t+1}\right)(1-\phi)}{\frac{\kappa_t}{q_t} - \zeta_t} \tag{36}$$

And it satisfies the asset Euler equation.[12]

$$1 = \mathbb{E}_t\left[M_{t+1}R_{t+1}^S\right], \quad M_{t+1} = \beta\frac{\lambda_{t+1}}{\lambda_t} \tag{37}$$

When positive persistent productivity shock hits the economy, the stock price capitalizes all future productivity gains on impact. If the wage rate does not absorb too large a fraction

[11] On the contrary, if δ goes to one, the equilibrium wage becomes the same as the Nash bargained wage.

[12] The time subscript of R_t^f and R_{t+1}^S indicates the date on which the relevant payoff becomes known. In both cases, the payoff is realized in period $t+1$.

of the productivity movement, the stock price increases, discounting higher future cash flows at a lower discount rate. As the smaller R^S_{t+1}, or higher M_{t+1}, pushes up the expected payoffs from hiring a new worker in the right-hand side of (20), the firm is inclined to invest more resources in recruitment.

If the large EIS makes changes in consumption less costly, the substitution effect overwhelms the wealth effect. When the stock returns decline, the household has a stronger desire to save temporarily-increased consumption for the future, which encourages the firm to invest more resources in hiring. This tends to push up stock prices further, which elevates labor market tightness further. Therefore, the large EIS produces the amplification mechanism of labor market fluctuations through the discount rate effect.[13]

2.6 Competitive Equilibrium

Let $\Phi_t = (n_t, x_t)$ denote the state vector in period t. The competitive equilibrium for the economy is defined by (a) family's indirect utility J_t, and consumptions of employed and unemployed workers $c_{n,t}$ and $c_{u,t}$, (b) the number of vacancies posted by the firm v_t, and the Lagrange multiplier on the nonnegative vacancy condition ζ_t, (c) hours worked h_t, a wage rate w_t, (d) the labor market outcomes q_t and f_t, (e) the stochastic discount factor M_{t+1}, (f) the laws of motion for the state Φ_t, such that the following statements hold.

- J_t maximizes family's problem (5) and (8). And $c_{n,t}$ and $c_{u,t}$ are the associated consumption rules.
- v_t and ζ_t satisfy the firm's optimality conditions (20) and the Kuhn-Tucker conditions (21).
- h_t is chosen by (25). And w_t is set by (33), (34) and $w_t = w^f_t$.
- q_t and f_t are determined by (2) and (3).
- M_{t+1} is given by (9), and $a_t = 1$

[13]In the MP model, employment is determined by firm's vacancy posting, to which the substitution and wealth effects from the discount rate is more related. On the other hand, hours worked are determined by the wage bargaining, to which the substitution and wealth effects from wages are more relevant.

- The good market clears.

$$x_t h_t n_t - \kappa_t v_t = n_t c_{n,t} + u_t c_{u,t} \tag{38}$$

- The aggregate laws of motion are consistent with the individual decisions, the employment evolution condition (4), and the stochastic process of labor productivity (15).

3 Numerical Solution and Parameterization

To analyze how the utility curvature affects labor market fluctuations, we choose three different values of the EIS parameters: $\psi = 0.4$ from Hall and Milgrom (2008), $\psi = 1.0$ that leads to log utility, and $\psi = 2.0$ from Barro (2009) and Gourio (2012). And we perform an quantitative analysis using the calibrations. Section 3.1 discusses the numerical solution method, and Section 3.2 presents the parameter values.

3.1 Computation

The log-linearization is generally used for the quantitative analysis in the search literature. However, the local solution method is not suitable to study the effects of utility curvature on unemployment fluctuations. In addition, Petrosky-Nadeau and Zhang (2013a) show that the log-linearization understates the mean and volatility of unemployment and overstates the correlation between unemployment and vacancy in the MP model. Therefore, the global solution method is crucial for our quantitative analysis.

Our numerical method is based on the policy function iteration with the finite element method. The key goal of the algorithm is to find the equilibrium vacancy-filling rate q_t satisfying the intertemporal job creation condition (20) over the state variables, n_t and z_t, which we discretize into an equidistance grid. Petrosky-Nadeau, Zhang, and Kuehn (2013) (with the Nash wage bargaining) and Petrosky-Nadeau and Zhang (2013b) (with the alternating-offer wage bargaining) rely on the projection method proposed by Christiano and Fisher (2000) that is developed to deal with occasionally binding constraints. Their method approximates the conditional expectation in the right-hand side of (20) with a polynomial, and solves for q_t. Our solution algorithm has some advantages over their projection method without paying much computational costs. (a) Our method is more robust to get solutions. The kinds of polynomials used by the projection method are defined on a bounded domain over state variables. Therefore, endogenous state variables should be updated within the domain interval, the failure of which collapses the algorithm. Therefore, two studies seem to use the homotopy method to widen a grid of n_t in the model, as well as choosing initial solutions carefully. Also they fail to get solutions for some parameter values of the model. This is not the case with our method based on the finite element method. (b) Our method is easier and simpler to implement for more complex specifications of the model. In particular, allowing both extensive and intensive margins of labor supply in the preference makes it necessary to utilize a non-linear solver not only for the equilibrium vacancy-filling rate q_t but also for hours worked h_t. (c) Our method is more suitable to deal with the non-linearity of the model. It is well-known that the projection method cannot fully capture steep curvatures or kinks of solutions. The method of Christiano and Fisher (2000) cannot overcome this disadvantage, because the nonnegative vacancy constraint is not a root for the non-linearity. A supplemental technical appendix contains further details on our solution algorithm.

3.2 Calibration

Table 1 summarizes the parameter values for the calibrations with three alternative EIS parameters. Because of the nonlinearity, we do not calibrate the model by relying on the steady state equilibrium. Instead, we match moments from simulated data with the corresponding targets from observed data (as much as possible). Throughout the paper we obtain model moments from 10,000 artificial samples, each of which has 956 observations. Because we discard the first 100 observations to eliminate the effect of initial conditions, the samples span 63 years or 856 months. As the model period is one month, we time-aggregate model-generated data properly in accordance with a frequency of the targets. Table 2 contains the performance of three calibrations in matching the targets. The sample period of the observed data is from 1951 to 2013.[14] We describe the data source in more detail in the technical appendix.

Using the HP-filtered[15] real output per hour in the nonfarm business sector, we find that quarterly labor productivity has an autocorrelation of 0.72 and an standard deviation of 0.011. This requires setting $\rho = 0.935$ and $\sigma = 0.006$ at monthly frequency. We approximate

[14]We pick 1951 as a beginning year of the sample period, following the literature. In 1951, the Conference Board began to construct the help-wanted advertising index, which Shimer (2005) uses as a proxy for the stock of vacancies.

[15]Throughout the paper we use a smoothing coefficient of 1,600 to filter quarterly data.

Table 1: Calibration values (monthly)

Parameter	Interpretation	Consumption curvature		
		$\psi = 0.4$	$\psi = 1.0$	$\psi = 2.0$
Technology				
ρ	Persistence of productivity		0.935	
σ	Volatility of productivity		0.006	
Preference				
χ	Hours worked curvature		0.80	
τ	Complementarity in utility	0.5352	-0.2658	-0.2502
φ	Disutility of hours worked	0.7687	1.3061	1.7045
β	Time discount factor		0.9988	
Q	Value of home production	0.354	0.265	0.241
Labor market				
ϕ	Separation rate		0.025	
ι	Elasticity of matching		1.17	
κ	Vacancy posting costs		0.268	
η	Unemployment benefits		0.041	
Wage bargaining				
ξ	Bargaining delay costs to employer		0.285	
δ	Bargaining termination probability		0.03	

the labor productivity process (15) with the 41-state Markov chain, using the method of Tauchen (1986).

