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Abstract

Two key features of the postwar Japanese economy are the delay of catch up during the 50s followed by rapid economic growth during the 60s and early 70s and the consistent decline in labor supply during the rapid growth period. A standard neoclassical growth model can quantitatively account for the Japanese postwar growth patterns of capital, output, consumption and investment taking the destruction of capital stock during the war and postwar TFP growth as given. The decline in labor can be explained by strong income effects caused by subsistence consumption during the rapidly growing period.

Keywords: Japanese Postwar Growth; Neoclassical Growth Model; TFP
JEL classification: E13, O40

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1 Introduction

Two key features of the postwar Japanese economy are the delay of catch up during the 50s followed by rapid economic growth during the 60s and early 70s and the consistent decline in labor supply during the rapid growth period. This paper quantitatively accounts for these features with a standard neoclassical growth model.

The main objective of this paper is to quantitatively account for the impact of key shocks on the postwar Japanese economy and understanding the channels through which they operated within a standard neoclassical stochastic dynamic general equilibrium model. The model consists of an infinitely lived representative household, a firm with constant returns to scale production technology using capital and labor as inputs and a government who collects labor income tax and fully rebates with lump-sum transfer. I introduce the destruction of capital stock, TFP and labor wedges as exogenous shocks to the economy, compute the equilibrium, and compare the time paths of key variables generated by the model to data from 1952 to 2000. The main findings are that the destruction capital stock and observed TFP can account for the growth pattern of postwar Japanese capital stock, output, consumption and investment and that the decline in labor can be explained by strong income effects caused by subsistence consumption during the rapidly growing period.

Japanese postwar recovery has been a large topic in economic growth and development literature. The interesting fact is that capital and output growth was rapid during the 50s but dramatically accelerated during the 60s and 70s. Christiano (1989) and King and Rebelo (1993) show that the destruction of capital stock alone within a neoclassical framework implies an unrealistically high return on capital which causes counterfactually rapid capital accumulation immediately after the war. They claim that preference with subsistence consumption can explain the delay in capital accumulation by encouraging agents to substitute consumption for investment during early periods of recovery. Recent studies such as Chen, Imrohoroglu and Imrohoroglu (2006) and Braun, Ikeda and Joines (2006) show that the neoclassical model with exogenous TFP and the loss of capital stock can account for the postwar Japanese savings rate defined as capital stock accumulation. I show that with endogenous labor supply, subsistence consumption is not enough and that TFP is needed to explain the delay in catch up.

Another interesting issue of the postwar Japanese economy is the consistent decline in labor during the 60s and early 70s. With standard preference, exogenous wedges in the labor market formulated by Chari, Kehoe and McGrattan (2004) are important in explaining the fluctuation of labor. Ohanian, Raffo and Rogerson (2006) argue that a large part of this wedge can be explained by labor income tax in OECD countries through. Unfortunately data on labor income tax in Japan is not available for early 60s. In Braun, Ikeda and Joines (2006), this wedge is created by exogenous changes in the family scale which affects the utility weights between consumption and leisure. Alternatively, I introduce a variation of the preference with subsistence consumption used by Christiano (1989) and King and Rebelo (1993) and show that the model can quantitatively account for the decline in labor through strong income effects on leisure during the rapidly growing period without relying on labor wedges.

This paper has two major distinctions from recent literature on the postwar Japanese economy such as Chen, Imrohologlu and Imrohologlu (2006), Braun, Ikeda and Joines (2006) and Braun, Okada and Sudou (2006). First, this paper focuses on growth paths of macroeconomic variables such as capital stock, output, consumption, investment and labor as opposed to saving rates, capital output ratios or filtered series. Instead of taking ratios or filtering the time paths, I assess the data and simulated time paths in terms of their deviation from the balanced growth path. By doing so, the transition of each variable toward the steady state becomes clear. Second, labor wedge is explicitly included into the model with endogenous labor supply. I show that the model with preference which depends on subsistence consumption can quantitatively account for the decline in labor without relying on labor wedges.

The remaining of the paper is organized as follows. Section 2 discusses empirical regularities of the Japanese economy. Section 3 and 4 describes the benchmark model and the quantitative method. Section 5 presents the quantitative results. Section 6 concludes the paper.

2 Japanese Economy

In this section, I discuss the main facts of the Japanese economy during 1952-2000. Figure 1 shows the evolution of five key variables; capital stock, output, consumption, investment and labor per adult during this period. All variables except for labor are logged and detrended with a 2% linear trend normalizing the 1989 values as 0. The main objective of this paper is to understand the features of the evolution of these variables and why they followed such paths.

First I present the growth accounting results and discuss how the economy evolved on the production side. Next I turn to the demand side and assess the evolution of GNP shares. These show that heavy investment took place in the 60s rather than right after the war. This coincides with the period of highest output and productivity growth. Finally, I discuss the evolution of TFP and the labor wedge which I assume to be exogenous. The data sources are Hayashi and Prescott (2002) for 1956-2000 and Ohkawa and Rosovsky (1973) for earlier periods.

2.1 Growth Accounting

Table 1 shows the growth accounting results for Japan by decade. Growth accounting is based on the following Cobb-Douglas production function

$$Y_t = A_t K_t^{\theta} L_t^{1-\theta}. \tag{1}$$

Output per adult Y_t is GNP divided by working age population, i.e. the number of people aged 20-69. Capital stock per adult K_t includes both private and government capital stock[1] held domestically, capital stock owned abroad and inventory stock. Labor input L_t is the number of people employed per adult times the average weekly hours worked per worker. Capital share θ is set at 0.362 which was computed by Hayashi and Prescott (2002). Productivity A_t is computed as a residual in the production function which is also know as Solow residuals.

The analysis starts from 1952 when the occupation by the allied powers ended. In the 50s, the economy was growing at an average rate of 7.0%. A textbook explanation for this fast growth in Japan would be that the destruction of capital stock during the war created high marginal product of capital and led to rapid capital accumulation. However, output growth peaked in the 60s at 7.7%, not in the 50s. During the 50s the growth rate of capital stock was only 2.8% and most of the growth came from productivity and labor growth. Capital stock started to grow rapidly during the 60s. After the 60s the economic growth slowed down but not monotonically. During the 80s, the average growth rate was slightly above 3% and almost the same as in the 70s while the growth rate fell below 1% during the 90s. The 80s is known as the bubble economy period where a common perception is that the economy was led by overheated investment. However, growth accounting shows that TFP was actually growing in a significantly faster rate than in the 70s.

An interesting feature of the postwar Japanese economy is the secular decline in labor except for during the 50s. The decline in labor is especially outstanding during the 60s and early 70s where the 1975 level is 30% below the 1960 level. It turns out that the main challenge of the theory is to explain this pattern on labor.

[1] Hayashi and Prescott (2002) abstract government owned capital stock from their analysis. However, since capital accumulation is one of the key issues in this paper, I add government capital stock. The results in this paper are not sensitive to this difference.

2.2 GNP Component Shares

Table 2 shows the evolution of GNP shares. The demand side of the economy is divided into consumption and investment. The table shows that rapid investment took place in the 60s.

Consumption consists of private consumption C_P and government consumption C_G. For simplicity, I combine them together and treat them as total consumption[2]. Investment consists of gross domestic capital formation I_D and current account CA. Gross domestic capital formation includes both private and government investment as well as changes in inventories where inventory stocks are included in capital stock. Current account is included in investment where capital stock is adjusted for capital stock owned abroad[3]. In short, the resource constraint is,

$$Y_t = C_t + I_t = C_{Pt} + C_{Gt} + I_{Dt} + CA_t. \tag{2}$$

In the 50s, both private and government consumption share were in peak while domestic investment and current account were at the lowest. Domestic investment grew rapidly in 60s and peaked in 70s which indicates the rapid capital accumulation during these periods. Current account improved dramatically in 80s and stayed high during 90s. However, the share of current account on total GNP is not large and does not seem to be a major source of growth[4]. The share of both private and government consumption fell in the 60s reflecting the rapid increase in investment. Private consumption fell further in 70s and grew back in 80s. Government consumption grew back in 70s and stayed roughly constant.

2.3 Trend and Productivity Shocks

In order to incorporate the concept of balanced growth into the analysis, I alter the production technology from (1) to,

$$Y_t = z_t K_t^{\theta} (X_t l_t)^{1-\theta} \tag{3}$$

where z_t is detrended TFP and X_t is the world technical progress. Obviously the Solow residual A_t in (1) is equal to $z_t X_t^{1-\theta}$. World technical progress is assumed to follow the process

$$X_t = (1+\gamma) X_{t-1} \tag{4}$$

[2] Alternatively the model can include government consumption separately as an exogenous variable. This alternative specification will not change the results of this paper.

[3] See Hayashi and Prescott (2002) for details.

[4] There are studies such as Gilchrist and Williams (2004) which emphasize the importance of trade in terms of importing technology embeded in vintage capital.

where γ is a constant growth rate which I assume to be 2%[5]. Along the balanced growth path, all variables except for labor should grow at this trend rate. In order to make the system stationary, all growing variables are divided by X_t.

