Unemployment Benefits and Matching Efficiency in an Estimated DSGE Model with Labor Market Search Frictions*

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Abstract

To explain the high and persistent unemployment rate in the US during and after the Great Recession, I develop and estimate a DSGE model with search and matching frictions, endogenous wage inertia, and shocks to unemployment benefits and matching efficiency. By using a general equilibrium model, considering both the labor market and the aggregate demand responses, I find that a shock to the unemployment benefits has a large impact on the cyclical movement of unemployment by affecting labor demand. During the Great Recession, extended unemployment benefits increased the unemployment rate by 1 percentage point. In the meanwhile, matching efficiency changes have less effect on the cyclical movement of unemployment. These findings are robust to different model setups and estimations.

Keywords: DSGE, search and matching frictions, unemployment benefits, matching efficiency

JEL codes: E24, E32, E52

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1 Introduction

The unemployment rate in the US began increasing in 2007, and continued increasing until it reached the 10% level at the end of 2009. With the subsequent recovery of the economy, the unemployment rate began to decrease, but at a very slow pace that did not keep up with the increase in output. As of the beginning of 2013, the unemployment rate was still almost 8%, far above pre-recession levels (below 5%), despite the fact that the recession had been over for more than 3 years. This problem has received significant attention from policy makers and economists. It has been shown that the large decline in output and investment has contributed to the extraordinarily high unemployment rate and the slow recovery of the labor market. However, there must be other explanations too. In general, these fall into two categories. The first posits that the extended unemployment benefits have raised the unemployment rate in the recession and slowed down recovery, while the second points to that the deterioration of the matching efficiency as the primary reason.

Which one is more important to the persistently high unemployment rate in the past few years, the extended unemployment benefits or the deterioration of the matching efficiency? In order to investigate this problem, I build a New Keynesian DSGE model with labor market search and matching frictions, endogenous separation, as in den Haan, Ramey and Watson (2000), and endogenous wage inertia, as in Christiano, Eichenbaum and Trabandt (2013). The key innovation of this paper is inclusion of shocks to both matching efficiency and unemployment benefits. This allows us to explore the role of general equilibrium effects that are overlooked in previous analyses. Most of the previous literature on unemployment benefits considers only the partial equilibrium effects on labor supply and search intensity. However, general equilibrium feedbacks could also be important. On the one hand, higher unemployment benefits may boost income and spending and thereby have a stimulative effect in an economic recession, as argued for example by the Council of Economic Advisors (2013). Weighing against this is the fact that more generous unemployment benefits increase equilibrium wages and reduce the value of any given match to the firm, in response to which firms are more likely to terminate existing matches and have less incentive to post new vacancies. These can push up the unemployment rate and make the recession worse. By studying these effects in a dynamic general equilibrium model, we can assess the quantitative importance of the various changes that occur as a result of changes in unemployment benefits or matching efficiency.

One of the primary findings of this paper is the shocks to unemployment benefits have historically played a very important role in unemployment fluctuations. They account for around 12% of variation in unemployment as well as vacancies in the short run and the long run. During the Great Recession, extended unemployment benefits shocks increased the unemployment rate by more than one percentage point, while matching efficiency shocks had very little effect on it. The primary channel through which the unemployment benefits affect the labor market is the creation of vacancies. This finding is consistent with the results Hagedorn, Karahan, Manovskii, and Mitman (2013). On the other hand, there are also a lot of papers, both theoretically and empirically, arguing that the extended unemployment benefits cannot have a big impact on unemployment. Most of these studies focused on the effect of the extended unemployment benefits on labor supply, especially workers' search efforts. The second important finding of this paper is that matching efficiency shocks have historically accounted for less than 6% of the unemployment fluctuations in the short run; this is consistent with the result in Furlanetto and Groshenny (2012) and Michaillat (2011).

This paper is primarily related to three strands of literature. The first strand of literature is on the DSGE models with labor market frictions. A number of papers have introduced labor market search and matching frictions into a New Keynesian DSGE model. Walsh (2003, 2005), Krause and Lubik (2007), Blanchard and Gali (2010), Kuester (2010), and Groshenny (2012) focused on the effects of monetary policy and inflation responsiveness to shocks when search and matching frictions exist in the labor market. Gertler, Sala and Trigari (2008), Christiano, Trabandt and Walentin (2010), Gali, Smets and Wouters (2011) attempted to construct a complete medium scale DSGE model to fit the data better. However, none of these papers allowed for shocks to matching efficiency or unemployment benefits, which is the primary motivation of this paper.

Since the effect of the unemployment benefits shocks is the primary problem investigated in this paper, the second strand of literature that is closely related to this paper is the studies on the unemployment benefits programs. Several empirical works have focused on studying the role of extended unemployment benefits in the US labor market during the Great Recession. Valletta and Kuang (2010) measured the increase in involuntary job losses and the average duration of unemployment. Fujita (2011) used monthly CPS data to quantify the effects of extended unemployment benefits in recent years, and suggested that extended benefits have raised the male workers' unemployment rate by 1.2 percentage points. Calibrated models are also used in some papers to assess the effects of a countercyclical unemployment benefits policy. Nakajima (2012) measured the effect of extensions of unemployment insurance benefits on the unemployment rate using a calibrated structural model. Moyen and Stahler (2012) and Landais, Michaillat, and Saez (2013) studied optimal unemployment insurance over the business cycle. Instead of only relying on either labor market data or the calibrated model, I introduce unemployment benefits shocks into an estimated medium scale DSGE model and use the data and the model together to study how these shocks affect labor market dynamics.

In this paper, besides the unemployment benefits, I also investigate the role matching efficiency plays in the labor market and on unemployment benefits in accounting for historical variations in unemployment. Hence, the third strand of literature related to this paper is on the matching efficiency. Recently, there have been many studies on matching efficiency. Some papers focus on studying the mismatch problem during the Great Recession. Dickenson (2010) studied the labor market tightness data of different industries, which suggests that it would be hard to make a case for structural mismatch being a major problem today. Barlevy (2011) and Veracierto (2011) found a big decline in matching efficiency during the Great Recession. Sahin, Song, Topa and Violante (2012) measured the contribution of mismatch to the recent rise in US unemployment and found that mismatch across industries and occupations explain at most 1/3 of the increase in unemployment. Instead of specializing in studying the Great Recession, some studies consider the mismatch problem throughout history. Barnichon and Figura (2011) constructed a matching efficiency time series from CPS micro data back to 1976 and studied the determinants of matching efficiency fluctuations over the last four decades. Michaillat (2011) found that in bad times, frictional unemployment is only a very small part of total unemployment, using a calibrated model of the labor market. All of these previously mentioned papers only focused on the labor market, none of them studied the labor market using a complete economic framework. Instead, they used either different versions of a calibrated Mortensen-Pissarides model or a matching function as convenient devices to capture the job seeking process without considering its connections to other parts of the economy. Furlanetto and Groshenny (2012) made an important advance on these earlier studies, introducing matching efficiency shocks into an estimated DSGE model with labor market search and matching frictions. They found that matching efficiency shocks are irrelevant to unemployment fluctuations historically, but did increase unemployment during the Great Recession. However, their model assumes exogenous employment separations and Calvo type nominal wages; hence, it may be important to see whether alternative formulations are more successful empirically. In contrast to the previously mentioned papers, my paper uses a complete general equilibrium structural model with labor market search frictions and endogenous separation to study the importance of matching efficiency shocks over the period of 1976 through 2011.

The remainder of the paper is structured as follows. Section 2 sets up the model. Section 3 presents the estimation of the model parameters. Section 4 presents the results of the baseline model. Section 5 gives the results of 4 robustness checks. Finally, in Section 6 I conclude the paper.

2 The Model

The primary framework of the model I use follows Smets and Wouters (2007). The model considers three types of agents: households, intermediate goods firms, and final goods firms. And like Smets and Wouters (2007), I introduce a number of exogenous shocks in the model.

2.1 Household

There is a representative household in the economy and there are a continuum of members, indexed by i, measured on $[0,1]$ in the household. Every member has the same period utility function: $\frac{(c_t - h\mathcal{C}_{t-1})^{1-\sigma}}{1-\sigma}$, where the utility depends not only on their own consumption of final goods c_t, but also on the past aggregate consumption in the economy, $\mathcal{C}_{t-1}$. I define h as the habit formation parameter. Unlike Smets and Wouters (2007), I don't include the intensive margin of employment, because Gertler, Sala and Trigari (2008) found that most of the cyclical variation in employment in the United States is on the extensive margin and including the intensive margin does not affect the model very much. Leisure is not considered in the utility function here. Instead, it appears in the budget constraint. That is, the value of being unemployed is measured in consumption goods and considered a part of the household's income. People in a household pool their income together for consumption. The household does not make the labor supply decision. All unemployed members search on the job market and the frictional search and matching process determines who is employed. The representative household maximizes:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \frac{(C_t - h\mathcal{C}_{t-1})^{1-\sigma}}{1-\sigma} \tag{1}$$

s.t.

$$\begin{aligned} C_t + I_t + \frac{B_t}{\epsilon_t^b r_t P_t} = & \int_0^1 \chi_{it} Y_{it}^L di + \frac{B_{t-1}}{P_t} + r_t^k d_t K_{t-1}^H - D(d_t) K_{t-1}^H \\ & + D_t + \int_0^1 (1-\chi_{it})(A_t + G_t^u) di - T_t \end{aligned} \tag{2}$$

The inter-temporal discount factor is β, and the consumption of the family members at period t is C_t. The consumption C_t is a CES function over a continuum of goods with elasticity of substitution ϵ_t^p,

$$C_t = [\int_0^1 (C_{\widetilde{j}t})^{\frac{\epsilon_t^p - 1}{\epsilon_t^p}} d\widetilde{j}]^{\frac{\epsilon_t^p}{\epsilon_t^p - 1}}, \epsilon_t^p > 1$$

where $\widetilde{j}$ is the index of the differentiated final consumption goods, and ϵ_t^p follows $\log \epsilon_t^p = (1-\rho^p)\log \epsilon^p + \rho^p \log \epsilon_{t-1}^p - \mu^p \nu_{t-1}^p + \nu_t^p$. All innovations in this paper, including ν_t^p, are *i.i.d.* random variables with mean 0.

The price for the consumption good is P_t. The investment is represented by I_t. The bond holding is B_t, and the gross nominal interest rate controlled by the central bank is r_t. The risk premium shock is ϵ_t^b, which follows $\log \epsilon_t^b = \rho^b \log \epsilon_{t-1}^b + \nu_t^b$.

The household's disposable real labor income earned by member i is represented by Y_{it}^L. The indicator for employment status, χ_t, equals 1 when the person is employed in period t, and 0 otherwise. The flow value from unemployment includes unemployment benefits paid by the government G_t^u, as well as other factors (such as leisure) that can be measured in units of consumption goods $A_t = \iota^t A$, where ι is the deterministic growth rate of output. I assume A_t grows at the same rate as output; in this way, leisure wouldn't become less and less valuable as the economy grows.

The stock of capital at the end of period $t-1$ held by the household is K_{t-1}. The net return to capital is expressed as the return on the capital used minus the cost associated with variations in the degree of capital utilization: $(r_t^k d_t K_{t-1}^H - D(d_t) K_{t-1}^H)$. The income from renting out capital services depends on the level of capital stock and its utilization rate d_t. The cost of capital utilization is assumed to be zero when capital is fully used (*i.e.* $D(1) = 0$).

The profit from the final goods sector is D_t; the lump-sum tax is T_t.

The accumulation of capital obeys the following rule:

$$K_t^H = (1-\delta)K_{t-1}^H + \epsilon_t^I[1-\psi(I_t/I_{t-1})]I_t, \tag{3}$$

where $\psi(\cdot)$ is the investment adjustment costs, which equals zero when the investment grows at the deterministic growth trend ι ($\psi(\iota)=0$). The adjustment cost function also satisfies $\psi'(\iota)=0$ and $\psi''(\iota)>0$. ϵ_t^I is the shock to installation cost, which follows $\log\epsilon_t^I = \rho^I \log\epsilon_{t-1}^I + \nu_t^I$.

The representative household maximizes its utility by choosing consumption, bond holdings, investment, capital stock, and the capital utilization rate. The first order conditions for the household's problem are:

$$C_t : (C_t - h\mathcal{C}_{t-1})^{-\sigma} = \widetilde{\lambda}_{1t} \tag{4}$$

$$B_t : \widetilde{\lambda}_{1t} = \beta\mathbb{E}_t(\widetilde{\lambda}_{1t+1}\epsilon_t^b r_t \frac{P_t}{P_{t+1}}) \tag{5}$$

$$\begin{aligned} I_t : Q_t\psi'(\frac{I_t}{I_{t-1}})\frac{\epsilon_t^I I_t}{I_{t-1}} - \beta\mathbb{E}_t[Q_{t+1}\frac{\widetilde{\lambda}_{1t+1}}{\widetilde{\lambda}_{1t}}\psi'(\frac{I_{t+1}}{I_t})\frac{\epsilon_{t+1}^I I_{t+1}}{I_t}\frac{I_{t+1}}{I_t}] + 1 \\ = Q_t\epsilon_t^I(1-\psi(\frac{I_t}{I_{t-1}})) \end{aligned} \tag{6}$$

$$K_t^H : Q_t = \beta\mathbb{E}_t\{\frac{\widetilde{\lambda}_{1t+1}}{\widetilde{\lambda}_{1t}}[Q_{t+1}(1-\delta) + d_{t+1}r_{t+1}^k - D(d_{t+1})]\} \tag{7}$$

$$d_t : r_t^k = D'(d_t) \tag{8}$$

where

$$Q_t = \frac{\widetilde{\lambda}_{2t}}{\widetilde{\lambda}_{1t}}. \tag{9}$$

Tobin's q is represented by Q_t, and the Lagrangian multipliers for the budget constraint and capital accumulation constraint are represented by $\widetilde{\lambda}_{1t}$ and $\widetilde{\lambda}_{2t}$ respectively.

2.2 Intermediate Goods Sector

The intermediate goods sector is perfectly competitive; each firm hires one worker and rents capital to produce identical intermediate goods.

