*The Pakistan Development Review*
39 : 4 Part II (Winter 2000) pp. 729–740

# An Empirical Analysis of Convergence Hypothesis

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## 1. INTRODUCTION

A useful contribution of wide ranging debate in the growth literature is that it has put forward a number of testable hypotheses. One of such hypotheses is known as the convergence hypothesis whereby it is postulated that in the long run developing countries would catch-up with the developed countries in terms of per capita income. Although the convergence hypothesis has gained researchers' interest in recent times, the basic proposition was laid down in the neo-classical growth model of Solow (1956) and Swan (1956). Traditionally Solow-Swan model has been regarded as a theoretically consistent answer to Harrods's (1939) twin problems of discrepancy between the warranted and natural rates of growth and instability in the growth process. Although Solow-Swan model is designed to study growth process within a single country, the concept of conditional convergence is far from being alien to the model; it in fact forms the core of argument in the attack on Harrod-Domar model [Harrod (1939) and Domar (1946)].

The model predicts that under perfect competition and in the absence of market distortions, an economy converges to equilibrium capital-labour ratio to yield steady state growth rate that is equal to the natural growth rate and is dynamically stable. More assertively under diminishing marginal returns to capital the growth process postulates conditional convergence, which means that lower the starting level of real per capita GDP relative to the long run or steady state position; the faster would be the growth rate. Thus the economies that have less capital per worker

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*Authors' Note:* We are thankful to Dr Musleh-ud Din of PIDE for his cooperation in downloading the data.

(relative to their long-run positions) tend to have higher rates of returns to capital and higher rates of growth. The convergence in Solow-Swan model is conditional because the steady state growth path depends on the saving rate, the growth rate of population, and the rate of technological progress that might vary across economies.

More recent contributions to growth literature, especially Romer (1986, 1987) and Lucas (1988) have undermined the theoretical foundations underlying the convergence hypothesis. Romer (1986, 1987) presented long-run growth models in which the rate of economic growth is not pre-determined at the natural rate level as in case of Solow-Swan and Harrod-Domar models [Harrod (1939) and Domar (1946)]. In Romer's growth framework knowledge is taken as public input that results in increasing return to scale with respect to private inputs. This is essentially a competitive equilibrium model with endogenous technological change giving rise to increasing returns at the aggregate level despite constant returns at the firm level. Thus a decentralised competitive equilibrium is possible with externalities arising from the spillover of knowledge. Romer's model implies that the return to investment in knowledge can be amplified by the collective behaviour of private agents and large countries may always grow faster than small countries, thereby contradicting the convergence implied by Solow-Swan formulation.

Lucas's (1988) formulation emphasises the role of human capital accumulation through education and learning-by-doing in the growth process. The growth dynamics of the model imply that the economies that are poor can remain relatively poor, though their long-run rate of income growth will be the same as that of initially (and permanently) wealthier economies. A world consisting of such economies would exhibits uniform rates of growth across countries and would maintain a perfectly stable distribution of income and wealth. Thus Lucus's model can be taken as a compromise or dividing line between the two opposite positions taken up by Solow-Swan and Romer models.

The present study attempts to test empirically convergence hypothesis using both the formal and informal statistical techniques. The study is based on a sample of 54 countries and it covers the period 1961 to 1992.

The study is organised as follows. After a brief description of data in Section 2, the study presents formal tests of convergence in Section 3. The informal analysis based on per capita income ranks is presented in Section 4.

## 2. DATA

The study is based on a sample of 54 countries. As can be seen from Table 1, our sample has a fair representation of developed, less developed and underdeveloped countries. The analysis covers a period of 32 years from 1961 to 1992. The data are taken from Penn Word Tables (version 5.6) of [Heston and Summers (1997)].

