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CRITICAL EVALUATION OF THE HAYASHI-PRESCOTT HYPOTHESIS ON JAPAN'S LOST DECADE

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Abstract

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ABSTRACT

Hayashi and Prescott [Rev. Econ. Dyn. 5 (2002) 206] present a controversial hypothesis stating that Japan's economic slump during the 1990s was a purely supply-side phenomenon, caused by a fall in total factor productivity as in workweek length. This paper scrutinizes their model and exercise to critically evaluate their case and reports three major findings. First, their simulation outcomes are sensitive to the values of the discount factor and the capital income tax rate. Second, in a hypothetical situation in which the total factor productivity (TFP) continues to grow, as in the 1980s, the model yields a counterfactual outcome whereby Japan would have experienced a *more severe* recession in the first half of the 1990s. These two results are driven by the feature of the endogenous labor supply added to the standard growth model. Third, the model's performance is rather poor when applied to the 1980s. These findings cast some doubt on the validity of their hypothesis on Japan's lost decade.

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Abstract

Hayashi and Prescott [2002. The 1990s in Japan: a lost decade. Review of Economic Dynamics 5, 206-235] present a controversial hypothesis that Japan's economic slump during the 1990s was a purely supply-side phenomenon, caused by a fall in TFP growth rates and workweek length. This paper scrutinizes their model to critically evaluate their case and reports three major findings. First, their simulation outcomes are sensitive to the values of the discount factor and the capital income tax rate. Second, in a hypothetical situation in which TFP continues to grow as in the 1980s, the model yields a counterfactual outcome whereby Japan would have experienced a more severe recession in the first half of the 1990s. These two results are driven by the endogenous labor supply feature added to the standard growth model. Third, the model performs rather poorly when applied to the 1980s. These findings weaken their hypothesis on Japan's lost decade.

CRITICAL EVALUATION OF THE HAYASHI-PRESCOTT HYPOTHESIS ON JAPAN'S LOST DECADE

1. Introduction

After some 40 years of rapid growth, Japan suddenly fell into serious economic stagnation at the beginning of the 1990s. This lasted for more than 10 years and turned out to be the worst recession since the end of World War II. The search for the true cause of this recession, or, more popularly "Japan's lost decade," has dominated much of the discourse on economic policies in Japan over the last 15 years or so, but has not yet been resolved. A range of explanations has been offered, such as fiscal and monetary policy mistakes and malfunctioning of the financial sector. In stark contrast to these views, Hayashi and Prescott (2002) offer a vastly different account, stating that the true cause was a fall in growth rates for total factor productivity (TFP), together with a decline in workweek length initiated by the labor law amendments in the late 1980s. They base this claim on the results of a simulation exercise using a variant neoclassical growth model. Their paper, although controversial, seems to have gained support in the academic literature.[1]

In view of its clear-cut understandability, the controversies it engenders, and its increasing importance in the literature, we think it worthwhile to examine Hayashi and Prescott's (2002) exercise in greater detail to critically evaluate their case. More specifically, after briefly reviewing their model and exercise,[2] we report three major findings. First, the model's fit sensitively depends on the values of the discount factor and the capital income tax rate. Second, in working with hypothetical TFP series, the model yields a counterfactual outcome, whereby the real GNP per working-age person would have been lower, implying a more severe recession, in the first half of the decade if TFP had continued to grow as in the 1980s. Third, the model performs rather poorly when applied to the 1980s. These findings weaken the Hayashi-Prescott hypothesis on Japan's lost decade.

2. Brief Overview of the Hayashi-Prescott Model

[1] More studies seem to be emerging along the same lines; see Morana (2004) and Andolfatto (2003), for example.

[2] Such a review may be regarded as redundant, but we consider it beneficial to the reader, because the bulk of the modeling and exercise details discussed here are expanded only in the appendix of their unpublished postscript in August 2003, and not in the original article.

Hayashi and Prescott (2002) use a one-sector neoclassical growth model of an infinitely lived household in a perfect-foresight setting; its production function is $Y_t = A_t K_t^{\theta} E_t^{1-\theta}$, where Y, A, K, E, and θ are, respectively, real output, TFP, capital input, labor input, and capital share of income. This is a standard set-up, but the Hayashi and Prescott model deviates by assuming an indivisible labor supply according to Hansen (1985) and Rogerson (1988), whereby a member of the household either works for a set number of hours or does not work at all. The representative household chooses *c*, the consumption per working-age member of the household, and *e*, the ratio of those who actually work to the total number of working-age members, to maximize the household's instantaneous utility over the infinite horizon:

$$N_t * U(c_t, e_t, h_t; z_t) = N_t * [\log c_t - g(h_t; z_t) e_t],$$

were N is the number of working-age members in the household[3] and U denotes the utility of one such member; h and z are weekly hours and days worked, respectively, if employed, so $g(h_t; z_t)$ represents the loss of utility due to being employed. $E_t = h_t e_t N_t$ is taken as the total number of hours worked per week. Labor disutility is affected by the number of *hours* worked per week, as well as the number of *days* worked a week; thus, g is written as $g(h_t; z_t)$. It is important to note that, in maximizing its utility, the household controls the number of household members to be employed, *e*. Because of this, the level of output changes through the choice of *e*.[4]

The usual household optimization, together with factor market-clearing conditions, reduces the model, after some modifications, to:

$$\tilde{c}_{t+1} = \frac{\tilde{c}_t}{\gamma_t} \beta [1 + (1-\tau)(\theta \left(\frac{\tilde{c}_{t+1}}{(1-\theta)(h(z_{t+1})/g(h(z_{t+1}); z_{t+1}))} \right)^{\frac{\theta-1}{\theta}} - \delta)] \tag{1}$$

$$\tilde{k}_{t+1} = \frac{1}{\gamma_t n_t} [(1-\delta)\tilde{k}_t + (1-\psi_t) \left(\frac{\tilde{c}_t}{(1-\theta)(h(z_t)/g(h(z_t); z_t))} \right)^{\theta} - \tilde{c}_t], \tag{2}$$

where the tilde over the variable indicates a specific form of normalization to adjust for TFP as, for instance, $\tilde{k} \equiv k / A^{1/(1-\theta)}$. When the household acts to minimize the disutility, h_t is uniquely determined by z_t as $h(z_t)$, such that $g(h_t; z_t) \equiv g(h(z_t); z_t)$.[5] The current

[3] Thus, household maximization does not take into account at all those younger and older than the working age; it chooses the consumption per working-age person to maximize the total utility of working-age members. This assumption is slightly awkward, since in reality households do care for pre-working age youths and retired seniors.

[4] The assumption that a person can always obtain a job if so desired may appear too unrealistic, but recall that this is a completely supply-side model in a perfect-foresight environment. In the original papers by Hansen (1985) and Rogerson (1984), in which a stochastic environment is considered, a person chooses employment probability in the form of lotteries that determine whether he/she actually obtains employment or not, once chosen.

[5] Note a unique feature that, unlike the standard growth model, $\tilde{c}$ has its own law of motion,

values for $\tilde{k}$ and $\tilde{c}$ given by the actual data are very different from the Hayashi-Prescott steady-state values, $\tilde{k}^*$ and $\tilde{c}^*$, dictated by their choice of values for the parameters and exogenous variables in the steady state. Hayashi and Prescott (2002) therefore regard the current economy as in the transition path towards the steady state. They then solve the two equations computationally given the initial value for $\tilde{k}$ taken from actual data on the one hand, and $\tilde{k}^*$ and $\tilde{c}^*$, on the other. The initial value for $\tilde{c}$ and the "solution" to the above dynamic equations are simultaneously determined using a shooting algorithm. In doing so, Hayashi and Prescott (2002) specify $h(z_t)/g(h(z_t);z_t)$ by linearly approximating $g(\,;\,)$ in the neighborhood of $h(z_0)$, where z_0 denotes the steady value of z, which leads to $h(z_t)/g(h(z_t);z_t)) = z_0/\alpha$. This cannot be done, however, when z_0 is not stationary, as in 1990–1992, but this issue is ignored.[6]

Finally, the parameters and exogenous variables are calibrated, basically using SNA data. Together with these values, Hayashi and Prescott (2002) projected TFP into the future, assuming that its growth rate, γ_t for t =2001, 2002, …, will be the same as in the 1990s. The results of their simulation are compared against actual data in terms of the real GNP per working-age person, $y \equiv Y/N$, the capital-output ratio, and the after-tax rate of return to capital, in Figures 6–8 of their paper. Hayashi and Prescott (2002) stated that differences are "not bothersome," and claimed good explanatory power of their model.

3. Parametric Sensitivity

In the first phase of our evaluation, we examine the sensitivity of the simulation outcomes to the parameter values. We performed this task for all five parameters α, n, β, τ, and θ within a meaningful range of values, and found that the results for the real GNP per working-age person are rather sensitive to β and τ. Hayashi and Prescott (2002) used 0.976 for β and 0.48 for τ. They obtained these values as follows. They first calculated τ =0.48 for each year as the sum of direct taxes on corporate income, 50% of indirect taxes, and 8% of operating surpluses in the non-housing component of the non-corporate sector, and averaged these year-by-year values over 1983–1990. Note that

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independent of $\tilde{k}$. This stems from the first order condition for e, which provides the third "bridge" between c and k (via wages), whereby reducing the usual simultaneity. Very likely because of this, $\tilde{c}$ exhibits very strong convergence to its steady-state value, the graphical presentations of which are available upon request.