Matching

At the beginning of period t, there are N_t matched workers and firms; $U_t = 1 - N_t$ workers are unmatched. The matched workers at the start of period t travel to their places of employment. At that point, with an exogenous probability $0 \leq \rho^x < 1$ the match is terminated. The remaining $(1-\rho^x)N_t$ pairs of matched workers and firms, indexed by j, jointly observe the realization of social common productivity z_t, and match-specific productivity a_{jt}, which follows a Lognormal distribution with mean 0 and standard deviation σ_a, and then decide whether to continue the match. If a_{jt} is larger than some threshold $\widetilde{a}_{jt}$, the match continues and production occurs. Since all the intermediate goods firms are identical ex ante, we can eliminate the subscript j. All the matches with match specific productivity lower than $\widetilde{a}_t$ are endogenously terminated. So the endogenous separation rate is given by:

$$\rho_t^n = F(\widetilde{a}_t) = \int_{-\infty}^{\widetilde{a}_t} f(a_t) da_t \tag{10}$$

The total separation rate is $\rho_t = \rho^x + (1-\rho^x)\rho_t^n$ and the survival rate is $\rho_t^s = 1 - \rho_t$.

The number of new matches in period t is M_t. These new matches don't produce any goods in the current period; they can only enter production in the next period, after surviving both the exogenous and endogenous separations. The total number of matches evolves according to:

$$N_{t+1} = (1-\rho_{t+1})(N_t + M_t). \tag{11}$$

The number of new matches in period t depends on the amount of vacancies posted by the firms, V_t, and the number of unemployed workers, U_t. The matching function $M_t(U_t, V_t)$ takes the form $\epsilon_t^M \mathcal{M} U_t^\zeta V_t^{1-\zeta}$, where $\mathcal{M}$ is the scale parameter representing the aggregate matching efficiency. The matching efficiency shock ϵ_t^M follows $\log \epsilon_t^M = \rho^M \log \epsilon_{t-1}^M + \nu_t^M$. In the literature, many papers have attempted to estimate the matching efficiency. They found that the matching efficiency does change pro-cyclically. A shock to the scale parameter of the matching function allows fluctuations in the matching efficiency in the model. An increase in the degree of the mismatch, such as the skill mismatch and geographic mismatch, worsens the efficiency of the labor market, and could be considered a negative matching efficiency shock.

The probability of a worker finding a job (the job-finding rate) is given by

$$\rho_t^w = \frac{M_t(U_t, V_t)}{U_t} = \epsilon_t^M \mathcal{M} \theta_t^{1-\zeta}, \tag{12}$$

and the probability of a vacancy being filled (the vacancy-filling rate) is

$$\rho_t^f = \frac{M_t(U_t, V_t)}{V_t} = \epsilon_t^M \mathcal{M} \theta_t^{-\zeta}, \tag{13}$$

where $\theta_t = V_t/U_t$ is the labor market tightness.

Firm's Decision

The production function of the matched firms follows

$$Y(a_{jt}) = z_t a_{jt} \iota^{t(1-\alpha)} K_{jt}^{\alpha}. \tag{14}$$

The common technology shock z_t follows an AR(1) process: $\log z_t = \rho^z \log z_{t-1} + \nu_t^z$. And ι is the deterministic labor-augmenting growth rate. Intermediate goods are sold in a competitive market at the given price P_t^I.

Firms that survived from the separations choose capital optimally by maximizing

$$\frac{z_t a_{jt} K_{jt}^{\alpha} \iota^{t(1-\alpha)}}{\mu_t} - r_t^k K_{jt},$$

where $\mu_t = \frac{P_t}{P^I_t}$ is the price markup. The optimal capital level is:

$$K^*(a_{jt}) = \iota^t (\frac{\alpha z_t a_{jt}}{\mu_t r^k_t})^{\frac{1}{1-\alpha}}. \tag{15}$$

Unmatched firms seeking workers have to pay a cost, $\gamma\iota^t$, to post a vacancy. The vacancy posting cost grows at the same deterministic rate as output. The vacancy could be filled with probability ρ^f_t and the filled vacancy could be separated with probability $1 - \rho_{t+1}$. The unmatched firm will only post a vacancy when the discounted expected future value of doing so is bigger than or equal the cost. Free entry ensures that unmatched firms post vacancies until

$$\gamma\iota^t = \beta\rho^f_t \mathbb{E}_t[\frac{\widetilde{\lambda}_{1t+1}}{\widetilde{\lambda}_{1t}}(1 - \rho_{t+1})J_{t+1}] \tag{16}$$

where J_{t+1} is the expected future value of a matched firm; this is identical for all firms.

The marginal revenue of a matched firm, net of costs on capital, is ϑ_t, which is equal to $\frac{1}{\mu_t}$. And the discounted future expected value of ϑ_t is represented by ϑ^p_t, which satisfies:

$$\vartheta^p_t = \vartheta_t + \beta\rho_{t+1}\mathbb{E}_t\lambda_{t+1}/\lambda_t\vartheta^p_{t+1}.$$

The wage at time t is $W_t(a_{jt})$, and the discounted future expected wage payments of a firm is W^p_t:

$$W^p_t(a_{jt}) = W_t(a_{jt}) + \beta\rho_{t+1}\mathbb{E}_t\lambda_{t+1}/\lambda_t W^p_{t+1}.$$

The value of a matched firm at time t is given by:

$$J_t(a_{jt}) = \vartheta^p_t - W^p_t(a_{jt}).$$

A matched worker's value, $H^w(a_{jt})$, is equal to the real wage that he/she can obtain from the work in this period, plus the discounted future value of the work:

$$H^w(a_{jt}) = W_t(a_{jt}) + \beta \mathbb{E}_t \{ \frac{\widetilde{\lambda}_{1t+1}}{\widetilde{\lambda}_{1t}} [(1-\rho_{t+1}) H^w_{t+1} + \rho_{t+1} H^u_{t+1}] \}. \tag{17}$$

Where H^u_t is the value of an unemployed person; that is, the benefits of being unemployed (benefits of leisure and government unemployment benefits) during this period and the future expected value:

$$H^u_t = A_t + G^u_t + \beta \mathbb{E}_t \{ \frac{\widetilde{\lambda}_{1t+1}}{\widetilde{\lambda}_{1t}} [(1-\rho_{t+1}) \rho^w_t H^w_{t+1} + (1-(1-\rho_{t+1})\rho^w_t) H^u_{t+1}] \} \tag{18}$$

We can now rewrite the value of an employed worker as follows:

$$H^w(a_{jt}) = W^p_t(a_{jt}) + S_t, \tag{19}$$

where

$$S_t = \beta(1-\rho_{t+1}) \mathbb{E}_t \lambda_{t+1}/\lambda_t [\rho^w_{t+1} H^w_{t+1} + (1-\rho^w_{t+1}) H^u_{t+1}] + \beta \rho_{t+1} \mathbb{E}_t \lambda_{t+1}/\lambda_t S_{t+1}. \tag{20}$$

Firms that survived from the exogenous separation should make a decision on endogenous separation; that is, they should decide upon the threshold of the match specific productivity, $\widetilde{a}_t$. Following Krause and Lubik (2007), since under small shocks, real wages are always above workers' reservation wage, the critical value of a_t, below which separation takes place, is given by $J(\widetilde{a}_t) = 0$.

Having $\widetilde{a}_t$, we can define the average capital used in production as follows:

$$K^*_t = \int_{\widetilde{a}_t}^{a_{max}} K^*(a_{jt}) \frac{f(a_t)}{1-F(\widetilde{a}_t)} da_t. \tag{21}$$

The aggregate output net of the vacancy posting costs of the intermediate goods sector is:

$$Y_t = N_t \iota^t \frac{\mu_t r_t^k}{\alpha} K_t^* - \iota^t \gamma V_t. \tag{22}$$

Wage Determination

Instead of assuming that wages are subject to exogenous nominal or real rigidities, the wage determination process is modeled following Chistiano, Eichenbaum, and Trabandt (2013), where wage inertia is an equilibrium outcome of an alternating offer bargaining process. Every time period is divided into F sub-periods, where F is even. Workers make a wage offer at the beginning of every even sub-period and firms make offers at the beginning of every odd sub-period. At an even sub-period, a take-it-or-leave-it offer is made. If the worker's offer is rejected by the firm, the negotiations break down with probability δ_b and the firm makes a counteroffer with probability $1 - \delta_b$ and a cost γ_b. We can obtain the analytical solution of the discounted future expected wage as follows:

$$W_t^p = \frac{1}{\alpha_1 + \alpha_2} [\alpha_1 \vartheta_t^p + \alpha_2 (H_t^u - S_t) + \alpha_3 \gamma^b \epsilon_t^L - \alpha_4 (\vartheta_t - G_t^u - A_t)] \tag{23}$$

where

$$\alpha_1 = 1 - \delta_b + (1 - \delta_b)^F$$

$$\alpha_2 = 1 - (1 - \delta_b)^F$$

$$\alpha_3 = \alpha_2 \frac{1 - \delta_b}{\delta_b} - \alpha_1$$

$$\alpha_4 = \frac{1 - \delta_b}{2 - \delta_b} \frac{\alpha_2}{F} + 1 - \alpha_2.$$

I assume the bargaining power shock, ϵ_t^L, is a shock to the cost the firms pay when they make counteroffers and $\log \epsilon_t^L$ follows an AR(1) process with a random error term. The previous equation can be rewritten as:

$$J_t = \frac{\alpha_2}{\alpha_1}(H_t^w - H_t^u) - \frac{\alpha_3}{\alpha_1}\gamma^b\epsilon_t^L + \frac{\alpha_4}{\alpha_1}(\vartheta_t - G_t^u - A). \tag{24}$$

The Nash bargaining rule is

$$J_t = \frac{1-\eta}{\eta}(H_t^w - H_t^u),$$

where η is the bargaining power of the workers. The difference between the two rules is that the rule used in this paper states that wages depend on both $H_t^w - H_t^u$ and a constant term γ^b, which makes the wages less sensitive to shocks in the economy.

2.3 Final Goods Sector

The final goods sector is monopolistically competitive. Each final good firm, indexed by $\widetilde{j}$, buys the output of the intermediate goods firms at the price P_t^I. They then convert this output into a differentiated final good, $Y_{\widetilde{j}t}$, with no cost and sells the final goods in the market at price $P_{\widetilde{j}t}$. The demand for each variety is:

$$Y_{\widetilde{j}t} = (\frac{P_{\widetilde{j}t}}{P_t})^{-\epsilon_t^p} Y_t \tag{25}$$

and the aggregate price is

$$P_t = [\int_0^1 (P_{\widetilde{j}t})^{1-\epsilon_t^p} d\widetilde{j}]^{\frac{1}{1-\epsilon_t^p}}. \tag{26}$$

Prices are sticky in the final goods sector. In the following analysis, the index $\widetilde{j}$ is eliminated, because every firm faces an identical problem. Following Calvo(1983), during each period, only a fraction of $(1-\omega)$ firms can choose their prices optimally. For the firms which could not re-optimize their prices at period t, they can adjust their prices according to the past inflation rate: $P_t = P_{t-1}\Pi_{t-1}^{\xi}$. Now, let P_t^* be the optimal price set by firms that can reoptimize prices in period t. The optimization problem for a final goods firm is:

$$\max_{P_t^*} \sum_{s=0}^{\infty} \omega^s \mathbb{E}_t \{\Lambda_{t,t+s}[P_t^* \Pi_{t+s-1,t-1}^{\xi} Y_{t,t+s} - P_{t+s}^I Y_{t,t+s}]\}$$

where

$$Y_{t,t+s} = (\frac{P_t^* \Pi_{t+s-1,t-1}^{\xi}}{P_{t+s}})^{-\epsilon_{t+s}^p} C_{t+s}$$

The result of the optimization problem is:

$$P_t^* = \frac{\mathbb{E}_t \sum_{s=0}^{\infty} \omega^s \Lambda_{t,t+s} C_{t,t+s} \epsilon_{t+s}^p \mu_{t+s}^{-1} P_{t+s}^{1+\epsilon_{t+s}^p} \Pi_{t+s-1,t-1}^{-\xi \epsilon_{t+s}^p}}{\mathbb{E}_t \sum_{s=0}^{\infty} \omega^s \Lambda_{t,t+s} C_{t,t+s} (\epsilon_{t+s}^p - 1) P_{t+s}^{\epsilon_{t+s}^p} \Pi_{t+s-1,t-1}^{\xi(1-\epsilon_{t+s}^p)}} \tag{27}$$

where $\mathbb{E}_t \Lambda_{t,t+s} \equiv \beta^s \mathbb{E}_t[(\widetilde{\lambda}_{1t+s}/\widetilde{\lambda}_{1t})(P_t/P_{t+s})]$ is the stochastic discount factor for nominal payoffs, and $\Pi_{t+s,t} = P_{t+s}/P_t$. So the aggregate price is given by

$$P_t = [\omega(P_{t-1}(\frac{P_{t-1}}{P_{t-2}})^{\xi})^{1-\epsilon_t^p} + (1-\omega)(P_t^*)^{1-\epsilon_t^p}]^{\frac{1}{1-\epsilon_t^p}}. \tag{28}$$

2.4 Government

In order to close the model, we need to specify the monetary policy and the fiscal policy. Here, the monetary policy obeys the following simple Taylor rule:

$$\widehat{r}_t = (1-\phi_r)(\phi_\pi \widehat{\pi}_t + \phi_y \widehat{y}_t) + \phi_r \widehat{r}_{t-1} + \widehat{\epsilon}_t^r, \tag{29}$$

where $\widehat{x}_t$ is the log-deviation from the steady state value and the temporary interest rate shock is given by $\log \epsilon_t^r = \rho^r \log \epsilon_{t-1}^r + \nu_t^r$.

The government budget constraint is of the form:

$$G_t + G_t^{utotal} + \frac{B_{t-1}}{P_t} = T_t + \frac{B_t}{r_t P_t} \tag{30}$$

where $G_t^{utotal} = G_t^u U_t$ is the total unemployment benefits.