Among the preference parameters, we set the hours worked curvature to be $\chi = 0.8$, following Hall and Milgrom (2008). Note empirical studies using the household data, such as Pistaferri (2003), show that a Frisch elasticity of labor supply is below one for male workers, while it is above one for women, and younger and older men. We calibrate the parameter for disutility of hours worked φ at the point where hours worked h are normalized to be one on average. Chodorow-Reich and Karabarbounis (2014) shows that a ratio of consumption between employed and unemployed workers c_u/c_n is 0.79. We determine the complementarity parameter τ to accomplish this target inside the model. We vary the value of home production Q to match the flow value of unemployment of $z = 0.71$ that is required

Table 2: Matching the calibration targets

Targets	Data	$\psi = 0.4$	$\psi = 1.0$	$\psi = 2.0$
Autocorrelation of quarterly labor productivity	0.716	0.719	0.719	0.718
Standard deviation of quarterly labor productivity	0.011	0.011	0.011	0.011
Job-finding rate	0.417	0.402	0.408	0.417
Vacancy/unemployment	0.635	0.576	0.599	0.637
Unemployment rate (%)	5.87	5.86	5.86	5.88
Risk-free rate (%)	1.38	1.40	1.43	1.45

to match the observed average monthly unemployment rate of 5.87% under the standard calibration with the Nash-bargained wages.[16] We take the time discount factor $\beta = 0.9988$ to match the 3-month T-bill rate of 1.4% per annum.

For the labor market parameters, we use targets from the observed data. As in Hagedorn and Manovskii (2008) and Chodorow-Reich and Karabarbounis (2014), we calculate monthly separation rates as the ratio of the number of unemployed workers for fewer than five weeks in the next month to the number of employed workers in the current month: $\phi_t = u^s_{t+1}/n_t$.[17] This procedure leads us to set ϕ to be the average separation rate of 0.025. To choose the matching function parameter ι and the vacancy-posting costs κ, we also compute monthly job-finding rates and vacancy/unemployment ratios. For the job-finding rate, we use the employment evolution condition: $f_t = 1 - (u_{t+1} - u^s_{t+1})/u_t$. And we find that the average job-finding rate is 0.42. For the vacancy/unemployment ratio, we divide the number of job openings for total nonfarm by the number of unemployed workers. As the Job Openings and Labor Turnover Survey (JOLTS) reports the job openings only after December 2000, we extend the data using two more sources as in Petrosky-Nadeau and Zhang (2013b): the metropolitan life insurance company help-wanted advertising index and the composite help-wanted index of Barnichon (2010). This procedure reveals that the average vacancy/unemployment ratio is 0.64. These estimates imply the vacancy-filling rate of 0.66 ($= f/\theta$) and the unemployment rate of 5.66% ($= \phi/(\phi + f)$) in the steady state. We take

[16]See Section 5.1 for more details

[17]Shimer (2005) points out that this procedure understates the separation rate, because it ignores workers who lose a job but find new one within a month. However, an adjustment of this time-aggregation bias is not consistent with the employment evolution condition, and thus impedes matching targets. Chodorow-Reich and Karabarbounis (2014) show that the bias is negligible, as the separation rate estimated at a monthly frequency and averaged at a quarterly level is similar to that estimated at a quarterly frequency.

the matching function parameter $\iota = 1.17$ to match the average job-finding rate, and vary the vacancy-posting costs κ to match the average vacancy/unemployment ratio inside the model. We set the public benefits $\eta = 0.041$ that is the estimation of Chodorow-Reich and Karabarbounis (2014). In this analysis, we neglect the countercyclicality of η, as the portion of η in z is quite small.

For the wage bargaining parameters, we follow Hall and Milgrom (2008). We take the bargaining delay costs $\xi = 0.285$ to match the average unemployment rate of 5.87%. And we set the bargaining termination probability $\delta = 0.03$, which matches the observed unemployment volatility of 0.13. with $\psi = 2.0$.

4 Quantitative Results

In this section, we show that three alternative values of the EIS have very different quantitative results for the labor market volatility. Section 4.1 presents labor market moments from the calibrations of the model. To illustrate intuition underlying the relationship between the EIS and unemployment fluctuations, Section 4.2 and 4.3 examine the effects of utility curvature on the flow value of unemployment and the stock returns, respectively. Finally, Section 4.4 derives the implications for the value of the EIS from the results.

4.1 Labor Market Moments

Table 3 reports labor market statistics from simulating the model with labor productivity shocks and their empirical counterparts from U.S. data. The search literature generally regards the marginal product of employment, rather than labor productivity, as the driving force, as it does not contain the intensive margin of labor supply in the model. To compare with the previous studies, we present labor market moments using the marginal product of employment (p_t). And we add impulse responses with respect to labor productivity (x_t) instead. Note that "the flow value of unemployment is procyclical" in this paper means both that z_t rises in respond to increase in p_t and that z_t/h_t rises in respond to increase in x_t. We use the real output per person in the nonfarm business sector as a proxy for the marginal product of employment.

As utility curvature gets smaller, the volatility of unemployment, vacancies, and labor market tightness becomes larger. In particular, the results with $\psi = 2.0$ are line with the

Table 3: Labor market moments

$\hat{x}$ is the percent deviation of x_t from its trend. We obtain trends of variables using the HP-filter with a smoothing parameter of 1,600. E(x), SD(x) and AC(x) denote a mean, a standard deviation, and an autocorrelation of x, respectively. COR(x_1, x_2) is a correlation between x_1 and x_2. $\mathcal{E}(x_1, x_2)$ is an elasticity of x_1 to x_2, or the regression coefficient of $\hat{x}_1$ on $\hat{x}_2$

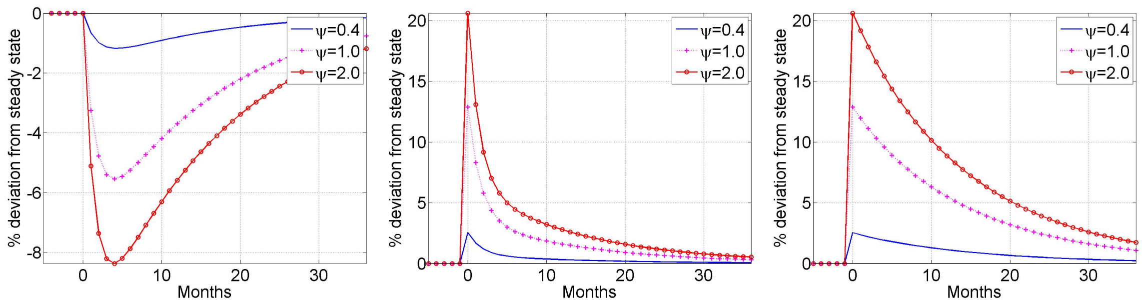
	Data	$\psi = 0.4$	$\psi = 1.0$	$\psi = 2.0$
SD($\hat{u}_t$)	0.129	0.016	0.078	0.129
SD($\hat{v}_t$)	0.143	0.017	0.081	0.137
SD($\hat{\theta}_t$)	0.266	0.029	0.138	0.229
AC($\hat{u}_t$)	0.881	0.802	0.803	0.804
AC($\hat{v}_t$)	0.899	0.416	0.422	0.424
AC($\hat{\theta}_t$)	0.899	0.712	0.712	0.707
COR($\hat{u}_t, \hat{v}_t$)	-0.919	-0.509	-0.507	-0.487
COR($\hat{u}_t, \hat{\theta}_t$)	-0.977	-0.866	-0.863	-0.852
COR($\hat{u}_t, \hat{p}_t$)	-0.232	-0.843	-0.828	-0.817
COR($\hat{v}_t, \hat{\theta}_t$)	0.982	0.871	0.873	0.872
COR($\hat{v}_t, \hat{p}_t$)	0.386	0.889	0.896	0.874
COR($\hat{\theta}_t, \hat{p}_t$)	0.319	0.998	0.994	0.982

observed labor market fluctuations. Note our results are consistent with Petrosky-Nadeau and Zhang (2013a) in that the negative correlation between unemployment and vacancies, or the slope of the Beverage curve, is much lower than that in the results of the previous studies using the log-linearization. Also, we confirm two drawbacks of the MP model: the correlation between tightness and the marginal product of employment is too high, and vacancies are less persistent compared to the data.