Table 1

*The Sample of Selected Countries*

| Poor Countries | Lower Middle-Income Countries | Upper Middle-Income Countries | Rich Countries |
|---|---|---|---|
| China | Bangladesh | Algeria | Argentina |
| Egypt | Indonesia | Brazil | Australia |
| Gambia | Korea | Chile | Belgium |
| Ghana | Madagascar | Colombia | Canada |
| India | Malaysia | Greece | France |
| Kenya | Paraguay | Hong Kong | West Germany |
| Liberia | Philippines | Japan | Italy |
| Mauritania | Senegal | Mexico | Netherlands |
| Morocco | Sri Lanka | Peru | New Zealand |
| Nigeria | Taiwan | Portugal | Norway |
| Pakistan | Thailand | Singapore | UK |
| Tanzania | Tunisia | Spain | USA |
| Uganda | Zambia | Turkey | Venezuela |
| | Zimbabwe | Uruguay | |

## 3. TESTS OF CONVERGENCE

There are two well-known concepts of convergence that appear in discussions of economic growth across countries or regions. According to one concept convergence applies if poor economies tend to grow faster than the rich ones so that the former tend to catch-up with the latter in terms of the level of per capita income. This type of catch-up or convergence is known as β-convergence. The second concept concerns cross sectional dispersion. According to this concept convergence occurs if the dispersion, measured by the standard deviation of the logarithm of per capita income across a group of countries or regions, declines over time. This type of process is known as σ-convergence.[1] In general the convergence of first type (poor countries grow faster than rich ones) tends to generate convergence of second type (reduced dispersion of per capita income), but the converse is not true. Furthermore the convergence process can by disturbed by new shocks that tend to increase dispersion.

In order to make the relationship between the two concepts more precise we consider the following version of growth equation predicted by the neoclassical growth model that relates the growth rates of per capita income between two periods to the initial level of income.

$$\log\left(Y_t^i / Y_{t-1}^i\right) = \alpha - \left(1 - e^{-\beta}\right) \log Y_{t-1}^i + U_t^i \qquad \ldots \qquad \ldots \qquad \ldots \qquad (1)$$

[1]For more detail, see Barro and Sala-i-Martin (1995).

where $Y_t^i$ is per real capita output of country *i* in period *t*, $U_t^i$ is a random disturbance term, and β is the speed of convergence. We assume the random disturbance term has zero means and constant variance and is distributed independently of $\log Y_{t-1}^i$ and the lagged disturbance terms. We can think of random disturbance as reflecting unexpected changes in production condition or preferences. If the intercept in Equation (1) is the same in all economies and β>0 than the equation implies that poor counties trend to grow faster than rich one. The same conclusion holds for various endogenous growth models that incorporate linearity in the production function.[2]

We now discuss the σ -convergence. Let $\sigma_t^2$ be the cross-country variance of $\log Y_{t-1}^i$ at time *t*. Equation (1) and the assumed property of $U_t^i$ implies that $\sigma_t^2$ evolves over time in accordance with the first order difference equation.

$$\sigma_t^2 = e^{-2\beta}\sigma_{t-1}^2 + \sigma_{U_t}^2 \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \qquad (2)$$

In the above formulation we have assumed that the sample variance of $\log Y_{t-1}^i$ corresponds to the population variance. If variance of disturbance $\sigma_{U_t}^2$ is constant over time, denoted $\sigma_U^2$, than the solution of the first order difference Equation (2) will be given by:

$$\sigma_t^2 = \frac{\sigma_U^2}{1-e^{-2\beta}} + \left(\sigma_0^2 - \frac{\sigma_U^2}{1-e^{-2\beta}}\right)e^{-2\beta t} \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \qquad (3)$$

where $\sigma_0^2$ is the variance of $\log Y_0^i$.

It can be readily verified that the solution in Equation (3) satisfies Equation (2) and that $\sigma_t^2$ monotonically approaches its steady state value:

$$\sigma_t^2 = \frac{\sigma_U^2}{1-e^{-2\beta}} \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \qquad (4)$$

It follows from above that the steady-state value of $\sigma_t^2$ rises with $\sigma_U^2$ but it declines with the convergence coefficient β. If β is positive then over time $\sigma_t^2$ falls (rises) if the initial value $\sigma_0^2$ is greater (less) than steady state value of $\sigma_t^2$. Thus a positive coefficient β (β-convergence) does not necessarily result in a falling $\sigma_t^2$ (σ-convergence). Or to put it another way, β-convergence is a necessary but not sufficient condition for σ-convergence.

