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The Business Cycle with Nominal Contracts and Search Frictions*

Weh-Sol Moon†

Abstract

I construct a dynamic stochastic general equilibrium (DSGE) model characterized by flexible prices, search frictions, and nominal wage contracts, and examine to what extent the model can explain the quantitative business cycle properties of real macroeconomic variables in the U.S. economy. I consider efficient bargaining that the firm and the worker enter into bargaining over the future nominal hourly wage rate and future hours worked under the generalized Nash bargaining framework. The Nash product is assumed to consist of the discounted present value of the expected match surplus. Under efficient bargaining, the model hardly produces unrealistically high volatility of real variables or countercyclical productivity because hours per worker are fixed ahead of time and employment is a slow-moving variable with search frictions. Moreover, efficient bargaining requires firms to rely on job creation heavily to adjust the wedge between the marginal product of labor and the real wage rate in response to shocks. As contract length increases, the volatilities of the unemployment rate and vacancy rate increase significantly, but those of output and total hours worked do not appreciably change. I also investigate the model under different assumptions such as the right-to-manage approach, the Nash product with the current value of match surplus, and instantaneous hiring. Efficient and forward-looking bargaining are important in accounting for the U.S. business cycle properties.

Keywords: Business Cycles, Search Frictions, Nominal Wage Contracts, Efficient Bargaining

JEL Classifications: E24, E32

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1 Introduction

This study investigates a dynamic stochastic general equilibrium (DSGE) model that contains flexible prices, search frictions, and nominal wage contracts (Cho and Cooley 1995). Janko (2008) argues that the equilibrium business cycle model with wage contracts, which was motivated by the work of Gary (1976) and Fischer (1977), does not capture the business cycle statistics of the US economy. This argument considerably limits the theory. Nominal rigidities improve monetary transmission and amplification mechanisms when nominal wage contracts are incorporated into real business cycle models. However, these models lead to unrealistically high volatility among real variables and countercyclical productivity. In this paper, a model economy with wage contracting is examined to show that search frictions and efficient bargaining have important roles in overcoming model limitations.

I follow the existing assumption by adhering to the future nominal wage rate. However, my approach differs with regard to the contract regime. The nominal wage rate in Cho and Cooley (1995) is derived from the decision rule of the model without contract by assuming that the contract wage rate is the expected market-clearing level of the wage rate. However, I derive the contract wage counterpart from the solution to a forward-looking Nash bargaining problem. This component is important in explaining why firms and workers enter into nominal contracts. In my model, wage contracts are based on bargaining conducted by workers and firms because of the coordination failure raised by labor market frictions.

Forward-looking bargaining is also important in matching the volatility of vacancies with nominal wage contracts and matching the contributions of intensive and extensive margins of labor hours to total hours worked. I consider an alternative bargaining problem to examine the role of forward-looking bargaining. In this problem, the Nash product consists of the current surplus of each party. Moreover, only currently employed workers and operating firms enter into bargaining. In the current surplus bargaining model, the bargaining power of a worker varies with contract length in the steady state. The steady-state nominal wage rate decreases and per-period profits increase significantly with contract length. These features are not observed in the forward-looking bargaining model. A substantial increase in the steady-state value of per-period profits dampens the volatilities of per-period profits and vacancies.

This paper also investigates why the incorporation of nominal wage contracts into the equilibrium business cycle model does not lead to results that match US data. In doing so, the importance of labor market frictions and efficient bargaining is emphasized. This approach reveals unexamined information in literature. Under the nominal contracting arrangements following Cho and Cooley (1995), employees and firms agree on the nominal hourly wage rate in advance. Furthermore, firms are free to choose employment on the hours margin at the wage rate. This approach is referred to as the right-to-manage (RTM) approach. Under the RTM framework, firms adjust to shocks during the contract period by choosing hours to equate the marginal product of labor to the realized real wage. Consequently, the volatilities of hours worked and output are unrealistically high. This issue is raised not only for the flexible price model but also for the New Keynesian model. Christoffel et al. (2009) examine a New Keynesian model with staggered wages and report that the model, combined with an RTM assumption, does not replicate the dynamics of hours worked because hours per worker are too volatile relative to data. On the other hand, the existing RTM framework does not allow employment to have an effort dimension despite being able to better capture actual labor contracts.[1] If labor input varies because of responses in effort and hours, the effect of wage rigidities on hours worked can be offset by variations in effort at work.[2] Therefore, I assume that efficient bargaining is a reasonable approximation for bargaining. Under efficient bargaining, the nominal wage rate and work hours are jointly determined. Little attention has been paid to the role of labor market frictions with efficient bargaining as a way to resolve an unrealistic degree of real variable volatility. Hence, this paper contributes to the further study of this issue.[3]

The model no longer generates unrealistically high volatility among real variables and countercyclical productivity when efficient bargaining and nominal wage contracts are incorporated into the flexible price model. Among all the models with different contract lengths, the volatilities of output and total hours worked are less than those found in US data. Moreover, productivity remains procyclical during the business cycle. The volatilities of unemployment rate and vacancy rate rise significantly with increasing contract length.

Efficient bargaining requires firms to rely on job creation heavily to adjust the wedge between the marginal product of labor and the real wage rate in response to technology and monetary shocks because hours per worker are fixed ahead of time. After the realizations of shocks, vacancies increase

[1] Among others, see Trigari (2006) and Christoffel and Kuester (2008).

[2] Using a DSGE model with endogenous effort, Bils and Chang (2003) show that workers are willing to trade off exertion and hours in production.

[3] Krause et al. (2008) analyze a DSGE model with price rigidities, search frictions and efficient bargaining. But they do not investigate the relationship between nominal wage rigidities and the volatility of output through efficient bargaining.

sharply and unemployment decreases. Given that hours per worker are fixed because of efficient bargaining, an increase in total hours worked is driven primarily by employment. However, employment per se is unable to generate large fluctuations of output because employment is dictated by a law of motion in the search and matching framework.

With regard to productivity, technology shocks and monetary shocks notably play different roles in the model. Although technology shocks directly affect both individual and aggregate outputs, monetary shocks indirectly increase aggregate output by expanding the number of matched firms. The output response to monetary shocks is slightly less than the response of total hours worked. Hence, productivity falls in response to monetary shocks. With regard to technology shocks, which remain extremely strong with increasing contract length, the output response is much greater than the response of total hours worked. Thus, productivity becomes procyclical for both shocks.

Several papers in real business cycle literature have studied the implications of nominal wage contracts in the transmission of monetary shocks. Cho (1993) first examines the quantitative implications of one-period nominal wage contracts. Cho and Cooley (1995) study the properties of model economies with nominal wage contracts. Cho et al. (1997) quantitatively estimate the welfare cost of nominal wage contracting. Janko (2008) provides empirically plausible labor adjustment costs to the equilibrium business cycle model with wage contracting to overcome several shortcomings that are present with nominal wage rigidities. However, Janko (2008) does not discuss unemployment and vacancies.

With respect to labor market frictions, Merz (1995) and Andolfatto (1996) first bring the concept into a real business cycle model. Shimer (2005) discusses the lack of an amplification mechanism in the context of the search and matching model of Mortensen and Pissarides (1994). Shimer (2005) finds that the wage bargaining process is a source of inability that amplifies shocks. The bargaining wage is extremely volatile because it absorbs most of the shocks. Therefore, the cyclical movements in the incentives of firms to hire are dampened. Consequently, Hall (2005) proposes real wage rigidity, which allows firms to achieve cyclical movements in their incentives to create jobs. Following Shimer (2005) and Hall (2005), numerous studies have introduced real and nominal wage rigidities into the DSGE models.[4] To my knowledge, the current paper is the first work that revitalizes DSGE models

[4]Krause and Lubik (2007), Gertler and Trigari (2009), and Blanchard and Galí (2010) focus on real wage rigidities based on the New-Keynesian DSGE model. Most studies employ Hall (2005)'s notion of a wage norm, but Gertler and Trigari (2009) assume that in each period a subset of firms and workers renegotiate wage contracts, and modify the conventional Mortensen and Pissarides (1994) model to allow for Calvo-type staggered wage contracts. On the other

characterized by nominal wage contracts in a frictional labor market environment.

This paper is organized as follows. Section 2 presents the model and shows how the nominal wage rate is derived. Section 3 discusses the calibration and steady-state properties of the model. Section 4 quantifies the model, presents the results, and compares the benchmark model with various versions of the model. Section 5 concludes.

2 Model

The model economy used in this paper is a variant of the models of Mortensen and Pissarides (1994) and Cho and Cooley (1995), which consists of households, firms, and government.

2.1 Households

A representative household consists of a continuum of expected-utility-maximizing infinitely lived individuals with a measure of one. Each member has time-separable preferences over his/her consumption $c_t(i)$ and her labor supply $(h_t(i), n_t(i))$. Each person may be either employed by a firm $n_t(i) = 1$ with the hours of work $h_t(i)$ or unemployed $n_t(i) = 0$. The period utility of each member is given by the following:

$$\begin{cases} \ln c_t(i) - B\frac{1}{1+\phi} h_t(i)^{1+\phi} & \text{if } n_t(i) = 1, \\ \ln c_t(i) & \text{if } n_t(i) = 0, \end{cases}$$

where $1/\phi$ denotes the elasticity of intertemporal substitution of leisure. Following Merz (1995), I assume that the household serves as a full insurance mechanism by pooling the resources of all its members. The household allocates total consumption to maximize the sum of household utility, which can be obtained by equalizing the marginal utility of consumption of each household member. The household, which makes all members obtain an identical consumption bundle, serves a utility function

$$E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \ln c_t - B\frac{h_t^{1+\phi}}{1+\phi} n_t \right\},$$

where $0 < \beta < 1$ is a discount factor, c_t is consumption, h_t is hours worked by each employed household member, and n_t is the fraction of employed household members.

hand, Gertler et al. (2008) and Galí (2010) incorporate nominal wage rigidities into the New-Keynesian DSGE model. Notice that nominal wage rigidities are introduced in the form of staggered nominal wage setting à la Calvo.

Households in this economy are required to hold money to purchase consumption goods and face a cash-in-advance constraint with the following form:

$$c_t \leq \frac{\widetilde{m}_{t-1} + T_t}{\widetilde{P}_t},$$

where $\widetilde{m}_{t-1}$ is money carried over from the previous period, T_t is the lump-sum money transfer, and $\widetilde{P}_t$ is the price level in period t.

The budget constraint of the representative household can be expressed as follows:

$$c_t + i_t + \frac{\widetilde{m}_t}{\widetilde{P}_t} \quad = \quad \frac{\widetilde{W}_t^{t-j}}{\widetilde{P}_t} n_t h_t^{t-j} + (1 - n_t)\, b + r_t k_t + \pi_t + \frac{\widetilde{m}_{t-1} + T_t}{\widetilde{P}_t},$$

where i_t denotes investment in capital (k_t); n_t is the fraction of employed household members; $\widetilde{W}_t^{t-j}$ and h_t^{t-j} are the nominal hourly wage rate and work hours, respectively, determined in period $t - j$ through bargaining; b is household production; r_t is the real rental rate of capital; π_t is the profits received by household from firms. The issue of how bargaining occurs over nominal wages and hours worked will be further analyzed in the next section.

Employment n_t evolves according to the following law of motion:

$$n_{t+1} = (1 - s)\, n_t + f_t\, (1 - n_t)\,,$$

where s denotes an exogenous separation rate in which employees lose their jobs each period. The existing workforce at the beginning of period $t + 1$ is denoted by $(1 - s)n_t$ and new hires entering into employment agreement in period $t + 1$ are denoted by $f_t\,(1 - n_t)$, where f_t is the job-finding probability of a worker.

2.2 Firms

A firm (or entrepreneur) produces output $\overline{y}_t$ by using capital $\overline{k}_t$ and hours h_t^{t-j} under the following technology:

$$\overline{y}_t = z_t \overline{k}_t^{\alpha} \left(h_t^{t-j}\right)^{\theta},$$

where z_t is an aggregate productivity shock and h_t^{t-j} is the hours of work determined through bargaining in period $t - j$. Without loss of generality, we can conveniently assume that a single firm or entrepreneur corresponds to each worker. Therefore, the number of employees is 1 in the production technology of an individual firm. The productivity shock follows an AR(1) process in logs:

$$\ln z_t = \rho_z \ln z_{t-1} + \varepsilon_t^z,$$

where ε_t^z is a normal random variable with mean zero and variance σ_z^2. Technology shock is recognized at the beginning of each period before decisions are made.

The expected discounted sum of real profits for an individual firm is given by the following:

$$J_t = z_t \overline{k}_t^{\alpha} \left(h_t^{t-j}\right)^{\theta} - \frac{\widetilde{W}_t^{t-j}}{\widetilde{P}_t} h_t^{t-j} - r_t \overline{k}_t + \beta \Big\{ (1-s) E_t \left[\psi_{t+1} J_{t+1}\right] + s E_t \left[\psi_{t+1} \mathcal{O}_{t+1}\right] \Big\}, \tag{1}$$

where $\psi_{t+1} \equiv \mu_{t+1}/\mu_t$ and $\mathcal{O}_{t+1}$ is the value of a vacancy in period $t+1$. I assume that matched firms and workers bargain on the nominal hourly wage rate and work hours. Given the hours of work, the firms choose the amount of capital.

The value of a vacancy $\mathcal{O}_t$ is given by the following:

$$\mathcal{O}_t = -\kappa + \beta \big\{ q_t E_t \left[\psi_{t+1} J_{t+1}\right] + (1 - q_t) E_t \left[\psi_{t+1} \mathcal{O}_{t+1}\right] \big\},$$

where q_t is the probability that each vacancy will be filled and κ is the cost of posting a vacancy. Under equilibrium with no entry barrier, the value of a vacancy must be zero:

$$\kappa = \beta q_t E_t \left[\psi_{t+1} J_{t+1}\right]. \tag{2}$$

2.3 Government

The government budget constraint for each period is expressed as follows:

$$T_t = M_t - M_{t-1},$$

where T_t is the lump-sum money transfer and M_t is the stock of money.[5] The government budget constraint implies that money is injected into the economy through lump-sum transfers. If g_t denotes

[5] As in Cooley and Hansen (1995), I set government spending and nominal government debt to zero for all t.

the (gross) growth rate of money between periods $t-1$ and t, money is assumed to grow at rate $g_t - 1$:

$$M_t = g_t M_{t-1}.$$

The growth rate of money g_t is known at the beginning of each period. The lump-sum money transfer T_t is then equal to $(g_t - 1) M_{t-1}$. The growth rate g_t is assumed to evolve according to the following AR(1) process in logs:

$$\ln g_t = \rho_g \ln g_{t-1} + \varepsilon_t^g,$$

where ε_t^g is a normal random variable with mean zero and variance σ_g^2. I assume that ε_t^g is independent of ε_t^z.

2.4 Matching

In this economy, another technology describes how matches occur. The so-called matching technology or matching function can be expressed as follows:

$$\mathcal{M}(u_t, v_t) = \eta u_t^{\xi} v_t^{1-\xi},$$

where $\mathcal{M}(u_t, v_t)$ is the total number of matches or hires, u_t is the number of unemployed workers, and v_t is the aggregate number of vacancies. Assuming that the size of the labor force is fixed and normalized to unity, the number of unemployed workers is $u_t = 1 - n_t$. The probability a firm fills its vacancy q_t is given by the following:

$$q_t = \frac{\mathcal{M}(u_t, v_t)}{v_t}.$$

The probability an unemployed worker finds a job f_t is expressed as follows:

$$f_t = \frac{\mathcal{M}(u_t, v_t)}{u_t}.$$

2.5 Resource Constraint

Finally, the aggregate resource constraint is obtained by combining the equilibrium budget constraint of the household and the value of the firm under the binding cash-in-advance constraint:

$$c_t + k_{t+1} + \kappa v_t = y_t + (1-\delta)\, k_t,$$

where $y_t = n_t \overline{y}_t$ is the sum of the output produced by the matched firms and $k_t = n_t \overline{k}_t$ is the sum of the capital stock of an individual firm.