The unemployment benefits obtained by each unemployed person are $G_t^u = \epsilon_t^{g^u} \overline{rr} Y_t^L$, where $\overline{rr}$ is the replacement rate – the steady state ratio between unemployment benefits and the real wage. The unemployment benefits shock $\epsilon_t^{g^u}$ follows $\log \epsilon_t^{g^u} = \rho^{g^u} \log \epsilon_{t-1}^{g^u} + \nu_t^{g^u}$. I include an unemployment benefits shock because I find that the growth rate average unemployment benefits received by an unemployed person in the data do fluctuate throughout time and move counter-cyclically; the fluctuations are not exactly the same as those of the growth rate of real wages. Figure 1 plots the growth rate of benefits per unemployed worker and the growth rate of the real wage, which reflects that besides wages and unemployment, there is something else causing the change in the benefits. That is where the shocks come into the model.

As indicated in the introduction, in order to maintain the simplicity of the model, the setup of the unemployment benefits here is not exactly the same as that in the real economy. However, both setups reflect how generous the unemployment benefits program is. We can obtain a mapping from the setup in the model to that of the real economy. A 1% permanent increase in G^u at period t in the model implies that the lifetime expected benefits obtained by an unemployed worker can increase by $\mathbb{E}_t \sum_{\tau=0}^{\infty} \beta^\tau \Pi_{s=0}^{\tau}(1-\rho_s^w)$. Suppose $\mathbb{E}_t \rho_{t+s}^w \equiv \overline{\rho}^w$, then the increase in expected benefits will be $\frac{1}{1-\beta(1-\overline{\rho}^w)}$. If the 1% increase in G^u is transitory, which means there is a 1% positive unemployment benefits shock with autocorrelation ρ^{g^u}, then the increase in expected benefits obtained will be $\frac{1}{1-\beta\rho^{g^u}(1-\overline{\rho}^w)}$, which is around 1.64% according to my parameter calibration and estimation. In the real world, the unemployment benefits program extends from T weeks to T' weeks, then the expected benefits increase from $\mathbb{E}_t \sum_{\tau=t}^{T} \beta^\tau \Pi_{s=0}^{\tau}(1-\rho_s^w) G_\tau^u$ to $\mathbb{E}_t \sum_{\tau=t}^{T'} \beta^\tau \Pi_{s=0}^{\tau}(1-\rho_s^w) G_\tau^u$, which equals $\mathbb{E}_t \sum_{\tau=T}^{T'} \beta^\tau (1-\overline{\rho}^w)^\tau G_\tau^u$. If the benefits program in the real world extends from 39 weeks to 99 weeks, the expected benefits increase by less than 11%, which is equivalent to a 7% positive unemployment benefits shock in the model.

Government spending expressed relative to steady state output $g_t^y = \frac{G_t}{Y_t t}$ follows the process: $\log g^y_t = (1-\rho^g)\log g^y + \rho^g \log g^y_{t-1} + \nu^g_t + \mu^{gz}\nu^z_t$.

2.5 Market Equilibrium

To obtain the goods market equilibrium, the production should equal the household's demand for consumption and investment, and the government spending:

$$Y_t = C_t + I_t + G_t + \psi(d_t)K^H_{t-1} \tag{31}$$

The equilibrium condition for the capital market is obtained by equalizing the capital used in the intermediate good sector and the capital stock times the utilization rate:

$$n_t K^*_t = d_t K^H_{t-1}. \tag{32}$$

3 Parameter Estimation

3.1 Estimation Equations

The previously defined model is detrended and estimated with Bayesian method using nine key macroeconomic quarterly US time series as observable variables: the log difference of real GDP ($dGDP_t$), log difference of real consumption ($dCONS_t$), log difference of real investment ($dINV_t$), log difference of the real wage ($dWAG_t$), log difference of the GDP deflator (INF_t), the federal funds rate (FFR_t), log deviation of the unemployment rate from its mean ($UNEM_t - \overline{UMEM}$), log deviation of vacancies from its mean ($VAC_t - \overline{VAC}$), and log difference of the total government unemployment insurance ($dINS_t$). Every observable is in percentage points; population growth is abstracted, since the variables in the model are all in per capita terms. The time period of the data is from 1976Q1 to 2011Q2.[1]

[1] I chose 1976 as the initial year for two reasons. Firstly, it is because I use the dataset constructed by Fujita and Ramey (2009) to form the priors of the labor market parameters and use their data on the job-finding rate to conduct the robustness check; their data was constructed using CPS micro data back to 1976. The second reason is that the unemployment insurance data used in robustness checks only goes back

The details of the data are described in Table 1 to 2 in Appendix D. The first 6 observed variables are the same as those in Smets and Wouters (2007) and Gertler, Sala and Trigari (2008). The 7th variable I use is the unemployment rate, which corresponds with the unemployment in my model directly. I add 2 new observed variables: vacancies and unemployment insurance. I also add 2 new structural shocks, a matching technology shock and an unemployment benefits shock, to equalize the number of observables and the number of shocks.

The comparison of the observed variables and shocks used in Smets and Wouters (2007) and Gertler, Sala and Trigari (2008), as well as in this paper, is summarized in Table 3. Table 4 illustrates the mapping between each observed variable and the shock. Equation (33) are the measurement equations, where d means the first difference, $\overline{X}$ is the mean of X, $\bar{\iota} = 100 * (\iota - 1)$ is the quarterly trend growth rate to the real GDP, $\bar{r} = 100 * (r - 1)$ is the quarterly average steady state net nominal interest rate, and $\overline{\pi}_c = 100 * (\pi - 1)$ is the quarterly steady state inflation rate.

$$\begin{bmatrix} dGDP_t \\ dCONS_t \\ dINV_t \\ dWAG_t \\ INF_t \\ FFR_t \\ UNEM_t - \overline{UNEM} \\ VAC_t - \overline{VAC} \\ dINS_t \end{bmatrix} = \begin{bmatrix} \bar{\iota} \\ \bar{\iota} \\ \bar{\iota} \\ \bar{\iota} \\ \overline{\pi}_c \\ \bar{r} \\ 0 \\ 0 \\ \bar{\iota} \end{bmatrix} + \begin{bmatrix} \widehat{y}_t - \widehat{y}_{t-1} \\ \widehat{c}_t - \widehat{c}_{t-1} \\ \widehat{i}_t - \widehat{i}_{t-1} \\ \widehat{w}_t - \widehat{w}_{t-1} \\ \widehat{\pi}_t \\ \widehat{r}_t \\ \widehat{u}_t \\ \widehat{v}_t \\ \widehat{g}_t^{utotal} - \widehat{g}_{t-1}^{utotal} \end{bmatrix} \tag{33}$$

to the 1970s. I attempted to use data back to 1966 in the baseline estimation, which is the same as Smets and Wouters (2007), and the results are not affected. Therefore, in order to maintain consistency with the data used in the robustness checks, I restrict the dataset to the period starting from 1976.

3.2 Prior and Posterior of the Parameters

Several parameters are calibrated as shown in Table 5. The quarterly depreciation rate δ is fixed at 0.025. The elasticity of the production function α is set to be 0.33; the discount factor β is assumed to be 0.99. Government spending, as a proportion of output, is fixed at 0.18. The elasticity of substitution among the differentiated final goods, ϵ^p, is set at 11. The maximum bargaining rounds per quarter F is 60. These parameters are conventionally fixed in the literature. There are ten new parameters coming from the modified labor market comparing with Smets and Wouters' model, and two of them are fixed here. The exogenous separation rate is set to 0.068, which is consistent with the value used in the literature, such as den Haan, Ramey and Watson (2000). The matching specific productivity is assumed to be log normally distributed, and the standard deviation is set to 0.15. The reason to fix these parameters is that we cannot obtain information about them from the data used. As such, they would be difficult to estimate, unless they were used directly in the measurement equations.

The priors of the stochastic processes are set based on the setup in Smets and Wouters (2007): the standard errors of the exogenous innovations are drawn from an Inverse-Gamma distribution with a mean of 0.10 and standard deviation 0.15. The persistence of the $AR(1)$ processes is Beta distributed with mean 0.5 and standard deviation 0.2. The top panel of Table 6 illustrates the prior and posterior distribution of the shock processes.

The priors of the conventional structural parameters are consistent with the papers in the literature. For the new parameters related to the labor market, I set the mean to be consistent with the data and the calibration results in the literature. I choose priors that are reasonably loose. The bottom panel of Table 6 shows the prior and posterior distribution of the structural parameters.

The steady state job finding rate $\overline{\rho}^w$ is 0.77 (0.39 on a monthly basis), lying between the results in Fujita and Ramey (2009) (0.72 on a quarterly basis) and Shimer (2005) (0.45 on a monthly basis). The steady state labor market tightness θ is 0.81. The threshold of the matching-specific productivity for the endogenous separation is 0.68, and this indicates that the endogenous separation rate is 0.005. The endogenous separation rate used in den Haan, Ramey and Watson (2000) is 0.032, much higher than the estimation result here. The primary reason for the low endogenous separation rate here is that following Christiano, Eichenbaum and Trabandt (2013), during the wage determination process, the counteroffer costs as a share of the daily revenue ($\gamma^b/(\vartheta/F)$) is as large as 0.27. With a matched formed with such a large cost, firms are really reluctant to terminate it. So the endogenous separation rate is relatively low here. The estimated endogenous separation rate, together with the calibrated exogenous separation rate, implies that the total separation rate is 0.073, which means 2.5% of existing jobs are separated (either exogenously or endogenously) every month.

The estimates of the conventional parameters are very close to the results in Smets and Wouters (2007) and Gertler, Sala and Trigari (2008).

4 Sources of Fluctuations

In this section, I examine the sources of the labor market fluctuations through investigating the impulse responses, variance decomposition and historical decomposition of variables with respect to the shocks in the model.

4.1 Impulse Response

Figure 2 to Figure 4 are the impulse responses of 9 key variables to 3 of the structural shocks. Six of the variables are labor market variables: the unemployment rate, vacancies, the separation rate, the vacancy-filling rate, the job-finding rate, and wage . The rest three variables are consumption, the inflation rate, and the nominal interest rate. These impulse responses are calculated with parameter values at the posterior means. The x-axis represents the time in quarters and the y-axis is the deviation from the steady state in percentage points in response to a 1% positive shock.

As illustrated in Figure 2, a positive technology shock benefits the economy as a whole. Consumption increases and the labor market conditions become better. Unemployment decreases and firms post more vacancies. The vacancy-filling rate decreases and the job finding rate largely increases, both of which are because of the increase in the number of vacancies and the decrease in the number of people unemployed.

In Figure 3, a positive matching efficiency shock increases the efficiency of the matching process, and hence, effectively and largely increases the job-finding rate, so that unemployment decreases. As expected, unemployment and vacancies move in the same direction under a matching efficiency shock. This implies the shift of the Beveridge curve.

Figure 4 shows the impulse responses to a positive unemployment benefits shock. Consumption, inflation and the nominal interest rate are barely affected. However, labor market variables have much larger responses. The comovement of unemployment and vacancies, in response to an unemployment benefits shock, differs from that in response to a matching efficiency shock. In this figure, unemployment and vacancies change in the opposite directions. This is because after an unemployment benefits shock, although the decreased labor market tightness due to the increase in unemployment encourages the firms to post vacancies, the decrease in economic surplus has a counter effect on the vacancy posting and leads to a reduction in vacancies. In addition, with a positive unemployment benefits shock, the worker's reservation wage also increases, which leads to an increase in the real wage.

From the above figures, it is easy to find that the magnitude of the separation rate responding to the shocks is very small when compared with other variables, especially the labor market variables. The reason is that the endogenous separation only accounts for less than 5% of the total separation, so the changes in the endogenous separation will not cause big fluctuations in the total separation rate.

4.2 Variance Decomposition

Table 8 and Table 9 illustrate the variance decompositions of 9 key variables (the same variables analyzed in the previous section) in the model both right after and 40 quarters after the shocks.

As in most DSGE models and the recent literature on unemployment fluctuations, the technology shock and investment shock are still very important in the economy, especially for the non-labor market variables. However, the bargaining power shock is the major driving force of unemployment and other labor market variables. This result is similar to Gali, Smets and Wouters(2011).

The unemployment benefits shock is ignored in other papers, but it appears to be empirically important. 9% of the unemployment variation is caused by this shock in the short run. In the long run, it is even more important, and accounts for more than 13% of the fluctuations in unemployment. Intuitively, the changes in unemployment benefits change the wage required and the surplus created by a matched worker with given match-specific productivity. In this case, firms will change their threshold of endogenous separation and the number of vacancies posted, and unemployment is affected as a result. This argument can be supported by the results that in the long run the unemployment benefits shock accounts for over 13% and 11% of the changes in vacancies and the separation rate respectively.

The matching efficiency shock doesn't account for as much of the fluctuations in unemployment as the unemployment benefits shock, especially in the short run. It only explains less than 1% of the fluctuations in vacancies both in the short run and long run. Although we hear claims of high structural unemployment every time unemployment is high, they have yet to receive much econometric confirmation. Different from the unemployment benefits shock, the matching efficiency shock affects the unemployment rate mainly through affecting the job-finding rate and vacancy-filling rate, instead of through affecting the vacancy posting and endogenous separation. Over 10% of fluctuations in both the job-finding rate and vacancy-filling rate are explained by the matching efficiency shock.

4.3 Application: Unemployment over 2008-2011

Figure 5 summarizes the historical contribution of each of the 9 types of shocks to unemployment fluctuations during the recent recession, starting from 2005Q3. The solid line is the log deviation of the unemployment rate from its average level. The bars in different colors represent how much of the change in unemployment is caused by the corresponding shocks. This decomposition is based on the estimation of the baseline model. Figure 6 plots the estimated smoothed shocks used in the historical decomposition, and the y-axis of each subplot represents how many percentage points each corresponding shock deviates from the zero steady state.

