Capital Utilization in Japan during the 1990s *

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Abstract

This paper examines the role of capital utilization in the Japan's slump during the 1990s. We incorporate variable capital utilization into the neoclassical growth model of Hayashi and Prescott (2002), calculate TFP taking into account capital utilization, and simulate the aggregate output and capital-output ratio in the Japanese economy. The result indicates that, althought the drop of our TFP growth rate in the 1990s is smaller than assumed in Hayashi and Prescott (2002), it can generate the Japan's slump because it causes a decline in capital utilization rates.

JEL classification: E2; E13; O4; O53

Keywords: Capital utilization; TFP; Japan's lost decade

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1 Introduction

In the 1990s, for the first time since W.W.II, Japan experienced a prolonged period of economic stagnation. The GNP growth rate per working-age person declined rapidly from 3.2 percent in the 1980s to 0.7 percent in the 1990s. This decade is also characterized by capital deepening. The capital-output ratio increased dramatically from 1.86 in 1990 to 2.36 in 2000.[1] The economic slump of the 1990s—known as *the lost decade* in Japan—has been a puzzle for economic researchers.

The paper by Hayashi and Prescott (2002) (hereafter, HP) is a seminal work that analyzes the lost decade by using a neoclassical growth model calibrated to Japanese data.[2] They find that the main cause of the economic stagnation in Japan was a decline in the total factor productivity (TFP) growth rate. Furthermore, they demonstrate that the aggregate output and capital-output ratio predicted by their model are consistent with the data. However, some researchers point out that HP underestimate the TFP growth rate for the 1990s, and that the drop of capital utilization rates accounts for a large part of the decline in the TFP growth rate.

The purpose of this paper is to incorporate variable capital utilization into the theory of HP. To this end, we modify their model with capital utilization as an endogenous variable, calculate TFP taking into account the effect of capital utilization rates, and simulate the aggregate output and capital-output ratio in the Japanese economy. Our model's simulations are consistent with the observed data, despite the fact that our

[1] Our data source is Hayashi and Prescott (2002).`http://fhayashi.fc2web.com/Hayashi-Prescott1_data.htm`

[2] Braun and Waki (2006) analyze the lost decade with a costly price adjustment model.

calculated TFP growth rate for the 1990s is higher than that of HP. The key is a prolonged decline in capital utilization rates. Because the drop of TFP growth rate decreases the level of capital utilization rates, our model with the smaller drop of TFP growth rate can explain the lost decade.

Changes in capital utilization rates have another important implication, namely, their effect on the net national saving rate. It is reported that the net national saving rate in Japan, whose height had been well known, fell sharply over the 1990s. However, this "fact" is based upon the assumption that the depreciation rate remained constant. Our model, in which the depreciation rate is a function of the capital utilzation, predicts that the depreciation rates decrease, and that the net saving rates became higher than that predicted by the HP model.

The remainder of this paper is divided into four sections. Section 2 reviews the related literature on the Japan's lost decade. Section 3 explains our methodology and results. In section 4 we discuss the implications of our model with respect to the net saving rate in Japan. Section 5 contains concluding remarks.

2 Related Literature

This section reviews the the related literature on the Japan's lost decade, especially on its TFP and capital utilization. First, we confirm the analysis of HP, in particular their TFP calculation and its problem due to ignoring variable capital utilization. Next, some researches are introduced which estimate the Japan's TFP in the 1990s taking account into capital utilization. Finally, we mention the difference between our theory and the related literature which studies the variable capital utilization in the Japanese economy.

HP analyze the lost decade by using a neoclassical growth model calibrated to Japanese data. They find that their predictions are consistent with the observed aggregate output (Figure 1) and capital-output ratio (Figure 2).[3] According to their analysis, the main cause of the lost decade is the drop of TFP growth rate. Assuming the Cobb-Douglas functional form, HP calculate their TFP (A_{HP}) as follows:

$$A_{HP} = \left(\frac{Y}{K^{\theta}(hE)^{1-\theta}} \right)^{1/(1-\theta)}, \tag{1}$$

where Y is GNP, K is capital, h is average hours worked per worker, E is the aggregate employment, and θ is the calibrated cost share of capital. In Figure 3, we depict the TFP growth rate calculated in HP which fell sharply starting from 1991.

However, HP ignore the effect of capital utilization in the TFP calculation. If variable capital utilization is assumed, the production function becomes

$$Y = (uK)^{\theta}(AhE)^{1-\theta} , \tag{2}$$

where A is TFP and u is capital utilization. Thus, TFP can be expressed as follows:

$$A = \left(\frac{Y}{(uK)^{\theta}(hE)^{1-\theta}} \right)^{1/(1-\theta)}. \tag{3}$$

Therefore, the relation between TFP in HP and that which takes into account capital

[3] We follow HP's definition of capital, according to which capital comprises domestic investment, net export, and net factor payment. Note that it does not include government capital.

utilization would become

$$A_{HP} = u^{\theta/(1-\theta)} A. \tag{4}$$

Thus, if capital utilization rates did indeed decline in the 1990s, HP would underestimate the TFP over this period.

To calculate TFP taking into account capital utilization, two methodologies are well known. One is to use the hours worked per worker. Kawamoto (2005) and Miyagawa, Sakuragawa, and Takizawa (2006) estimate the Solow residual which takes into account the effect of capital utilization rates, using the technique employed in Basu, Fernald, and Kimball (2006).[4] According to Kawamoto (2005), the Solow residual is higher than HP's TFP growth rate for the 1990s, and the drop of utilization accounts for a large part of the decrease in the TFP growth rate.

A different approach involves the use of the *Index of Utilization*. This index is a statistic constructed by the Ministry of Economy, Trade and Industry (METI). Figure 4 displays that this index declined sharply in the 1990s. The average value in the 1990s is lower than that in the 1980s by approximately 10 percent. If this index is assumed to represent the entire Japanese economy, changes in capital utilization rates would have a large impact on the economy.

Fukao and Kwon (2003) provide two estimates of the TFP growth rate: one taking into account capital utilization with the Index of Utilization as the measure in the man-

[4]Basu, Fernald, and Kimball (2006) estimate the *purified technology*, which is a Solow residual that excludes the effects of variable factor utilization, increasing return to scale, and reallocation of inputs across sectors. They use estimation tools from Basu and Fernald (1997) and Basu and Kimball (1997), who are based upon Solow (1957) and Hall (1990).

ufacturing sector, and the other ignoring them. Their result indicates that for the 1990s the former is higher than the latter, and that the drop in the former from the 1980s to the 1990s is smaller than that in the latter.