[2]For detail, see Nonneman and Vanhout (1997).

The β-convergence hypothesises that the value of β is positive and therefore poor countries tend to grow faster than rich ones. In order to test this hypothesis we have estimated the value of β for our Equation 1 with the help of non-linear least squares method. Table 2 shows the results for β convergence for our sample of 54 countries for the period 1961 to 1992. The results for real GDP and real consumption show that estimated values of β are positive but statistically insignificant, implying absence of strong convergence or catch-up among the different countries of the world selected for our study. If we estimate the Equation 1 for the per capita GDP or per consumption we get a negative value for beta, which is somewhat significant, indicating divergence in per capita income and consumption.

The above results suggest that although the poor countries are on average at least maintaining their relative position with respect to aggregate real income and consumption, their relative position has worsened in terms of per capita real income and consumption. In other words the little catching-up observed in aggregate income and consumption is more than offset by a faster population growth rate among the poor countries as compared to the rich countries.

Table 2

*Results of β-Convergence*

| Parameter | Real GDP | Real Consumption | Per Capita Real GDP | Per Capita Real Consumption |
|---|---|---|---|---|
| β | 0.0010 | 0.0008 | –0.0030 | –0.0035 |
| | (1.27) | (0.76) | (–2.13*) | (–1.90*) |

In order to test σ-convergence we now perform non-linear estimation of Equation 2. The results presented in Table 3 show that the value of β is negative and statistically significant in each of the four cases. The catching-up hypothesis, on the other hand, requires a positive value of β, which is the necessary condition for sigma convergence. Thus we can conclude that dispersion across countries has risen over time.

There may be many economic and non-economic reasons for this lack of catch-up ability. In fact countries with high per capita incomes such as America, United kingdom, Germany, Canada, Hong Kong, etc. are more advanced in technology and in other fields of life (welfare, education, health, etc.). Countries with low per capita income lack suitable initial condition that can enable them catch-up, such as a well develop infrastructure, political stability, sufficient expenditure on education and health, strong institutional structure and good governance.

Table 3

*Results of σ-Convergence*

| Parameter | Variance of Real GDP | Variance of Real Consumption | Variance of Per Capita Real GDP | Variance of Per Capita Real Consumption |
|---|---|---|---|---|
| β | –0.0352 | –0.0358 | –0.0263 | –0.0280 |
| | (–9.10*) | (–9.88*) | (–9.89*) | (–12.11*) |

## 4. ANALYSIS OF PER CAPITA INCOME RANKS

We now address the convergence hypothesis using descriptive analysis of inter country data mainly because it gives a clear picture of the standing of various countries with respect to economic well-being over time. This technique is also used in some other studies such as Baumal (1986); Dowsick (1992) and Jones (1995) in detecting the same problem. But our technique is slightly different from them in choosing variables. We make use of per capita income ranks and study the changes in these ranks over time and over groups of countries. For the construction of our convergence graphs, following definitions and concepts are used.

We ranked sampled countries separately, for each year on the bases of their per capita incomes in ascending order. As our sample contains data on 54 countries for thirty-two years, this gives us 32 cross sections of ranks, each containing 54 ranks. We then classify the sampled countries in four groups on the basis of per capita income ranks. These four groups are poor, lower middle income, upper middle income and rich. Each group contains thirteen to fourteen countries. We make these groups because it is easy to analyse behaviour of a group having some common characteristics rather than analysing a country individually. Here we calculate the average ranks for each period across all the countries within a group (poor, rich, etc.). This exercise gives four time series profiles of ranks one each for the poor, lower middle, upper middle and rich countries.

For further analysis, we then divide the whole period of analysis into four sub-periods, each containing eight years: 1961–68, 1969–76, 1977–84 and 1985–92 and then determine for each country the average ranks in each of the four sub-periods. The justification for taking the averages is that the growth process cannot be approximated in a short period of one year. This gives us four sets of cross sectional rank profiles for 54 sampled countries.