[6] As mentioned in section 5, the appendix of the Hayashi-Prescott 2003 postscript uses *actual data* to obtain $\left(\dfrac{\tilde{c}_t}{(1-\theta)(h(z_t)/g(h(z_t);z_t)}\right)^{1/\theta} = \dfrac{\tilde{k}_t}{e\ h(z_t)}$ and circumvent this problem.

these figures are not well grounded in any empirical evidence[7] and that the derivation procedure completely omits the interest and dividend taxes in personal income tax. After obtaining τ in this way, they calculated β to be 0.976 using the Euler equation for each year and again averaged them over the same period. Note, however, that there is no general agreement on these values in the empirical literature. For β, for instance, Abe and Yamada (2005) reported 0.983 and 0.971 for two different assumptions regarding the real interest rate. Hamori (1996) estimated that β ranges from 0.941 to 0.984 from various sample periods. For τ, Tajika and Yui (1990) reported 0.390 and 0.424 for 1987 and Ueda (2001) reported 0.372 and 0.414 for the period 1985–1998, each using two estimation methods.

In view of all these observations, we experimented with other possible values for β and τ than those used by Hayashi and Prescott (2002). Our choices of β are 0.941 and 0.984, the two extreme values estimated by Hamori (1996). For τ, we chose 0.40 and 0.55; choice of the former is motivated by the empirical estimation, while 0.55 was the value obtained using the Hayashi-Prescott calibration if, keeping the 50% and 8% figures above, we add the household capital income taken from SNA and multiply it by the rate of 0.15.[8] Note, however, that the two parameters are dependent on one another in the Euler equation, so that changing one necessarily alters the other. Therefore, the combinations of (β, τ) in the experiments would be (0.941, 0.13), (0.984, 0.56), (0.967, 0.40), and (0.983, 0.55). β=0.41 leads to an implausible value of τ =0.13, however, and thus was dropped. The second and fourth pairs are very similar, so only the second and third pairs are used below. Figure 3-1 shows the results, which indicate that the trajectories shift rather sensitively. This seems to challenge the Hayashi-Prescott claim that their model predicts well the movement of y.

[Figure 3-1]

At this conjecture it is worth exploring the mechanism behind this parametric sensitivity; for, the reader may recall that in the standard neoclassical growth model, the non-sensitivity to changes in τ is supposedly warranted by the offsetting adjustments in β, and vice versa. To confirm this, we experimented with the same

[7] For 50%, it is stated (p. 22, l-6-7 in the 2003 version) that they use this value "for lack of better alternative." No mention is made at all of 8%.

[8] Various combinations of the corporate sector share of total indirect taxes and the tax burden of the operating surpluses in the non-housing component of the non-corporate sector can yield these two values easily. When the interest and dividend taxes are considered, values greater than 0.55 can be obtained more plausibly. This is also true when values greater than 0.15 are used for the tax rate on household capital income. The statutory tax rates on the interest and dividend income in the late 1980s

parameter changes for the standard model. For the Hayashi-Prescott and standard models, Figure 3-2 compares the trajectories of y under the two sets of alternative parameter values *relative to* that under the original values of β =0.976 and τ =0.48. For each year, the value of y under the alternative parameters is divided by that under the original parameter, so that the line would be a straight horizontal line if there were no shift at all. It can be confirmed that the Hayashi-Prescott model is certainly more sensitive than the standard model. Since the major difference between the two models lies in the labor supply, the difference in parametric sensitivity must arise from this. When future utility becomes more "valued," the agent consumes less and saves more, so that he/she can enjoy more consumption in the future. This is the end of the story in the standard model, in which labor supply is exogenous. When labor supply is endogenous, however, the agent can also change the labor supply to boost output, so that even greater consumption can be enjoyed in the future. In other words, the current value of y is boosted in two ways in the Hayashi-Prescott model: first, by cutting current consumption and increasing savings; and second, by increasing the labor supply. Figure 3-3 exhibits the movements of employment, e, together with the actual data, when the parameters β and τ are changed.[9] Consistent with the logic above, higher β is associated with higher e. The consumption profiles in the Hayashi-Prescott and standard models in Figure 3-4 are also consistent with the above rationale.

[Figure 3-2]

[Figure 3-3]

[Figure 3-4]

4. Experiments with Hypothetical TFP Growth Rates

Next, we examine the model's performance with respect to the most important variable, γ, the growth rate of TFP. Recall that Hayashi and Prescott (2002) projected TFP into the future assuming that its growth rate, γ, would be the same as in the 1990s. In what follows, we determine the model prediction of what would have happened to the Japanese economy had the TFP growth rate not fallen as much as it actually did during the decade. To do so, we conduct the same simulation as Hayashi and Prescott (2002),

are 0.26 and 0.2, respectively.

[9] By the way, besides the points of the current paper, the Hayashi-Prescott model does not overcome one weakness of the real business cycle model to match the data on labor input.

with hypothetical TFP series that are increasing at a constant rate γ_{mean} from 1990 onward. For γ_{mean}, we choose two values: (a) 1.0029 and (b) 1.0188. Value (a) is the average TFP growth rate in the 1990s and used for 2001 onward in the original Hayashi-Prescott model; it reproduces the Hayashi-Prescott outcome without the fluctuations during the 1990s. Value (b) is the average TFP growth rate between 1981 and 1986, i.e. the 1980s exclusive of the bubble period. Figure 4-1 shows that, surprisingly, the trajectory for (b) lies below that for (a) before it "surpasses" (a) around 1996.[10] This would imply that if the TFP growth rate had not fallen as much as it did in the 1990s and continued to growth as in the 1980s, the real GNP per working-age person would have been *lower*, not higher, until 1996. In other words Japan would have experienced a *more severe* downfall in output in the early 1990s. This is rather the opposite of the Hayashi-Prescott claim that the fall in TFP caused the recession in the 1990s.

[Figure 4-1]

This curious movement in y deserves further discussion. Recall that in the simulation exercise, $\tilde{k}$ is fixed as the actual value on the initial date when the transition path is searched for; thus, the fall in y *on the initial date* must be driven by the fall in e. Figure 4-2, which depicts the trajectories of e for the above two values of γ_{mean}, confirms this. The trajectory for γ_{mean} =1.0188 lies below that for γ_{mean} =1.0029 on the initial date, as well as along the rest of the transition path. To better understand the mechanism behind this, it is worth checking the movements of c and k as well. According to Figure 4-3, c shifts upward throughout when γ_{mean} is higher. Figure 4-4, on the other hand, shows that k shifts first downward and then upward all the way to the steady state. One interpretation of these outcomes, which is consistent with this perfect-foresight model, is as follows. If the agent knows for sure that the TFP growth rate will be "higher" in the future, he/she increases *both* consumption and leisure (i.e. cuts back labor supply) at present, as well as in the future, since, with higher productivity now and in the future, he/she can afford not to save or work as much as

[10] The simulation program does not yield convergence with a high value for γ_{mean} when the original convergence criterion of 1/1000 is employed. The result reported here for (b) is based on the "looser" criterion of 1/200. To supplement this, retaining the original criterion, we conduct the simulation with γ_{mean} =1.013, the average growth rate of the 1970s, and obtain the same type of outcome, a lower y in the first half of the 1990s. In this case, the interpretation is "the real GNP per working-age person would have been lower if the TFP growth rate had not fallen as much and only reverted to that in the 1970s." Since choice of the criterion is *not* of essential significance in this exercise, we report the result for 1.0188 with the changed convergence criterion because it is simpler to interpret.

he/she would otherwise. Because *both* consumption and leisure increase, capital accumulation slows down in the near future, although it picks up eventually due to the higher productivity.

[Figure 4-2]

[Figure 4-3]

[Figure 4-4]

It is important to note, however, that the increase in leisure (decrease in labor supply) can only occur when labor supply is endogenous. In fact, an endogenous labor supply drives down y, which is most clearly shown by the fall in y on the initial date. To better grasp this point, Figures 4-5 through 4-7 report the results of the same exercise for y, c, and k in the standard model. Here, c and k exhibit similar shifts, but y does not shift down at all.[11] The movements of c and k are interpreted in the same way, but, since there is no decrease in labor supply here, y is not pulled down in the near future. Since the movement of e in the Hayashi-Prescott model is perfectly consistent with utility-maximizing behavior, the "reverse shift" in y during the early 1990s does not represent an anomaly in terms of *theory*, but may cast some doubt on the validity of its *application* to the Japanese economy in the 1990s. In particular, while supposedly being of intrinsic value, adding the endogenous labor feature brings in these counterfactual movements in y and e.