Figure 1 shows the impulse response of labor market variables to 1 percent increase in labor productivity. Along the qualitative dimension, the model performs well: in booms, unemployment rate declines and the firm posts more vacancies, boosting labor market tightness. However, the amplification mechanism is very different depending on the magnitude of

Figure 1: Impulse response of labor market variables to 1% increase in productivity

(a) u_t (b) v_t (c) θ_t



utility curvature. 1 percent increase of productivity leads to 20 percent increase of tightness with $\psi = 2.0$. This elasticity is almost 10 times larger than that resulting from $\psi = 0.4$.

4.2 Wage Channel: Procyclical Flow Value of Unemployment

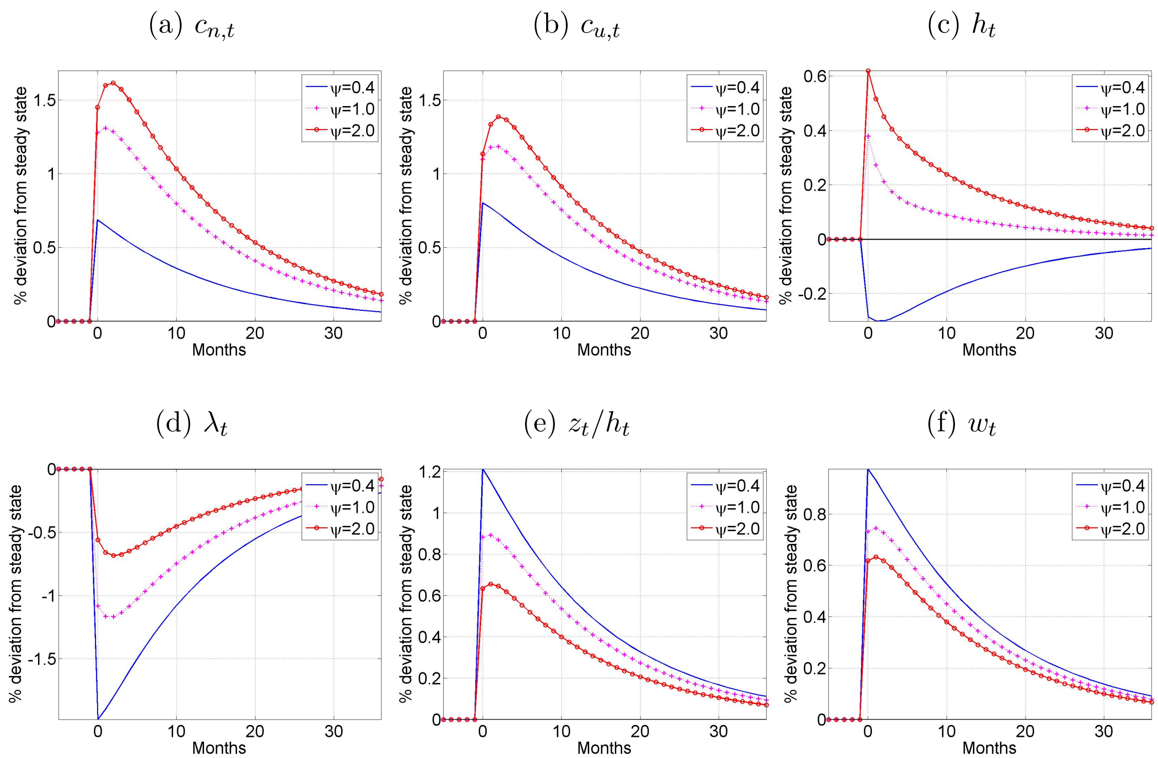
Figure 2 illustrates the impulse response of the flow value of unemployment to 1 percent increase in labor productivity. During expansions, consumption increases and hours worked are raised (when $\psi > 1$)[18], decreasing the marginal utility. This lifts up the flow value of unemployment.

If the EIS becomes higher, changes in consumption is more tolerable. Also, hours worked increase more in response to positive productivity shocks, as the substitution effect more dominates the wealth effect from the higher wage rate. Greater disutility from hours worked more offsets additional utility from larger consumption of the employed, which is manifested by the lower sensitivity of the marginal utility to productivity. Therefore, the higher EIS lessens the elasticity of the flow value of unemployment per a hour with respect to productivity. In sum, smaller utility curvature makes the flow value of unemployment less procyclical and the wage rate more inelastic to productivity.

Table 4 reports the cyclicality of the flow value of unemployment from simulations of the model. The flow value of unemployment is highly procyclical, and as volatile as labor productivity. Consistent with the impulse responses, the higher EIS drops the elasticity

[18]In contrast, $\psi = 0.4$ counterfactually causes hours worked to be countercyclical, as the wealth effect dominates the substitution effect from the higher wage rate. Note the complementarity between consumption and hours does not mean that consumption and hours worked move synchronously.

Figure 2: Impulse response of the flow value of unemployment to 1% increase in productivity



of the flow value of unemployment per a person to the marginal product of employment through weaker movements in the marginal utility of consumption. This leads to larger unemployment fluctuations, as the wage rate becomes more insulated from the driving force.

Following Chodorow-Reich and Karabarbounis (2014), we also compute the data-generated flow value of unemployment by using our utility specification (HM utility). To be specific, (a) we first generate time-series of a ratio of consumption when unemployed to consumption when employed, denoted by $\tilde{\gamma}_t^u$, that makes the first-order conditions for $c_{u,t}$ and $c_{n,t}$ hold exactly in the data, given the parameter values and the data on hours per worker from Cociuba, Prescott, and Ueberfeldt (2012).[19] (b) We obtain consumption series of the employed $\tilde{c}_{n,t}$ by applying the following formula derived from the adding-up identity of the NIPA consumption.

$$\tilde{c}_{n,t} = \frac{c_t^{NIPA}}{\pi_t^n + \pi_t^u \tilde{\gamma}_t^u + \pi_t^o \gamma^o + \pi_t^r \gamma^r} \tag{39}$$

where c_t^{NIPA} is consumption expenditures on non-durable goods and services. π_t^n, π_t^u, π_t^o, and π_t^r are the population ratio of the employed (16 years or older), the unemployed (16

[19]Because hours per worker from Cociuba, Prescott, and Ueberfeldt (2012) is available only up to 2011, we reduce the sample period for this analysis to be from 1951 to 2011.