2.6 Transformation

All consumption mechanisms for household members are equal through full insurance arrangements. I focus on the representative household's problem in equilibrium. To obtain stationary variables in equilibrium, I divide all nominal variables, namely, $\widetilde{m}_t$, $\widetilde{P}_t$, and $\widetilde{W}_t^{t-j}$, by the aggregate money stock M_t. The maximization problem of the representative household is expressed as follows:

$$\max E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \ln \left(\frac{m_{t-1} + g_t - 1}{g_t P_t} \right) - B \frac{(h_t^{t-j})^{1+\phi}}{1+\phi} n_t \right\} \tag{3}$$

subject to

$$\begin{aligned} \frac{m_t}{P_t} + k_{t+1} &= \frac{W_t^{t-j}}{P_t \Pi_{i=1}^{j} g_{t+1-i}} n_t h_t^{t-j} + (1-n_t)\, b + (r_t + 1 - \delta)\, k_t + \pi_t \\ n_{t+1} &= (1-s)\, n_t + f_t\, (1-n_t)\,, \end{aligned}$$

where $P_t \equiv \widetilde{P}_t / M_t$, $W_t^{t-j} \equiv \widetilde{W}_t^{t-j} / M_{t-j}$, and $m_{t-1} \equiv \widetilde{m}_{t-1} / M_{t-1}$. Note that the expression $\Pi_{i=1}^{j} g_{t+1-i}$ links the real hourly wage rate to the monetary shocks realized between period $t-j$ and period t.[6]

The representative household aims to choose contingent plans for $\{k_{t+1}, m_t\}$, which takes the nominal hourly wage rate and work hours as given. The first-order conditions for the maximization imply the following:

$$\begin{aligned} \mu_t &= \beta E_t \left[\frac{1}{c_{t+1}} \frac{P_t}{g_{t+1} P_{t+1}} \right], \\ \mu_t &= \beta E_t \left[\mu_{t+1} \left(r_{t+1} + 1 - \delta \right) \right], \end{aligned}$$

[6] Let me define $\Pi_{i=1}^{j} g_{t+1-i} = 1$ if $j = 0$.

where μ_t is the marginal utility of income in period t, that is, the multiplier attached to the budget constraint. In equilibrium, $m_t = M_t = 1$. The equilibrium cash-in-advance constraint implies that consumption is the reciprocal of the price level:

$$c_t = \frac{1}{P_t}.$$

I denote V_t as the worker's surplus when another household member is employed:[7]

$$V_t = \frac{W_t^{t-j}}{P_t \Pi_{i=1}^{j} g_{t-i+1}} h_t^{t-j} - b - B\frac{(h_t^{t-j})^{1+\phi}}{1+\phi}\frac{1}{\mu_t} + \beta\left(1-s-f_t\right) E_t\left[\frac{\mu_{t+1}}{\mu_t}V_{t+1}\right]. \tag{4}$$

For the value of a matched firm, Eqs. (1) and (2) provide the following expression:

$$J_t = (1-\alpha)\, z_t \overline{k}_t^{\alpha}\left(h_t^{t-j}\right)^{\theta} - \frac{W_t^{t-j}}{P_t \Pi_{i=1}^{j} g_{t-i+1}} h_t^{t-j} + (1-s)\frac{\kappa}{q_t}. \tag{5}$$

Given the hours of work, the first-order condition with respect to $\overline{k}_t$, which equalizes the marginal product of capital to its rental rate, is expressed as follows:

$$r_t = \alpha z_t \overline{k}_t^{\alpha-1}\left(h_t^{t-j}\right)^{\theta}.$$

The per-period profits $\overline{\pi}_t$ is given by the following:

$$\overline{\pi}_t = (1-\alpha)\, z_t \overline{k}_t^{\alpha}\left(h_t^{t-j}\right)^{\theta} - \frac{W_t^{t-j}}{P_t \Pi_{i=1}^{j} g_{t-i+1}} h_t^{t-j}.$$

2.7 Bargaining over Wages and Hours

The nominal wage contract established in this section follows the study of Cho and Cooley (1995). The nominal wage contract states that agents agree to a contract arranged for j periods ahead at the beginning of each period. For example, consider $j = 2$. At t, workers and firms agree to a nominal wage rate for period $t + 2$ and firms pay to employees the nominal wage rate agreed in period $t - 2$. At $t + 1$, workers and firms agree to a wage rate for period $t + 3$. The firms then pay to employees the

[7]The worker's surplus can be obtained by taking the derivative of the indirect utility function of the household with respect to n_t subject to the budget constraint and the law of motion for employment. It is expressed in terms of current consumption of final goods.

nominal wage rate agreed upon in period $t-1$. This process is repeated over time.

Efficient bargaining is assumed once the labor market is characterized by search frictions. In this approach, the firm and worker enter into bargaining over the nominal hourly wage rate and hours worked under the generalized Nash bargaining framework. The nominal hourly wage rate W_{t+j}^t and hours worked h_{t+j}^t in time $t+j$ are agreed upon in period t by both parties, where the hourly wage rate and hours worked jointly maximize the Nash product after the aggregate shocks are realized:

$$\left(W_{t+j}^t, h_{t+j}^t\right) = \arg\max \left(\beta^j E_t \frac{\mu_{t+j}}{\mu_t} V_{t+j}\right)^{\gamma} \left(\beta^j E_t \frac{\mu_{t+j}}{\mu_t} J_{t+j}\right)^{1-\gamma}, \tag{6}$$

where γ denotes the worker's bargaining power in wage negotiations and the surpluses for a matched worker and firm are given by Eqs. (4) and (5), respectively. At the time of the contract, the nominal wage is paid to all employees and employees supply the work as specified in the contract. Under this nominal wage contract rule, new hires are paid the same nominal wage rate that is predetermined through bargaining between firms and workers.

The first-order conditions with respect to the nominal hourly wage rate W_{t+j}^t and hours of work h_{t+j}^t at time $t+j$ are expressed by the following:

$$(1-\gamma) E_t \left[\frac{\mu_{t+j}}{\mu_t} V_{t+j}\right] = \gamma E_t \left[\frac{\mu_{t+j}}{\mu_t} J_{t+j}\right], \tag{7}$$

$$B \left(h_{t+j}^t\right)^{\phi} \frac{1}{\mu_t} = E_t \left[\frac{\mu_{t+j}}{\mu_t} \theta z_{t+j} \overline{k}_{t+j}^{\alpha} (h_{t+j}^t)^{\theta-1}\right]. \tag{8}$$

The nominal hourly wage rate chosen by a firm–worker match is derived from the expected discounted surplus of firms and workers. The hours of work are chosen by the match such that the marginal rate of substitution between consumption and leisure is equated to the expected discounted value of the marginal product of labor. In this paper, the economies are approximated by the log-linearization around the steady state because models with nominal contracts cannot be solved analytically.

I also consider the following alternative bargaining problem:

$$\left(W_{t+j}^t, h_{t+j}^t\right) = \arg\max V_t^{\gamma} J_t^{1-\gamma}. \tag{9}$$

Unlike Eq. (6), wherein firms negotiate with all potential workers who will be working in period $t+j$ regardless of current employment status, Eq. (9) assumes that currently operating firms negotiate only with currently employed workers.

Under the alternative bargaining problem, the first-order conditions with respect to the nominal hourly wage rate and hours of work at time $t+j$ $(j \geq 1)$ are expressed as follows:

$$\begin{aligned}
&\gamma J_t E_t \left[\frac{\mu_{t+j}}{\mu_t} \frac{h_{t+j}^t}{P_{t+j} \prod_{i=1}^j g_{t+i}} \prod_{i=1}^{j} (1 - s - f_{t+i-1}) \right] \\
&\quad = (1-\gamma) V_t E_t \left[\frac{\mu_{t+j}}{\mu_t} \frac{h_{t+j}^t}{P_{t+j} \prod_{i=1}^j g_{t+i}} (1-s)^j \right], \qquad (10) \\
&\gamma J_t E_t \left[\frac{\mu_{t+j}}{\mu_t} \prod_{i=1}^{j} (1 - s - f_{t+i-1}) \left\{ B \left(h_{t+j}^t\right)^{\phi} \frac{1}{\mu_{t+j}} \right\} \right] \\
&\quad = (1-\gamma) V_t E_t \left[\frac{\mu_{t+j}}{\mu_t} (1-s)^j \left\{ \theta z_{t+j} \overline{k}_{t+j}^{\alpha} (h_{t+j}^t)^{\theta - 1} \right\} \right]. \qquad (11)
\end{aligned}$$

The hours of work determined through bargaining equate the expected discounted value of the marginal rate of substitution between leisure and consumption with the expected discounted value of the marginal product of labor.[8]

With regard to the steady state under the alternative bargaining problem, the steady-state nominal wage rate varies with changing contract length. The matched firms and households place different weights on the continuation values because of the different probabilities of the continuation of their employment relationships. In the steady state, contract length determines those probabilities. The steady-state nominal wage rate satisfies the following for $j \geq 1$:

$$\gamma J (1 - s - f)^j = (1-\gamma) V (1-s)^j .$$

I call the model with bargaining problem of Eq. (6) the *benchmark model* and the model with bargaining problem of Eq. (9) the *current surplus bargaining model*.

3 Calibration

I set the discount factor β to .99 to imply an interest rate of 1% per quarter. The capital's share of total income α is calibrated to be .33, and δ is set equal to .025. I assume that the technology of the

[8]The log-linearized versions of the hours of work are equalized for Eq. (6) and Eq. (9).

representative firm exhibits decreasing returns-to-scale. Thus, I set $\alpha+\theta$ to .9.[9] The worker's bargaining power in wage negotiations γ is set to .5, and household production b is set to approximately 40% of the steady-state (real) bargaining wage. The elasticity of the matching function ξ is set to .5; this value is consistent with literature. I set the steady-state value of the worker's job-finding probability f to .6 to imply an average duration of unemployment of 1.67 (Cole and Rogerson 1990). The steady-state unemployment rate u is set to 6% per quarter. Moreover, the labor force size is normalized to unity. Given the job-finding rate and employment rate, the exogenous separation s is made constant from the steady-state version of the law of motion for employment $n = f/(s+f)$ such that $s = .0383$. The steady-state level of hours worked h is normalized to 1/3, and utility parameter B is adjusted accordingly. Following Cho and Cooley (1995), I set the intertemporal substitution elasticity of leisure to .5, thus implying $\phi = 2$. This value is extremely close to Chang and Kim (2006).

The parameters governing the money growth rate, namely, ρ_g and σ_g, are set to .49 and .00623, respectively (Cooley and Quadrini 1999). Finally, parameters ρ_z and σ_z, which control the process for technology shocks, are set to .95 and .007, respectively. These values are commonly used in related literature. Table 1 summarizes the set of parameters used in the simulation.

I follow Shimer (2005) by calibrating household production b to 40% of the steady-state real compensation per employee $\frac{W}{p}h$, that is, $b = .4\frac{W}{p}h$. The steady-state real bargaining wage W/P is given by 2.01. Hence, the value of household production is .27. The endogenously determined parameter of the utility function B is 24.87. Therefore, disutility from working in terms of current consumption of final goods is .22.[10] The sum of household production and disutility from working is equal to .49, which corresponds to the flow utility from leisure or nonmarket activity in the standard search and matching model. The benchmark model generates the capitalized value of a matched job J of .277 and production per period net of capital cost $(1-\alpha)\,\overline{k}^{\alpha}h^{\theta}$ of .68. Note that the surplus from employment V is equal to J because the worker's bargaining power is set to .5. Thus, per-period profits $(\overline{\pi})$ and vacancy posting cost (κ) are given by .013 and .165, respectively.

[9] This assumption is not critical in this study, but is made for the comparison with the model economies with wage bargaining only (the right-to-manage approach). The value of a matched firm becomes zero under the RTM approach if the firm's technology exhibits constant returns-to-scale.

[10] See Appendix for the steady-state conditions for the benchmark model.

4 Findings

I investigate the extent in which the model economy with wage contracts, as well as frictional labor markets, amplify monetary and real shocks (Cho and Cooley 1995). Table 2 presents the standard deviations of output and other key variables of interest. To evaluate predictive accuracy, I first present the relevant statistics obtained from quarterly US data between 1956 and 2005. The output measure (y) is production (real output) in the non-farm business sector. Consumption (c) is the sum of the personal consumption expenditures of nondurables and services, which are deflated by the associated price indexes plus real government consumption expenditures. Investment (i) is the sum of the real private domestic investment and real personal consumption expenditures of durables. Employment (n) is measured by using the quarterly average number of non-farm employees. Hours (h) are the average weekly hours for the non-farm business sector. Unemployment (u) is the quarterly averages of monthly data from the Current Population Survey. Vacancy (v) is the quarterly average of monthly help-wanted indexes constructed by the Conference Board. The real wage (w) is the real hourly compensation in the non-farm business sector. Finally, the level of price (P) is measured by the CPI divided by $M1$ money stock for consistency with the counterpart of the model. All data are seasonally adjusted and HP filtered with smoothing parameter 1,600.

The summary statistics for the models subject to both monetary and technology shocks, monetary shock only, and technology shock only are presented. Statistics for the model economies are computed by simulating for 200 periods and by repeating the simulation 1,000 times.[11] This approach highlights the role of each shock and enables the determination of the relative importance of each shock with the introduction of nominal wage contracts and search frictions.

4.1 Wage Contracts and Role of Search Frictions

I begin by investigating a DSGE model with money and nominal rigidity following Cho and Cooley (1995). I also introduce search frictions into the model in which firms choose the amount of hours, such as Trigari (2006), Christoffel and Kuester (2008), and Christoffel and Linzert (2010). Blanchard and Fischer (1989) argue that actual labor contracts appear only to set wages and leave the employment decision to the firm. This approach is referred to as the RTM approach, wherein the firm and union bargain over the wage, and the firm chooses employment freely to maximize profit. Hence, Cho and

[11] I generate a set of artificial time-series data of the length of 1,000 periods and drop the first 800 periods.

Cooley (1995) examine nominal contracts with the RTM approach.

From a DSGE model with money and nominal contracts following Cho and Cooley (1995), I find unrealistically high fluctuations in output and total hours worked upon the incorporation of nominal wage contracts.[12] In the case of two-period contracts, output is more than twice as volatile as in the model without contracts. Table 2 shows that the volatility of output increases from 1.30 for no contract to 2.83 for two-period contracts. On the other hand, total hours worked in the two-period contract case fluctuate more than output. The relative volatility of total hours worked is 1.30 for two-period contracts, which is greater than .46 for no contract. These dramatic increases in volatility are attributed to the RTM approach and the strong monetary transmission mechanism induced by nominal wage contracts.

Under the nominal contracting arrangements in Cho and Cooley (1995), households and firms enter into a wage contract and agree upon the nominal wage set in advance. The workers are assumed to cede the firm the right to determine the aggregate hours, thus leaving firms to maximize profits. The firms adjust to shocks during the contract period by choosing total hours worked Q_t to equate the marginal product of labor to the realized real wage as follows:

$$\frac{W_t^c}{P_t} = (1-\alpha)\, z_t k_t^{\alpha} Q_t^{-\alpha}, \tag{12}$$

where W_t^c denotes the specified equilibrium nominal wage and $Q_t = n_t h_t$. Nominal wage and total hours worked become highly volatile even for relatively minor shocks upon the introduction of nominal contracts. This increase can be attributed to the response of firms to shocks by choosing aggregate hours worked along Eq. (12). Consequently, the volatilities of total hours worked and output are unrealistically high.

In the model with contracts, monetary shocks play significant roles in generating high volatilities in output and other variables compared with technology shocks as contract length increases. For instance, the volatility of output by both shocks is 3.60 for the case of four-period contracts. The volatility of output driven only by monetary shocks is 3.09. Hence, a sizable share is explained by monetary shocks.

Table 3 reports the correlations with output. One of the notable features of the model characterized by the RTM setup is that total hours worked are strongly positively correlated with output. The

[12] See Appendix for a detailed description of the model.

correlations of total hours worked with output are .94 and .96 for two-period contracts and four-period contracts, respectively. On the other hand, the correlation of labor productivity with output becomes negative with nominal contracts. Although positive technology shocks cause higher labor productivity, a positive shock to the money growth rate decreases nominal and real wages. The cyclical behavior of labor productivity and real wages are identical. Thus, labor productivity becomes countercyclical.[13] Procyclical total hours worked and countercyclical labor productivity imply a negative correlation between labor productivity and aggregate labor.

I introduce search frictions into the model with money and nominal contracts and assume that bargaining occurs over the nominal hourly wage rate only to maximize the Nash product:

$$W_{t+j}^{t} = \arg\max \left(\beta^{j} E_t \frac{\mu_{t+j}}{\mu_t} V_{t+j}\right)^{\gamma} \left(\beta^{j} E_t \frac{\mu_{t+j}}{\mu_t} J_{t+j}\right)^{1-\gamma}.$$

The resulting optimality condition with respect to the nominal wage rate is the same as Eq. (7). The employment decision is left to the firm. Hence, the amount of hours worked is chosen by the firm. The condition states that hours per worker are determined to equate the marginal product of labor with the bargained wage:

$$\frac{W_t^{t-j}}{P_t \prod_{i=1}^{j} g_{t-i+1}} = \theta z_t \overline{k}_t^{\alpha} h_t^{\theta-1},$$

where the left-hand side is the real bargained wage and the right-hand side is the marginal product of labor. Unlike frictionless labor markets wherein firms choose total hours worked ($Q_t = n_t h_t$), employment (n_t) in frictional labor markets is a state variable and not an individual firm's choice variable. The cyclical changes in real wages induced by both technology and monetary shocks are absorbed mainly by the movements of hours per worker. Therefore, the high volatility of total hours worked is predicted.

Another feature is the lack of an amplification mechanism associated with fluctuations in unemployment and hiring activity. Under the RTM approach, period profits of matched firms are given by $(1-\alpha-\theta) z_t \overline{k}_t^{\alpha} h_t^{\theta}$, which can be expressed as follows:

$$\left(\frac{1-\alpha-\theta}{\theta}\right) \frac{W_t^{t-j}}{P_t \prod_{i=1}^{j} g_{t-i+1}} h_t. \tag{13}$$

[13] Bils and Chang (2003) also show that a model with sticky wages but no effort response predicts a strong negative relationship between labor productivity and hours worked.

Wage costs are proportional to the revenue and per-period profits; thus, the percentage fluctuations in wages are equal to the percentage fluctuations in per-period profits. If wages per employee $\frac{W_t^{t-j}}{P_t \prod_i^j g_{t-i+1}} h_t$ do not fluctuate significantly over the business cycle, per-period profits will not fluctuate enough to generate incentives for the firms to create jobs. Table 2 shows that the model with wage bargaining only is unable to amplify the effect of shocks on unemployment and vacancies.

Table 2 presents the standard deviations of output and other variables. The results from the model with wage bargaining only are similar to those from the model without search frictions. Hours per worker and total hours worked fluctuate more than output and their data counterparts. For example, in the four-period contract case, hours worked and total hours worked fluctuate more than one and a half times output. The volatility of output also rises with increasing contract length because hours worked are volatile. Table 2 also shows that the model with RTM bargaining fails to amplify the effect of technology and monetary shocks on unemployment and vacancies over the business cycle. In the four-period contract case, the relative standard deviations of unemployment and vacancies are .21 and .39, respectively.