[Figure 4-5]

[Figure 4-6]

[Figure 4-7]

5. Application to the 1980s

In this section, we apply the Hayashi-Prescott simulation to the preceding decade to determine whether it has the same level of "explanatory power." That is, we use the

[11] Recall that the increase in γ_{mean} offsets the fall in $\tilde{k}$.

model to predict what would have happened from 1980 onward, taking the parameter values from the data in the 5 years prior to the initial date, 1980, as in the original Hayashi-Prescott exercise. One caution must be exercised here. Although this extension yields the results in the 1990s as well, the closeness between the model and the data in that period cannot be properly assessed, because the parameter values may have changed in 10 years or so. Therefore, the model's performance should be judged only in the 1980s.

Here, we run two versions of the Hayashi-Prescott simulation. Recall that Hayashi and Prescott (2002) linearized the labor disutility function around the steady value between 1990 and 2000, but this linearization is inappropriate for 1990–1992, since z showed a decline in these years. To circumvent this, in the appendix of the 2003 postscript, Hayashi and Prescott (2002) used *actual data* to obtain $\left(\frac{\tilde{c}_t}{(1-\theta)(h(z_t)/g(h(z_t);z_t)}\right)^{1/\theta} = \frac{\tilde{k}_t}{e\ h(z_t)}$ and call the decrease in $\tilde{y}$ due to a fall in z the level-down effect. Here, simulations are performed based on models both with and without this level-down effect, since it is not clear whether it would be more appropriate to use the actual data to circumvent this problem or to ignore the steady decline in z in 1989–1992 completely.

Figures 5-1 through 5-3 present the results.[12] The overall impression is that both models perform rather poorly in the 1980s. It may be argued that the model with the level-down effect is somewhat closer to the data for real GNP per working-age person, y, in the second half of the decade, but this could be due to use of the actual data for 1989–1992; the model's anomalous movements after 1988 for the capital-output ratio and after-tax rate of return may clearly reflect this. Besides these technicalities, the second part of the 1980s is the well-known bubble period, during which macroeconomic performances were beyond all expectations several years prior. In this sense, the model's performances towards the end of the decade may not be accurately assessed in any case; however, performances in the first half of the decade, which was a "normal" period, can be. Therefore, the failure of both models to replicate the data closely, particularly the counterfactual of falling GNP per working-age person in the first half of the decade, suggests that the Hayashi-Prescott model may have problems in explaining Japanese macroeconomic growth in the 1980s.

[Figure 5-1]

[12] LDE in the figures refers to the level-down effect.

[Figure 5-2]

[Figure 5-3]

Of course, it can be argued that the model proposed by Hayashi and Prescott (2002) is intended *only* for the 1990s and therefore that its poor performance for the 1980s has no significant meaning. While it is logically *possible* and is probably impossible to refute, at least in this framework, we disagree with this argument. For, we think that the model should be tested over a longer period than a decade or so; in fact they are usually tested over several decades in the typical RBC literature. We wonder how much confidence we should place on the model that can account for the 1990s but not other periods. In this sense, we think that the inapplicability of the model in the 1980s as shown constitutes a drawback of this model.[13]

6. Concluding Remarks

This paper has closely examined the simulation exercise of Hayashi and Prescott (2002) to evaluate their main claim that Japan's lost decade was caused purely by supply-side factors, a downfall in the TFP growth rates and workweek length, rather than by, say, policy mistakes, as popularly argued. After a brief overview of their model/exercise, we first checked the parametric sensitivity of the original exercise and found that the outcomes are rather sensitive to changes in the tax rate and discount factor. This contrasts with the standard neoclassical growth model and results from the labor supply endogeneity assumed in the Hayashi-Prescott model; the agent changes not only the consumption profile, but also the labor supply schedule, leading to greater variability in the output. Since there is no general agreement on the values of these parameters, this parametric sensitivity may represent a certain weakness in the Hayashi-Prescott claim. Next, we examined how the simulation result alters when the key variable in this model, the TFP growth rate, changes. In particular, in a hypothetical experiment, we determined what the model predicts would have happened had the TFP continued to grow as in the 1980s and surprisingly found that the real GNP per working-age person

[13] Prof. Hayashi commented that these poor performances may be due to the unreasonable assumption in this experiment that at the beginning of the 1980s the household "exactly knew" the downfall in the TFP growth rates in the 1990s. In responding, we conducted the same exercise, but cut the forecasting period off in 1990 and do not use subsequent data, and found that the variables do not converge to the steady-state values; thus, no definitive counterarguments can be made. However, if such an assumption is unreasonable, we wonder whether the assumption in the original exercise is not, because, for several decades until the economy reaches a steady state, the household exactly knows that the TFP growth rates remained the same as the average in the 1990s.

would have been *lower*, implying a more severe recession, until approximately 1996. This curious result is also driven by the labor supply specification featured in the Hayashi-Prescott model; knowing for sure that the TFP growth rates will be higher now and in the future, unlike in the standard model, an agent increases leisure (cuts labor supply) as well as consumption from the present time onward, shifting output downwards. While this behavior is perfectly consistent with the utility-maximizing behavior, it casts some doubt on the validity of its *application* to Japan's lost decade. Finally, we applied the simulation exercise to the 1980s and found that the model performs rather poorly. In particular, the model yields the counterfactual behavior of a falling GNP per working age-person in the early 1980s. Although it may be argued that the model is intended for the 1990s, confidence in the model is doubtful if it fails as badly as it does in other periods. These three findings warrant a reconsideration of the validity of the Hayashi-Prescott claims for the true cause of Japan's lost decade.

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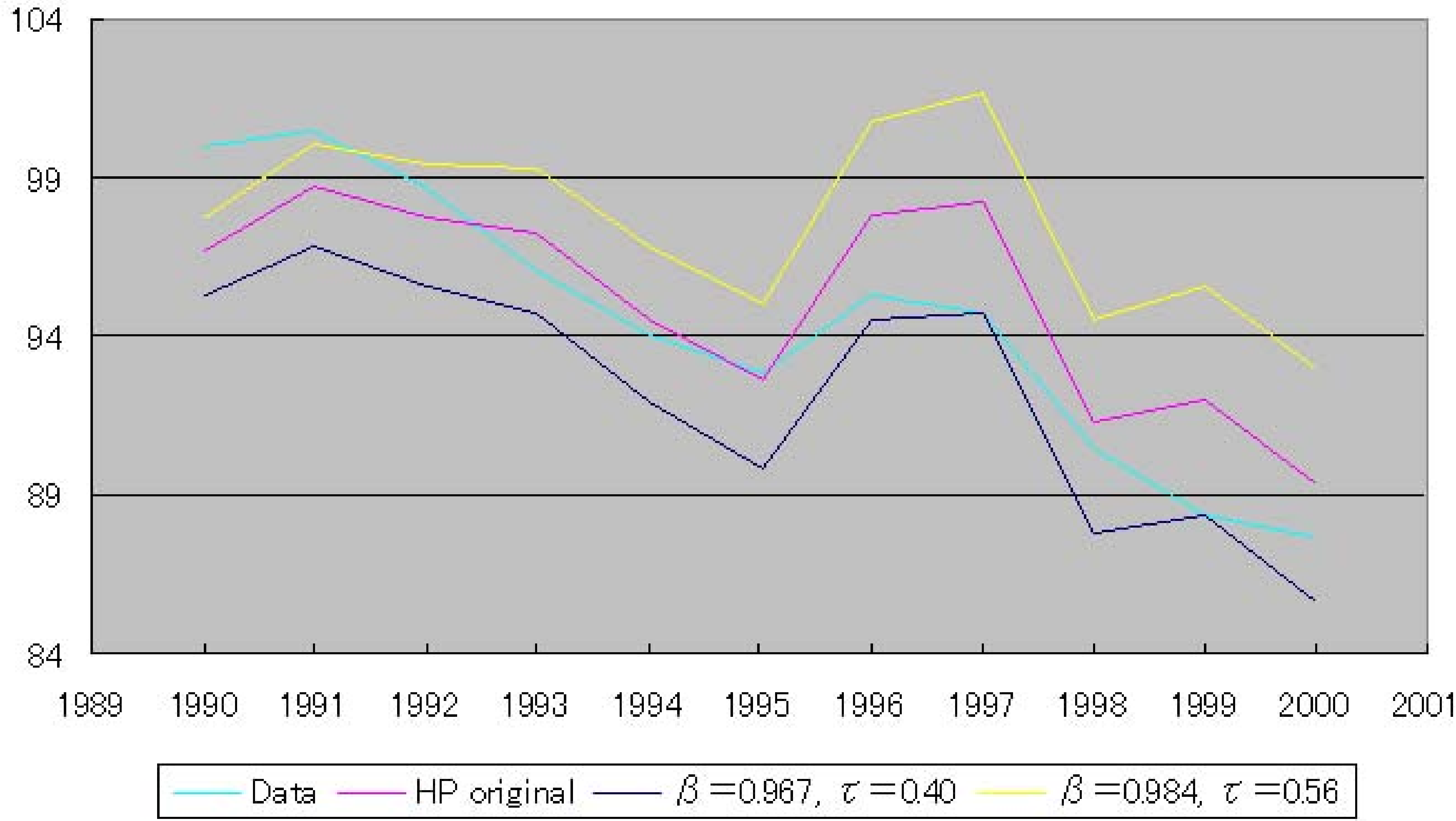
Figure 3-1: Sensitivity to discount rate and capital income tax rate



