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A Test of the Convergence Hypothesis by Rates of Return to Capital:
Evidence from OECD Countries

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Abstract

While the convergence hypothesis implies that poor countries or regions tend to grow faster than rich ones, it can be reformulated such that poor countries or regions tend to have higher rates of return on their capital than rich ones but their rates of return would ultimately decline and converge to the level of rich ones. We test this reformulated convergence hypothesis by estimating Harberger's before-tax gross rates of return on total capital from the data of OECD countries. The major finding is that the convergence hypothesis is accepted: there could be an outlier during a certain period but the rate of return on its capital eventually declines and converges to the steady-state level.

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1. Introduction

While there have been voluminous theoretical developments in new growth theories after Romer (1986) and Lucas (1988), their empirical support is rather weak and inconclusive at best. The core proposition of new growth theories is the non-convergence hypothesis. The convergence hypothesis implied in the Solow-type neoclassical growth model stipulates that as an economy grows and accumulates its capital, the rate of return on its capital will decline and ultimately converge to a steady-state level. The convergence applies in the neoclassical growth model with money as either consumer good or producer good (Levhari and Patinkin(1968)) or both (Yoo and Pyo(1986)). But the new growth theory endogenizes technical progress and views it as a cumulative factor so that there can be lack of diminishing returns to the broad concept of capital and therefore, the non-convergence could occur.

To test this hypothesis, for example, Baumol(1986) and Barro(1991) directly compare per capita output and growth rates among countries. They plot per capita output for several countries against time horizon, or regress average growth rates of per capita output against their initial per capita output. They find convergence among some groups of countries. On the other hand, they find a lack of convergence for other groups of countries. Growth economists found lack of convergence across the world as a whole, which is referred to as the rejection of the absolute convergence hypothesis.

After finding this fact, they adopted the conditional convergence hypothesis. If countries or regions have similar structural characteristics such as preferences, population growth, technology levels, and investment rates, then the relatively poor among them will grow faster, so that all of them will eventually have the same steady states. For example, Barro(1991), Mankiw, et al.(1992) and Barro and Sala-i-Martin(1995) provided cross-country estimation supporting the conditional convergence hypothesis. But as a whole, the empirical evidence on the convergence hypothesis is not conclusive. Srinivasan(1995) argues that the cross-country data on aggregate measure such as growth rates, literacy rates, and life expectancy suffer from many deficiencies and that no conclusive answers have yet emerged. The result of time series tests by Jones(1995) is more puzzling: Many AK-style models and R&D-based models of endogenous growth are rejected.

The purpose of this paper is to reformulate the convergence hypothesis in the Solow-Ramsey model and test it by using the data of 15 OECD countries during the period of 1961-1995. The major findings include: (1) The rates of return in most of OECD countries except Japan and Korea reveal a consistent pattern, which indicates they have been indeed in steady-state growth path (2) Both Japan and Korea started off from early 1960's as being "outliers" as Harberger(1977) termed with unusually high rates of return but started to experience a rapid decline from 1985 in Japan and 1990 in Korea. It is consistent with the empirical finding in Pyo(1995) which observes that in case of Korea, human capital has been used as a productive input and did not arrive yet at the level of threshold point to provide economy-wide externality.

Based upon these findings, we advance the following proposition; (1) An empirical test of the convergence hypothesis through rates of return among OECD countries support the neoclassical proposition as discussed in Krugman (1994) and Pyo (1996). (2) The episode of exceptionally high rates of return by Japan and Korea during 1960's and early 1970's indicates that their human capital were not adequately paid during the period. As a result, the higher rates of return to capital were made possible and the rapid accumulation of physical capital were followed. (3) The current stagnation in Japanese economy and the Korean financial crisis in 1997-1998 could have originated from real sector which has suffered from rapid decline in capital productivity rather than financial sector.

The paper is organized as follows. In section 2, we reformulate the convergence hypothesis in terms of rates of return to capital in the Solow-Ramsey model. Section 3 presents empirical results of estimating rates of return in 15 OECD countries during the period of 1961-1995. Section 4 tests the convergence hypothesis and examines determinants of the convergence. Section 5 concludes the paper.

2. The Rates of Return in the Solow-Ramsey Model

The augmented Solow(1956) model provides us with a basis framework to reformulate the convergence hypothesis by deriving a dynamic profile of return to capital. But since it assumes a constant savings rate, it can be modified by the Ramsey model which explicitly considers optimization of households and firms so that savings rate becomes a function of time preference rate and risk parameter. During the period of 1961-1995, the savings rate of Japan increased from 17.5 % to 30.5 % and that of Korea increased from 11.7 % to 35.5 %. Therefore, the assumption of constant savings rate is not a realistic one, when we consider a long-run growth path.

In what follows, we reformulate the convergence hypothesis in Solow-Ramsey model. The augmented Solow model assumes an exogenous technical progress in the form of labor-augmenting Harrod-neutral type. Such a technical progress is denoted as A and its growth rate is assumed to be a constant, g;

(1) $$\dot{A}/A = g$$

Further, the production function is assumed to obey constant returns to scale and satisfy the Inada condition with strict concavity. Under such neoclassical assumptions, a Cobb-Douglas specification of production function becomes as follows;

(2) $$Y = F(K, L; A) = K^{\alpha}(AL)^{1-\alpha},$$

where $0< \alpha <1$ and Y is output; K is the capital input: and L is labor input. We further assume that labor grows at an annual rate of n: $L = L_0 e^{nt}$

If we impose competitive factor market conditions, the following equilibrium factor prices are derived from the above Cobb-Douglas production function:

(3) $$w = (1-\alpha)(\frac{K}{AL})^{\alpha}$$

(4) $$r = \alpha(\frac{K}{AL})^{\alpha-1}$$

where w is the wage rate and r is the price of capital.

In other words, if factor markets are perfectly competitive, firms will hire labor and capital up to the point at which factor prices are equal to marginal productivity of each factor. It also should be noted from eq.(3) that wages is a compensation to effective labor (AL) rather than simple quantity of labor (L).

Let us adopt the convention of denoting $x=X/L$ and $\tilde{x} = X / AL$ where the former denotes a variable in terms of per labor (L) while the latter denotes a variable in terms of per effective labor (AL). Then the Cobb-Douglas production function of eq.(2) can be written as;

(5) $$y = k^{\alpha}$$

which reveals diminishing returns to capital per effective labor as capital accumulates.

Next, we can derive the following equation to describe how capital accumulation can be related to other variables;

(6) $$\dot{k} = y - c - (n + g + \delta)k$$

where δ is the rate of depreciation. The above equation states that the growth in capital stock is made by deducting two components from income (y). One is consumption and the other is the capital requirement for keeping up with population growth and technological growth, $(n+g)k$ and replacement of depreciated capital, δk.

Now, we turn to the optimization by household. An infinitely-lived representative household is assumed to decide its consumption and saving as follows;

$$\text{(7)} \qquad Max\int_0^{\infty} U(\tilde{c})e^{-(\rho-n)t}dt$$

s.t.

$$\text{(8)} \qquad c+\dot{k}+(n+g+\delta)k \leq w+rk$$

$$\text{(9)} \qquad k_0 \text{ given, } c,k \geq 0 \text{ for all t.}$$

$$\text{(10)} \qquad U(c)=\frac{c^{1-\sigma}}{1-\sigma}$$

where ρ is rate of time preference; σ is the degree of relative risk aversion; and $U(c)$ is the utility function of the representative household.

We assume that the household supplies one unit of labor and in return earns wage rate, w. Its income from renting the capital is rk. Therefore, eq.(8) is the household's budget constraint.

The first-order conditions from the above constrained optimization problem are as follows;

$$\text{(11)} \qquad \frac{\dot{c}}{c}=\frac{1}{\sigma}[f'(k)-(\rho+\delta+\sigma g)]$$

$$\text{(12)} \qquad \frac{\dot{k}}{k}=\frac{f(k)}{k}-\frac{c}{k}-(n+g+\delta)$$

If the economy arrives at the steady-state, all of consumption, capital and output per effective labor cease to grow by definition. Therefore, if we impose such conditions on eq.(11), we get;

$$\text{(13)} \qquad f'(k^*)=\rho+\delta+\sigma g$$

where k^* denotes the equilibrium capital stock per effective labor at steady-state. If we further assume a Cobb-Douglas specification of production function, we can derive the following equation explicitly;

(14)
$$k^* = \left(\frac{\alpha}{\rho + \delta + \sigma g} \right)^{\frac{1}{1-\alpha}}$$

By substituting this expression to eq.(5), we obtain:

(15)
$$y^* = \left(\frac{\alpha}{\rho + \delta + \sigma g} \right)^{\frac{\alpha}{1-\alpha}}$$

From the above two equalities, we can be sure that, in the Solow-Ramsey model, the capital stock (k^*) and the output (y^*) at the steady state are functions of not only supply-side parameters such as the rate of technical progress (g), depreciation rate (δ), and the capital coefficient (α) but also preference parameters such as time preference rate (ρ) and the degree of relative risk aversion (α).