Table 1 summarizes the results of Kawamoto (2005) and Fukao and Kwon (2003). Their results tell us that capital utilization rates declined in the Japanese economy in the 1990s, and that HP understimate the TFP growth rate for this period. However, we can not explain the cause of the drop in capital utilization rates so far.

Sugo and Ueda (2008) study the movement of capital utilization rates in the Japanese economy by using a dynamic stochastic general equilibrium model with variable capital utilization.[5] There are two important differences between this paper and theirs. First, although they discuss changes in capital utilization rates around the steady state, they do not consider the changes in the steady state. This paper pays attention to the prolonged decline in capital utilization rates. Next, they discuss whether their model can replicate the Index of Utilization. However, we doubt whether the Index of Utilization represents capital utilization rates of the entire Japanese economy, because its sample is limited to the manufacturing sector. For this reason, we calculate capital utilization rates using our model's properties, and compare the calculated values with our model's predictions.

[5]Following Greenwood et al. (1988), Sugo and Ueda (2008) modify the formulation of capital utilization in the model of Christiano, Eichenbaum, and Evans (2005). Then they estimate their model by using Bayesian techniques. The period of their data set is from 1981:Q1 to 1995:Q4. They end up their analysis in 1995 because of the zero lower bound on nominal interest rates.

3 Analysis

In this section, we first construct the neoclassical growth model in which the capital utilization and depreciation rate endogenously change. Next, by using the model's properties, the capital utilization rates, depreciation rates, and capital stocks are calculated, simultaneously with the calibration. Then, we perform the growth accounting with the calculated capital utilization rates and capital stocks. Finally, we explain the simulation procedure and results.

3.1 Model

Our model is based upon HP. Firms and households are homogenous, and markets are perfectly competitive. The government imposes capital income taxes and a lump-sum tax, and there is no uncertainty in the economy. The differences from HP are the inclusion of the variable capital utilization and depreciation.

We begin with the firm. The representative firm's profit, π_t, is

$$\pi_t \equiv Y_t - w_t h_t E_t - (r_t + \delta_t) K_t \ , \tag{5}$$

where Y_t is the output; h_t is hours worked per employee; E_t is the number of employees; w_t is the real wage; K_t is the amount of capital stock that households possess and firms can borrow. We employ a Cobb-Douglas production function as in equation (2).

Note that the cost of capital comprises two components: the net rental rate of capital r_t and the variable depreciation rate δ_t. As in Greenwood et al. (1988) and Burnside and Eichenbaum (1996), the depreciation rate is a function of capital utilization rate u_t as follows:

$$\delta_t = \bar{\delta} u_t^{\phi}. \tag{6}$$

The firm can choose its capital utilization rate but is required to pay for the depreciation of capital. The condition $\phi > 1$ is necessary in order to guarantee an interior solution.

The utility of the infinitely-lived representative household is

$$\sum_{t=0}^{\infty} \beta^t [N_t \log(C_t/N_t) - g(h_t)E_t] \ , \tag{7}$$

where C_t denotes consumption and N_t denotes the exogenous working-age population. We assume indivisible labor, that is, a household member can choose to work either h_t hours or not at all. $g(h_t)$ denotes disutility per employee which is a linear function of h_t as follows:

$$g(h_t) = \alpha(1 + (h_t - 40)/40). \tag{8}$$

The household decides the amount of investment X_t, and the accumulation of capital is

$$K_{t+1} = (1 - \delta_t)K_t + X_t \ . \tag{9}$$

The budget constraint at time t is

$$C_t + X_t \leq \omega_t h_t E_t + (r_t + \delta_t)K_t - \tau r_t K_t + \pi_t - T_t \ , \tag{10}$$

where τ is a capital income tax and T_t is a lump-sum tax.

Finally, the market-clearing condition is

$$C_t + X_t + G_t = Y_t \ , \tag{11}$$

where G_t denotes the government consumption.

3.2 Capital Utilization in the Steady State

In this subsection, we explain the most important feature of this model, that is, the capital utilization rate declines in conjunction with a decrease in the TFP growth rate in the steady state.

The first-order condition for u_t is given by

$$\theta \frac{Y_t}{u_t} = \phi \bar{\delta} u_t^{\phi - 1} K_t \ . \tag{12}$$

According to the depreciation function (6), this equation can be transformed into

$$\delta_t = \frac{\theta}{\phi} \frac{Y_t}{K_t} \ . \tag{13}$$

Then, the F.O.C. for K_t is

$$\theta \frac{Y_t}{K_t} = r_t + \delta_t \ . \tag{14}$$

Using equations (13) and (14), the Euler equation can be transformed as follows:

$$\begin{aligned} \frac{N_t}{C_t} &= \beta \frac{N_{t+1}}{C_{t+1}} [1 + (1-\tau) r_t] \\ &= \beta \frac{N_{t+1}}{C_{t+1}} \left[1 + (1-\tau) \left(\theta \frac{Y_t}{K_t} - \delta_t \right) \right] \\ &= \beta \frac{N_{t+1}}{C_{t+1}} \left[1 + (1-\tau) \theta \frac{\phi - 1}{\phi} \frac{Y_t}{K_t} \right] \ . \end{aligned} \tag{15}$$

In the steady state, the growth rate of consumption, C_{t+1}/C_t, converges to the growth rate of A_t. Hence, the Euler equation in the steady state is

$$\frac{\bar{Y}}{\bar{K}} = \frac{\gamma/(n\beta) - 1}{1-\tau} \frac{1}{\theta} \frac{\phi}{\phi - 1} \ , \tag{16}$$

where γ is the steady state TFP growth rate and n is the steady state population growth rate.

Equations (13) and (16) show the relation between the TFP growth rate and the capital utilization in the steady state. Equation (16) indicates that the capital-output ratio, which is the inverse of the expression on the left-hand side, increases when the TFP growth rate (γ) decreases. From equations (6) and (13), we can see the negative relation between the capital utilization rate and the capital-output ratio. This negative relation is the reason why a decrease in the TFP growth rate causes the drop in the capital utilization rate in the long run.