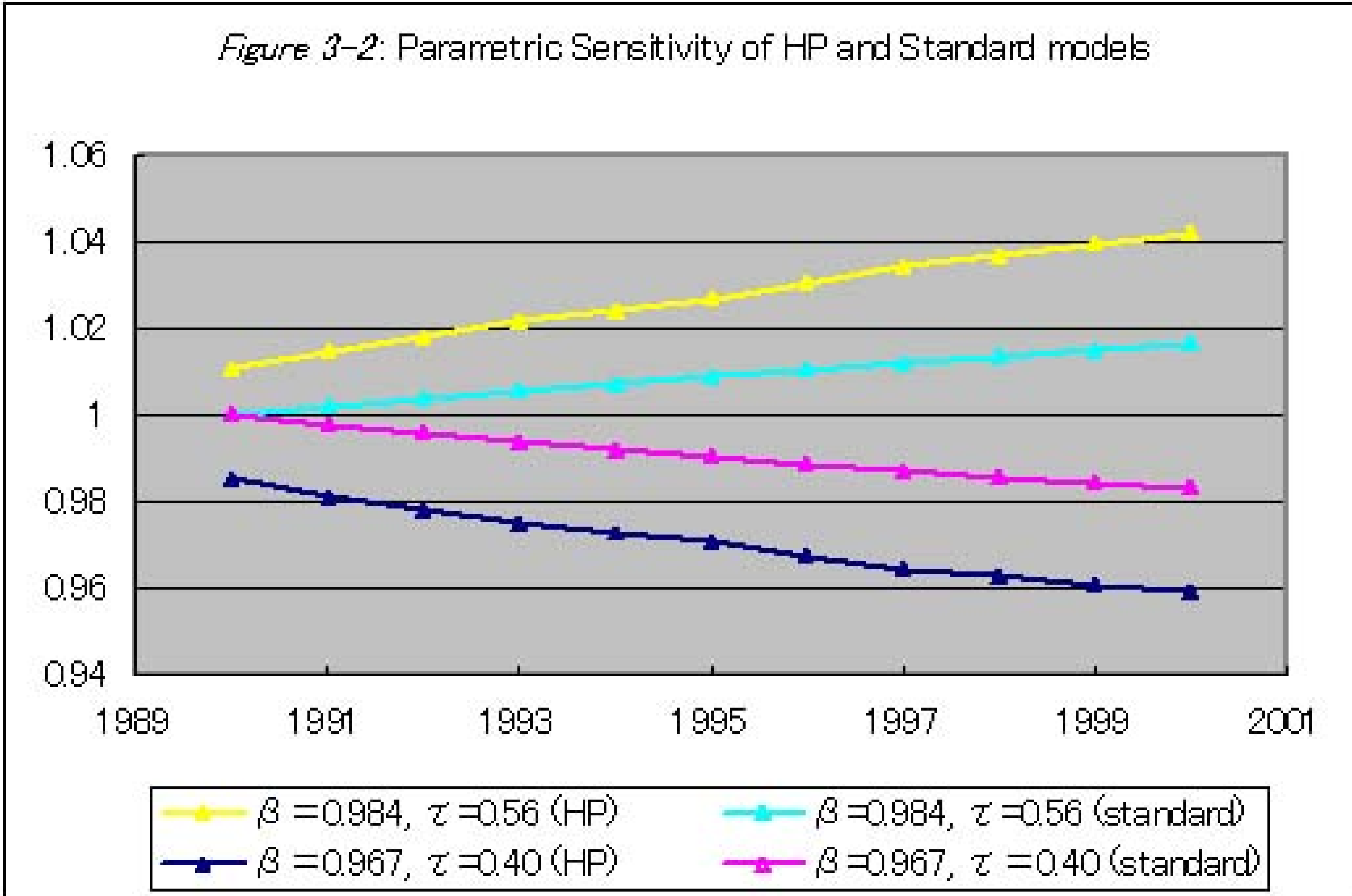
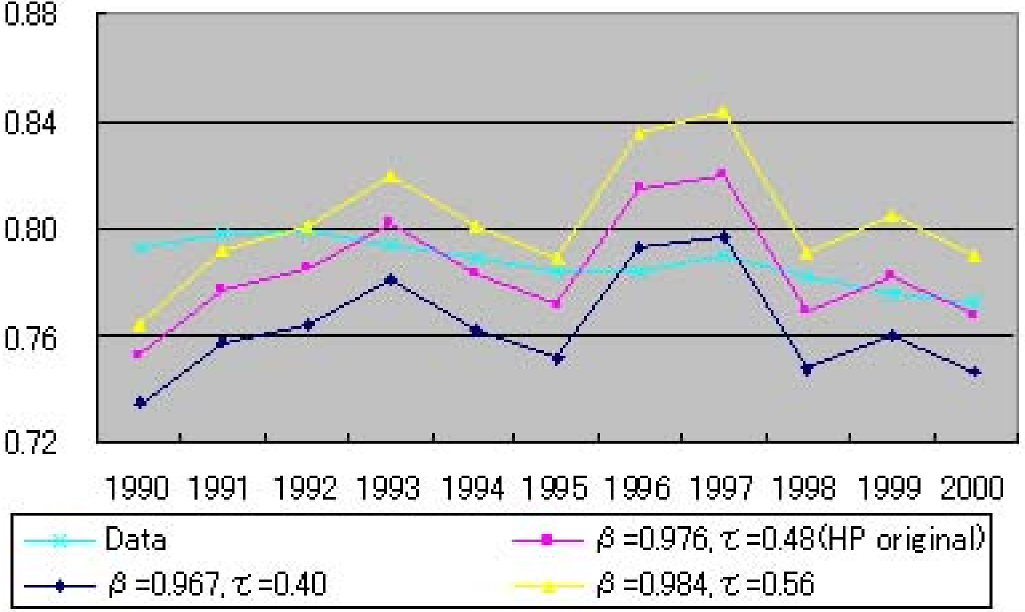


Figure 3-2: Parametric Sensitivity of HP and Standard models
1.06
1.04
1.02
1
0.98
0.96
0.94
1989
1991
1993
1995
1997
1999
2001
β =0.984, τ =0.56 (HP)
β =0.984, τ =0.56 (standard)
β =0.967, τ =0.40 (HP)
β =0.967, τ =0.40 (standard)

