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Abstract

This paper examines the effects of uncertainty shocks on Japan's labor market. Using a measure of uncertainty from the stock market data and a structural VAR model, I find that an increase in uncertainty leads to a rise in unemployment and declines in output, vacancies, and inflation. I then develop a dynamic general equilibrium model with labor market frictions and examine the transmission mechanism of uncertainty shocks. In the model, uncertainty shocks are defined as unexpected increases in the volatility of technology shock. My model can replicate the observed pattern of labor market responses to uncertainty shocks. I also discuss how the job separation channel influences the macroeconomic effect of uncertainty shocks.

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1 Introduction

Both policymakers and economists are increasingly concerned about uncertainty and its detrimental effects on the economy. In particular, it has been suggested that uncertainty surged during the Great Recession of 2008-2009 and it contributed to a persistently high unemployment. Recently, a number of studies investigates the effects of uncertainty shocks on the labor market (Caggiano et al. 2014; Choi and Loungani, 2015; Guglielminetti, 2015; Leduc and Liu, 2015; Schaal, 2015). However, these studied mainly focus on the U.S. economy, and less is known about the effects of uncertainty shock on labor markets in other countries. Especially, there has no study on the Japanese case.

This paper examines the impact of uncertainty shocks on the Japanese economy by focusing on the labor market. Uncertainty is not directly observable and thus existing studies have been proposed different measures of uncertainty.[1] Since the literature of uncertainty shows that stock market volatility is good proxy of uncertainty, I use historical volatility of the Nikkei Stock Average as a measure of uncertainty. Using this measure of uncertainty and a structural VAR model, I first empirically examine the effects of an uncertainty shock on the economy.

My empirical analysis demonstrates that an increase in uncertainty leads to a persistent increase in unemployment. It also reduces output and inflation significantly. This result suggests that the uncertainty shock acts as a "demand shock" because it reduces both economic activity and prices. I also examine the response of job finding and separation rates to the uncertainty shock. Heightened uncertainty reduces the job finding rate and raises the separation rate, which contributes to increase unemployment. Furthermore, this paper finds that the uncertainty shock reduces working hours and vacancies posted.

I then develop a dynamic general equilibrium model with labor market frictions to analyze the transmission mechanism of the uncertainty shock. The model considers technology shocks that have time-varying second moments, which I interpret as uncertainty shocks. Motivated by the empirical finding that the uncertainty shock affect both job finding and separation rates, I assume that job separation is endogenously determined in the model.[2] Furthermore, reflecting the empirical observation that the intensive margin accounts for a large proportion of working hours' variation in Japan, I incorporate the intensive margin into the model.[3] By doing so, my model provides a more realistic and comprehensive description of Japan's labor market.

[1]There are both micro and macro measures of uncertainty. For example, Bloom (2009) use the stock market volatility to measure uncertainty. Bachmann et al. (2013) use survey expectations data to construct empirical proxy for time-varying business-level uncertainty. Baker et al. (2016) develop the Economic Policy Uncertainty (EPU) index based on the frequency of newspaper articles about economic uncertainty. See Bloom (2014) for surveys.

[2]It is also known that both unemployment inflow and outflow rates significantly contribute the unemployment dynamics in Japan. See Miyamoto (2011) and Lin and Miyamoto (2012) for the detail.

[3]Kudoh et al. (2015) demonstrate that the intensive margin accounts for a particularly large proportion of cyclical fluctuations in the aggregate labor input in Japan.

The most striking finding is that the effects of uncertainty shocks on labor market variables differ between models with and without endogenous job separation. In the model without endogenous job separation, an increase in uncertainty reduces vacancies and the job finding rate and raises unemployment, which is consistent with data. In contrast, in the model with endogenous job separation, the uncertainty shock increases both vacancies and unemployment. This is because of the feed-back effect of job separation on job creation. With endogenous job separation, the uncertainty shock increases unemployment by increasing job separation, which in turn makes it easier for firms to post more vacancies and thus increases the job finding rate.

This paper is related to the growing literature on the macroeconomic effect of uncertainty. Since the seminal contribution by Bloom (2009), a number of studies examines the quantitative impact of uncertainty on economic activity by using different measures of uncertainty and VAR models. Recent contributions include Bloom (2009), Alexopoulos and Cohen (2009), Bachmann et al. (2013), Baker et al. (2013), Denis and Kannan (2013), Gilchrist et al. (2013), Caggiano et al. (2014), Choi and Loungani (2015), Leduc and Liu (2015), and Mecikovsky and Meier (2015). Most of these studies are focus on the U.S. and European countries, and less is known about the case of Japan. By analyzing the case of Japan, the present paper fills this gap.

This paper is closely related to Leduc and Liu (2015) and Guglielminetti (2015) that examine the effect of uncertainty shocks on unemployment in the U.S. economy by using a DSGE model with search frictions. In their model, firms adjust their labor inputs by changing only the extensive margin and job separation takes place exogenously. In contrast, my model assumes that firms adjust labor inputs along both extensive and intensive margins. Furthermore, in my model, job separation is endogenously determined. Schaal (2015) considers the effects of volatility shocks in a direct search model with heterogeneous firms and endogenous job separation. While search is directed in his model, this paper assumes random search and matching.

The reminder of this paper is organized as follows. Section 2 examines the effect of uncertainty shocks on the labor market by using structural VAR models. Section 3 develops a dynamic general equilibrium with search frictions. In Section 4, I calibrate the model parameters and presents the quantitative results of the effects of uncertainty shocks on the economy. Section 5 concludes.

2 Empirical analysis

This section empirically examines the effects of uncertainty shocks on Japan's labor market using structural VAR models. Uncertainty is not directly observable and thus existing studies construct a measure of uncertainty from various sources of data. Since the literature of uncertainty demonstrates that stock market volatility is a good proxy for uncertainty, I use historical volatility (HV) of the Nikkei Stock Average as a measure of uncertainty.[4] The HV is calculated based on daily returns of the Nikkei Stock Average for the past 20 days. Specifically, it is calculated as follows:

$$HV = 100\sqrt{\frac{1}{20}\sum_{i=1}^{20}(\ln S_i - \ln S_{i-1})^2 \times 250},$$

where S_i is the closing value of the Nikkei Stock Average.

The constructed HV is presented in Figure 1. The HV varies over the period from 1980 to 2016. There are sudden increases in the volatility index that are associated with internal shocks and economic events such as the collapse of the Japanese asset bubble in the early 1990s, the Great East Japan Earthquake and nuclear issue in 2011Q1, and a sharp drop in Japanese stock prices in 2013Q2. The volatility index also reflects the international shocks such as the Asian financial and currency crisis in 1997, and the recent global financial crisis in 2008-2009.

For the baseline specification, I consider a SVAR model consisting of four variables: the measure of uncertainty, output, the unemployment rate, and the inflation rate. In order to examine the effect of an uncertainty shock on other labor market variables such as the vacancy rate, the job finding rate, the separation rate, hours of work, and wages. I also estimate tri-variable SVAR models which include the measure of uncertainty, output, and one of these labor market variables.