3.3 Calibration

Our model is calibrated to Japanese data. We follow HP's procedure to calibrate the values of θ (capital share), τ (capital income tax rate), α (disutility of working), and β (discount factor). To determine ϕ (curvature of depreciation) and $\bar{\delta}$ (parameter of depreciation), we use the features of the model.

The procedure for the calibration is as follows. The average capital income share in GNP from 1984 to 1989 is used for θ, while the average income tax rate is used for τ. The value of α, which is calculated from the first-order condition for e_t or h_t, is the average of the values from 1993 to 2000. The value of β is calibrated with the Euler equation, and is the average value over 1984–1989. Since we employ same procedure and data used in HP, the values for θ, τ, and α are identical those in HP. The value of β is slightly different because the data of capital stock constructed below is different from that in HP.

The most important parameter is the curvature parameter ϕ in depreciation function (6). However, no data is available to determine the values of the variables for capital utilization rate u_t and variable depreciation rate δ_t. For this reason, we calibrate ϕ using the characteristics of the model.

We set 1984 as the initial year, and use HP's data for the capital stock in 1984 (K_{1984}), GNP (Y_t) and investment (X_t). By pinning down $\hat{\phi}$, we can compute the depreciation rate in 1984 from equation (13):

$$\hat{\delta}_{1984} = \frac{\theta}{\hat{\phi}} \frac{Y_{1984}}{K_{1984}} \ , \tag{17}$$

and the aggregate capital in 1985 from

$$\hat{K}_{1985} = (1 - \hat{\delta}_{1984}) K_{1984} + X_{1984} \ . \tag{18}$$

Using the same procedure, we can calculate $\hat{\delta}_{1985}$ and $\hat{K}_{1986}$ from

$$\hat{\delta}_{1985} = \frac{\theta}{\hat{\phi}} \frac{Y_{1985}}{\hat{K}_{1985}} \ , \tag{19}$$

and

$$\hat{K}_{1986} = (1 - \hat{\delta}_{1985}) \hat{K}_{1985} + X_{1985} \ , \tag{20}$$

respectively. Repeating these steps, we can obtain a sequence of depreciation rates $\{\hat{\delta}_t\}_{t=1984}^{2000}$. Following the idea of Burnside and Eichenbaum (1996), we adopt a value for ϕ such that the average of the values generated for $\{\delta_t\}_{t=1984}^{2000}$ over 1984–89 is the same as that in HP.

The only remaining parameter to be calibrated is $\bar{\delta}$ in equation (6). We normalize u_t over 1984–89 to be one, and set $\bar{\delta}$ so as to satisfy this condition. Table 2 reports the calibrated values of the parameters and compares them with those in HP.

3.4 Growth Accounting

In the previous subsection, we calculated the capital utilization rates and capital stocks. The calculated capital utilization rates and METI's Index of Utilization are illustrated in figure 5. Although the Index of Utilization is more volatile,[6] both valuables show similar trends.

Given the calculated capital utilization rates and capital stocks, we can calculate TFP which takes into account capital utilization rates:

$$A_t = \left(\frac{Y_t}{(\hat{u}_t \hat{K}_t)^{\theta} (h_t E_t)^{1-\theta}} \right)^{1/(1-\theta)} . \tag{21}$$

Figure 6 compares our calculated TFP values with those of HP. We can see that for the 1990s our TFP growth rate is higher than that of HP. This is the result of taking into account the drop in the capital utilization rate. The calculated capital utilization rate in 2000 is 14 percent lower than the average over 1984–1989.

Table 3 reports the results of the growth accounting, which we divide into two subperiods. We can observe that, our theory regards the contribution of the TFP growth rate as the primary factor in the decline of the output growth rate per working-age person. On the other hand, we also consider the drop in the capital utilization rate to be important, the contribution of which is found to be as much as that of workweek length.

[6] Our interpretation is that this result reflects the well-known fact that the output of the manufacturing sector is more volatile than that of the entire economy.

3.5 Simulation

We begin the simulations at the year 1990, taking the calculated capital stock in 1990 as the initial state. The exogenous variables are the TFP (A_t), the working-age population (N_t), and share of government consumption in the GNP (ψ_t). From 1990 to 2000, we use the calculated values of A_t and data for N_t and ψ_t. For the simulations for the years after 2000, we assume the following: (i) the growth rate of A_t is 0.8%,[7] which is the average over 1991–2000; (ii) the growth rate of N_t is zero; and (iii) ψ_t is the 1999–2000 average, that is, 0.151. Since our theory is deterministic, we can find the perfect foresight solution by using a shooting algorithm.

3.6 Results

Figure 7 illustrates the aggregate output. Our model can replicate the actual GNP as closely as the one in HP. As shown in section 3.4 (growth accounting), there is a substantial difference between our TFP and that of HP. However, both theories lead to very similar results with respect to the Japanese GNP in the 1990s.

This result is due to the drop in capital utilization rates. Figure 8 illustrates the capital utilization rates calculated from the calibration (calculated) and the simulation (model). Both graphs show a sharp decline in the 1990s, and rates in 2000 are approximately 86 percent of the average over 1984–89. The decline in the TFP growth rate decreases the level of capital utilization, and worsens the depression compared to the economy in which

[7] *Japan Industrial Productivity Database 2008* (JIP 2008) reports that the TFP growth rate recovers after 2000. Thus, our assumption is unrealistic. However, this assumption has little effects on the results over 1990–2000.

the capital utilization rate are constant. The trends of the two lines are similar.

Figure 9 displays the capital-output ratio. Note that our data of capital stocks is different from that of HP because this is calculated such that the consistency with the model is guaranteed. Our model also performs well with the respect to the capital-output ratio.

4 Discussion: Depreciation and Saving Rate

We are basically interested in two aspects of the Japanese economy in the 1990s: economic stagnation and capital deepening. However, our theory has other important implications, that is, the Japanese depreciation and saving rates.

In Japan, although the net nation saving rate was prominently high, it is pointed out that the saving rate declined sharply over the 1990s. According to data in HP, the saving rate averaged 11.5 percent in 1984–1989, but it fell to 4.6 percent by 2000.[8] However, if variable capital utilization and depreciation are taken into account, these figures change. According to our data, the average net saving rate was 11.1 percent in 1984–89, which is not very different from HP's data; however, we find it to be 6.9 percent in 2000, which is 2.3 percent higher than that in HP. Figure 10 demonstrates that our model tracks the empirical fact reasonably well.