Figure 2 shows the long run log output series linearly detrended by 2% setting 1905 as 0. This shows that Japan was in a steady state before the war and that the economy seems to have been growing towards a new steady state after war. The sudden drop of output immediately after the war can be attributed to the loss of capital stock. However, a temporary loss of capital stock does not affect the steady state level of capital nor output. Thus, I conjecture that the steady state level of z has increased, i.e. the balanced growth path shifted upwards. It is convenient to assume that there was a one-shot shift of the balance growth path after the war since now we can evaluate all variables as deviations from the new steady state. Parente and Prescott (1994) suggest this shift is due to a reduction of barriers to technology adoption after WWII[6].

Figure 3 shows linearly detrended postwar TFP and GNP setting the values in 1989 as the new steady state. Clearly, there is high positive correlation between TFP growth and GNP growth. The transition of TFP to its new steady state level was not instantaneous but gradual. Eaton and Kortum (1997) claims that a set of current leading economies including Japan experienced rapid growth and a slow down in postwar productivity because of the gradual adoption of more productive technology. Gilchrist and Williams (2004) argues that the gradual growth of TFP comes from the accumulation of vintage capital.

In this paper, instead of modeling the source of TFP growth I take it as exogenous. I implicitly assume that productivity grows because Japan gained access to leading technology after the war following Parente and Prescott (1994) and Eaton and Kortum (1997). Once technology reaches the balanced growth path, it will grow at the same rate as the frontier[7]. Quantitative results show that TFP is important in explaining the rapid capital accumulation during the60s and early 70s.

[5]This number is assumed to be the average trend growth rate in US in many studies such as King and Rebelo (1993).

[6]They consider gradual reductions of barriers with multiple shifts in balance growth paths whereas I assume that there is a one shot reduction in the barrier associated with a single shift in the balanced growth path.

[7]There might be a gap between detrended steady state productivity in Japan and the frontier due to a remaining barrier to the diffusion of new ideas. Thus, convergence to the new steady state is not necessarily equivalent to convergence to US productivity level.

2.4 Labor Wedge

In this section I introduce "labor wedges" which is known to be a powerful source of labor fluctuation. Following Chari, Kehoe and McGrattan (2004), I compute labor wedge d_t from the labor-leisure first order condition. That is,

$$-\frac{u_{l_t}}{u_{c_t}}d_t = MPl_t.$$

Following the literature, labor wedge is modeled as distortionary labor income tax and is considered as an exogenous variable. In general, there are many other possible sources of this wedge. Nonetheless labor wedges generated by other sources are observationally equivalent to labor income tax in equilibrium. Since specifying the source of labor wedge is beyond the scope of this paper, I do not further complicate the model.

Figure 4 plots the log deviation of labor and d_t from their 1989 level where I assume $d_{1989} = 1$[8]. Labor wedges are computed for Cobb-Douglas preference and Stone-Geary preference cases where the preference and the production functions are described in the following section. Obviously labor wedges and labor are negatively correlated.

Figure 4 also plots the log deviation of labor income tax series defined as $\frac{1}{1-\tau}$ from their 1989 level. Ohanian, Raffo and Rogerson (2006) show that a large part of labor wedges in OECD countries can be explained by labor income taxes using the Mendoza, Razin and Tesar (1994) tax data. This data plotted by a dotted line is based on the OECD revenue statistics which only goes back to 1965 for Japan. The solid line represents a crude measure of labor income tax computed as (*labor share*) $*$ (*income tax*)/(*national income*) using the Hayashi and Prescott (2002) dataset for labor share and Japanese Statistics Bureau data for the others in order to complement the missing periods. The discrepancies between the labor income tax data and labor wedges imply that labor income tax is not the only source of distortion in the labor market.

There are several other possible sources of labor wedges. Chari, Kehoe and McGrattan (2004) shows that monetary shocks can generate fluctuation d_t given sticky wages. In their model, money growth will affect the price level which affects real wages given sticky nominal wages. Thus, labor allocation will be distorted from the level of which the model would have generated without wage stickiness. Cooley and Hansen (1989) show that money growth can create this disturbance through

[8]The selection of the steady state value d does not affect the quantitative results much since it will only affect the calibration of the preference parameter Ψ.

a cash in advance constraint. In their model, final goods can be purchased only with cash where labor income earned after the purchase is divided into cash held for tomorrow and financial assets. Shocks to money growth affect the relative price of consumption to labor through inflation tax which is equal to the nominal interest rate. Christiano and Eichenbaum (1992) shows that the wedge can be caused by interest rate shocks with a working capital on labor assumption. In this model, firms must borrow resources in order to process wage payment so that shocks to the borrowing cost will affect the effective wages.

There are also recent literatures which document possible sources of labor wedges in Japan. Braun, Ikeda and Joines (2006) show that the decline in family sizes in a life-cycle model can account for the secular decrease in labor input through 1960-2000. In their model, family size determines the utility weights on consumption relative to leisure. Thus, the shift in family size works as labor wedges by affecting the marginal rate of substitution of leisure for consumption. Inaba and Kobayashi (2005) claim that the continuously declining asset price can be a candidate for the labor market deterioration during the 90s. In their model, there is a collateral constraint such that final goods can be purchased only up to a fixed amount of the current value of land. A decline in asset prices which causes this constraint to bind increases the effective price of final goods relative to labor.

In this paper I show that the model with preference which depends on subsistence consumption can quantitatively account for the decline in labor during the 60s and early 70s without relying on labor wedges. The remaining role of labor wedges is to explain the labor growth during the 50s and the labor drop during the 90s.

3 Model

In this section, I describe the model used to analyze the Japanese economy. The foundation of the model is a standard stochastic neoclassical growth model which consists of an infinitely lived representative household who has preference over consumption and leisure and a firm who uses constant returns to scale technology to convert capital stock and labor into output. I also assume a government who collects labor income tax and fully rebates by lump-sum transfer.

3.1 Household

The preference for the representative household depends on utility from consumption and leisure;

$$\max U = E_0 \sum_{t=0}^{\infty} \beta^t u(c_t, 1 - l_t) \tag{5}$$

where β is the subjective discount rate such that $0 < \beta < 1$, c_t is detrended consumption and l_t is labor supply which is the fraction of total hours available allocated to work[9]. For the functional form of $u(\bullet)$, I consider a Cobb-Douglas preference case and a Stone-Geary preference case.

The Cobb-Douglas preference function is widely used in macroeconomic literature;

$$u(c_t, l_t) = \frac{(c_t^{\Psi}(1 - l_t)^{1-\Psi})^{1-\sigma}}{1 - \sigma}. \tag{6}$$

σ represents the relative risk aversion where $0 \leq \sigma < \infty$ and Ψ is the weight the household assigns to consumption where $0 < \Psi < 1$.

Stone-Geary preference function is used in growth literature such as Christiano (1989) and King and Rebelo (1993);

$$u(c_t, l_t) = \frac{((c_t - \underline{c})^{\Psi}(1 - l_t)^{1-\Psi})^{1-\sigma}}{1 - \sigma}. \tag{7}$$

$\underline{c} \geq 0$ is the subsistence level of consumption set at $\underline{c} = 0.35c$ such that initial consumption is slightly higher than the subsistence level. This preference is consistent with balanced growth since the subsistence consumption is defined as a constant relative to the trend. (7) is slightly different from the preference used in Christiano (1989) and King and Rebelo (1993) since it includes leisure as an argument. It turns out that this modification brings several interesting implications on labor which is discussed in the following section.

The household maximizes (5) subject to a budget constraint;

$$(1 - \tau_t^l)w_t l_t + r_t k_t + T_t = c_t + i_t. \tag{8}$$

[9] In specific,

$$l_t = \frac{E_t}{N_t} \frac{H_t}{16 * 7}$$

where E_t is the number of people employed, N_t is the adult population and H_t is the average weekly hours worked per worker. I assume that the hours available to work per day are 16 hours.

τ_t^l is labor income tax rate where $\frac{1}{1-\tau_t^l} = d_t$ and T_t is the lump-sum transfer. i_t is detrended investment such that the capital law of motion;

$$(1+\gamma)(1+n)k_{t+1} = i_t + (1-\delta)k_t \tag{9}$$

holds. For simplicity, I assume that the population growth rate n is constant.

3.2 Firm

The detrended firm's problem is;

$$\max \pi_t = y_t - w_t l_t - r_t k_t \tag{10}$$

where y_t, w_t, r_t are detrended output, wage and return on capital, and

$$y_t = z_t k_t^{\theta} l_t^{1-\theta}. \tag{11}$$

3.3 Government

For simplicity, I assume that the government rebates all the labor income tax collected by lump-sum transfer;

$$\tau_t^l w_t l_t \equiv \left(1 - \frac{1}{d_t}\right) w_t l_t = T_t \tag{12}$$

Notice that there are no sign restrictions on τ_t^l such that when $\tau_t^l < 0$ the government gives subsidy on working and a collects lump-sum tax. The role of government is simplified as above since the key feature of interest is the labor market distortion created by labor income tax. Models such as Chari, Kehoe and McGrattan (2004) consider the role of government expenditure as an exogenous shock. It turns out that the effect of government purchase shocks is very small in Japan.