With regard to correlations with output, the model with search frictions along with RTM bargaining also predicts that total hours worked are significantly positively correlated with output, labor productivity is negatively correlated with output, and labor productivity and total hours worked move in opposite directions (Table 3).

The results show that the model characterized by the RTM regime is unable to account for reasonable fluctuations in real variables and correlations with output over the business cycle regardless of the existence of search frictions. I employ the model with search frictions and efficient bargaining in this study. The nominal wage rate and hours of work are jointly determined in this model.

4.2 Wage Contracts and Efficient Bargaining

Table 5 presents the results from the benchmark model with period-by-period wage bargaining. The results show that labor market variables have low volatility. Compared with the output volatility, the relative standard deviations of total hours worked (nh), unemployment (u), and vacancies (v) are .26, .94, and 1.78, respectively. Hence, the model in which the nominal wage rate and hours of work are Nash-bargained in every period lacks amplification mechanisms.[14] This result is consistent

[14]In order to have highly volatile labor market variables, Cooley and Quadrini (1999) set the worker's bargaining power (or the sharing parameter in their paper) in the range of 0.01-0.1. Decreasing this parameter leads to the higher

with that of Galí (2010), who states that realistic labor market frictions have limited effects on the equilibrium dynamics of the economy. The benchmark model shows that monetary shocks are not propagated in this economy. Technology shocks generate most of the observed volatility in output (y). The benchmark model with both shocks produces essentially the same results as the model with technology shocks only.

When search frictions and efficient bargaining are considered in the model, nominal wage contracts increase the volatility of variables but do not produce unrealistically high volatilities in output and total hours worked. In the four-period contract case, the volatility of output and the relative volatility of total hours worked are 1.03 and .43, respectively. As regards labor market variables, nominal wage contracts result in high degrees of volatility. The volatilities of employment (n), unemployment, and vacancies increase to .41, 6.35, and 15.66 under the four-period contract scenario, respectively. The corresponding effect on the volatilities of unemployment and vacancies is notably large.

Table 5 also shows that nominal wage contracts along with efficient bargaining play important roles in amplifying monetary shocks. In the case of four-period contracts, monetary shocks have more weight in generating fluctuations in employment, unemployment, and vacancies than technology shocks. The effect of monetary shocks on the volatilities of the labor market variables, including real wages, is more significant than the effect of technology shocks.

Under efficient bargaining, the introduction of nominal wage contracts slightly decreases the volatility of output from 1.09 to 1.01 for two-period contracts because hours worked are predetermined through bargaining. All else being equal, the volatility of hours worked plays an important role for capturing the volatility of output. The hours of work for the multi-period contract case are less dependent on the state variables, including shock components, than those for the period-by-period contract case. For example, in the case of two-period contracts, the hours of work in period $t+2$ are determined in period t when workers and firms form their expectations about the shocks to be realized two periods

volatility of both employment and unemployment. Note that the weaker bargaining power workers hold, the more rigid real wages become when the worker's period value from unemployment is not time-varying. Hagedorn and Manovskii (2008) also set the worker's bargaining power to .052 in their proposed calibration strategy. As discussed by Hagedorn and Manovskii (2008), the the bargaining weight parameter determines the volatility of real wages. All else being equal, lower values of the bargaining parameter imply more cyclical real wages and less cyclical profits. The purpose of this paper is not to account for the cyclical properties of unemployment and vacancies, but to show that the search and matching model with nominal wage contracts and efficient bargaining is able to predict a low volatility of hours worked and output as well as generate procyclical productivity.

later. The log-linearized model expresses hours worked as follows:

$$(\phi + 1 - \theta)\,\widehat{h}_{t+2}^{t} = E_t\widehat{\mu}_{t+2} + E_t\widehat{z}_{t+2} + \alpha E_t\widehat{\overline{k}}_{t+2}.$$

Given that all shocks have zero mean, the second term of the right-hand side representing the expected value of future technology shocks is equal to $\rho_z^2\widehat{z}_t$. Moreover, under the rational expectations assumption, the current state variables become less persistent. The hours of work for multi-period contracts are also less dependent on the state variables, thus generating less volatile work hours and leading to less volatile output (Table 5).

Nominal wage contracts and efficient bargaining lead to significant changes in the relative volatility of real wages. None of the models with different contract lengths is able to match the relative volatility observed in US data. For example, for four-period contracts, the real wage rate depends on the nominal wage rate determined in period $t-4$, monetary shock components, and other state variables. With increasing contract length, the long-term monetary shocks realized from $t-4$ through t lead to significant fluctuations in the real wages.

Table 6 shows the correlations with output. Under the RTM setup, I observe that productivity is negatively correlated with total hours worked and that real wages and productivity are negatively correlated with output (Table 3). By contrast, the benchmark model with different contract lengths correctly predicts a positive correlation between output and productivity, with .97 for two-period contracts and .90 for four-period contracts. However, in response to monetary shocks, productivity exhibits a countercyclical behavior. This countercyclical behavior becomes strong with increasing contract length. If monetary shocks dominate, countercyclical productivity will occur.

The last column of Table 6 shows the correlation between productivity and total hours worked. The correlation coefficient of .98 supports a strong positive relationship with total hours worked in the benchmark model of period-by-period bargaining. However, correlation decreases with increasing contract length. The correlation simulated from the model with four-period contracts (i.e., .15) is close to the observed level from the data (i.e., .27). The real wage rate is highly procyclical in the benchmark model of period-by-period bargaining with a correlation of .99 but its procyclicality weakens with increasing contract length. The correlation between output and real wages is .02 for four-period contracts; thus, real wages appear acyclical.

The model predicts the low volatility of hours worked (h), and the volatility of hours worked relative to employment (n) decreases with increasing contract length. This reduction in volatility comes at the expense of reducing the correlation of output and hours per worker and the correlation of output and employment. A trade-off between the capability of the model to match volatilities and its capacity to generate correlations is emphasized.

Although models with nominal wage contracts and efficient bargaining overcome the limitations observed in Cho and Cooley (1995) successfully, the setup predicts the weak correlations of unemployment and vacancies with output as contract length increases. The correlations of unemployment and vacancies are $-.84$ and .90 for period-by-period bargaining, respectively, but are $-.49$ and .18 for four-period contracts, respectively. Nevertheless, the model with four-period contracts shows significant negative correlations of unemployment for each shock, with $-.99$ for monetary shocks and $-.71$ for technology shocks. [15] A similar trade-off between correlations and volatilities is apparent in unemployment and vacancies with increasing contract length. Compared with the model of the RTM regime or other models investigated in the following sections, this trade-off does not seem to be common to all models with nominal rigidities.

Table 7 shows the correlations with unemployment. For different contract lengths, the model can account for a negative relationship between unemployment and total hours worked. The correlation between unemployment and total hours worked in the model with four-period contracts is $-.93$, which is close to the level seen in the US data (i.e., $-.94$). As contract length increases, the volatilities of employment and unemployment become more driven by monetary shocks than technology shocks, whereas hours worked remain less volatile for either shock. Thereafter, the cyclical behavior of total hours worked is explained mainly by the cyclical behavior of employment, that is, employment moves in the opposite direction of unemployment over the business cycle.

The model is unable to produce a negative relationship between unemployment and vacancies (i.e., the Beveridge curve). To observe the Beveridge relationship, unemployment should be significantly countercyclical and vacancies should be significantly procyclical. All the models investigated in this paper do not generate such features successfully. Moreover, the benchmark model predicts a positive relationship between unemployment and real wages. The correlation is $-.13$ for the US economy over the last 50 years, whereas the correlation is .21 for two-period contracts and .69 for four-period

[15] As contract length increases, vacancies are more correlated with output for monetary shocks only and similarly correlated for technology shocks only. When both shocks are in place, however, the aggregate correlation somehow goes down. This can happen because both positive shocks produce counteractive effects on the correlations of output with vacancies as in Table 6. The impulse response functions in Figure 1 also show these counteractive effects.

contracts. The results are different from the data, but the model with technology shocks only predicts a weak negative correlation between unemployment and real wages.

Impulse Response Functions

This study investigates how shocks are propagated by nominal contracts and efficient bargaining in the model economy. For several key variables, such as output, hours worked, and productivity, the impulse response functions for innovations in monetary shocks and technology shocks are shown in Figure 1. The two-period and four-period contracting economies, as well as the economy with period-by-period efficient bargaining, are displayed in Figure 1.

The impulse response functions to innovations in technology shock are shown in Figure 1(a). With regard to output, total hours worked, and productivity, the model economy with nominal contracts does not increase the propagation of technology shocks dramatically. However, for unemployment and vacancies, the model is able to propagate technology shocks. Under efficient bargaining, per-period profits of matched firms (Eq. (13)) fluctuate significantly in response to shocks. Thus, the incentives generated by an increase in per-period profits lead the firms to post vacancies.

The second panel (Figure 1(b)) shows the impulse response functions to innovations in monetary shocks. The model economy with period-by-period efficient bargaining confirms the fact that the basic real business cycle model characterized by frictional labor markets does not propagate monetary shocks at all. However, the introduction of nominal wage contracts makes a significant difference. In response to monetary shocks, output and total hours worked exhibit a hump-shaped pattern. In the two-period and four-period contracting economies, the response of total hours worked is slightly greater than the response of output. Thus, productivity falls. Considering the nominal wage rate and hours of work through bargaining, innovations in monetary shocks have a strong negative effect on real wages, thus decreasing real wages. This situation in turn increases the incentive of firms to post vacancies. As a consequence of monetary shocks, vacancies increase and unemployment decreases.

Sensitivity Analysis

I report a sensitivity analysis conducted to examine the robustness of results to the use of other parameter values. I consider different values of γ to represent the bargaining power of workers, different values of ξ to represent the matching function elasticity with respect to unemployment, and different values of θ to represent the hours elasticity of the production function.

Figure 2(a) shows that the volatilities of output, total hours worked, unemployment, and vacancies rise sharply with increasing worker bargaining power. However, this phenomenon does not occur for the model with period-by-period bargaining. A high value of γ with four-period contracts produces unrealistically volatile unemployment and vacancies. If the bargaining power of workers is strong under efficient bargaining, a relatively small amount of rigidity will be necessary to cause the real side of the economy to generate the volatilities of the magnitude observed.

When considering correlations, the contemporaneous relationships among output, hours, and productivity are sensitive to a significant change in γ in the four-period contract case (Figure 2(b)). In the four-period contract case, the strong positive correlations between output and hours per worker and between output and productivity disappear when the bargaining power of workers is close to one. Furthermore, the weak positive relationship between productivity and total hours worked becomes a negative correlation.

Figure 3 shows the results of a sensitivity analysis conducted with respect to matching function elasticity. Figure 3(a) shows that the volatilities of output, total hours worked, unemployment, and vacancies increase with decreasing unemployment elasticity. Similar to the bargaining power of workers, this phenomenon occurs only to the model with nominal rigidity. For example, a low ξ value with four-period contracts leads to large fluctuations in unemployment and vacancies. The positive correlation coefficients between output and hours per worker and between output and productivity decrease substantially with low ξ values (Figure 3(b)).

Figure 4 shows the results of a sensitivity analysis with respect to the labor share that determines the returns-to-scale of the production function. The benchmark parameter is set to .66; thus, the production function exhibits decreasing returns-to-scale of .99. Unlike the sensitivity analyses with respect to the bargaining power of workers or the matching function elasticity, a change in the labor share does not show a noticeable change in the volatilities of key variables and the contemporaneous correlations among them. Under the RTM approach, the production function should have decreasing returns-to-scale; otherwise, the value of a matched firm is zero and the firm has no incentive to post a vacancy. The assumption of a decreasing returns-to-scale production function is required under the RTM approach. However, Figure 4 shows that the restriction is unnecessary under efficient bargaining.

Contract length really matters because a sensitivity analysis depends on contract length. The results are more likely to be sensitive to the changes in parameter values with increasing contract length. Nevertheless, the simulation results are insensitive to the slight changes in parameter values around the benchmark calibration.

4.3 Bargaining over Current Surplus

In this subsection, I consider an alternative bargaining problem under which the Nash product consists of the current surplus of each party (Eq. (9)). Only currently employed workers and currently operating firms enter into bargaining and negotiate over the current joint surplus.

One of the major differences in bargaining over current surplus compared with bargaining over future surplus is that some probabilities are attached to the first-order condition with respect to the nominal hourly wage (Eq. (10)). The probabilities attached to the current surplus of firms denote the weights on the future match surplus of workers. The probabilities attached to the current surplus of workers denote the weights on the future match surplus of firms. This result leads to an interesting feature that the steady-state bargaining wage rate depends on the exogenous separation rate and job-finding probability, which play important roles in decreasing the actual bargaining power of workers with increasing contract length. The steady-state nominal wage rate satisfies the following equation:

$$\left[\gamma\left(\frac{1-s-f}{1-s}\right)^{j}\right] J = (1-\gamma)\, V,$$

where γ denotes the ex-ante bargaining power of workers and j denotes the contract length. When contract length increases, the actual bargaining power of workers decreases. Thus, the steady-state nominal wage rate decreases. However, the match surplus of firms increases with contract length because per-period profits increase. In the steady state, I observe that per-period profits significantly rise with increasing contract length. Per-period profits are .075 for two-period contracts and .214 for four-period contracts.

An increase in the steady-state value of per-period profits decreases the volatilities of per-period profits and vacancies. Table 5 shows that real wages and hours worked fluctuate significantly with increasing contract length. Thus, the real compensation per employee $w_t h_t$ also fluctuate significantly.[16] However, an increase in the volatility of the real compensation per employee is attenuated by the increase in the steady-state value of per-period profits. This phenomenon can be understood by ex-

[16] The standard deviation of the real compensation per employee increases from 1.65 for two-period contracts to 2.18 for four-period contracts.

amining the percentage fluctuations in per-period profits $\widehat{\pi}_t$:

$$\widehat{\pi}_t = \frac{\overline{y}}{\pi}\left(\widehat{y}_t - \widehat{n}_t\right) - \frac{r\overline{k}}{\pi}\left(\widehat{r}_t + \widehat{k}_t - \widehat{n}_t\right) - \frac{wh}{\pi}\left(\widehat{w}_t^{t-j} + \widehat{h}_t^{t-j}\right),$$

where variables with hats denote log deviations from their steady-state values. The coefficient on the real compensation per employee wh/π plays an important role in decreasing the amplitude of fluctuations in per-period profits. The coefficient is 8.19 for two-period contracts, but decreases to 2.20 for four-period contracts because the nominal wage rate decreases and per-period profits increase significantly in the steady state. The decrease in the coefficient dominates the increase in volatility of the compensation per employee. Thus, per-period profits and vacancies fluctuate less for four-period contracts than for two-period contracts.

The second moments of variables from the model with bargaining over current surplus are shown in the second panel of Table 5 to 7. Compared with the results from the model with bargaining over discounted expected future surplus, the model with bargaining over current surplus seems to have similar quantitative implications. Nevertheless, the current surplus bargaining model has a limitation on matching the volatility of vacancies with nominal wage contracts and matching the contributions of intensive and extensive margins of labor hours to total hours worked. However, the benchmark model with forward-looking Nash bargaining performs better in such dimensions. When hours worked are fixed ahead of time through forward-looking Nash bargaining, firms have to rely on job creation more heavily to adjust the marginal product of labor in response to shocks.

4.4 Instantaneous Hiring

In the standard search and matching model, a one-period lag is observed between hiring and employment. For the model economy analyzed in this study, a one-period lag is equivalent to a lag of three months because the model runs at quarterly. Given that the nominal wage rate and hours of work are predetermined through bargaining, economic activity does not respond in the period when the shocks occur. Thus, I introduce instantaneous hiring into the model and examine how much of the attenuation in output fluctuations is driven by a lag between hiring and employment.

Following Blanchard and Galí (2010) and Krause et al. (2008), I assume that vacancies are filled immediately by paying the hiring cost. Separation occurs at the beginning of period t. Job searchers in period t consist of those who separate at the beginning of period t and those who are unemployed at the end of period $t-1$. Job searchers can be expressed as follows:

$$u_t^o = 1 - n_{t-1} + s \cdot n_{t-1},$$

where $1 - n_{t-1}$ denotes the unemployed at the end of period $t-1$ and $s \cdot n_{t-1}$ denotes workers who separate at the beginning of period t. The beginning-of-period job searchers u_t^o find employment with probability f_t and start working in the same period. The standard measure of unemployment is expressed by the following:

$$u_t = 1 - n_t.$$

I make a distinction between unemployment u_t and beginning-of-period job searchers u_t^o. The job-finding probability is given by the following:

$$f_t = \frac{m_t}{u_t^o},$$

where $m_t = \mathcal{M}\left(u_t^o, v_t\right)$. Aggregate employment in period t is then expressed as follows:

$$n_t = (1-s)n_{t-1} + m_t. \tag{14}$$

In contrast to Blanchard and Galí (2010) and Krause et al. (2008), I express the cost per hire as a function of the vacancy-filling probability q_t and assume that the cost per hire is κ/q_t.[17] The match surplus of workers and match value of firms should be discussed because instantaneous hiring makes

[17] It can be shown that given matching function $m_t = \eta(u_t^o)^{\xi} v_t^{1-\xi}$, the cost per hire, κ/q_t, is equivalent to $\kappa\eta^{\frac{1}{1-\xi}} f_t^{\frac{\xi}{1-\xi}}$, which is a function of the job-finding probability.

the timing of events completely different. The match surplus of workers is expressed as follows: [18]

$$V_t = \frac{W_t^{t-j}}{P_t \prod_{i=1}^{j} g_{t-i+1}} h_t^{t-j} - b - B \frac{\left(h_t^{t-j}\right)^{1+\phi}}{1+\phi} \frac{1}{\mu_t} + \beta E_t \left[\frac{\mu_{t+1}}{\mu_t} \left(1-s\right)\left(1-f_{t+1}\right) V_{t+1} \right].$$

The match value of firms is expressed by the following:

$$J_t = \overline{y}_t - \frac{W_t^{t-j}}{P_t \prod_{i=1}^{j} g_{t-i+1}} h_t^{t-j} - r_t \overline{k}_t + \beta \left(1-s\right) E_t \left[\frac{\mu_{t+1}}{\mu_t} J_{t+1} \right].$$

Given that the free-entry condition holds and hiring is instantaneous, the value of a vacancy becomes zero and the following relationship holds:

$$\frac{\kappa}{q_t} = J_t.$$

When considering bargaining, the hourly wage rate and hours worked jointly maximize the Nash product (Eq. (6)). The first-order condition with respect to the hours of work is shown in Eq. (8). Even under contemporaneous hiring, the hours of work are determined by using Eq. (8), thus implying that the marginal rate of substitution between consumption and leisure should be equal to the marginal product of labor.

