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CROSS-COUNTRY DIFFERENTIALS IN GROWTH AND THE ROLE HUMAN CAPITAL: AN EMPIRICAL ANALYSIS BASED ON NEO-CLASSICAL APPROACH

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Abstract
This paper actually supplements the Mankiw, Romer and Wail's model on the empirics of cross-country growth. It tries to examine the role of human capital in the cross-country differential in the level and growth of per-capital income by further augmenting the neo-classical Solow-Swan model through the incorporation of two fundamental ingredients method for the empirical analysis. It is found that the physical capital, health and educational capital together explain a highly significant proportion of cross-country differentials in the level and growth of real per-capita income. However, the inclusion of health and education capital in the model makes per-capita investment as explanatory variable weaker. We find the perfect unconditional divergence and also a tendency of conditional convergence. Our study not only reinforces the finding of Mankiw et. al but it also reinforces the validity of the neo-classical Solow-Swan model by discarding the criticism leveled by the endogenous growth theorists against it.

Introduction

This paper tries to examine the role of human capital in the cross-country differentials in the level and growth of per-capita income by further augmenting the neo-classical Solow-Swan model through the incorporation of two fundamental ingredients of human capital viz; the health and education capital. After augmenting the model we have examined its empirical validity in explaining cross-country differentials in the level and growth of real per capita income for two separate periods viz. (a) 1960-85 and (b) 1980-98. We have also examined whether the inclusion of the two crucial ingredients of human capital in the Solow model brings about any change in the major conclusion about the pattern of cross-country differentials in the level of real per capita income and the notion of convergence as is concluded by Solow (1956, 2000), Cass (1961), Koopmans (1965) and also by the modern economists Baumol (1986), Barro (1991, 1997, 1999), Lucas (1988) and Rebelo (1991), Romer (1986), Mankiw et al (1992), Bils et al (2000), Caballe and Santos (1993); Islam (1995); Young (1995); Evans (1996); Lones (1995) etc. this work is actually a complementary to Mankiw, Romer and Weil's study. However, the main contrasts of our study with that of Mankiw et al and others are in respect of the use of proxy variable for human capital; period of study and the choice of sample countries. Instead of using an inadequate proxy of human capital (viz. the proportion of working age population that is in secondary school) as is done by Mankiw et al, we have considered gross enrolment ratio in primary, secondary, tertiary education and life expectancy at birth as the proxy variables for education capital and health capital. In fact, unlike the recent endogenous growth models [Romar (1986), Rebelo (1991), Lucus (1988), Caballc & Santos (1993), Barro (199 t. 1997, 1999)], the main emphasis of which is on role of human capital on the growth process of the economics with constant or increasing returns to capital, we have included both the education capital and health capital as components of human capital in the augmented Solow model. Interestingly we find that even in presence of diminishing returns to physical capital and human capital, the augmented Solow model can explain a highly significant proportion of cross-country differentials in the level and growth of real per capita income. Further, we find that the explanatory power of the model becomes much higher after the incorporation of education and health capital than what is found by Munkiw et al and others. Thus, the analysis reported in this paper not only reinforces the conclusions of Mankiw et al (1992), Solow (1956), Islam (1995) etc. but also provides a strong defense against the criticism labeled by the endogenous growth theorists to the neo-classical Solow growth model. In fact, the augmented Solow model of Mankiw et al suffers from misspecification bias due to the exclusion of health capital and the Use of inadequate proxy of education capital, which in presence of high standard errors of estimates in cross-country regression analysis makes the estimates to some extent unstable.

So our analysis seems to be free of specification error and it also seems to provide a complete explanation for the cross-country variations in real per capita income in terms of stable estimates. Therefore, it is plausible to say that the endogenous growth model does not make Solow model redundant. Rather, these models may be an alternative approach to neo-classical model. In fact, Solow' himself has argued and also established that even if we assume increasing or constant returns to physical and human capital, the growth rate in the endogenous growth models would be determined exogenously (Solow, 2000).

Now the underlying notion behind the inclusion of human capital in the form of education and health in our study can be outlined along the following lines. In fact, the recent years particularly after the resurgence of the growth theory since mid 80's in the name of endogenous theory, witness an increasing interest on the part of the economists to pay more emphasis on the role of the level and growth of human capital which contains certain factors or qualities of life like improvement in health, education, nutrition, on-the-job training and other social securities in the growth process. So the logic behind the incorporation of this factor as an explanatory variable may be given as follows. If we think of at the micro-level then it is quite likely that an individual embodied with good health and education will have higher productive capacity, which, in turn, will increase his productivity and income. So, the commitment of more resources to the improvement of health, education and other social amenities will definitely increase future productivity and income of the individual. Further an individual embodied with such human capital will have easy and quick access to modern technology and knowledge, which is basically non-rival in character than the individual without it. Therefore, an individual embodied with such kind of human capital will have more income than other. So the variation of expenditure on such ingredients of human capital which we call 'Social expenditure', across individuals in an economy is likely to produce inequality in the distribution of income and wealth within the economy.