I identify the uncertainty shock by using the widely adopted recursive strategy. Specifically, I assume that uncertainty is not contemporaneously affected by the state of the economy. Thus, I place the uncertainty measure as the first variable in the SVAR model.[5]

Data I obtain quarterly data on Indices of Industrial Production from the Ministry of Economy, Trade and Industry. The unemployment rate is taken from the Labour Force Survey (LFS) published by the Statistics Bureau. The inflation rate is measured as the year-over-year increase in the consumer price index excluding fresh food (Core CPI). We obtain the data on the Core CPI from the Statistics Bureau. The vacancy rate is obtained from the monthly Report on Employment Service (Shokugyo Antei Gyomu Tokei) conducted by the Ministry of Health, Labour and Welfare (MHLW). Following Miyamoto (2011) and Lin and Miyamoto (2012), we construct the job finding and separation rates from the LFS. Hours of work per worker and hourly real wages are obtained from the Monthly Labour Survey conducted by the MHLW.

The lag lengths of the SVAR models are determined based on information criteria. Each

[4] Instead of using the HV, as a measure of uncertainty, I may use the Nikkei Stock Average Volatility Index (VIX) which indicates the expected degree of fluctuations of the Nikkei Stock Average in the future. However, the data period of the VIX is much shorter than the HV. Since the correlation between the HV and the VIX is high, I use the HV as the measure of uncertainty in this paper.

[5] This identification strategy is similar to that in Caggiano et al. (2014) and Leduc and Liu (2015). Note that results are robust to alternative recursive ordering.

variable is logged and expressed as percentage deviations from its HP trend with smoothing parameter 1600. The sample covers the period from 1980Q1 to 2016Q1.

Estimation results Figure 2 shows that the impulse responses of the relevant variables to a one-standard deviation uncertainty shock with 95% confidence bands constructed by the bootstrap method.[6] I show the impulse response functions for a horizon of 20 quarters.

An increase in uncertainty leads to a persistent increase in the unemployment rate. Following the uncertainty shock, the unemployment rate rises and reaches its peak about 5 quarters and gradually returns to its steady state. The increase in the unemployment rate remains statistically significant in about 2 years.

The uncertainty shock reduces both output and inflation. Output decreases significantly and follows a U-shaped path before going back to its initial value. The inflation rate also falls and the response of the inflation rate is statistically significant at the peak. These results are in line with those obtained by Caggiano et al. (2014) and Leduc and Liu (2015). Thus, my empirical analysis suggests that uncertainty shock acts as a "demand shock" in the sense that it reduces both economic activity and prices.

I next examine the effect of uncertainty shock on other labor market variables. Figure 3 shows the results. I begin to see the response of job finding and separation rates to the uncertainty shock, since they determine unemployment dynamics. Following the shock, the job finding rate falls and the separation rate increases significantly. These two effects contribute to the increase in the unemployment rate.

Hours of work falls and follows a U-shaped path before going back to its steady-state value. The response of hours of work is statistically significant at the peak. Heightened uncertainty initially increases the wage rate and then reduce it, although the effect is hardly significant. The reaction of the vacancy rate is negative, and it is statistically significant at the peak.

3 The model

This section presents a dynamic general equilibrium model with labor market frictions in which job separation is endogenously determined. Using this model, I examine the effects of uncertainty shocks on the economy.

Environment The economy consists of a representative household, firms, and a government. The representative household consists of a continuum of workers whose measure is normalized to one. I assume that all agents live forever. The labor market is subject to frictions. Thus,

[6]As a robustness check, I consider an alternative measure of uncertainty: Economic Policy Uncertainty (EPU) index computed by Baker et al. (2016). I find that the results are robust to using a different measure for uncertainty.

workers and firms cannot meet instantaneously but must go through a time-consuming search process. Time is discrete.

The household consumes goods, accumulates capital, and provides labor services. Due to labor market frictions, some workers are employed and earn wages while others are unemployed and search for jobs. To produce output, firms hire workers in the frictional labor market and rent capital from the household. The firms sell their output to the household in a competitive market. While employment is the outcome of workers' and firms' search behavior, wages and hours of work are determined through bargaining between a worker and a firm.

Production technology A firm-worker pair produces output y_t according to a constant-returns-to-scale production function

$$y_t = z_t f(k_t h_t),$$

where z_t is a common technology shock, k_t is the level of capital per worker, and h_t is hours of worker per worker.

In order to produce output, a firm-worker pair needs to pay an operating cost x_t besides labor and capital renting costs.[7] The operating cost is idiosyncratic to each match. The match-specific operating cost x_t is assumed to be independent and identically distributed across firms and time, with a cumulative distribution function $\Gamma : [\underline{x}, \bar{x}] \rightarrow [0, 1]$. Every period a match draws a new idiosyncratic cost and decides whether producing output at the new level of cost or terminating the employment relationship. Each match chooses a reservation value x^*; if the match-specific cost falls below x^*, it continues producing output.

Besides endogenous separation, a match might be terminated for an exogenous reason in any given period. Let s denote the probability of exogenous separation, which is assumed to be independent of the idiosyncratic cost x. When job separation, either endogenously or exogenously, occurs, the firm can either reopen a job as a new vacancy or exit the labor market. At the same time, the worker becomes unemployed and starts to look for a new job.

Matching technology The labor market is subject to search frictions. Let u_t be the number of unemployed workers and v_t be the number of vacancies in period t. The number of matches m_t is determined by the Cobb-Douglas production function

$$m_t = m_0 u_t^{\xi} v_t^{1-\xi},$$

where the parameter $m_0 > 0$ represents the efficiency of the matching technology and $0 < \xi < 1$ is the elasticity of the matching function with respect to unemployment. The probability that

[7] I incorporate endogenous separation by having idiosyncratic additive operational costs as opposed to multiplicative idiosyncratic productivity as seen in Mortensen and Pissarides (1994). This is because multiplicative idiosyncratic productivity would lead to heterogeneity in hours per worker across matches, while the additive idiosyncratic operational cost leads to homogenous hours across matches.

a firm fills its vacancy is given by $q_t = m_t/v_t$. Similarly, the probability that an unemployed worker finds a job is given by $p_t = m_t/u_t$. Note that both firms and workers take q_t and p_t as given.

Timing of the model The timing of the model is as follows. At the beginning of each period, every match draws an idiosyncratic cost and observes whether or not exogenous separation shock hits the job. After observing all the shocks, the match may choose to separate endogenously. If either exogenous or endogenous separation takes place, the match does not produce anything in the period. After job separation occurs, the levels of employment and unemployment are determined. At the point, matches start production and unemployed workers search for jobs. At the end of the period, wages are paid, firm's profits are distributed, and household's consumption decisions are made.

Household's problem A representative household consists of a continuum of members of mass one. A member of the household is either employed or unemployed. In period t, there are n_t employed worker and $u_t = 1 - n_t$ unemployed workers. Following Merz (1995), I assume that the family provides perfect consumption insurance for its members. Thus, consumption is the same for each member, regardless of whether she or he is employed or not.