Figure 3-3: the movements of employment rate in HP model



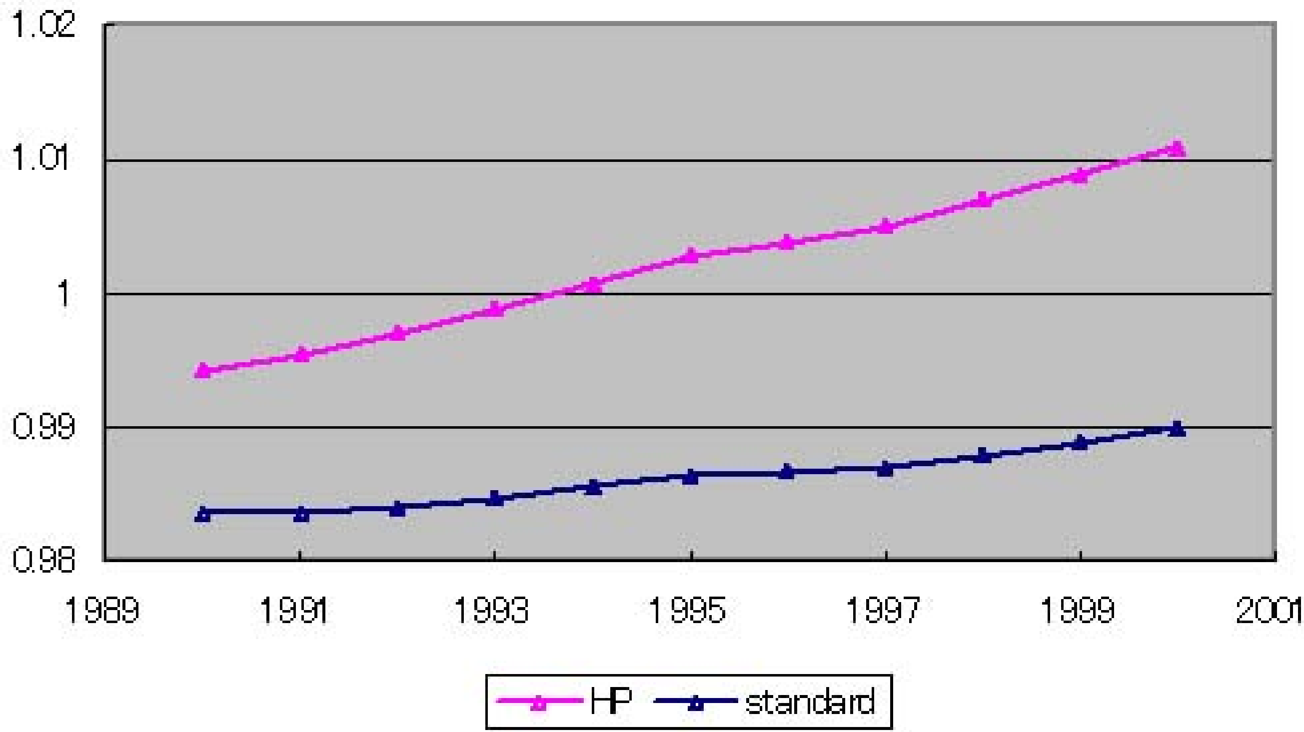


Figure 3-4: the relative movement of consumption in HP and standard models

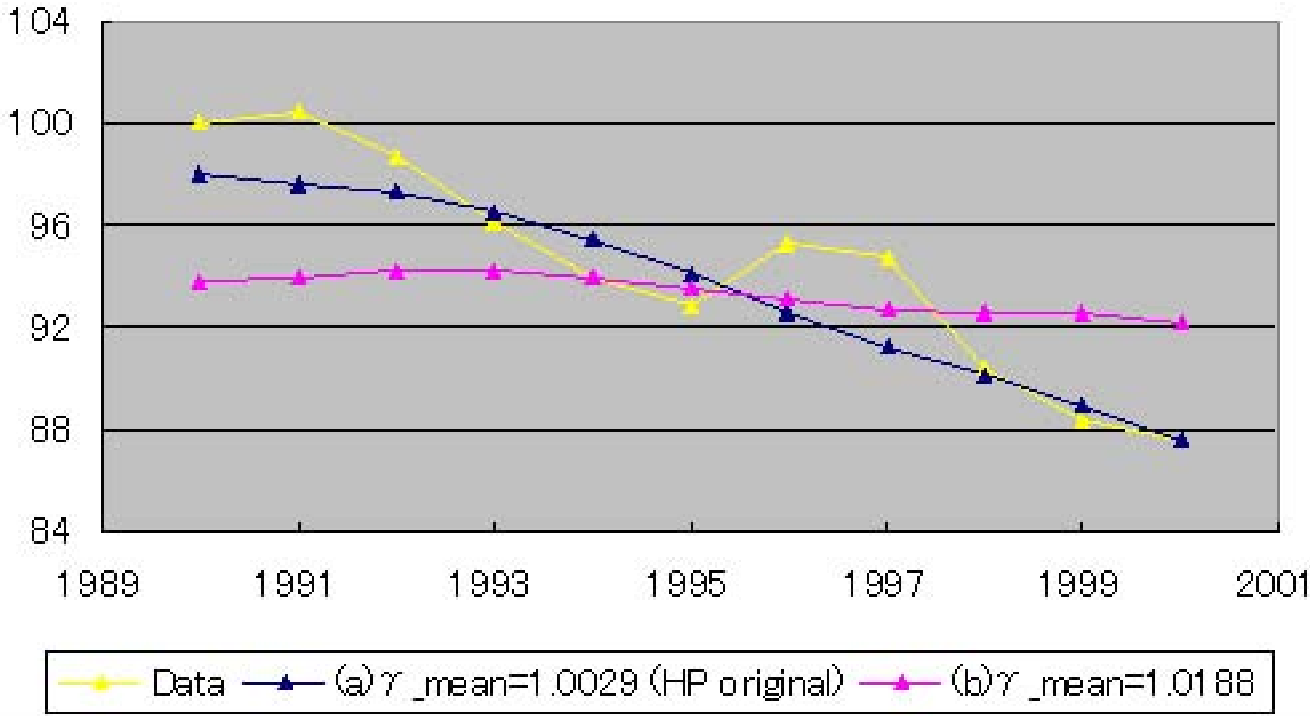


Figure 4-1: the movements of GNP per working-age person for hypothetical TFP growth rate (HP model)

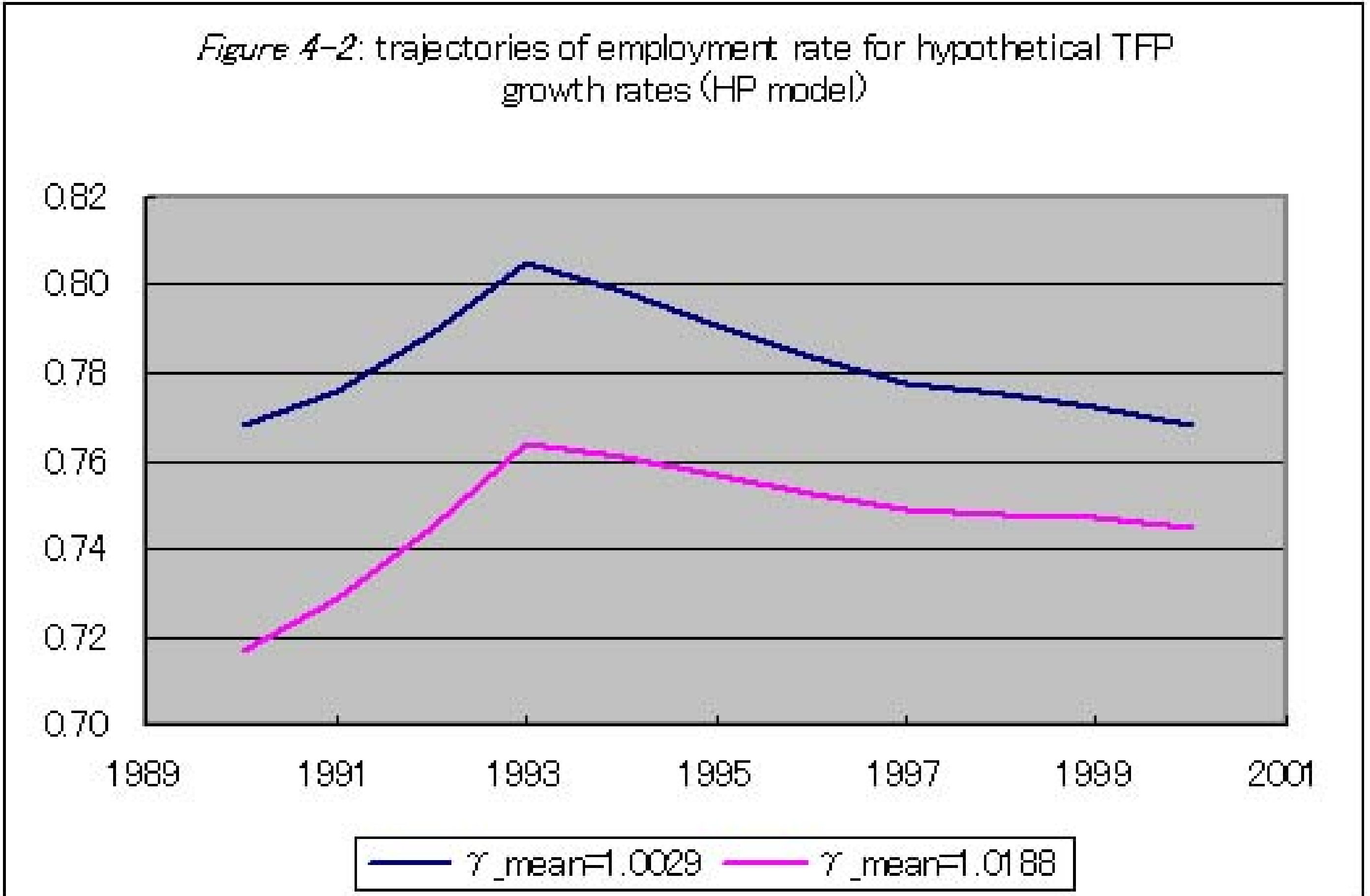


Figure 4-2: trajectories of employment rate for hypothetical TFP growth rates (HP model)
0.82
0.80
0.78
0.76
0.74
0.72
0.70
1989
1991
1993
1995
1997
1999
2001
γ_mean=1.0029
γ_mean=1.0188

