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Working Effort and the Japanese Business Cycle*

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A well known fact of Japanese business cycles discussed in studies such as Ohkusa and Ariga (1995) is that the labor adjustment is done more in the intensive margin (hours worked per worker) rather than in the extensive margin (employment), which is the opposite to the U.S. Moreover, as shown in Braun, Esteban-Pretel, Okada and Sudo (2006), the fluctuation of hours worked per worker leads the business cycle while the fluctuation of the number of workers lags it. In this paper, I show that a dynamic stochastic general equilibrium model with effort, productivity, and investment specific technology shocks can account for these facts.
JEL Classification Codes: E13, E32

1. Introduction

A well known fact of Japanese business cycles discussed in studies such as Ohkusa and Ariga (1995) is that the labor adjustment is done more in the intensive margin (hours worked per worker) rather than in the extensive margin (employment), which is the opposite to the U.S. Moreover, as shown in Braun, Esteban-Pretel, Okada and Sudo (2006), the fluctuation of hours worked per worker leads the business cycle while the fluctuation of the number of workers lags it. In this paper, I show that a dynamic stochastic general equilibrium model with effort, productivity, and investment specific technology shocks can account for these facts.

There are several related studies on the Japanese labor market during the lost decade. Hayashi and Prescott (2002) shows the legislation which shrunk the workweek along with the slow-down of productivity growth can account for the lost decade. Kobayashi and Inaba (2006) and Otsu and Pyo (2009) use the business cycle accounting method and show that total factor productivity and disturbances in the labor market are important in accounting for the lost decade. While these studies focus on the medium term fluctuations in labor, there are also more related studies focusing on the high frequency fluctuation patterns of Japanese hours worked and employment. Ohkusa and Ariga (1995) shows that labor hoarding is important in accounting for the low volatility in employment relative to hours worked per worker. Braun et al (2006) show that the difference in labor adjustment patterns in Japan and the U.S. can be accounted for by the differences in the elasticities of workers. In this paper, I also account for the lead in hours worked and the lag in employment; not only their relative volatilities.

In this paper, I do not include long term labor contracts in the model. There is a belief that Japanese employment has been stable thanks to the "lifetime employment" tradition where the workers work for the firm they entered until retirement. Flath (2005) states indeed that in 1990 the average tenure in Japan was 22 years while in the U.S. that was 14 years; however, there is no explicit contract that guarantees lifetime employment in Japan. Furthermore, the fact that the tenure is longer in Japan does not immediately explain the lag of employment fluctuation from the business cycle. Even if the firms are committed to hire workers for at least a fixed period of time, they could hire new workers in booms and fire those who reached their tenure during recessions. Therefore, a model with long term employment contracts does not seem to be suitable for the analysis.

The the model is based on a standard real business cycle model with a 10 distinction between hours worked and employment as in Cho and Cooley (1994). Since I focus on the behavior of both hours worked per worker and the number of workers employed, the indivisible labor model with fixed hours such as Hansen (1985) and Rogerson (1988) is not suitable. The social planner maximizes the expected lifetime utility of the representative agent not only choosing the level of consumption and leisure but also the fraction of people working. Business cycle fluctuations are driven by shocks to government purchases, investment specific technology, preference weight on consumption and leisure, working effort and productivity. The quantitative method follows that used in Chari, Kehoe and McGrattan (2007). I specify the dynamic stochastic general equilibrium model, obtain parameter values from the data using calibration and estimation, compute the exogenous variables including those that are not directly observed from data, and simulate the model using the computed exogenous variables.

The remainder of the paper is organized as follows. In section 2, I discuss the business cycle facts in Japan compared to those in the U.S. In section 3, I describe the model. In section 4, I explain the procedure of the quantitative analysis and present the results. Section 5 concludes the paper.

2. Japanese Business Cycle Facts

In this section, I will present the key characteristics of the Japanese business cycles. Table 1 lists the quarterly cyclical behavior of Japanese key macroeconomic variables over the 1980-2007 period. Output is defined as GDP plus the flow income from durable goods and government capital stock, consumption is defined as the sum of expenditures on nondurable goods and services and the service flow from durable goods and government capital stock, investment is defined as the sum of gross capital formation, government fixed investment, and expenditure of durable goods, and the labor supply is divided into employment and the average weekly hours worked per worker. For comparison, I also present the same set of variables for the US. The data sources are the Economic and Social Research Institute and the Statistics Bureau websites for Japan and the Bureau of Economic Analysis and Bureau of Labor Statistics websites for the U.S.