3.4 Shocks

The exogenous shocks are assumed to follow the process:

$$\begin{pmatrix} \ln z_t \\ \ln d_t^i \end{pmatrix} = \begin{pmatrix} \rho_z & 0 \\ 0 & \rho_d^i \end{pmatrix} \begin{pmatrix} \ln z_{t-1} \\ \ln d_{t-1}^i \end{pmatrix} + \begin{pmatrix} \varepsilon_{zt} \\ \varepsilon_{dt}^i \end{pmatrix}, \quad \begin{pmatrix} \varepsilon_{zt} \\ \varepsilon_{dt}^i \end{pmatrix} \sim N\left(0, \begin{bmatrix} \sigma_z^2 & 0 \\ 0 & (\sigma_d^i)^2 \end{bmatrix}\right). \tag{13}$$

Where $i = CD$ for Cobb-Douglas preference and $i = SG$ for Stone-Geary preference. For simplicity, I assume that the shocks are uncorrelated. This simplification does not affect the quantitative analysis since the linear decision rules do not depend on the error terms and the simulation uses the observed shocks, not random draws from the joint distribution[10].

As mentioned in the previous section, I assume that there was a one-time upward shift in the balance growth path after the war. The gap between initial TFP and the new steady state shown in figure 2 does not reflect a drop in technological level but was caused by this rare event. Once the balanced growth path shifted out, the AR1 process gives the expected TFP growth rate as

$$\ln z_t - \ln z_{t-1} = (\rho_z - 1)\ln z_{t-1}.$$

This means that agents expect TFP growth to slow down as it approaches the steady state.

This is a very strong assumption for the shock process. This requires the agents to know where the new steady state is from the beginning as well as the average convergence rate of technology to the new steady state level. Nonetheless, I use this setting as a benchmark since it is a convenient way to simplify the model. Later I compare different cases on expectation assumptions and show that the actual time path of the shocks is important rather than the expectation generating process.

3.5 Equilibrium

A competitive equilibrium is, $\{c_t, l_t, k_{t+1}, y_t, i_t, w_t, r_t\}_{t=0}^{\infty}$ such that;

1. Households optimize given $\{w_t, r_t, d_t\}_{t=0}^{\infty}$ and k_0
2. Firm optimizes given $\{w_t, r_t, z_t\}_{t=0}^{\infty}$
3. Markets clear and the government budget constraint (12) holds.
4. The resource constraint holds:

$$y_t = c_t + i_t \tag{14}$$

5. Shocks follow the exogenous process (13).

[10] The assumption on errors affects the estimation of persistence parameters. With the simplification, OLS estimation can be used to obtain the parameter. However, if there were correlations between shocks, OLS estimation on seemingly unrelated regression will lead to efficiency loss in the parameter estimation. It turns out that all of the quantitative results hold for wide ranges of persistence parameters.

The optimization yields the first order condition for labor;

$$-\frac{u_{l_t}}{u_{c_t}} d_t = (1-\theta)\frac{y_t}{l_t} \tag{15}$$

and the Euler equation for capital stock;

$$u_{c_t}(1+\gamma)(1+n) = \beta E_t\left[u_{c_{t+1}}\left\{\theta\frac{y_{t+1}}{k_{t+1}} + 1 - \delta\right\}\right] \tag{16}$$

where the marginal utilities of consumption and labor are;

$$\begin{aligned} u_{c_t} &= \Psi c_t^{\Psi(1-\sigma)-1}(1-l_t)^{(1-\Psi)(1-\sigma)} \\ -u_{l_t} &= (1-\Psi)c_t^{\Psi(1-\sigma)}(1-l_t)^{(1-\Psi)(1-\sigma)-1} \end{aligned}$$

for Cobb-Douglas preference and

$$\begin{aligned} u_{c_t} &= \Psi(c_t-\underline{c})^{\Psi(1-\sigma)-1}(1-l_t)^{(1-\Psi)(1-\sigma)} \\ -u_{l_t} &= (1-\Psi)(c_t-\underline{c})^{\Psi(1-\sigma)}(1-l_t)^{(1-\Psi)(1-\sigma)-1} \end{aligned}$$

for Stone-Geary preference.

4 Quantitative Method

In this section, I describe how the quantitative analysis is conducted. First, I discuss how the parameter values were obtained from data. Most parameters were obtained by calibration. Next, I describe the method used to simulate the time paths of capital stock, output, consumption, investment and labor. The simulation is based on a standard dynamic stochastic general equilibrium solution method.

4.1 Parameter Values

Most of the parameter values were calibrated to data over the 1984-1989 period in Japan. The obtained parameter values are listed in table 3.

δ is calibrated by the steady state version of capital accumulation equation (9)

$$\delta = 1 + \frac{i}{k} - (1+n)(1+\gamma),$$

β was calibrated by the steady state version of the capital Euler equation (16);

$$(1+\gamma)(1+n) = \beta(\theta\frac{y}{k} + 1 - \delta),$$

and Ψ was calibrated by the steady state version of the labor first order condition (15);

$$\frac{1-\Psi}{\Psi} = (1-\theta)\frac{y}{c}\frac{1-l}{l}$$

where n, $\frac{i}{k}$, $\frac{y}{k}$, and l were set at the data average, γ was set at 2% and θ was borrowed from Hayashi and Prescott (2002). ρ_z and ρ_d were estimated by a regression of the AR1 processes (13) for 1952-2000.

4.2 Simulation Method

The quantitative analysis uses linearized equilibrium conditions. I followed the method introduced by Uhlig (1997) to compute linear decision rules for the endogenous variables. All variables are defined as their deviations from the steady state which I set at the 1989 value. Thus, the values of all variables in 1989 are 0. The deviation of a variable x_t is defined as

$$\widetilde{x_t} = \ln x_t - \ln \overline{x}.$$

The decision rules depend on state variables – capital stock and exogenous variables. I set capital stock at its actual level in the initial period 1952[11]. I substitute linearly detrended shocks into the linearized decision rules to compute the time paths of the endogenous state variable – capital stock – for each period. Plugging the shocks and the simulated series of capital stock into the decision rules, I simulate the time paths of other endogenous variables. Finally, I plot the simulation results of output, consumption, investment and labor and compare them to the linearly detrended data normalizing the 1989 values as 0.

Since the initial period is far away from the steady state, there is a fear that the linearized model provides poor results for early periods. In the appendix I show that results from this linearized method is close to results from a nonlinear deterministic simulation.

[11] The detrended log deviation from steady state was -1.54 in the initial period. This implies that the capital stock in 1952 was $\exp(-1.54) = 0.214$ relative to the new steady state or in other words 78.6% below the new steady state level. Existing literature such as Chen, Imrohologlu, Imrohologlu (2006) uses more moderate numbers since they capture the loss of capital stock relative to the prewar level which is considerably lower than the new steady state.

5 Results

In this section I conduct three types of simulations with both Cobb-Douglas and Stone-Geary preferences. First, one with the destruction of capital as the only shock to the economy. Second, one with the destruction of capital and TFP shocks. Third, one with the destruction of capital and TFP and labor wedge shocks. For all cases, I set the relative risk aversion parameter $\sigma = 2$ where all of the following results hold with wide ranges of parameter values for $\sigma \geq 1$. The results are presented in figures 5, 6 and 7 where dotted lines and solid lines represent simulation results with Cobb-Douglas and Stone-Geary preferences respectively.

The results show that without TFP, the model cannot explain the features of postwar Japanese economy. With Cobb-Douglas preference, the model with TFP can explain the growth pattern of capital, output consumption and investment considerably well. However, in order to explain the drop of labor supply, the model needs labor wedges which exogenously increase during this period. On the other hand, with Stone-Geary preference, the model with TFP can account for both the rapid economic growth and labor decline during the 60s and early 70s without labor wedges. In the following, I summarize the results by each type of simulation carried out.

5.1 Capital Loss

The first experiment uses capital destruction as the only shock to the economy[12]. This corresponds to the analysis of King and Rebelo (1993) which focuses on the transitional dynamics of postwar economies. The results show that in both preference cases the model cannot account for the delay of catch up.

The reason why the model fails to explain the delay of catch up is because in the earlier periods the marginal product of capital is too high due to the loss of capital stock during the war. This causes the model to predict rapid capital accumulation immediately after the war. Capital accumulation depends on σ since this parameter governs the intertemporal elasticity of substitution which represents the willingness to smooth consumption over time by saving capital stock as discussed in King and Rebelo (1993). However there is no realistic value of σ that can quantitatively account for the time path of capital stock in both preference cases.

Christiano (1989) and King and Rebelo (1993) claim that Stone-Geary prefer-

[12] In my model, low capital stock relative to the new steady state in the initial period is a result of both the loss of capital stock during the war and the jump of steady state to a higher level. For simplicity, I will call this combined effect as the destruction of capital.

ence can cause a delay in capital accumulation whereas my results show that both preferences give virtually the same outcome in terms of capital accumulation. The reason my model cannot account for the delay of capital accumulation is because I include leisure in the preference, or in other words because labor supply is endogenous. Since subsistence consumption increases the relative importance of consumption in early periods, initial consumption will be higher. With inelastic labor supply, this will cause investment to fall during early periods because of the resource constraint. With endogenous labor supply, high consumption will substitute out leisure so that labor will be higher. Since this increases output, the resource constraint loosens and investment does not fall as much. Thus the model cannot explain the delay of capital accumulation even with the Stone-Geary preference.