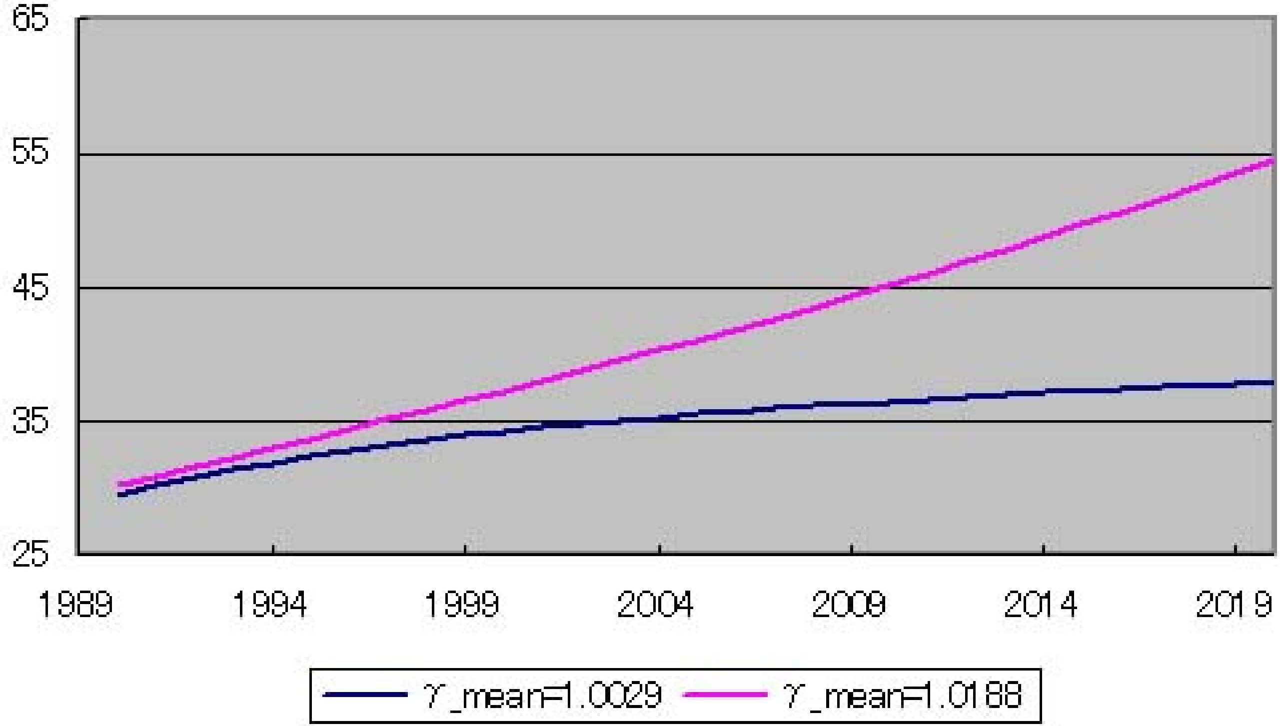
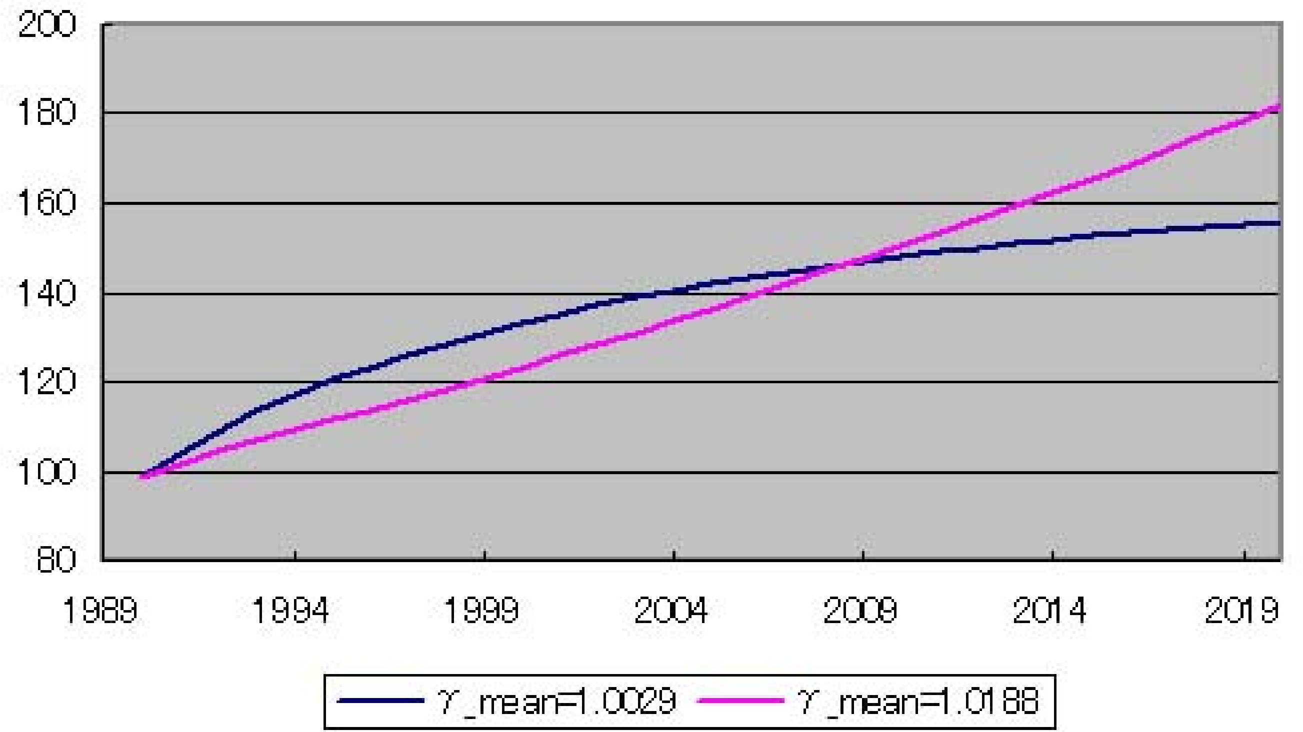


Figure 4-3: trajectories of consumption for hypothetical TFP growth rates (HP model)

Figure 4-4: trajectories of capital stock for hypothetical TFP growth rates (HP model)



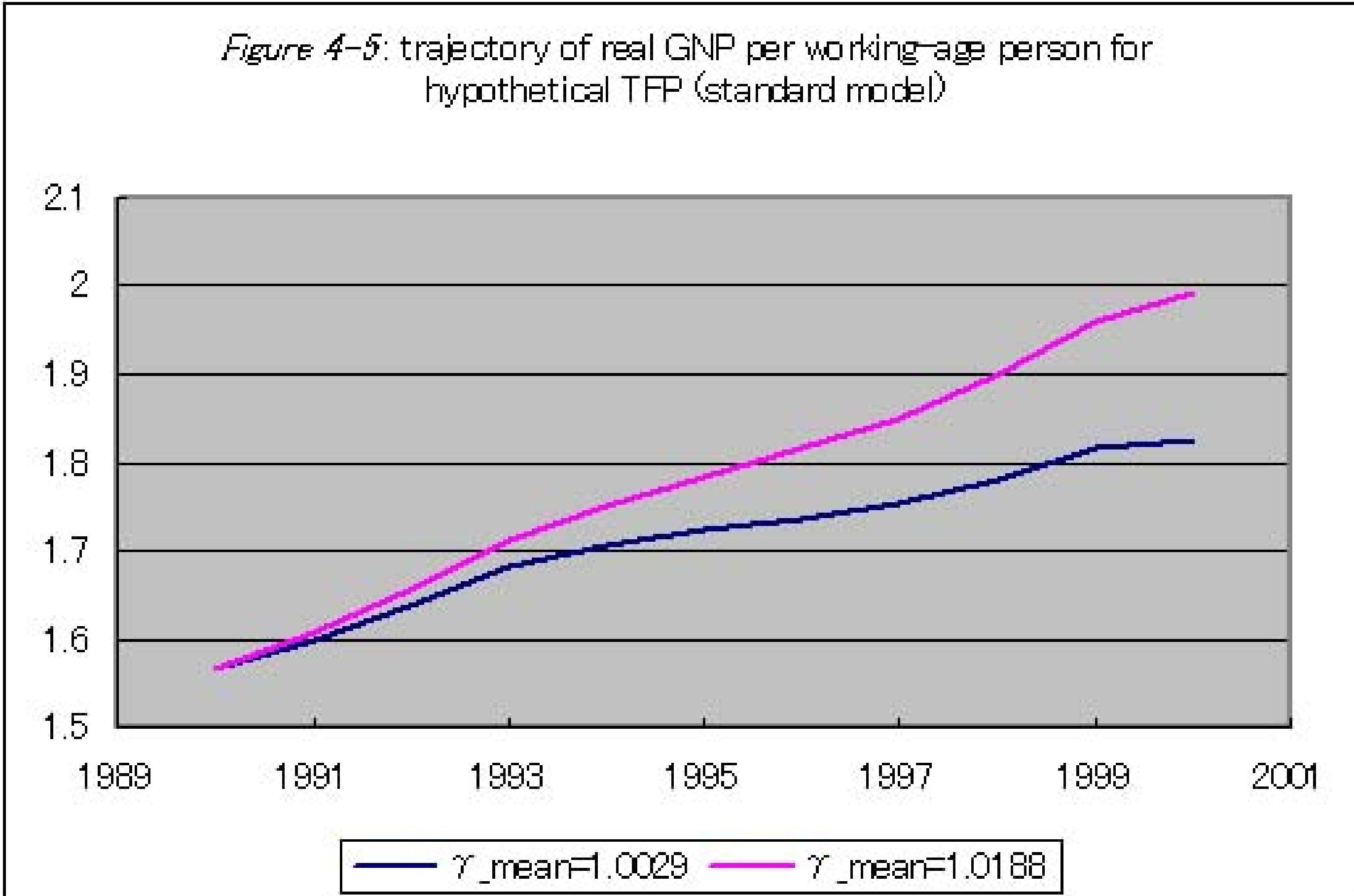


Figure 4-5: trajectory of real GNP per working-age person for hypothetical TFP (standard model)
2.1
2
1.9
1.8
1.7
1.6
1.5
1989
1991
1993
1995
1997
1999
2001
γ_mean=1.0029
γ_mean=1.0188