In the time series rank profiles we analyse changes in averaged ranks for the four groups (poor, lower middle income, upper middle income and rich) over time. On the other hand, in the cross sectional rank profile we are interested in analysing the changes in relative positions of the individual countries over the four sub-periods.

Figure 1 shows time series rank profiles for per capita income. The graph shows that there are no significant changes in the average ranks of the four groups of countries over time. Although there are slight changes in the averaged ranks of poor and lower middle income groups of countries, but these changes are not substantial. This means that the evidence on convergence is not strong enough to substantiate the so-called convergence hypothesis. In case of upper middle income group of countries there is slight decrease in averaged ranks? This result is similar to the result obtained by Dowsick (1992) through a residual approach. In case of rich countries we can see a constant trend in the ranks, which breaks in the last two years when the averaged ranks for the rich group slightly declined.

Figure 2 shows cross-sections of rank profiles. Here we observe changes in averaged ranks of each country in the four sub-periods (1961–68, 1969–76, 1977–84, and 1985–92). The changes in averaged ranks are analysed in four sub-periods, for each country individually. Countries are arranged in ascending order with respect to averaged ranks of per capita income of 1961. This helps us in studying separately the changes in the ranks of individual countries in the sample. We find that some major changes have occurred for the poor group of countries, for the second sub-period of 1969–76, in which Nigeria and Egypt progressed considerably and jumped into the next group of ranks, i.e. lower middle income group of countries. In the second group of countries, Taiwan jumped from second to third group of ranking. For the third sub-period 1977-84 China and Uganda showed slight progress, while Korea jumped from second to third group of ranking and Hong Kong jumped from third to fourth group of ranking. For the fourth sub-period 1985–1992 many of the countries show a decline in their ranks such as Singapore and Uruguay. Only Hong Kong showed a slight progress in its rank. We thus conclude that there is catch-up among some countries like Korea, Singapore, Taiwan and Hong Kong. But for the poor and lower middle income countries the given evidence does not support the prediction of catching-up hypothesis. In other words low level of per capita alone is not the sufficient condition for catching-up, there must be some other reasons for the catch-up, which are not explained by the theory.

The figure shows that East Asian countries like Korea, Taiwan, Singapore, Hong Kong, and Japan showed a remarkable upgrading of ranks. In the rich group most of the countries retained their initial ranks for the third sub-period of 1977–84 but some countries such as New Zealand and Venezuela showed a significant decline in their initial ranks. Thus the evidence supports the catching-up hypothesis mainly for the East Asian countries. Country with low per capita income rank showed no strong and considerable degree of catch-up.