Table 4: Cyclicality of the flow value of unemployment in the model

$\hat{x}$ is the percent deviation of x_t from its trend. We obtain trends of variables using the HP-filter with a smoothing parameter of 1,600. E(x), SD(x) and AC(x) denote a mean, a standard deviation, and an autocorrelation of x, respectively. COR(x_1, x_2) is a correlation between x_1 and x_2. $\mathcal{E}(x_1, x_2)$ is an elasticity of x_1 to x_2, or the regression coefficient of $\hat{x}_1$ on $\hat{x}_2$

	$\psi = 0.4$	$\psi = 1.0$	$\psi = 2.0$
SD($\hat{z}_t$)	0.010	0.014	0.014
AC($\hat{z}_t$)	0.71	0.71	0.72
COR($\hat{z}_t, \hat{p}_t$)	1.00	1.00	1.00
$\mathcal{E}(z_t, p_t)$	1.37	1.00	0.84
$\mathcal{E}(\lambda_t, p_t)$	-3.23	-1.11	-0.56
$\mathcal{E}(w_t, p_t)$	1.56	0.68	0.48
$\mathcal{E}(u_t, p_t)$	-1.90	-4.69	-6.27

years or older), out of the labor force but of working age (16 to 64 years), the retired (over 65 years), respectively. And γ^o and γ^r are the consumption ratio of out of the labor force and the retired over the employed, respectively. We take $\gamma^o = 0.743$ and $\gamma^r = 0.940$ as in Chodorow-Reich and Karabarbounis (2014). (c) Using $\tilde{c}_{n,t}$ and $\tilde{\gamma}^u_t$, we obtain consumption series of the unemployed $\tilde{c}_{u,t}$. (d) Finally, we compute time-series of the flow value of unemployment.[20] For comparison, we also measure the flow value of unemployment under the utility specification and the parameter values used by Chodorow-Reich and Karabarbounis (2014) (CK utility).[21]

Table 5 reports the cyclicality of the flow value of unemployment estimated by the above procedure. First of all, our results using the CK utility are similar to the original estimations of Chodorow-Reich and Karabarbounis (2014), even though the data sources and the sample period are different.[22] When ψ of the CK utility increases from 0.727 to 1.0 , the flow

[20]Chodorow-Reich and Karabarbounis (2014) show that the mean level of $\tilde{c}_{n,t}$ and $\tilde{c}_{u,t}$ are estimated to be 0.543 and 0.430 relative to the mean level of the marginal product of employment. Therefore, we scale down the consumption series so as to be those figures on average, before computing the flow value of unemployment. Also, we adjust the real output per person to be one on average over the sample period. For simplicity, we set $\eta = 0.041$ and $Q = 0.0$.

[21]See Section 5.2 for more details on the CK utility.

[22]The elasticity of the flow value of unemployment is slightly lower than that in Chodorow-Reich and

Table 5: Cyclicality of the flow value of unemployment in the data

$\hat{x}$ is the percent deviation of x_t from its trend. We obtain trends of variables using the HP-filter with a smoothing parameter of 1,600. E(x), SD(x) and AC(x) denote a mean, a standard deviation, and an autocorrelation of x, respectively. COR(x_1, x_2) is a correlation between x_1 and x_2. $\mathcal{E}(x_1, x_2)$ is an elasticity of x_1 to x_2, or the regression coefficient of $\hat{x}_1$ on $\hat{x}_2$

	CK utility		HM utility		
	$\psi = 0.727$	$\psi = 1.0$	$\psi = 0.4$	$\psi = 1.0$	$\psi = 2.0$
SD($\hat{z}_t$)	0.033	0.043	0.029	0.031	0.032
$\mathcal{E}(z_t, p_t)$	0.90	1.07	0.86	0.78	0.71
	[0.15]	[0.20]	[0.13]	[0.15]	[0.15]
$\mathcal{E}(\lambda_t, p_t)$	-0.44	-0.46	-0.86	-0.33	-0.16
	[0.06]	[0.05]	[0.11]	[0.04]	[0.02]

value of unemployment becomes more procyclical. The reason is that both of the EIS and the complementarity between consumption and hours worked are controlled by only one parameter ψ in the CK utility. Particulary, $\psi = 1$ transforms the CK utility into the log-separable preference, which implies that utility that the employed obtains from consumption is not anymore offset by disutility from hours worked. Excluding non-separability between consumption and hours worked dominates the smaller utility curvature in determining the cyclicality of z_t.

The HM utility shows different outcomes, because its ψ does not affect the non-separability between consumption and hours worked. Higher ψ makes the flow value of unemployment less procyclical by inducing the marginal utility of consumption to be less sensitive to the marginal product of employment. This is consistent with the results from simulated data.

4.3 Discount Rate Channel: Countercyclical Stock Returns

Figure 3 depicts the impulse response of financial market variables to 1 percent decrease in labor productivity. When negative productivity shocks arrive, the stock price plunges, which discounts lower future cash flows at a higher discount rate. As a result, investment in hiring declines. In contrast, the risk-free rate is not affected in the initial period. This

Karabarbounis (2014). It is because Chodorow-Reich and Karabarbounis (2014) correct measurement error for $\hat{p}_t$ by instrumenting with the cyclical component of the unadjusted TFP series of Fernald (2014).

significant drop in the value of stocks relative to bills upon impact coincides with increase in the marginal utility of consumption. In the subsequent period, the risk-free rate falls when $\psi \geq 1.0$, because consumption keeps declining by the strong substitution effect.[23] This corresponds to "flight to quality": the household tries to shift the portfolio towards safer assets. The prices adjust thereafter, as the net supply of the financial assets equals zero in the equilibrium.

When the EIS becomes higher, the households would like to save more, reinforcing the countercyclicality of stock returns. This implies that the amplification mechanism of the discount rate effect also critically depends on the degree of utility curvature; the higher ψ corresponds to larger unemployment fluctuations, as well as greater movements in output and consumption.

Figure 3: Impulse response of financial market variables to 1% decrease in productivity

(a) S_t (b) R^S_t (c) R^f_{t-1}

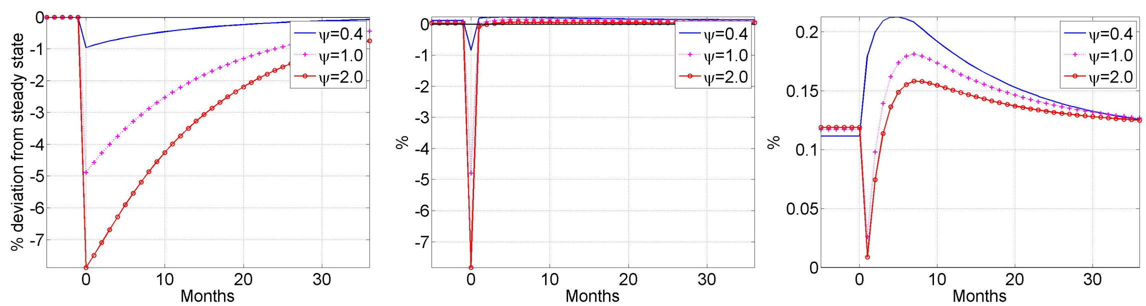


Table 6: Financial market moments

$\hat{x}$ is the percent deviation of x_t from its trend. We obtain trends of variables using the HP-filter with a smoothing parameter of 1,600. E(x), SD(x) and AC(x) denote a mean, a standard deviation, and an autocorrelation of x, respectively. COR(x_1, x_2) is a correlation between x_1 and x_2. $\mathcal{E}(x_1, x_2)$ is an elasticity of x_1 to x_2, or the regression coefficient of $\hat{x}_1$ on $\hat{x}_2$

	Data	$\psi = 0.4$	$\psi = 1.0$	$\psi = 2.0$
$SD(R^f_t)$ (A%)	2.60	2.32	1.32	0.82
$SD(R^S_{t+1} - R^f_t)$ (A%)	18.37	2.00	10.52	16.79
$E(R^S_{t+1} - R^f_t)$ (A%)	7.39	0.06	0.23	0.22

The financial market moments from the model in Table 6 also confirms the relationship

[23]See the persistence of consumptions in Figure 2a and 2b

Table 7: Labor market moments when $z_t = \bar{z}p_t$

$\hat{x}$ is the percent deviation of x_t from its trend. We obtain trends of variables using the HP-filter with a smoothing parameter of 1,600. E(x), SD(x) and AC(x) denote a mean, a standard deviation, and an autocorrelation of x, respectively. COR(x_1, x_2) is a correlation between x_1 and x_2. $\mathcal{E}(x_1, x_2)$ is an elasticity of x_1 to x_2, or the regression coefficient of $\hat{x}_1$ on $\hat{x}_2$