The household's expected life time utility is given by

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[\ln \left(C_t - \mathfrak{h} C_{t-1} \right) - \Phi n_t \frac{h_t^{1+\mu}}{1+\mu} \right],$$

where $\mathbb{E}$ is an expectation operator, $\beta \in (0,1)$ is the household's subjective discount factor, C_t is consumption, $\mathfrak{h}$ controls habit persistence, $\Phi > 0$ measures the disutility of working, and μ is the inverse of the Frisch elasticity of labor supply.

Employed household members earn wages and unemployed ones receive unemployment benefits b from the government. The household receives profits D_t from the firms and pays lump-sum taxes T_t to the government. The household may either consume C_t or accumulate capital K_{t+1} through investment I_t according to $K_{t+1} = (1-\delta)K_t + I_t$, where δ is the depreciation rate. Thus, the budget constraint of the household is

$$C_t + K_{t+1} = \bar{W}_t + b(1 - n_t) + r_t K_t + (1-\delta) K_t + D_t - T_t,$$

where $\bar{W}$ is the total wage income for the household, which will be explained latter and r_t is the rental rate of capital.

The household's optimal decisions with respect to C_t and K_{t+1} yield

$$\begin{aligned} \Lambda_t &= \frac{1}{C_t - \mathfrak{h} C_{t-1}} - \mathbb{E}_t \frac{\beta \mathfrak{h}}{C_{t+1} - \mathfrak{h} C_t}, \\ \Lambda_t &= \beta \Lambda_{t+1} \mathbb{E}_t (1 + r_{t+1} - \delta), \end{aligned}$$

where Λ is the Lagrange multiplier on the budget constraint.

Firm's problem The problem of firms and works are characterized by the Bellman equations. I begin by seeing a firm's problem. The value of a filled job with an idiosyncratic operating cost x_t, $\mathcal{J}_t(x_t)$, satisfies

$$\begin{aligned}\mathcal{J}_t(x_t) &= z_t f(k_t, h_t) - w_t(x_t)h_t - r_t k_t - x_t \\ &+ \mathbb{E}_t\beta_t\left\{(1-s)\int_{\underline{x}}^{x^*_{t+1}} \mathcal{J}_{t+1}(x_{t+1})d\Gamma(x_{t+1}) + \left[1-(1-s)\Gamma(x^*_{t+1})\right]\mathcal{V}_{t+1}\right\}, \end{aligned} \tag{1}$$

where $\beta_t = \beta\Lambda_{t+1}/\Lambda_t$ is the stochastic discount factor, $w_t(x_t)$ is the wage paid to the employee, and $\mathcal{V}$ is the value of a firm with a vacant job. In the current period, the firm produces output $z_t f(k_t, h_t)$ and pays the labor cost $w_t(x_t)h_t$, the rental cost of capital $r_t k_t$, and the operating cost x_t. In the following period, if the match is not destroyed by an exogenous shock and if the idiosyncratic cost is below the reservation value x^*_{t+1}, the match continues and obtains $\mathcal{J}_{t+1}(x_{t+1})$; otherwise, the match is destroyed and the firm gets the value of posting a vacancy $\mathcal{V}_{t+1}$.

The first-order condition with respect to k_t yields

$$z_t f_k(k_t, h_t) = r_t,$$

which states that the optimal capital is chosen to equate the marginal product of capital to the capital rental rate.

The value of a firm with a vacant job is given by

$$\mathcal{V}_t = -\kappa + \mathbb{E}_t\beta_t\left\{q_t(1-s)\int_{\underline{x}}^{x^*_{t+1}} \mathcal{J}_{t+1}(x_{t+1})d\Gamma(x_{t+1}) + \left[1-q_t(1-s)\Gamma(x^*_{t+1})\right]\mathcal{V}_{t+1}\right\}, \tag{2}$$

where κ is a flow cost of posting a vacancy. In the current period, a firm with a vacant job pays the vacancy cost and searches for a worker. With probability q_t, the firm matches with an unemployed worker. If the match is not destroyed by the exogenous shock and the idiosyncratic cost is below the reservation value x^*_{t+1}, the firm starts production in the following period and obtains the value of a filled job; otherwise, it remains vacant and obtains the value of the vacant job.

In equilibrium, all profit opportunities from new jobs are exploited so that the following free entry condition holds:

$$\mathcal{V}_t = 0.$$

Using equations (1) and (2) with the free entry condition, I have the following job creation condition:

$$\frac{\kappa}{q_t} = \mathbb{E}_t\beta_t\left\{(1-s)\int_{\underline{x}}^{x^*_{t+1}} \mathcal{J}_{t+1}(x_{t+1})d\Gamma(x_{t+1})\right\}. \tag{3}$$

The job creation condition states that the expected cost of positing a vacancy, the left-hand side of (3), is equal to the firm's share of the expected new surplus from a new job match, the right-hand side of (3).

Total profits of firms in the economy are defined as follows:

$$D_t = (z_t f(k_t, h_t) - r_t k_t)\, n_t - \bar{x}_t - \bar{W}_t - \kappa v_t,$$

where $\bar{x}_t = \frac{n_t}{\Gamma(x_t^*)} \int_{\underline{x}}^{x_t^*} x d\Gamma(x)$ is total operating costs. Total wages paid to the workers are defined as the average wage, conditional on working, times the number of employed workers and hours of work. Thus,

$$\bar{W}_t = \frac{n_t h_t}{\Gamma(x_t^*)} \int_{\underline{x}}^{x_t^*} w_t(x_t) d\Gamma(x).$$

Worker's problem I now turn to the worker's side. The value of an employed worker in a job with idiosyncratic cost x_t, $\mathcal{W}_t(x_t)$, satisfies

$$\begin{aligned} \mathcal{W}_t(x_t) &= w_t(x_t)h_t - \frac{\Phi}{\Lambda_t}\frac{h_t^{1+\mu}}{1+\mu} \\ &+\mathbb{E}_t\beta_t \left\{ (1-s) \int_{\underline{x}}^{x_{t+1}^*} \mathcal{W}_{t+1}(x_{t+1}) d\Gamma(x_{t+1}) + \left[1 - (1-s)\,\Gamma(x_{t+1}^*)\right] \mathcal{U}_{t+1} \right\}, \end{aligned}$$

where $\mathcal{U}$ is the value of being unemployed. The value of an employed worker is composed of the wage income $w_t(x_t)h_t$, the disutility from supplying labor $\Phi h_t^{1+\mu}/\Lambda_t(1+\mu)$, and the continuation value, which is the value of being employed if the match is not destroyed, or the value of being unemployed if it is destroyed.