The economy with higher depreciation rate will have lower steady-state level of capital stock and output because it requires more capital replacement. On the other hand, if the economy is characterized by lower time preference rate and lower degree of risk aversion and, therefore, a higher-rate level of capital and output will tend to be higher.

Now, let us formulate the rate of return to capital in the Solow-Ramsey Model. From (4), we can derive the following relationship:

(16)
$$r = \alpha \left(\frac{K}{AL} \right)^{\alpha - 1} = \alpha \frac{Y}{K}$$

But, since the capital coefficient (α) is the share of capital income in production function with the constant returns to scale, we can obtain the following relationship:

(17)
$$r = \frac{\text{Capital Income}}{Y} \times \frac{Y}{K} = \frac{\text{Capital Income}}{K}$$

The above equation reaffirms that the rate of return to capital can be measured by the ratio of capital income to capital stock.

Thus, in the Solow-Ramsey model, the rate of return to capital is equal to the marginal productivity of capital and it can be expressed in terms of effective labor units as follows;

(18) $$r = \frac{\partial y}{\partial k} = \alpha k^{\alpha-1}$$

Finally, if we take derivative of (18) with respect to capital stock per effective labor, we obtain;

(19) $$\frac{\partial r}{\partial k} = \alpha(\alpha-1)k^{\alpha-2} < 0$$

which ensures the convergence in rate of return.

As the economy grows at a lower level of capital stock, the rate of return would be high. But as it approaches to the steady-state, the rate of return declines and ultimately converges to the steady-state level, $r^* = f'(k^*) = \rho + \delta + \sigma g$ which becomes a constant.

3. The Estimation of Rates of Return

(1) The Empirical Concept of Rates of Return

The rate of return to capital as derived in (17) above provides us with a simple definition. But its empirical measurement is not an easy task. First, we have to determine how we measure capital stock to begin with. As reviewed in Pyo(1998), there are multiple definitions of capital in terms of coverage and also in terms of net or gross concept. Second, we also have to determine how to impute capital income. For example, we have to decide whether capital gain is included and how we treat depreciation and tax in such imputation.

For the present study, we have aimed at a more consistent cross-national comparison of rates of return. Therefore, we have decided to minimize the potential measurement error by adopting the economy-wide gross rate of return before tax as the working definition. In other words, since each country has different depreciation system and tax treatment on capital gains, etc, we adopted gross capital stock rather than net capital stock and excluded land and inventory stock from consideration. The capital income is also defined as a gross before-tax concept. We have measured it as gross operating surplus by deducting compensation to employees from total domestic factor income in national income accounts and by adding consumption of fixed capital as follows:

Gross capital income = gross operating surplus =
(net operating surplus) + (consumption of fixed capital) =
(gross domestic factor income) - (compensation to employees) +
(consumption of fixed capital)

Therefore, we measured gross rate of return to capital as follows:

$$\text{(20)} \qquad \text{gross rate of return on capital} = \frac{\text{gross operating surplus}}{\text{gross aggregate capital}}$$

The above definition is almost identical to Harberger's(1977) before-tax gross rate of return. We also note that the rate of return to capital as defined above is equivalent to marginal productivity of capital under the conditions of constant returns to scale and perfectly competitive factor markets. In reality, these conditions are hard to be met, but the profile of rate of return to capital provides us with some clue to the movement of marginal productivity of capital over time. The marginal productivity of capital is also often measured by real interest rate but it is also difficult to be measured consistently because each country has different financial system and market structure and the inflation rate being used in estimating the real interest rate reflects different economic system and the results of market intervention and distortions. Therefore, the working concept of rate of return as the ratio of gross operating surplus to gross capital stocks seems to be the most reliable and consistently comparable measurement of return to capital.

(2) Estimates of Cross-national Rates of Return

We have estimated rates of return to capital in 15 OECD countries during the period of 1961-1995. The basic sources of data are OECD's, ISDB(International Sectoral Data Base) and national income accounts. For Korea, which has been admitted to OECD recently and therefore, was not included in ISDB, we have used national income accounts by the Bank of Korea for gross operating surplus and estimates of Pyo(1998) which has been adopted by statistical office of OECD for gross capital stock data. For some countries, the data from ISDB were not available in selected years and therefore, we treated them as missing values.

The estimation result is presented in Table 1. Figure 1 presents the estimates of G7 countries and Korea only to sharpen the comparison, while Figure 2 presents those of other OECD countries and Korea. Each country's separate profile is shown in Figure 3. Looking at the result by country, we observe that both Japan and Korea were distinctive "outliers" during 1970s and early 1980s. Japan's average rates of return during 1971-94 reached 18.2 percent. Its highest rate is estimated as 32.8 percent in 1971 and it gradually declined to the lowest level of 11.9 percent in 1994. Korea's rate of return follows closely that of Japan with some time lag. Its average rate of return during 1970-95 reached 20.1 percent with the highest rate of 34.4 percent in 1970 and the lowest rate of 9.5 percent in 1995. It interesting to note that Korea's rate of return in 1980's declined so fast that by 1988 it started to be lower than Japan's rate of return as shown in Table 1.

Other OECD countries' rates of return do not reveal any discernable pattern of either upward or downward trend. The only exception seems to be Finland of which rate of return declined steadily from 10 percent level in 1960's to 6 percent level in 1990's. We would interpret that they have already reached steady-state and that Japan also reached it by early 1980's. But in case of Korea, the trend of rates of return is too volatile implying that it is still away from reaching the steady state.

Aside from its dynamic pattern, if we compare absolute levels of rates of return by computing average rates of return from Table 1, we can identify the following groups:(1) Japan and Korea(18%-20%), (2) Italy, Canada, and Belgium(13%), (3) Netherlands, West Germany, Australia, France, England, and U.S. (9%-11%) (4) Finland and Sweden (7%) and (5) Denmark and Norway (5%).

4. A Test of the Convergence Hypothesis

In order to test the convergence hypothesis and identify determinants of the rates of return, we have conducted the following four types of analysis

(1) Equality Test on Capital Growth and Income Growth

As we have examined in the theoretical context, the growth rate of capital and that of income per effective labor are to converge to an identical rate at steady state. Therefore, by examining two growth rates and conducting equality test, we can test the convergence pattern for each country independently of rates of return. Figure 4 is the profile of gross capital stock per employed and GDP per employed for the entire 15 OECD countries. All other countries except Japan and Korea have almost identical pattern of growth between per-employed gross capital and per-employed GDP. In Japan and Korea, the growth of per-employed gross capital outpaced that of per-employed GDP. More formally, we present the result of equality test in Table 2 confirming the pattern observed in Figure 4. Both the Japanese and Korean data reject at 1% significance level that per-employed gross capital grew at the same rate as per-employed GDP. These results indicate that Japan up until early 1980's and Korea throughout the entire period did not arrive yet at the stage of steady-state.

(2) Test of Trend in Rates of Return

A more direct test of convergence can be made by applying a trend analysis. The result is presented in Table 3. Among 15 OECD countries, Japan, Korea, U.S., Canada, West Germany, Denmark, and Finland have had statistically significant downward trends in the rate of return. In particular, Japan's and Korea's rates of return revealed distinctively larger magnitude of decline. In addition, as summarized in the second column of Table 3, Japan's rate of return alone reveals at 5% significance level that its declining rate is slowing down as it should be for an economy near the steady-state. All other countries (except Korea) which revealed rather mild declining rates of return seem to have arrived at the steady-state because the degree of decline has been too weak.