The difference from HP can be easily understood. We can express the net saving rate

[8] On this issue, Chen, Imrohoroglu, and Imrohoroglu (2006) claim that a simple RBC model with TFP can capture the movements of the net saving rate. Braun, Ikeda, and Joines (2006) reveal that an overlapping generations model incorporating the population structure and TFP can explain the historical variation.

as follows:

$$\frac{X_t}{Y_t} - \frac{\delta_t K_t}{Y_t} \ . \tag{22}$$

In the case of a constant depreciation rate ($\delta_t = \delta$), the rise in the capital-output ratio (K_t/Y_t) decreases the net saving rate. However, with respect to an economy with variable capital utilization and depreciation rate, the second term of the right-hand side in equation (22) becomes constant because equation (13) is transformed as follows:

$$\frac{\delta_t K_t}{Y_t} = \frac{\theta}{\phi} \ . \tag{23}$$

Our calculated capital stocks and depreciation rates hold in this relation because our calibration procedure guarantees the consistency with the model.

In this section, we established the possibility that the official statistics overestimates the depreciation rates in the Japanese economy in the 1990s. As a result, the net saving rate calculated in HP might be lower than the true value. Thus, the above discussion implies that assumptions on capital utilization and depreciation rate are important. In particular, this problem is crucial because it can have a large impact on capital measurement.

5 Conclusion

This paper examined the role of capital utilization during the lost decade in Japan. We calibrated a neoclassical growth model—incorporating variable capital utilization—to

Japanese data and simulated the aggregate output and capital-output ratio.

The results can be summarized as follows. Although the TFP growth rate that we employ is higher than that of earlier research (i.e., in Hayashi and Prescott (2002)), the aggregate output predicted by our model is as close to the data as HP's predictions. According to our analysis, a decline in the TFP growth rate decreases the level of capital utilization, which explains the lower growth rate of output in the 1990s. At the same time, the simulated capital-output ratio is consistent with the data. In addition, by taking into account variable capital utilization and variable depreciation rate, we found that the Japanese net saving rate in the 1990s was actually higher than previously indicated. This is because a decline in the depreciation rate is concurrent with a drop in the capital utilization rate.

It is well known that capital utilization is an important mechanism in the propagation of shocks over the business cycle. However, this paper implies that even in the long-run, the capital utilization rate can change, which, in turn, can have vital effects on many aspects of the economy. Therefore, although it is difficult to investigate variable capital utilization rates and depreciation rates because of data limitations, we believe that further research is required on this issue.

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Table 1: Purified TFP

	Proxy	80s	90s
Fukao and Kwon (2003)	Index of Utilization	0.43 (0.54)[1]	0.23 (0.11)[2]
Kawamoto (2005)	hours worked	2.3 (2.6)	2.1 (1.1)[3]
Hayashi and Prescott (2002)	- - -	- - - (3.7)	- - - (0.3)

Note: This table displays the estimated TFP growth rates (%) which takes into account the effect of capital (factor) utilization. The values in parentheses show the TFP growth rates in the case of ignoring the capital (factor) utilization.

[1] from 1983 to 1991
[2] from 1991 to 1998
[3] from 1990 to 1998

Table 2: Calibration

Parameter	Value	HP[1]
θ (Capital Share)	0.362	0.362
β (Discount Factor)	0.975	0.976
α (Working Disutility)	1.373	1.373
τ (Capital Income Tax Rate)	0.480	0.480
ϕ (Curvature of Depreciation)	2.203	- - -
$\bar{\delta}$ (Parameter of Depreciation)	0.0889	- - -

[1] Hayashi and Prescott (2002)

Table 3: Accounting for Japanese Growth per Person Aged 20-69

Period	GrowthRate	Factors				
		TFP	Capital Intensity	Capital-Utilization	Workweek Length	Employment Rate
	Y_t/N_t	A_t	$(K_t/Y_t)^{\theta/(1-\theta)}$	$u_t^{\theta/(1-\theta)}$	h_t	E_t/N_t
1984-1991	3.6 %	3.7 %	0.7 %	-0.4 %	-0.7 %	0.2 %
1991-2000	0.5 %	0.8 %	1.7 %	-0.8 %	-0.9 %	-0.4 %

Note: from Cobb-Douglas production function (2), our growth accounting becomes

$$\frac{Y_t}{N_t} = A_t \left(\frac{K_t}{Y_t}\right)^{\theta/(1-\theta)} u_t^{\theta/(1-\theta)} \, h_t \, \frac{E_t}{N_t}.$$