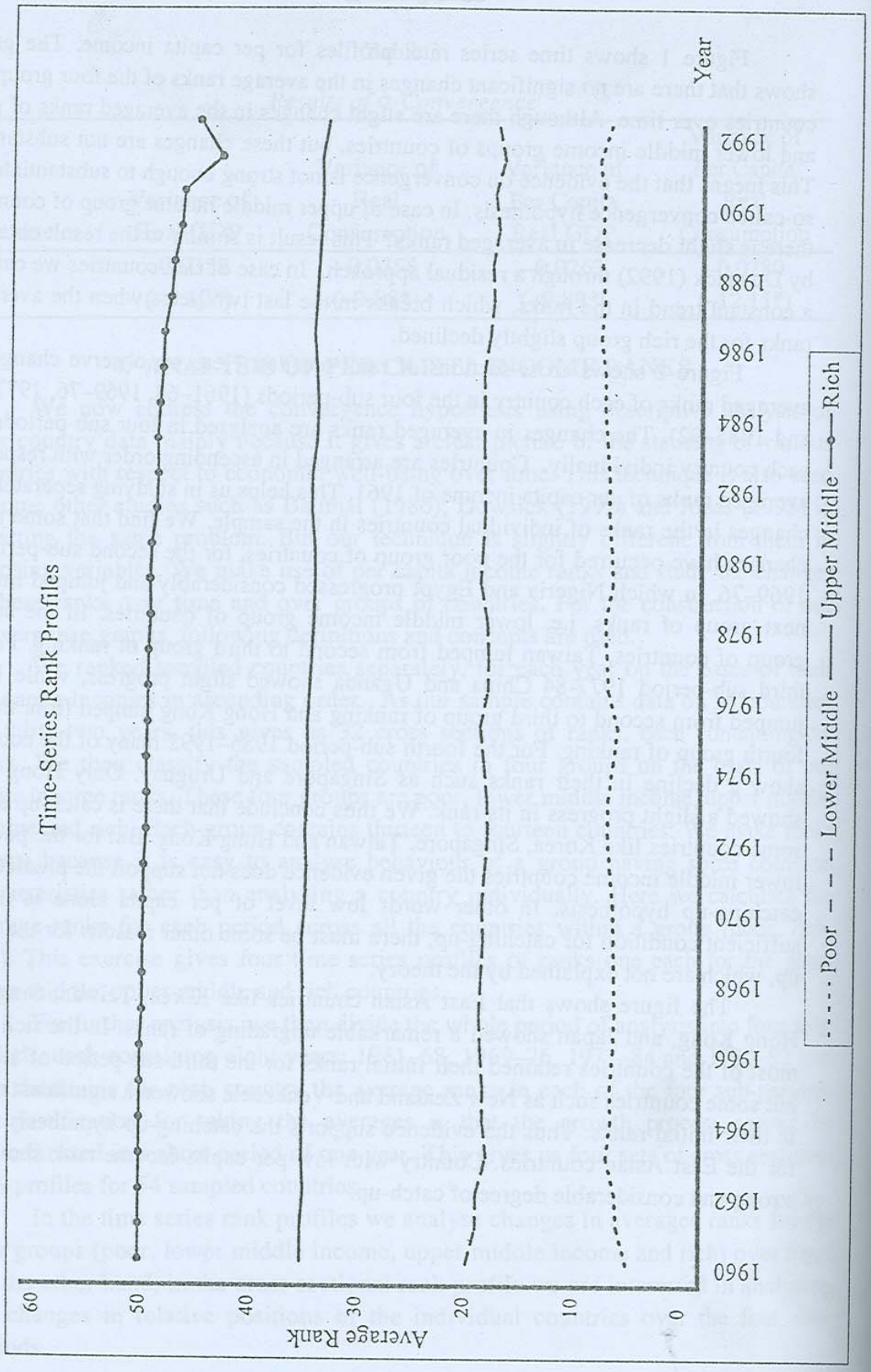
Time-Series Rank Profiles
Average Rank
60
50
40
30
20
10
0
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
Year
Poor
Lower Middle
Upper Middle
Rich

Figure 1.