The second moments of variables simulated from the model wherein hiring is contemporaneous are shown in the bottom panel of Table 5 to 7. Compared with the benchmark model wherein a one-period lag between hiring and employment is observed, instantaneous hiring does not make a significant difference in fluctuations and correlations. If bargaining occurs over hours per worker and wages, the optimal hours satisfy the condition that equalizes the marginal product of hours worked with the marginal rate of substitution of workers between leisure and consumption even though instantaneous hiring is introduced.

[18] If a worker, unemployed in period t, finds a job with probability f_{t+1} at the beginning of period $t+1$, (s)he becomes employed in period $t+1$. With probability $1-f_{t+1}$ (s)he remains unemployed in period $t+1$. The value of an unemployed worker $\mathcal{U}_t$ is expressed as follows:

$$\mathcal{U}_t = b + E_t \left[\frac{\mu_{t+1}}{\mu_t} \left\{ f_{t+1} \mathcal{E}_{t+1} + \left(1-f_{t+1}\right) \mathcal{U}_{t+1} \right\} \right],$$

where $\mathcal{E}$ denotes the value from working. A worker, employed in period t, continues to work with probability $1 - s\left(1-f_{t+1}\right)$. With probability $s\left(1-f_{t+1}\right)$ (s)he will be unemployed next period. The value of an employed worker is given by the following:

$$\mathcal{E}_t = \frac{W_t^{t-j}}{P_t \prod_{i=1}^{j} g_{t-i+1}} h_t^{t-j} - B \frac{{h_t^{t-j}}^{1+\phi}}{1+\phi} \frac{1}{\mu_t} + \beta E_t \left[\frac{\mu_{t+1}}{\mu_t} \left\{ \left(1 - s\left(1-f_{t+1}\right)\right) \mathcal{E}_{t+1} + s\left(1-f_{t+1}\right) \mathcal{U}_{t+1} \right\} \right].$$

When hiring is instantaneous, aggregate employment in period t follows the law of motion (Eq. (14)), where the total number of hires $m_t = u_t^o f_t$ captures those who search and find employment at the beginning of period t, and start working in the same period. Therefore, in frictional labor markets, employment can be more volatile when hiring is instantaneous than when hiring is not. Table 5 shows that instantaneous hiring causes significant volatility in employment, that is, the relative volatility of employment (n) increase from .15 for period-by-period bargaining to .87 for four-period contracts. An increase in employment variability contributes to increased volatilities of total hours worked and output.

As far as correlations with output are concerned, total hours worked are more procyclical and unemployment is more countercyclical in the model with contemporaneous hiring than in the benchmark model with a one-period lag. Some of the differences of the two models come from the cyclical movements of real wages and productivity. In the four-period contract case, the model with instantaneous hiring predicts that real wages are countercyclical with a correlation of $-.21$ and productivity is weakly procyclical with a correlation of .50. The weak procyclicality of productivity points to a negative correlation with total hours worked. However, in the two-period contract case, the model is able to show the positive relationship between productivity and total hours worked and other correlations with output.

5 Conclusion

The DSGE model examined in this study is characterized by flexible prices, search frictions, and nominal wage contracts. This study assumes efficient bargaining under which the trade takes place between the firm and worker in both the wage rate and hours of work. Considering search frictions, a firm-worker pair negotiates its future nominal wage rate on the basis of the expected value for the future match surplus. Once the flexible price model accounts for search frictions, efficient bargaining, and nominal wage contracts, the model hardly produces unrealistically high volatility of real variables or countercyclical productivity. In the model, the volatilities of the unemployment rate and vacancy rate increase significantly with contract length. However, the volatility of output does not increase for a long contract period.

To examine the role of efficient bargaining, I use the model with the RTM approach. The firm and workers bargain over wages and then the firm chooses employment freely to maximize profit. Without search frictions, the model with the RTM regime generates unrealistically high fluctuations in output and total hours worked, similar to that obtained by Cho and Cooley (1995), because firms adjust the marginal product of labor in response to shocks by choosing total hours worked. The model with the RTM regime does not perform well with search frictions in terms of the volatilities of output and total hours worked, as well as those of unemployment and vacancies. Under the RTM scheme, wages per employee and per-period profits do not fluctuate enough to generate incentives for the firms to create jobs. The model with frictions and the RTM approach is also unable to amplify the effect of shocks on unemployment and vacancies.

Forward-looking bargaining is important to match the volatility of vacancies with nominal wage contracts and to match the contribution of intensive margin of hours per worker to total hours worked. Forward-looking bargaining has a useful feature wherein the steady state of the model is independent of contract length. To observe what happens when an alternative bargaining problem is considered, I examine a bargaining problem on the basis of the current surplus through the match. If a firm-worker pair bargains on the basis of the current surplus, the steady-state nominal wage rate falls with increasing contract length. Moreover, the steady-state value of per-period profits increases significantly with contract length. A significant increase in the steady-state value of per-period profits decreases the volatilities of per-period profits and vacancies.

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A Steady States, Linearized Economies and Contract Wages

The appendix presents the steady states of the model economies both with nominal wage contracts in the frictionless labor markets and with efficient bargaining in which the nominal hourly wage rate and the hours of work are jointly determined, and the equilibrium conditions linearized around the steady states.

A.1 Cho-Cooley Economy

The representative household's maximization problem is given by

$$\max E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \ln \left(\frac{m_{t-1} + g_t - 1}{g_t P_t} \right) - B \frac{Q_t^{1+\phi}}{1+\phi} n_t^{-\phi} - D \frac{n_t^{1+\tau}}{1+\tau} \right\}$$

subject to

$$\begin{aligned} \frac{m_t}{P_t} + k_{t+1} &= \frac{W_t^c}{P_t} Q_t + (r_t + 1 - \delta) k_t \\ Q_t &= n_t h_t. \end{aligned}$$

The representative firm maximizes its profit each period:

$$\max \quad P_t z_t k_t^{\alpha} Q_t^{1-\alpha} - W_t^c Q_t - r_t k_t.$$

Both processes governing monetary and technology shocks are the same.

In equilibrium, the model economy is characterized by the following equations. For the households, the cash-in-advance constraint and the first-order conditions with respect to n_t, h_t, k_{t+1}, and m_t are expressed as follows:

$$
\begin{aligned}
c_t &= \frac{1}{P_t}, \\
B\frac{\phi}{1+\phi}h_t^{1+\phi} &= Dn_t^{\tau}, \\
Bh_t^{\phi} &= \mu_t \frac{W_t}{P_t}, \\
\mu_t &= \beta E_t\left[\mu_{t+1}\left(r_{t+1}+1-\delta\right)\right], \\
\mu_t &= \beta E_t\left[\frac{P_t}{g_{t+1}}\right].
\end{aligned} \tag{A-1}
$$

For the firms, the production function, total hours worked, and the first-order conditions with respect to capital and total hours worked are given by

$$
\begin{aligned}
y_t &= z_t k_t^{\alpha} Q_t^{1-\alpha}, \\
Q_t &= n_t h_t, \\
r_t &= \alpha z_t k_t^{\alpha-1} Q_t^{1-\alpha}, \\
\frac{W_t}{P_t} &= \left(1-\alpha\right) z_t k_t^{\alpha} Q_t^{-\alpha}.
\end{aligned}
$$

Finally, the resource constraint and the law of motion for the capital stock are written as follows:

$$
\begin{aligned}
y_t &= c_t + i_t, \\
k_{t+1} &= \left(1-\delta\right) k_t + i_t.
\end{aligned}
$$

Notice that when nominal wage contracts are introduced into the model economy, the households are not allowed to choose hours worked and thus I do not take into account the household's first-order condition with respect to hours worked, Eq. (A-1).

Steady State

From the household's first-order condition, the real interest rate is given by $r = 1/\beta - 1 + \delta$. The representative firm's optimality condition yields the capital-labor ratio, $k/Q = \left(\alpha/r\right)^{1/(1-\alpha)}$, where k is pinned down because n(employment rate) and h(hours worked) are set to .94 and 1/3, respectively, and $Q = nh$. The real wage rate, which is equal to the marginal product of labor, is given by

$W/P = (1-\alpha)(k/Q)^{\alpha}$. Given the steady state capital stock, the steady state level of consumption is determined by the resource constrain: $c/k = (k/Q)^{\alpha-1} - \delta$. The steady state value of the multiplier attached to the budget constraint, μ, is derived from the first-order condition with respect money, so that $\mu = \beta/c$.

The first-order conditions with respect to the number of workers (n) and hours worked (h) are given by

$$\begin{aligned} B &= h^{-\phi}\mu\frac{W}{P}, \\ D &= \left(B\frac{\phi}{1+\phi}h^{1+\phi}\right)n^{-\tau}, \end{aligned}$$

from which utility parameters, B and D, can be determined.

Contract Wages

Following Cho and Cooley (1995), I assume that the contract wage rate is the expected value of the wage rate when there is market clearing. Thus, the contract wage can be determined from the decision rules of the model economy without contracts.

- No Contracts:

$$\begin{aligned} \ln W_t &= 1.3189 - 0.1332\ln k_t + 0.3549\ln z_{t-1} + 0.3736\varepsilon_t^z \\ &\quad +0.2281\ln g_{t-1} + 0.4656\varepsilon_t^g \end{aligned}$$

- One-Period Contract Wage:

$$\begin{aligned} \ln W_t &= 1.3189 - 0.1332\ln k_t + 0.3549\ln z_{t-1} \\ &\quad +0.2281\ln g_{t-1} - \varepsilon_t^g \end{aligned}$$

- Two-Period Contract Wage:

$$\begin{aligned} \ln W_t &= 1.3043 - 0.1265\ln k_{t-1} + 0.3220\ln z_{t-2} \\ &\quad +0.8397\ln g_{t-2} - 1.49\ln g_{t-1} - \varepsilon_t^g \end{aligned}$$

- Three-Period Contract Wage:

$$\begin{aligned}\ln W_t &= 1.2903 - 0.1201 \ln k_{t-2} + 0.2916 \ln z_{t-3} \\ &\quad +0.8994 \ln g_{t-3} - \ln g_{t-2} - 1.49 \ln g_{t-1} - \varepsilon_t^g\end{aligned}$$

- Four-Period Contract Wage:

$$\begin{aligned}\ln W_t &= 1.2771 - 0.1141 \ln k_{t-3} + 0.2633 \ln z_{t-4} \\ &\quad +0.9287 \ln g_{t-4} - \ln g_{t-3} - \ln g_{t-2} - 1.49 \ln g_{t-1} - \varepsilon_t^g\end{aligned}$$

A.2 Benchmark Model

Steady State

Given the steady state job-finding rate (f) and the employment rate (n), the exogenous separation is derived from the employment dynamics:

$$s = \frac{1-n}{n} f,$$

If the vacancy-unemployment ratio, $v/(1-n)$, is set to unity, then the job-finding rate and the job-filling rate are equalized, $f = q$. From the household's first-order condition, the real interest rate is given by $r = 1/\beta - 1 + \delta$. Given the steady state hours of work (h), the individual firm's demand for capital ($\overline{k}$) is equal to

$$\overline{k} = \left(\frac{\alpha}{r}\right)^{1/(1-\alpha)} h^{\frac{\theta}{1-\alpha}}.$$

The aggregate capital stock, output, and investment are given by $k = n\overline{k}$, $y = k^{\alpha} n^{1-\alpha} h^{\theta}$, and $i = \delta k$, respectively.

The steady state bargained wage and hours of work satisfy

$$\begin{aligned}\frac{W}{P} h &= \gamma \left((1-\alpha)\overline{y} + f \frac{\kappa}{q} \right) + (1-\gamma) \left(b + B \frac{h^{1+\phi}}{1+\phi} \frac{1}{\mu} \right), \\ \frac{B}{\mu} &= \theta \overline{k}^{\alpha} h^{\theta-1-\phi}.\end{aligned}$$

In the steady state, the free-entry condition can be expressed as

$$\begin{aligned}\frac{\kappa}{q} &= \beta\left\{(1-\alpha)\overline{y} - \frac{W}{P}h + (1-s)\frac{\kappa}{q}\right\}\\ &= \frac{\beta}{1-\beta(1-s)}\left\{(1-\alpha)\overline{y} - \frac{W}{P}h\right\}.\end{aligned}$$

Assuming that $b \equiv \rho\frac{W}{P}h$ with ρ the ratio of household production and substituting κ/q in the bargained wage for the free-entry condition, the steady state real wage, $\frac{W}{P}$, solves the following:

$$\left[1-(1-\gamma)\rho + \frac{\gamma\beta f}{1-\beta(1-s)}\right]\frac{W}{P}h = \gamma(1-\alpha)\overline{y}\left(1+\frac{\beta f}{1-\beta(1-s)}\right) + (1-\gamma)B\frac{h^{1+\phi}}{1+\phi}\frac{1}{\mu}.$$

Given the real bargained wage, the vacancy posting cost κ is determined by

$$\kappa = q\frac{\beta}{1-\beta(1-s)}\left\{(1-\alpha)\overline{y} - \frac{W}{P}h\right\}.$$

From the market clearing condition, the aggregate consumption is given by

$$c = y - i - \kappa v.$$

The steady state level of price is $P = 1/c$, and the Lagrange multiplier is then $\mu = \beta/P$. The parameter of the utility function B is determined by

$$B = \mu\theta\left(\frac{k}{n}\right)^{\alpha} h^{\theta-1-\phi}.$$

Linearized Model Economy

In this subsection, the log-linearized model economy with efficient bargaining is presented. The log-linearized equations of the representative household's first-order conditions are given by

$$\widehat{\mu}_t = \widehat{P}_t - E_t\left[\widehat{g}_{t+1}\right], \tag{A-2}$$

$$\widehat{\mu}_t = E_t\widehat{\mu}_{t+1} + (\beta r)\, E_t\widehat{r}_{t+1}. \tag{A-3}$$

The log-linearized cash-in-advance constraint and budget constraint (resource constraint in equilibrium) are given by

$$\begin{aligned}
\widehat{c}_t &= -\widehat{P}_t, \\
\widehat{y}_t &= \frac{c}{y}\widehat{c}_t + \frac{i}{y}\widehat{i}_t + \frac{\kappa v}{y}\widehat{v}_t.
\end{aligned}$$

Output, the free-entry condition, and capital demand are given by

$$\begin{aligned}
\widehat{y}_t &= \widehat{z}_t + \alpha\widehat{k}_t + (1-\alpha)\,\widehat{n}_t + \theta\widehat{h}_t^{t-j}, \\
-\frac{\kappa}{\beta q}\widehat{q}_t &= (1-\alpha)\,\frac{y}{n}E_t\left(\widehat{y}_{t+1} - \widehat{n}_{t+1}\right) - \frac{W}{P}hE_t\left(\widehat{w}_{t+1}^{t+1-j} + \widehat{h}_{t+1}^{t+1-j}\right) \\
&\quad - (1-s)\,\frac{\kappa}{q}E_t\widehat{q}_{t+1} + \frac{\kappa}{\beta q}\left(E_t\widehat{\mu}_{t+1} - \widehat{\mu}_t\right), \\
\widehat{r}_t &= \widehat{z}_t - (1-\alpha)\,\widehat{k}_t + (1-\alpha)\,\widehat{n}_t + \theta\widehat{h}_t^{t-j},
\end{aligned}$$

where w_{t+1}^{t+1-j} denotes the real wage in $t+1$ determined in period $t+1-j$. The law of motion for the capital stock and the shock processes are

$$\begin{aligned}
\widehat{k}_{t+1} &= (1-\delta)\,\widehat{k}_t + \delta\widehat{i}_t, \\
\widehat{z}_t &= \rho_z\widehat{z}_{t-1} + \varepsilon_t^z, \\
\widehat{g}_t &= \rho_g\widehat{g}_{t-1} + \varepsilon_t^g.
\end{aligned}$$

The linearized labor market variables are summarized by

$$\begin{aligned}
\widehat{\mathcal{M}}_t &= \xi\widehat{u}_t + (1-\xi)\,\widehat{v}_t, \\
\widehat{n}_{t+1} &= (1-s-f)\,\widehat{n}_t + s\widehat{f}_t, \\
\widehat{u}_t &= -\frac{n}{1-n}\widehat{n}_t, \\
\widehat{f}_t &= \widehat{\mathcal{M}}_t - \widehat{u}_t, \\
\widehat{q}_t &= \widehat{\mathcal{M}}_t - \widehat{v}_t.
\end{aligned}$$

The linearized nominal wage and hours worked should depend on contract length.