5.2 With TFP

With TFP and capital destruction, the model can account for the delay in capital accumulation remarkably well. The main difference between the two preference cases are that Cobb-Douglas preference cannot explain the fluctuation of labor whereas the Stone-Geary preference can explain the decline in labor during the 60s and early 70s.

Both preference cases capture the postwar growth patterns of capital, output, consumption and investment. Low TFP during initial periods more than offsets the increasing effect of marginal product of labor from low initial capital stock. As productivity grows, the return on capital grows so investment increases rapidly during the 60s. This result is consistent with Chen, Imrohoroglu and Imrohoroglu (2006) and Braun, Ikeda and Joines (2006) which show that the fluctuation of postwar Japanese saving rates can be well accounted for by changes in TFP where the saving rate they compute is directly connected to capital accumulation as it is defined as the ratio of net investment to net national product. The time path of output follows the TFP series both because of the direct effect of TFP on production and its indirect effect through capital stock.

The Cobb-Douglas case fails to explain the time path labor. On the other hand, the Stone-Geary case can explain the labor decline during the 60s and early 70s. The main channel through which subsistence consumption affects the outcome is the marginal rate of substitution of leisure for consumption. The marginal rate of substitution with Stone-Geary preference is

$$\frac{1-\Psi}{\Psi}\frac{c_t-\underline{c}}{1-l_t} \tag{17}$$

compared to

$$\frac{1-\Psi}{\Psi}\frac{c_t}{1-l_t} \tag{18}$$

with Cobb-Douglas preference. With subsistence consumption, consumption growth will cause a greater growth in the marginal rate of substitution than in the Cobb-Douglas case which works as an extra income effect creating extra demand for leisure. Thus, the model with Stone-Geary preference can explain the decline in labor during the rapid growth period.

5.3 With Labor Wedge

With labor wedges, the model can quantitatively account for the fluctuation of labor. However, they are less important in explaining capital accumulation and long-run economic growth.

The mechanism through which labor wedges operate is quite simple. An increase in labor wedges decreases the effective wage workers receive which decreases labor supply since the intratemporal substitution effect dominates the income effect. Although labor wedges are important in understanding labor fluctuation, they do not significantly affect the long run behaviors of other variables. This result is related to a well known fact such that in an optimal growth model capital stock accumulation is important in understanding growth towards the steady state whereas fluctuation in labor is key to understand the business cycle fluctuation about the steady state. In the appendix, I show that labor shocks are important in understanding the business cycle fluctuation during the bubble economy period and the subsequent decade of stagnation.

With Cobb-Douglas preference labor wedges play an important role in explaining the fluctuation of labor whereas with Stone-Geary preference the gain from including labor wedge is decimal since TFP alone can account for the decline in labor during the 60s and early 70s. The key role labor wedges plays in the Stone-Geary case is explaining the growth in labor during the 50s and the drop in labor during the 90s. Inaba and Kobayashi (2005) claim that continuous decline in the asset prices caused growth in the labor wedge during the 90s. Hayashi and Prescott (2002) claim that labor fell during the 90s due to shortened work weeks by legislation. The source of labor wedge decline during the 50s is left to future research.

6 Conclusion

In this paper I use a standard neoclassical growth model to quantitatively account for the key features of postwar Japanese economy; the delay of catch up during the 50s followed by rapid economic growth during the 60s and early 70s and the decline in labor during the rapid growth period. I calibrate the model economy to the Japanese economy and conduct a stochastic simulation from 1952 to 2000 taking the destruction of capital stock, TFP and labor wedge shocks as given. The model quantitatively accounts for time paths of capital, output, consumption, investment and labor relative to the balanced growth path extremely well for the whole simulation period. The main finding is that TFP along with the loss of capital stock during the war plays an important role in explaining the delay of catch up in the 50s and the rapid growth during the 60s and early 70s while the decline in labor can be explained by strong income effects caused by subsistence consumption during the rapid growth period.

I conclude that in order to deepen the understanding of postwar Japanese growth, we need to study the nature of productivity growth. In this paper the growth in TFP was taken as exogenous where the economy adopted technology from abroad as in Eaton and Kortum (1997). Therefore, TFP growth is treated not as innovation but as the rate of adoption. Braun, Okada and Sudou (2006) argue that the medium term productivity cycle in Japan can be explained by diffusion of US R&D. This can explain the non-monotonic convergence of TFP to the new steady state in my model. The remaining question is, "why did it take so long to adopt technology?" A model with learning-by-doing features perhaps is suited to answer this question through human capital accumulation.

Finally, although the model with Stone-Geary preference can explain the decline in labor during the 60s and early 70s, it is silent with regard to where the remaining fluctuation in labor comes from. The labor growth in the 50s and the labor drop in the 90s are especially interesting. While there are literature such as Hayashi and Prescott (2002) and Inaba and Kobayashi (2005) which document the labor drop during the 90s, further work to deepen the understanding of labor wedges during the 50s is required.

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A Variable Utility Weight Model

In this section, I introduce a model with a variable consumption-leisure weight and show that shifts in these weights work as labor wedges. This model is based on an assumption such that the utility weights on consumption and leisure depend on the consumption level. This preference assumption gives virtually the same results as the Stone-Geary preference case.

Consider a household preference with variable consumption-leisure weights

$$u(c_t, 1-l_t, \Psi_t) = \frac{(c_t^{\Psi_t}(1-l_t)^{1-\Psi_t})^{1-\sigma}}{1-\sigma}. \tag{19}$$

Also assume that there is no government sector. The marginal rate of substitution is now

$$\frac{1-\Psi_t}{\Psi_t}\frac{c_t}{1-l_t} \tag{20}$$

Therefore labor wedges defined in the benchmark model can be captured as changes in Ψ_t in this model. The Euler equation (16) will also be affected since marginal utilities depend on Ψ_t[13] when $\sigma \neq 1$. Figure A1 shows the implied consumption-leisure utility weight computed by (20). In Braun, Ikeda and Joines (2006), exogenously determined family size is used for Ψ_t.

A simple regression shows that utility weights are negatively correlated with consumption. The reduced form regression of demeaned utility weights on detrended consumption normalized at the steady state gives,

$$\ln\Psi_t - \ln\Psi = \eta * (\ln c_t - \ln c) + \nu_t \tag{21}$$

where $\eta = -0.31$ with the t-value -21.93. This implies that the household values consumption more when he is poor. I use this relationship in the model and assume

$$\Psi_t = \Psi\left(\frac{\overline{c_t}}{c}\right)^{\eta}$$

where $\overline{c_t}$ is the average consumption. I assume that the weights depend on average consumption $\bar{c}_t$[14] simply for convenience such that the household does not internalize

[13] The marginal utilities are

$$\begin{aligned} u_{c_t} &= \Psi_t c_t^{\Psi_t(1-\sigma)-1}(1-l_t)^{(1-\Psi_t)(1-\sigma)} \\ -u_{l_t} &= (1-\Psi_t)c_t^{\Psi_t(1-\sigma)}(1-l_t)^{(1-\Psi_t)(1-\sigma)-1}. \end{aligned}$$

[14] The household is the representative agent so average consumption must be the same as his consumption.

the effect of consumption decisions on utility weights. Since Ψ_t converges to Ψ in the long-run due to the mean reversion of consumption, the preference function is consistent with balanced growth.

The results for the variable utility weight model are virtually the same as the Stone-Geary preference case. The mechanism is quite similar as well. When the household is poor, he values more consumption and less leisure so labor is high in the early periods. As the household becomes richer he values more leisure so labor supply gradually falls as consumption approaches the steady state.

B The Role of Expectation

In this section, I will compare the results with alternative assumptions on expectation. First I alternate the persistence parameters in the TFP shock process. Next, I compare the stochastic model to a deterministic model. In each cases, I use the model with Cobb-Douglas preference given both TFP and labor shocks as the benchmark. The results show that the role of expectation is limited.

B.1 Optimistic and Pessimistic Expectations

The benchmark assumption on TFP is that it exogenously grows toward a new steady state where agents can anticipate the future TFP path correctly on average using the AR1 process. In this section I will consider cases where the agents do not know the correct average convergence rate of TFP i.e. the persistence parameter ρ_z. Results show that the key aspects of the model hold for these alternative assumptions.

Figure A2 shows the results with alternative expectations. First I assume the persistence parameter $\rho_z = 1$ which means that the agents believe no TFP growth. Next I consider $\rho_z = 0.9$ which means that they expect too much growth. Hence, $\rho_z = 1$ corresponds to pessimistic expectations while $\rho_z = 0.9$ corresponds to optimistic expectations. With pessimistic expectations, the investment and capital series becomes flatter. Since agents do not expect TFP growth, they are not enthusiastic about investing and save only to smooth consumption over the life time when faced by an unexpected productivity growth. On the other hand, with optimistic expectations, investment grows rapidly since agents expect productivity to be higher in the future. Other variables do not differ that much from the benchmark case. Thus, the realization of TFP is more important to explain the postwar Japanese growth than what the agents believed.

B.2 Deterministic Model

I also consider a case in which the agent has full information on future exogenous variables. I simultaneously solve a system of nonlinear dynamic equations for the capital stock series and compute the other variables using the static equilibrium conditions. I normalize the results in order to make them comparable to previous results.