During the Great Recession, the decrease in matching efficiency did increase the unemployment rate; however, it was by less than 0.5%, even at the peak. It is very popular to use the following words to describe the current US labor market: "A lot of firms need workers, but the vacancies cannot be filled. A lot of unemployed workers want to work, but cannot find proper jobs." Although the mismatch seems to be a natural reason for this labor market situation, it is a one-sided view. When considering the matching efficiency issues, it is not sufficient to look at the labor market with a static view. Too many people are still unemployed, but many people are finding new jobs and many vacancies are being filled at the same time. Therefore, we need to take the large flows both into and out of unemployment into consideration. Diamond (2011) illustrated that although the average flow rate from unemployment to employment from November 2009 to October 2010 fell to 20% from its average 37% during the last 2 decades, the large increase in unemployment roughly offsets this fall. And the hires per month during November 2009 and October 2010 were 5.7million, which is not far from the 6 million average over the last 20 years. Moreover, there is no evidence illustrating that we have a widespread difficulty in hiring in some industries or locations. Replicating the exercise in Dickens (2010), we do not see any industries with high vacancy-unemployment ratios after the Great Recession (Figure 7). The ratio increased considerably in the early phase of the recent recession, but it dropped off significantly since then and has already returned to the pre-recession level. This initial rise in mismatch may be taken for structural unemployment. Besides the initial rise in the mismatch during the recession, the slow recovery of unemployment after the recession doesn't mean a lower matching efficiency.

Compared with matching efficiency shocks, extended unemployment benefits shocks accounted for a much larger proportion of the increase in unemployment. The increase in the unemployment rate caused by the extended compensation was more than 1% in 2010. Since 2008, the Federal-State Extended Benefit Program (EB) and Emergency Unemployment Compensation 2008 (EUC2008) largely increased the unemployment benefits.

Figure 8 supports the results drawn from the historical decomposition of unemployment. The figure shows the actual Beveridge curve (black line) and its counterfactual counterparts (red and green lines) during 2007Q4 and 2011Q2. The x-axis represents how many percentage points the unemployment rate is away from its mean; the y-axis is how many percentage points the vacancies are away from its steady mean. To obtain the counterfactual Beveridge Curve with the unemployment benefits shocks (the green line), I input the estimated shocks on the unemployment benefits to the estimated model and set all other shocks to 0 during 2007Q4 and 2011Q2. In this way, the effect of the unemployment benefits shocks on the Beveridge curve is isolated. It is clear that the unemployment benefits shocks pushed the labor market down along the Beveridge curve during the Great Recession. To obtain the counterfactual Beveridge curve with the matching efficiency shocks (the red line), I input the estimated shocks on matching efficiency to the estimated model. The matching efficiency shocks did not shift the Beveridge curve to the right, which means the decrease in matching efficiency did not play a very important role in affecting the US labor market during the Great Recession.

4.4 Why are the Unemployment Benefits Shocks so Important?

The unemployment benefits shock significantly affects unemployment through the response of labor demand. In the literature, people study the effect of the unemployment benefits from the labor supply aspect. They focus on how the changes in unemployment benefits affect workers' search efforts. In their story, labor market matching efficiency is not exogenous, but depends on people's search efforts, and higher unemployment benefits make the unemployed people put less effort into finding new jobs. Hence, this lowers the labor market matching efficiency and increases the unemployment duration and the unemployment rate, as a result. According to Landais, Michaillat, and Saez (2010), search efforts have little effect on aggregate unemployment because: (1) the total number of jobs available is limited, and (2) while higher search efforts increase the individual probability of finding a job, they create a negative externality by reducing other people's ability of finding new jobs. This is why people cannot find much evidence on the effect of the unemployment benefits if they only focus on the labor supply side. Therefore, it is natural and necessary to study the unemployment benefits from the labor demand angle. The unemployment benefits shocks affect the labor demand through two channels: one is the change in the endogenous separation rate, and the other is the change in vacancy posting.

An increase in the unemployment benefits increases the value of being unemployed, H_t^u, and hence, increases the workers' reservation wage and makes it harder for them to obtain new jobs. Why? Since a higher value of being unemployed means lower economic surplus of a match and lower firm's value – J_t defined by Eq. (24), which reduces a firm's incentive in both keeping a match with relatively low productivity unseparated and posting new vacancies. According to the determination of the separation threshold, $J(\widetilde{a}_t) = 0$, the threshold $\widetilde{a}_t$, and hence, the endogenous separation will increase, because under a higher level of unemployment benefits, the same level of match-specific productivity will generate less profits for firms. In order for the equation to hold, $\widetilde{a}_t$ has to be increased. Vacancy posting of a firm is determined by Eq. (16). Since the vacancy posting cost is constant with a deterministic growth trend, the change in the number of vacancies, V_t, is determined by the change in the firm's value, J_t. J_t and V_t changes in the same direction. Since the firm's value correspondence to each level of match-specific productivity decreases, its mean value also decreases, which leads to a reduction in the number vacancies. The changes in the separation rate and vacancy posting, in response to an unemployment benefits shock, can be supported by the impulse responses in Figure 4. So at the labor demand side, firms reduce their vacancy posting and increase their endogenous separation rate because of the higher employment costs implied by the higher unemployment benefits. This makes the labor market situation worse.

Of course, only considering the partial equilibrium effects on labor market is not convincing enough, since the labor market is closely related to the other parts of the economy, and the unemployment benefits policy could affect the economy from other channels such as the aggregate demand. President Obama's Council of Economic Advisors suggests that Hagedorn et al. (2013) does not model the aggregate demand effects of benefit extensions, which is claimed to be "the key channel through which EUC can aid economic growth and the recovery". In a simple model, it is true that not every aspect of the economy can be taken into consideration. However, in the medium scale DSGE model investigated in this paper, aggregate demand is sufficiently considered. Even so, consumption still decreases in response to a positive unemployment benefits shock, which is opposite to the Council's statement. So, according to the rich macroeconomic model, the stimulative effects of the extended unemployment benefits cannot overcome their detrimental effect on job creation.

5 Robustness Checks

This section reports the results of five types of robustness checks. The first robustness check is related to a different setup of the unemployment benefits policy. The second is the estimation using different observables, which helps to obtain a realistic matching efficiency series. The third maps the unemployment benefits in the model to the average weekly benefits amount, instead of the total benefits paid by the government in the data. The fifth uses Nash bargaining and real wage rigidity wage setup.

5.1 Estimation with an Alternative Specification of Unemployment Benefits Policy

The US set weekly benefit amounts as a fraction of the individual's average weekly wage up to some state-determined maximum. The total maximum duration available under permanent law is 39 weeks. The regular state programs usually provide up to 26 weeks of unemployment benefits. The permanent Federal-State Extended Benefits program provides up to 13 additional weeks. The permanent Extended Benefits (EB) program is triggered when the unemployment situation has worsened dramatically. During recessions and while unemployment remains high during recoveries, the federal government has historically created Temporary Emergency Unemployment Compensation (EUC) Program. Thus, extended unemployment benefits programs are triggered empirically by high unemployment rates, causing unemployment benefits per worker to depend on the unemployment rate in the data. However, in the baseline model, changes in unemployment benefits depend on changes in real wages and unemployment benefits shocks. This specification assumes that the unemployment benefits shocks are orthogonal to real wage changes and assumes no feedback from the unemployment rate to unemployment benefits.

In order to investigate the potential importance of allowing for such feedback, I re-estimate the model with an alternative policy rule. In this case, unemployment benefits received by each unemployed worker depend on the lagged unemployment rate, in addition to a contemporaneous unemployment shock:

$$\widehat{g}_t^u = \widehat{\epsilon}_t^{g^u} + \widehat{y}_t^L + \phi_u \widehat{u}_{t-1} \tag{34}$$

Under this setup, unemployment benefits respond to both wages and the unemployment rate.

By comparing the results in the second and third column of Table 7, we find that the posterior means of structural parameters don't change much from the baseline case. The third column of Table 10 gives us the short run and long run variance decomposition of unemployment under this specification of the unemployment benefits policy. The importance of unemployment benefits is also robust under different setups in the unemployment policy. In the long run, unemployment benefits shocks account for 31% of unemployment fluctuations historically, even higher than the contribution in the baseline case (12%). Figure 9 plots the unemployment benefits shock series implied by the baseline model and the model with alternative unemployment benefits policy. We find that the two series have very similar patterns, although the patterns are not exactly the same. Allowing for the endogeneity of unemployment benefits does not change the primary results.

5.2 Alternative Measures of Unemployment Benefits

In the estimation of the baseline model, I use data on total unemployment insurance paid by the government. This measurement corresponds to the total unemployment benefits G_t^{utotal} in my model, where $G_t^{utotal} = G_t^u U_t$. However, in the data total unemployment insurance depends on unemployment benefits per unemployed person, the number of unemployed people and the unemployment duration. Some may worry that the measure in the data is inconsistent with that in the model. In order to test for this, I repeat the analysis with an alternative measure of unemployment benefits which only includes the weekly benefits received by each unemployed worker. I use the log difference of the average weekly benefits for all programs (including the regular program, extended program, and emergency unemployment compensation program) as one observable to substitute for the total unemployment insurance paid by the government. This measurement directly corresponds to the unemployment benefits per person defined in my model. The corresponding measurement equation becomes: $d\log AWB_t = \bar{\iota} + \widehat{g}_t^u - \widehat{g}_{t-1}^u$. Figure 10 plots both the levels and the growth rates of the real average weekly benefits amount and the real wage from 1976Q1 to 2011Q2. This figure implies that the unemployment benefits do fluctuate over time and the large part of the fluctuations are not a result of the changes in real wages.

The fifth column in Table 7 illustrates the estimation results of the structural parameters when the average weekly benefit is used as the observable. The fifth column in Table 10 also gives the variance decomposition of unemployment, both in the short run (on impact) and in the long run (40 quarters). Unemployment benefits shocks still contribute more than 11% of the unemployment fluctuations; this number is still larger than the contribution of matching efficiency shocks (less than 10%). This means that under different measures of unemployment benefits, the results obtained from the baseline model are robust.

5.3 Estimation with Job-finding Rate and Labor Market Tightness as Observables

Furlanetto and Groshenny (2012) found that when using the unemployment rate and vacancies as observables, it is difficult to see much decline in the model generated matching efficiency during the Great Recession, while using the job finding rate and labor market tightness as observables; the implied matching efficiency series matches the data better. In my baseline model, implied matching efficiency does not decline much. Does that cause an underestimation of the role played by matching efficiency on unemployment? In order to determine whether the importance of unemployment benefits and the irrelevance of matching efficiency I obtain in the previous sections depends on which observables I use, in this part, I follow Furlanetto and Groshenny (2012) by using the data on the job finding rate constructed by Fujita and Ramey (2009) and labor market tightness to back out the matching efficiency series and use that series as one observable, instead of vacancies during the estimation.[2] Figure 11 is the matching efficiency series implied by the estimated model; this series has very similar pattern to that derived in Furlanetto and Groshenny (2012) and Barnichon and Figura (2011).

Although different data is used, we can find that estimation results from this estimation

[2] I also use the job-finding rate data in Furlanetto and Groshenny (2012), which differs from the Fujita-Ramey dataset in dealing with the margin error. Similar results were found with this specification.

are very similar to what were obtained before by comparing the second and fourth columns in Table 7. Matching efficiency shocks are still unimportant for unemployment, as shown in the second to fourth columns in Table 10. Matching efficiency shocks explain less than 0.3% of the unemployment fluctuations, while unemployment benefits shocks could explain 9% of them.

5.4 A Model with Nash Bargaining and Real Wage Rigidities

In order to illustrate that the above results are not driven by the specific model I use, in this part, I use a traditional technique to model the wage bargaining process. Following Hall(2005a), I assume that firms and workers split the surplus through Nash bargaining every period; however, real wage rigidities prevent the real wage to change with the Nash bargaining result one for one.

The economic surplus of a match is $S(a_{jt}) = J(a_{jt}) + H^w(a_{jt}) - H^u_t$. When there is no real wage rigidity, the surplus is divided between the firm and worker through Nash bargaining, and the bargaining power of the worker is η. There is a shock to the bargaining power, which is indicated as ϵ^η_t and follows the AR(1) process: $\log \epsilon^\eta_t = \rho^\eta \log \epsilon^\eta_{t-1} + \nu^\eta_t$. The notional real wage, W^N_t, resulting from the Nash bargaining process is as follows:

$$W^N(a_{jt}) = \epsilon^\eta_t \eta [\frac{Y(a_{jt})}{\mu_t} - r^k_t K^*(a_{jt}) + \gamma \iota^t \theta_t] + (1 - \epsilon^\eta_t \eta)(A_t + G^u_t)$$

However, when there exists a wage norm, the real wage, $W(a_{jt})$, is rigid in the sense that the real wage depends on the wage norm. Then the real wage is the weighted average of the notional wage and the steady state value of the real wage:

$$W(a_{jt}) = \omega^W [\epsilon^\eta_t \eta (\frac{Y(a_{jt})}{\mu_t} - r^k_t K^*(a_{jt}) + \gamma \iota^t \theta_t) + (1 - \epsilon^\eta_t \eta)(A_t + G^u_t)] + (1 - \omega^W) W \iota^t$$

The real wage rigidity index is ω^W. If ω^W=0, the real wage is solely determined by the steady state surplus, and if $\omega^W = 1$, the real wage is perfectly flexible.

The estimated parameter values from this estimation are presented in the last column of Table 7. The variance decompositions of unemployment are in the last column of Table 10. Since, in the model with Nash bargaining, the wage determination process does not yield as large costs as in the baseline model, firms are relatively more flexible in firing workers, so the endogenous separation rate is larger and the responses of the separation rate to shocks are stronger. The primary difference in the variance decompositions between the baseline model and the model with Nash bargaining and real wage rigidities is the importance of the bargaining power shock. This is because, in the baseline model, firms respond to the bargaining power shocks through reducing vacancy postings, instead of firing workers with lower productivity and then finding someone more productive. In the baseline case, there are less opportunities for the unemployed workers to find new jobs. But in the model with Nash bargaining and real wage rigidities, although more workers are endogenously separated, the labor market is still active, both the inflow and outflow of the unemployed pool are larger, and the labor market is not affected too much.

6 Conclusions

In an estimated medium scale DSGE model with labor market frictions and wage inertia, the unemployment benefits shocks are responsible for more unemployment fluctuations than the matching efficiency shock. Over 10% of the unemployment variation is caused by the unemployment benefits shocks. In the current recession, extended unemployment benefits contribute to the unemployment rate, while the effect of a deteriorating matching efficiency is very small. During the Great Recession, extended unemployment benefits contributed to more than a 1% increase in the unemployment rate. The results are robust to different data series used in the estimation, as well as different setups in the unemployment benefits policy and the wage bargaining process.