Figure 1: Detrended Real GNP per Working-age Person

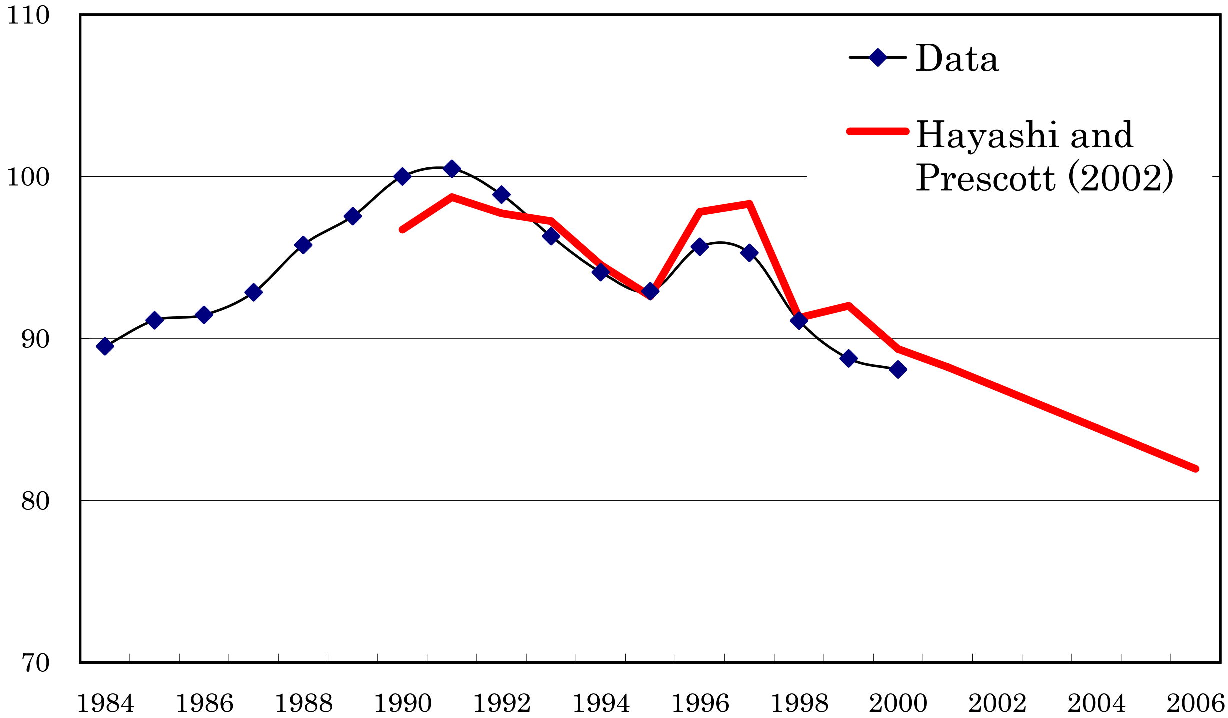

Figure 2: Capital-Output Ratio

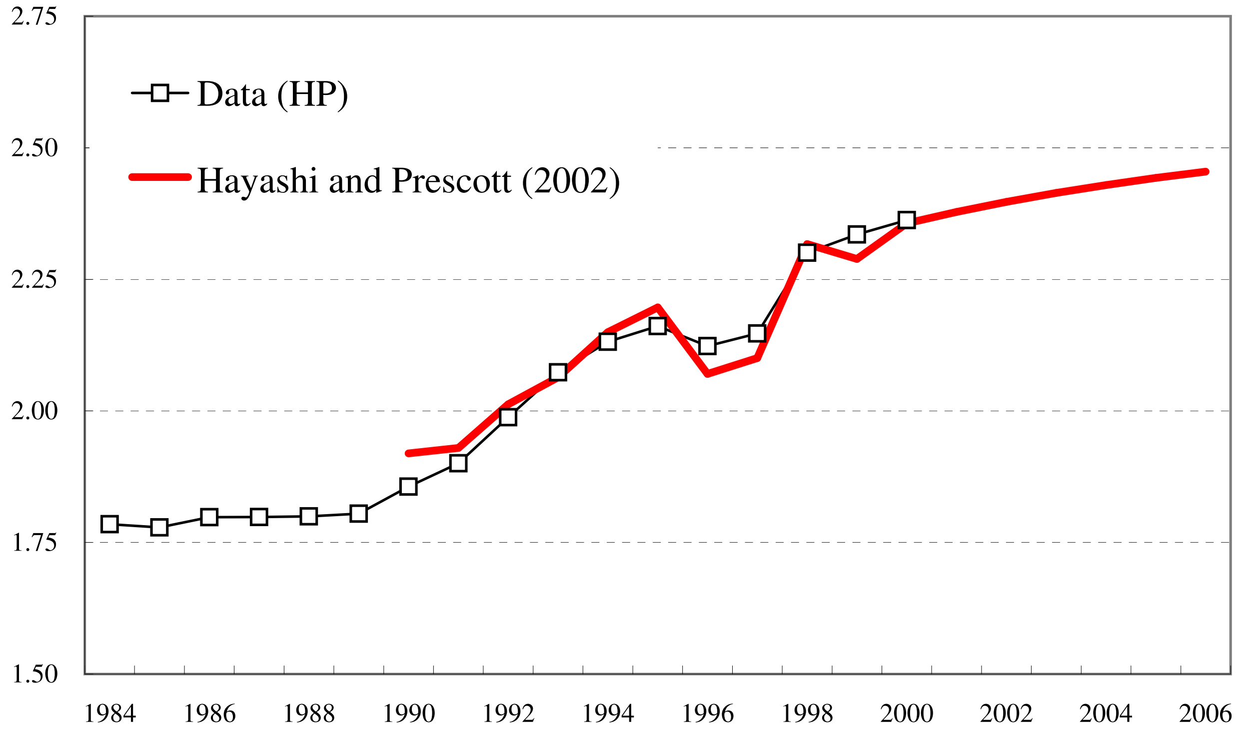

Figure 3: TFP of Hayashi and Prescott (2002) (Level, 1984 = 1.00)