The value of an unemployed worker is given by

$$\mathcal{U}_t = b + \mathbb{E}_t\beta_t \left[p_t(1-s) \int_{\underline{x}}^{x_{t+1}^*} \mathcal{W}(x_{t+1}) d\Gamma(x_{t+1}) + \left[1 - p_t\,(1-s)\,\Gamma(x_{t+1}^*)\right] \mathcal{U}_{t+1} \right].$$

In the current period, an unemployed worker receives the unemployment benefit b and searches for a job. With probability p_t, she matches with a firm posting a vacancy. If the match is not destroyed by the exogenous shock and the idiosyncratic cost is below the reservation value x_{t+1}^*, the worker will be employed in the following period and obtain the value of being employed; otherwise, she remains unemployed and obtains the value of being unemployed.

Wage bargaining and hours choice Wages and hours of work are determined as the outcome of a bilateral bargaining process between workers and firms. In each period, workers and firms negotiate through Nash bargains. Thus, wages and hours of work are chosen to maximize the Nash product

$$\max_{w_t(x_t), h_t} \left(\mathcal{W}_t(x_t) - \mathcal{U}_t\right)^{\eta} \left(\mathcal{J}_t(x_t) - \mathcal{V}_t\right)^{1-\eta},$$

where $\eta \in (0,1)$ is a worker's bargaining power.

The first-order condition with respect to $w_t(x_t)$ yields the wage equation

$$w_t(x_t)h_t = \eta \left[y_t - r_t k_t - x_t + \frac{p_t \kappa}{q_t} \right] + (1-\eta) \left(b + \frac{\Phi}{\Lambda_t}\frac{h_t^{1+\mu}}{1+\mu} \right).$$

The worker is compensated for a proportion η of the flow profits to the firm, and for a measure of the saved cost of searching for new matches. She is also compensated for a fraction $(1-\eta)$ of the forgone home production and the disutility of supplying labor services.

The first-order condition with respect to h_t yields the hours supply equation

$$z_t f_h(k_t, h_t) = \frac{\Phi}{\lambda_t} h_t^{\mu}.$$

which states that hours of work are determined by equalizing the marginal product of hours and the worker's marginal rate of substitution between leisure and consumption.

Job separation A match is destroyed when the idiosyncratic cost is so high that it makes the match surplus to zero. Let $\mathcal{S}_t(x_t)$ be the joint gross return from a match with an idiosyncratic cost x_t. Then, the match surplus function is given by

$$\mathcal{S}_t(x_t) = \mathcal{J}_t(x_t) + \mathcal{W}_t(x_t) - \mathcal{V}_t - \mathcal{U}_t.$$

Using value functions and the free entry condition, I have

$$\begin{aligned} \mathcal{S}_t(x_t) &= z_t f(k_t, h_t) - r_t k_t - x_t - b - \frac{\Phi}{\lambda_t} \frac{h_t^{1+\mu}}{1+\mu} \\ &\quad + \mathbb{E}_t \beta_t \left(1 - \eta p_t\right) (1-s) \int_{\underline{x}_{t+1}}^{x_{t+1}^*} \mathcal{S}(x_{t+1}) d\Gamma(x_{t+1}). \end{aligned}$$

Since the surplus function $\mathcal{S}_t(x_t)$ is strictly decreasing in x_t, the firm and the worker choose a reservation policy, i.e., they will continue their match if $\mathcal{S}_t(x_t) \geq 0$ but stop if $\mathcal{S}_t(x_t) < 0$. Thus, separation takes place when $x_t \geq x_t^*$, where x_t^* is defined by $\mathcal{S}_t(x_t^*) = 0$. Note that the reservation value at the time the match is formed is the same as the one at match dissolution.

Labor market dynamics Let N_t be the number of employed workers at the beginning of the period t. Then, the evolution of N_t is given by

$$N_{t+1} = (1-s)\,\Gamma(x_t^*) N_t + m_t = n_t + m_t.$$

Note that due to endogenous and exogenous separation, the number of employed workers who produce output in the period t is $n_t = (1-s)\,\Gamma(x_t^*) N_t$. The number of unemployed workers is determined by $u_t = 1 - n_t$. The job finding rate and the separation rate are given by p_t and $s + (1-s)(1-\Gamma(x_t^*))$, respectively.

Resource constraint The government finances the unemployment benefits bu_t by imposing the lump-sum tax T_t to the household. Thus, the government budget constraint is given by

$$bu_t = T_t.$$

Aggregate output and capital are given by

$$\begin{aligned} Y_t &= n_t y_t, \\ K_t &= n_t k_t. \end{aligned}$$

By combining the household and government budget constraints as well as profits of firms, the resource constraint of the economy is obtained by

$$Y_t = C_t + I_t + \kappa v_t + \bar{x}_t.$$

Shocks The description of the model is completed by specifying the properties of the shocks. A technology shock z_t follows a first-order autoregressive process:

$$\ln z_t = \rho_z \ln z_{t-1} + \sigma_t \varepsilon_{zt}, \quad \varepsilon_{zt} \sim \text{i.i.d. } N(0,1),$$

where ρ_z measures the persistence of the technology shock. The term σ_t is a time-varying standard deviation of the innovation, which is interpreted as a technology uncertainty shock. I assume that the uncertainty shock follows a stationary stochastic process:

$$\ln \sigma_t = (1-\rho_\sigma) \ln \sigma + \rho_\sigma \ln \sigma_{t-1} + \sigma_\sigma \varepsilon_{\sigma t},\ \varepsilon_{\sigma t} \sim \text{i.i.d. } N(0,1),$$

where ρ_σ represents the persistence of the uncertainty shock and the parameter σ_σ is the standard deviation of the innovation to technology uncertainty.

4 Quantitative analysis

This section examines the effect of the uncertainty shock on the model economy. I first calibrate the model to match several dimensions of the Japanese data. I then solve the model and simulate it. Since the uncertainty shock is a second-moment shock in my model, due to certainty equivalence, it does not play any role in the first-order approximation of the policy function. Therefore, I solve the model using a third-order approximation to the equilibrium condition around the deterministic steady state. This allows me to analyze the effect of second moment shocks. Then, following Fernández-Villaverde et al. (2011), I compute the impulse responses to the uncertainty shock.

4.1 Calibration

The parameters of the model are chosen to match some long-run Japanese labor market facts. Table 1 presents the calibrated parameter values. I calibrate the model at a quarterly frequency and set the subjective discount factor $\beta = 0.996$, implying the annual real interest rate of approximately 4 percent. Based on Kuo and Miyamoto's (2016) estimate of the habit persistence parameter, I set $\mathfrak{h} = 0.4$. The labor supply disutility Φ is pinned down such that in steady state an average hours of work per employee is equal to $1/3$. Kuroda and Yamamoto (2008) estimate the labor supply elasticity in Japan. They find that the elasticity for males is in the range of 0.2 to 0.7, so I set $\mu = 2.0$, which implies the Frisch elasticity of 0.5.

Based on Lin and Miyamoto's (2014) estimate of the matching function for Japan's labor market, I set $\xi = 0.6$. As a benchmark calibration, in order to maintain comparability with existing studies, I impose symmetry in bargaining and set the worker's bargaining power to $\eta = 0.5$.