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A Stationary Model

$$u_t = 1 - n_t \tag{35}$$

$$n_{t+1} = (1-\rho_{t+1})(n_t + m(u_t, v_t)) = (1-\rho_{t+1})(n_t + \epsilon_t^M E u_t^{\zeta} v_t^{1-\zeta}) \tag{36}$$

$$\rho_t^w = m(u_t, v_t)/u_t = \epsilon_t^M \mathcal{M} u_t^{\zeta} v_t^{1-\zeta}/u_t = \epsilon_t^M \mathcal{M} \theta_t^{1-\zeta} \tag{37}$$

$$\rho_t^f = m(u_t, v_t)/v_t = \epsilon_t^M \mathcal{M} u_t^{\zeta} v_t^{1-\zeta}/v_t = \epsilon_t^M \mathcal{M} \theta_t^{-\zeta} \tag{38}$$

$$\rho_t = \rho^x + (1-\rho^x)\rho_t^n = \rho^x + (1-\rho^x)\int_{-\infty}^{\widetilde{a}_t} f(a_t)da_t = \rho^x + (1-\rho^x)F(\widetilde{a}_t) \tag{39}$$

$$\overline{\beta}\mathbb{E}_t\{\frac{\lambda_{1t+1}}{\lambda_{1t}}(1-\rho_{t+1})\rho_t^f[J_{t+1}]\} = \gamma/\iota \tag{40}$$

$$W_t^p = W_t + \beta\rho_{t+1}\mathbb{E}_t\lambda_{t+1}/\lambda_t W_{t+1}^p \tag{41}$$

$$J_t = \vartheta_t^p - W_t^p \tag{42}$$

$$\vartheta_t^p = \vartheta_t + \overline{\beta}\rho_{t+1}\mathbb{E}_t\lambda_{t+1}/\lambda_t\vartheta_{t+1}^p \tag{43}$$

$$\vartheta_t = \frac{(1-\alpha)r_t^k k_t^*}{\alpha} \tag{44}$$

$$H_t^w = W_t^p + S_t \tag{45}$$

$$S_t = \beta(1-\rho_{t+1})\mathbb{E}_t\lambda_{t+1}/\lambda_t[\rho_{t+1}^w H_{t+1}^w + (1-\rho_{t+1}^w)H_{t+1}^u] + \beta\rho_{t+1}\mathbb{E}_t\lambda_{t+1}/\lambda_t S_{t+1} \tag{46}$$

$$H_t^u = rr * W_t + \beta\mathbb{E}_t\lambda_{t+1}/\lambda_t[\rho_{t+1}^w H_{t+1}^w + (1-\rho_{t+1}^w)H_{t+1}^u] \tag{47}$$

$$J_t = \frac{\alpha_2}{\alpha_1}(H_t^w - H_t^u) - \frac{\alpha_3}{\alpha_1}\gamma^b + \frac{\alpha_4}{\alpha_1}(\vartheta_t - G_t^u - A) \tag{48}$$

$$\widetilde{W}_t^p = \widetilde{W}_t + \overline{\beta}\rho_{t+1}\mathbb{E}_t\lambda_{t+1}/\lambda_t W_{t+1}^p \tag{49}$$

$$\widetilde{J}_t = \widetilde{\vartheta}_t^p - \widetilde{W}_t^p \tag{50}$$

$$\widetilde{\vartheta}_t^p = \widetilde{\vartheta} + \overline{\beta}\rho_{t+1}\mathbb{E}_t\lambda_{t+1}/\lambda_t\vartheta_{t+1}^p \tag{51}$$

$$\widetilde{\vartheta}_t = \frac{(1-\alpha)r_t^k \widetilde{k}_t^*}{\alpha} \tag{52}$$

$$\widetilde{H}_t^w = \widetilde{W}_t^p + S_t \tag{53}$$

$$\widetilde{J}_t = \frac{\alpha_2}{\alpha_1}(\widetilde{H}_t^w - H_t^u) - \frac{\alpha_3}{\alpha_1}\gamma^b + \frac{\alpha_4}{\alpha_1}(\widetilde{\vartheta}_t - G_t^u - A) \tag{54}$$

$$\widetilde{J}_t = 0 \tag{55}$$

$$1 = \overline{\beta} r_t \mathbb{E}_t[\frac{\lambda_{1t+1}}{\lambda_{1t}}\frac{P_t}{P_{t+1}}] \text{ where } \overline{\beta} = \beta\iota^{-\sigma} \text{ and } \lambda_{1t} = \widetilde{\lambda}_{1t}\iota^{\sigma t} \tag{56}$$

$$Q_t = \overline{\beta}\mathbb{E}_t\{\frac{\lambda_{1t+1}}{\lambda_{1t}}[Q_{t+1}(1-\delta) + d_{t+1}r_{t+1}^k - D(d_{t+1})]\} \tag{57}$$

$$\begin{aligned} Q_t\psi'(\frac{\iota i_t}{i_{t-1}})\frac{\epsilon_t^I \iota i_t}{i_{t-1}} - \overline{\beta}\mathbb{E}_t[Q_{t+1}\frac{\lambda_{t+1}}{\lambda_t}\psi'(\frac{\iota i_{t+1}}{i_t})\frac{\epsilon_{t+1}^I \iota i_{t+1}}{i_t}\frac{\iota i_{t+1}}{i_t}] + 1 \\ = Q_t(1 - \psi(\frac{\iota i_t}{i_{t-1}})) \end{aligned} \tag{58}$$

$$r_t^k = D'(d_t) \tag{59}$$

$$k_t^H = \frac{1-\delta}{\iota}k_{t-1}^H + \epsilon_t^I(1 - \psi(\frac{\iota i_t}{i_{t-1}}))i_t \tag{60}$$

$$k_t^* = \int_{\widetilde{a}_t}^{a_{max}} k(a_{jt})^* \frac{f(a_t)}{1-F(\widetilde{a}_t)}da_t = (\frac{\alpha z_t}{\mu_t r_t^k})^{\frac{1}{1-\alpha}} \int_{\widetilde{a}_t}^{a_{max}} a_t^{\frac{1}{1-\alpha}} \frac{f(a_t)}{1-F(\widetilde{a}_t)}da_t = (\frac{\alpha z_t}{\mu_t r_t^k})^{\frac{1}{1-\alpha}} \frac{X(\widetilde{a}_t)}{1-F(\widetilde{a}_t)} \tag{61}$$

$$\text{where } X(\widetilde{a}_t) = \int_{\widetilde{a}_t}^{a_{max}} a_t^{\frac{1}{1-\alpha}} f(a_t)da_t = e^{\frac{\mu_a}{1-\alpha} + \frac{\sigma_a^2}{2(1-\alpha)^2}} \Phi(\frac{\mu_a + \sigma_a^2/(1-\alpha) - \log\widetilde{a}_t}{\sigma_a})$$

$$\widetilde{k}_t^* = k^*(\widetilde{a}_t) = (\frac{\alpha z_t \widetilde{a}_t}{\mu_t r_t^k})^{\frac{1}{1-\alpha}} \tag{62}$$

$$n_t \iota k_t^* = d_t k_{t-1}^H \tag{63}$$

$$\lambda_{1t} = (c_t - h/\iota c_{t-1})^{-\sigma} \tag{64}$$

$$y_t = n_t \frac{\mu_t r_t^k}{\alpha} k_t^* - \gamma v_t \tag{65}$$

$$y_t = c_t + i_t + g_t + D(d_t)k_{t-1}^H/\iota \tag{66}$$

$$P_t^{1-\epsilon_t^P} = \omega(P_{t-1}\Pi_{t-1}^{\xi})^{1-\epsilon_t^P} + (1-\omega)(P_t^*)^{1-\epsilon_t^P} \text{ where } \Pi_t = \frac{P_t}{P_{t-1}} \tag{67}$$

$$g_t^y = \frac{g_t}{y} \tag{68}$$

$$g_t^{utotal} = g_t^u u_t = \epsilon_t^{g^u} \overline{rr} y_t^L \tag{69}$$

$$\widehat{r}_t = (1-\phi_r)(\phi_\pi \widehat{\pi}_t + \phi_y \widehat{y}_t) + \phi_r \widehat{r}_{t-1} + \widehat{\epsilon}_t^r, \tag{70}$$

B Steady State

$$u = 1 - n \tag{71}$$

$$\rho n = m(u, v) = (1-\rho)\mathcal{M} u^\zeta v^{1-\zeta} \tag{72}$$

$$\rho^w = \frac{m(u, v)}{u} = \mathcal{M}\theta^{1-\zeta} \tag{73}$$

$$\rho^f = \frac{m(u, v)}{v} = \mathcal{M}\theta^{-\zeta} \tag{74}$$

$$\rho = \rho^x + (1-\rho^x)F(\widetilde{a}) \tag{75}$$

$$\overline{\beta}\rho^f(1-\rho)J = \gamma/\iota \tag{76}$$

$$W = (1-\overline{\beta}\rho)W^p \tag{77}$$

$$J = \theta^p - W^p \tag{78}$$

$$\theta = (1-\overline{\beta}\rho)\theta^p \tag{79}$$

$$\theta = \frac{r^k k^*}{\alpha\mu} \tag{80}$$

$$H^w = W^p + S \tag{81}$$

$$(1-\beta\rho)S = \overline{\beta}(1-\rho)[\rho^w H^w + (1-\rho^w)H^u] \tag{82}$$

$$(1-\beta(1-\rho^w))H^u = G^u + \overline{\beta}\rho^w H^w \tag{83}$$

$$J = \frac{\alpha_2}{\alpha_1}(H^w - H^u) - \frac{\alpha_3}{\alpha_1}\gamma^b + \frac{\alpha_4}{\alpha_1}(\vartheta - G^u - A) \tag{84}$$

$$\widetilde{W} = \widetilde{W}^p - \overline{\beta}\rho w^p \tag{85}$$

$$\widetilde{J} = \widetilde{\theta}^p - \widetilde{W}^p \tag{86}$$

$$\widetilde{\theta}^p = \widetilde{\theta} + \overline{\beta}\rho\theta^p \tag{87}$$

$$\widetilde{\theta} = \frac{r^k \widetilde{K}^*}{\alpha\mu} \tag{88}$$

$$\widetilde{H^w} = \widetilde{W}^p + S \tag{89}$$

$$\widetilde{H}^u = rr * \widetilde{W} + \overline{\beta}[\rho^w H^w + (1-\rho^w)H^u] \tag{90}$$

$$\widetilde{J} = \frac{\alpha_2}{\alpha_1}(\widetilde{H}^w - H^u) - \frac{\alpha_3}{\alpha_1}\gamma^b + \frac{\alpha_4}{\alpha_1}(\widetilde{\vartheta}_t - G^u - A) \tag{91}$$

$$\overline{\beta} = \frac{\pi}{r} \tag{92}$$

$$q = 1 \text{ where } \Psi'(\frac{I}{K}) = 1 \tag{93}$$

$$1 = \overline{\beta}(1 - \delta + r^k) \tag{94}$$

$$r^k = D'(1) \text{ where } d = 1 \tag{95}$$

$$\frac{i}{k^H} = 1 - \frac{1-\delta}{\iota} \tag{96}$$

$$k^* = \frac{1}{1 - F(\widetilde{a})}(\frac{\alpha}{\mu r^k})^{\frac{1}{1-\alpha}} \int_{\widetilde{a}}^{a_{max}} a^{\frac{1}{1-\alpha}} f(a) da \tag{97}$$

$$\widetilde{k}^* = (\frac{\alpha\widetilde{a}}{\mu r^k})^{\frac{1}{1-\alpha}} \tag{98}$$

$$nk^*\iota = k^H \tag{99}$$

$$y = \frac{n\mu r^k k^*}{\alpha} - \gamma v \tag{100}$$

$$y = c + i + g \tag{101}$$

$$\lambda_1 = c^{-\sigma}(1 - h/\iota)^{-\sigma} \tag{102}$$

$$\mu = \frac{\epsilon^P}{\epsilon^P - 1} \tag{103}$$

$$g = g^y y \tag{104}$$

$$g^{utotal} = g^u u = \overline{rr} y^L u \tag{105}$$

C Log-linear Model

$$\widehat{u}_t = -\frac{n}{u}\widehat{n}_t \tag{106}$$

$$\widehat{n}_{t+1} = (1-\rho)\widehat{n}_t - \frac{\rho}{1-\rho}\widehat{\rho}_{t+1} + \rho[\widehat{\epsilon}_t^M + \zeta\widehat{u}_t + (1-\zeta)\widehat{v}_t] \tag{107}$$

$$\widehat{\rho}_t^w = \widehat{\epsilon}_t^M + (\zeta - 1)\widehat{u}_t + (1-\zeta)\widehat{v}_t \tag{108}$$

$$\widehat{\rho}_t^f = \widehat{\epsilon}_t^M + \zeta\widehat{u}_t - \zeta\widehat{v}_t \tag{109}$$

$$\widehat{\rho}_t = [\frac{(1-\rho^x)\rho^n}{\rho}]\widehat{\rho}_t^n = [\frac{(1-\rho^x)\rho^n}{\rho}]\frac{f(\widetilde{a})\widetilde{a}}{F(\widetilde{a})}\widehat{\widetilde{a}}_t \tag{110}$$

$$-\widehat{\rho}_t^f = \widehat{\lambda}_{1t+1} - \widehat{\lambda}_{1t} - \frac{\rho}{1-\rho}\widehat{\rho}_{t+1} + \mathbb{E}_t\widehat{J}_{t+1} \tag{111}$$

$$W^p\widehat{w}_t^p = W\widehat{w}_t + \overline{\beta}\rho W^p\mathbb{E}_t(\widehat{w}_{t+1}^p + \widehat{\rho}_{t+1} + \widehat{\lambda}_{1t+1} - \widehat{\lambda}_{1t}) \tag{112}$$

$$J\widehat{J}_t = \vartheta^p\widehat{\vartheta}_t^p - W^p\widehat{w}_t^p \tag{113}$$