In specific, I simultaneously solve for $\{k_{t+1}\}_{t=1952}^{1999}$ from a system of dynamic equations;

$$u_{c_t}(1+\gamma)(1+n) = \beta u_{c_{t+1}} \left\{ \theta z_{t+1} k_{t+1}^{\theta-1} l_{t+1}^{1-\theta} + 1 - \delta \right\}$$

over $t = 1952-1999$ substituting $u_{c_t}(c_t(z_t, k_t, l_t, k_{t+1}), l_t, \sigma, \Psi)$ and taking $\{z_t, l_t\}_{t=1952}^{2000}$, k_{1952}, k_{2001}as given. Assuming exogenous l_t buys tremendous computational simplicity as in Chen, Imrohologlu and Imrohologlu (2006). Once the capital stock series are computed, this can be used to compute other endogenous variables from equilibrium conditions. The computed series are normalized as deviations from their 1989 values.

Figure A3 shows the results for the deterministic simulation and the simulation of the stochastic model with both shocks. Both cases produce virtually the same result. Also, the fact that the stochastic model uses a linearized method does not seem to cause problems as the deterministic model uses a nonlinear method and produces close results.

C Bubble Economy

Figure A4 summarizes the results with Stone-Geary preference from 1980 to 2000 in order to focus on the "bubble" period[15]. The time paths of macroeconomic variables can be accounted for by the model not only during the recovery period but also during the 80s and 90s, i.e. the "bubble economy" and the subsequent "lost decade" except for the peak of investment in 1991. The result such that unusually high investment cannot be explained by TFP shocks is consistent with the conjecture of Hayashi and Prescott (2002).

The model does considerably well in accounting for the 80s with only TFP shocks. Therefore the rapid economic growth and investment as well as consumption growth during the 80s are products of rapid TFP growth. However, the model with only TFP shocks cannot account for the fluctuation in labor as the model predicts labor

[15]It turns out that there are no large differences between result from Cobb-Douglas and Stone-Geary preferences during this period.

to increase whereas the data shows labor decrease throughout the 80s. With both TFP and labor wedges the simulated series almost overlaps data for all variables.

The model with only TFP predicts the output stagnation considerably well but has a problem in accounting for the 90s in several aspects. First, the model cannot explain the fluctuation of labor. Second, the model cannot account for the consumption drop in 1990. Third, the model cannot account for the high investment in 1991. Finally, the model cannot account for the increase in capital stock throughout the 90s. The model with labor wedges can explain the labor drop during the 90s which leads to a further output drop as stated in Inaba and Kobayashi (2005). It turns out that the model with both shocks overstates the lost decade. I conjecture that exogenous shocks to hours worked along with TFP shocks in an indivisible labor model such as Hayashi and Prescott (2002) can account for the lost decade better than labor wedges with TFP shocks in an endogenous labor model. The consumption drop in 1990 is well captured by the model with both TFP and labor shocks. In fact, the model with both shocks predicts a consumption drop even greater than data. The timing of consumption drop coincides with the introduction of consumption tax[16] where consumption tax is implicitly included in labor wedges under the current setting since consumption tax will appear in the labor-leisure first order condition as labor income tax does.

The interesting result is that the model cannot explain the high investment in 1990-1991. This verifies the statement by Ando, Christelis and Miyagawa (2003) such that there has been excessively large investment in Japan especially in the 90s[17]. They claim that this overinvestment occurred because of extraordinarily low dividend payments. Hayashi (2004) argues that low dividends indeed lead to overinvestment but does not account for the lost decade since it has no implication on TFP. My results show that the lost decade can be accounted for by low TFP growth while high investment in 1991 is due to an alternative shock which does not have much impact on output. Hayashi and Prescott (2002) mention that overinvestment can be due to high expected productivity growth that did not materialize[18]. The discrepancy in the capital stock simulation and data reflect the discrepancy in the investment series.

[16] Prime minister Takeshita introduced 3% consumption tax in mid-1989 and later this was raised to 5% in 1997 by Prime minister Hashimoto.

[17] They look at corporate investment whereas the investment series in this paper includes government investment and current account. However, the share of the latter is small so the result is not sensitive to the definition of investment.

[18] In terms of business cycle accounting, this will show up as a drop in capital wedge which has an increasing effect on capital stock.

D Tables and Figures

Table 1. Growth Accounting (% Growth Rates)

	Y_t	K_t	L_t	A_t
$52-59$	7.0	5.1	1.9	3.8
$60-69$	7.7	9.0	-1.6	5.6
$70-79$	3.2	8.2	-1.0	1.1
$80-89$	3.2	3.6	-0.2	2.0
$90-99$	0.7	3.4	-1.2	0.3

Table 2. GNP Component Shares (%)

	C			I		
		C_P	C_G		I_D	CA
$52-59$	73.9	63.8	10.1	26.1	25.9	0.2
$60-69$	65.1	57.3	7.9	34.9	34.7	0.2
$70-79$	64.7	55.7	9.0	35.3	34.5	0.8
$80-89$	68.3	58.7	9.6	31.7	29.5	2.2
$90-99$	68.3	58.9	9.5	31.7	29.1	2.5

Table 3. Parameter Values

β	Discount Factor	0.98
δ	Depreciation Rate	0.116
Ψ	Consumption-Leisure Parameter	0.32
θ	Capital Share	0.362
n	Population Growth	0.009
γ	Trend Growth	0.02
ρ_z	TFP Persistence	0.94
σ_z	TFP Volatility	0.027
ρ_d^{CD}	Labor Shock Persistence	0.975
σ_d^{CD}	Labor Shock Volatility	0.031
ρ_d^{SG}	Labor Shock Persistence	0.801
σ_d^{SG}	Labor Shock Volatility	0.030

Figure 1. The Postwar Japanese Economy (Log Deviation From 1989 Level)

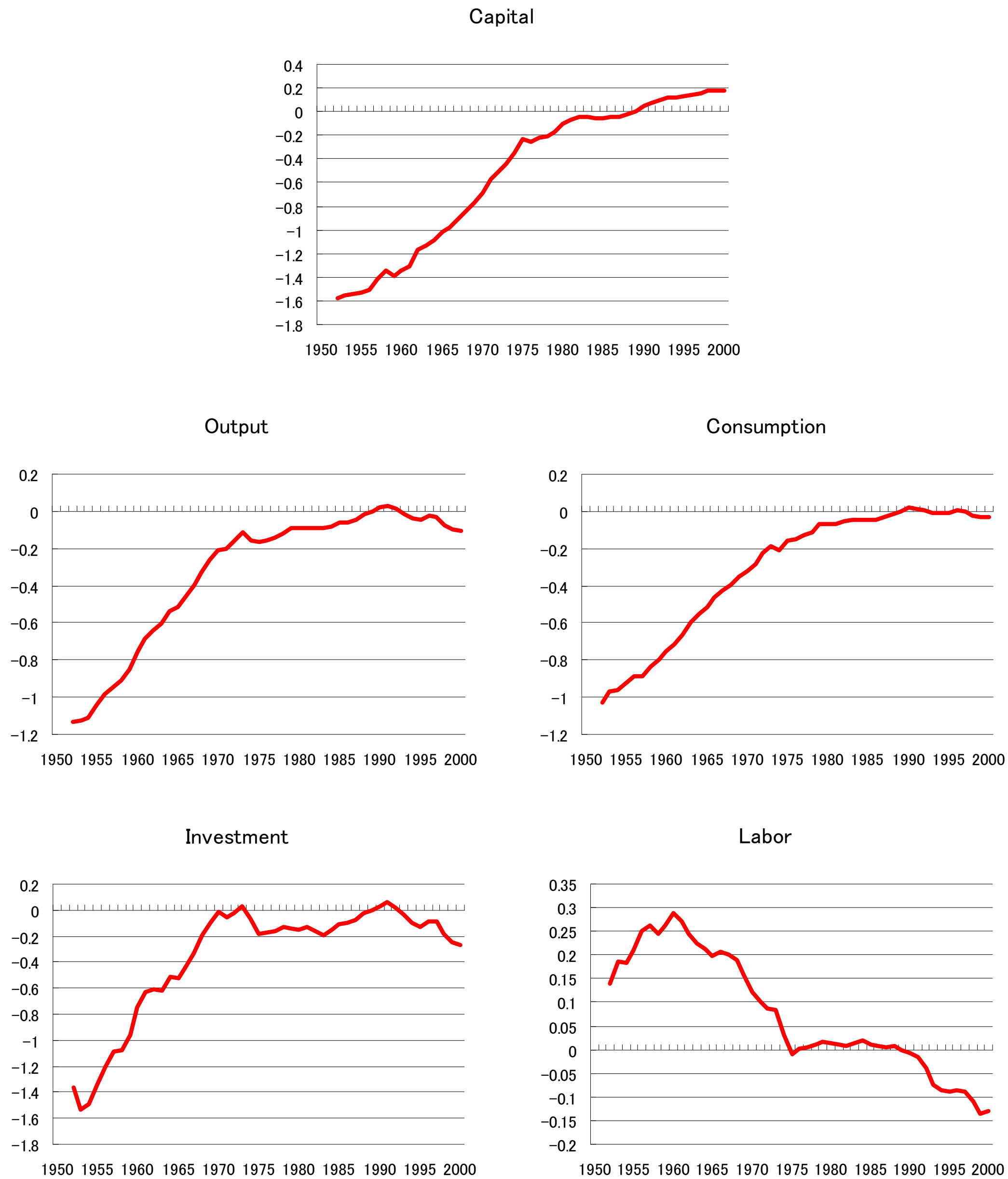


Figure 2. Long-Run Detrended Japanese Output (1905=0)