I target the steady-state vacancy-unemployment ratio to 0.78 as reported by Miyamoto (2011). Using the monthly LFS, Miyamoto (2011) and Lin and Miyamoto (2012) give a mean value of 0.142 for the job finding rate and 0.0048 for the separation rate in Japan. In order to pin down the scale parameter m_0, I combine the monthly job finding rate with the vacancy-unemployment ratio.

I now turn to parameters related to job separation. Following Mortensen and Pissarides (1994), I assume that the idiosyncratic cost distribution Γ is uniform in the range $[0, \zeta]$, so that $\Gamma(x) = x/\zeta$. The parameter ζ is chosen to match the monthly endogenous job separation rate. Following Silva and Toledo (2009), I assume that endogenous job separation accounts 35% of total separations. Since I target the quarterly separation rate of 0.014, we set the quartely exogenous separation rate $s = 0.009$.

The production function is specified by $f(k, h) = k^{\alpha} h^{1-\alpha}$. I set the technology parameter $\alpha = 0.33$. Following Esteban-Pretel et al. (2010), I set the capital depreciation rate $\delta = 0.028$. I normalize the technology level to $z = 1$ without loss of generality.

According to Martin (1998) and Nickell et al. (2005), the replacement rate in Japan is about 0.6. I target the unemployment benefits b to be 60% of the average wage of employed workers in the economy. Following Shimer (2005), the vacancy cost κ is obtained from the steady state of the model.

For the exogenous technology process, I set the persistence parameter to $\rho_z = 0.95$ and the average standard deviation to $\sigma = 0.0095$, based on data. Following Leduc and Liu (2015), I calibrate the parameters in the uncertainty shock based on my VAR evidence. Empirical analysis in Section 2 shows that a one standard deviation uncertainty shock increases the level of uncertainty 29.4 percent. Since I calibrate the mean standard deviation in my model to 1 percent, I set the standard deviation of the uncertainty shock σ_{σ} to 0.262. The value of the persistence parameter ρ_{σ} is calibrated based on the HV data series. Using the HV data series, I estimate a simple AR(1) model and find the persistent parameter is 0.696. Thus, I set $\rho_{\sigma} = 0.696$.

4.2 The effects of uncertainty shock

I now study the dynamic responses of the economy to an uncertainty shock. I first consider a simplified version of my model, in which job separation is purely exogenous. I then extend my discussion to the general case that includes endogenous job separation.

Results in exogenous separation model I develop a version of my model in which separation takes place due to only exogenous shocks. I then simulate a quantitative version of the model under my calibration strategy. Figure 4 displays the impulse responses of relevant variables to a one standard deviation volatility shock. An increase in uncertainty reduces consumption and increases hours of work due to household's precautionary motives. The uncertainty shock reduces vacancies and increase unemployment significantly. It also reduces the job finding rate and wages. The pattern of labor market variables' responses is in line with empirical findings in Section 2.

The effect of uncertainty shock on the labor market can be understood by examining the response of the firm's expected value of hiring a worker. A firms decides whether to post a vacancy based on the value of hiring a worker, which is determined by the stochastic discount factor and the share of the expected surplus of a new job match. A higher value of hiring a worker encourages the firm post a vacancy. Uncertainty shock reduces both the stochastic discount factor and the new match value, which induces firms to post less vacancies. This makes it harder for unemployed workers to find jobs, and raises the unemployment rate.

Results in endogenous separation model I now shift my focus to the model with endogenous job separation. As seen in Section 2, empirical evidence shows that the uncertainty shock affects the unemployment dynamics through not only job creation but also job separation margins. This suggests that, in order to examine the effect of the uncertainty shock, it is necessary to use a model that endogenously determines both job creation and separation margins.

Figure 4 shows impulse responses to the uncertainty shock in the model with endogenous job separation. An increase in uncertainty reduces consumption and increases hours of work as in the model without endogenous job separation. The uncertainty shock also increases job separation and unemployment, which is consistent with data. However, the pattern of responses of vacancies and the job finding rate differs between two models. While the uncertainty shock reduces both vacancies and the job finding rate in the model without endogenous job separation, it increases them in the model with endogenous job separation.

This can be explained as follows. In the model with endogenous job separation, the uncertainty shock can substantially increase unemployed workers by increasing job separation, which in turn makes it easier for firms to post vacancies and thus increases the probability that an unemployed worker finds job. Although job finding rises, the increase in separation is large enough to increase unemployment under the calibrated parameter values.

The different responses of the model economies with or without endogenous job separation are consequence of both i) the relatively large responsiveness of the separation margin and ii) the feed-back effect of job separation on job creation. This feed-back effect is also the main reason why these models have difficulty in generating a Beveridge curve conditional on technology shocks. The endogenous job separation model presented in this paper similarly fails to general a Beveridge curve, conditional on the uncertainty shock.

4.3 Sensitivity analysis

The model without endogenous job separation generates empirically consistent pattern of the labor market responses to the uncertainty shock. I now examine how these results vary with different parameters for the labor supply elasticity μ, the habit persistency $\mathfrak{h}$, and the worker's wage bargaining power η. When I change these parameters, I also re-calibrate other parameters to maintain the calibration targets.

I first consider the sensitivity of the results to a change in the labor supply elasticity. Figure 5 shows that the impact of the uncertainty shocks on the economy is magnified as μ decreases. With decreasing convexity in the disutility of labor, the marginal cost of production decreases and thus marginal profits are magnified. This amplifies the effect of the uncertainty shock on the economy.

I next consider the impact of changes in the habit persistency and the worker's bargaining power. Figure 6 shows that while a decrease in $\mathfrak{h}$ magnified the effect of the uncertainty shock on consumption, it does not affect the responses of labor market variables to the shock. Figure 6 also shows that the effect of a change in η on the responses of the labor market to the uncertainty shock is trivial.

5 Conclusion

This paper examines the effect of an uncertainty shock on the labor market in Japan, both empirically and theoretically. In the empirical part, I use the stock market volatility as a measure of uncertainty and estimate a structural VAR model with the proxy of uncertainty and labor market variables. My analysis demonstrates that heightened uncertainty increases unemployment and reduces output, vacancies, and inflation significantly. This suggests that the uncertainty shock acts as a demand shock because it reduces both economic activity and prices.

In the theoretical part, I develop a dynamic general equilibrium model with labor market frictions and examine the transmission mechanism of the uncertainty shock. In the model, uncertainty shocks are defined as unexpected increases in the volatility of technology shock. I demonstrate that the model is able to generate the empirically consistent pattern of the responses of labor market variables to the uncertainty shock when job separation is completely exogenous. However, the model with endogenous job separation fails to replicate the observed pattern of labor market variables to the uncertainty shock because of the feedback effect of job separation on job creation.