Several aspects of the business cycles are similar between Japan and the U.S. Consumption is less volatile than output while investment is more volatile. The degree of consumption smoothing, measured as the standard deviation of consumption relative to that of output, is in the mid 50% in both countries. The volatility of investment is slightly greater in the US than in Japan but are in the same ballpark, 3.34 and 3.81 relative to output, respectively. However, when it comes to labor market statistics, there are large differences in the two countries.

A well-known fact is that in Japanese labor adjustment mainly takes place in the intensive margin while that in the U.S. mainly takes place in the extensive margin. The standard deviation of hours worked per worker and employment shows this difference. Also, total hours worked in Japan leads the business cycle by one quarter in Japan whereas, they fluctuate coincidently with output in the US. Furthermore, the quarterly lead of total hours in Japan is coming from the four quarter lead of hours worked per worker while employment lags output by three quarters. Employment also lags by one quarter in the US while hours worked per worker fluctuate coincidently with output. These facts are consistent with those of Braun, Esteban-Pretel, Okada and Sudo (2006) who analyzed the Japanese economy over the 1960-2000 period.

A potentially problem in the Japanese labor data is the measurement of hours worked per worker. The data source for this is the household survey conducted by the statistical bureau where randomly selected workers report the hours they worked each month. However, Japanese workers are accustomed to under report overtime hours. These working hours are not included as official working hours but contribute to production. In addition, shirking, either intentionally or unintentionally, also creates a wedge between actual working hours and reported and paid working hours. Unfortunately, there is no data on the under-reported overtime hours nor labor hoarding[1]. In this paper, I estimate it as a latent variable using the model described below.

3. Model

In the model, the social planner maximizes the expected lifetime utility of a representative agent in the economy by allocating the resources. The social planner optimizes taking productivity shocks, investment specific technology shocks, preference shocks, employment adjustment shocks and government expenditure shocks as given.

3.1 Preference

The planner wants to maximize the expected lifetime utility of the society

$$U = E_0 \sum_{t=0}^{\infty} \beta^t u(c_t, l_t).$$

Each agent receives utility from consumption and leisure. The planner can choose the fraction of people working so that the utility of the representative agent will be maximized[2]. The preference function takes the form of

$$u = et[\Psi_t \log c_{et} + (1-\Psi_t)\log(1-\phi_t h_t) - \mu] + (1-e_t)[\Psi_t \log c_{nt} + (1-\Psi_t)\log(1)],$$

where e_t is the fraction of agents working, c_{et} and c_{ut} stand for consumption of the employed and unemployed agents, respectively.

Leisure $1-\phi_t h_t$ is defined as total available hours minus hours worked h adjusted for working effort ϕ. This implies that the utility of a worker is lower if he has to work harder given a certain number of hours.

The constant μ represents the fixed cost accrued to being employed. The utility cost μ is qualitatively important since with $\mu=0$ it is efficient for all agents to work. This includes the time and trouble to commute to work.

In the log utility case, it is well known that the optimal consumption choice will be the same for both type of consumers in equilibrium. Thus, the preference function can be rewritten as;

$$u = \Psi_t \log c_t + e_t(1-\Psi_t)\log(1-h_t) - \mu e_t$$

where c_t is the common consumption level for both workers and non-workers.

3.2 Production

The single good in the economy is produced by capital and labor. Labor input is the total hours worked which is the fraction of people working multiplied by the number of hours worked per worker. Following Hansen and Sargent (1988), I will introduce adjustment cost on employment in the production function in order to explain the employment lag. I introduce this adjustment cost as a time cost such that workers will loose time when there is a change in the employment level. Thus the production function looks like;

$$y_t = z_t k_t^{\theta}(e_t \phi_t h_t)^{1-\theta} \tag{1}$$

where y_t is output, z_t is productivity shocks, k_t is capital stock, and $\phi_t h_t$ is the effective hours used for production.

A fall in effort ϕ_t can be considered as labor hoarding, i.e., hours reported that are not devoted to productive activities. For instance, smoking breaks or extended lunch time should be considered as leisure rather than working time. A rise in ϕ_t captures an increase in the intensity of work possibly including voluntary overtime work that is not reported to the survey.

3.3 Resource Constraint

Aggregate output is used for consumption, investment, or government expenditure. Thus, the resource constraint of the economy will look like;

$$y_t = c_t + x_t + g_t, \tag{2}$$

where x_t is investment and g_t is government expenditure.