In the likewise manner the variations in the accumulation of human capital as an outcome of variations in the social expenditure across the nations is also likely to bring about differentials in the level of per-capita real income and its growth rates across time and space through the variations in the ratio of embodied labour force to total population. This sort of causality serves as a powerful device and may prove useful in exploring the link between the social expenditure and distribution of income and wealth across the countries in the world. Moreover, it is likely that there may be a two-way causality between income and human capital. For instance, the countries with higher level and growth rates of per-capita income will be able to afford more as social expenditure for human capital formation than the countries with lower per-capita income and its growth. Further, higher initial level of human capital may lead to higher rate of growth of income in future. Surprisingly, recent endogenous growth models including the models in the neo-classical tradition (Mankiw et al 1992) have either used inadequate proxy of human capital or excluded health as an important component of human capital.

The motivation behind our study stems from this. So in this paper we intend to explore empirically the impact of the accumulation of human capital in the form of education and health along with other factors like the initial level of per-capita real income, real investment-GDP ratio, growth of population, technology etc. on the cross-country differentials in the level of per-capita real incomes and its growth following Solow model and by augmenting it. Our study refers to the two separate period’s viz. (i) 1960-1985 and (ii) 1980-1998. We augment Solow model by retaining the assumptions of competitive general equilibrium framework with one sector production technology, which is subject to constant returns to scale but diminishing returns to factors and closed economy in which case saving equals investment and output equals income.

We find that in contrast with the study of Mankiw, Romer and Weil (1992), the incorporation of education capital in its full form and health capital as two separate explanatory variables into the cross-country regression of first period containing two sets of sample countries of which, first set contains twenty industrialized countries and second set contains forty nine developed and developing countries brings about remarkable improvement in the explanatory power of the model. Almost similar result is found to hold in cross country regression for a set of fifty-three developed and developing countries for the period 1980-98. Although we find varying results from the alternative cross-country regression analysis, it is more or less established that human capital and investment-GDP ratio are the two crucial factors in explaining the cross-country differentials in the level and growth of real per-capita income, However in most of the cases we find that the incorporation of human capital makes the coefficient of physical capital weaker. We have also tested the convergence hypothesis in terms of Solow model and it's augmented from and found tendency, of conditional convergence and unconditional divergence for the three sets of’ samples of countries. Our conclusion however resembles Solow’s prediction in respect of coefficient of population growth, but there are some contrasts with the findings of others [Baumol (1986) Barro (991) etc.]. So we say that the poor countries in the sample may not necessarily grow faster than the rich countries. Further, since there are variations in the rate of saving and population growth across countries, different countries reach different steady states. However, the explanatory power of our model reveals a remarkable improvement in explaining cross-country differentials in real per capita income. The overall results of our empirical study therefore leads us to conclude that the allegations against Solow model such that it lacks empirical validity and fails to explain cross-country differentials in the level and growth of per-capita real income do not hold in reality. Further even in the presence of diminishing return to all factors Solow model is able to explain cross-country variation in the per-capita income. In fact, the augmented Solow model gives a complete explanation for the cross-country differentials in real per capita income irrespective of choice of simple countries and period of studies. Therefore, the endogenous theory of growth may be said to be an alternative to Solow model instead of making the latter redundant. This paper is structured as follows: Section II presents a historical, background of the origin of modern growth theory and its relation with present study. Section III presents augmented Solow model. Section IV gives empirical specifications of the cross-country regression model. Section V explains the data and methodology. Section VI is devoted to the analysis of the, empirical results. Finally Section VII gives the concluding observations.

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I. A Brief History of the Origin of Modern Growth Theory

Starting with growth models in the Keynesian tradition developed by Harrod (1939.) and Domar (1946) we find that they have explained long run growth of an economy in terms of rate of saving, growth of population and capital output ratio all of which have been assumed to be exogenously determined by using one sector fixed coefficient production technology obeying constant returns to scale. In Harrod model, the condition of steady state growth is the equality between ratio of the rate of saving to capital-output ratio and rate of growth, of population, such that the steady state becomes a singular phenomenon in this model. However, since savings rate (s), capital-output ratio (v) and rate of growth of population (n) are determined exogenously it is unlikely to expect that these parameters would take such good values which make s/v always be equal to 'n'. So, there is every possibility of divergence from the steady state growth path which leads to the famous problem of knife-edge instability in the model, thereby leading to disastrous results of either excess supply of capital or excess supply of labour. Domar however pinpoints the underutilization of the productive capacity of the economy as a source of long run instability. Later Solow (1956) and Swan,(1956) have tried to overcome this problem of instability and to explain the long run growth and cross-country differentials in the level and growth of per-capita real income in terms of rate of saving, population growth and technological change; all of which are also assumed to be exogenously determined. They have, however, used neo-classical continuously differentiable one sector production technology in their model, which is subject to diminishing return to each factor of production and obeys Inada condition. Consequent on the assumptions of their model the prediction of conditional convergence has recently been an interesting topic of empirical research. In fact, what we find in Solow model is that the changes in the saving rate and population growth have only the level effect but not the growth effect. In other words the increase in the rate of saving of the countries may bring about increase, in level of per-capita real income but not the growth of the same. It is only the technological progress, which has growth effect. Therefore the long run growth in Solow model is not possible without continuous technological progress, which is also' exogenously determined. In the 60’s Cass (1965) and Koopman (1965) by using Ramasey's (1928) method of analysis developed a model with micro-foundation in a neo-classical framework in which the crucial factors of growth i.e., saving rate vis-á-vis investment are determined endogenously through optimization of household. However, in this model also the long run growth depends on exogenously determined technological progress. It also predicts conditional convergence. In the similar manner Uzawa (1965) developed a model in which both intangible human and physical capital can be produced endogenously. The models of Solow, Ramsey, Cass and Koopman and Uzawa etc. gave rise to the further serious thinking about the problem of long-run growth through endogenization of the parameters of growth through the application of control optimization theorem.