- Period-by-Period Bargaining:

$$
\begin{aligned}
\frac{W}{P}h\left(\widehat{W}_t^t-\widehat{P}_t+\widehat{h}_t^t\right) &= \gamma\left(1-\alpha\right)\frac{y}{n}\left(\widehat{y}_t-\widehat{n}_t\right)+\gamma f\frac{\kappa}{q}\left(\widehat{f}_t-\widehat{q}_t\right)\\
&\quad+\left(1-\gamma\right)\frac{B}{\mu}\frac{h^{1+\phi}}{1+\phi}\left(\left(1+\phi\right)\widehat{h}_t^t-\widehat{\mu}_t\right)\\
\left(1-\theta+\phi\right)\widehat{h}_t^t &= \widehat{z}_t+\alpha\left(\widehat{k}_t-\widehat{n}_t\right)+\widehat{\mu}_t\\
\widehat{w}_t^t &= \widehat{W}_t^t-\widehat{P}_t.
\end{aligned}
$$

- One-Period Contract Model:

$$
\begin{aligned}
\frac{W}{P}hE_t\left(\widehat{W}_{t+1}^t-\rho_g\widehat{g}_t-\widehat{P}_{t+1}+\widehat{h}_{t+1}^t\right) &= \gamma\left(1-\alpha\right)\frac{y}{n}E_t\left(\widehat{y}_{t+1}-\widehat{n}_{t+1}\right)+\gamma f\frac{\kappa}{q}E_t\left(\widehat{f}_{t+1}-\widehat{q}_{t+1}\right)\\
&\quad+\left(1-\gamma\right)\frac{B}{\mu}\frac{h^{1+\phi}}{1+\phi}E_t\left(\left(1+\phi\right)\widehat{h}_{t+1}^t-\widehat{\mu}_{t+1}\right)\\
\left(1-\theta+\phi\right)\widehat{h}_{t+1}^t &= \rho_z\widehat{z}_t+\alpha\left(\widehat{k}_{t+1}-\widehat{n}_{t+1}\right)+E_t\widehat{\mu}_{t+1}\\
\widehat{w}_t^{t-1} &= \widehat{W}_{t-1}^t-\widehat{g}_t-\widehat{P}_t.
\end{aligned}
$$

- Two-Period Contract Model:

$$
\begin{aligned}
&\frac{W}{P}hE_t\left(\widehat{w}_{t+2}^t+\widehat{h}_{t+2}^t\right)+\gamma\left(\frac{1-s-f}{1-s}\right)\frac{W}{P}hE_t\left[\widehat{w}_{t+2}^t+\widehat{h}_{t+2}^t+\frac{\widehat{w}_{t+1}^{t-1}+\widehat{h}_{t+1}^{t-1}}{\beta(1-s)}\right]\\
=\;&\gamma\left(1-\alpha\right)\frac{y}{n}E_t\left(\widehat{y}_{t+2}-\widehat{n}_{t+2}\right)+\gamma\left(\frac{1-s-f}{1-s}\right)\left(1-\alpha\right)\frac{y}{n}E_t\left[\widehat{y}_{t+2}-\widehat{n}_{t+2}+\frac{\widehat{y}_{t+1}-\widehat{n}_{t+1}}{\beta(1-s)}\right]\\
&+\gamma\frac{\kappa}{q}fE_t\widehat{f}_{t+2}-\gamma\left(1-s\right)\frac{\kappa}{q}E_t\widehat{q}_{t+2}+\gamma\left(\frac{1-s-f}{1-s}\right)\frac{J}{\beta(1-s)}\widehat{q}_t\\
&+\left(1-\gamma\right)\frac{B}{\mu}\frac{h^{1+\phi}}{1+\phi}E_t\left(\left(1+\phi\right)\widehat{h}_{t+2}^t-\widehat{\mu}_{t+2}\right)\\
&+\gamma\left(\frac{1-s-f}{1-s}\right)JE_t\left[\widehat{\mu}_{t+2}-\widehat{\mu}_{t+1}+\frac{\widehat{\mu}_{t+1}-\widehat{\mu}_t}{\beta(1-s)}\right]
\end{aligned}
$$

$$
\begin{aligned}
\left(1-\theta+\phi\right)\widehat{h}_{t+2}^t &= \rho_z^2\widehat{z}_t+\alpha E_t\left(\widehat{k}_{t+2}-\widehat{n}_{t+2}\right)+E_t\widehat{\mu}_{t+2}\\
\widehat{w}_t^{t-2} &= \widehat{W}_{t-2}^t-\widehat{g}_{t-1}-\widehat{g}_t-\widehat{P}_t.
\end{aligned}
$$

where $\widehat{w}_{t+2}^t=\widehat{W}_{t+2}^t-\left(\rho_g+\rho_g^2\right)\widehat{g}_t-E_t\widehat{P}_{t+2}$ and $\widehat{w}_{t+1}^{t-1}=\widehat{W}_{t+1}^{t-1}-\left(1+\rho_g\right)\widehat{g}_t-E_t\widehat{P}_{t+1}$.

- Three-Period Contract Model:

$$
\begin{aligned}
& \frac{W}{P} h E_t\left(\widehat{w}_{t+3}^t+\widehat{h}_{t+3}^t\right) \\
& +\gamma\left(\frac{1-s-f}{1-s}\right) \frac{W}{P} h E_t\left[\widehat{w}_{t+3}^t+\widehat{h}_{t+3}^t+\frac{\widehat{w}_{t+2}^{t-1}+\widehat{h}_{t+2}^{t-1}}{\beta(1-s)}+\frac{\widehat{w}_{t+1}^{t-2}+\widehat{h}_{t+1}^{t-1}}{\beta^2(1-s)^2}\right] \\
= \; & \gamma(1-\alpha) \frac{y}{n} E_t\left(\widehat{y}_{t+3}-\widehat{n}_{t+3}\right) \\
& +\gamma\left(\frac{1-s-f}{1-s}\right)(1-\alpha) \frac{y}{n} E_t\left[\widehat{y}_{t+3}-\widehat{n}_{t+3}+\frac{\widehat{y}_{t+2}-\widehat{n}_{t+2}}{\beta(1-s)}+\frac{\widehat{y}_{t+1}-\widehat{n}_{t+1}}{\beta^2(1-s)^2}\right] \\
& +\gamma \frac{\kappa}{q} f E_t \widehat{f}_{t+3}-\gamma(1-s) \frac{\kappa}{q} E_t \widehat{q}_{t+3}+\gamma\left(\frac{1-s-f}{1-s}\right) \frac{J}{\beta^2(1-s)^2} \widehat{q}_t \\
& +(1-\gamma) \frac{B}{\mu} \frac{h^{1+\phi}}{1+\phi} E_t\left((1+\phi) \widehat{h}_{t+3}^t-\widehat{\mu}_{t+3}\right) \\
& +\gamma\left(\frac{1-s-f}{1-s}\right) J E_t\left[\widehat{\mu}_{t+3}-\widehat{\mu}_{t+2}+\frac{\widehat{\mu}_{t+2}-\widehat{\mu}_{t+1}}{\beta(1-s)}+\frac{\widehat{\mu}_{t+1}-\widehat{\mu}_t}{\beta^2(1-s)^2}\right]
\end{aligned}
$$

$$
\begin{aligned}
(1-\theta+\phi) \widehat{h}_{t+3}^t & =\rho_z^3 \widehat{z}_t+\alpha E_t\left(\widehat{k}_{t+3}-\widehat{n}_{t+3}\right)+E_t \widehat{\mu}_{t+3} \\
\widehat{w}_t^{t-3} & =\widehat{W}_{t-3}^t-\widehat{g}_{t-2}-\widehat{g}_{t-1}-\widehat{g}_t-\widehat{P}_t .
\end{aligned}
$$

where $\widehat{w}_{t+3}^t=\widehat{W}_{t+3}^t-\left(\rho_g+\rho_g^2+\rho_g^3\right) \widehat{g}_t-E_t \widehat{P}_{t+3}$, $\widehat{w}_{t+2}^{t-1}=\widehat{W}_{t+2}^{t-1}-\left(1+\rho_g+\rho_g^2\right) \widehat{g}_t-E_t \widehat{P}_{t+2}$, and $\widehat{w}_{t+1}^{t-2}=\widehat{W}_{t+1}^{t-2}-\widehat{g}_{t-1}-\left(1+\rho_g\right) \widehat{g}_t-E_t \widehat{P}_{t+1}$.

- Four-Period Contract Model:

$$
\begin{aligned}
& \frac{W}{P} h E_t\left(\widehat{w}_{t+4}^t+\widehat{h}_{t+4}^t\right) \\
& +\gamma\left(\frac{1-s-f}{1-s}\right) \frac{W}{P} h E_t\left[\widehat{w}_{t+4}^t+\widehat{h}_{t+4}^t+\frac{\widehat{w}_{t+3}^{t-1}+\widehat{h}_{t+3}^{t-1}}{\beta(1-s)}+\frac{\widehat{w}_{t+2}^{t-2}+\widehat{h}_{t+2}^{t-2}}{\beta^2(1-s)^2}+\frac{\widehat{w}_{t+1}^{t-3}+\widehat{h}_{t+1}^{t-3}}{\beta^3(1-s)^3}\right] \\
= \; & \gamma(1-\alpha) \frac{y}{n} E_t\left(\widehat{y}_{t+4}-\widehat{n}_{t+4}\right) \\
& +\gamma\left(\frac{1-s-f}{1-s}\right)(1-\alpha) \frac{y}{n} E_t\left[\widehat{y}_{t+4}-\widehat{n}_{t+4}+\frac{\widehat{y}_{t+3}-\widehat{n}_{t+3}}{\beta(1-s)}+\frac{\widehat{y}_{t+2}-\widehat{n}_{t+2}}{\beta^2(1-s)^2}+\frac{\widehat{y}_{t+1}-\widehat{n}_{t+1}}{\beta^3(1-s)^3}\right] \\
& +\gamma \frac{\kappa}{q} f E_t \widehat{f}_{t+4}-\gamma(1-s) \frac{\kappa}{q} E_t \widehat{q}_{t+4}+\gamma\left(\frac{1-s-f}{1-s}\right) \frac{J}{\beta^3(1-s)^3} \widehat{q}_t \\
& +(1-\gamma) \frac{B}{\mu} \frac{h^{1+\phi}}{1+\phi} E_t\left((1+\phi) \widehat{h}_{t+4}^t-\widehat{\mu}_{t+4}\right) \\
& +\gamma\left(\frac{1-s-f}{1-s}\right) J E_t\left[\widehat{\mu}_{t+4}-\widehat{\mu}_{t+3}+\frac{\widehat{\mu}_{t+3}-\widehat{\mu}_{t+2}}{\beta(1-s)}+\frac{\widehat{\mu}_{t+2}-\widehat{\mu}_{t+1}}{\beta^2(1-s)^2}+\frac{\widehat{\mu}_{t+1}-\widehat{\mu}_t}{\beta^3(1-s)^3}\right]
\end{aligned}
$$

$$
\begin{aligned}
(1-\theta+\phi)\,\widehat{h}_{t+4}^{t} &= \rho_z^4\widehat{z}_t+\alpha E_t\left(\widehat{k}_{t+4}-\widehat{n}_{t+4}\right)+E_t\widehat{\mu}_{t+4}\\
\widehat{w}_t^{t-4} &= \widehat{W}_{t-4}^{t}-\widehat{g}_{t-3}-\widehat{g}_{t-2}-\widehat{g}_{t-1}-\widehat{g}_t-\widehat{P}_t.
\end{aligned}
$$

where $\widehat{w}_{t+4}^{t}=\widehat{W}_{t+4}^{t}-\left(\rho_g+\rho_g^2+\rho_g^3+\rho_g^4\right)\widehat{g}_t-E_t\widehat{P}_{t+4}$, $\widehat{w}_{t+3}^{t-1}=\widehat{W}_{t+3}^{t-1}-\left(1+\rho_g+\rho_g^2+\rho_g^3\right)\widehat{g}_t-E_t\widehat{P}_{t+3}$, $\widehat{w}_{t+2}^{t-2}=\widehat{W}_{t+2}^{t-2}-\widehat{g}_{t-1}-\left(1+\rho_g+\rho_g^2\right)\widehat{g}_t-E_t\widehat{P}_{t+2}$ and $\widehat{w}_{t+1}^{t-3}=\widehat{W}_{t+1}^{t-3}-\widehat{g}_{t-2}-\widehat{g}_{t-1}-(1+\rho_g)\,\widehat{g}_t-E_t\widehat{P}_{t+1}$.

A.3 Search Frictions and Current Surplus Bargaining (Not For Publication)

Steady State

All other conditions except for the nominal wage rate are the same as those appearing on the benchmark model with future surplus bargaining. The steady state bargained wage is given by

$$
\begin{aligned}
&\frac{W}{P}h\left[(1-\gamma)(1-s)^j(1-\rho)+\gamma(1-s-f)^j\left(1+f\frac{\beta}{1-\beta(1-s)}\right)\right]\\
=\;&\gamma(1-s-f)^j\left(1+f\frac{\beta}{1-\beta(1-s)}\right)(1-\alpha)\frac{y}{n}+(1-\gamma)(1-s)^jB\frac{h^{1+\phi}}{1+\phi}\frac{1}{\mu}
\end{aligned}
$$

for $j\geq 1$.

Linearized Model Economy

- One-Period Contract Model:

$$
\begin{aligned}
&\frac{W}{P}hE_t\left(\widehat{F}_t+\widehat{\mu}_{t+1}-\widehat{\mu}_t+\widehat{w}_{t+1}^{t}+\widehat{h}_{t+1}^{t}\right)\\
=\;&\gamma(1-\alpha)\frac{y}{n}E_t\left(\widehat{F}_t+\widehat{\mu}_{t+1}-\widehat{\mu}_t+\widehat{y}_{t+1}-\widehat{n}_{t+1}\right)\\
&+(1-\gamma)\,bE_t\left(\widehat{F}_t+\widehat{\mu}_{t+1}-\widehat{\mu}_t\right)\\
&+(1-\gamma)\,B\frac{h^{1+\phi}}{1+\phi}\frac{1}{\mu}E_t\left(\widehat{F}_t+\widehat{\mu}_{t+1}-\widehat{\mu}_t+(1+\phi)\,\widehat{h}_{t+1}^{t}-\widehat{\mu}_{t+1}\right)\\
&+\gamma(1-s)\frac{\kappa}{q}E_t\left(\widehat{F}_t+\widehat{\mu}_{t+1}-\widehat{\mu}_t-\widehat{q}_{t+1}\right)\\
&-(1-\gamma)\,\beta\frac{f}{1-s-f}VE_t\left(\widehat{F}_t+\widehat{F}_{t+1}+\widehat{F}_{t+2}+\widehat{\mu}_{t+1}-\widehat{\mu}_t-\widehat{q}_{t+1}\right)\\
&-\gamma\frac{\kappa}{\beta q}\left(\widehat{F}_t-\widehat{q}_t\right)+(1-\gamma)\,VE_t\left(\widehat{F}_t+\widehat{F}_{t+1}-\widehat{q}_t\right)
\end{aligned}
$$

and

$$
(1-\theta+\phi)\,\widehat{h}_{t+1}^{t} \;=\; \rho_z \widehat{z}_t + \alpha\left(\widehat{k}_{t+1} - \widehat{n}_{t+1}\right) + E_t \widehat{\mu}_{t+1}
$$

where $\widehat{F}_t = -\frac{f}{1-s-f}\widehat{f}_t$ and $\widehat{w}_{t+1}^{t} = \widehat{W}_{t+1}^{t} - \rho_g \widehat{g}_t - E_t \widehat{P}_{t+1}$.

- Two-Period Contract Model:

$$
\begin{aligned}
& (1-s)\,\beta \frac{W}{P} h E_t\left(\widehat{F}_{t+1} + \widehat{\mu}_{t+2} - \widehat{\mu}_{t+1} + \widehat{w}_{t+2}^{t} + \widehat{h}_{t+2}^{t}\right) \\
& + (1-\gamma)\,\frac{1-s}{1-s-f}\frac{W}{P} h E_t\left(\widehat{w}_{t+1}^{t-1} + \widehat{h}_{t+1}^{t-1}\right) + \gamma \frac{W}{P} h E_t\left(\widehat{F}_{t+1} + \widehat{w}_{t+1}^{t-1} + \widehat{h}_{t+1}^{t-1}\right) \\
= \; & \gamma\,(1-\alpha)\,\frac{y}{n} E_t\left(\widehat{F}_{t+1} + \widehat{y}_{t+1} - \widehat{n}_{t+1}\right) \\
& + \gamma\beta\,(1-s)\,(1-\alpha)\,\frac{y}{n} E_t\left(\widehat{F}_{t+1} + \widehat{\mu}_{t+2} - \widehat{\mu}_{t+1} + \widehat{y}_{t+2} - \widehat{n}_{t+2}\right) \\
& + (1-\gamma)\,\frac{1-s}{1-s-f}\overline{B} E_t\left((1+\phi)\,\widehat{h}_{t+1}^{t-1} - \widehat{\mu}_{t+1}\right) \\
& + (1-\gamma)\,\beta(1-s)\left(b+\overline{B}\right) E_t\left(\widehat{F}_{t+1} + \widehat{\mu}_{t+2} - \widehat{\mu}_{t+1} + \frac{\overline{B}}{b+\overline{B}}\left((1+\phi)\,\widehat{h}_{t+2}^{t} - \widehat{\mu}_{t+2}\right)\right) \\
& + \gamma\beta(1-s)^2 \frac{\kappa}{q} E_t\left(\widehat{F}_{t+1} + \widehat{\mu}_{t+2} - \widehat{\mu}_{t+1} - \widehat{q}_{t+2}\right) \\
& - (1-\gamma)\,\beta^2(1-s)\,(1-s-f)\,V E_t\left(\widehat{F}_{t+1} + \widehat{F}_{t+2} + \widehat{F}_{t+3} + \widehat{F}_{t+4} + \widehat{\mu}_{t+2} - \widehat{\mu}_{t+1} - \widehat{q}_{t+2}\right) \\
& - \gamma \frac{\kappa}{\beta q} E_t\left(\widehat{F}_{t+1} - \widehat{q}_t - \left(\widehat{\mu}_{t+1} - \widehat{\mu}_t\right)\right) \\
& + (1-\gamma)\,\frac{1-s}{1-s-f} V E_t\left(\widehat{F}_{t+1} + \widehat{F}_{t+2} - \widehat{q}_t - \left(\widehat{\mu}_{t+1} - \widehat{\mu}_t\right)\right)
\end{aligned}
$$

and

$$
(1-\theta+\phi)\,\widehat{h}_{t+2}^{t} \;=\; \rho_z^2 \widehat{z}_t + \alpha E_t\left(\widehat{k}_{t+2} - \widehat{n}_{t+2}\right) + E_t \widehat{\mu}_{t+2}
$$

where $\widehat{w}_{t+2}^{t} = \widehat{W}_{t+2}^{t} - \rho_g \widehat{g}_t - \rho_g^2 \widehat{g}_t - E_t \widehat{P}_{t+2}$, $\widehat{w}_{t+1}^{t-1} = \widehat{W}_{t+1}^{t-1} - \widehat{g}_t - \rho_g \widehat{g}_t - E_t \widehat{P}_{t+1}$, and $\overline{B} = B\frac{h^{1+\phi}}{1+\phi}\frac{1}{\mu}$.