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Table 1: Parameter values

Parameter	Description	Value	Source/Target
β	Discount factor	0.996	Data
δ	Depreciation rate	0.028	Esteban-Pretel et al. (2010)
z	Aggregate productivity	1.0	Normalization
α	Parameter in production function	0.33	Data
m_0	Matching efficiency	0.471	Job-finding rate and $v-u$ ratio
ξ	Matching elasticity of unemployment	0.6	Lin and Miyamoto (2014)
s	Exogenous separation rate	0.009	65% of total separation
ζ	The upper support of Γ	0.106	35% of total separation
Φ	Disutility of labor	28.39	Set to target $h = 1/3$
μ	The inverse of Frisch elasticity	2.0	Kuroda and Yamamoto (2008)
$\mathfrak{h}$	Habit persistence	0.4	Kuo and Miyamoto (2016)
z	Unemployment benefits	0.405	Replacement rate 60%
η	Worker's bargaining power	0.5	See text
κ	Vacancy cost	0.014	$v-u$ ratio
ρ_z	Persistency of the technology shock	0.95	See text
σ	Mean SD of the technology process	0.0095	See text
ρ_σ	Persistency of the uncertainty shock	0.696	See text
σ_σ	SD of the uncertainty shock	0.262	See text

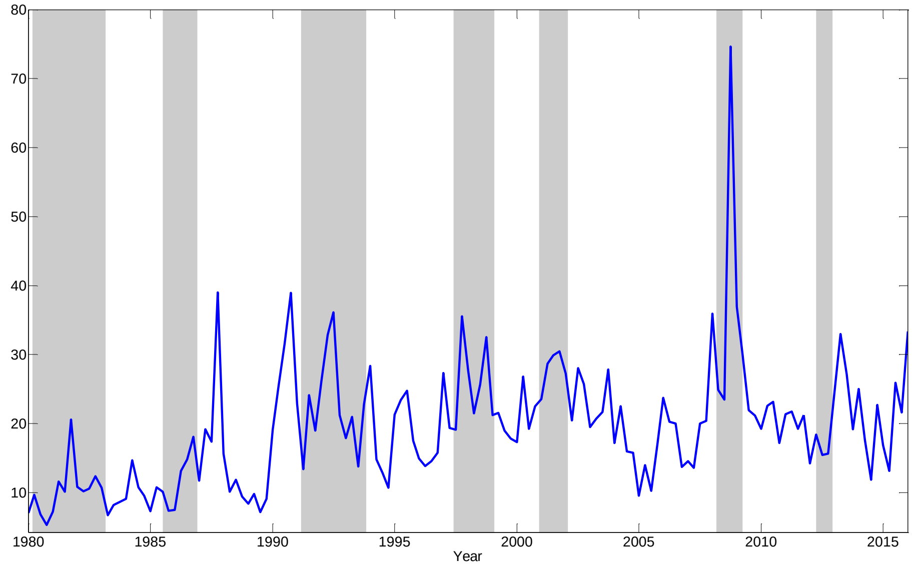

Figure 1: Historical volatility constructed from Nikkei Average Stock

Note: Shaded areas indicate ESRI-dated recessions.

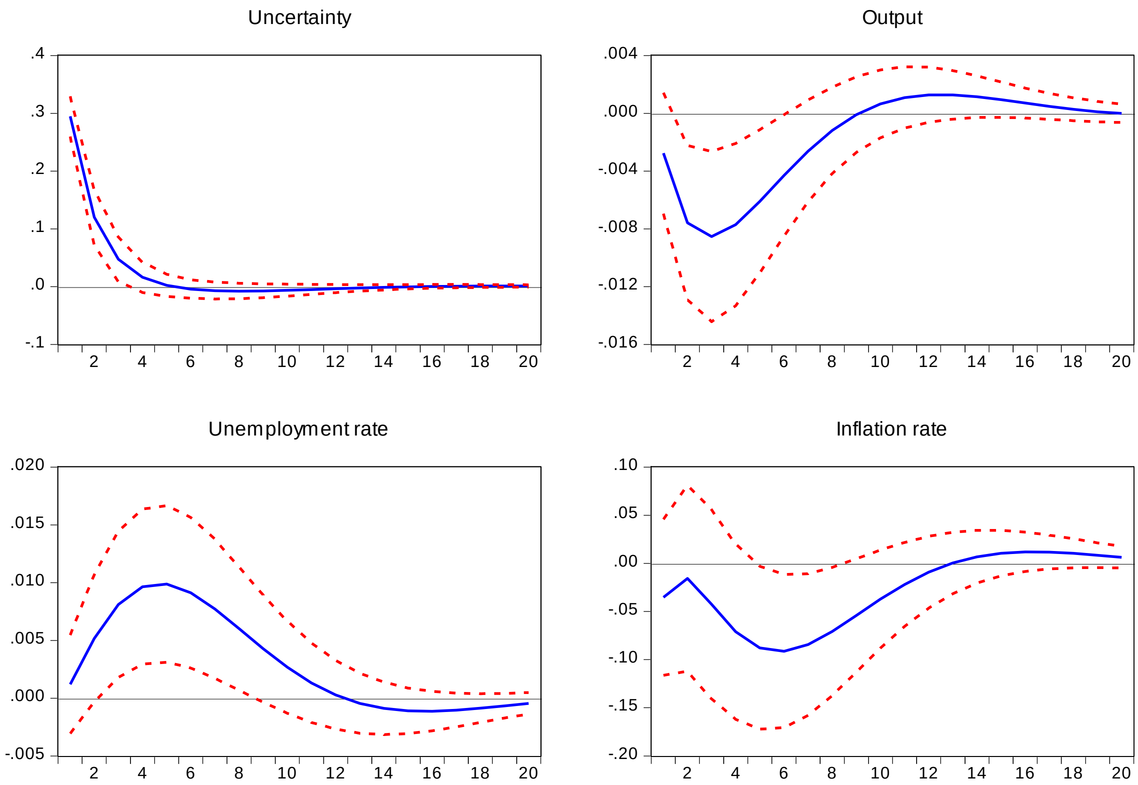

Figure 2: Impulse response functions to a one standard deviation uncertainty shock
Note: The horizontal axis represents quarters after the shock. Dashed lines indicate the 95 percent confidence bands, constructed by the bootstrap method.