(3) Regression Results

Eq. (4) in Section 2 specifies the fundamental relationship between the rate of return to capital (r) and factor inputs and technical progress in the neoclassical growth model with Cobb-Douglas production function. But as pointed out in Pyo(1995), the estimates of parameters in Cobb-Douglas specification tend to be unstable even at economy-wide aggregate level. Therefore, we impose only constant returns to scale to a neoclassical production function as:

(2a) $$Y_t = B_t^{\beta_3}\,\mathrm{F}\,(K_t, L_t)$$

or $$y_t = B_t^{\beta_3} f(k_t)$$

Then, the following equation of rate of return to capital can be derived:

(18a) $$r_t = B_t^{\beta_3} f'(k_t)$$

By taking a log-linear form and taking one-period differential form to avoid unit root problem, we obtain:

(22) $$\Delta\log r_t = \beta_1 + \beta_2\,\Delta\log k_t + \beta_3\,\Delta\log B_t$$

(23) $\Delta \log r_t = \beta_1 + \beta_2 \Delta \log k_t$ if $\beta_3 = 0$

If we assume the total factor productivity does not contribute to output, then eq(23) would be right. On the other hand, if it does, eq(22) will have to be estimated. First, we have conducted an augmented Dickey-Fuller(ADF) test on the variables in eq(22). We have found that most of variables including the rate of return to capital (r) and per capita capital (K/L) reveal the existence of unit roots and that they become stationary after being taken as first-order differentials. Therefore, we have run regressions to eq (23) and eq (22) as presented in Table 4 and 5 respectively.

According to Table 4, the per capita capital is to affect the rate of return negatively: the convergence hypothesis is accepted. In particular, the coefficient is statistically significant at 5% level of significance for Korea, U.S., Canada, West Germany, Australia, and Denmark. As shown in Table 5, the regression result in Table 5 indicates that the addition of total factor productivity as a variable does not affect the regression results in any significant way. The coefficient of total factor productivity term is positive except West Germany as expected but statistically insignificant.

(4) A Simulation Analysis

We have also conducted a simulation analysis for Korea, which has shown the most vivid profile of the convergence in the rate of return to capital. For the purpose of conducting a simulation, we must determine the parameter values in the Solow-Ramsey model. For Korea, we have decided to use the rate of population growth, n=0.01. For depreciation rate, we could have used δ =0.066 following Pyo(1998). But we adopted δ =0.05 to be consistent with Barro and Sala-i-Martin(1995). Mankiw, Romer, and Weil(1992) used δ =0.03 but it seems too low for the fast-growing economy like Korea. For the time preference rate(ρ), we have used ρ =0.04 as a benchmark rate, which is higher than the rate ρ =0.02 adopted by Barro and Sala-i-Martin(1995). We assumed that Korea as an economy with higher marginal productivity of capital is likely to demand higher real interest rate than other OECD countries. Because of lack of *a priori* information on the degree of relative risk aversion, we adopted σ =3 following Barro and Sala-i-Martin(1995). Since the rate of labor augmentation(g) should reflect a rate prevailing in the steady state, we have adopted g = 0.02 as a benchmark rate. According to Pyo et al.(1993), the share of capital income (α) has declined from around α =0.6 in 1970s to around α =0.4 in 1990s. Barro and Sala-i-Martin have argued that the share of capital income should be as large as α =0.75 to reflect the contribution of human capital as part of capital input in explaining the economic growth of the United States.

In fact, the regression result with human capital as a separate factor in Pyo(1995) reports a value of $\alpha = 0.78$ from the Korean data. However, in the present study, we adopted α =0.5 as a benchmark value taking the average between α =0.6 and α =0.4.

Figure 5 illustrates the theoretical time path of capital accumulation where the vertical axis is the ratio of the present level of capital stock to the steady-state level of capital stock. The discrepancy between two levels of capital stock indicates how far it is from arriving at the steady-state. By its convex shape, we can be sure that the speed of convergence toward the steady-state becomes slower as the accumulation of capital proceeds. On the other hand, Figure 6 depicts the speed of such convergence more directly by making use of the following relationship:

(24) $$\beta = -\frac{\dot{k}/k}{\log(k/k^*)}$$

As the economy approaches to a steady-state ($k/k^* \to 1$), the speed of convergence declines and becomes:

(25) $$2\beta = \{\xi^2 + 4(\frac{1-\alpha}{\alpha})(\rho+\delta+\sigma g)[\frac{\rho+\delta+\sigma g}{\alpha} - (n+g+\delta)]\}^{1/2} - \xi$$

where $\xi = \rho - n - (1-\sigma)g = 0.47$, if we use our benchmark values of parameters. It should be noted that in a pure Solow model where savings rate is fixed, we should have obtained $\beta = (1-\alpha)(n+g+\delta) = 0.4$.

In order to compare the above result with the observed one from Korean data, we have drawn Figure 7 where the actual growth of capital stock is plotted as a block dotted line. As revealed in the figure, there is a discrepancy between two profiles in particular during the latter half of 1970's. It may have reflected the government-initiated investment drive for heavy and chemical industries in Korea during the period. Therefore, we obtained a predicted series of the rate of capital accumulation by using the following regression equation:

(26) $$\begin{aligned} \dot{k}/k &= 0.0547 - 0.0926 \times trend \\ &\quad\ (0.0934) \quad (0.0717) \\ R^2 &= 0.05 \end{aligned}$$

where the values in parentheses indicates standard errors of estimates.

The predicted series is also plotted as a simple dotted line in Figure 7. We note that there is a well-matched correspondence between the simulated plot during the 22nd year-53rd year and the predicted plot during 1964-1995. With this in mind, we have constructed a comparative dynamic profile of the rates of return to capital in Figure 8. As the diagram indicates there is a significant discrepancy between the simulated profile and the observed profile of the rate of return.

It is interesting to note that the observed profile reveals a faster rate of decline than the simulated profile. In addition, after 1990, while the simulated profile stopped declining further after reaching a point of steady-state, the observed profile continued to decline sharply and its absolute levels were lower than those of the simulated levels.

Finally, we have attempted a sensitivity analysis by varying benchmark values of some parameters. Figure 9 illustrates that when the share of capital is assumed to be $\alpha = 0.3$, the variation in parameter values did not produce drastically different results from the benchmark results. In addition, from Figure 10 where $\alpha = 0.3 \ or \ \sigma = 1$ is assumed, we can identify even a larger discrepancy between the simulated profile and observed one supporting our earlier conjecture.

The overall implication of these simulation results is that the rate of return to capital in Korea after 1990 has experienced a sharp decline and its absolute levels became lower than those being theoretically postulated by the Solow-Ramsey growth model. It indicates strongly that there has been a rapid decline in Korea's capital productivity in result of the cumulated over-investment as discussed in detail in Pyo (1999) in the context of excess competition under moral hazard.

(5) Decline in Capital Productivity: Further Evidences

The marked decline in the rates of return in Japan and Korea after mid-1980s could be the results of two factors: over-investment beyond optimal level and inefficient utilization of invested capital. One indicator to capture these factors is the capital-output ratio, which measures the required amount of capital to produce unit output. Figure 11 is the plot of the ratio for OECD countries over the respective sample period.. Both Japan's and Korea's capital-output ratio increased sharply since around 1985. Korea's ratio reached the highest level (4.2) among OECD countries in 1994. Fukuda and Toya (1998) also notes that the time-series data of capital output ratios in the East Asian Economies show a significant upward trend in their capital-output ratios except for Hong Kong.

Another indicator of the inefficient use of capital stock is the incremental capital-output ratio, which can capture a dynamic pattern of the incremental capital requirement. Its average rate in Korea during the period of 1981-1989 was 3.6. But it increased to the level of 5.0 during the period of 1990-1996.

A plausible explanation for this marked upward trend in both absolute and incremental level of capital-output ratio can be given by looking at the trend in the share of labor income among OECD countries as shown in Figure 12. The share of labor income in Japan increased sharply during the first half of the 1970s from 0.44 to 0.57, remained at that level until 1988, and started increasing again after 1988 to reach around 0.60 by 1995. According to Yoshikawa (1994), the share of labor income on national income accounts (SNA) increased from 0.58 in 1960 to 0.74 in 1990. The share in Korea follows closely that in Japan with about 15-year time-lag. It was as low as 0.35 in 1974 but started to increase during the latter half of the 1970s to the level of 0.48. It remained at that level until 1987 but started to increase sharply again since then to reach 0.54 by 1990 (Pyo et. al. (1993)) and remained at that level by 1995. The sharp increase in the share of labor income due to the rapid increase in wage rate has contributed to lowering rates of return to capital.