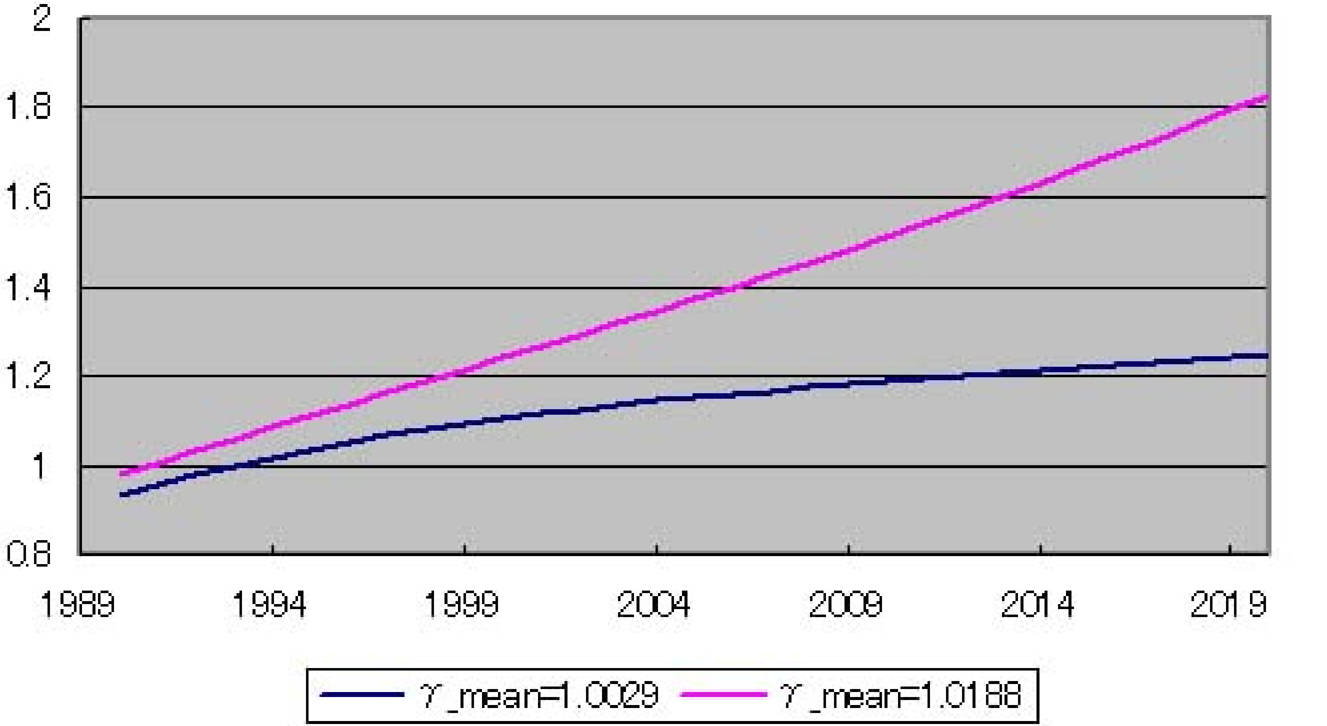


Figure 4-6: trajectories of consumption for hypothetical TFP growth rates (standard model)

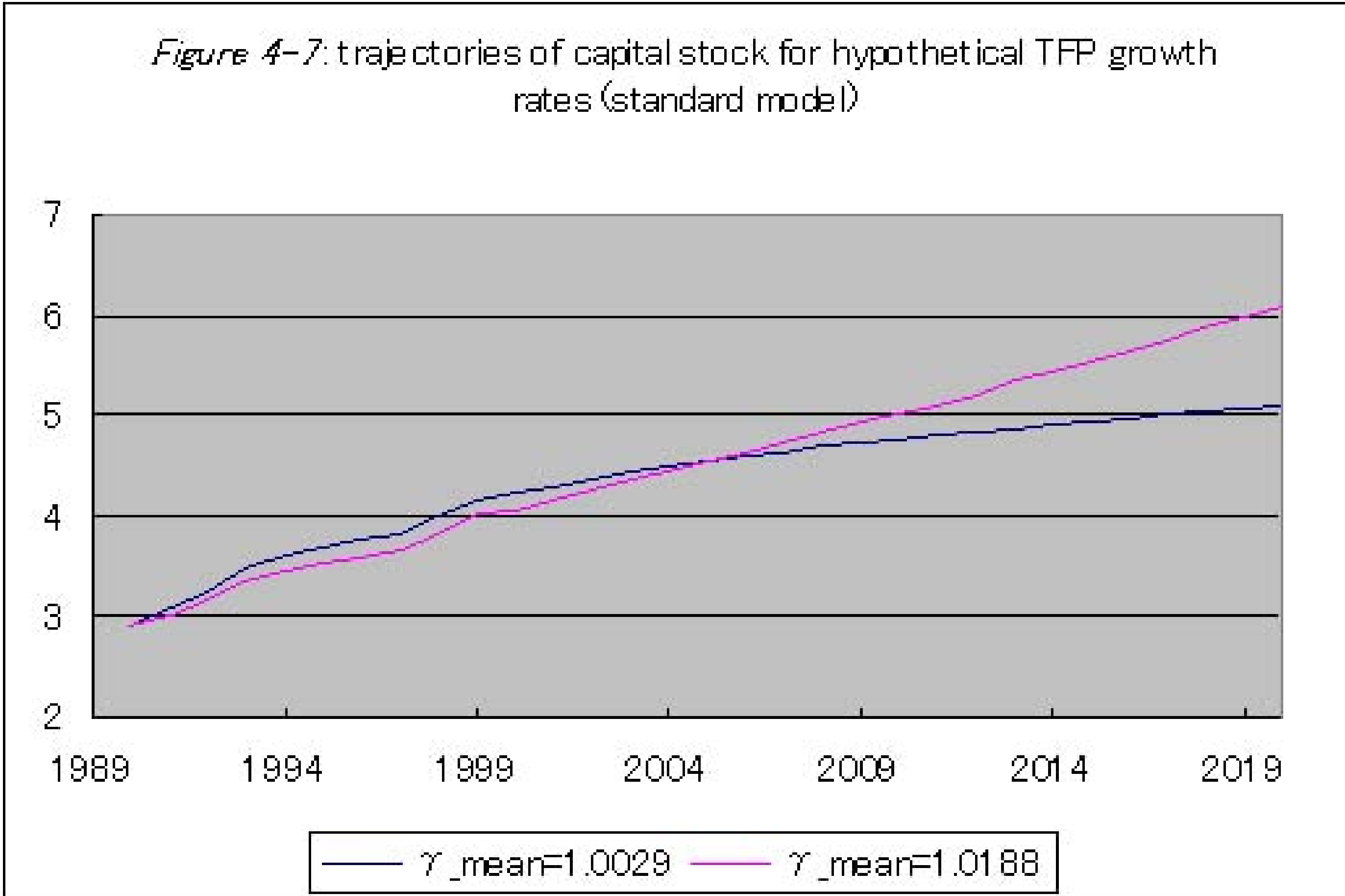


Figure 4-7: trajectories of capital stock for hypothetical TFP growth rates (standard model)
7
6
5
4
3
2
1989
1994
1999
2004
2009
2014
2019
γ_mean=1.0029
γ_mean=1.0188