Investment is used to accumulate capital stock according to the capital law of motion;

$$\Gamma k_{t+1} = \eta_t x_t + (1-\delta)k_t \tag{3}$$

where Γ is the growth trend of the economy and δ is the depreciation rate of capital stock and η_t is the investment specific technology shock.

3.4 Shocks

There are five exogenous shocks in the economy; productivity shocks, investment specific technology shocks, preference shocks, adjustment cost shocks and government expenditure shocks denoted as $st=\{g_t, \eta_t, \Psi_t, \phi_t, z_t\}$. I assume that they follow a VAR process:

$$\tilde{s}_t = P\widetilde{s_{t-1}}+\varepsilon_t \tag{4}$$

where "~" represents the deviation from trend. The error terms $\varepsilon_t=\{\varepsilon_{gt}, \varepsilon_{\eta t}, \varepsilon_{\Psi t}, \varepsilon_{\phi t}, \varepsilon_{zt}\}$ are defined as

$$\varepsilon_t \sim N(0, V)$$

where V is a five by five variance covariance matrix. Since, there is no restriction on the V matrix, the model allows contemporaneous correlation between the shocks.

3.5 Equilibrium

The equilibrium is characterized by the following set of equations. The capital Euler equation

$$\frac{\Gamma}{\eta_t}\frac{\Psi_t}{c_t} = \beta E_t\left[\frac{\Psi_{t+1}}{c_{t+1}}\left(\theta\frac{y_{t+1}}{k_{t+1}}+\frac{1}{\eta_{t+1}}(1-\delta)\right)\right] \tag{5}$$

the hours first order condition

$$e_t\frac{1-\Psi_t}{1-h_t} = \frac{\Psi_t}{c_t}(1-\theta)\frac{y_t}{A_t}, \tag{6}$$

the employment first order condition

$$\mu-(1-\Psi_t)\log(1-h_t) = \frac{\Psi_t}{c_t}(1-\theta)\frac{y_t}{e_t}, \tag{7}$$

the production function (1), the resource constraint (2), the capital law of motion (3), and the shock process (4).

4. Quantitative Analysis

The quantitative analysis is carried out as follows. First, I use the equilibrium conditions and quarterly data of output, consumption, investment, employment and hours worked over the 1980-2007 period to calibrate and estimate the parameter values. Second, I obtain linear decision rules for endogenous variables using the method of undetermined coefficients. Third, I compute the exogenous variables using data and the linear decision rules. Finally, I simulate the model using the computed exogenous variables and linear decision rules.

4.1 Calibration

The capital share parameter θ is calibrated as follows for each country. Since output is defined as GDP plus the flow income from consumer durables and government capital stock ($FLOW$), the capital share is computed as

$$\theta = \frac{\theta_p * GDP+FLOW}{GDP+FLOW},$$

where the capital income share

$$\theta_p = \frac{\text{unambiguous capital income+fixed capital consumption}}{GDP\text{-ambiguous capital income}}$$

is directly calculated from national income and product accounts[3]. The depreciation rate δ is computed directly from data using the capital law of motion (3)[4]. The average growth rate of per capita output is used for the growth trend Γ. The subjective discount rate β is calibrated to data of the average capital to output ratio using the steady state version of capital Euler equation (5)

$$\frac{\Gamma}{\eta} = \beta\left(\theta\frac{y}{k}+(1-\delta)\frac{1}{\eta}\right),$$

assuming that the investment specific technology shock η is equal to unity in the steady state. The steady state of preference shocks Ψ is calibrated to match the marginal rate of substitution of hours to consumption with the marginal product of hours using the steady state version of the hours first order condition (6)

$$\frac{c}{1-h}\frac{1-\Psi}{\Psi} = (1-\theta)\frac{y}{eh}.$$

The utility cost of employment μ is calibrated to match the marginal rate of substitution of employment to consumption with the marginal product of employment using the steady state version of the employment first order condition

$$\mu-(1-\Psi)\log(1-h) = (1-\theta)\frac{y}{e}.$$

The steady state level of government expenditure g is computed directly from data. Finally, for simplicity, I assume that the steady state productivity level z is equal to unity. The calibrated parameter values and the steady state values of exogenous and endogenous variables are listed in Table 2.

4.2 Impulse Responses

In order to understand how the shocks affect the economy, it is useful to examine the impulse responses of the variables of interest to the shocks. For convenience, I assume that the stochastic lag matrix P is diagonal with lag parameters of 0.9 for this exercise. This allows us to ignore the spillover effects from other shocks in the VAR process and focus on the direct impacts of each shocks[5].