	$\psi = 0.4$	$\psi = 1.0$	$\psi = 2.0$
$\mathcal{E}(z_t, p_t)$	1.00	1.00	1.00
$\mathcal{E}(w_t, p_t)$	1.60	0.69	0.54
$SD(R_t^f)$ (A%)	2.25	1.34	0.77
$SD(R_{t+1}^S - R_t^f)$ (A%)	6.04	10.60	12.55
SD($\hat{u}_t$)	0.050	0.088	0.105
SD($\hat{v}_t$)	0.050	0.090	0.108
SD($\hat{\theta}_t$)	0.087	0.154	0.184

between the EIS and stock returns. The higher ψ shows the larger volatility of the excess stock returns. Particularly, the standard deviation of the excess stock return from $\psi = 2.0$ is close to the data. On the other hand, the higher EIS leads to the lower standard deviation of the risk-free rates with a less desire for consumption smoothing. Many financial studies have difficulty in achieving both the low risk-free rate volatility and the high stock return volatility simultaneously.[24]

To identify the discount rate channel of utility curvature in isolation, we exclude the wage channel by setting $z_t = \bar{z}p_t$, and then recalculate the labor market moments from the model in Table 7. Although the elasticity of the flow value of unemployment to the marginal product of employment equals one across all values of ψ, the higher EIS still involves the more rigid wages, because the bargaining delay costs and the bargaining termination probability bring about wage rigidity together with the more procyclical hours worked. In addition, the stock returns fluctuates further with the higher EIS. Therefore, the higher ψ implies the larger labor market fluctuations.

To verify the magnitude of the effects of the countercyclical stock returns, we exclude the discount rate channel by assuming that the firm discounts future profits with the constant

[24] Jermann (1998), Boldrin, Christiano, and Fisher (2001), Kaltenbrunner and Lochstoer (2010), etc

Table 8: Labor market moments when the firm discounts with β

$\hat{x}$ is the percent deviation of x_t from its trend. We obtain trends of variables using the HP-filter with a smoothing parameter of 1,600. E(x), SD(x) and AC(x) denote a mean, a standard deviation, and an autocorrelation of x, respectively. COR(x_1, x_2) is a correlation between x_1 and x_2. $\mathcal{E}(x_1, x_2)$ is an elasticity of x_1 to x_2, or the regression coefficient of $\hat{x}_1$ on $\hat{x}_2$

	$\psi = 0.4$	$\psi = 1.0$	$\psi = 2.0$
$\mathcal{E}(z_t, p_t)$	1.18	0.96	0.82
$\mathcal{E}(w_t, p_t)$	1.36	0.72	0.51
$\mathcal{E}(u_t, p_t)$	4.62	-1.72	-4.58
SD($\hat{u}_t$)	0.046	0.029	0.092
SD($\hat{v}_t$)	0.048	0.030	0.097
SD($\hat{\theta}_t$)	0.081	0.051	0.164

discount factor in the model: we replace M_{t+1} with β in the equilibrium equations related to the firm, (17), (20), and (34). Table 8 reports the results implied by the alternative assumption. $\psi = 1.0$ and $\psi = 2.0$ present smaller labor market fluctuations than those in the baseline model, which implies that the lack of the discount rate channel reduces unemployment volatility. In the case of $\psi = 0.4$, labor market fluctuations become larger. However, unemployment becomes counterintuitively procyclical, as the sensitivity of unemployment to the marginal product of employment increases positively without the countercyclical stock returns.

4.4 Implications for Elasticity of Intertemporal Substitution

There is a considerable debate in the macroeconomics and finance literature about the magnitude of the EIS. Hall (1988) and Campbell (1999) estimate the EIS to be close to zero using the aggregate data. Attanasio and Weber (1993) also estimate the EIS to be below one using the household-level data, although their estimate is higher than those in the above studies. On the contrary, Attanasio and Vissing-Jorgensen (2003), Gruber (2006), and van Binsbergen, Fernández-Villaverde, Koijen, and Rubio-Ramírez (2012) estimate the EIS to be in excess of one. In addition, many challenge the low EIS, because it incurs counterfactual implications in some models. In the long-run risk model of Bansal and Yaron (2004), the EIS below one causes that higher expected growth and lower uncertainty decrease asset prices. In the disaster-risk model of Gourio (2012) and Nakamura, Steinsson, Barro, and Ursúa (2013), the low EIS induces the risk premium to be procyclical. In our results of the MP model, the following observations provide evidence against low values of the EIS.

First, we regress the quarter $t+1$ consumption growth rate on the quarter t risk-free rate in model-generated data as in Hall (1988). We obtain the EIS estimate of 0.18 with the EIS parameter of $\psi = 2.0$, which is substantially lower than one as Hall (1988) argues.[25] Bansal and Yaron (2004) also obtain an EIS estimate of 0.62 in the long-run risk model with the parameter value of 1.5, while Gourio (2012) gets 0.36 in the disaster risk model with the parameter value of 2.0, respectively. These results support the argument that the regression of Hall (1988) may be misspecified and create the downward bias.

Second, low values of the EIS are inconsistent with the observed behavior of hours worked. It is well-known that hours worked are highly correlated with output and employment.[26] However, Figure 2c illustrates that $\psi = 0.4$ brings bout countercyclical hours worked in contrast to $\psi = 2.0$. We also gain the same outcomes in the models with the Nash wage bargaining (Figure 5b) and with the preference specification of Chodorow-Reich and Karabarbounis (2014) (Figure 6a). The low EIS implies that the wealth effect during booms overwhelms the substitution effect from the higher wage rate, and thus causes labor hours to fall in response to positive productivity shocks. This is not the case with the high EIS.

Third, the low EIS implies the negative autocorrelation of dividends. In Figure 4, dividends in the calibration of $\psi = 0.4$ initially increases in response to positive productivity shocks.[27] However, they decline thereafter, which contradicts to the observed persistence of dividends. In the case of Chodorow-Reich and Karabarbounis (2014), which allows only lower values of the EIS for the complementarity between consumption and hours, dividends initially respond negatively to positive productivity shocks, and thus the stock prices counterintuitively are countercyclical. These results are mainly driven by excessively procyclical wages that cause the firm to experience deficit during booms. This is associated with the strong wealth effect that makes the household save less and the firm invest less in hiring during expansions, weakening the persistence of the firm's profits.

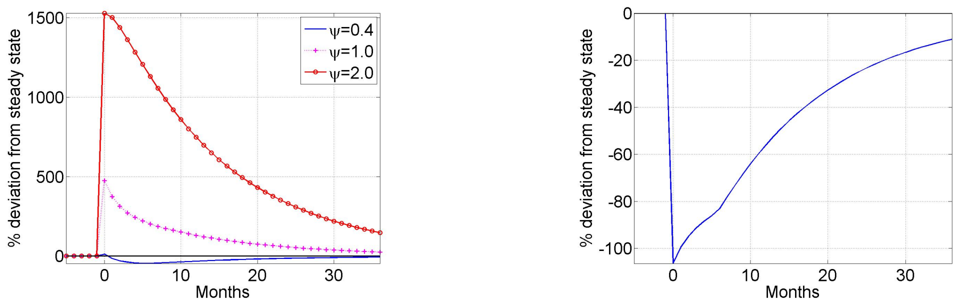
[25]The EIS parameters of $\psi = 0.4$ and $\psi = 1.0$ generate the EIS estimate of 0.06 and 0.15, respectively.

[26]See Ohanian and Raffo (2012) and Nakajima (2012) for more details

[27]The excess responses of dividends to productivity is induced by too high price/dividend ratios generated by the linear production and the assumption of dividends payout policy in the model. The decreasing-return-to-scale production or adding physical capital into production may enable us to generate the realistic level of the price/dividend ratios, which is beyond the scope of the paper.