On the other hand, the rapid transformation of industrial structure from labor-intensive industries to capital-intensive industries such as steel, petrochemical, automobile, and semiconductor industries must have been accountable for declining capital productivity as discussed in Pyo (1996) and Fukuda and Toya (1999). The share of heavy and chemical industries in manufacturing in Korea increased from 0.59 in 1985 to 0.76 in 1995 surpassing the corresponding share in Japanese manufacturing (0.64 in 1994). A report by the Bank of Korea (1997) compares the two economies' manufacturing investment in 1996 by purpose. While the investment for capacity expansion in the Japanese manufacturing occupied 44.3 percent in their total investment, that in the Korean manufacturing occupied 69 percent. On the other hand, the share of investment for rationalization and R&D in Korea and Japan were 20.9 percent and 42.8 percent respectively. Therefore, the over-investment drive in Korea was mostly directed to capacity expansion rather than productivity increase.

In an attempt to search for an optimal growth rate for Korea, Pyo (1994) used the following value-added growth accounting equation:

$$\Delta Y/Y = \Delta A/A + 0.47\ \Delta K/K + 0.53\ \Delta L/L \quad (27)$$

where the first term on the right-hand side is the rate of growth in total factor productivity. In addition, based on Blanchard and Summers (1984), the following identity of optimal growth path was imposed to (27):

$$K/Y = \alpha / (r + \delta)$$

Then, we obtain the following result:

(28) $\Delta Y/Y = \Delta K/K$ – (growth rate of labor share) + (growth rate of real interest rate) + (growth rate of depreciation rate)

$= \Delta K/K$ if all of the three growth rates are assumed to be zero.

Further if we assume 3 percent growth rate in total factor productivity which was the estimate by Pyo et. al. (1993) for the period of 1986-1990 and 1.7 percent growth rate of effective labor, we obtain the following optimal growth rate of income and capital:

(29) $$\Delta Y/Y = \Delta K/K = 0.074\ (7.4\%)$$

But according to Pyo (1998), the gross and the net non-residential capital stock in Korea during 1980-1996 increased at the average annual rate of 12 percent and 10.9 percent respectively. Therefore, the rate of over-investment has been at least as much as 3.5 percent point above the estimated optimal growth rate.

5. Concluding Remarks

The convergence hypothesis implied in the Solow-type neoclassical growth model stipulates that as an economy grows and accumulates its capital, the rate of return on its capital will decline and ultimately converge to a steady-state level of rate of return as the law of diminishing returns sets in. But the new growth theory endogenizes technical progress and views it as a cumulative factor so that there can be lack of diminishing returns to the broad concept of capital and therefore, the non-convergence could occur. In the present paper, we have reformulated the convergence hypothesis implied in the neoclassical growth models in the context of the Ramsey model which allows a varying savings rate. Empirically the hypothesis implies that poor countries or regions tend to grow faster than rich ones. It can be reformulated such that poor countries or regions tend to have higher rates of return on their capital than rich ones but their rates of return would ultimately decline and converge to the level of rich ones.

We have tested this reformulated convergence hypothesis by estimating Harberger's before-tax gross rates of return on aggregate capital from the data of OECD countries. The rates of return in most of OECD countries except Japan and Korea reveal a consistent pattern, which indicates they have been indeed in steady-state growth path. Both Japan and Korea started off as being "outliers" from early 1960's having unusually high rates of return but started to experience a rapid decline from 1985 in Japan and 1990 in Korea. We observe that both Japan and Korea were distinctive outliers during 1970s and early 1980s. Japan's average rates of return during 1971-94 reached 18.2 percent. Its highest rate is estimated as 32.8 percent in 1971 and it gradually declined to the lowest level of 11.9 percent in 1994. Korea's rate of return follows closely that of Japan with some time lag. Its average rate of return during 1970-95 reached 20.1 percent with the highest rate of 34.4 percent in 1970 and the lowest rate of 9.5 percent in 1995. It interesting to note that Korea's rate of return in 1980's declined so fast that by 1988 it started to be lower than Japan's rate of return.

The major finding from a set of regression analysis and a simulation study is that the convergence hypothesis is accepted: there could be an "outlier" during a certain period but the rate of return on its capital eventually declines and converges to the steady-state level. Other OECD countries' rates of return do not reveal any discernable pattern of either upward or downward trend. The only exception seems to be Finland of which rate of return declined steadily from 10 percent level in 1960's to 6 percent level in 1990's. We would interpret that they have already reached steady-state and that Japan also reached it by early 1980's. But in case of Korea, the trend of rates of return is too volatile implying that it is still away from reaching the steady state.

Based upon these findings, we advance the following proposition; (1) An empirical test of the convergence hypothesis through rates of return among OECD countries support the neoclassical proposition. (2) The episode of exceptionally high rates of return by Japan and Korea during 1960's and early 1970's indicates that their human capital was not adequately paid during the period. As a result, the higher rates of return to capital were made possible and the rapid accommodation of physical capital were followed. (3) The current stagnation in Japanese economy and the Korean financial crisis in 1997-1998 could have originated from real sector rather than financial sector.

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Table 1. Gross rates of return on capital

	USA	CAN	JPN	DEU	FRA	ITA	GBR
1961	0.103	n.a	n.a	0.135	n.a	n.a	n.a
1962	0.106	n.a	n.a	0.130	n.a	n.a	n.a
1963	0.107	n.a	n.a	0.125	n.a	n.a	n.a
1964	0.108	n.a	n.a	0.127	n.a	n.a	n.a
1965	0.112	n.a	n.a	0.125	n.a	n.a	n.a
1966	0.112	n.a	n.a	0.120	n.a	n.a	n.a
1967	0.108	n.a	n.a	0.115	n.a	n.a	n.a
1968	0.106	n.a	n.a	0.126	n.a	n.a	n.a
1969	0.102	n.a	n.a	0.126	n.a	n.a	n.a
1970	0.094	0.135	n.a	0.122	n.a	n.a	n.a
1971	0.094	0.137	0.328	0.116	n.a	0.136	0.099
1972	0.097	0.137	0.312	0.114	n.a	0.133	0.101
1973	0.099	0.149	0.290	0.111	n.a	0.139	0.109
1974	0.092	0.149	0.239	0.103	n.a	0.143	0.097
1975	0.091	0.144	0.209	0.099	n.a	0.132	0.086
1976	0.093	0.142	0.197	0.102	n.a	0.138	0.093
1977	0.096	0.139	0.185	0.101	0.104	0.135	0.099
1978	0.099	0.143	0.184	0.102	0.103	0.140	0.100
1979	0.097	0.150	0.182	0.103	0.103	0.146	0.096
1980	0.091	0.148	0.177	0.097	0.098	0.149	0.088
1981	0.092	0.140	0.167	0.094	0.096	0.144	0.085
1982	0.088	0.124	0.160	0.092	0.095	0.140	0.089
1983	0.090	0.132	0.154	0.096	0.094	0.138	0.095
1984	0.097	0.140	0.153	0.098	0.095	0.140	0.095
1985	0.098	0.141	0.155	0.099	0.096	0.140	0.099
1986	0.097	0.135	0.151	0.100	0.101	0.142	0.098
1987	0.098	0.137	0.150	0.098	0.103	0.141	0.102
1988	0.099	0.137	0.152	0.101	0.105	0.142	0.105
1989	0.099	0.133	0.153	0.103	0.108	0.141	0.104
1990	0.096	0.123	0.151	0.108	0.105	0.136	0.100
1991	0.092	0.112	0.146	0.109	0.102	0.133	0.090
1992	0.092	0.107	0.137	0.106	0.100	0.130	0.089
1993	0.094	n.a	0.126	0.102	0.096	0.126	0.093
1994	n.a	n.a	0.119	0.106	0.097	0.130	0.097
1995	n.a	n.a	n.a	n.a	n.a	n.a	n.a
mean	0.098	0.136	0.182	0.109	0.100	0.138	0.096
max	0.112	0.150	0.328	0.135	0.108	0.149	0.109
min	0.088	0.107	0.119	0.092	0.094	0.126	0.085
s.d	0.006	0.011	0.056	0.012	0.004	0.005	0.006

Table 1. Gross rates of return on capital(Continued)