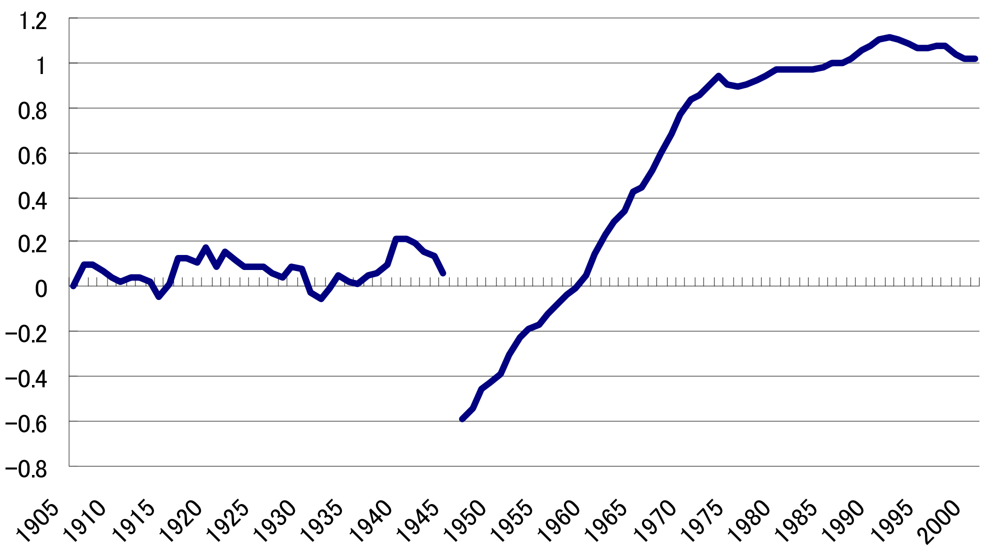


Figure 3. Detrended TFP and Output (1989=0)

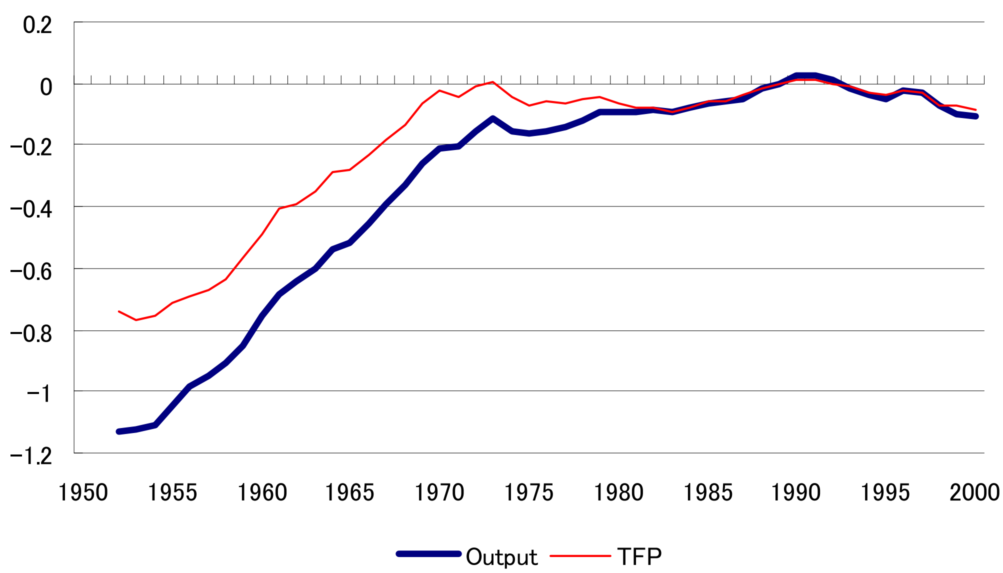
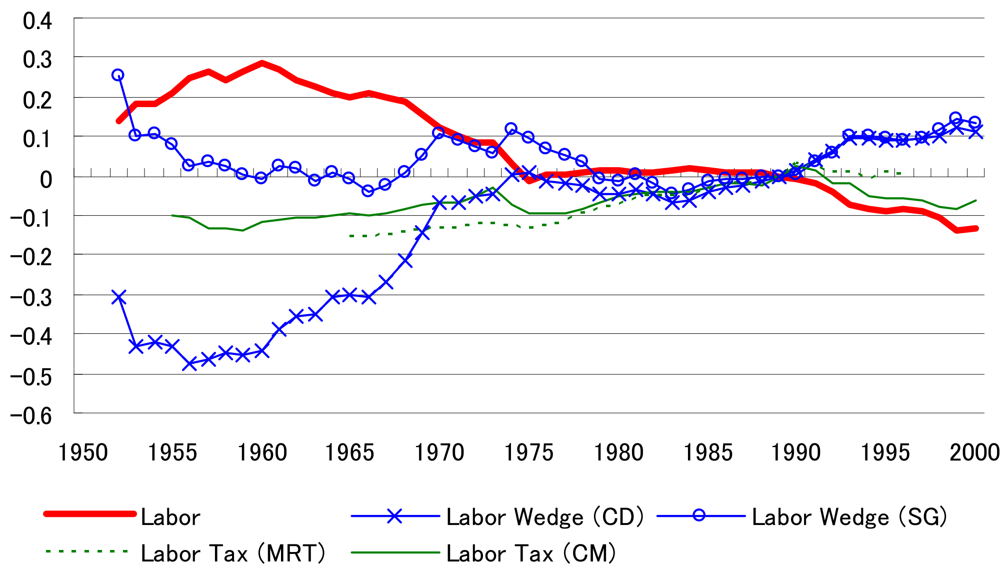


Figure 4. Labor Wedge (1989=0)[19]



[19] CD stands for Cobb-Douglas preference. SG stands for Stone-Geary preference. MRT stands for Mendoza, Razin and Tesar data. CM stands for crude measure.