Figure 4: Impulse response of dividends to 1% increase in productivity for different utilities

(a) Hall and Milgrom (2008) (b) Chodorow-Reich and Karabarbounis (2014)



5 Robustness and Extensions

This section discusses different approaches to modeling, and reports the sensitivity analysis. Section 5.1 shows the results from the Nash wage bargaining model under the standard calibration and the small surplus calibration of Hagedorn and Manovskii (2008). Section 5.2 and 5.3 present the results with the utility used by Chodorow-Reich and Karabarbounis (2014) and the recursive preference of Epstein and Zin (1989), respectively. Section 5.4 discusses the effects of raising the bargaining termination probability, lowering the bargaining delay costs, and making the bargaining delay costs procyclical. Finally, Section 5.5 reports the impacts of adding the fixed component into the vacancy posting costs.

5.1 Nash Wage Bargaining

The standard MP model postulates that the matched worker and the firm split the joint surplus by setting the wage rate through the Nash bargaining. Let $\omega \in (0, 1)$ to be a relative bargaining power of the worker. Then the worker and the firm receive $\omega\Lambda_t$ and $(1-\omega)\Lambda_t$ from the match, respectively. And the equilibrium wage is set by

$$w_t = \frac{1}{h_t}\Big\{\omega\left[x_t h_t + \theta_t \kappa_t\right] + (1-\omega) z_t\Big\} \tag{40}$$

The search literature typically sets ω by appealing to the Hosios (1990) condition that firm entry is socially efficient when the bargaining power of the worker equals the elasticity parameter of the Cobb-Douglas matching function. For example, Shimer (2005) and Pissarides (2009) use $\omega = 0.4$ and $\omega = 0.5$, respectively. In the case of z_t, it is common to use an average ratio of benefits to wages as the proxy. The replacement rates are generally estimated

Table 9: Calibration values for the Nash wage bargaining (monthly)

Parameter	Standard			Hagedorn-Manovskii		
	$\psi = 0.4$	$\psi = 1.0$	$\psi = 2.0$	$\psi = 0.4$	$\psi = 1.0$	$\psi = 2.0$
Preference						
φ	0.7914	1.3115	1.7070	0.7902	1.3110	1.7067
Q	0.360	0.267	0.242	0.916	0.621	0.547
Labor market						
κ		0.453			0.445	
Wage bargaining						
ω		0.5			0.052	

to be 0.2 in the U.S. and 0.7 in Europe. Given these parameter values, the Nash-bargained wages are too closely linked to productivity even with constant z_t. This is the unemployment volatility puzzle suggested by Shimer (2005).

To resolve the puzzle, Hagedorn and Manovskii (2008) proposes the calibration strategy of reducing the worker's bargaining power and pining up the flow value of unemployment close to the marginal product of employment. They set ω and z to match the labor market tightness and the elasticity of wages to the marginal product of employment in the data. In (40), lower ω makes w_t more inelastic to movements in labor market tightness. And higher z_t increases w_t, causing smaller surplus from the match. If z_t is constant, firm's profits, therefore, respond significantly in percentage terms to modest changes in the marginal product of employment. As a result, the firm becomes more inclined to change the number of vacancies frequently.

However, adding the curvature of utility to the MP model makes the flow value of unemployment comove with productivity. In the alternating-offer wage bargaining, the worker's threat is the disagreement payoff that depends not only on z_t but also on ξ and δ. In the Nash wage bargaining, it is, however, the outside option payoff, which reacts flexibly to productivity. Therefore, the procyclical flow value of unemployment causes the Nash-bargained wages even under the the small surplus calibration to be more vulnerable to labor market fluctuations than it does the alternating-offer-bargained wages. Therefore, the Nash-bargained wages not only reduce variations in firm's margin, but also hampers the amplification mechanism of the countercyclical stock return. This depresses firm's incentive

Table 10: Labor and financial market moments in the Nash wage bargaining

$\hat{x}$ is the percent deviation of x_t from its trend. We obtain trends of variables using the HP-filter with a smoothing parameter of 1,600. E(x), SD(x) and AC(x) denote a mean, a standard deviation, and an autocorrelation of x, respectively. COR(x_1, x_2) is a correlation between x_1 and x_2. $\mathcal{E}(x_1, x_2)$ is an elasticity of x_1 to x_2, or the regression coefficient of $\hat{x}_1$ on $\hat{x}_2$

	Standard			Hagedorn-Manovskii		
	$\psi = 0.4$	$\psi = 1.0$	$\psi = 2.0$	$\psi = 0.4$	$\psi = 1.0$	$\psi = 2.0$
SD($\hat{u}_t$)	0.005	0.011	0.016	0.041	0.022	0.076
SD($\hat{v}_t$)	0.005	0.011	0.016	0.042	0.022	0.078
SD($\hat{\theta}_t$)	0.008	0.020	0.027	0.072	0.039	0.133
$\mathcal{E}(\lambda_t, p_t)$	-3.04	-0.93	-0.44	-2.39	-0.96	-0.49
$\mathcal{E}(z_t, p_t)$	1.34	0.95	0.80	1.53	0.96	0.73
E(z_t)	0.705	0.706	0.706	0.969	0.968	0.968
$SD(R_t^f)$ (A%)	2.359	1.361	0.744	2.666	1.327	0.712
$SD(R_{t+1}^S - R_t^f)$ (A%)	0.283	1.223	1.827	6.256	2.872	9.881
$\mathcal{E}(w_t, p_t)$	1.61	0.79	0.64	1.63	0.75	0.49
$\mathcal{E}(u_t, p_t)$	-0.52	-0.65	-0.76	4.33	-1.30	-3.73

to open new vacancies.

To see how the utility curvature affects unemployment fluctuations of the MP model with the Nash-bargained wages, we carry out the same quantitative analysis for the standard calibration and for the small surplus calibration of Hagedorn and Manovskii (2008). The parameter values are listed in Table 9. For the standard calibration, we set the bargaining weight of workers to be $\omega = 0.5$, following Pissarides (2009). And we vary the value of home production Q to set the average flow value of unemployment $z_t = 0.705$. This value is necessary to match the observaed unemployment rate of 5.87%. Finally, we pick the vacancy-posting costs $\kappa = 0.453$ to match the observed tightness of 0.66. For the small surplus calibration, we take $\omega = 0.052$, following Hagedorn and Manovskii (2008). We alter Q for $z_t = 0.968$ that generates the observed unemployment rate. And, we set $\kappa = 0.47$ to match the vacancy/unemployment ratio. Note the original calibration strategy of Hagedorn and Manovskii (2008) is infeasible because of the time-varying z_t from the curvature of utility. Other parameters have the same value as in the calibration of the alternating-offer wage bargaining model in Table 1.

Table 10 reports the statistics of interest computed from the model. Under the standard calibration, the elasticity of w_t to p_t is higher than that in the alternating-offer wage bargaining, even though the elasticity of z_t to p_t is a little lower. Also, the excess stock returns display much weaker volatility. Therefore, unemployment fluctuations are quite small. However, the larger EIS reduces the procyclicality of the flow value of unemployment and increases the countercycicality of the discount rates, confirming the wage channel and the discount rate channel of the utility curvature.

The calibration strategy of Hagedorn and Manovskii (2008) presents similar results to the standard calibration. However, the small surplus generates several interesting differences. First, the elasticity of z_t to p_t becomes more sensitive to the level of the EIS than in the standard calibration. Therefore, w_t from $\psi = 2.0$ reacts more significantly in percentage term to p_t, which leads to larger unemployment fluctuations. Second, $\psi = 0.4$ shows larger labor market volatility than $\psi = 1.0$. However, this result comes from the counterfactual mechanism: unemployment declines in recessions because of the excessive response of wages to productivity. Figure 5 illustrates the impulse response of labor market variables to 1% increase in productivity under the calibration of Hagedorn and Manovskii (2008). In the case of $\psi = 0.4$, the strong desire for consumption smoothing and the small surplus causes the elasticity of w_t to x_t to be well over one. Moreover, hours worked decline in response to positive productivity shocks. Therefore, firm's margin falls in booms, dropping vacancies.