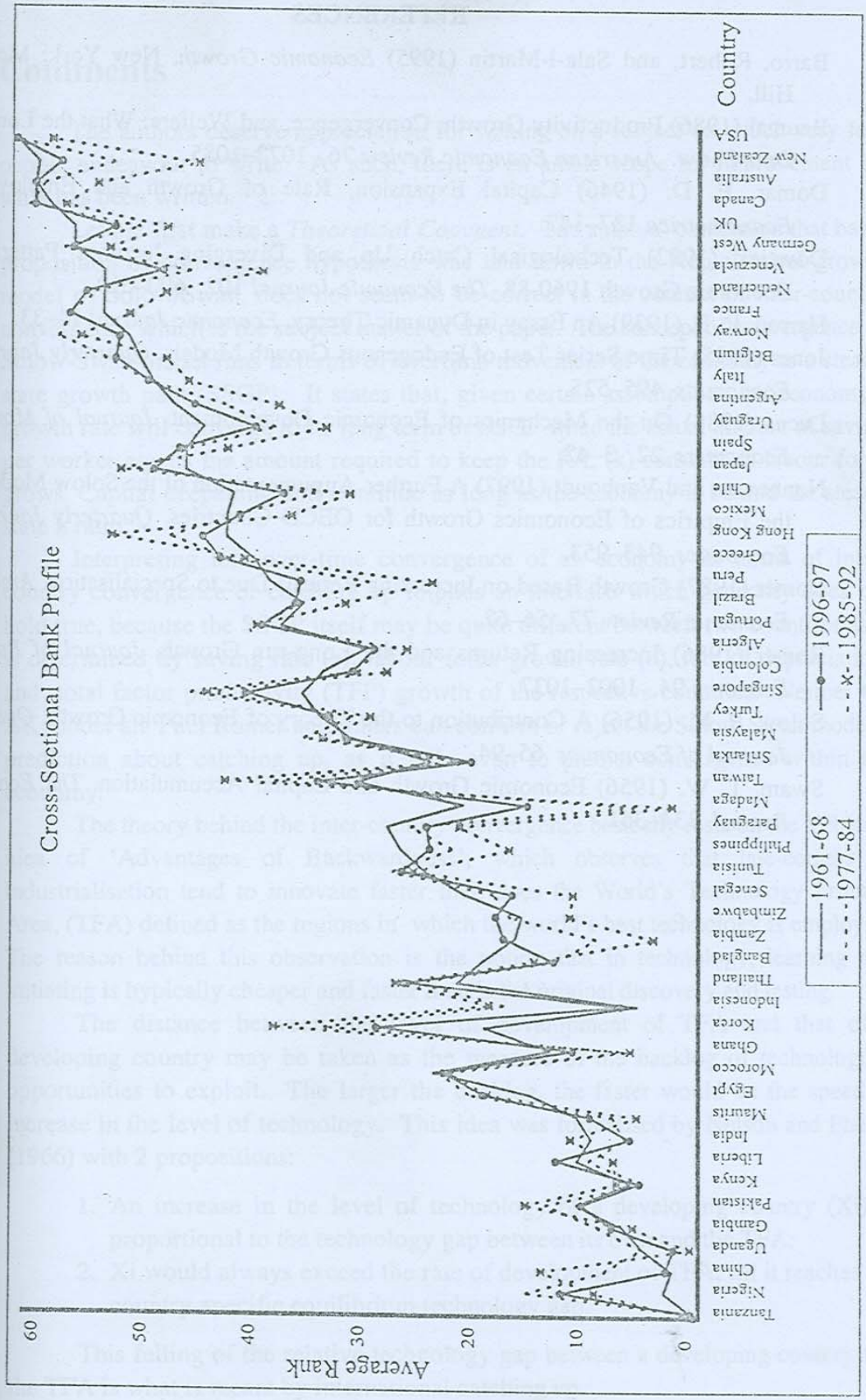
Cross-Sectional Bank Profile
Average Rank
0
10
20
30
40
50
60
Country
Tanzania
Nigeria
China
Uganda
Gambia
Pakistan
Kenya
Liberia
India
Mauritis
Egypt
Morocco
Ghana
Korea
Indonesia
Thailand
Bangladesh
Zambia
Zimbabwe
Senegal
Tunisia
Philippines
Paraguay
Nicaragua
Taiwan
Srilanka
Malaysia
Turkey
Singapore
Colombia
Algeria
Portugal
Brazil
Peru
Greece
Hong Kong
Mexico
Chile
Japan
Spain
Uruguay
Argentina
Italy
Belgium
Norway
France
Netherland
Venezuela
Germany West
UK
Canada
Australia
New Zealand
USA
1961-68
1977-84
1996-97
1985-92

Figure 2.

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# Comments

The authors deserve appreciation for writing on a subject on which very few people endeavour to write. As such, there is an ample scope for improvement on what has been written.

Let me first make a *Theoretical Comment*. The authors' contention that basic proposition of convergence hypothesis was laid down in the Neo-classical growth model of Solow/Swan, does not seem to be correct in the context of inter-country convergence which is the subject matter of the paper. The concept of convergence of Solow-Swan model runs in terms of overtime movement of the economy to a steady state growth path (SSGP). It states that, given certain assumptions, an economy's growth rate will converge to its long term or SSGP when the actual amount of saving per worker equals the amount required to keep the K/L (k) constant as labour force grows. Capital deepening will continue as long as the economy is behind the steady state k ratio.