$$\vartheta^p\widehat{\vartheta}_t^p = \vartheta\widehat{\vartheta}_t + \rho\overline{\beta}\vartheta^p\mathbb{E}_t(\widehat{\rho}_{t+1} + \widehat{\lambda}_{1t+1} - \widehat{\lambda}_{1t} + \widehat{\vartheta}_{t+1}^p) \tag{114}$$

$$H^w\widehat{H}_t^w = W^p\widehat{w}_t^p + S\widehat{s}_t \tag{115}$$

$$\begin{aligned} S\widehat{s}_t =& (1-\rho)\overline{\beta}(\rho^w H^w + (1-\rho^w)H^u)\mathbb{E}_t(-\frac{\rho}{1-\rho}\widehat{\rho}_{t+1} + \widehat{\lambda}_{1t+1} - \widehat{\lambda}_{1t}) \\ &+ (1-\rho)\overline{\beta}\rho^w H^w\mathbb{E}_t(\widehat{\rho}_{t+1}^w + \widehat{H}_{t+1}^w) + (1-\rho)\overline{\beta}(1-\rho^w)H^u(-\frac{\rho^w}{1-\rho^w}\mathbb{E}_t\widehat{\rho}_{t+1}^w + \widehat{H}_t^u) \\ &+ \overline{\beta}\rho S\mathbb{E}_t(\widehat{\rho}_{t+1} + \widehat{\lambda}_{1t+1} - \widehat{\lambda}_{1t} + \widehat{s}_{t+1}) \end{aligned} \tag{116}$$

$$H^u\widehat{H}_t^u = G^u\widehat{g}_t^u + \overline{\beta}\rho^w H^w\mathbb{E}_t(\widehat{\lambda}_{1t+1} - \widehat{\lambda}_{1t} + \widehat{\rho}_{t+1}^w + \widehat{H}_{t+1}^w) + \overline{\beta}(1-\rho^w)H^u\mathbb{E}_t(-\widehat{\rho}_{t+1}^w + \widehat{H}_{t+1}^u) \tag{117}$$

$$J\widehat{J}_t = \frac{\alpha_2}{\alpha_1}(H^w\widehat{H}_t^w - H^u\widehat{H}_t^u) - \frac{\alpha_3}{\alpha_1}\gamma^b\widehat{\epsilon}_t^L + \frac{\alpha_4}{\alpha_1}(\vartheta\widehat{\vartheta}_t - G^u\widehat{g}_t^u) \tag{118}$$

$$\widehat{\vartheta}_t = \widehat{r}_t + \widehat{k}_t^* \tag{119}$$

$$\widetilde{W^p}\widehat{\widetilde{w}}_t^p = \widetilde{W} * \widehat{\widetilde{w}}_t + \overline{\beta}\rho W^p \mathbb{E}_t(\widehat{w}_{t+1}^p + \widehat{\rho}_{t+1} + \widehat{\lambda}_{1t+1} - \widehat{\lambda}_{1t}) \tag{120}$$

$$\widetilde{J}\widehat{\widetilde{J}}_t = \widetilde{\vartheta}^p\widehat{\widetilde{\vartheta}}_t^p - \widetilde{W^p}\widehat{\widetilde{w}}_t^p \tag{121}$$

$$\widetilde{\vartheta}^p\widehat{\widetilde{\vartheta}}_t^p = \widetilde{\vartheta}\widehat{\widetilde{\vartheta}}_t + \rho\overline{\beta}\vartheta^p \mathbb{E}_t(\widehat{\rho}_{t+1} + \widehat{\lambda}_{1t+1} - \widehat{\lambda}_{1t} + \widehat{\vartheta}_{t+1}^p) \tag{122}$$

$$\widetilde{H}^w\widehat{\widetilde{H}}_t^w = \widetilde{W^p}\widehat{\widetilde{w}}_t^p + S\widehat{s}_t \tag{123}$$

$$\widetilde{J}\widehat{\widetilde{J}}_t = \frac{\alpha_2}{\alpha_1}(\widetilde{H}^w\widehat{\widetilde{H}}_t^w - H^u\widehat{H}_t^u) - \frac{\alpha_3}{\alpha_1}\gamma^b\widehat{\epsilon}_t^L + \frac{\alpha_4}{\alpha_1}(\widetilde{\vartheta}\widehat{\widetilde{\vartheta}}_t - G^u\widehat{g}_t^u) \tag{124}$$

$$\widehat{\vartheta}_t = \widehat{r}_t + \widehat{k}_t^* \tag{125}$$

$$\widehat{\widetilde{J}}_t = 0 \tag{126}$$

$$\widehat{\lambda}_{1t} = \widehat{r}_t + \mathbb{E}_t(\widehat{\lambda}_{1t+1} - \widehat{\pi}_{t+1}) + \widehat{\epsilon}_t^b \tag{127}$$

$$\widehat{q}_t = -(\widehat{r}_t - \mathbb{E}_t\widehat{\pi}_{t+1}) + \overline{\beta}(1-\delta)\mathbb{E}_t\widehat{q}_{t+1} + (1 - \overline{\beta}(1-\delta))\mathbb{E}_t\widehat{r}_{t+1}^k - \widehat{\epsilon}_t^b \tag{128}$$

$$\widehat{i}_t = \frac{1}{1+\overline{\beta}\iota}\widehat{i}_{t-1} + \frac{\overline{\beta}\iota}{1+\overline{\beta}\iota}\widehat{i}_{t+1} + \frac{\phi}{\iota^2(1+\overline{\beta}\iota)}\widehat{q}_t - \frac{1}{1+\overline{\beta}\iota}\widehat{\epsilon}_t^I \text{ where } \phi = \frac{1}{\psi''(\iota)} \tag{129}$$

$$\widehat{r}_t^k = \sigma_d\widehat{d}_t \tag{130}$$

$$\widehat{k}_t^H = \frac{1-\delta}{\iota}\widehat{k}_{t-1}^H + \delta\widehat{i}_t \tag{131}$$

$$\widehat{k}_t^* = \frac{\rho^n}{1-\rho^n}\widehat{\rho}_t^n + \frac{1}{1-\alpha}(\widehat{z}_t - \widehat{\mu}_t - \widehat{r}_t^k) + \frac{X'(\widetilde{a})}{X(\widetilde{a})}\widetilde{a}\widehat{\widetilde{a}}_t \tag{132}$$

$$\widehat{\widetilde{k}}_t^* = \frac{1}{1-\alpha}(\widehat{z}_t + \widehat{\widetilde{a}}_t - \widehat{\mu}_t - \widehat{r}_t^k) \tag{133}$$

$$\widehat{k}_{t-1}^H = \widehat{n}_t + \widehat{k}_t^* - \widehat{d}_t \tag{134}$$

$$\widehat{\lambda}_{1t} = \frac{-\sigma}{1-h/\iota}\widehat{c}_t + \frac{\sigma h}{\iota - h}\widehat{c}_{t-1} \tag{135}$$

$$\widehat{y}_t = (1 + \gamma\frac{v}{y})(\widehat{n}_t + \widehat{\mu}_t + \widehat{r}_t^k + \widehat{k}_t^*) - \gamma\frac{v}{y}\widehat{v}_t \tag{136}$$

$$\widehat{y}_t = \frac{c}{y}\widehat{c}_t + \frac{i}{y}\widehat{i}_t + \widehat{g}_t + \frac{r^k k^H}{y\iota}\widehat{k}_{t-1}^H \tag{137}$$

$$\widehat{\pi}_t = \frac{\overline{\beta}}{1+\overline{\beta}\xi}\mathbb{E}_t\widehat{\pi}_{t+1} + \frac{\xi}{1+\overline{\beta}\xi}\widehat{\pi}_{t-1} - \frac{(1-\overline{\beta}\omega)(1-\omega)}{\omega(1+\overline{\beta}\xi)}\widehat{\mu}_t + \widehat{\epsilon_t^P} \tag{138}$$

$$\widehat{r}_t = (1-\phi_r)(\phi_\pi\widehat{\pi}_t + \phi_y\widehat{y}_t) + \phi_r\widehat{r}_{t-1} + \widehat{\epsilon}_t^r \tag{139}$$

$$\widehat{g}_t = \widehat{g}_t^y \tag{140}$$

$$\widehat{g}_t^{utotal} = \widehat{\epsilon}_t^{g^u} + \widehat{y}_t^L + \widehat{u}_t \text{ and } \widehat{g}_t^u = \widehat{\epsilon}_t^{g^u} + \widehat{y}_t^L \tag{141}$$

There are 36 equations and 36 unknown variables (u_t, n_t, v_t, ρ_t, ρ_t^f, ρ_t^w, $\widetilde{a}_t$, w_t^p, w_t, J_t, ϑ_t, ϑ_t^p, H_t^w, H_t^u, S_t, $\widetilde{w}_t$, $\widetilde{w}_t^p$, $\widetilde{J}_t$, $\widetilde{\vartheta}_t$, $\widetilde{\vartheta}_t^p$, $\widetilde{H}_t^w$, r_t, π_t, Q_t, d_t, i_t, K_t^H, $\widetilde{K}_t^*$, Y_t, μ_t, C_t, G_t, G_t^u, λ_t, r_t^k, K_t^*).

D Data Appendix

Data sources and description are listed in Table 1 and 2.

Table 1: Data Description and Sources

Data Title	Data Description	Data Sources
GDPC96	Real Gross Domestic Product Billions of Chained 1996 Dollars Seasonally Adjusted Annual Rate	U.S. Department of Commerce: Bureau of Economic Analysis
GDPDEF	Gross Domestic Product Implicit Price Deflator, 1996=100 Seasonally Adjusted	U.S. Department of Commerce: Bureau of Economic Analysis
PCEC	Personal Consumption Expenditure Billions of Dollars Seasonally Adjusted Annual Rate	U.S. Department of Commerce: Bureau of Economic Analysis
CE16OV	Civilian Employment Sixteen Years & Over, Thousands Seasonally Adjusted, 1996=100	U.S. Department of Labor: Bureau of Labor Statistics
FEDR	Federal Funds Rate Averages of Daily Figures Percent	Board of Governors of the Federal Reserve System
LNS10000000	Labor Force Status Civilian noninstitutional population Seasonally Adjusted	U.S. Department of Labor: Bureau of Labor Statistics
LNSindex	LNS10000000(1992:3)=1	
FPI	Fixed Private Investment Billions of Dollars Seasonally Adjusted Annual Rate	U.S. Department of Commerce: Bureau of Economic Analysis
RWAGE	Nonfarm Business, All Persons Hourly Compensation Duration index, 1992=100	U.S. Department of Labor: Bureau of Economic Analysis
UNRATE	Unemployment Rate Civilian Unemployment Rate Seasonally Adjusted	U.S. Department of Labor: Bureau of Economic Analysis
HELPWANT	Index of Help-Wanted Advertising 1987=100 Seasonally Adjusted	Composite Help-Wanted Index by Regis Barnichon
UNINS	Unemployment Insurance Billions of Dollars Seasonally Adjusted	U.S. Department of Commerce: Bureau of Economic Analysis
AWB	Average Weekly Benefit Amount Dollars Seasonally Adjusted	U.S. Department of Labor: Bureau of Labor Statistics

Table 2: Definition of Data Variables

Data Variable	Mnemonic	Formula
Output	GDP	$= \log(GDPC96/LNSindex) * 100$
Consumption	CONS	$= \log(PCED/(GDPDEF * LNSindex)) * 100$
Investment	INV	$= \log(FPI/(GDPDEF * LNSindex)) * 100$
Real wage	WAG	$= \log(RWAGE/GDPDEF) * 100$
Unemployment insurance	INS	$= \log(UNINS/(GDPDEF * LNSindex)) * 100$
Unemployment	UNEM	$= \log(UNRATE) * 100$
Inflation	INF	$= \log(GDPDEF/GDPDEF(-1)) * 100$
Federal funds rate	FFR	$= FEDR/4$
Vacancy	VAC	$= \log(HELPWANT/LNSindex) * 100$
Average Weekly Benefits	AWB	$= \log(AWB/GDPDEF) * 100$

E Tables and Figures

Table 3: Observed Variables and Shocks Comparison

SW (2007)[1]		GST (2008)[2]		Zhang (2011)[3]	
Obs. Var.	Shocks	Obs. Var.	Shocks	Obs. Var.	Shocks
GDP	Gov. Spending	GDP	Gov. Spending	GDP	Gov. Spending
CONS	Risk Prem.	CONS	Risk Prem.	CONS	Risk Prem.
INV	Invest. Tech.	INV	Invest. Tech.	INV	Invest. Tech.
WAG	Wage Markup	WAG	Bargain Power	WAG	Bargain Power
INF	Price Markup	INF	Price Markup	INF	Price Markup
FFR	Monetary	FFR	Monetary	FFR	Monetary
Employ	Technology	Employ	Technology	UNEM	Technology
-	-	-	-	VAC	Matching
-	-	-	-	INS/REPR	Unemp. Ben.