The resurgence of the modern theories of growth Romer (1986), Lucas (1988), Rebelo (1991), Caballe an Santos (1993) etc. In the name of endogenous theory of growth since mid-80’s of the last country has again led to generate an increasing interest amongst the economists to explain long-run economic growth and cross-country differentials in the level and growth of per-capita output empirically by incorporating human capital, R&D, and fiscal and monetary policies of government into the system with either constant returns to scale or increasing returns to scale. All these models in this class have tried to determine long run growth through optimization of household i.e. through the maximization of integrals of discounted value of instantaneous utility function. One can distinguish these models into two classes viz. (a) infinite horizon optimizing models [Lucas (1988); Caballe & Santos (1993); King & Rebelo (1990)] descending from Ramsey, Cass and Koopman and (b) overlapping generation model following diamond (1965). Both of these models are non-monetary one commodity general equilibrium models in which, the dynamics of economics aggregates are determined by the decisions at micro economic levels. They have reached different conclusions regarding the explanatory power of their model and also about the hypothesis of convergence. The motivation behind such resurgence was actually the alleged failure of the Solow model in explaining long-run growth rates empirically2. In fact it is argued by the modern theorists that the main enemy of the Neo-classical Solow model is the assumption of diminishing returns to factors. So if one waives this assumption then it is possible to have long run growth has been made through inclusion of accumulation of human capital but not in its broader form like that of ours or by dropping the assumption of diminishing return to physical capital and other factors. Another attempt for indogenization has been made by treating accumulation of physical capital of an economy, which is at its steady-state may lead to three possible situations viz., (a) a normal situation when the economy reaches another steady state with both higher levels of physical and human capital, (b) a paradoxical situation when the economy reaches another steady state with lower level of both physical and human capital and finally (c) an exogenous growth situation in which case the economy turns back to its initial steady state (Caballe & Santos, 1993). In fact, the class of endogenous growth models involves three parameters viz., technological parameters, demographical parameters and preference parameters such that the growth rate of per-capita consumption, output and investment depend on technological and demographical parameters but not on the preference parameters. This amounts to say that growth rate is again determined exogenously. Further, it has been shown by Solow (2000) that the increasing returns to scale which forms basis of endogenous growth theory dies not help getting rates of growth endogenous. In fact Solow has shown that the steady state growths in such models are exogenous (Solow, 2000). Evans (1996) in his study of 13 industrial countries has claimed that “Endogenous growth models are fundamentally flawed or else the effect they predict must be relatively unimportant for countries considered here.”

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There has been a parallel attempt made by Mankiw, Romer and Weil (1992) in explaining cross-country differentials in the level and growth of real per-capita income in terms of variations in the initial level of per-capita real income, physical capital, human capital, population growth given the growth rate of knowledge by developing an otherwise Solow model termed as augmented Solow model. But in this model, Mankiw et al have used not only a completely inadequate proxy for human capita but even they have excluded the health capital as an important component of human capital. There are also several other studies, which have estimated the role of human capital measured in different forms on economic growth by using neo-classical Solow model as benchmark [Benhabib & Spiegel, 1994; Islam,1995; Lee, et al, 1997; Bills & Klenow, 2000]. Of these, some have used panel data technique also (Islam 1995). However, in our study we have examined the empirical relevance of Solow model in explaining cross-country differentials in income for two separate periods viz., (i) 1960-85 and (ii) 1980-98 by augmenting it through the inclusion of human capital in a broader sense viz. education capital and health capital and concluded that these two have significant contributions to the cross-country differentials in level of real per capita income and its growth and the endogenous growth theory does .not make Solow model redundant rather the former may be an alternative to the latter. In tact the incorporation at the stock of human capital in the form of 'school' variable (i.e. the percentage of total working age population enrolled in secondary level) into Mankiw et al's mode has indeed improved the explanatory power of Solow model. But it could be improved further, had a complete proxy for human capital been used. In fact, one can argue that Mankiw et al model is subject to misspecification bias, Therefore, instead of using 'school' variable of Mankiw et al, we include human capital in the form of two additional explanatory variables namely (a) stock of education capital measured in terms of gross enrolment ratio in primary, secondary and tertiary education and (b) the stock of heath capital measured in terms of life expectancy at birth into Solow model and find a remarkable improvement in the explanatory power of the cross-country regression models for both of the two phases of our study. Interestingly, to avoid the problem of multi co linearity and to obtain stable estimates we have used both the Ordinary Least Square (OLS) method and Ridge Regression Method for the cross-country regression analysis. Therefore, our analysis basically differs from that of Mankiw et al study and the studies of others not only in respect of coverage of the period, choice of sample countries but also in respect of use of proxies for human capital in the model and in respect of some crucial findings, Further, our study reinforces the empirical validity of the Solow model and its augmented form not only across different sets of sample countries but at the inter-temporal level also.