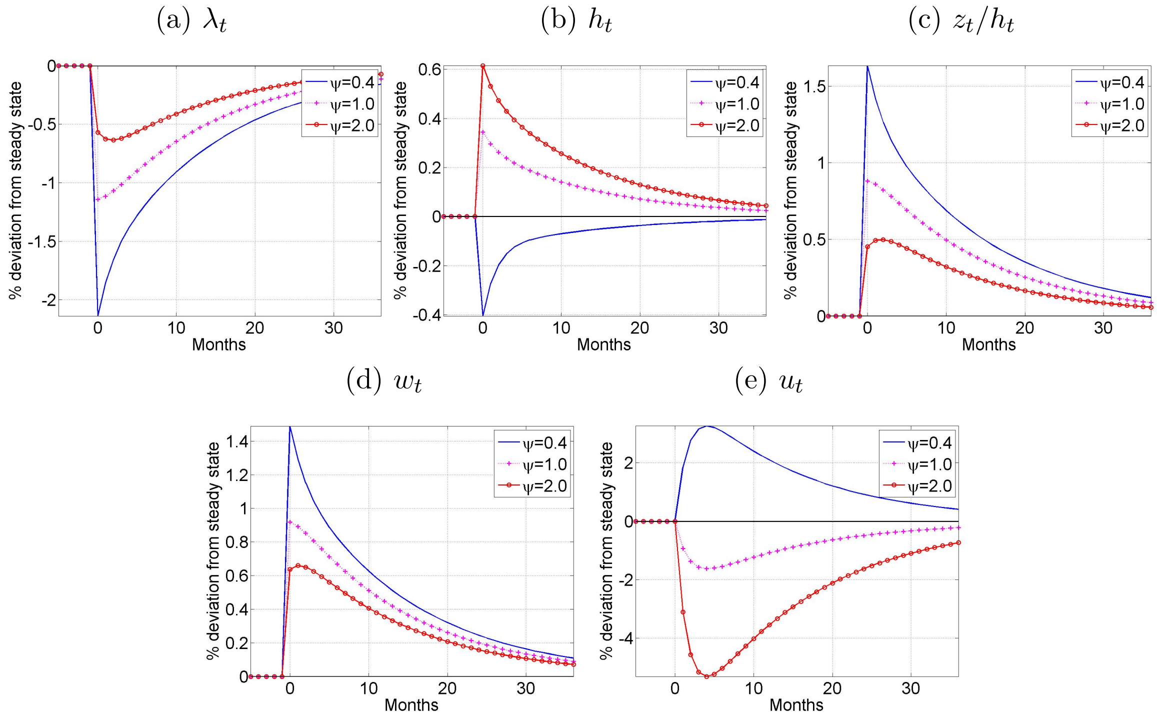
5.2 Utility of Chodorow-Reich and Karabarbounis (2014)

To measure the flow value of unemployment from the observed data, Chodorow-Reich and Karabarbounis (2014) adopt the following utility specification. (Shimer, 2010; Trabandt and Uhlig, 2011)

$$U_t(c_t, h_t) = \frac{1}{1-1/\psi}\left[c_t^{1-1/\psi}\left(1 - \frac{(1-1/\psi)\varphi}{1+1/\chi}h_t^{1+1/\chi}\right)^{1/\psi} - 1\right] + Q \qquad (41)$$

ψ determines both the EIS and the non-separability between consumption and hours worked. And the Frisch elasticity of labor supply is constant at χ. Other parameters play the same role as in the baseline utility specification of (7): φ decides the disutility of hours worked,

Figure 5: Impulse response to 1% increase in productivity in Hagedorn and Manovskii (2008)

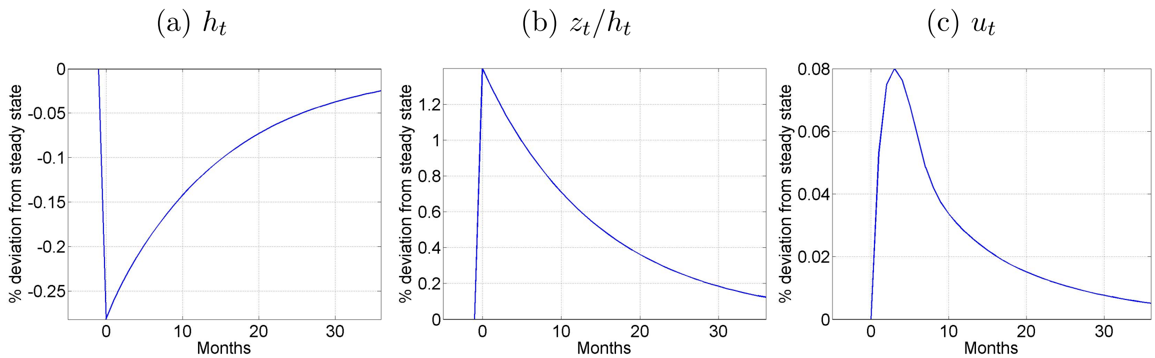


and Q parameterizes the additional utility from home production. Note $\psi < 1$ is required to make the marginal utility of consumption higher when workers work more. In addition, higher ψ implies both smaller curvature of the utility function and the less complementarity between consumption and hours worked at the same time. The less costs of adjusting consumption with higher ψ alleviate the procyclicality of z_t. On the other hand, more separability between consumption and hours worked restricts counteracting increase in the marginal utility from smaller consumption during recessions by reducing hours worked, which elevates the procyclicality of z_t. Therefore, this utility function not only is inappropriate to analyze the effects of adjusting the EIS on unemployment fluctuations, but also implies the high procyclicality of the flow value of unemployment regardless of the magnitude of the EIS.

With the quantitative analysis, we also derive the labor market volatility implied by the CK utility. Following Chodorow-Reich and Karabarbounis (2014), we take $\psi = 0.7267$ and $\chi = 0.7$. Chodorow-Reich and Karabarbounis (2014) use this value of ψ to target levels of consumptions, $c_n = 0.543$ and $c_u = 0.430$. Therefore, we include the additional consumption parameter $c_0 = 0.4$ in the resource constraint (38) to generate those levels of consumptions on average inside the model. c_0 can be interpreted as consumption expenditures by the out-of-labor-force and the government. Other parameters are chosen under the same calibration strategy as before.[28]

Consistent with the results with the HM utility of the low EIS, the CK utility counterfactually features the negative response of hours worked to positive productivity shocks in Figure 6a. In addition, the CK utility induces the flow value of employment to be quite procyclical in Figure 6b and the first column of Table 11. This intensifies the sensitivity of the wage rate to the marginal product of employment and subdues the discount rate effect. As a result, the CK utility involves extremely low labor market volatility.

Figure 6: Impulse response to 1% increase in productivity in Chodorow-Reich and Karabarbounis (2014)



5.3 Recursive Preference

From (35) and (37), we can derive the following equation for the expected excess stock returns.

$$\mathbb{E}_t\left[R^S_{t+1}\right] - R^f_t = -\frac{COV\left[\lambda_{t+1}, R^S_{t+1}\right]}{\mathbb{E}_t\left[\lambda_{t+1}\right]} \tag{42}$$

From the main results, we have seen that the excess stock returns show significant volatility. In addition, stocks pay off poorly during recessions, when consumption is low. Thus, (42) implies that stocks must yield a considerable return-premium over bills in normal times to get the household to hold them. However, the household is able to absorbs productivity shocks to stock prices not only with changes in consumption of the employed and the unemployed, but also with changes in hours.[29] Therefore, the average excess stock returns are much lower

[28] $Q = 0.818$ and $\varphi = 1.7169$ are selected inside the model.

[29] Swanson (2012) shows that risk aversion can vary depending on the household's labor margin.