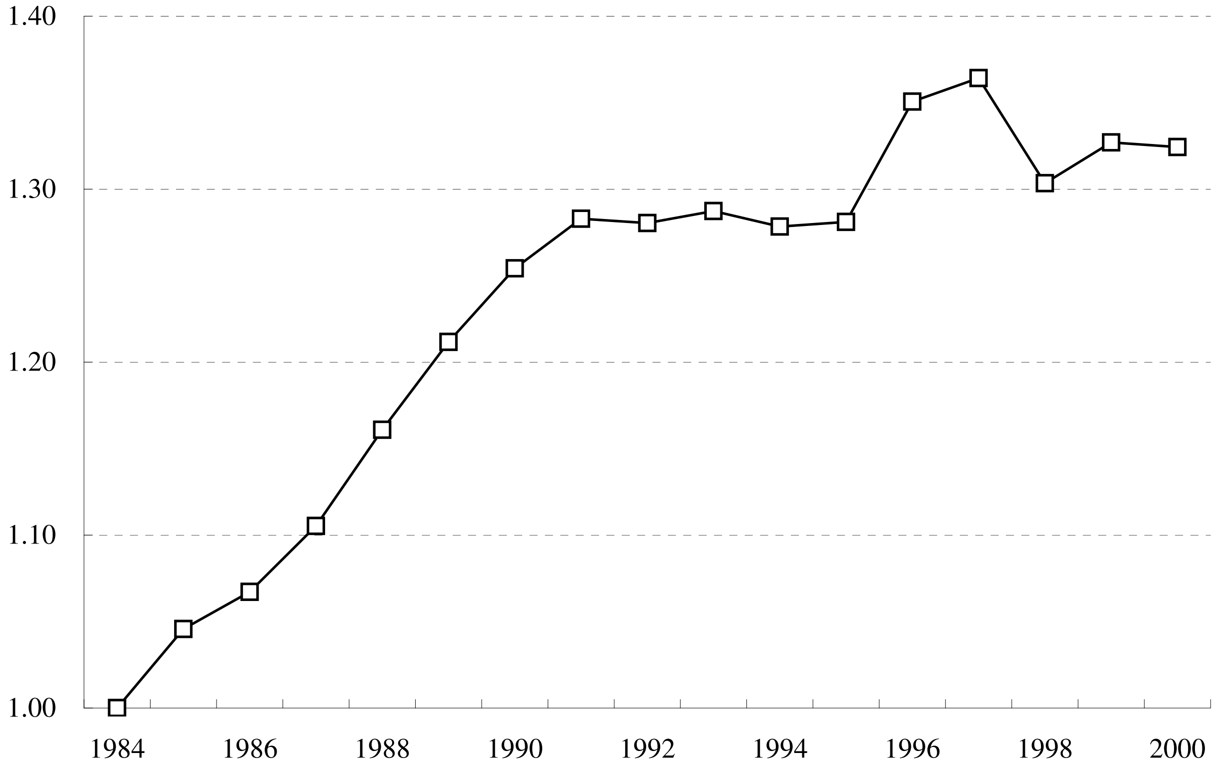

Figure 4: Index of Utilization (84-89 average = 1.00)

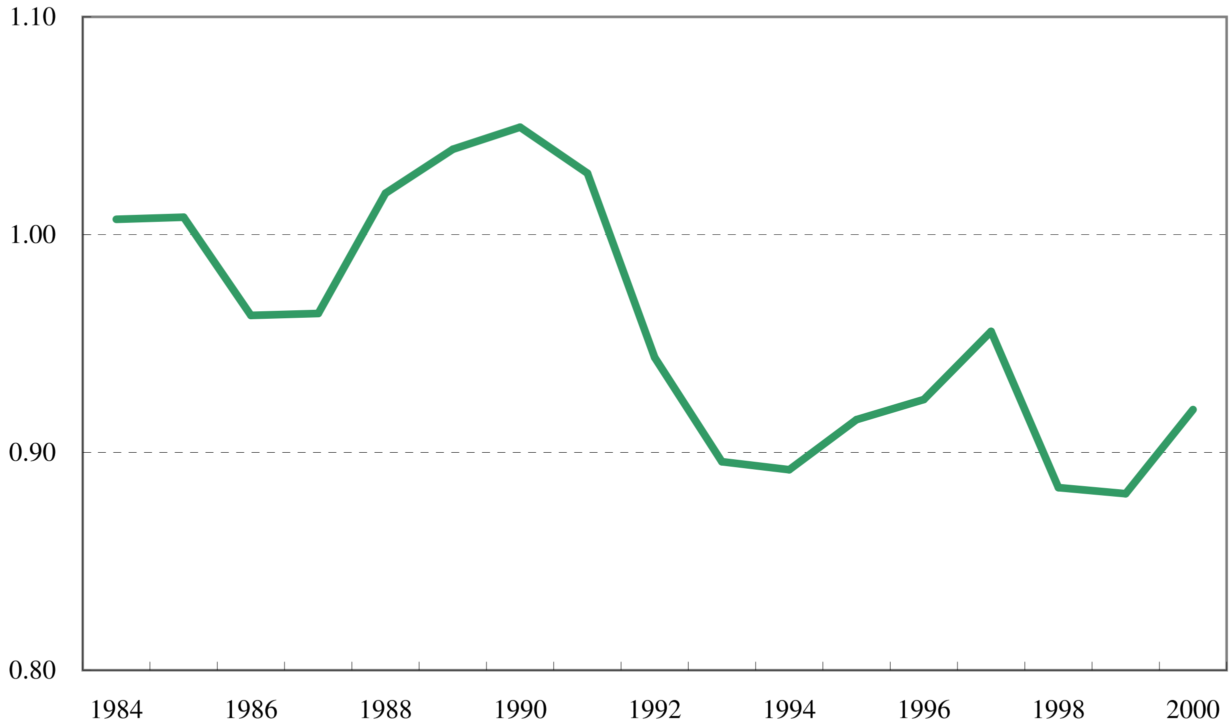

Figure 5: Capital Utilization (84-89 average = 1.00)

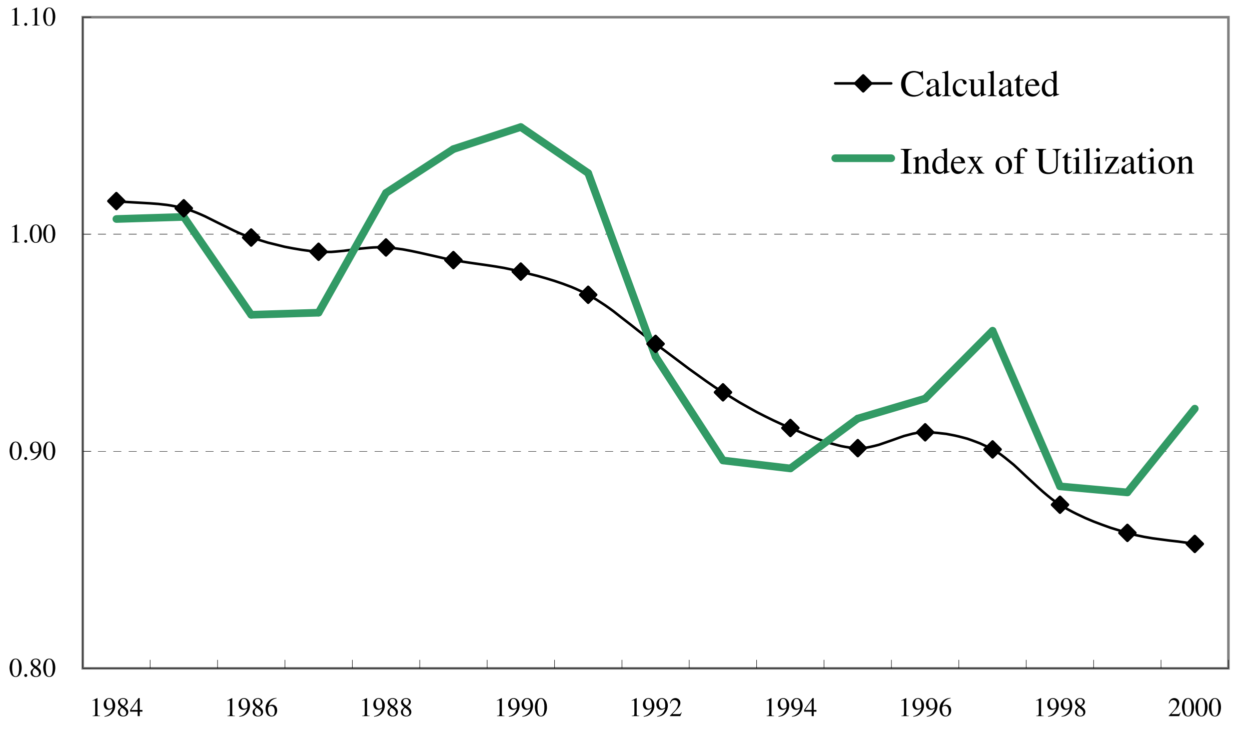

Figure 6: TFP (Level, 1984 = 1.00)

