

A Study of Convergence and the Impact of Health
Capital on Economic Growth across Countries

by

Jin Woong Kim

(3000102)

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Supervisor: Professor Kathleen Day

ECO 7997

Ottawa, Ontario

ABSTRACT

This paper examines the evidence for convergence, that is, for whether poor countries tend to grow faster than rich countries. The results indicate that, after holding other variables on the right-hand side constant, there is a negative correlation between the growth of income and initial income. Also, I examine the impact of health capital on three different groups of countries. I find strong evidence of a positive impact of health capital on economic growth in high-income countries and in the full sample. However, the impact of health capital on economic growth is not statistically significant in the case of low- and intermediate-income countries.

Kim, Jin Woong

Department of Economics

University of Ottawa

kjwisking@hotmail.com

1. Introduction

In recent years, there have been many empirical studies of cross-country growth. These empirical studies have been conducted based on two different but closely related theories: “endogenous growth theory” and “standard neoclassical growth theory.” An important focus of these studies has been the existence of convergence, which has two different interpretations. The first is in terms of income. If countries are similar in their technology, preferences or other factors such as social infrastructure, government policy, etc., income levels will eventually be the same. The second is in terms of the growth rate. Because the steady state growth rate is decided by the exogenous rate of technological growth in the Solow model, if technology is equally shared because of its public good characteristics, all countries will finally achieve the same rate of steady state growth.

The existence of convergence is supportive of standard neo-classical growth models, but the absence of convergence is regarded as upholding endogenous growth theories. Later, this controversy led to the development of the concept of conditional convergence, which means that each country reaches a different steady state. The existence of conditional convergence has been tested by several economists.

Barro (1991), in his first empirical work on growth, showed that if differences in the initial level of human capital, as proxied by educational attainment, are controlled for, then the relation between the initial level of income and the growth rate turns out to be negative even in a wide sample of countries. Also, Barro and Sala-i-Martin (1992) and Mankiw, Romer, and Weil (1992) emphasized that the implication of neo-classical convergence is that countries would reach their respective steady states instead of

reaching the same level of income per capita (conditional convergence), and illustrated this point empirically using a cross-sectional data approach.

However, a more important subject than the issue of convergence is the question of the determinants of growth. Most empirical studies have examined the contribution of human capital to economic growth, and have shown that human capital has a strong and positive impact on economic growth.

Nevertheless, most of their definitions of human capital have focused only on schooling, and this simple relation between schooling and growth may reflect omitted factors since it has long been realized that human capital can also be accumulated by improving health. That is, healthier workers are more productive and get higher wages, and they are less likely to be absent from their work. Therefore, they contribute more to economic growth (Bloom, Canning, and Sevilla 2001).

In this paper, I add health status, in the form of life expectancy, as another element of human capital in order to examine more precisely the effect of human capital on economic growth. For my analysis, I use a panel data approach with 67 countries and six time periods: 1970, 1975, 1980, 1985, 1990 and 1995. The production function should not be identical for all countries because they have different technology and institutions of quality which usually are unobservable and as Islam (1996) pointed out, the panel data approach makes it possible to allow for differences in the form of unobservable and unmeasured individual country effects. It is impossible to take such effects into account using a cross-sectional approach. I take the recent work by Mankiw, Romer, and Weil (1992) as my starting point and follow the reformulation of their model that was proposed by Islam (1996), to transform the regression equation used in the study of convergence

and economic growth determinants into a dynamic panel data model with individual country effects, and use the panel data process to estimate it.

In this paper, first I examine the evidence for convergence within three groups of countries defined by their economic level: low-income, middle-income and high-income countries. For this examination, I assume that the countries within each group have similar types of institutions and preferences, and observe whether there is convergence within a group or across groups using panel data. Finding (absolute) convergence within a group but not across groups, and detecting conditional convergence across groups are strong supportive facts for neo-classical theory, which implies the concept of conditional convergence.

Second, I use the augmented Solow model including health capital as proxied by life expectancy and educational capital as additional explanatory variables in the Solow model, and examine how the impact of these two variables on economic growth differs within a group and across groups of countries. I believe that these two types of human capital have different effects on economic growth, in terms of sign and magnitude, in different groups, and that this analysis will lead to some suggestions for successful economic growth for less developed countries such as most countries in Africa.

This paper is organized as follows. In section 2, I provide a review of the literature on convergence and health capital. In section 3, I reformulate the augmented Solow model into a dynamic panel data model. In section 4, I discuss the Least Squares with Dummy Variables (LSDV) estimation process, which I use to allow a country specific effect across countries, and the data and samples. Estimation results and their interpretation are presented in Section 5. Section 6 concludes the paper.

2. Literature Review

A. The Issue of “Convergence” and the Empirical Search for It

The issue of convergence has been the major focus of recent empirical studies of growth since Solow (1956) provided the Solow model. The important assumption the Solow model makes is that there are diminishing marginal returns to capital; this assumption leads to the conclusion that the growth process in the economy eventually reaches a steady state in which output per capita, capital stock per capita, and consumption per capita grow at a constant rate which is equal to the exogenous rate of technology growth. This leads to the concept of (absolute) convergence.

Since Summers and Heston (1988, 1991) first constructed comparable national accounts data for a large cross-section of countries for a long period of time, researchers have conducted analyses of convergence using “real data” and several types of econometric specifications. Romer (1989a) was influential in drawing the attention of macroeconomists to this issue by showing that the correlation between initial income levels and subsequent growth rates is either zero or positive in a wide sample of countries, and this evidence of non-convergence has been interpreted as confirming the persistence of significant differences in income levels and growth rates among countries that was also demonstrated theoretically by Rebelo (1991).