[1] SW (2007): Smets and Wouters (2007, AER)
[2] GST (2008): Gertler, Sala, and Trigari (2008, JMCB)
[3] Zhang (2011): this paper

Table 4: Mapping Between Observables and Shocks

Variables		Shocks
dGDP	$\Leftarrow$	Government Spending
dCONS	$\Leftarrow$	Risk Premium
dINV	$\Leftarrow$	Investment Specific Technology
dWAG	$\Leftarrow$	Bargaining Power
dINS & dAWB	$\Leftarrow$	Unemployment Benefit
INF	$\Leftarrow$	Price Markup
FFR	$\Leftarrow$	Monetary Policy
UEMP	$\Leftarrow$	Technology
VAC	$\Leftarrow$	Matching Efficiency

Table 5: Calibrated Parameters

β	δ	α	g^y	$\bar{\epsilon}^P$	ρ^x	σ_a
0.99	0.025	0.33	0.18	11	0.068	0.15

Table 6: Prior and Posterior Distribution of Shocks and Structural Parameters

		Prior Distribution			Posterior Distribution			
		Distribution	Mean	St. Dev.	Mode	Mean	5 percent	95 percent
Standard deviations								
Risk premium	σ_b	InvGamma	0.10	0.15	3.60	3.18	2.89	3.48
Bargaining power	σ_η	InvGamma	0.10	0.15	4.89	4.89	4.59	5.22
Investment	σ_I	InvGamma	0.10	0.15	1.68	1.57	1.27	1.86
Price markup	σ_p	InvGamma	0.10	0.15	0.31	0.32	0.28	0.35
Technology	σ_z	InvGamma	0.10	0.15	0.69	0.69	0.62	0.75
Matching efficiency	σ_m	InvGamma	0.10	0.15	7.50	7.32	6.32	7.92
Government	σ_g	InvGamma	0.10	0.15	0.65	0.67	0.59	0.74
Unemployment benefits	σ_{g^u}	InvGamma	0.10	0.15	2.17	2.34	2.11	2.56
Monetary	σ_r	InvGamma	0.10	0.15	0.29	0.29	0.25	0.33
Autoregressive parameters								
Risk premium	ρ_b	Beta	0.50	0.20	0.08	0.28	0.15	0.39
Bargaining power	ρ_η	Beta	0.50	0.20	0.99	0.99	0.98	0.99
Investment	ρ_I	Beta	0.50	0.20	0.99	0.91	0.87	0.94
Price markup	ρ_p	Beta	0.50	0.20	0.72	0.71	0.64	0.78
	μ_p	Beta	0.50	0.20	0.99	0.99	0.98	0.99
Technology	ρ_z	Beta	0.50	0.20	0.99	0.98	0.97	0.99
Matching efficiency	ρ_m	Beta	0.50	0.20	0.58	0.51	0.41	0.62
Government	ρ_g	Beta	0.50	0.20	0.97	0.97	0.96	0.98
	μ_{gz}	Beta	0.50	0.20	0.49	0.54	0.43	0.55
Unemployment benefits	ρ_{g^u}	Beta	0.50	0.20	0.99	0.98	0.98	0.99
Monetary	ρ_r	Beta	0.50	0.20	0.23	0.19	0.09	0.30
Structural parameters								
Taylor rule inertia	ϕ_r	Beta	0.75	0.10	0.73	0.77	0.74	0.81
Taylor rule: inflation	ϕ_π	Normal	2.20	0.10	2.16	2.24	2.09	2.37
Taylor rule: output	ϕ_y	Beta	0.50	0.20	0.14	0.16	0.12	0.21
Consumption habit	h	Beta	0.70	0.10	0.85	0.71	0.66	0.78
Steady-state growth rate	$\bar{\iota}$	Normal	0.40	0.10	0.50	0.49	0.47	0.51
Inv. adj. cost elast.	ϕ	Normal	0.70	0.05	0.60	0.70	0.62	0.78
Price indexation	ξ	Beta	0.50	0.15	0.87	0.66	0.51	0.80
Calvo price para.	ω	Beta	0.50	0.10	0.82	0.82	0.81	0.82
Capital util. adj. cost elast.	σ_d	Normal	1.50	0.10	1.38	1.34	1.26	1.42
Steady-state inflation	$\overline{\pi}_c$	Beta	0.50	0.20	0.94	0.93	0.87	0.99
Job-finding rate	ρ^w	Normal	0.71	0.1	0.77	0.77	0.70	0.84
Labor market tightness	θ	Normal	0.60	0.05	0.81	0.63	0.55	0.71
Replacement rate	$\overline{rr}$	Normal	0.40	0.05	0.40	0.37	0.29	0.46
Separation threshold	$\widetilde{a}$	Uniform (0.6,0.8)[1]	-	-	0.68	0.63	0.60	0.66
Matching function para.	ζ	Normal	0.4	0.05	0.38	0.38	0.32	0.44
Counter offer cost	$100 * \gamma_b$	Uniform (1,50)[2]	-	-	48.50	22.09	0.10	43.42
Prob. of barg. breakup	$100 * \delta_b$	Uniform (0.01,2)[3]	-	-	1.98	0.94	0.02	1.75

[1] $\widetilde{a} = 0.68$ corresponds to $\rho^n = 0.005$, and $\widetilde{a} = 0.9$ corresponds to $\rho^n = 0.068$.

Table 7: Model Sensitivity – Estimation Results for Structural Parameters in Robustness Checks

		Baseline	Benefits Policy with Unemploy. Feedback	Job-finding Rate as Observable	AWB as Observable	Nash Barg. & Real Wage Rigidity
Taylor rule inertia	ϕ_r	0.73	0.52	0.70	0.79	0.77
Taylor rule: inflation	ϕ_π	2.16	2.43	2.35	2.26	2.34
Taylor rule: output	ϕ_y	0.14	0.05	0.04	0.17	0.11
Consumption habit	h	0.85	0.11	0.67	0.75	0.78
Steady-state growth rate	$\bar{\iota}$	0.50	0.43	0.42	0.48	0.38
Inv. adj. cost elast.	ϕ	0.60	0.73	0.77	0.70	0.56
Price indexation	ξ	0.87	0.21	0.75	0.65	0.83
Calvo price para.	ω	0.82	0.31	0.61	0.82	0.81
Capital util. adj. cost elast.	σ_d	1.38	1.28	1.35	1.36	1.35
Steady-state inflation	$\overline{\pi}_c$	0.94	0.97	0.98	0.96	0.91
Job-finding rate	ρ^w	0.77	0.80	0.71	0.74	0.75
Labor market tightness	θ	0.81	0.69	0.63	0.62	0.75
Replacement rate	$\overline{rr}$	0.40	0.34	0.48	0.41	0.20
Separation threshold	$\widetilde{a}$	0.68	0.70	0.68	0.70	0.75
Matching function para.	ζ	0.38	0.60	0.23	0.38	0.57
Counter offer cost	$100 * \gamma_b$	48.50	28.52	42.32	50.00	-
Prob. of barg. breakup	$100 * \delta_b$	1.98	1.72	1.23	1.94	-
Benefits policy: unempl.	ϕ_u	-	0.19	-	-	-
Barg. power	η	-	-	-	-	0.36

Table 8: Variance Decomposition of Key Variables (on impact) in the Baseline Model and Models for Robustness Checking (in %)

Shocks \ Variables	c	u	v	ρ	ρ^f	ρ^w	w	π	i
Technology	7.11	5.05	5.62	2.72	5.13	5.08	6.03	12.13	11.04
Bargaining power	2.12	49.03	48.75	54.45	48.51	48.02	16.50	3.11	2.84
Investment	88.57	29.65	29.95	9.48	29.81	29.51	23.39	74.52	75.93
Price markup	0.02	0.82	1.43	0.38	0.88	0.87	0.50	1.20	0.46
Monetary	0.00	0.03	0.23	1.35	0.05	0.05	2.90	1.04	0.19
Matching efficiency	0.06	4.87	0.34	3.52	4.84	5.80	7.42	1.41	1.21
Government	1.71	0.58	1.76	4.52	0.70	0.69	10.46	2.06	2.84
Unemployment benefits	0.38	9.26	9.33	10.62	9.18	9.09	3.29	0.61	0.56
Risk premium	0.02	0.70	2.61	12.96	0.90	0.89	29.51	3.93	4.93

Table 9: Variance Decomposition of Key Variables (40 Quarters) in the Baseline Model and Models for Robustness Checking (in %)

Shocks \ Variables	c	u	v	ρ	ρ^f	ρ^w	w	π	i
Technology	17.86	5.08	6.18	2.98	5.20	5.08	5.78	20.87	15.80
Bargaining power	6.60	58.14	58.12	47.43	57.34	56.05	13.68	5.31	3.87
Investment	58.58	7.13	8.81	3.37	7.77	7.59	9.51	34.28	44.27
Price markup	0.15	1.91	3.05	0.58	1.99	1.94	0.67	4.82	1.70
Monetary	0.01	0.07	0.48	2.09	0.12	0.11	3.88	4.18	0.70
Matching efficiency	0.62	11.38	0.72	5.44	10.92	12.91	9.90	5.67	4.50
Government	14.45	1.25	3.69	6.96	1.49	1.46	13.95	7.74	9.74
Unemployment Benefits	1.49	13.40	13.38	11.12	13.17	12.88	3.22	1.28	0.95
Risk premium	0.25	1.64	5.58	20.03	2.02	1.97	39.41	15.84	18.46

Table 10: Variance Decomposition of Unemployment in the Baseline Model and Models for Robustness Checking (on impact / 40 quarters, in %)

	Baseline	Benefits Policy with Unemploy. Feedback	Job-finding Rate as Observable	AWB as Observable	Nash Barg. & Real Wage Rigidity
Techonology	5.05/5.08	4.13/5.53	1.67/2.34	3.61/2.63	47.12/40.19
Bargaining power	49.03/58.14	67.39/56.38	73.20/62.22	82.78/75.95	0.52/0.99
Investment	29.65/7.13	0.05/0.07	0.28/0.31	0.23/0.27	23.29/19.79
Price markup	0.82/1.91	8.12/8.89	9.70/16.62	0.58/1.00	4.14/7.32
Monetary	0.03/0.07	0.00/0.06	0.00/0.01	0.02/0.03	0.15/0.32
Matching efficiency	4.87/11.38	0.03/0.05	2.89/5.22	4.26/7.31	6.30/8.90
Government	0.58/1.25	0.06/0.06	0.15/0.21	0.23/0.35	2.17/1.27
Unemployment benefits	9.26/13.40	20.22/29.01	12.02/12.95	8.06/12.05	15.80/20.16
Risk premium	0.70/1.64	0.00/0.00	0.08/0.14	0.24/0.42	0.49/1.06