- Three-Period Contract Model:

$$
\begin{aligned}
& (1-s)\beta\frac{W}{P}hE_t\left(\widehat{F}_{t+2}+\widehat{\mu}_{t+3}-\widehat{\mu}_{t+2}+\widehat{w}_{t+3}^{t}+\widehat{h}_{t+3}^{t}\right) \\
& +(1-\gamma)\frac{1-s}{1-s-f}\frac{W}{P}hE_t\left(\widehat{w}_{t+2}^{t-1}+\widehat{h}_{t+2}^{t-1}\right)+\gamma\frac{W}{P}hE_t\left(\widehat{F}_{t+2}+\widehat{w}_{t+2}^{t-1}+\widehat{h}_{t+2}^{t-1}\right) \\
= \; & \gamma(1-\alpha)\frac{y}{n}E_t\left(\widehat{F}_{t+2}+\widehat{y}_{t+2}-\widehat{n}_{t+2}\right) \\
& +\gamma\beta(1-s)(1-\alpha)\frac{y}{n}E_t\left(\widehat{F}_{t+2}+\widehat{\mu}_{t+3}-\widehat{\mu}_{t+2}+\widehat{y}_{t+3}-\widehat{n}_{t+3}\right) \\
& +(1-\gamma)\frac{1-s}{1-s-f}\overline{B}E_t\left((1+\phi)\widehat{h}_{t+2}^{t-1}-\widehat{\mu}_{t+2}\right) \\
& +(1-\gamma)\beta(1-s)\left(b+\overline{B}\right)E_t\left(\widehat{F}_{t+2}+\widehat{\mu}_{t+3}-\widehat{\mu}_{t+2}+\frac{\overline{B}}{b+\overline{B}}\left((1+\phi)\widehat{h}_{t+3}^{t}-\widehat{\mu}_{t+3}\right)\right) \\
& +\gamma\beta(1-s)^2\frac{\kappa}{q}E_t\left(\widehat{F}_{t+2}+\widehat{\mu}_{t+3}-\widehat{\mu}_{t+2}-\widehat{q}_{t+3}\right) \\
& -(1-\gamma)\beta^2(1-s)(1-s-f)VE_t\left(\widehat{F}_{t+2}+\ldots+\widehat{F}_{t+6}+\widehat{\mu}_{t+3}-\widehat{\mu}_{t+2}-\widehat{q}_{t+3}\right) \\
& -\gamma\frac{\kappa}{\beta q}E_t\left(\widehat{F}_{t+2}-\widehat{q}_{t+1}-(\widehat{\mu}_{t+2}-\widehat{\mu}_{t+1})\right) \\
& +(1-\gamma)\frac{1-s}{1-s-f}VE_t\left(\widehat{F}_{t+2}+\widehat{F}_{t+3}+\widehat{F}_{t+4}-\widehat{q}_{t+1}-(\widehat{\mu}_{t+2}-\widehat{\mu}_{t+1})\right)
\end{aligned}
$$

and

$$
(1-\theta+\phi)\,\widehat{h}_{t+3}^{t} \;=\; \rho_z^3\widehat{z}_t+\alpha E_t\left(\widehat{k}_{t+3}-\widehat{n}_{t+3}\right)+E_t\widehat{\mu}_{t+3}
$$

where $\widehat{w}_{t+3}^{t}=\widehat{W}_{t+3}^{t}-\left(\rho_g+\rho_g^2+\rho_g^3\right)\widehat{g}_t-E_t\widehat{P}_{t+3}$, $\widehat{w}_{t+2}^{t-1}=\widehat{W}_{t+2}^{t-1}-\left(1+\rho_g+\rho_g^2\right)\widehat{g}_t-E_t\widehat{P}_{t+2}$, and $\overline{B}=B\frac{h^{1+\phi}}{1+\phi}\frac{1}{\mu}$

- Four-Period Contract Model:

$$
\begin{aligned}
& (1-s)\beta\frac{W}{P}hE_t\left(\widehat{F}_{t+3}+\widehat{\mu}_{t+4}-\widehat{\mu}_{t+3}+\widehat{w}_{t+4}^{t}+\widehat{h}_{t+4}^{t}\right)\\
& +(1-\gamma)\frac{1-s}{1-s-f}\frac{W}{P}hE_t\left(\widehat{w}_{t+3}^{t-1}+\widehat{h}_{t+3}^{t-1}\right)+\gamma\frac{W}{P}hE_t\left(\widehat{F}_{t+3}+\widehat{w}_{t+3}^{t-1}+\widehat{h}_{t+3}^{t-1}\right)\\
= \;& \gamma(1-\alpha)\frac{y}{n}E_t\left(\widehat{F}_{t+3}+\widehat{y}_{t+3}-\widehat{n}_{t+3}\right)\\
& +\gamma\beta(1-s)(1-\alpha)\frac{y}{n}E_t\left(\widehat{F}_{t+3}+\widehat{\mu}_{t+4}-\widehat{\mu}_{t+3}+\widehat{y}_{t+4}-\widehat{n}_{t+4}\right)\\
& +(1-\gamma)\frac{1-s}{1-s-f}\overline{B}E_t\left((1+\phi)\widehat{h}_{t+3}^{t-1}-\widehat{\mu}_{t+3}\right)\\
& +(1-\gamma)\beta(1-s)\left(b+\overline{B}\right)E_t\left(\widehat{F}_{t+3}+\widehat{\mu}_{t+4}-\widehat{\mu}_{t+3}+\frac{\overline{B}}{b+\overline{B}}\left((1+\phi)\widehat{h}_{t+4}^{t}-\widehat{\mu}_{t+4}\right)\right)\\
& +\gamma\beta(1-s)^2\frac{\kappa}{q}E_t\left(\widehat{F}_{t+3}+\widehat{\mu}_{t+4}-\widehat{\mu}_{t+3}-\widehat{q}_{t+4}\right)\\
& -(1-\gamma)\beta^2(1-s)(1-s-f)VE_t\left(\widehat{F}_{t+3}+\ldots+\widehat{F}_{t+8}+\widehat{\mu}_{t+4}-\widehat{\mu}_{t+3}-\widehat{q}_{t+4}\right)\\
& -\gamma\frac{\kappa}{\beta q}E_t\left(\widehat{F}_{t+3}-\widehat{q}_{t+2}-(\widehat{\mu}_{t+3}-\widehat{\mu}_{t+2})\right)\\
& +(1-\gamma)\frac{1-s}{1-s-f}VE_t\left(\widehat{F}_{t+3}+\ldots+\widehat{F}_{t+6}-\widehat{q}_{t+2}-(\widehat{\mu}_{t+3}-\widehat{\mu}_{t+2})\right)
\end{aligned}
$$

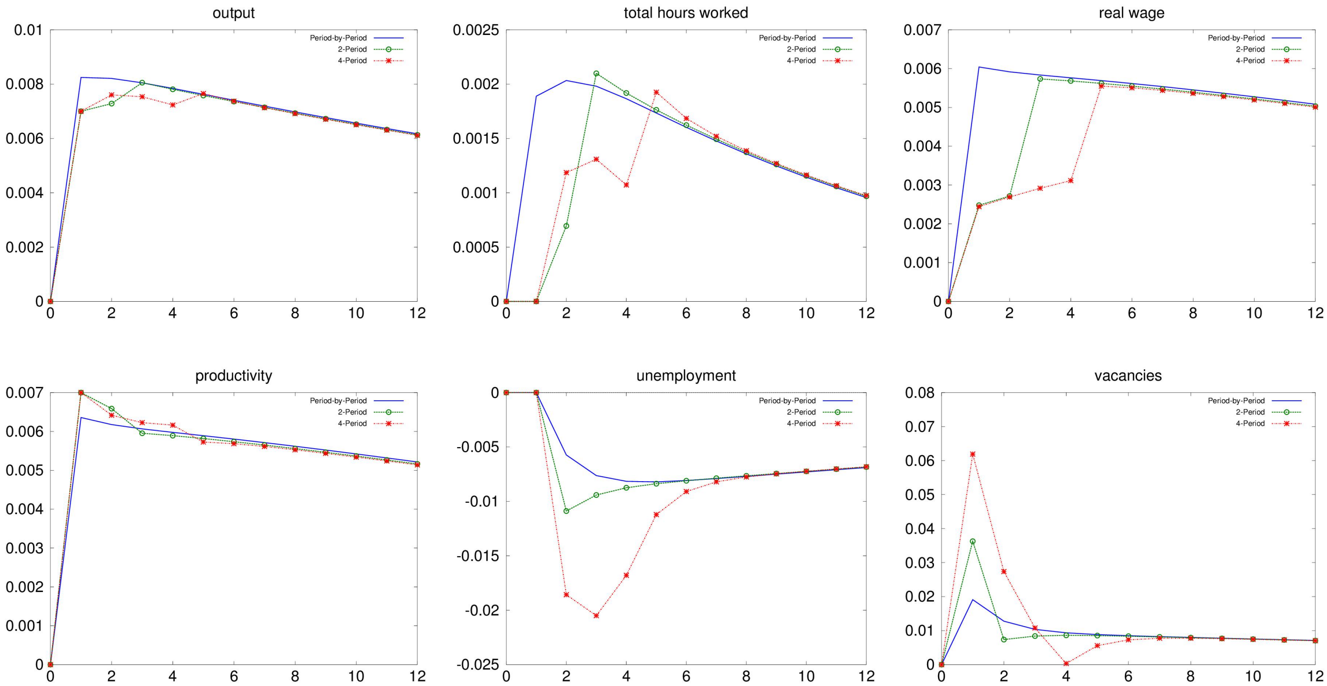
and

$$
(1-\theta+\phi)\,\widehat{h}_{t+4}^{t} \;=\; \rho_z^4\widehat{z}_t+\alpha E_t\left(\widehat{k}_{t+4}-\widehat{n}_{t+4}\right)+E_t\widehat{\mu}_{t+4}
$$

where $\widehat{w}_{t+4}^{t}=\widehat{W}_{t+4}^{t}-\left(\rho_g+\rho_g^2+\rho_g^3+\rho_g^4\right)\widehat{g}_t-E_t\widehat{P}_{t+4}$, $\widehat{w}_{t+3}^{t-1}=\widehat{W}_{t+3}^{t-1}-\left(1+\rho_g+\rho_g^2+\rho_g^3\right)\widehat{g}_t-E_t\widehat{P}_{t+3}$, and $\overline{B}=B\frac{h^{1+\phi}}{1+\phi}\frac{1}{\mu}$

Figure 1: Impulse Responses

(a) Technology Shock Only



(b) Monetary Shock Only

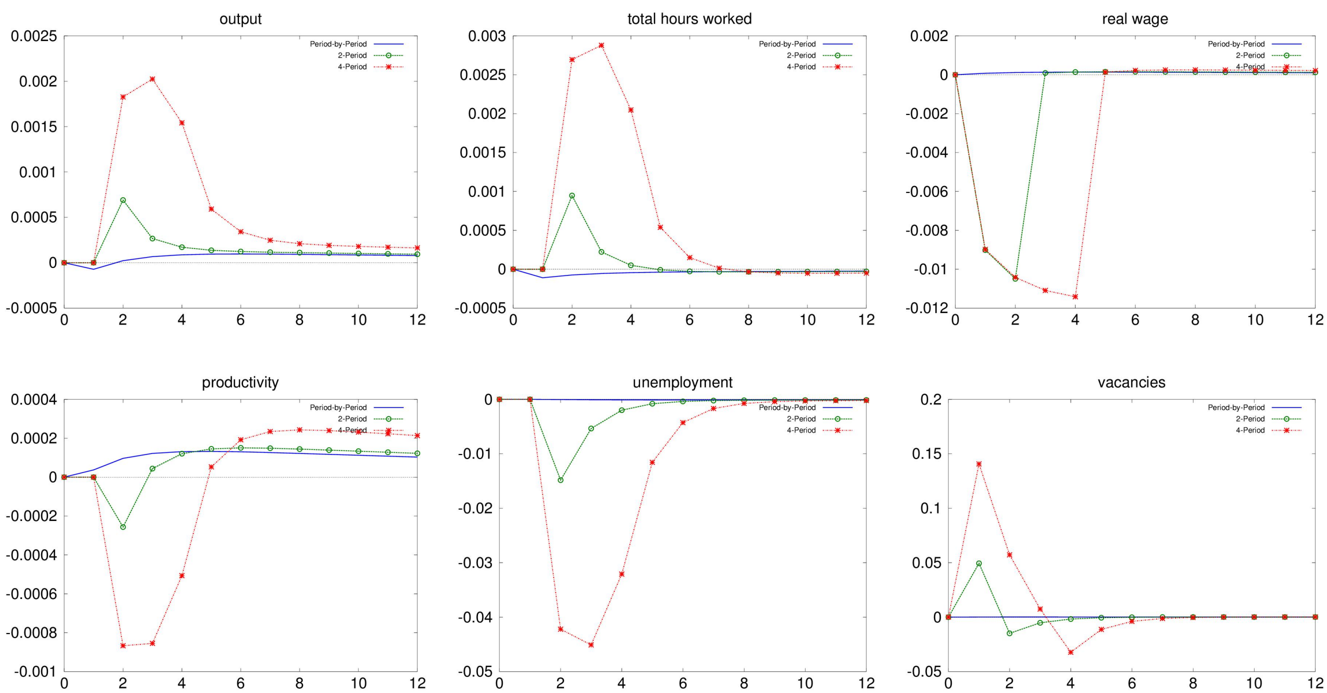
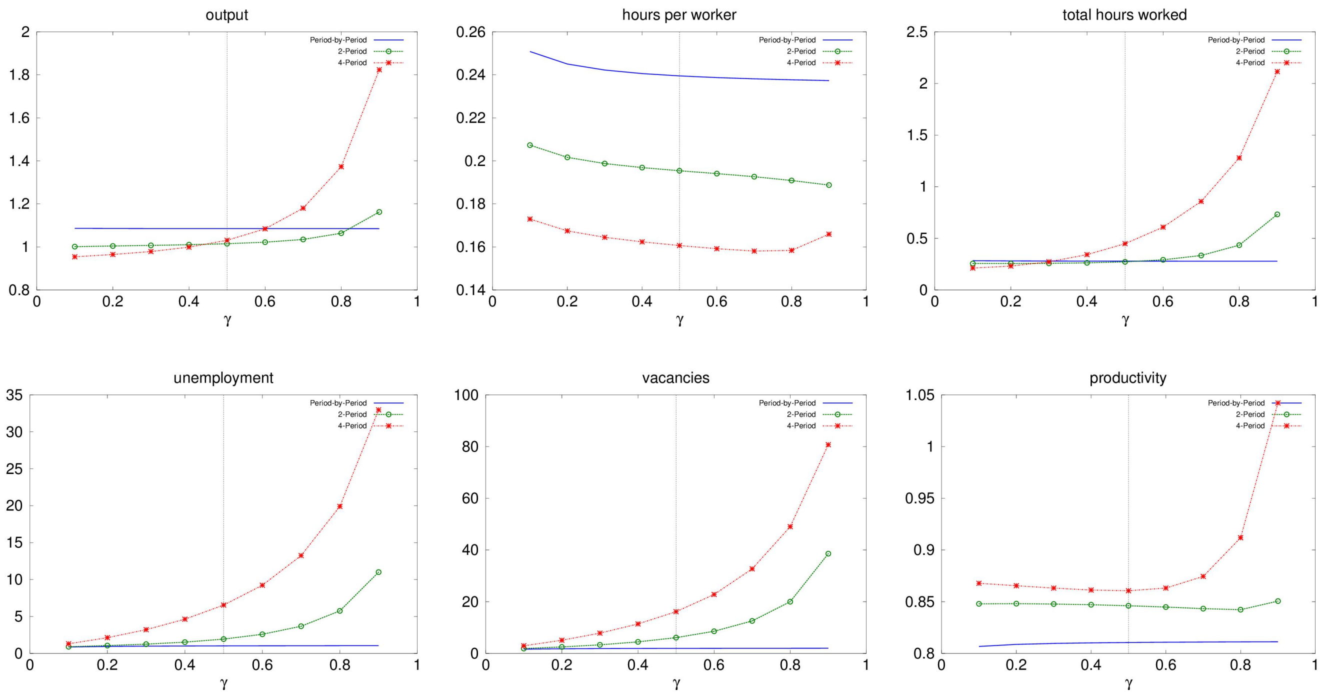