III. Augmented Solow Model:
We consider Cobb-Doglous form of production function and augment the Solow model by incorporating human capital in the form of two additional variables viz., (a) health capital (H1) and (b) education capital (H_2) into it.

So, we write the production function as:

$$Y(t) = K\alpha H_1\beta_1 H_2\beta_2(AL)1\text{-}\alpha\text{-}\beta1\text{-}\beta_2 \quad (1)$$

$\alpha, \beta_1, \beta_2 > 0$ **and**

$\alpha + \beta_1 + \beta_2 < 1$. Where, Y = Level of output, K = Level of stock of physical capital, A = Level of knowledge or technology, AL = Effective labor, t = time (for simplicity we do not add "t" to other variables in the function).

Like Solow model labor force and technology are assumed to grow exogenously at constant rates (n) and (g) respectively:

$$L(t) = L0e^{nt} \quad (1a)$$

$$A(t) = A0e^{gt} \quad (1b)$$

Here, we also consider one-sector production technology satisfying all the, traits or neo-classical production function with labour-augmenting technological progress and assume constant return to scale to operate in physical and human capital. In fact, we assume that (i) the availability of natural resources is not a constraint on growth and (ii) although the gain from specialization for large countries gets exhausted there is further Scope of specializations in small countries. So one may say that if the new inputs are used in the same way like that of the existing inputs, then the doubling of K & H is likely to double the output. Lucas (1988) has also assumed that the returns to all reproducible capital (Human plus Physical) are constant. Now, since we consider a one-sector production technology and further since there is no standard estimate of depreciation of physical and human capital across the countries we assume that the physical and human capital depreciate at same constant rate (d). We also assume that constant fractions of real GDP (i.e. sh and se) are spent for health and educations respectively3. Now, we express the stocks of human capital per unit of effective labour as:

$$\mathbf{h_1 = H_1/AL} \quad (2)$$

$$\mathbf{h_2 = H_2/AL} \quad (3)$$

Like previous model the dynamic behavior of our economy leads to the evolutions of k, hl, h2 such that we can write:

$$\mathbf{K^* = s_k k^{\alpha} h_1^{\beta 1} h2^{\beta 2} - (n + g + \delta)\ k} \quad (4)$$

$$\mathbf{h^* = s_h k^{\alpha} h_1^{\beta 1} h_2^{\beta 2} - (n + g + \delta)\ h_1} \quad (5)$$

$$\mathbf{h^* = s_e k^{\alpha} h_1^{\beta 1} h_2^{\beta 2} - (n + g + \delta)\ h_2} \quad (6)$$

Now, we assume that as an outcome of transitional dynamics the economy has reached its steady state such that $k^* = h^*_1 = h^*_2 = 0$ and in such situations $k = k^*$, $h_1 = h_1^*$, $h_2 = h_2^*$.

This implies that the economy is just making the break-even level of investment in physical capital, health and education so as to maintain their existing levels. So we write:

$$\mathbf{s_k k^{\alpha} h_1^{\beta 1} h_2^{\beta 2} = (n + g + \delta)\ k} \quad (7)$$

$$\mathbf{s_h k^{\alpha} h_1^{\beta 1} h_2^{\beta 2} = (n + g + \delta)\ h_1} \quad (8)$$

$$\mathbf{s_e k^{\alpha} h_1^{\beta 1} h_2^{\beta 2} = (n + g + \delta)\ h_2} \quad (9)$$

Now solving for $k = k^*$; $h_1 = h_1^*$ and $h_2 = h_2^*$ we have,

$$\mathbf{k^* = \left(\frac{S_k^{1-\beta_1-\beta_2}\ S_h^{\beta 1}\ S_e^{\beta_2}}{n + g + \delta} \right)^{\frac{1}{1-\alpha-\beta_1-\beta_2}}} \quad (10)$$

$$\mathbf{h_1^* = \left(\frac{S_k^{1-\beta_1-\beta_2}\ S_h^{\beta 1}\ S_e^{\beta_2}}{n + g + \delta} \right)^{\frac{1}{1-\alpha-\beta_1-\beta_2}}} \quad (11)$$

$$\mathbf{h_2^* = \left(\frac{S_k^{1-\beta_1-\beta_2}\ S_h^{\beta 1}\ S_e^{\beta_2}}{n + g + \delta} \right)^{\frac{1}{1-\alpha-\beta_1-\beta_2}}} \quad (12)$$