Table 11: Sensitivity Analysis

$\hat{x}$ is the percent deviation of x_t from its trend. We obtain trends of variables using the HP-filter with a smoothing parameter of 1,600. E(x), SD(x) and AC(x) denote a mean, a standard deviation, and an autocorrelation of x, respectively. COR(x_1, x_2) is a correlation between x_1 and x_2. $\mathcal{E}(x_1, x_2)$ is an elasticity of x_1 to x_2, or the regression coefficient of $\hat{x}_1$ on $\hat{x}_2$

	CK utility	Recursive preference	Higher δ	Lower ξ	Procyclical ξ	Fixed vacancy posting costs
$\mathcal{E}(\lambda_t, p_t)$	-2.69	-0.56	-0.49	-0.55	-0.48	-0.61
$\mathcal{E}(z_t, p_t)$	1.55	0.84	0.80	0.82	0.81	0.85
E(z_t)	0.704	0.706	0.744	0.744	0.706	0.706
$SD(R_t^f)$ (A%)	2.26	0.83	0.73	0.81	0.72	0.95
$SD(R_{t+1}^S - R_t^f)$ (A%)	0.38	16.82	9.32	16.27	7.82	15.16
$E(R_{t+1}^S - R_t^f)$ (A%)	-0.01	0.25	0.11	0.22	0.09	0.18
$\mathcal{E}(w_t, p_t)$	1.48	0.48	0.57	0.49	0.58	0.50
$\mathcal{E}(u_t, p_t)$	0.06	-6.29	-3.54	-6.07	-2.97	-8.11
SD($\hat{u}_t$)	0.001	0.129	0.071	0.124	0.060	0.166
SD($\hat{v}_t$)	0.001	0.137	0.073	0.132	0.062	0.183
SD($\hat{\theta}_t$)	0.001	0.230	0.126	0.221	0.107	0.302

than in the data as in Table 6. To see whether higher risk aversion raises the expected excess stock returns, we extend the baseline model by adding the recursive preference of Epstein and Zin (1989): we replace (5) with the following household problem.

$$J_t = \max_{c_{n,t}, c_{u,t}} n_t U_t(c_{n,t}, h_t) + u_t U_t(c_{u,t}, 0) + \beta \left(\mathbb{E}_t \left[J_{t+1}^{1-\gamma} \right] \right)^{\frac{1}{1-\gamma}} \tag{43}$$

where γ determines the risk aversion separately from ψ. The stochastic discount factor is then given by

$$M_{t+1} = \frac{\partial J_t / \partial c_{u,t+1}}{\partial J_t / \partial c_{u,t}} = \beta \left(\frac{\lambda_{t+1}}{\lambda_t} \right) \left(\frac{J_{t+1}}{\mathbb{E}_t [J_{t+1}^{1-\gamma}]^{\frac{1}{1-\gamma}}} \right)^{-\gamma} \tag{44}$$

In the second column of Table 11, the results with the recursive preference of $\gamma = 10.0$ and $\psi = 2.0$ is essentially the same as the baseline outcomes, indicating that the ability of the household to absorb shocks along consumption and labor margins depresses the risk premium despite the high volatility of stock prices. This result implies that we cannot appeal to the perfect consumption insurance to generate the observed level of the equity premium in the MP model with the intensive margins of labor supply.

5.4 Wage Bargaining Parameters

The bargaining termination probability δ and the bargaining delay costs ξ are the critical parameters to induce the wage rate to be partially isolated from productivity even under the procyclical flow value of unemployment. To evaluate their importance in the model, we compute model moments with $\psi = 2.0$ for alternative parameter values for δ and ξ. First, we increase δ to 0.1, rather than 0.03 in the baseline calibration. This requires Q to increase from 0.241 to 0.286 for matching the observed unemployment rate. In the third row of Table 11, the volatility of labor market variables becomes substantially smaller, even though the response of the flow value of unemployment to the marginal product of employment varies little. δ affects the wage rigidity meaningfully, because it directly controls the relative contribution of the flow value of unemployment over the continuation values in the alternating-offer-bargained wage. Second, we reduce ξ from 0.2850 to 0.2444, which is necessary to have the same value of $Q = 0.286$ and the same unemployment rate as in the case of lowering δ. Although the influence from the countercyclical marginal utility of consumption becomes larger through Q/λ_t, lowering ξ does not affect markedly abor market volatility in the fourth row of Table 11. The results are robust to change in ξ, because ξ is only a part of components that affect the continuation values.

The alternating-offer-bargained wages are relatively insensitive to productivity because ξ is assumed to constant independent of productivity. To evaluate the importance of this assumption, we replace ξ with $\xi_t = \xi p_t$, which implies the elasticity of the bargaining delay costs to the marginal product of employment equals one. In the fifth column of Table 11, the procyclical bargaining delay costs increase the sensitivity of the wage rate to the marginal product of employment, and, therefore, diminishes labor market fluctuations. Unemployment volatility is, however, still much higher than that in the standard calibration of the MP model, although the setting of ξ_t results in rather extreme procyclicality. We leave it for future research to assess the level of the bargaining termination probability and the cyclicality of the bargaining delay costs empirically using microeconomic data.

5.5 Fixed Component in Vacancy Posting Costs

Under the constant vacancy posting costs $\kappa_t = \kappa$, the marginal cost of hiring in the left-hand side of (20) is κ/q_t. Because the vacancy-filling rate is decreasing in labor market tightness ($q'(\theta_t) < 0$), the marginal cost of hiring is quite procyclical, which hinders the firm from holding more vacancies during booms. This is the outcome of the congestion externalities that the household and the firm do not internalize the adverse effects of their search decisions on the labor market. To reduce the procyclicality of the marginal cost of hiring, Mortensen and Nagypál (2007) and Pissarides (2009) suggest the fixed component in the vacancy posting costs, as follows.

$$\kappa_t = \kappa_v + \kappa_f q_t \tag{45}$$

Under the above specification, the marginal cost of hiring involves a proportional component κ_v/q_t and a fixed component κ_f. Because κ_f makes yields on posting vacancies less countercyclical, it tends to improve the performance of the MP model. To confirm this intuition, we replace $\kappa = 0.268$ with $\kappa_v = 0.17$ and $\kappa_f = 0.14$ in the baseline calibration with $\psi = 2.0$, and carry out the same quantitative analysis. Note this does not change the model's performance for matching the calibration targets. In the final column of Table 11, the fixed component boosts labor market fluctuations substantially, even though it lowers the volatility of the excess stock returns. Note Hall (2014) also reaches similar conclusion that the fixed component of the vacancy posting costs help lowering the implied volatility of the discount rate to account for a realistic increase in unemployment during recessions.

6 Conclusion

This paper embeds the curvature of utility into the MP model with both extensive and intensive margins of labor supply, and shows that the EIS plays an important role to accounting for the observed unemployment volatility. The high EIS undermines wages from absorbing all of productivity shocks by diminishing the procyclicality of the flow value of unemployment. It also widens variations in the expected discounted payoffs from hiring a new worker by reinforcing the countercyclicality of stock returns. Therefore, high values of the EIS are necessary to replicate the labor market fluctuation in the data.

The MP model, including our model, has the well-known shortcoming that the correlation of labor market tightness and productivity is too high compared to the data, which is often overlooked in the literature. As a result, the equilibrium wage is required to be insulated both from productivity and labor market tightness to resolve the unemployment volatility puzzle. However, the employment evolution condition (4) indicates that unemployment fluctuates only by movements in labor market tightness.[30] If we model the sluggish response of labor market tightness to productivity (Fujita and Ramey, 2007), the equilibrium wage is necessary to be inelastic only to labor market tightness. Then, the Nash-bargained wages under the small surplus calibration and the alternating-offer-bargained wages with the procyclical bargaining delay costs may produce larger unemployment volatility than in our results. The link between the weak amplification of unemployment volatility and the lack of internal propagation in the MP model could be an important research direction.

[30]The following equation is equivalent to the employment evolution condition (4) and $n_t = 1 - u_t$.

$$u_{t+1} = \phi(1 - u_t) + (1 - f(\theta_t))u_t \tag{46}$$

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