Figure 2: Sensitivity Analysis – Bargaining Power of Workers

(a) Standard Deviations



(b) Correlations

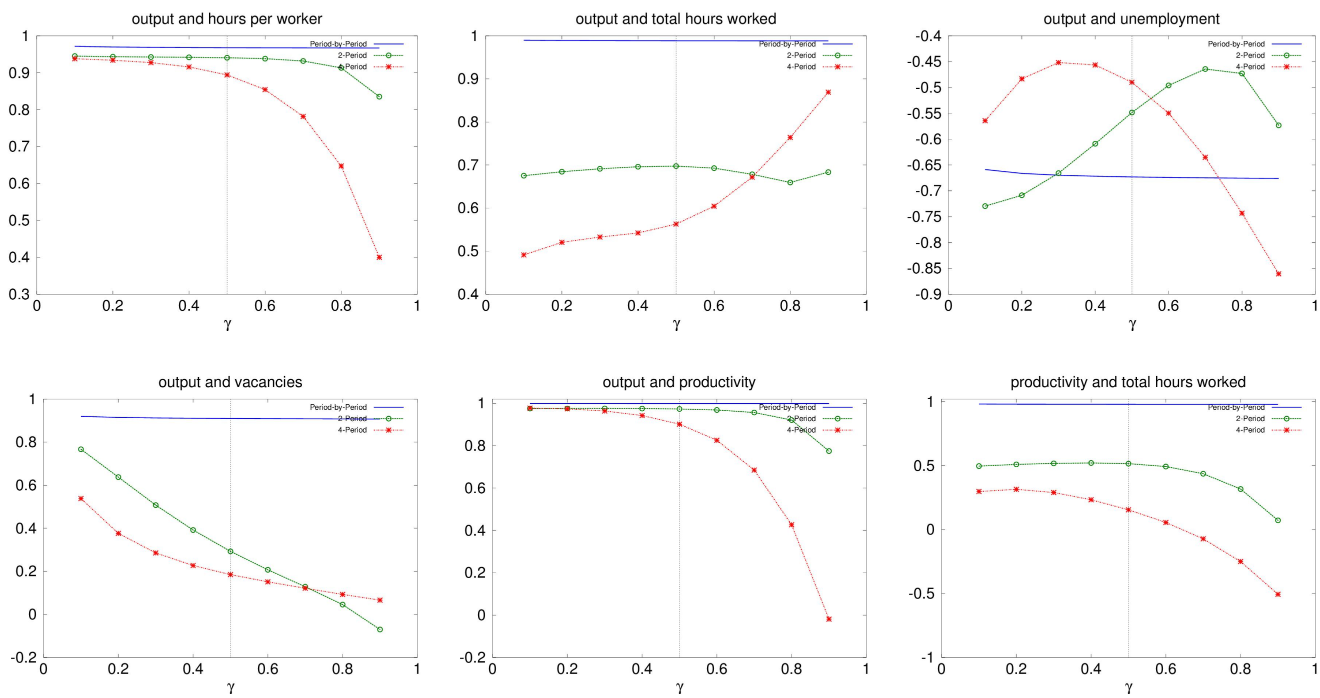
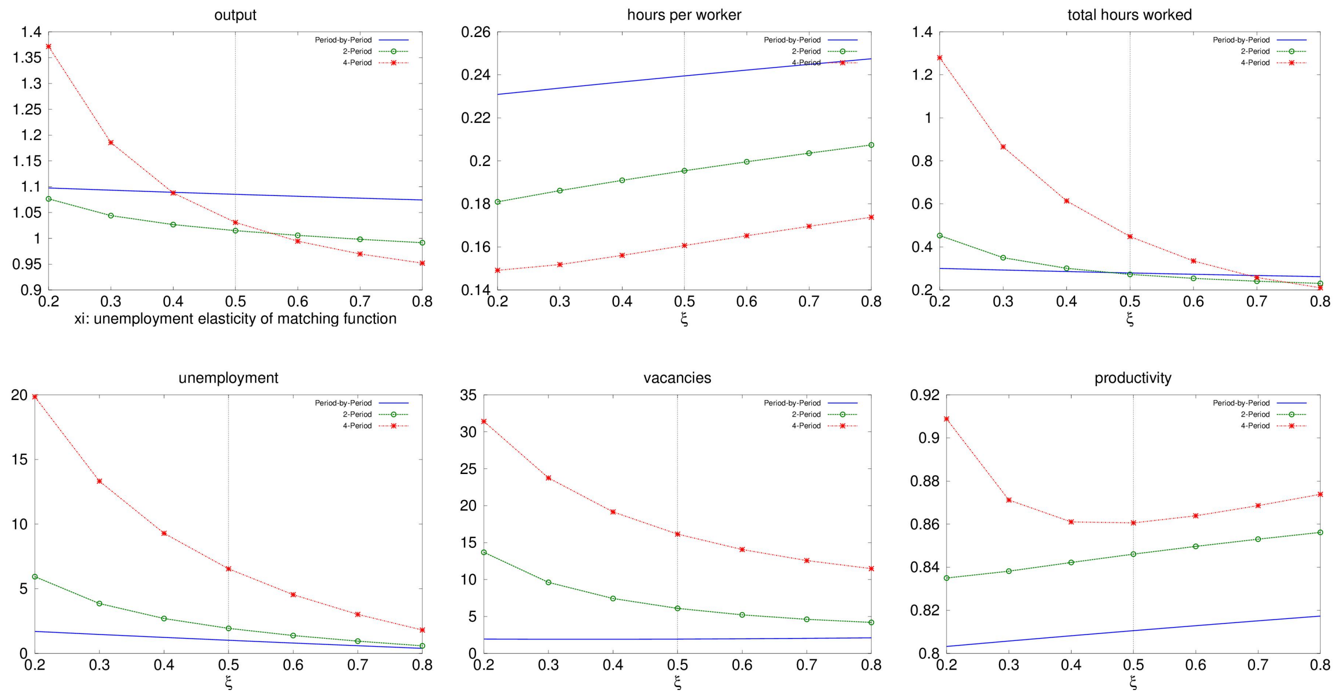


Figure 3: Sensitivity Analysis – Matching Function Elasticity

(a) Standard Deviations



(b) Correlations

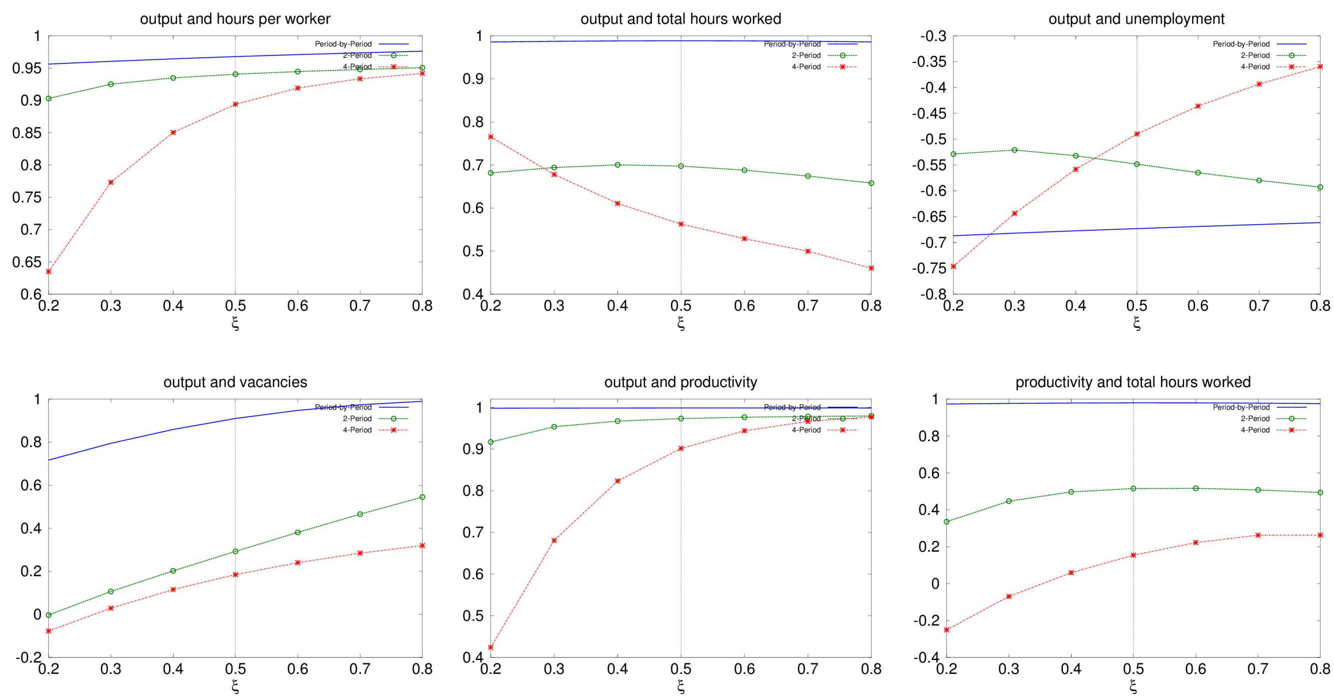
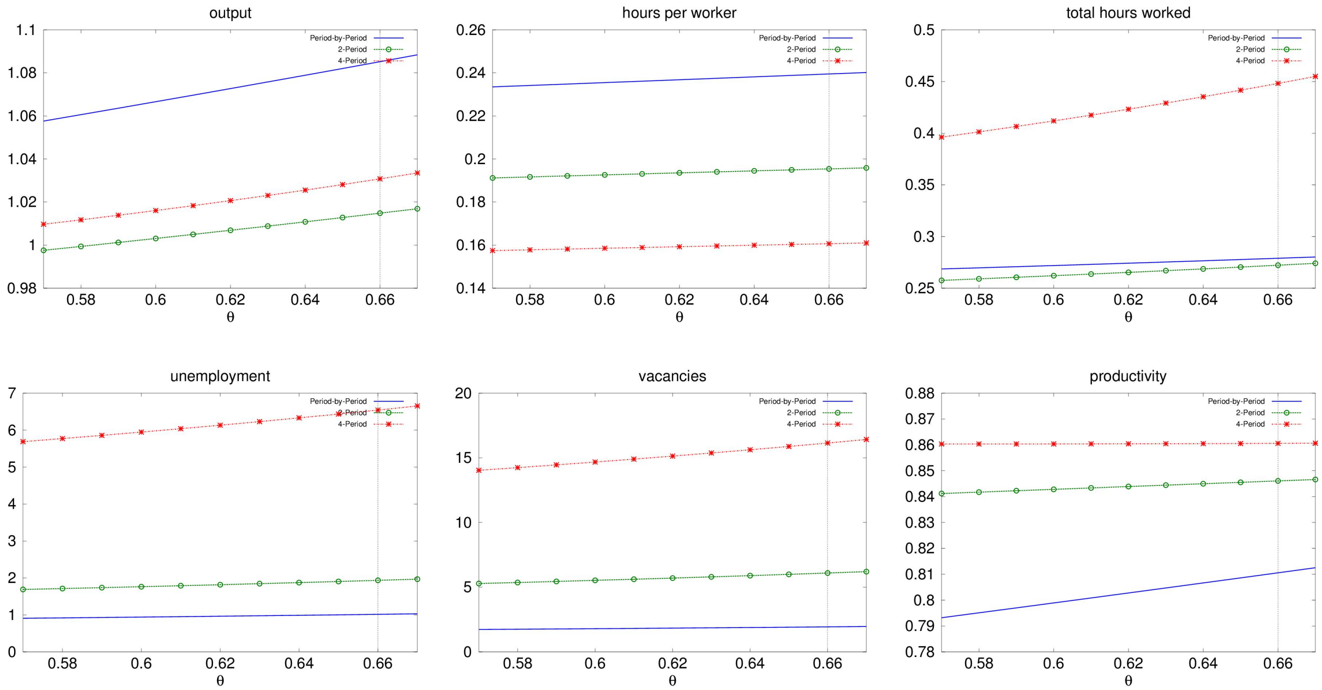


Figure 4: Sensitivity Analysis – Production Function Elasticity

(a) Standard Deviations



(b) Correlations

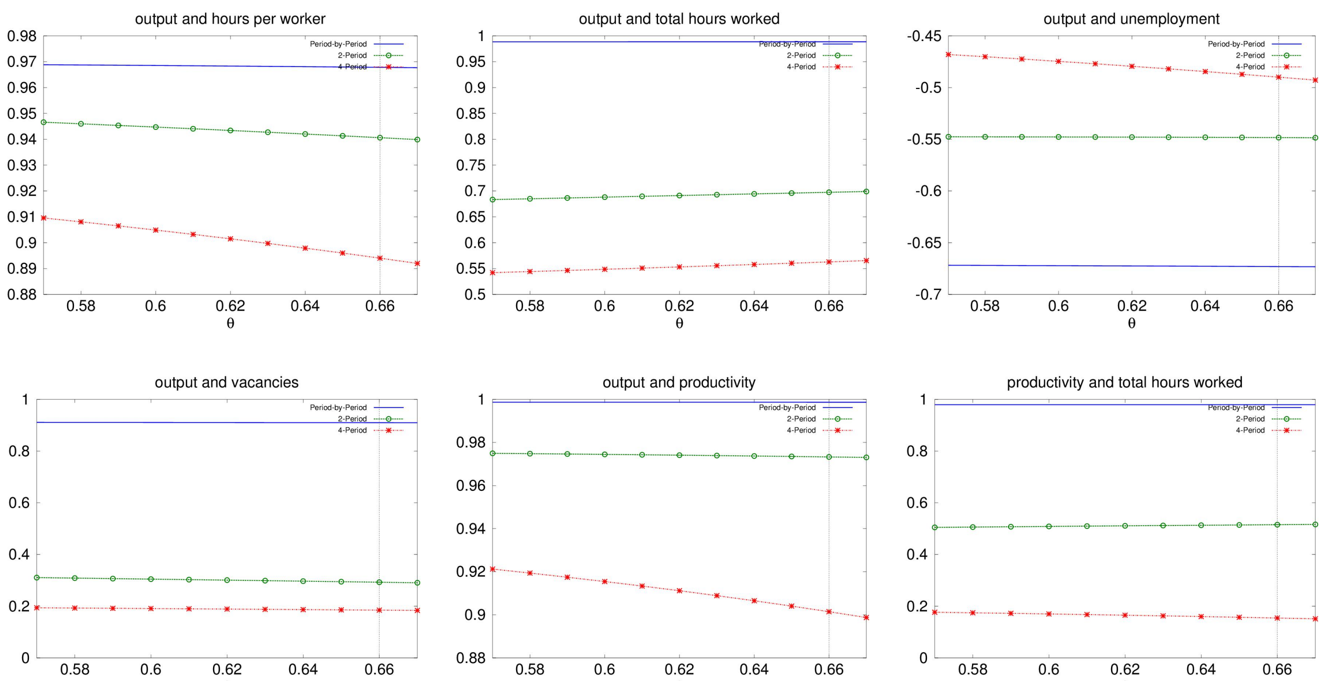


Table 1: Parameter Values

	(1) Benchmark	(2) Cho-Cooley	(3) Wage Only	(4) Current Surplus 2-Period (4-Period)	(5) Instant. Hiring
Frictions	Yes	No	Yes	Yes	Yes
Bargaining	(W, h)	–	W only	(W, h)	(W, h)
			Predetermined Parameters		
β	.99	.99	.99	.99	.99
δ	.025	.025	.025	.025	.025
ξ	.5	–	.5	.5	.5
α	.33	.33	.33	.33	.33
θ	.66	.67	.66	.66	.66
γ	.5	–	.5	.5	.5
f	.6	–	.6	.6	.6
n	.94	.94	.94	.94	.94
h	1/3	1/3	1/3	1/3	1/3
ϕ	2.0	2.0	2.0	2.0	2.0
τ	–	1.2	–	–	–
ρ_z	.95	.95	.95	.95	.95
ρ_g	.49	.49	.49	.49	.49
σ_z	.007	.007	.007	.007	.007
σ_g	.00623	.00623	.00623	.00623	.00623
			Parameters Determined Endogenously		
B	24.8688	24.906	29.5269	26.537 (31.329)	25.3538
D	0	.6624	0	0	0
κ	.1647	–	.1267	.924 (2.656)	.1583
s	.0383	–	.0383	.0383	.0957
w	2.0138	2.0203	2.0230	1.830 (1.411)	1.9707
b	.2685	–	.2697	.244 (.188)	.2628

Notes: β denotes the discount factor, δ the depreciation rate of capital, ξ the elasticity of the matching function, α the capital share, θ the share of hours worked, γ worker's bargaining power, f the job-finding probability, n the employment rate, ϕ the inverse of the elasticity of intertemporal substitution of leisure, ρ_z the persistence parameter of technology shocks, ρ_g persistence parameter of shocks to the money growth rate, σ_z (conditional) standard deviation of technology shocks, σ_g (conditional) standard deviation of the shock to the money growth rate, B utility parameter, κ vacancy posting cost, s the exogenous separation rate, w real bargaining wage, and b household production. See Appendix for parameters τ and D.