Substituting equations (10), (11) and (12) into the production function (1) and taking logarithm of both sides we have:

$$\mathbf{I_n\ (Y/L) = I_n A_0 + gt + a/(1-a-b_1-b_2)\ I_n\ (s_k) + b_1/(1-a-b_1-b_2) In\ (s_h) + b_2/(1-a-b_1-b_2) I_n(s_e) - (a+b_1+b_2)/(1-a-b_1-b_2) I_n(n+g+d)} \quad (13)$$

Equation (13) gives us empirical specification of augmented Solow model such that it indicates that per-capita income depends on growth of population and accumulation of physical capital and education and health capital. We use this for our cross-country regression analysis.

IV .Empirical Specification Of Ceoss-Country Regression

The empirical specifications of some of the cross-country regression equations are the outcome of dynamics of Solow model and its augmented form containing human capital. We estimate them by applying ordinary Least Squares method, assuming that investment, growth of population and accumulation of human capital are independent of the country specific factors leading to shift in production functions which are included in residual (e) term of the equation.4 It is worth mentioning that the regression equations with log per-capita real GDP as dependent variable hold only if the sample countries are at their respective steady states such that they are just able to undertake the break-even level of investment and social expenditure so as to maintain the steady state level of per-capita physical and human capital. The other regression equations incorporate the out-of-steady-state dynamics of Solow model. The specific regression equations, which we use for empirical estimation of cross-country differentials in the level and growth of per-capita real GDP and also for the test of convergence for both of the two periods of our study, are given below.

1. **Period 1960-85**
    1. $I_n(Y/L)_{1985} = \alpha + \beta_1 I_n(I/Y)_{60-85} - \beta_2 I_n(n+g+\delta) + \varepsilon$
    2. $I_n(Y/L)_{1985} = \alpha + \beta_1 [I_n(I/Y)_{60-85} - I_n(n+g+\delta)] + \varepsilon$
    3. $I_n(Y/L)_{1985} = \alpha + \beta_1 (I/Y)_{60-85} + \beta_2 I_n(ER)_{1960} + \beta_3 I_n(LE)_{1960} - \beta_4 I_n(n+g+\delta) + \varepsilon$
    4. $I_n(Y/L)_{1985} = a + b_1[I_n(I/Y)_{60-85} - I_n(n+g+d)] + b_2[I_n(ER)_{1960} - I_n(n+g+d)] + b_3[I_n(LE)_{1960} - I_n(n+g+\delta)] + \varepsilon$
    5. $I_n(Y/L)_{1985} - I_n(Y/L)_{1960} = \alpha + \beta I_n(Y/L)_{1960}$
    6. $I_n(Y/L)_{1985} - I_n(Y/L)_{1960} = \alpha + \beta_1 I_n(Y/L)_{1960} + \beta_2 I_n(I/Y)_{60-85} - \beta_3 I_n(n+g+\delta)$
    7. $I_n(Y/L)_{1985} - I_n(Y/L)_{1960} = \alpha + \beta_1 I_n(Y/L)_{1960} + \beta_2 I_n(I/Y)_{60-85} + \beta_3 I_n(LE)_{1960} + \beta_4 I_n(ER)_{1960} - \beta_5 I_n(n+g+\delta)$
    8. $I_n(Y/L)_{1985} - I_n(Y/L)_{1960} = \alpha + \beta_1 I_n(Y/L)_{1960} + \beta_2[I_n(I/Y)_{60-85} - I_n(n+g+\delta)] + \beta_3[I_n(ER)_{1960} - I_n(n+g+\delta)] + \beta_4[I_n(LE)_{1960} - I_n(n+g+\delta)]$