Interpreting this over-time convergence of an economy in terms of inter-country convergence or catching up implies an interface which generally does not hold true, because the SSGP itself may be quite different between two countries as it is determined by saving rate (s), labour force growth rate (n), rate of depreciation, and total factor productivity (TFP) growth of the respective countries. Neither the AK model ala Paul Romer and others can confirm or reject the Solow-Swan model's prediction about catching up, as it fails even to predict convergence within the economy.

The theory behind the inter-country convergence basically rests on the Veblen's idea of 'Advantages of Backwardness', which observes that late-comers in industrialisation tend to innovate faster than does the World's Technology Frontier Area, (TFA) defined as the regions in which the world's best technology is employed. The reason behind this observation is the notion that in technology, learning and initiating is hypically cheaper and faster than is the original discovery and testing.

The distance between the level of development of TFA and that of a developing country may be taken as the measure of the backlog of technological opportunities to exploit. The larger the backlog, the faster would be the speed of increase in the level of technology. This idea was formalised by Nelson and Phelps (1966) with 2 propositions:

1. An increase in the level of technology of a developing country (Xi) is proportional to the technology gap between its own and the TFA;
2. Xi would always exceed the rate of development of TFA, till it reaches the country-specific equilibrium technology gap.

This falling of the relative technology gap between a developing country and the TFA is what is meant by international catching up.

**Empirical Comment**

Empirically, the results of β as will as σ convergence testing from Equation (1) shows no convergence. But it is not difficult to find out cases where countries have experienced catching-up. Japan, Germany, Holland are good examples in the post 2nd world war period. In more recent years, convergence of Korea, Hong Kong, and Singapore can be cited.

The problem lies with the Equation (1) (taken from Barro and Salai-Martin) used for testing the hypothesis. The intercept 'α' in Equation (1) reflects two things: (i) steady state level of per capita income growth, and (ii) time trend. β convergence hypothesis assumes α equal for all countries—an assumption which does not hold across countries except for perfectly homogenous groups.[1] Similarly, in the σ convergence hypothesis, cross sectional dispersion of log $Y^i_t$ is sensitive to the shocks that have a common influence on a sub-group of countries. In such a case, the assumption about random term that *uit* is independent of *ujt* (for $i \neq j$) becomes unrealistic. To the extent that these shocks are correlated with the explanatory variable, the omission of such shocks from the regression will tend to bias the β estimates. Examples of such shocks can be: worsening of TOT for certain commodities, like coffee; or surge in oil prices. The former will reduce income for coffee growing countries; the latter will increase income for OPEC countries. That explains why Barro and Salai-Martin themselves, while analysing convergence, have introduced regional dummies and structural variables to capture shocks in the equation to obtain accurate estimates of β.

A meaningful analysis can be made only if countries are classified according to certain attributes. For example, Sachs and Warner (1995) while studying relation between economic policies and growth rate, with a sample of 111 countries divided into open and closed economies claim to have found that the open economies showed strikingly faster growth and convergence 8520/than the closed ones.

Interestingly, the authors also used another, descriptive, methodology in terms of "per capita income ranking" and found results totally different from those derived through econometric method. The paper ends inconclusively as it does not make any comment regarding which results are correct and why.

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[1]In terms of the Solow model, assuming s, n, same for all countries, k will be larger for the economy with lower initial value of k, i.e. poor country will grow faster. This is a kind of Absolute Convergence. This is possible only for a group of countries perfectly homogenous in nature. If we allow heterogeneity and change the assumption of uniform parameters, we get a result of non-convergence. For example, if $S_{rich} > S_{poor}$ (while still assuming the same n and s), the rich country will be proportionality more away from its Steady-state position, hence will grow more faster than the poor country (anti-convergence).