Figure 1 shows the responses to a one percent increase in the government shock. This shock creates a negative income effect on the economy. The economy reduces expenditures on consumption, leisure and investment. Labor input increases through employment while hours worked does not react. As a result, output increases.

Figure 2 shows the responses to a one percent increase in the investment specific technology shock. This shock temporarily increases the efficiency of investment. The economy temporarily cuts back on consumption and increases investment. Employment increases due to the rise in expected marginal product of labor through the increase in capital stock while hours worked does not react. As a result, output increases.

Figure 3 shows the responses to a one percent increase in the preference shock. This shock increases the utility the household gains from consumption. The economy increases consumption and investment, and reduces leisure. Labor increases because of the increase in both employment and hours worked. The increase in labor leads to an increase in output.

Figure 4 shows the responses to a one percent increase in the effort shock. This shock increases the benefit of hours worked on production as well as the cost of it on utility. The economy decreases hours by the same amount and neutralizes its effect on the economy. Nothing else is affected.

Figure 5 shows the responses to a one percent increase in the productivity shock. This shock generates a real business cycle type effect. The increase in the marginal product of labor leads to a rise in employment while hours worked is not affected. Output increases both from the direct effect of the shock on output and the indirect effect through the increase in labor. Consumption and investment both increase as the total production in the economy increases.

4.3 Estimation

In the previous section, I assumed a diagonal lag matrix for simplification. However, in order to simulate the model and obtain meaningful quantitative results, we need to estimate the entire stochastic process. In this paper, I use maximum likelihood estimation built into the Dynare code to estimate the stochastic process (4). Since there are five shocks in the model, I use the data of output, consumption, investment, hours and employment as observable variables to estimate the process.

The reason why we need structural estimation is because there are variables that are not directly observable. For instance, investment specific technology shocks and preference shocks are defined in (5) and (7) which involve expected variables that are not directly observed. Also, productivity shocks are computed from (1) using k and ϕ which are not directly observable since they are affected by investment specific technology shocks and effort. Finally, the effort shocks are defined in (6) and (7) which involve preference shocks. The maximum likelihood estimation method allows us to estimate the stochastic process treating the unobservables as latent variables.

The following is the estimation for the stochastic process. The process needs initial guesses for the persistence parameters, the standard deviation of shocks and the correlation among shocks. I assign 0.9 for the diagonal terms and 0 for the off-diagonal terms in P, 0.05 for the standard deviations of the innovations, and 0 for the correlations between innovations.

$$P = \begin{pmatrix} 0.95 & 0.09 & -0.40 & 0.23 & -0.05 \\ -0.00 & 1.02 & -0.08 & 0.19 & 0.08 \\ 0.00 & 0.05 & 0.89 & 0.16 & 0.09 \\ 0.00 & 0.28 & -0.02 & 0.86 & 0.18 \\ -0.00 & -0.12 & 0.12 & -0.23 & 0.86 \end{pmatrix}$$

$$V = 1.0{-}e003 * \begin{pmatrix} 0.02 & -0.03 & -0.01 & 0.01 & -0.03 \\ -0.03 & 0.29 & -0.01 & -0.04 & 0.02 \\ -0.01 & -0.01 & 0.05 & 0.01 & -0.00 \\ 0.01 & -0.04 & 0.01 & 0.02 & -0.02 \\ -0.03 & 0.02 & -0.00 & -0.02 & 0.04 \end{pmatrix}.$$

4.4 Computing Shocks

Once the parameter values are obtained, the model can be solved for decision rules numerically. I use the linear solution method a la Uhlig (1999) to solve the model. Following Chari *et al.* (2007) I compute the exogenous variables using the obtained linear decision rules and the data of the observable variables used for the estimation.

The linear decision rules DR of endogenous variables are functions of state variables $\{\tilde{k}_t, \tilde{g}_t, \tilde{\eta}_t, \widetilde{\Psi_t}, \tilde{z}_t, \tilde{\phi}_t\}$. Initial capital stock and employment in each country are assumed to be at the steady state level. Once the initial capital stock level is given, the whole series of exogenous variables can be computed. The detailed procedure is as follows.