Figure 5. Simulation Result with only Capital Loss

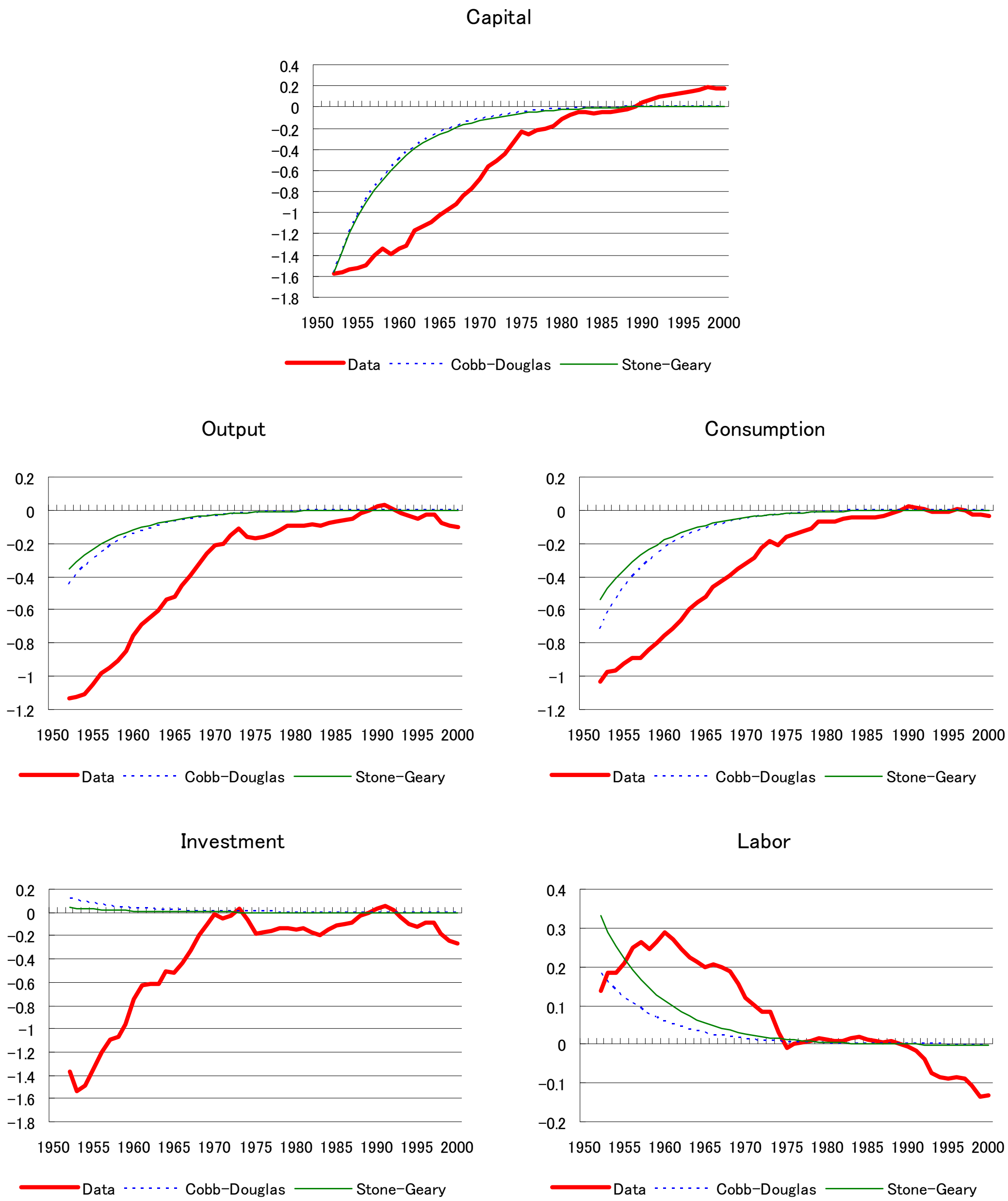


Figure 6. Simulation Results with TFP

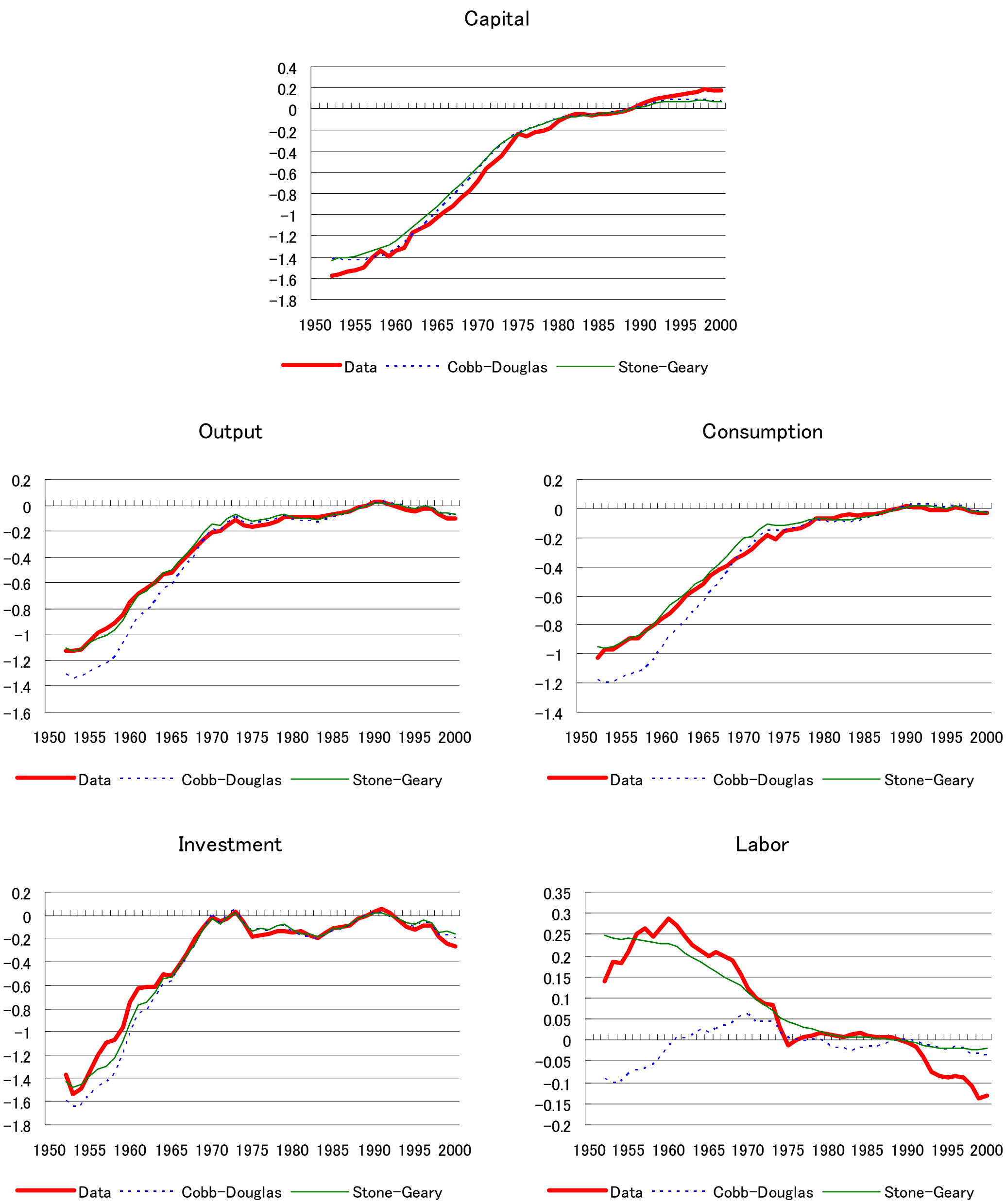


Figure 7. Simulation Results with TFP and Labor Wedge

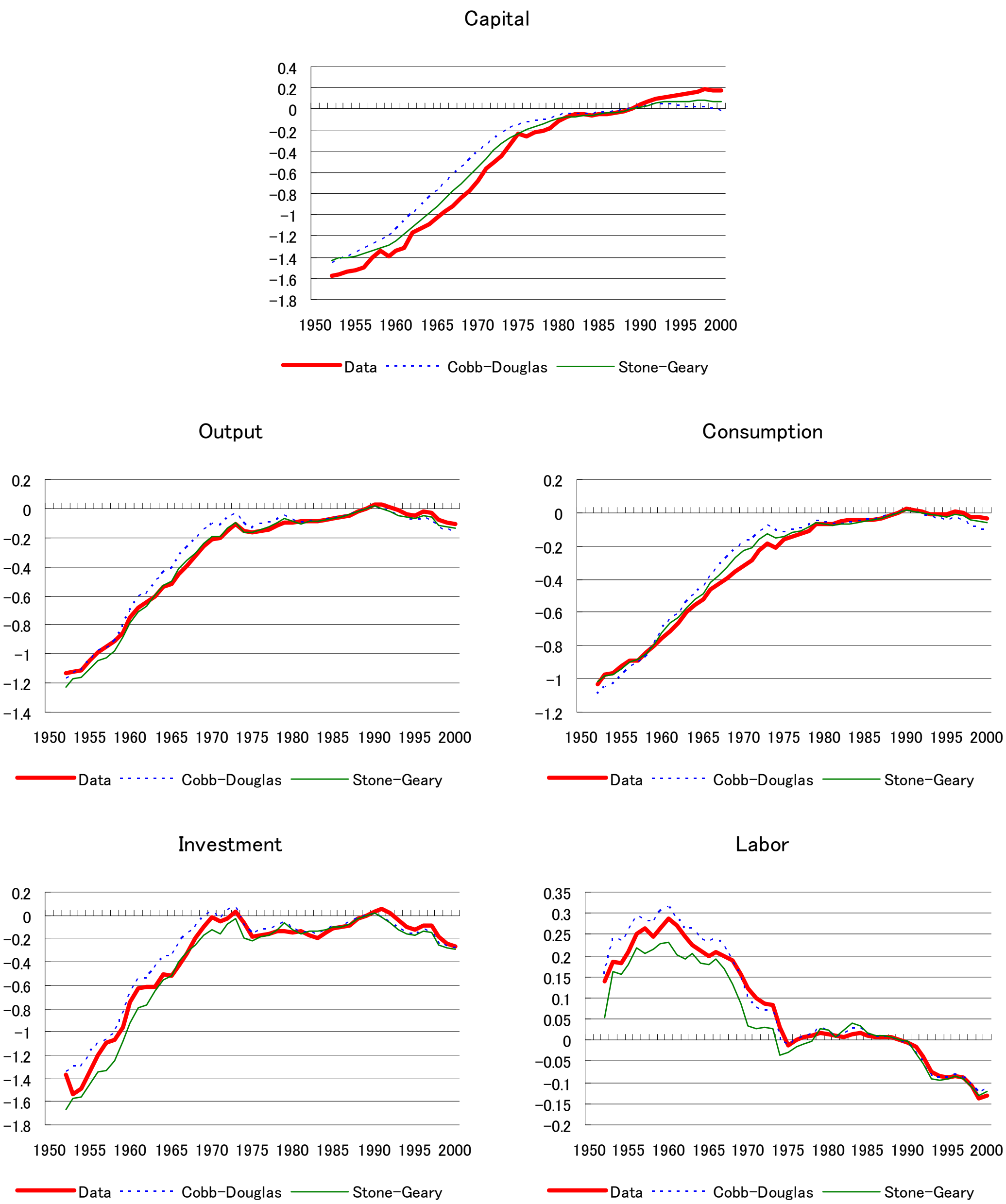


Figure A1. Variable Utility Weight ($\Psi = 0.32$)