Figure 1: Growth Rates of the Unemployment Benefits and Real Wage

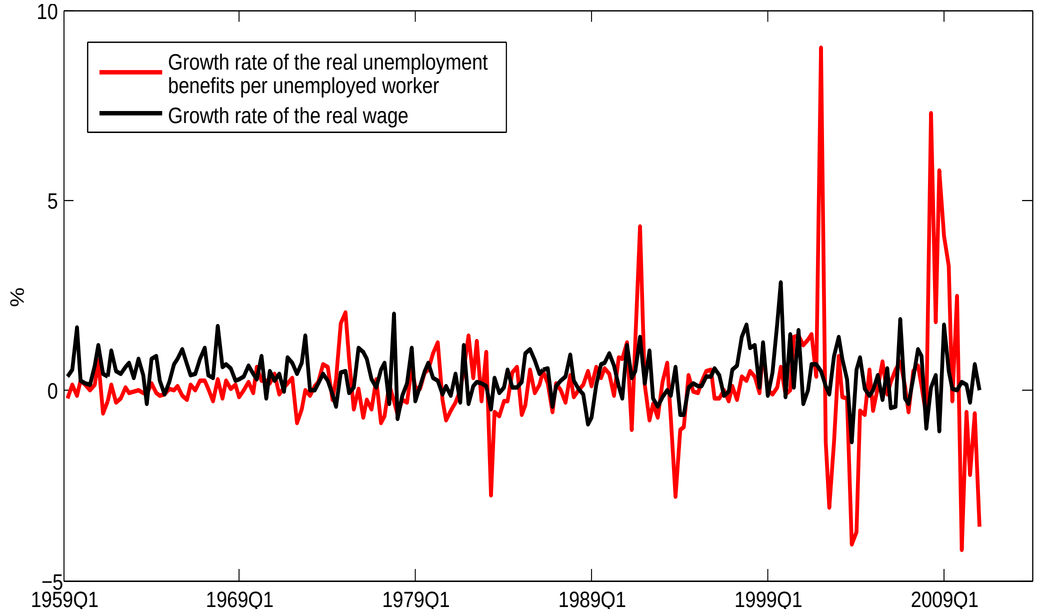

Figure 2: Technology Shock

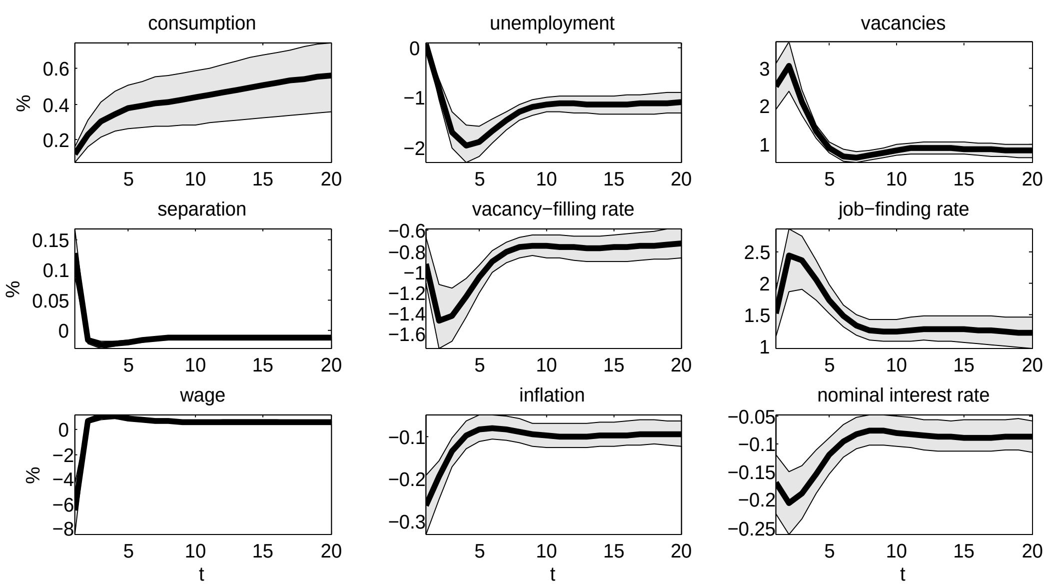

Figure 3: Matching Efficiency Shock

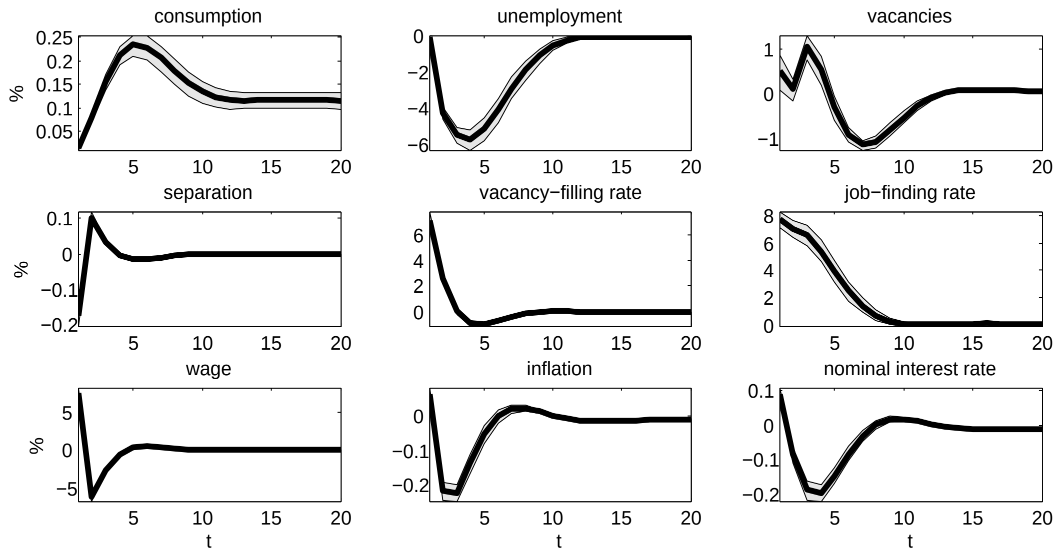

Figure 4: Unemployment Benefit Shock

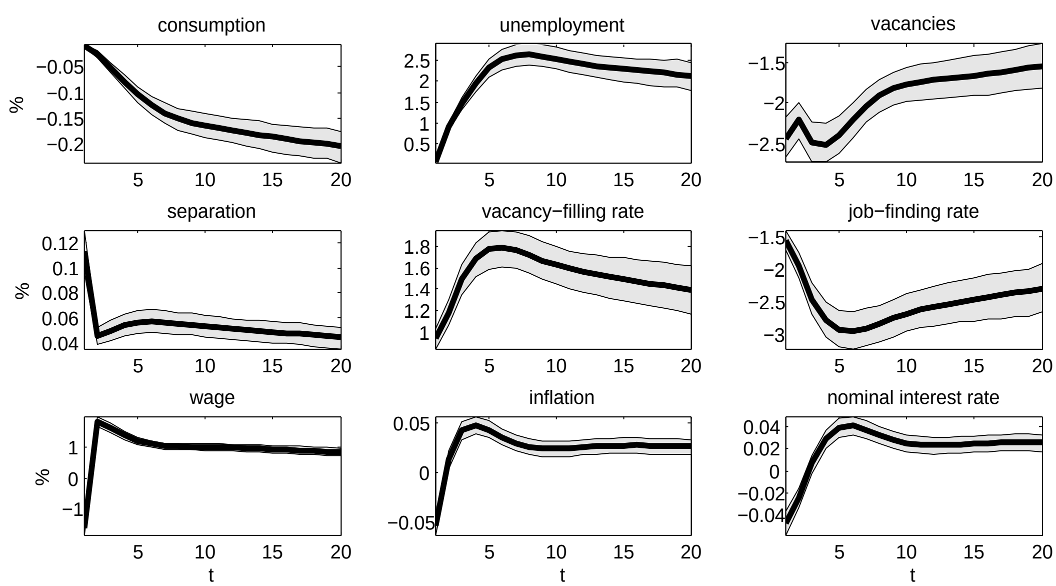

Figure 5: Historical Decomposition for Unemployment

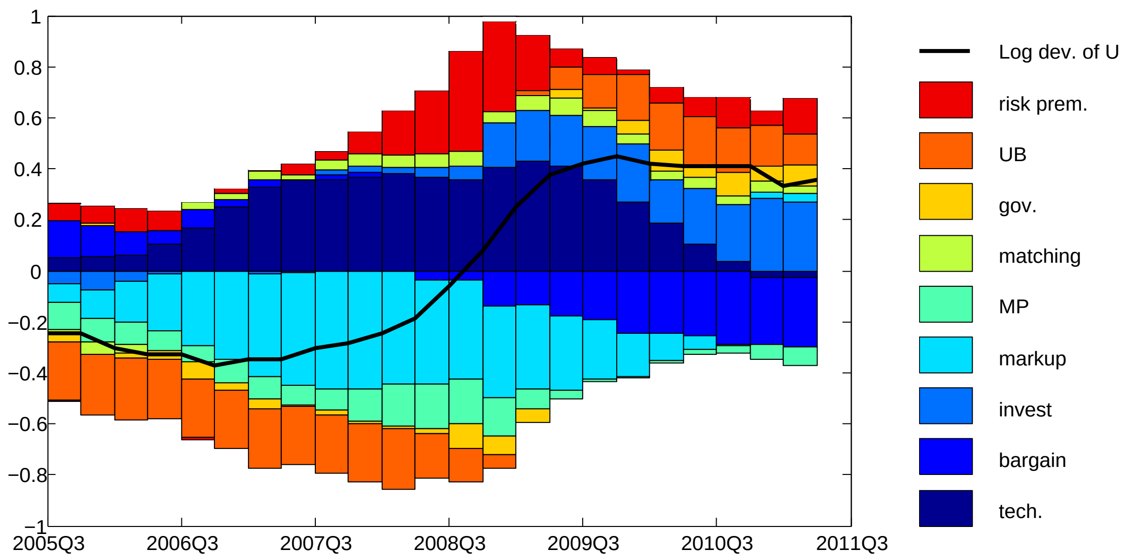

Figure 6: Shock Inputs of the Historical Decomposition

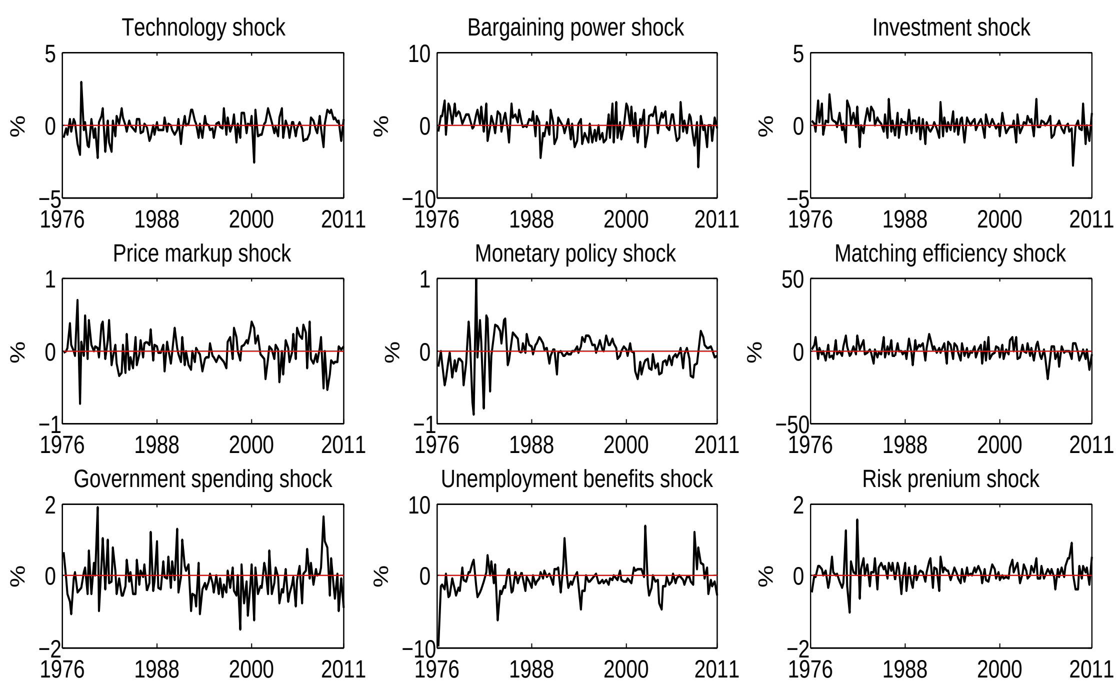

Figure 7: Vacancy / Unemployment by Industry

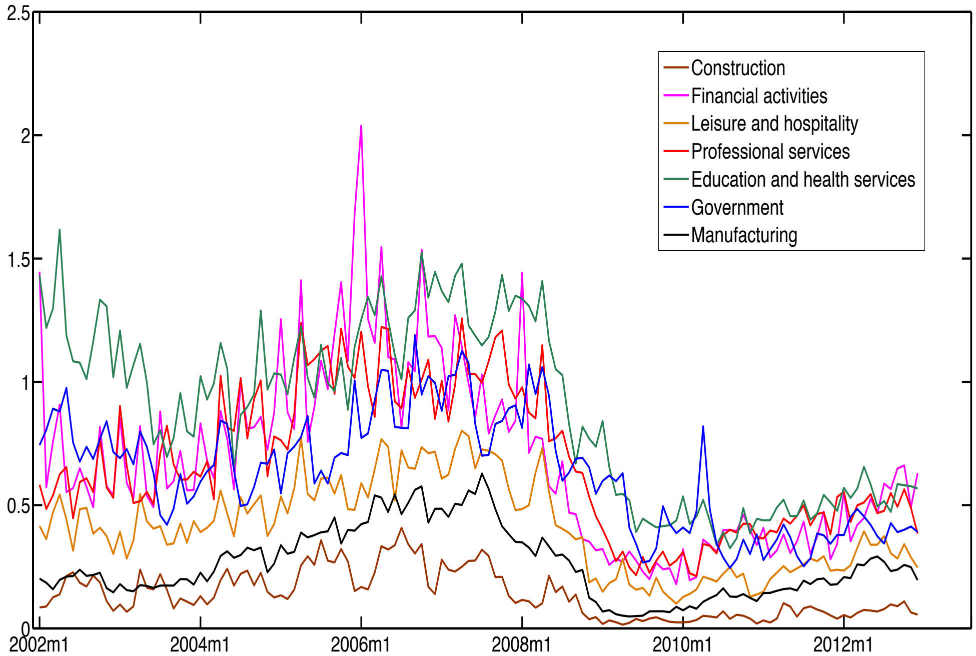

Figure 8: Actual and Counterfactual Beveridge Curves: 2007Q4 - 2011Q2

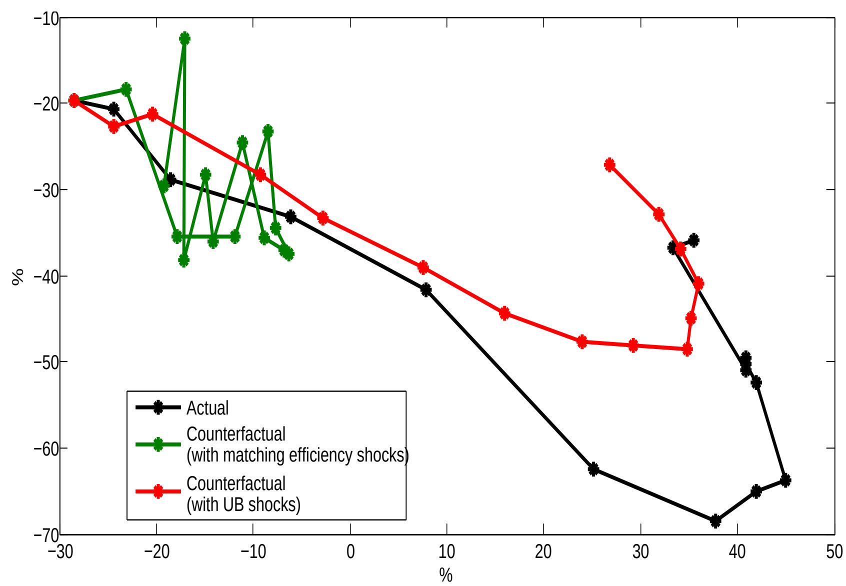

Figure 9: Estimated Unemployment Benefits Shock Series

Figure 10: Fluctuations in Average Weekly Benefits Amount (AWBA) and Real Wage

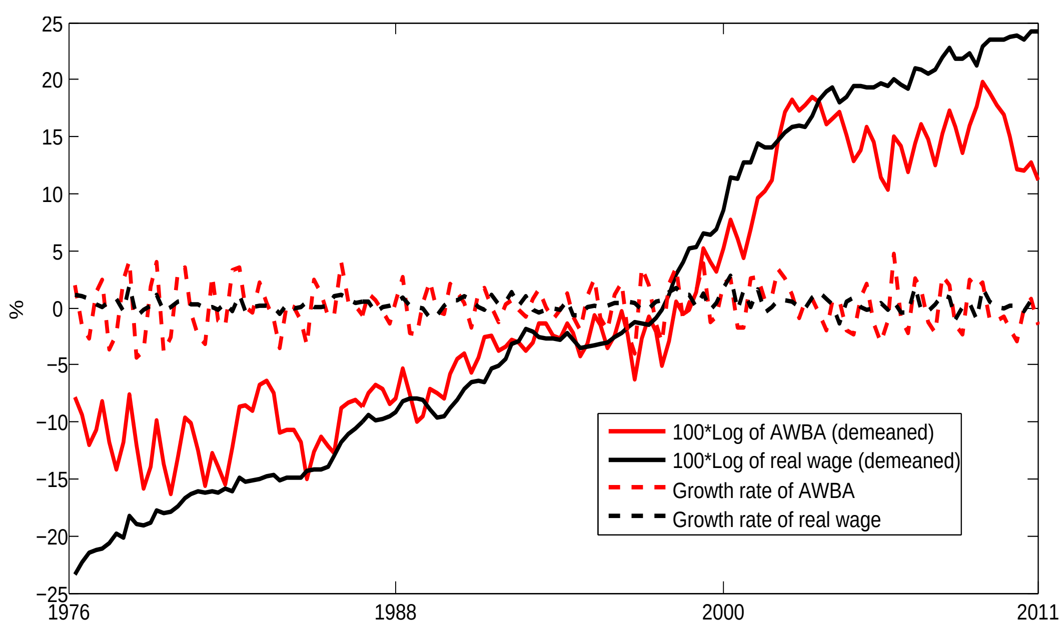

Figure 11: Matching Efficiency Implied by the Estimated Model When the Job-finding Rate and Labor Market Tightness are Used as Observables