1. solve the model for linear decision rules $\{\widetilde{k_{t+1}}, \tilde{e}_t, \tilde{y}_t, \tilde{c}_t, \tilde{x}_t, \tilde{h}_t\} = DR_{\{e_t, y_t, c_t, x_t, h_t\}}(\tilde{k}_t, \widetilde{e_{t-1}}, \tilde{g}_t, \tilde{\eta}_t, \widetilde{\Psi_t}, \tilde{z}_t, \tilde{\phi}_t)$
2. assuming $\tilde{k}_0=0$, $\widetilde{e_{-1}}=0$, compute $\{g_0, \eta_0, \Psi_0, z_0, \phi_0\}$ from $\{\tilde{e}_0, \tilde{y}_0, \tilde{c}_0, \tilde{x}_0, \tilde{h}_0\} = DR_{\{e_t, y_t, c_t, x_t, h_t\}}(0, 0, \tilde{g}_0, \tilde{\eta}_0, \widetilde{\Psi_0}, \tilde{z}_0, \tilde{\phi}_0)$
3. compute $\tilde{k}_1$ from $\tilde{k}_1 = DR_{\{k_{t+1}\}}(0, 0, \tilde{g}_0, \tilde{\eta}_0, \widetilde{\Psi_0}, \tilde{z}_0, \tilde{\phi}_0)$
4. solve for $\{\tilde{g}_1, \tilde{\eta}_1, \widetilde{\Psi_1}, \tilde{z}_1, \tilde{\phi}_1\}$ from $\{\tilde{e}_1, \tilde{y}_1, \tilde{c}_1, \tilde{x}_1, \tilde{h}_1\} = DR_{\{e_t, y_t, c_t, x_t, h_t\}}(\tilde{k}_1, \tilde{e}_0, \tilde{g}_1, \tilde{\eta}_1, \widetilde{\Psi_1}, \tilde{z}_1, \tilde{\phi}_1)$
5. repeat 4 and 5 for the whole period

The properties of the computed exogenous variables are presented in Table 3. I present the standard deviation and cross-correlation with output. The government shock is the most volatile shock among all. The main reason of this is that the trade balance is included in it. It has positive correlation with output and lags the business cycle by three quarters. Investment specific technology and preference shocks are counter-cyclical and coincident with output fluctuation. Effort shocks are counter-cyclical and lead the business cycle by 4 quarters. From this observation, we can conjecture that this shock is important in accounting for the lead in hours. Finally, productivity is procyclical and coincident as in the standard real business cycle model.

4.5 Simulation

In the following counterfactual simulations, I feed specific estimated shocks to the model separately. That is, I assume that the shocks except for those of interest are equal to zero for all periods. The moments of endogenous variables are computed from these single simulation results.

Table 4 present the simulation results of the model with only productivity shocks. Productivity shocks are shown to be important sources of business cycles in the real business cycle literature. However, there are several important aspects in which the model fails. First, hours worked are constant and employment fluctuation is coincident with the business cycle. Second, the output fluctuation is much greater than data. This is because the reaction of labor supply is too large. Third, consumption is much less volatile than data and lags the business cycle[6].

Table 5 presents the simulation results of the model with investment specific technology and productivity shocks. Recent literature shows that investment specific technology shocks are also important in accounting for business cycle fluctuations[7]. One major difference in the results is that the fluctuation of labor and output is closer to data. Furthermore, consumption is coincident with the business cycle. However, hours worked does not fluctuate and employment is coincident with the business cycle.

Table 6 presents the simulation results of the model with investment specific technology, effort and productivity shocks. Including effort shocks dramatically improves the fit of the model. Hours lead and employment lags the business cycle. The relative volatility is also comparable to that in the data as well. Therefore, effort shocks are important in accounting for the labor market features in Japan.

5. Conclusion

This paper constructs a dynamic stochastic general equilibrium model to account for the fluctuation patterns of labor market variables in Japan over the 1980–2007 period. I show that the model with effort shocks along with productivity and investment specific technology shocks can replicate the business cycle fluctuation patterns in Japan. Moreover, effort shocks are important in accounting for the lead of hours worked per worker and the lag of employment relative to the fluctuation of output.

In this paper I take workers efforts as exogenous. However, it is likely that efforts are reacting to some fundamental economic shock. Identification of this shock is necessary to deepen our understanding of the nature of the hours lead and employment lag. Moreover, this might lead to an answer to why effort shocks systematically lead productivity shocks in Japan. One candidate is that the anticipation of future productivity shocks affects the intensity of current work. Another would be that effort devoted to on-the-job training activities not only increases current production but also affects future productivity through human capital accumulation. Future study should pursue the underlying structure of the shocks to efforts.