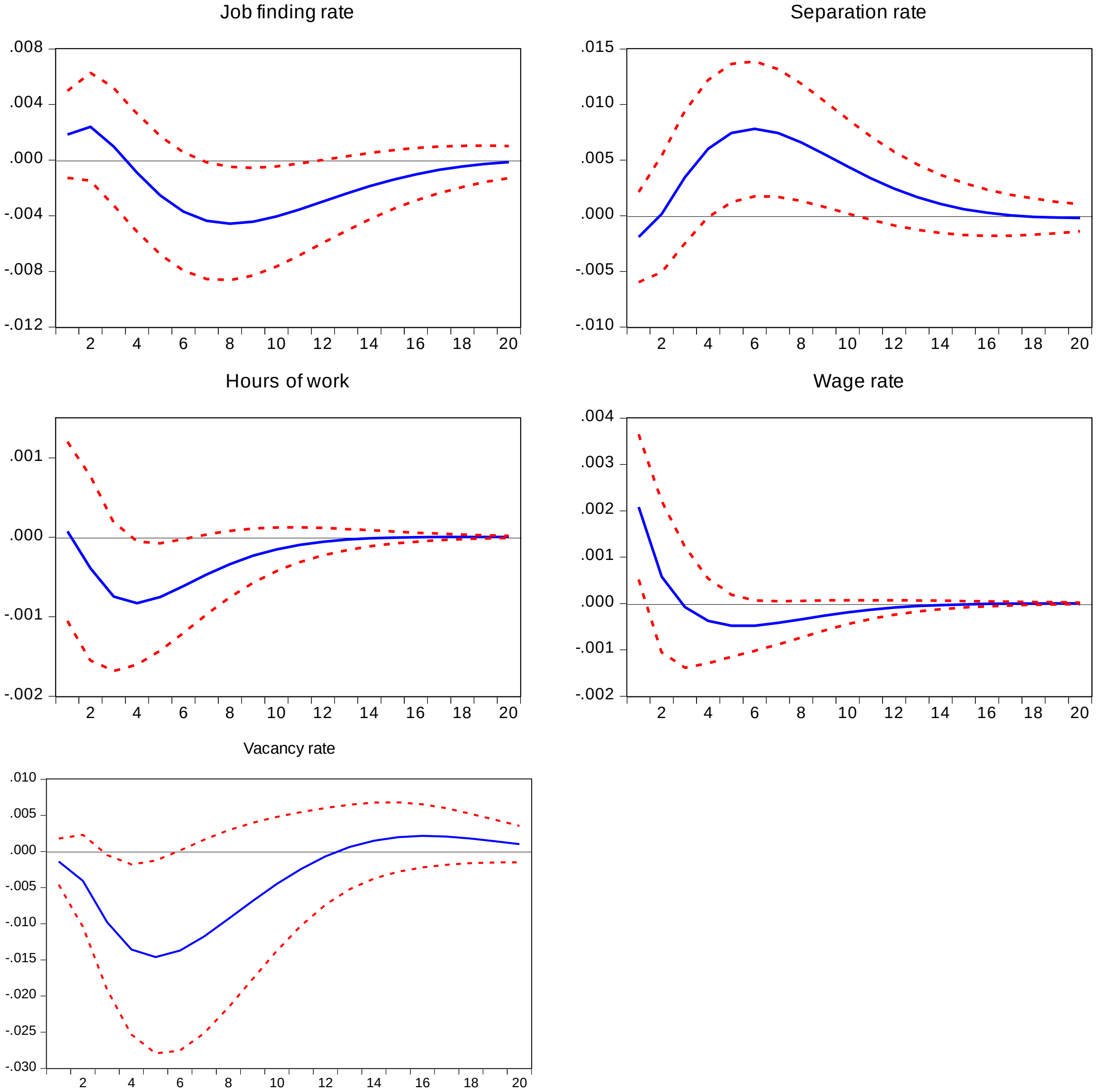

Figure 3: Impulse response functions to a one standard deviation uncertainty shock

Note: The horizontal axis represents quarters after the shock. Dashed lines indicate the 95 percent confidence bands, constructed by the bootstrap method.

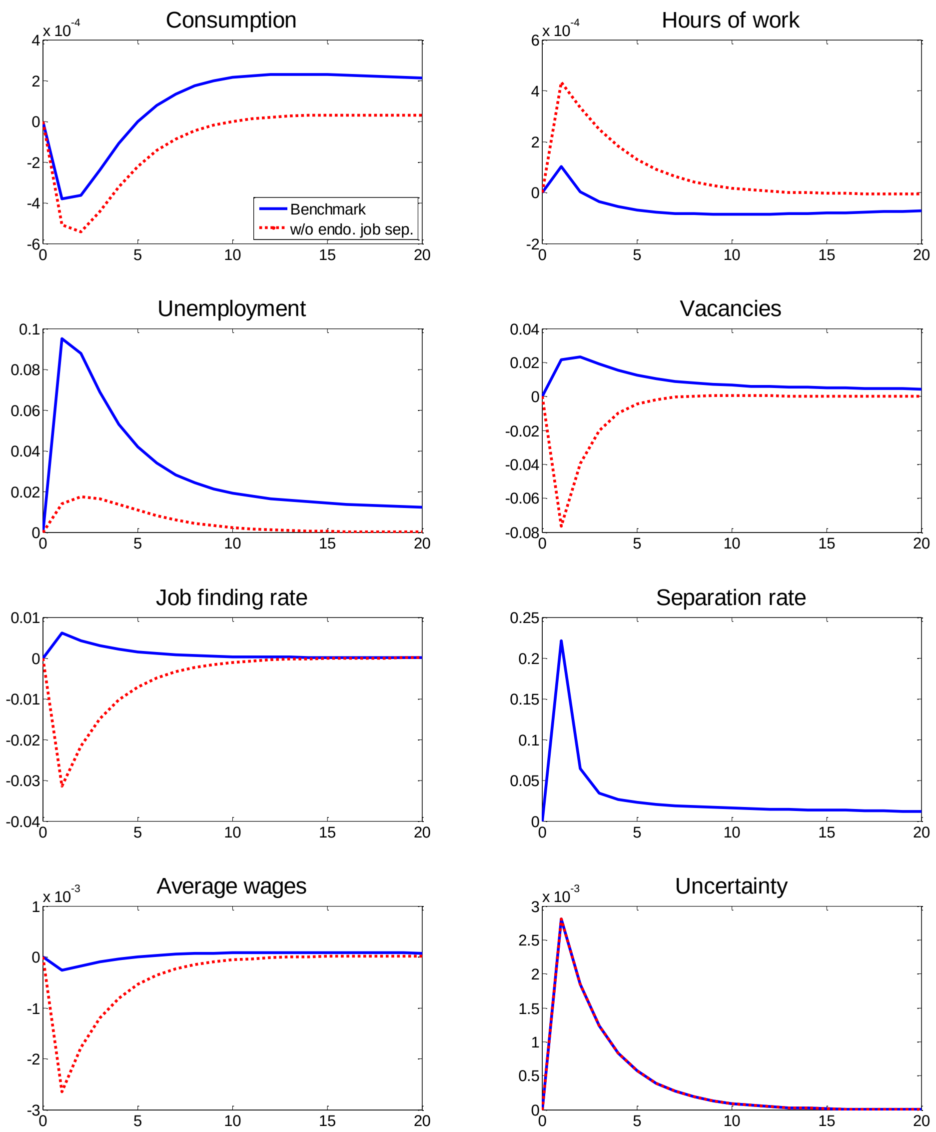

Figure 4: Dynamic responses of the economy to the uncertainty shock

Note: The solid lines labeled "Benchmark" plot the impulse responses to the uncertainty shock in the model with endogenous job separation. The dashed lines labeled "w/o endo. job sep." plot the impulse responses in the model without endogenous job separation. The horizontal axis represents months after the shock.