	AUS	NLD	BEL	DNK	NOR	SWE	FIN	KOR
1961	n.a	n.a	n.a	n.a	n.a	n.a	0.103	n.a
1962	n.a	n.a	n.a	n.a	n.a	n.a	0.095	n.a
1963	n.a	n.a	n.a	n.a	n.a	n.a	0.092	n.a
1964	n.a	n.a	n.a	n.a	n.a	n.a	0.090	n.a
1965	n.a	n.a	n.a	n.a	n.a	n.a	0.087	n.a
1966	n.a	n.a	n.a	0.066	n.a	n.a	0.082	n.a
1967	n.a	n.a	n.a	0.064	n.a	n.a	0.079	n.a
1968	n.a	n.a	n.a	0.063	n.a	n.a	0.080	n.a
1969	n.a	n.a	n.a	0.065	n.a	n.a	0.086	n.a
1970	0.115	n.a	n.a	0.061	n.a	n.a	0.085	0.344
1971	0.114	n.a	0.130	0.058	0.050	0.075	0.079	0.337
1972	0.116	n.a	0.132	0.063	0.049	0.074	0.079	0.327
1973	0.112	n.a	0.136	0.064	0.050	0.077	0.080	0.335
1974	0.099	n.a	0.131	0.060	0.052	0.079	0.082	0.330
1975	0.098	n.a	0.130	0.055	0.049	0.074	0.070	0.304
1976	0.098	n.a	0.132	0.057	0.050	0.066	0.065	0.295
1977	0.095	0.105	0.129	0.056	0.048	0.058	0.064	0.279
1978	0.104	0.104	0.128	0.054	0.051	0.059	0.066	0.254
1979	0.104	0.103	0.129	0.053	0.058	0.066	0.071	0.225
1980	0.101	0.103	0.124	0.050	0.063	0.067	0.072	0.180
1981	0.097	0.106	0.118	0.050	0.064	0.067	0.070	0.172
1982	0.087	0.105	0.123	0.053	0.062	0.074	0.070	0.164
1983	0.097	0.110	0.125	0.054	0.064	0.077	0.070	0.158
1984	0.099	0.118	0.129	0.058	0.067	0.079	0.071	0.156
1985	0.099	0.122	0.132	0.058	0.066	0.077	0.069	0.151
1986	0.098	0.120	0.134	0.059	0.061	0.078	0.068	0.154
1987	0.104	0.115	0.135	0.055	0.059	0.078	0.068	0.151
1988	0.108	0.117	0.144	0.055	0.058	0.079	0.070	0.146
1989	0.105	0.124	0.149	0.058	0.063	0.077	0.073	0.133
1990	0.100	0.125	0.144	0.058	0.065	0.073	0.068	0.124
1991	0.098	0.125	0.139	0.058	0.066	0.068	0.057	0.116
1992	0.100	0.121	0.136	0.057	n.a	0.069	0.055	0.104
1993	0.102	0.117	0.131	0.060	n.a	0.075	0.061	0.100
1994	0.103	0.121	n.a	n.a	n.a	0.078	0.065	0.099
1995	n.a	n.a	n.a	n.a	n.a	n.a	n.a	0.095
mean	0.102	0.115	0.132	0.058	0.058	0.073	0.075	0.201
max	0.116	0.125	0.149	0.066	0.067	0.079	0.103	0.344
min	0.087	0.103	0.118	0.050	0.048	0.058	0.055	0.095
s.d	0.007	0.008	0.007	0.004	0.007	0.006	0.011	0.088

Table 2. Test verifying whether capital stock and output grow at different rates

	Z statistic on $H_0 : \mu_{g(Y/L)} = \mu_{g(K/L)}$
USA	0.49
CAN	1.41
JPN	4.71***
DEU	1.85*
FRA	2.47**
ITA	1.65*
GBR	1.26
AUS	1.31
NLD	0.45
BEL	0.44
DNK	0.53
NOR	1.38
SWE	1.96*
FIN	2.23**
KOR	4.68***

***, **, * represents significance at the 1%, 5%, 10% levels, respectively

Table 3. Coefficients of trends

	Gross rate of return (level)	Gross rate of return (growth rate)
USA	-0.043(0.009)***	0.00004(0.0007)
CAN	-0.101(0.027)***	-0.003(0.002)*
JPN	-0.700(0.093)***	0.003(0.002)**
DEU	-0.097(0.014)***	0.0009(0.0007)
FRA	0.013(0.023)	-0.000002(0.002)
ITA	-0.016(0.017)	-0.002(0.001)
GBR	-0.009(0.020)	-0.00007(0.002)
AUS	-0.039(0.019)*	0.001(0.002)
NLD	0.140(0.021)***	-0.001(0.002)
BEL	0.045(0.020)**	-0.0003(0.001)
DNK	-0.026(0.009)***	0.001(0.001)
NOR	0.090(0.015)***	-0.00008(0.002)
SWE	0.016(0.019)	0.001(0.002)
FIN	-0.100(0.010)***	0.0007(0.001)
KOR	-1.108(0.065)***	-0.0006(0.0013)

Table 4. Regression results of equation (23)

Country \ Coefficient	β_1	β_2	AR(1)	R^2	D.W
USA	0.007 (0.009)	-0.982^{***} (0.212)	0.429^{**} (0.176)	0.458	1.825
CAN	-0.007 (0.022)	-0.944^{***} (0.262)	0.584^{**} (0.204)	0.442	1.393
JPN	-0.037 (0.028)	-0.315 (0.445)	0.664^{**} (0.208)	0.429	1.619
DEU	0.035^{***} (0.010)	-1.560^{***} (0.217)	0.526^{***} (0.173)	0.638	1.622
FRA	0.007 (0.017)	-0.293 (0.573)	0.138 (0.228)	0.036	1.893
ITA	0.013 (0.013)	-0.720 (0.466)	0.207 (0.310)	0.126	1.767
GBR	0.010 (0.022)	-0.971 (0.695)	0.252 (0.248)	0.149	1.733
AUS	0.022^{**} (0.010)	-2.040^{***} (0.344)	0.156 (0.224)	0.640	1.895
NLD	0.016 (0.021)	-0.668 (1.068)	0.434 (0.286)	0.197	1.489
BEL	0.010 (0.013)	-0.280 (0.319)	0.220 (0.239)	0.107	1.842
DNK	0.023^{*} (0.013)	-1.235^{***} (0.414)	0.235 (0.229)	0.322	1.676
NOR	0.005 (0.032)	0.434 (1.048)	0.257 (0.244)	0.096	1.866
SWE	0.043 (0.040)	-1.864 (1.076)	0.606^{**} (0.246)	0.280	1.308
FIN	0.033 (0.024)	-1.388^{**} (0.608)	0.278 (0.227)	0.254	1.485
KOR	0.062^{**} (0.025)	-1.297^{***} (0.280)	0.041 (0.202)	0.511	2.101

* Data period : USA('61-'93), CAN('70-'92), JPN('71-'94), DEU('61-'94), FRA('77-'94), ITA('71-'94), GBR('71-'94), AUS('70-'94), NLD('77-'94), BEL('71-93), DNK('66-'93), NOR('71-'91), SWE('71-'94), FIN('61-'94), KOR('70-'95)

Table 5. Regression results of equation (22)

Coefficient / Country	β_1	β_2	β_3	AR(1)	R^2	D.W
USA	0.006 (0.010)	-0.892*** (0.209)	0.024 (0.017)	0.508*** (0.179)	0.493	1.588
CAN	-0.01 (0.023)	-0.934*** (0.268)	0.005 (0.009)	0.581** (0.201)	0.452	1.491
JPN	-0.041 (0.033)	-0.006 (0.395)	0.041 (0.019)	0.740*** (0.171)	0.549	1.681
DEU	0.036*** (0.011)	-1.590*** (0.207)	-0.018 (0.01)	0.557*** (0.175)	0.677	1.619
FRA	0.001 (0.017)	-0.103 (0.619)	0.043 (0.029)	0.064 (0.098)	0.172	1.858
ITA	-0.006 (0.012)	0.127 (0.427)	0.059 (0.019)	0.280 (0.238)	0.432	1.095
GBR	-0.002 (0.026)	-0.475 (0.700)	0.042 (0.047)	0.382 (0.374)	0.228	1.517
AUS	0.020* (0.011)	-1.868*** (0.320)	0.017 (0.011)	0.303 (0.249)	0.684	1.727
NLD	0.007 (0.026)	-0.044 (1.126)	0.030 (0.035)	0.573 (0.378)	0.269	1.196
BEL	0.013 (0.015)	-0.539 (0.321)	0.044 (0.018)	0.499* (0.282)	0.367	1.590
DNK	0.0184 (0.014)	-1.012** (0.439)	0.021 (0.026)	0.293 (0.291)	0.349	1.606
NOR	0.005 (0.031)	0.608 (0.913)	0.038 (0.022)	0.484 (0.276)	0.283	1.497
SWE	0.036 (0.040)	-1.523 (1.097)	0.029 (0.039)	0.611** (0.279)	0.311	1.229
FIN	0.023 (0.025)	-1.109* (0.611)	0.021 (0.031)	0.337 (0.314)	0.275	1.383
KOR	0.053* (0.029)	-1.258*** (0.298)	0.160 (0.170)	0.087 (0.219)	0.530	2.111