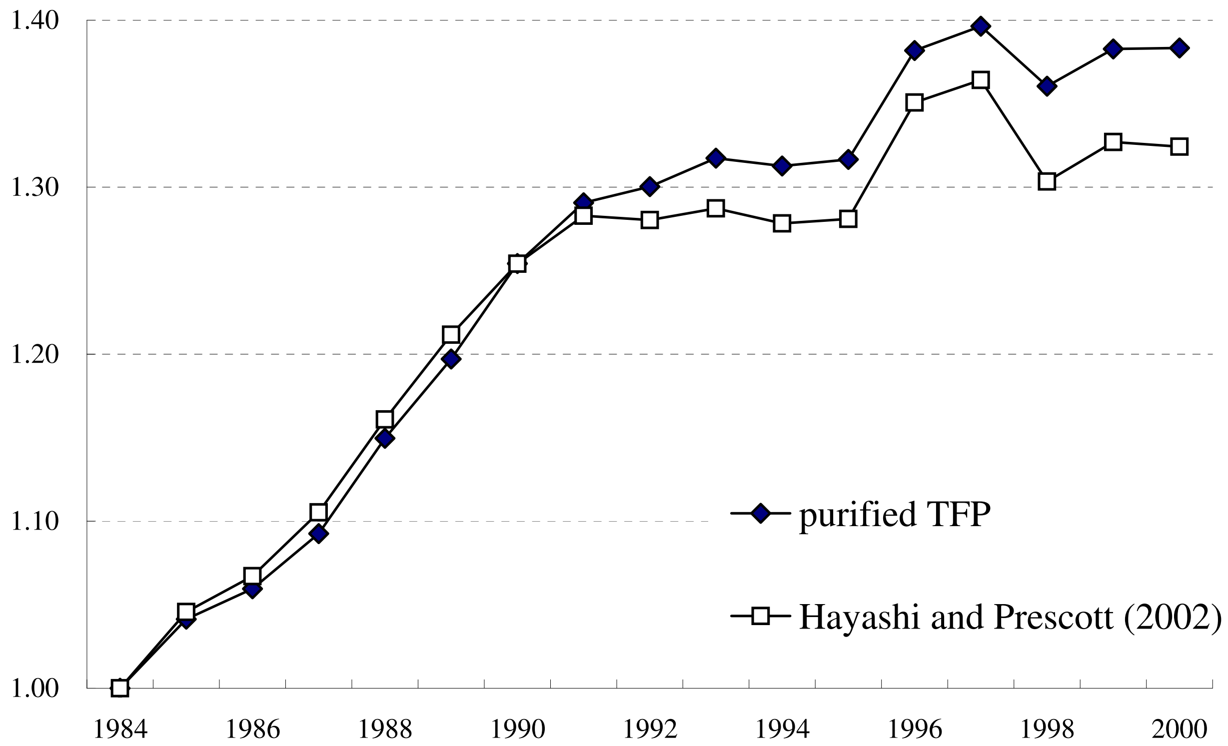

Figure 7: Detrended Real GNP per Working-age Person

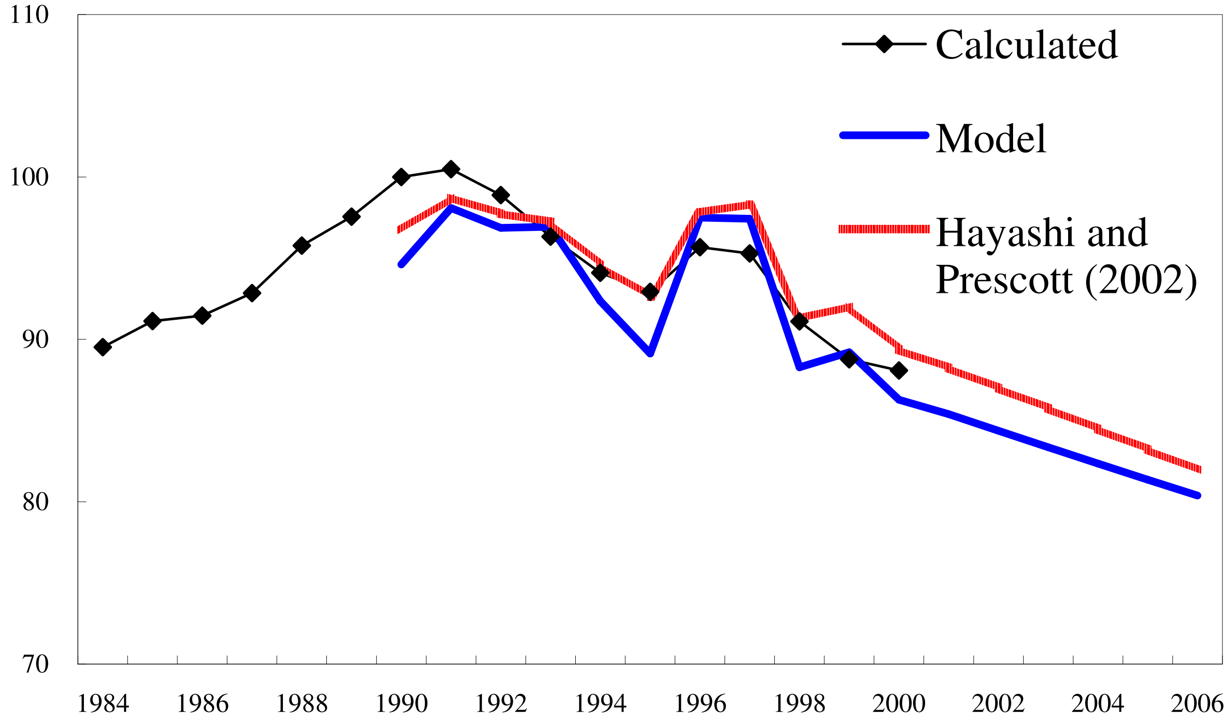

Figure 8: Capital Utilization (84-89 average = 1.00)