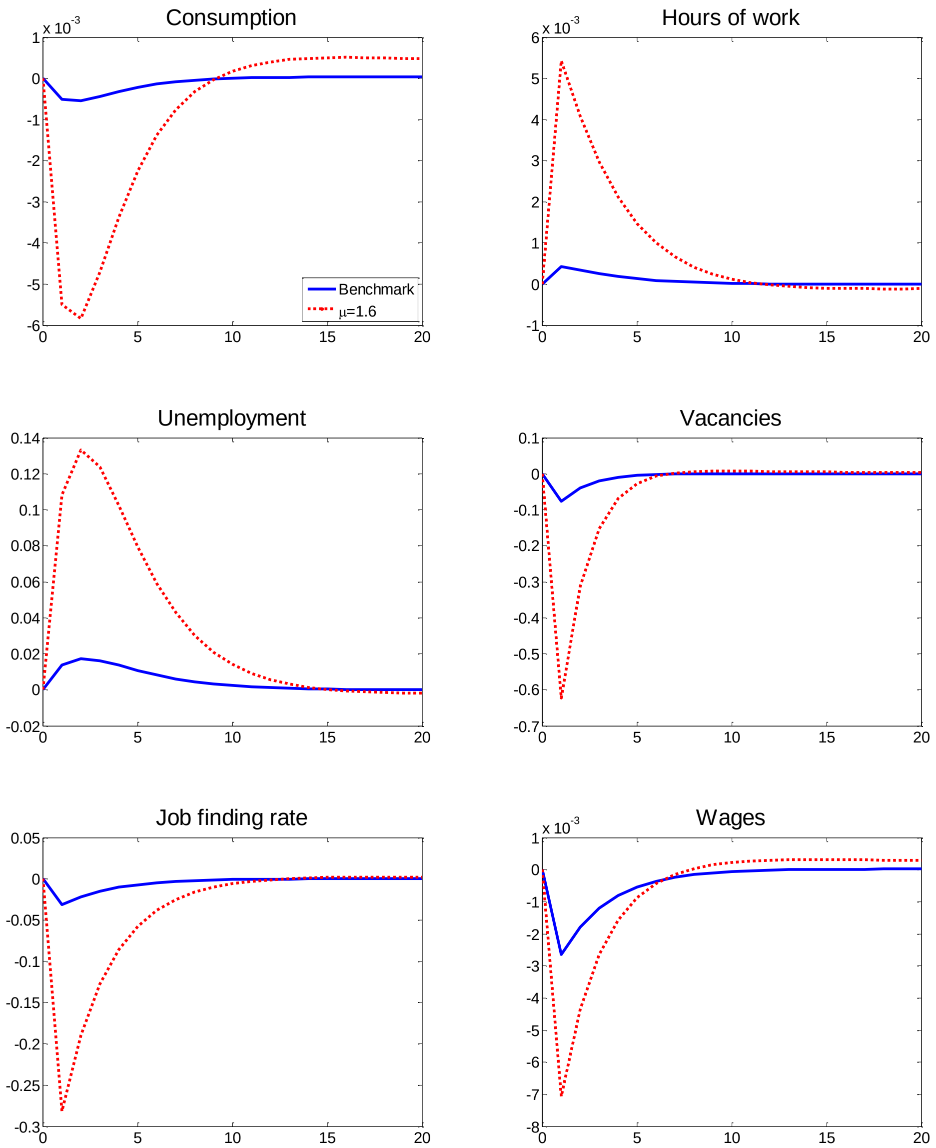

Figure 5: Sensitivity analysis with respect to μ

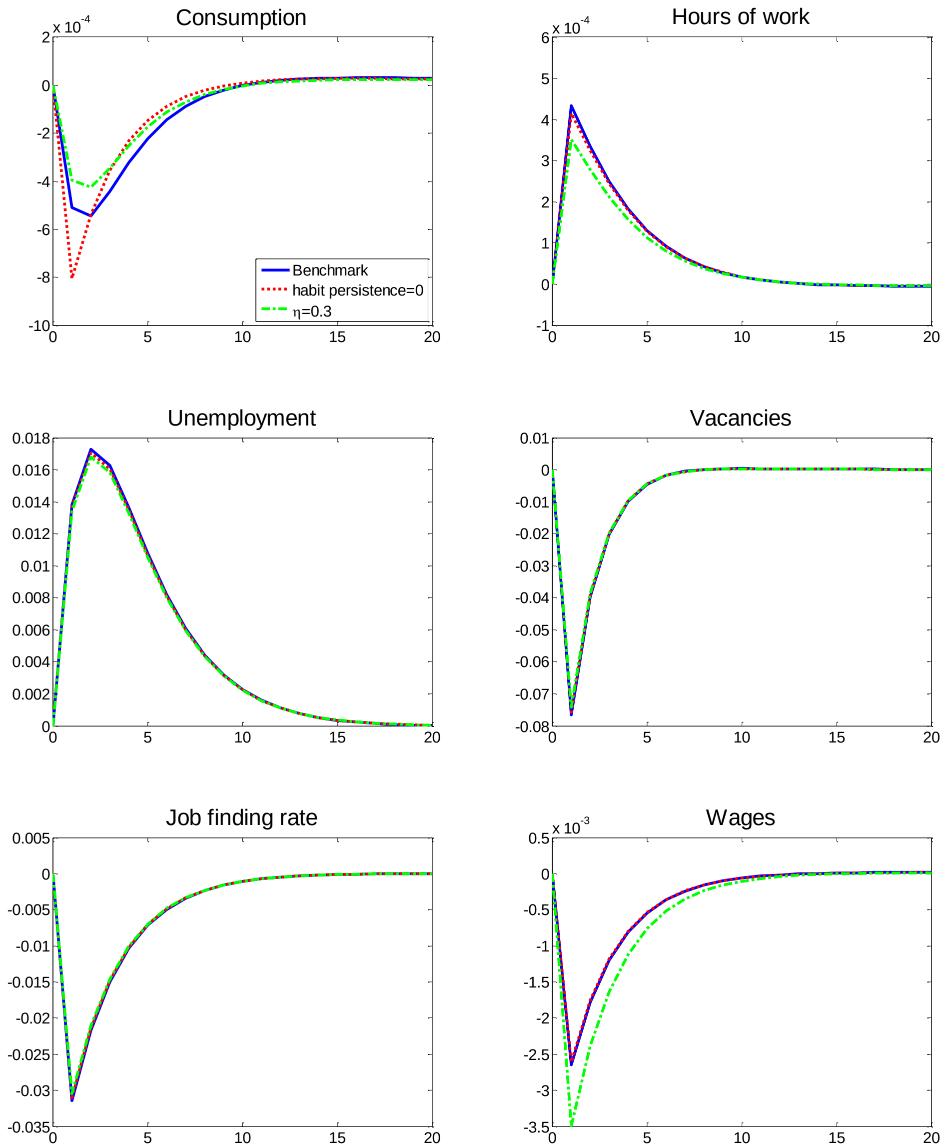

Figure 6: Sensitivity analysis with respect to $\mathfrak{h}$ and η