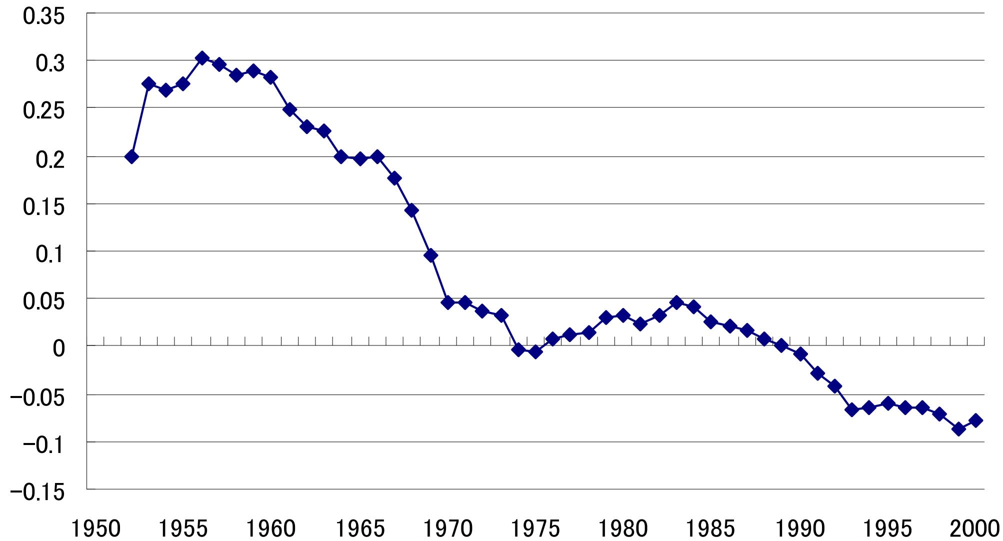


Figure A2. Simulation Results with Different Expectations

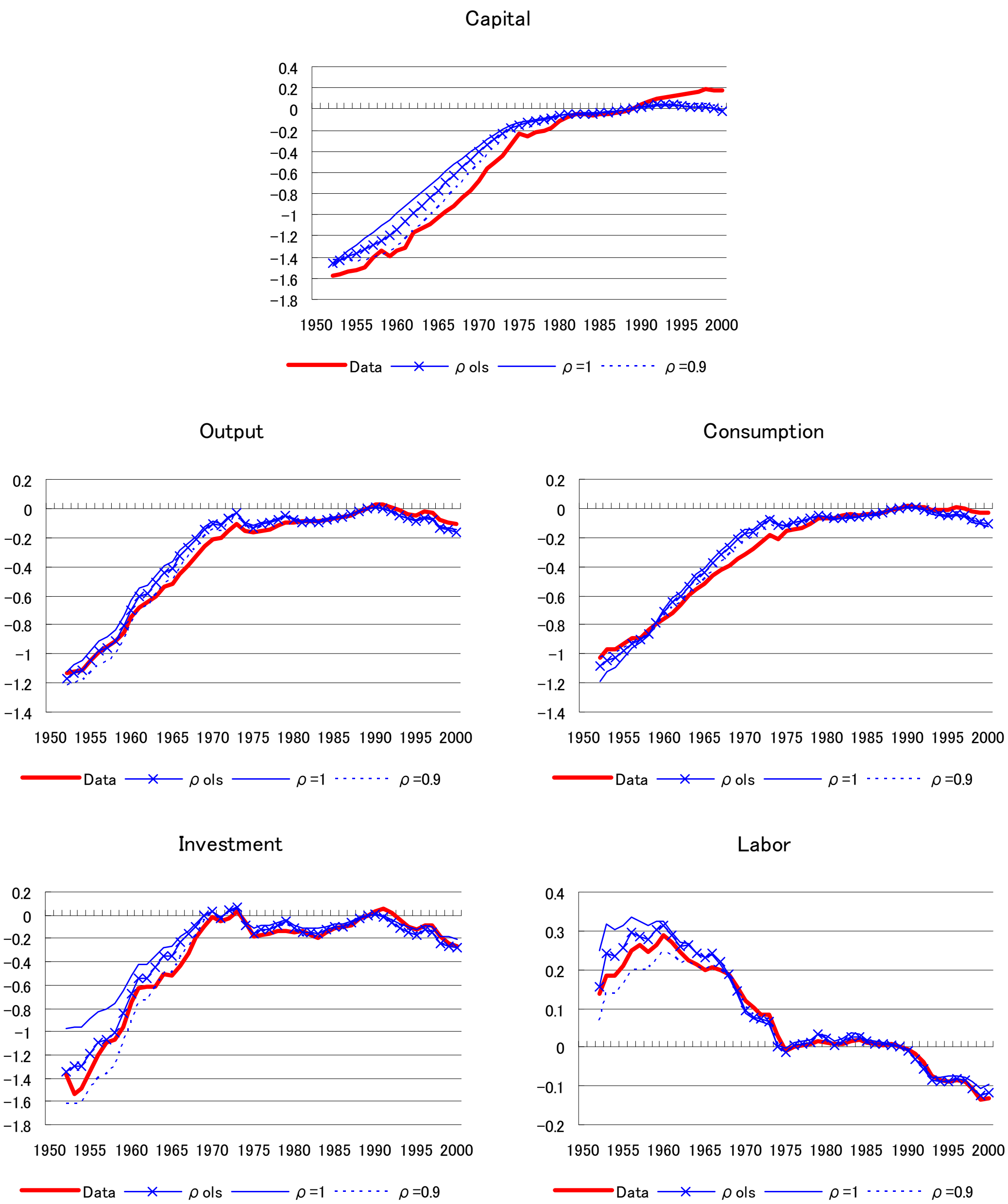


Figure A3. Simulation Results of Deterministic Model

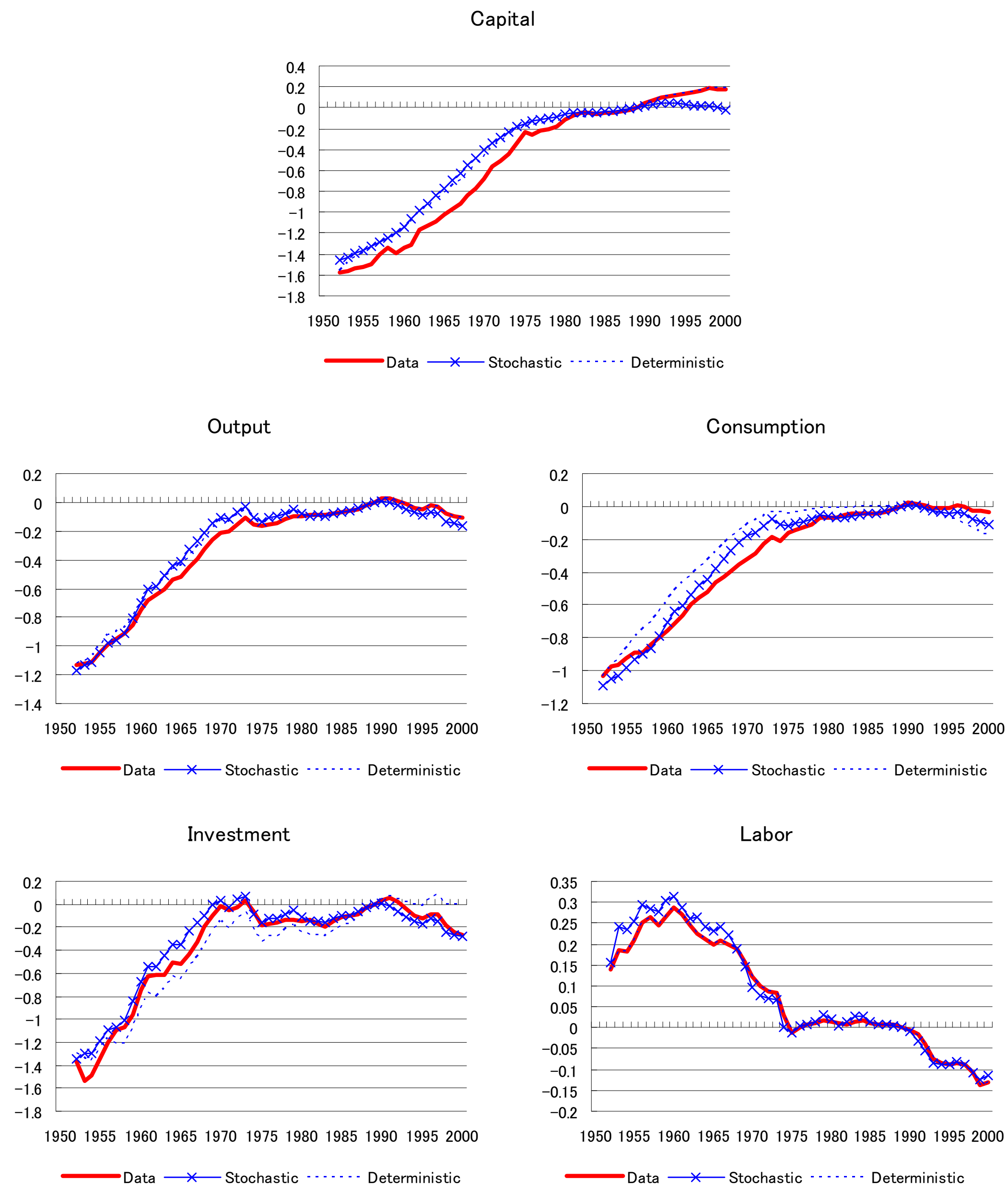


Figure A4. Simulation Results for Bubble Period