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Notes

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1) It is also not clear for some jobs whether some activities should be counted as labor or leisure such as researchers reading academic journals, designers reading magazines, financial investors watching news and so on.

2) This assumption follows the employment lottery literature.

3) The values are 0.36 for Japan and 0.29 for the US, respectively. I use the Hayashi and Prescott (2002) data set over the 1980–2002 period for Japan, and BEA data over the 1980–2006 period for the US, respectively.

4) The capital stock series is constructed by the perpetual inventory method. I separately computed the depreciation rate of residential, non residential, durable, inventory and government capital stock by interpolating observations of these assets using investment data per asset. I compute the total depreciation rate using the sum of interpolated capital stock and total investment. The capital stock data is only used to compute the depreciation rate and is not used in the estimation or simulation.

5) In the simulation section, I dismiss this simplification and estimate the entire stochastic process.

6) The third result is quite different from a result of a standard real business cycle model such as Hansen (1985). This is because productivity shocks create spillover effects on other exogenous variables through the stochastic process.

7) Fisher (2006) shows that productivity and investmetn specific technology shocks jointly account for 80 percent of the business cycle fluctuation in the U.S.

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A. Data Appendix

The sources of the data is as follows. For Japanese national income and products accounts, I used the SNA statistics provided by the Economic and Social Research Institute of the Cabinet Office. For Japanese labor, I used the Labor force survey provided by the Statistics Bureau of the Ministry of Internal Affairs and Communication. For U. S. national income and products accounts, I used the NIPA statistics provided by the Bureau of Economic Analysis website. For U.S. labor, I used the Bureau of Labor Statistics website.

For each country, the definition of variables are as follows. Computed variables are tagged as "comp" while original data obtained from the sources listed above are tagged as "data".

- Output (comp) = GNP (data) + flow services from durable goods stock (comp)
  —flow services from durable goods stock (comp) = quarterly durable stock (comp) × (quarterly rate of return on private capital stock (comp) + quarterly depreciation rate of durable stocks (comp))
  —quarterly rate of return on private capital stock (comp) = quarterly marginal product of capital (comp) quarterly depreciation rate of private capital (comp)
  —quarterly marginal product of private capital (comp) = capital share of income (Hayashi and Prescott) × quarterly private capital stock (comp)
  —quarterly stocks (comp) are computed using simple linear interpolation between observation points
  —quarterly depreciation rates (comp) are computed using the perpetual inventory method
- Consumption (comp) = final private consumption expenditure (data)-household expenditure on durable goods (data)
- Investment (comp) = gross domestic capital formation (data) + current account (data) + household expenditure on durable goods (data)
- Government final consumption expenditure (data)
- Hours worked (comp) = total hours worked in the non-agriculture sector (data) / number of workers employed in the non-agriculture sector (data)

B. Tables and Figures

Table 1a. Business Cycle Features of Japan (1980-2007)

	Standard Deviation		Correlation of Output with										
		relative to											
v	%	Output	$v(-5)$	$v(-4)$	$v(-3)$	$v(-2)$	$v(-1)$	$v(0)$	$v(1)$	$v(2)$	$v(3)$	$v(4)$	$v(5)$
Output	0.95%	1.00	0.07	0.24	0.46	0.61	0.78	1.00	0.78	0.61	0.46	0.24	0.07
Consumption	0.51%	0.53	0.03	0.06	0.24	0.19	0.24	0.49	0.24	0.17	0.23	0.18	0.17
Investment	3.17%	3.34	0.22	0.36	0.52	0.65	0.79	0.91	0.74	0.57	0.37	0.14	−0.06
Labor	0.74%	0.78	0.16	0.28	0.35	0.46	0.53	0.45	0.39	0.25	0.13	0.00	−0.11
Hours	0.46%	0.48	−0.35	−0.28	−0.09	0.11	0.28	0.40	0.54	0.59	0.62	0.59	0.48
Employment	0.68%	0.72	0.41	0.49	0.45	0.43	0.39	0.21	0.06	−0.13	−0.27	−0.39	−0.43

Table 1b. Business Cycle Features of the U.S. (1980-2007)