    Here, meanings of variables involved in the equations (1–8) are as follows:
    Y/L => Real GDP per unit of working age population (at 1980 International prices).
    n => Average rate of growth of working age population over the period 1960 – 85.
    I/Y => Average share of Investment in Real GDP over the period 1960 – 85.
    ER => Gross enrolment ratio in Primary, Secondary and Tertiary education of the respective countries (Average for the period).
    LE => Life expectancy at birth of the respective countries (Average for the period).
    $g + \delta$ => Sum of growth of knowledge and depreciation of stock of capital which is assumed to be constant ($g + \delta = 0.05$) across the countries (Mankiw *et. al,* 1992).
2. **Period 1980-1998**
    1. $I_n(Y/L)_{1998} = \alpha + \beta_1 I_n(I/Y)_{1980} - \beta_2 I_n(n+g+\delta) + \varepsilon$
    2. $I_n(Y/L)_{1998} = \alpha + \beta_1 [I_n(I/Y)_{1980} - I_n(n+g+\delta)] + \varepsilon$
    3. $I_n(Y/L)_{1998} = \alpha + \beta_1 I_n (I/Y)_{1980} + \beta_2 I_n(ER)_{1980} + \beta_3 I_n(LE)_{1980} - \beta_4 I_n(n+g+\delta) + \varepsilon$
    4. $I_n(Y/L)_{1998} = \alpha + \beta_1[I_n(I/Y)_{1980} - I_n(n+g+\delta)] + \beta_2[I_n(ER)_{1980} - I_n(n+g+\delta)] + \beta_3[I_n(LE)_{1980} - I_n(n+g+\delta)] + \varepsilon$
    5. $I_n(Y/L)_{1998} - I_n(Y/L)_{1980} = \alpha + \beta I_n(Y/L)_{1980}$
    6. $I_n(Y/L)_{1998} - I_n(Y/L)_{1980} = \alpha + \beta_1 I_n(n+g+\delta) + \beta_2 I_n(Y/L)_{1980} + \beta_3 I_n(I/Y)_{1980}$
    7. $I_n(Y/L)_{1998} - I_n(Y/L)_{1980} = \alpha + \beta_1 I_n(ER)_{1980} + \beta_2 I_n(LE)_{1980} + \beta_3 I_n(Y/L)_{1980} + \beta_4 (I/Y)_{1980} - \beta_5 I_n(n+g+\delta)$
    8. $I_n(Y/L)_{1998} - I_n(Y/L)_{1980} = \alpha + \beta_1[I_n(I/Y)_{1980} - I_n(n+g+\delta)] + \beta_2[I_n(ER)_{1980} - I_n(n+g+\delta)] + \beta_3[I_n(LE)_{1980} - I_n(n+g+\delta)] + \beta_4 I_n(Y/L)_{1980}$

    Here, the meanings of variables involved in the equations (1–8) are as follows:
    Y/L => Per-capita real GDP of the respective countries at constant 1995 (PPP US$)
    n => Annual average growth rate of population during 1980-98.
    $g+\delta$ => Same meaning and its value is assumed to be 0.05.
    I/Y => Gross Domestic Investment as percentage of real GDP of the respective countries.
    ER => Gross enrolment ratio in Primary, Secondary and Tertiary education of the respective countries (Average for the period).
    LE => Life expectancy at birth of the respective countries (Average for the period).

V. Data and Methodology

Our empirical analysis of international differentials in the level of per-capital real income is for two separate periods namely, (i) 1960-85 and (ii) 1980-98. The study of first period contains two sets of sample countries of which the first contains 20 industrialized countries and the second the 49 developed and developing countries. The second period contains samples of 53 developed and developing countries of the world5. The choice of the period and the sample countries is made on the basis of the availability of data. The data for tile variables [viz. GDP per adult (Y /L), Investment GDP ratio, growth of population (n)] included in the cross-country regression equations for the period 1960-85 are taken Summers & Heston's (1988) Estimates of Real National Product6. However, the data on the education capital and the human capital are taken from World Development Reports, World Development Indicators and Human Development Reports of UNDP. The rate of growth of population indicates average rate of growth of population in the working age group 15to 64 years. Like Mankiw et al we have also assumed that for both the periods of our study the growth rates of knowledge (g) and value of depreciation of stock of capital (d) remain constant across countries such that g+d=0.05. The data for the period 1960-85.

On the other hand for the period 1980-98 the data on the variables like per-capita GDP (Y/N), Gross Domestic Investment as percentage of GDP (I/Y), Life Expectancy at birth (LE), Gross enrolment ratio (ER) are taken from the human Development

Report of UNDP for the year 2000, World Development Report 1994, World Development Indicators 2000, World Table (1993) OF World Bank. The data for the period (1980-98).