* Data period : USA('61-'93), CAN('70-'92), JPN('71-'94), DEU('61-'94), FRA('77- '94), ITA('71-'94), GBR('71-'94), AUS('70-'94), NLD('77-'94), BEL('71-93), DNK('66-'93), NOR('71-'91), SWE('71-'94), FIN('61-'94), KOR('70-'95)

Fig1. Gross Rates of Return on Capital in G7 Countries & Korea

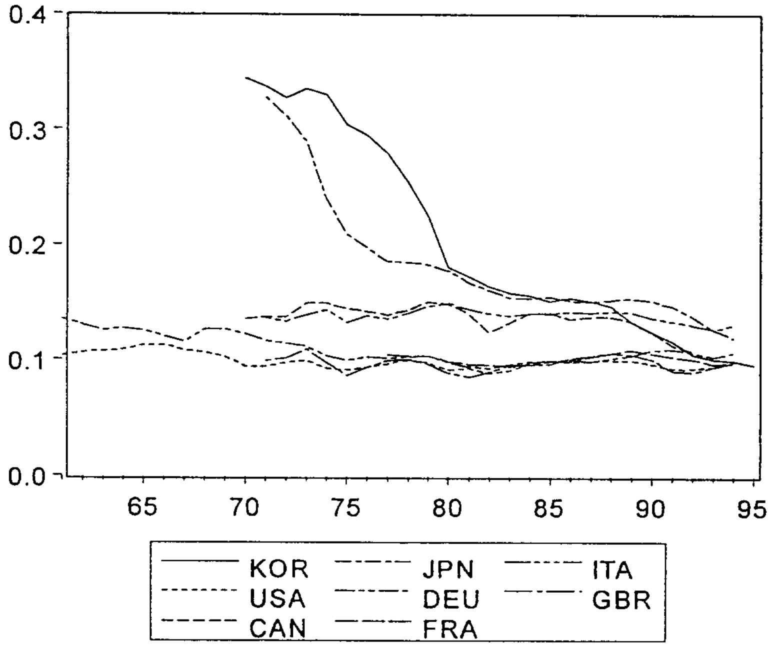

Fig2. Gross Rates of Return on Capital in Other OECD Countries and K

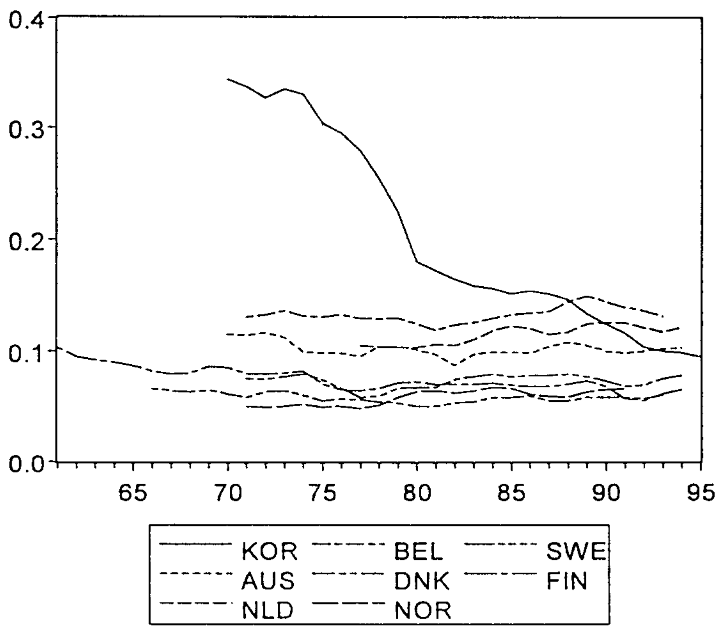

Fig 3. Gross Rates of Return on Capital

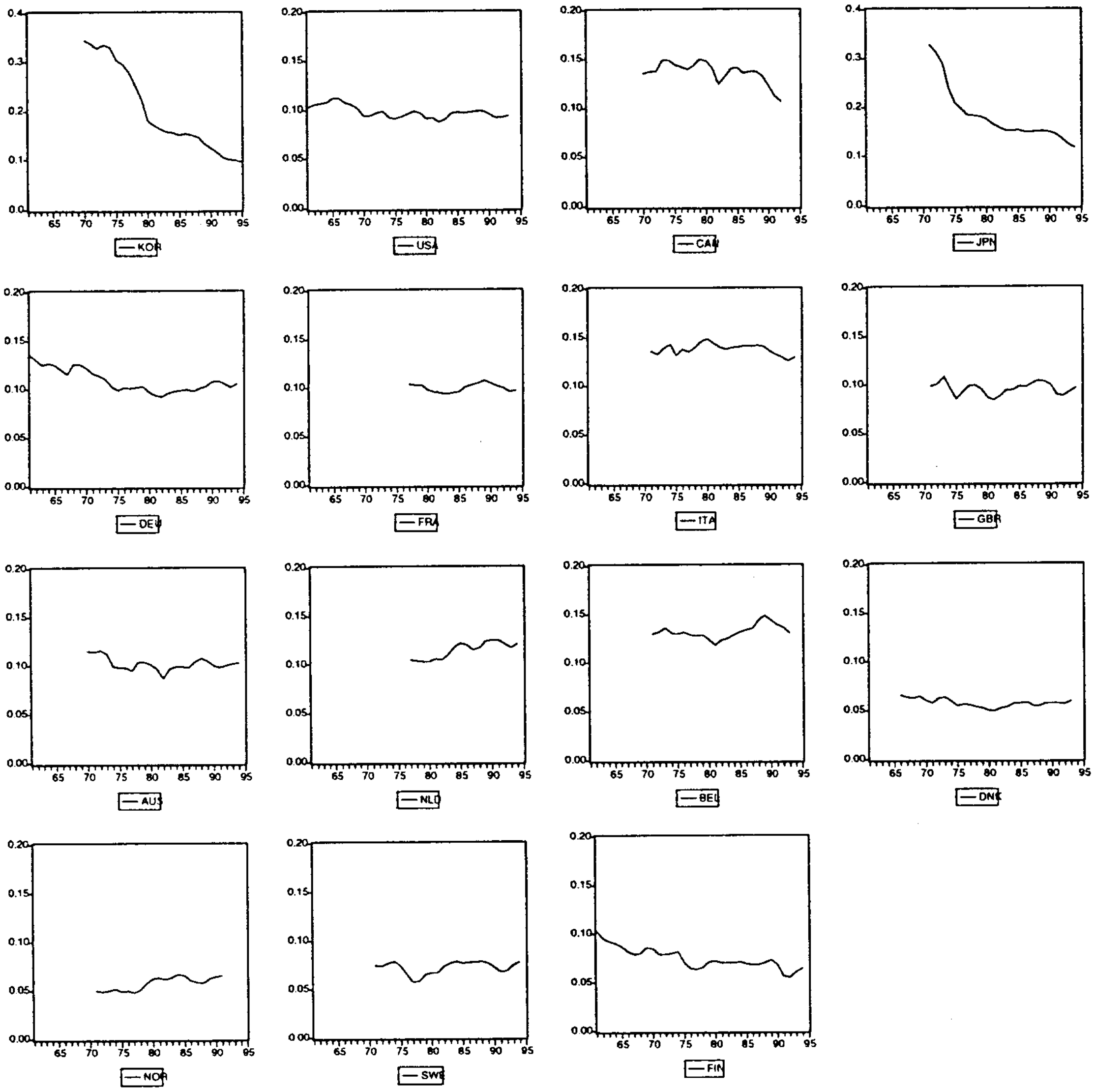

Fig 4. Capital Stock and Output(per capita)