	Standard Deviation		Correlation of Output with										
		relative to											
v	%	Output	$v(-5)$	$v(-4)$	$v(-3)$	$v(-2)$	$v(-1)$	$v(0)$	$v(1)$	$v(2)$	$v(3)$	$v(4)$	$v(5)$
Output	1.15%	1.00	0.05	0.28	0.50	0.68	0.86	1.00	0.86	0.68	0.50	0.28	0.05
Consumption	0.67%	0.58	0.14	0.39	0.56	0.68	0.78	0.84	0.73	0.61	0.47	0.31	0.17
Investment	4.37%	3.81	0.16	0.36	0.54	0.69	0.84	0.94	0.76	0.53	0.33	0.08	−0.18
Labor	1.31%	1.15	−0.04	0.16	0.36	0.56	0.75	0.89	0.87	0.78	0.66	0.46	0.26
Hours	1.10%	0.96	−0.11	0.08	0.28	0.47	0.67	0.84	0.88	0.84	0.76	0.60	0.41
Employment	0.36%	0.31	0.18	0.34	0.48	0.60	0.69	0.70	0.50	0.27	0.09	−0.14	−0.31

Table 2. Parameter and Steady State Values

structural	θ	δ	Γ	β	μ
parameters	0.457	0.020	1.0035	0.982	0.142
exogenous	g	η	Ψ	ϕ	z
steady state	0.282	1	0.331	1	1
endogenous	y	c	x	h	e
steady state	1.880	1.114	0.484	0.444	0.567

Table 3. Properties of the Exogenous Variables

	Standard Deviation		Correlation of Output with										
		relative to											
v	%	Output	$v(-5)$	$v(-4)$	$v(-3)$	$v(-2)$	$v(-1)$	$v(0)$	$v(1)$	$v(2)$	$v(3)$	$v(4)$	$v(5)$
Output	0.95%	1.00	0.07	0.24	0.46	0.61	0.78	1.00	0.78	0.61	0.46	0.24	0.07
Government	2.20%	2.32	−0.35	−0.26	−0.20	−0.04	0.09	0.18	0.21	0.20	0.22	0.19	0.20
Inv. Tech.	0.61%	0.64	−0.21	−0.34	−0.49	−0.55	−0.64	−0.83	−0.52	−0.31	−0.14	0.08	0.20
Preference	0.66%	0.70	−0.27	−0.40	−0.45	−0.55	−0.62	−0.65	−0.47	−0.28	−0.05	0.16	0.29
Effort	0.73%	0.77	−0.42	−0.52	−0.48	−0.48	−0.46	−0.29	−0.13	0.08	0.25	0.39	0.44
Productivity	0.94%	0.99	0.25	0.39	0.56	0.64	0.76	0.92	0.63	0.41	0.22	−0.02	−0.17

Table 4. Result of the Simulation with Productivity Shocks

	Standard Deviation		Correlation of Output with										
		relative to											
v	%	Output	$v(-5)$	$v(-4)$	$v(-3)$	$v(-2)$	$v(-1)$	$v(0)$	$v(1)$	$v(2)$	$v(3)$	$v(4)$	$v(5)$
Output	2.08%	1.00	0.08	0.23	0.43	0.57	0.75	1.00	0.75	0.57	0.43	0.23	0.08
Consumption	0.54%	0.26	−0.48	−0.43	−0.35	−0.23	−0.08	0.11	0.35	0.52	0.64	0.71	0.72
Investment	8.04%	3.86	0.15	0.30	0.49	0.61	0.77	0.99	0.70	0.49	0.33	0.12	−0.03
Labor	2.09%	1.01	0.20	0.34	0.52	0.63	0.77	0.97	0.65	0.43	0.26	0.05	−0.11
Hours	0.00%	0.00	—	—	—	—	—	—	—	—	—	—	—
Employment	2.09%	1.01	0.20	0.34	0.52	0.63	0.77	0.97	0.65	0.43	0.26	0.05	−0.11

Table 5. Result of the Simulation with Investment Specific Technology and Productivity Shocks

	Standard Deviation		Correlation of Output with										
		relative to											
v	%	Output	$v(-5)$	$v(-4)$	$v(-3)$	$v(-2)$	$v(-1)$	$v(0)$	$v(1)$	$v(2)$	$v(3)$	$v(4)$	$v(5)$
Output	1.11%	1.00	0.10	0.27	0.47	0.64	0.81	1.00	0.81	0.64	0.47	0.27	0.10
Consumption	0.87%	0.78	0.04	0.18	0.36	0.47	0.62	0.82	0.65	0.49	0.39	0.22	0.10
Investment	2.90%	2.60	0.12	0.28	0.46	0.63	0.78	0.92	0.76	0.61	0.43	0.25	0.08
Labor	0.63%	0.57	0.13	0.23	0.34	0.48	0.57	0.62	0.53	0.45	0.29	0.17	0.04
Hours	0.00%	0.00	—	—	—	—	—	—	—	—	—	—	—
Employment	0.63%	0.57	0.13	0.23	0.34	0.48	0.57	0.62	0.53	0.45	0.29	0.17	0.04