IV. ANALYSIS OF RESULTS

1. Period

(i) 1960-85

The cross-country regression results for the period 1960-85. The results that we have are in some cases strong contrast with the prediction of Solow model (1956) and Mankiw. Romer and Weil's study (1992) and the study of others and in some-other cases it supports their predictions. We interpret the result as follows. First, the Solow model as such is able to account for a significant proportion of cross-country variations in the level and growth 0f per-capita real income for the sample of 20 industrialized countries and also for the sam1ple of 49 developed and developing countries. In fact by applying the OLS method we find R^2= 0.999 in almost all the cross-country regressions for the first period. This along with high standard errors and very few variables being significant as well as the correct specification of the model indicate the presence of strong multicollinearity (Chatterjee and Price, 1977). So to have stable coefficient we have also used ridge regression method. The results of ridge regression analysis also reveal that about 80 to 91 per cent of the cross-country differentials in the level and growth of real per-capita income is explained in terms of variations in the per-capita savings, growth of population, education and health capital. Second, in contrast with Mankiw et a1 analysis we find positive sign of coefficients on population growth for the first period of our study, which is significant in some cases.[7] This also contradicts the prediction of Solow model that higher rate of population growth in the countries reduces the per-capita availability of capital and so there would be reduction in productivity of capital and consequently there would be lower per-capita income. This is also used to explain the cross-country movement of capital in Solow model. One of the possible explanation of positive sign of the coefficient of population growth in our study may however, be given as follows. In the industrialized countries the growth of population is likely to bring about a proportional increase in the labour force embodied with ingredients of human capital as the higher rates of savings in such countries cause high investment in human capital. So the increase in working age population is likely to produce positive impact on the level and growth of per-capita income.[8] Further, it seems that the unexpected sign of the coefficient of population growth may be due to the problem of multi co linearity. However, the sign of the coefficient of investment income ratio supports the prediction of Solow model that the variations in the saving rate measured in terms of investment results into the variation in the real per-capita GDP across the countries. In fact the result of our study diverge from that of Mankiw et al and others partly because of the differences in the data sources and the difference in the proxy variable used for human capital. Mankiw *et. al*. did not consider health as an important ingredient of human capital. Further their school variable is completely an inadequate proxy of human capital like education. Further since for the second phase of our study both the period and the sample countries differ from the studies at other one may expect the difference in results. Third, the initial level of investment net of effective depreciation (*i.e.* $n+g+\delta$) also accounts for a very large proportion of cross-country variations in the level of per-capita income of the industrialized countries. In such case we again find R^2 = 0.999 which is highly significant. Fourth, when we incorporate education capital and health capital as explanatory factors along with population growth and investment in the cross-country regression model, the coefficients of all these variables excepting that of investment become highly significant albeit the coefficient on population growth still remains positive.[9] Moreover, the explanatory power of the regression model improves further. However as we have already argued earlier that to deal the problem of multi co linearity and to have stable coefficient we use the ridge regression model, the result of which reveal that in some cases about 80 to 90 percent of cross Country differentials in the real per capita income is explained by the explanatory factors considered in our model. Thus we conclude that the initial stock of human capital along with population growth explain a significant proportion of cross-country differentials in the per-capita income. This leads us to conclude that human capital and (I/Y) act as crucial variables in explaining the cross-country differentials in the level and growth of income per-capita. This conclusion holds for the 20 industrialized sample countries. But for the sample of 49 countries we find the predicted signs of growth of population and the savings. Interestingly, the inclusion of human capital reduces the effect of population growth and savings. Of course in some cases the puzzling sign of health capital implies the presence of multi co linearity. Fifth, we also find that the inclusion of health capital reduces the effect of physical capital and population growth thereby making health capital and education capital significant in the cross-country regression analysis of the second set of sample countries. Since, by OLS method there are some puzzling signs of some variables with high R^2 and standard errors of the estimates such that very few explanatory variables being significant, the ridge regression results should be more appropriate albeit multi co linearity is mainly a sampling problem (Chatterjee & Price, 1977), Gujarati (1999).

Sixth, we have also made test of convergence. The results of our cross-country regressions are however in sharp contrast with the predictions of unconditional convergence [Baumol (1986), Mankiw *et, al.* (1992), Solow (1956), Uzawa (1965), Romer (1986)]. In fact we find a perfect unconditional divergence in the sense that there is no tendency on the part of the poor countries to grow faster than the rich countries. This supports the findings of De Long (1988) and also the predictions of simplest endogenous growth model, A K model (Barro, 1994) even in the presence of diminishing return. However, the inclusion of human capital, investment and growth of population given the growth of knowledge and depreciation of stock of capital gives the result of conditional convergence, which corroborates the finding of Mankiw, Romer and Weil's (1992) study. But if we use the variables human capital, and investment per capita net of effective rate of depreciation in the case of restricted regression, we have a contrasting result of conditional divergence, as the coefficient of the variable logarithm of initial level of per-capita real GDP becomes positive and significant.

(ii) 1980-98

The result of the cross-country regression analysis for period (1980-1998) are almost similar to the results that we obtained in the analysis for the period 1960-85 excepting the two cases. First, here the sign of the coefficient on population growth (n) and physical capital or savings per capital resembles the prediction of Solow model and the findings of Mankiw *et. al.* (1992) and others. Second, we also find a perfect unconditional divergence with higher positive value of the coefficient of initial per-capita real income and also the conditional convergence in the estimation made by following the augmented Solow model. In fact we m positive coefficient of initial per-capita GDP and it is highly significant in the former case and negative coefficient of the same for the latter case. This result is in sharp contrast with the prediction of Solow model and Maukiw, Romer and Weil's study 10 and the studies of Barro (1991), P. Romer (1986), Baumol (1986) etc. However, our result supports De-Long’s study (1988). But, if we use the variables investment-GDP ratio, education, health capital net of depreciation, then we find the tendency of conditional convergence. In fact Mankiw et al also argue that one should not expect the countries to converge.

On the other hand, another remarkable result which we get is that the population growth, initial per-capita real GDP and initial rate of investment together explains a substantial proportion of the differentials in per-capita real GDP of the sample of 53 developed and developing countries in the world ($R^2 = 0.78$) and coefficients on all these variables are found to be highly significant. Surprisingly, the inclusion of the variable life expectancy at birth and the gross enrollment ratio makes the variable investment rate insignificant. The negative sign of the coefficient of gross enrolment ratio is indeed puzzling and it seems to be due to the problem of multi co linearity. Further we see that initial level of per-capita real GOP or the initial rate of investment with growth of population or the initial level life expectancy with growth of population can account for a significant proportion of cross-country variation in the level and growth of per-capita real income or 53 sample countries for the period 1980-98. It seems that a there is a positive correlation between enrollment ratio and population growth. Moreover, it also leads to the conclusion that there seems to be high correlation between initial level of per-capita real GDP and social expenditure on health and education.