Table 2: Standard Deviations – RTM

		Relative to the Volatility of Output										
	y	c	i	n	h	nh	u	v	w	a	P	$\frac{P}{P_{-1}}$
U.S. Economy	2.09	.36	2.86	.61	.24	.74	5.31	6.36	.43	.50	1.43	.51
Cho-Cooley Model – No Frictions & Right-To-Manage												
No Contracts												
Both shocks	1.30	.40	3.39	.33	.13	.46	–	–	.56	.56	.40	.33
Monetary shock only	.02	14.05	41.65	.95	.38	1.32	–	–	.89	.89	14.05	15.89
Technology shock only	1.30	.33	3.32	.33	.13	.46	–	–	.56	.56	.33	.21
2-Period Contracts												
Both shocks	2.83	.20	4.15	.93	.37	1.30	–	–	.48	.48	.20	.14
Monetary shock only	2.27	.13	4.46	1.08	.43	1.51	–	–	.52	.52	.13	.12
Technology shock only	1.70	.28	3.53	.55	.22	.78	–	–	.40	.40	.28	.18
4-Period Contracts												
Both shocks	3.60	.19	4.05	.97	.39	1.36	–	–	.48	.48	.19	.12
Monetary shock only	3.09	.15	4.22	1.07	.43	1.50	–	–	.51	.51	.15	.09
Technology shock only	1.83	.28	3.54	.58	.23	.81	–	–	.34	.34	.28	.17
Search Frictions & Right-To-Manage (Wage Bargaining Only)												
Period-by-Period												
Both shocks	1.46	.40	3.28	.03	.56	.58	.41	.76	.43	.43	.40	.32
Monetary shock only	.02	11.93	34.53	.05	1.20	1.20	.74	1.36	.69	.69	11.93	13.49
Technology shock only	1.46	.35	3.23	.03	.56	.57	.41	.75	.43	.43	.35	.22
2-Period Contracts												
Both shocks	2.70	.22	4.10	.01	1.29	1.29	.23	.42	.49	.49	.22	.16
Monetary shock only	2.14	.13	4.47	.01	1.53	1.53	.08	.16	.54	.54	.13	.12
Technology shock only	1.64	.32	3.38	.02	.70	.71	.36	.67	.37	.37	.32	.20
4-Period Contracts												
Both shocks	3.34	.21	4.01	.01	1.36	1.36	.21	.39	.49	.49	.21	.13
Monetary shock only	2.87	.16	4.20	.01	1.52	1.52	.12	.23	.53	.53	.16	.09
Technology shock only	1.70	.31	3.39	.02	.72	.73	.36	.66	.34	.34	.31	.20

Notes: Data (1956:I-2005:IV) are seasonally adjusted and HP filtered with smoothing parameter 1,600. y = production in non-farm business; c = real personal consumption expenditures of non-durable goods and services + real government consumption expenditures; i = real gross private investment + real personal consumption expenditures of durables ; n = employed persons in the non-farm business sector; h = average weekly hours; nh = total hours worked; u = unemployed persons from the Current Population Survey; v = help-wanted indices; w = real hourly compensation; a = labor productivity (y/nh); P = price level measured by CPI; P/P_{-1} = inflation rate.

Table 3: Correlations with Output – RTM

	correlations with output											
	c	i	n	h	nh	u	v	w	a	P	$\frac{P}{P_{-1}}$	(a, nh)
U.S. Economy	.65	.94	.78	.72	.87	-.84	.90	.24	.70	-.37	.23	.27
Cho-Cooley Model – No Frictions & Right-To-Manage												
No Contracts												
Both shocks	.75	.97	.98	.98	.98	–	–	.99	.99	-.75	-.35	.93
Monetary shock only	.96	-.95	.74	.74	.74	–	–	.02	.02	-.96	-.64	-.66
Technology shock only	.90	.99	.98	.98	.98	–	–	.99	.99	-.90	-.55	.94
2-Period Contracts												
Both shocks	.23	.99	.94	.94	.94	–	–	-.47	-.47	-.23	-.43	-.73
Monetary shock only	-.47	.99	.99	.99	.99	–	–	-.98	-.98	.47	-.24	-.99
Technology shock only	.83	.99	.93	.93	.93	–	–	.69	.69	-.83	-.67	.38
4-Period Contracts												
Both shocks	.39	.99	.96	.96	.96	–	–	-.65	-.65	-.39	-.62	-.83
Monetary shock only	.13	.99	.99	.99	.99	–	–	-.97	-.97	-.13	-.67	-.99
Technology shock only	.83	.99	.95	.95	.95	–	–	.67	.67	-.83	-.62	.40
Search Frictions & Right-To-Manage (Wage Bargaining Only)												
Period-by-Period												
Both shocks	.80	.97	.93	.99	.99	-.60	.95	.99	.99	-.80	-.38	.96
Monetary shock only	.92	-.90	.07	.80	.82	-.58	-.56	.02	.02	-.92	-.64	-.56
Technology shock only	.92	.99	.93	.99	.99	-.60	.95	.99	.99	-.92	-.53	.96
2-Period Contracts												
Both shocks	.28	.99	.60	.94	.94	-.28	.75	-.45	-.45	-.28	-.41	-.72
Monetary shock only	-.46	.99	.46	.99	.99	.00	.77	-.98	-.98	.46	-.24	-.99
Technology shock only	.87	.99	.86	.95	.96	-.48	.98	.85	.85	-.87	-.62	.67
4-Period Contracts												
Both shocks	.42	.99	.69	.96	.96	-.42	.73	-.62	-.62	-.42	-.59	-.82
Monetary shock only	.15	.99	.71	.99	.99	-.45	.71	-.97	-.97	-.15	-.67	-.99
Technology shock only	.88	.99	.88	.96	.97	-.52	.96	.85	.85	-.88	-.59	.69

Table 4: Correlations with Unemployment – RTM

	c	i	n	h	nh	v	w	a	P	$\frac{P}{P_{-1}}$
U.S. Economy	-.57	-.78	-.92	-.56	-.94	-.93	-.13	-.29	.22	-.41
Search Frictions & Right-To-Manage (Wage Bargaining Only)										
Period-by-Period										
Both shocks	-.68	-.51	-.85	-.50	-.53	-.34	-.68	-.68	.68	-.20
Monetary shock only	-.22	.17	-.85	.02	-.02	-.34	-.82	-.82	.22	.48
Technology shock only	-.78	-.52	-.85	-.50	-.53	-.35	-.68	-.68	.78	-.29
2-Period Contracts										
Both shocks	-.77	-.15	-.85	-.04	-.05	-.33	-.43	-.43	.77	-.14
Monetary shock only	-.84	.08	-.81	.07	.06	-.26	-.18	-.18	.84	.49
Technology shock only	-.79	-.36	-.85	-.20	-.23	-.34	-.84	-.84	.79	-.30
4-Period Contracts										
Both shocks	-.82	-.30	-.84	-.24	-.25	-.32	-.15	-.15	.82	-.04
Monetary shock only	-.93	-.34	-.82	-.37	-.38	-.28	.23	.23	.93	.54
Technology shock only	-.79	-.41	-.85	-.30	-.33	-.34	-.82	-.82	.79	-.29

Table 5: Standard Deviations – Search Frictions and Efficient Bargaining

		Relative to the Volatility of Output										
	y	c	i	n	h	nh	u	v	w	a	P	$\frac{P}{P_{-1}}$
U.S. Economy	2.09	.36	2.86	.61	.24	.74	5.31	6.36	.43	.50	1.43	.51
Benchmark												
Period-by-Period												
Both shocks	1.09	.44	3.29	.06	.22	.26	.94	1.78	.71	.75	.44	.38
Monetary shock only	.02	19.00	58.12	.06	.74	.74	.89	1.39	1.09	1.04	19.00	21.47
Technology shock only	1.09	.35	3.19	.06	.22	.26	.94	1.78	.71	.75	.35	.22
2-Period Contracts												
Both shocks	1.01	.46	3.26	.12	.19	.27	1.91	6.01	1.43	.83	.46	.40
Monetary shock only	.06	4.52	14.55	1.44	.19	1.44	22.57	79.38	19.94	.55	4.52	5.11
Technology shock only	1.01	.36	3.13	.08	.19	.25	1.25	3.22	.64	.83	.36	.23
4-Period Contracts												
Both shocks	1.03	.45	3.23	.41	.16	.43	6.35	15.66	1.84	.83	.45	.39
Monetary shock only	.26	1.14	5.05	1.48	.08	1.50	23.15	57.24	6.91	.52	1.14	1.27
Technology shock only	1.00	.36	3.07	.16	.16	.22	2.47	6.04	.55	.85	.36	.23
Current Surplus												
Period-by-Period												
Both shocks	1.09	.44	3.29	.06	.22	.26	.94	1.78	.71	.75	.44	.38
Monetary shock only	.02	19.00	58.12	.06	.74	.74	.89	1.39	1.09	1.04	19.00	21.47
Technology shock only	1.09	.35	3.19	.06	.22	.26	.94	1.78	.71	.75	.35	.22
2-Period Contracts												
Both shocks	.97	.64	3.14	.28	.17	.32	4.46	8.51	1.64	.90	.64	.56
Monetary shock only	.18	2.34	4.46	1.55	.03	1.57	24.32	46.81	8.63	.57	2.34	2.51
Technology shock only	.96	.49	3.09	.05	.17	.16	.81	1.15	.52	.91	.49	.33
4-Period Contracts												
Both shocks	.94	1.19	3.43	.19	.25	.37	3.02	5.72	2.29	.96	1.19	1.01
Monetary shock only	.20	4.35	8.93	.88	1.10	1.68	13.78	26.20	10.06	.69	4.35	4.03
Technology shock only	.92	.74	2.90	.03	.07	.07	.41	.70	.72	.98	.74	.53
Contemporaneous Hiring												
Period-by-Period												
Both shocks	1.12	.43	3.19	.15	.20	.31	2.38	1.88	.66	.70	.43	.37
Monetary shock only	.02	18.77	56.30	.14	.72	.75	2.20	1.60	1.03	1.00	18.77	21.21
Technology shock only	1.12	.35	3.10	.15	.20	.31	2.38	1.88	.66	.70	.35	.22
2-Period Contracts												
Both shocks	1.14	.42	3.30	.49	.15	.53	7.69	8.61	1.24	.72	.42	.36
Monetary shock only	.30	1.00	5.45	1.62	.20	1.52	25.43	29.06	4.33	.53	1.00	1.13
Technology shock only	1.11	.34	3.09	.26	.15	.37	4.12	4.34	.55	.73	.34	.22
4-Period Contracts												
Both shocks	1.33	.37	3.37	.87	.11	.87	13.64	12.52	1.39	.66	.37	.31
Monetary shock only	.70	.45	4.11	1.53	.11	1.52	23.91	21.83	2.51	.53	.45	.48
Technology shock only	1.13	.34	3.03	.38	.11	.40	5.95	5.66	.46	.70	.34	.21

Table 6: Correlations with Output – Search Frictions and Efficient Bargaining

	correlations with output											
	c	i	n	h	nh	u	v	w	a	P	$\frac{P}{P_{-1}}$	(a, nh)
U.S. Economy	.65	.94	.78	.72	.87	-.84	.90	.24	.70	-.37	.23	.27
Benchmark												
Period-by-Period												
Both shocks	.73	.96	.97	.97	.99	-.67	.91	.99	.99	-.73	-.31	.98
Monetary shock only	.69	-.65	.74	.25	.32	-.90	.31	.56	.74	-.69	-.61	-.40
Technology shock only	.92	.99	.97	.97	.99	-.67	.91	.99	.99	-.92	-.51	.98
2-Period Contracts												
Both shocks	.71	.96	.64	.94	.70	-.55	.29	.36	.97	-.71	-.28	.52
Monetary shock only	-.26	.65	.18	-.43	.96	-.98	-.44	-.60	-.71	.26	-.62	-.87
Technology shock only	.93	.99	.97	.95	.72	-.77	.59	.87	.98	-.93	-.44	.56
4-Period Contracts												
Both shocks	.66	.98	.46	.89	.56	-.49	.18	.02	.90	-.66	-.37	.15
Monetary shock only	-.15	.97	.64	-.40	.99	-.99	-.02	-.82	-.95	.15	-.59	-.98
Technology shock only	.93	.99	.86	.94	.72	-.71	.53	.77	.98	-.93	-.45	.59
Current Surplus												
Period-by-Period												
Both shocks	.73	.96	.97	.97	.99	-.67	.91	.99	.99	-.73	-.31	.98
Monetary shock only	.69	-.65	.74	.25	.32	-.90	.31	.56	.74	-.69	-.61	-.40
Technology shock only	.92	.99	.97	.97	.99	-.67	.91	.99	.99	-.92	-.51	.98
2-Period Contracts												
Both shocks	.68	.96	.08	.94	.44	-.16	-.05	.13	.95	-.68	-.33	.13
Monetary shock only	-.13	.41	.83	-.05	.99	-.99	.29	-.73	-.99	.13	-.48	-.99
Technology shock only	.95	.99	-.43	.96	.60	.14	-.80	.86	.99	-.95	-.45	.48
4-Period Contracts												
Both shocks	.54	.86	.04	.20	.28	-.13	-.09	.19	.93	-.54	-.29	-.08
Monetary shock only	-.14	.51	.53	.35	.99	-.75	.07	-.41	-.97	.14	-.30	-.99
Technology shock only	.97	.99	-.67	.47	.37	.30	-.91	.95	.99	-.97	-.46	.31
Contemporaneous Hiring												
Period-by-Period												
Both shocks	.74	.96	.98	.94	.98	-.71	.90	.99	.99	-.74	-.30	.95
Monetary shock only	.70	-.66	.96	.25	.38	-.79	.84	.54	.71	-.70	-.58	-.37
Technology shock only	.92	.99	.98	.94	.98	-.71	.90	.99	.99	-.92	-.48	.96
2-Period Contracts												
Both shocks	.66	.97	.56	.83	.72	-.62	.20	.25	.86	-.66	-.36	.27
Monetary shock only	-.24	.99	.53	-.24	.99	-.99	-.12	-.52	-.96	.24	-.62	-.98
Technology shock only	.92	.98	.89	.94	.82	-.79	.49	.89	.96	-.92	-.40	.61
4-Period Contracts												
Both shocks	.58	.97	.63	.61	.76	-.74	.24	-.21	.50	-.58	-.45	-.17
Monetary shock only	-.04	.97	.73	-.21	.99	-.99	.14	-.79	-.98	.04	-.61	-.99
Technology shock only	.91	.98	.88	.94	.83	-.79	.53	.79	.95	-.91	-.39	.62

Table 7: Correlations with Unemployment – Search Frictions and Efficient Bargaining

	c	i	n	h	nh	v	w	a	P	$\frac{P}{P_{-1}}$
U.S. Economy	-.57	-.78	-.92	-.56	-.94	-.93	-.13	-.29	.22	-.41
Benchmark										
Period-by-Period										
Both shocks	-.62	-.60	-.84	-.52	-.68	-.31	-.68	-.67	.62	-.14
Monetary shock only	-.38	.33	-.92	.10	.03	-.55	-.78	-.89	.38	.30
Technology shock only	-.78	-.62	-.84	-.52	-.68	-.31	-.68	-.67	.78	-.25
2-Period Contracts										
Both shocks	-.22	-.64	-.41	-.40	-.76	.27	.21	-.41	.22	.28
Monetary shock only	.33	-.72	-.24	.42	-.99	.39	.66	.81	-.33	.58
Technology shock only	-.74	-.77	-.63	-.64	-.82	.03	-.78	-.67	.74	-.20
4-Period Contracts										
Both shocks	-.06	-.62	-.67	-.20	-.93	-.01	.69	-.10	.06	.42
Monetary shock only	.19	-.97	-.67	.40	-.99	-.01	.83	.97	-.19	.58
Technology shock only	-.61	-.75	-.68	-.67	-.69	-.02	-.38	-.65	.61	-.13
Current Surplus										
Period-by-Period										
Both shocks	-.62	-.60	-.84	-.52	-.68	-.31	-.68	-.67	.62	-.14
Monetary shock only	-.38	.33	-.92	.10	.03	-.55	-.78	-.89	.38	.30
Technology shock only	-.78	-.62	-.84	-.52	-.68	-.31	-.68	-.67	.78	-.25
2-Period Contracts										
Both shocks	.14	-.10	-.83	-.03	-.85	-.31	.72	.13	-.14	.43
Monetary shock only	.14	-.40	-.83	.04	-.99	-.30	.73	.99	-.14	.49
Technology shock only	.43	.04	-.95	-.15	.06	-.68	.60	.14	-.43	.38
4-Period Contracts										
Both shocks	.38	-.13	-.84	-.65	-.79	-.31	.71	.17	-.38	.42
Monetary shock only	.43	-.25	-.84	-.65	-.80	-.31	.73	.87	-.43	.45
Technology shock only	.52	.18	-.89	-.63	-.28	-.44	.55	.33	-.52	.44
Contemporaneous Hiring										
Period-by-Period										
Both shocks	-.63	-.66	-.82	-.47	-.81	-.33	-.67	-.66	.63	-.14
Monetary shock only	-.50	.46	-.87	-.13	-.31	-.43	-.44	-.56	.50	.00
Technology shock only	-.78	-.68	-.83	-.47	-.81	-.33	-.67	-.66	.78	-.24
2-Period Contracts										
Both shocks	-.13	-.77	-.55	-.26	-.96	.10	.22	-.15	.13	.37
Monetary shock only	.26	-.99	-.52	.24	-.99	.13	.50	.97	-.26	.60
Technology shock only	-.66	-.87	-.61	-.69	-.95	.03	-.71	-.61	.66	-.14
4-Period Contracts										
Both shocks	-.13	-.83	-.73	-.12	-.99	-.14	.65	.19	.13	.43
Monetary shock only	.07	-.97	-.73	.22	-.99	-.15	.79	.98	-.07	.60
Technology shock only	-.61	-.88	-.70	-.71	-.96	-.10	-.47	-.58	.61	-.11