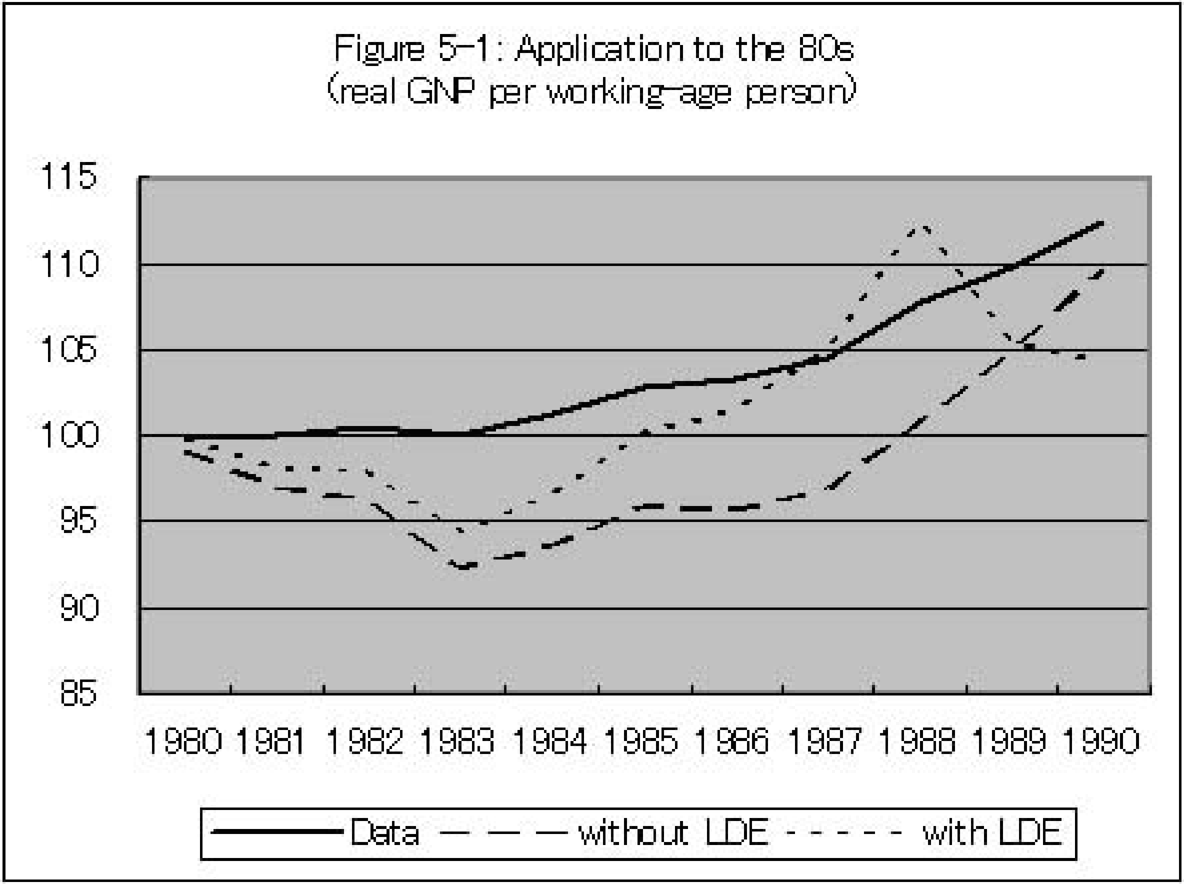


Figure 5-1: Application to the 80s
(real GNP per working-age person)
115
110
105
100
95
90
85
1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990
Data
without LDE
with LDE

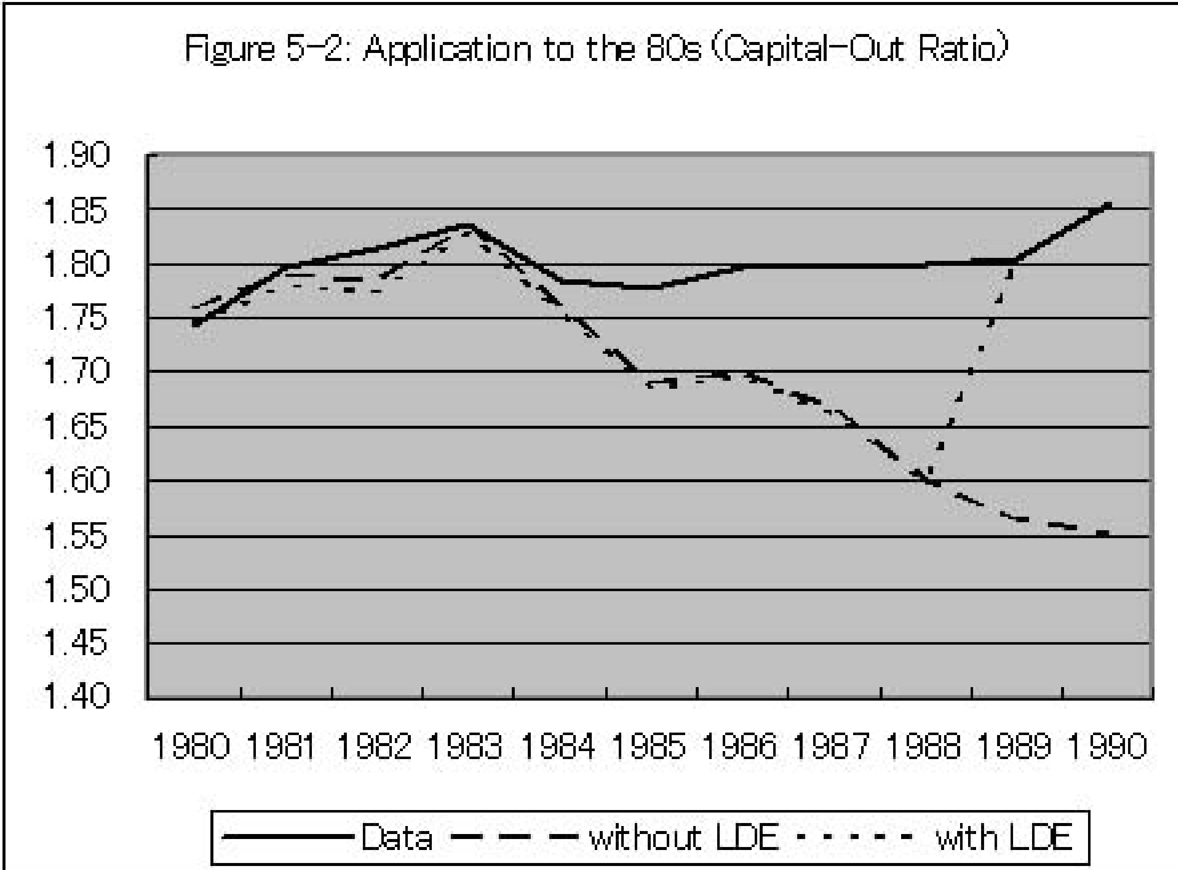


Figure 5-2: Application to the 80s (Capital-Out Ratio)
1.90
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990
Data
without LDE
with LDE

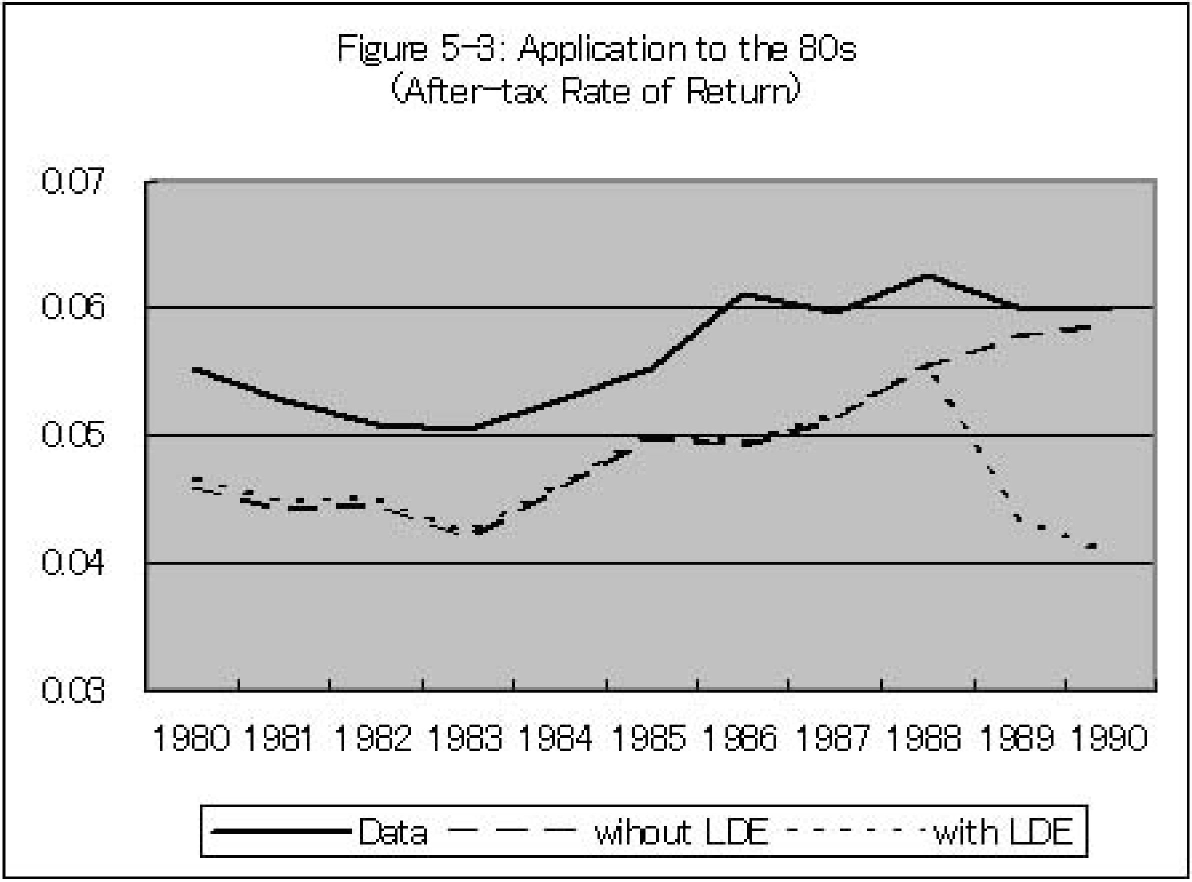


Figure 5-3: Application to the 80s
(After-tax Rate of Return)
0.07
0.06
0.05
0.04
0.03
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
Data
wihout LDE
with LDE