On the whole we see that Solow model and its augmented form are able to account for a significant proportion of cross-country variations in the level and growth of real per-capita income between the sample countries of both of the two periods of our study. So we say that the development of endogenous models does not make Solow model redundant. However our conclusion of perfect unconditional divergence does not support the prediction of Solow model and that of Mankiw *et. al.* (1992). Again the inclusion of human capital makes the variable, investment insignificant. Finally, the overall explanatory powers of the cross-country regression equations are found to be remarkably high.

VII. Concluding Observations

In our study we augment the Solow model by incorporating human capital in the form of educational capital and human capital and examine the empirical validity of the model for the two separate periods viz., (i) 1960-85 and (ii) 1980-98 of which the first period resembles Mankiw, Romer and Weil's period of study. However, for the first period we consider two sets of sample countries of which the first contains 20 industrialized countries and the second, the 49 developed and developing countries in the world and for the second phase we consider a sample of 53 developed and developing countries. Our study basically differs from that of Mankiw et al and of others not only in respect of the coverage of the period and choice of sample countries but also in respect of explanatory variables used in the augmented Solow model and in respect of some crucial findings.

In fact, we find that the inclusion of education capital and health capital along with initial level of real per-capita income, savings and population growth brings about remarkable improvement in the explanatory power of our cross-country regression such that these three variables together accounts for a significant proportions of international variations in the level and growth of real per-capita income. On the other hand, the initial level of real per-capita income, investment and population growth has larger impact on level and growth of per-capita income of the countries in our model than is predicted by Solow model and the studies of Mankiw et al and others. There seems to exist a high degree of causality between accumulation of physical capital and accumulation of human capital. In fact for some cases the puzzling signs of the coefficients of savings, population growth and enrolment ratio and the high standard errors as well as the very high R^2 along with insignificant explanatory variables reflected strong multi co linearity there by making the estimates unstable. This has induced us to use

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ridge regression model so as to have stable coefficients / estimates without paying heed to the signs of coefficients as there is correct specification of the regression model which is derived directly from Solow model and its augmented form. The most striking result that we find is the perfect unconditional divergence and also a tendency of conditional convergence. Further we find a positive significant coefficient of the variable growth of population given the growth of knowledge and depreciation of capital (*i.e.* $n+g+\delta$) for the first period, which is indeed puzzling and it is due to the presence of multi co linearity. However, for the second period the variables growth of population and savings reveal the predicted signs such that the larger the savings per capita the richer the countries and the higher the growth rates of population the poorer he the countries. Thus our study not only reinforces the findings of the studies of Mankiw et al and others hut it also establishes the empirical validity of the Solow model and augmented Solow model across time.

Finally we conclude that the Solow model and its augmented form through the inclusion of human capital are able to explain a significant proportion of cross-country differentials in per-capita income amongst the sample countries. Therefore, the allegations against Solow model do not hold in reality. In fact Solow model and its augmented form have high empirical validity. So, it is plausible to conclude that the development of endogenous growth theory does not make Solow model redundant, rather the former may be said to be an alternative to the latter.

Notes

1. In fact we have used human capital as a stock variable and expressed it per unit of effective labour such that it is measured in terms of fraction of resources devoted to human capital accumulation.
2. We will see that this allegation against Solow model is not valid. Mankiew et al (1992) have shown that it is possible to explain cross-country differentials in the level and growth of per-capita income empirically by including all the factors considered by the endogenous growth theorist, into the Solow's model. We also come to the same conclusion in our study.
3. Although we know that all expenditure on education and health may not produce productive human capital embodied with good education and health, we use combined gross enrolment ratio in primary, secondary and tertiary education as proxy of stock of education capital and life expectancy at birth as the proxy of stock of health capital.
4. This assumption is also made by Mankiw et al (1992).
5. Since a major proportion of GDP of oil producing countries accrues out of extraction of natural resources but not in the form of value added we have excluded such countries.
6. It is worth mentioning that the investment GDP ratio, per capita GDP for the first period are measured at 1980 constant international prices and the same for the second period are measured at 1995 US$ (ppp). So all these variables are in real terms.
7. It is worth, mentioning that we have made cross-country regression analysis for second period of our study by considering as much, number of sample countries as possible depending on the availability of data on the variables included an the specific regression equations. We don’t find any major change in the fundamental conclusion with the variation of number of simple countries.
8. It may so happen that there may be a positive correlation between investment-GDP ratio and population growth for the industrialized countries.
9. It is likely there is high positive correlation between educational attainment and investment GDP ratio, (Mankiw et. al. 1992).
10. It is worth mentioning that Mankiew et al (1992) also find unconditional divergence in case of non-oil producing countries.

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