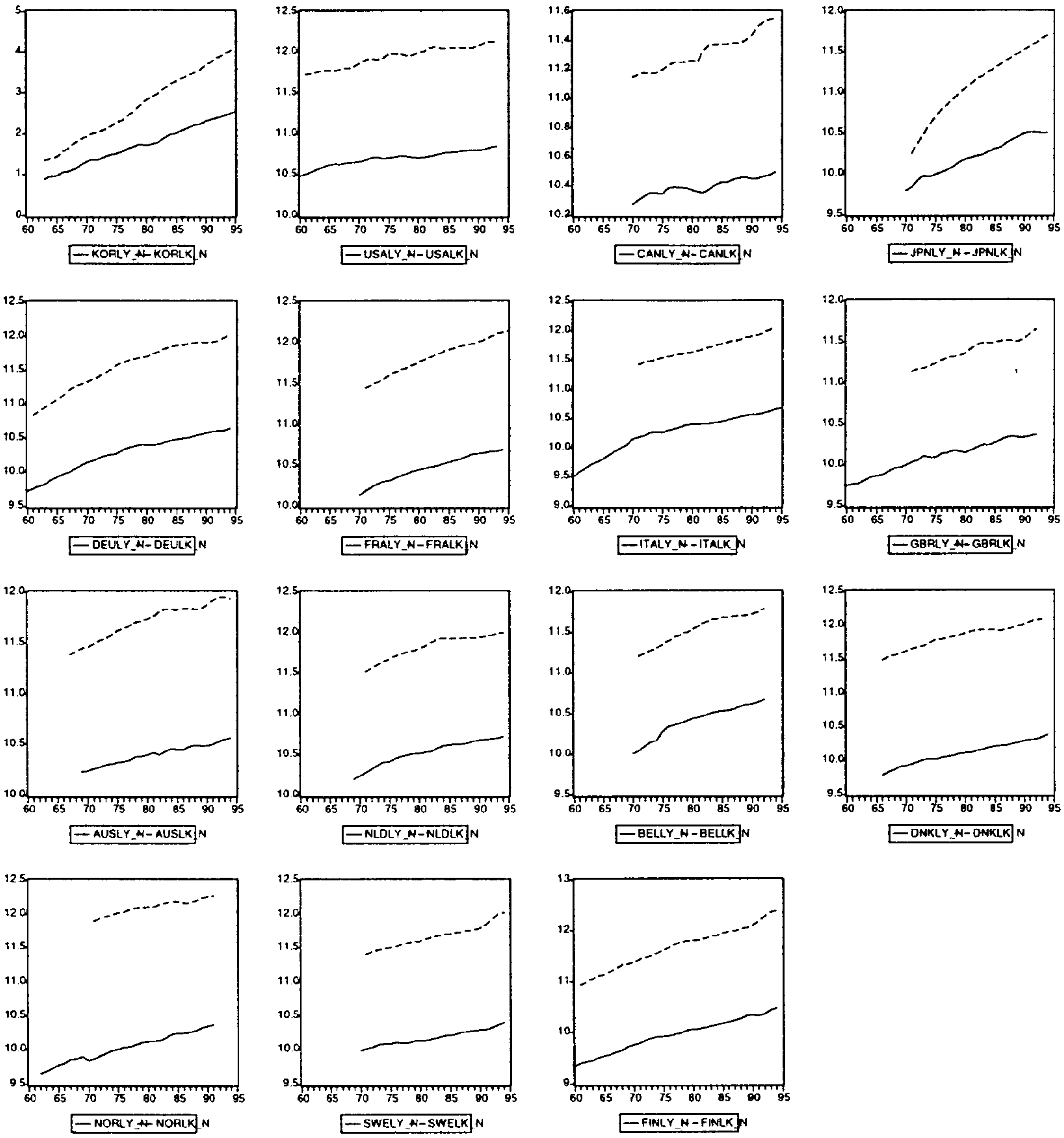

Figure 5. Path of Capital Accumulation

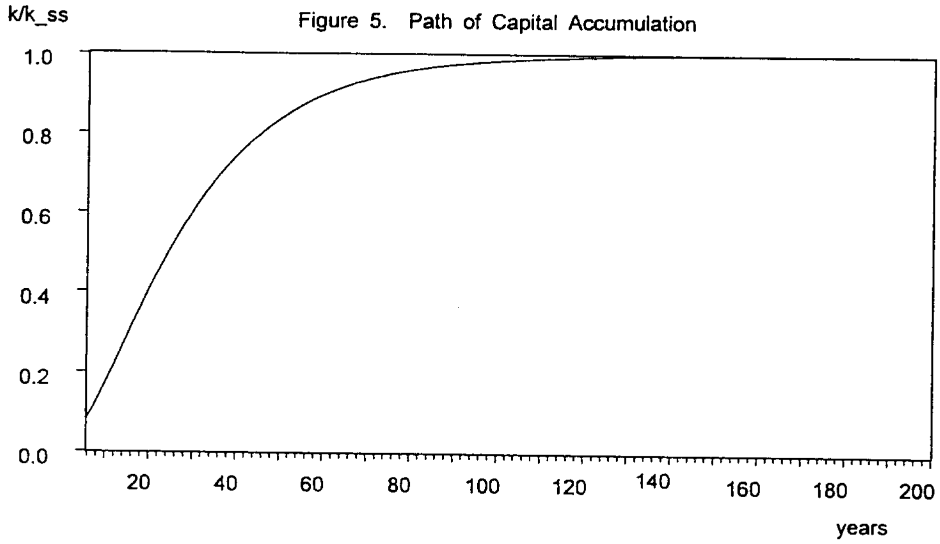

Figure 6. . Speed of Convergence

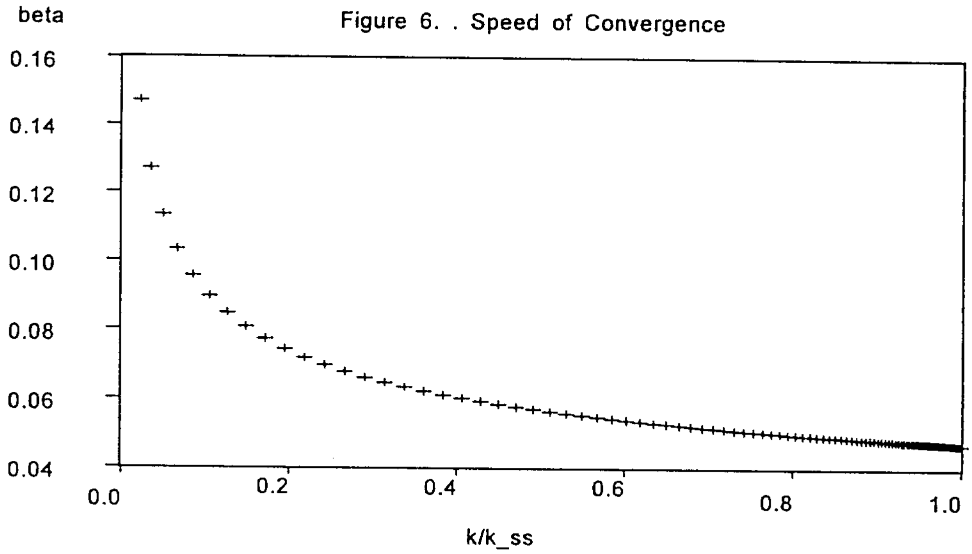

Figure 7. Growth Rates of Capit

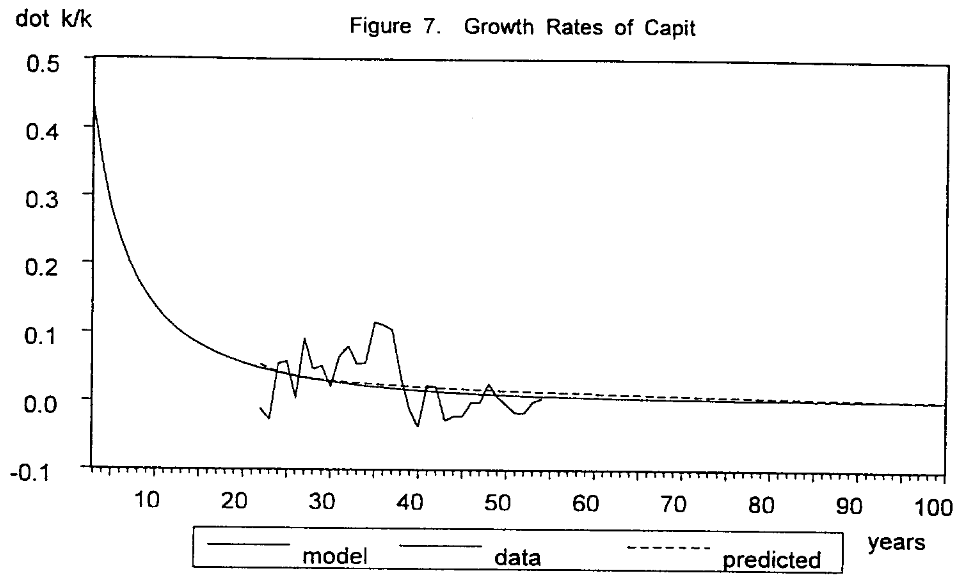

Figure 8. Rates of Return on Capital