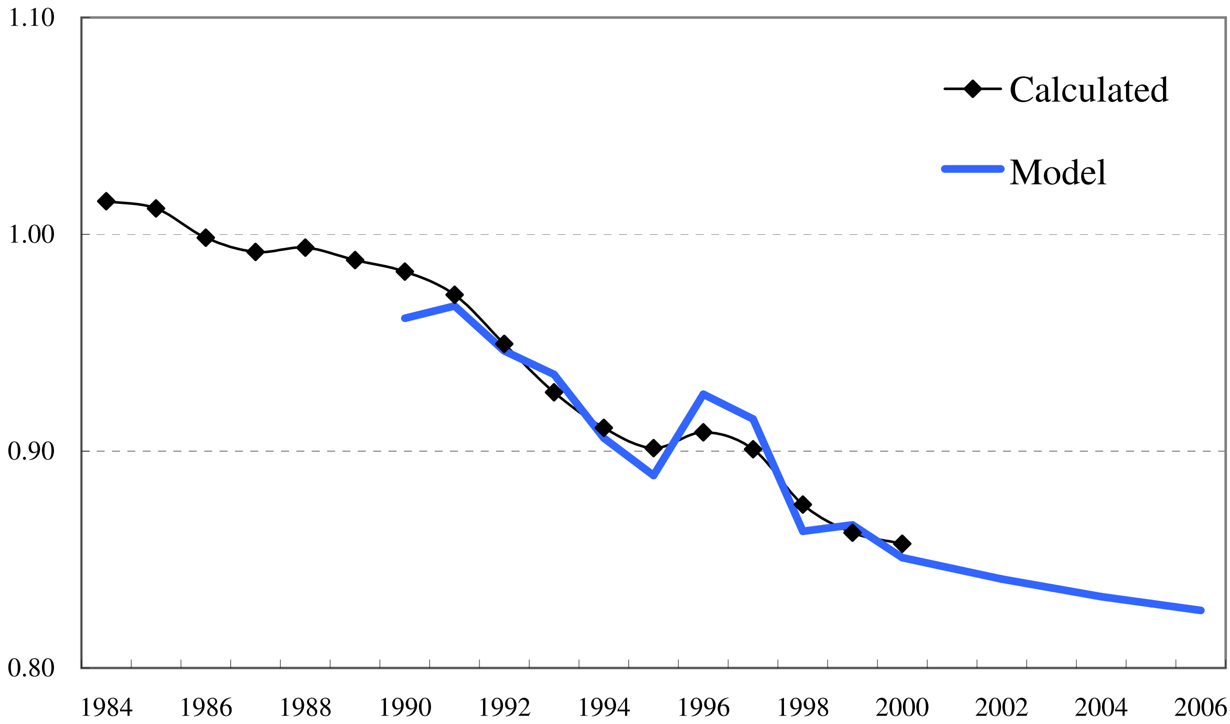

Figure 9: Capital-Output Ratio

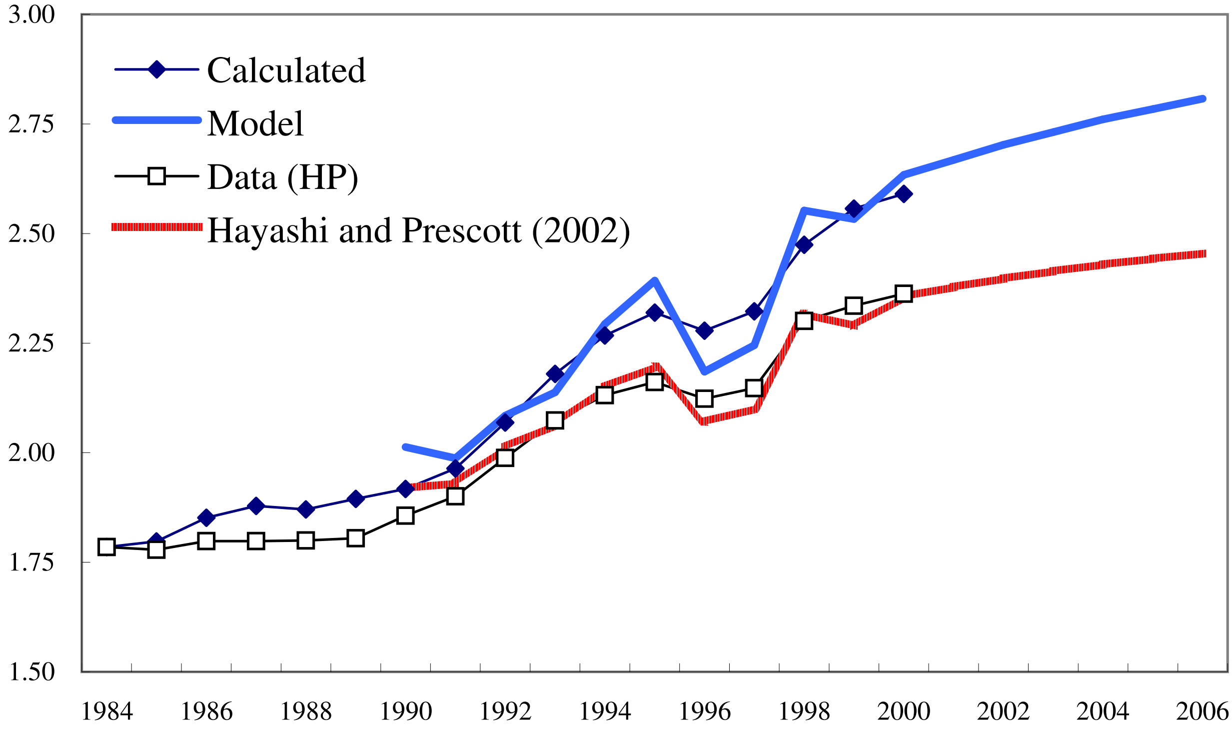

Figure 10: Net Saving Rate (%)