Table 6. Result of the Simulation with Investment Specific Technology, Effort and Productivity Shocks

	Standard Deviation		Correlation of Output with										
		relative to											
v	%	Output	$v(-5)$	$v(-4)$	$v(-3)$	$v(-2)$	$v(-1)$	$v(0)$	$v(1)$	$v(2)$	$v(3)$	$v(4)$	$v(5)$
Output	0.98%	1.00	0.10	0.26	0.47	0.62	0.78	1.00	0.78	0.62	0.47	0.26	0.10
Consumption	0.90%	0.91	0.19	0.35	0.50	0.59	0.70	0.87	0.58	0.37	0.22	0.00	−0.11
Investment	2.26%	2.30	−0.01	0.12	0.35	0.51	0.69	0.89	0.80	0.70	0.60	0.43	0.26
Labor	0.87%	0.89	0.30	0.41	0.50	0.58	0.64	0.55	0.47	0.32	0.16	0.03	−0.10
Hours	0.73%	0.75	0.46	0.56	0.56	0.58	0.55	0.38	0.21	0.00	−0.18	−0.31	−0.38
Employment	0.49%	0.50	−0.16	−0.12	0.04	0.17	0.30	0.42	0.52	0.56	0.56	0.53	0.39

Figure 1. Impulse Response to Government Shocks

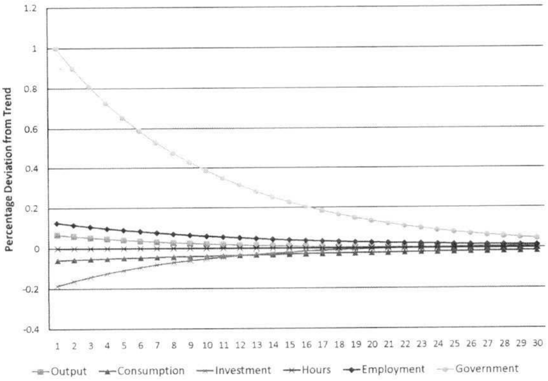

Figure 2. Impulse Response to Investment Specific Technology Shocks

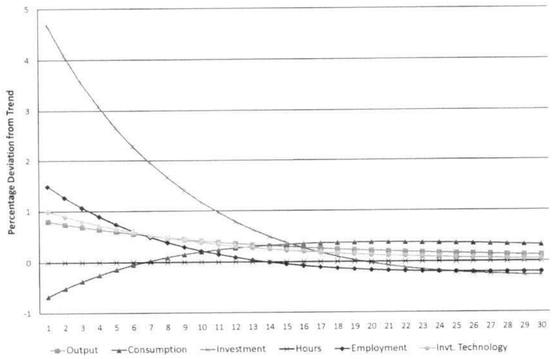

Figure 3. Impulse Response to Preference Shocks

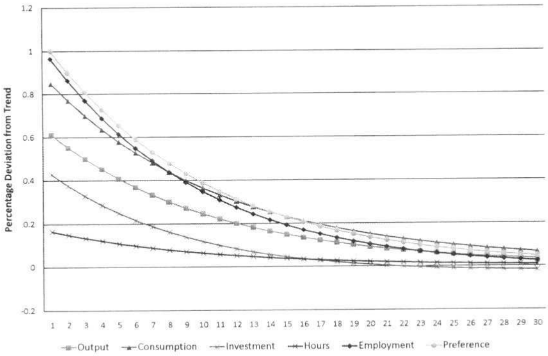

Figure 4. Impulse Response to Effort Shocks

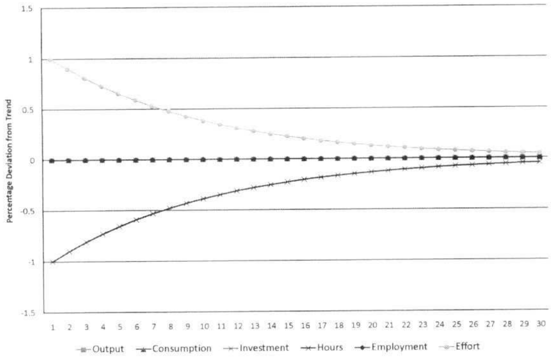

Figure 5. Impulse Response to Productivity Shocks