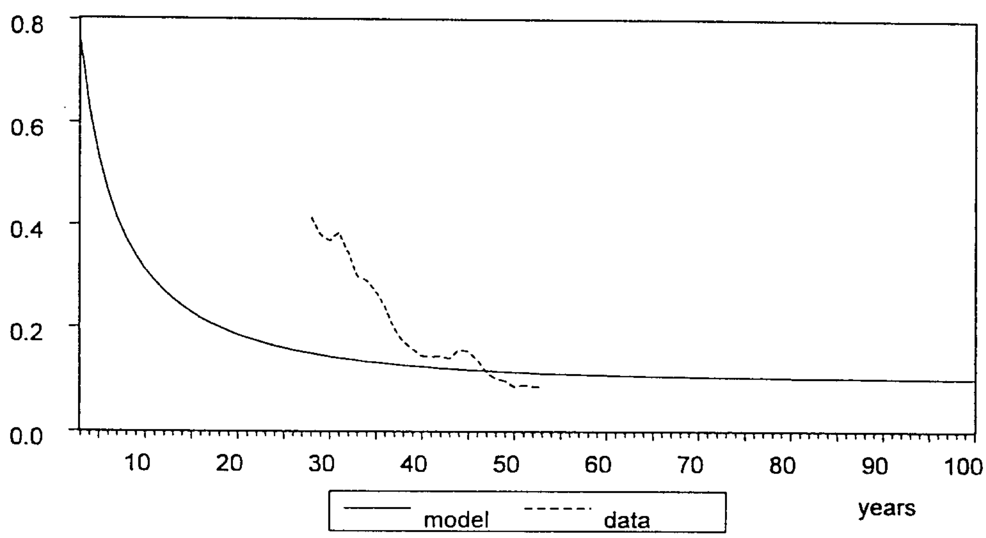

Figure 9. Sensitivity Analysis(Growth Rates of k)

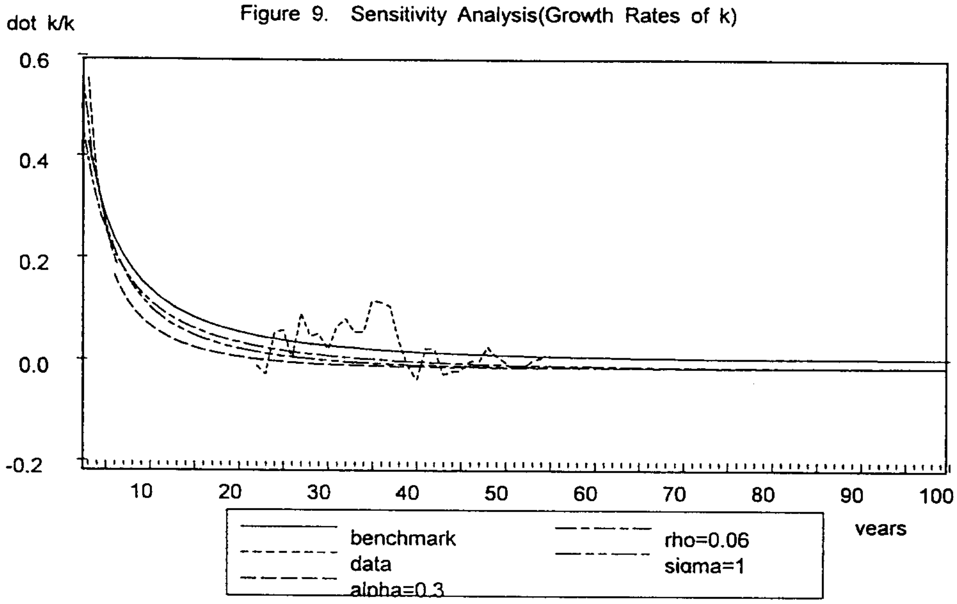

Figure 10 Sensitivity Analysis(Rates of Return)

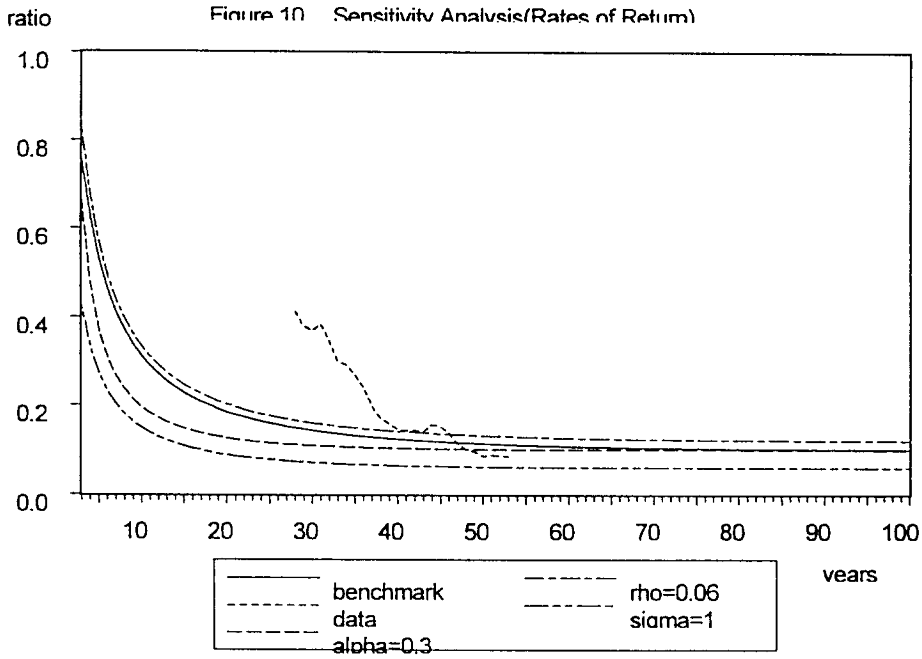

Figure 11. Capital-Output Ratio

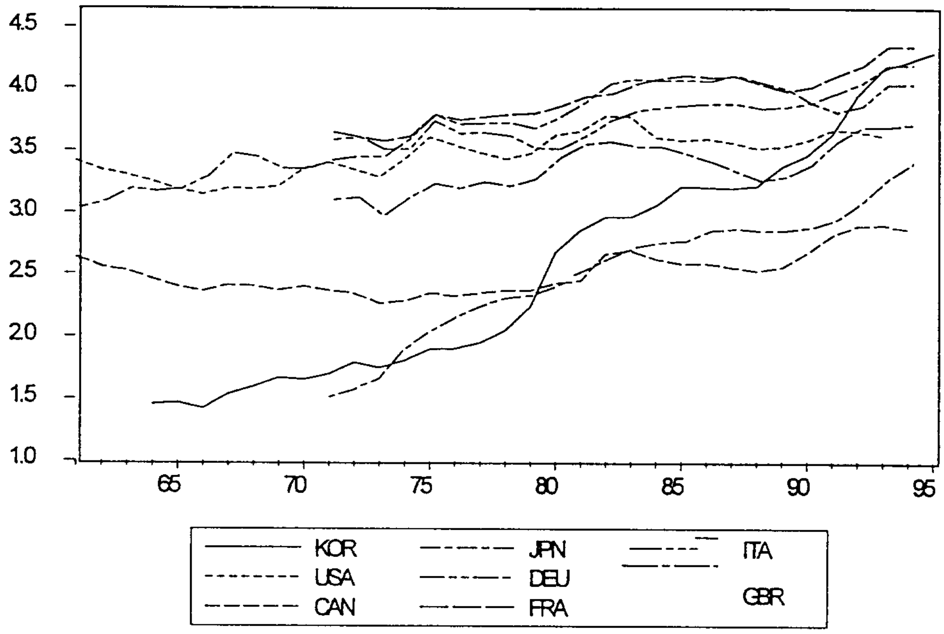

Figure 12. Labor Share