At first, this evidence of non-convergence confused economists who expected to observe convergence, but they finally responded by applying a different interpretation to the same facts the endogenous growth model interpreted: the concept of conditional convergence; that is, the idea that convergence is conditional on saving, population

growth and human capital. In most of these empirical studies of convergence, researchers use the estimating equation from the Solow model, whose dependent variable is the rate of growth of output or income per capita, usually measured as the first difference of the log of output per capita, and whose independent variables are the initial level of output per capita, the savings rate, the rate of growth of population or the workforce and other variables such as human capital. I also follow this approach to examine convergence and the determinants of growth in my paper.

Using the Summers and Heston (1988) data, United Nations data, the World Bank data set and Banks' (1979) data base, Barro (1991) sets up a cross-section data set which includes 98 countries over the period 1960-1985 and estimates an equation which contains two proxies for human capital: the 1960 values of school-enrollment rates at the secondary (SEC 60) and primary levels (PRIM 60). He shows that although the simple correlation between per capita growth (1960-1985) and the initial level of income (GDP60) is close to zero, the correlation becomes importantly negative if measures of initial human capital, proxied by the school-enrollment rate, are held constant.

Evidence of conditional convergence also was found by other studies such as Barro and Sala-i-Martin (1992), Mankiw, Romer, and Weil (1992) and Islam (1996). Barro and Sala-i-Martin (1992) use data from the U.S. Department of Commerce including the 48 contiguous U.S. states, and use the Ramsey-Cass-Koopmans (Ramsey 1928; Cass 1965; Koopmans 1965) growth model to derive an econometric equation that relates the growth of GDP per capita to the initial level of GDP. They find that over a long period (1840-1988) in the U.S., poor states tend to grow faster in per capita terms than rich states whether or not they hold constant any variables other than initial per

capita product or income, like regional dummy variables. This is convergence in the absolute and conditional sense. However, they find evidence of convergence for a sample of 98 countries from 1960 to 1985 drawn from the Summers-Heston data set only in a conditional sense; that is, convergence occurs only if they hold constant variables such as initial enrolment rates and the ratio of government consumption to GDP.

The concept of conditional convergence was further examined by Mankiw, Romer and Weil (hereafter MRW) (1992). They use data from the Real National Accounts constructed by Summers and Heston (1988) and reformulate the Solow model. They find that if the log of real output per capita appears on the right-hand side alone, then there is no evidence of convergence in a sample which is composed of countries that differ in terms of their level of income per capita. However, after adding their measures of the rates of investment and population growth to the right-hand side of the regression and further adding human capital, proxied by secondary school-enrollment from the UNESCO yearbook, they find a strong negative relationship between initial income and subsequent growth across countries, which they call "conditional convergence."

Also, Islam (1996) uses the same Solow model as MRW and further develops it for panel data estimation. He constructs a sample from Summers-Heston dataset (1988), which contains 96 countries and covers the 1960-1985 period. He chooses five time periods for his model: 1965, 1970, 1975, 1980 and 1985. The data are constructed in such a way that saving and population growth variables are averaged over 1960-1965, 1965-1970, 1970-1975, 1975-1980 and 1980-1985 and initial incomes are 1960, 1965, 1970, 1975, 1980 for the five time periods. Using a panel data approach with fixed effects, he finds strong evidence of conditional convergence. He also finds that the estimated rate of

convergence is much higher from the panel data regression than from a cross-sectional regression. Dalgaard (2003) explains this result by pointing out that due to the mean-reversing nature of the business cycle, shortening the period length could contribute to making the estimated rate of convergence faster.

Although the one sector model of endogenous growth (the AK model proposed by Romer (1986)) does not imply the concept of conditional convergence, more sophisticated models of endogenous growth indicating transitional dynamics are also consistent with the conditional convergence evidence. The two-sector endogenous growth models of Lucas (1988) were later shown to be consistent with this conditional convergence evidence. It was also shown that AK models with technological diffusion (where the technology term, A , flows slowly from rich countries to poor countries) are also consistent with conditional convergence.

Before I go further, I briefly summarize how neoclassical growth theory differs from endogenous growth theories. In neoclassical growth theory, there are three basic assumptions. First, the productive capacity of the economy can be characterized by a constant returns-to-scale production function with diminishing returns to capital and labour. Second, firms are price-takers in a competitive market place, that is, any individual firm has no influence over market prices, which means that individual firms are assumed to have no market power. Third, technological change (i.e. productivity growth) is exogenous and is available to all countries without any cost. Under these assumptions, the neoclassical model implies that sustained increases in per-capita income can be supported only by sustained increases in total factor productivity, and economies with lower initial levels of real output per worker relative to the long-run level should

experience faster economic growth, which implies convergence. The latter implication follows from the assumption of diminishing returns to capital, that is, the lower the level of capital per worker, the higher the return to investing in capital. Therefore, the lower the level of capital per worker, the faster the rate of capital accumulation and the faster the growth rate of output per worker. Furthermore, convergence is said to be conditional since the long-run level of capital per worker and output per worker depend on the saving rate, the growth rate of the population, and other variables that are unlikely to be identical across countries. On the other hand, endogenous growth theories assume that technological change, which arises mainly from the accumulation of knowledge, is not exogenous, and knowledge is an input to production with increasing returns to scale, which means that there is no convergence of income per capita in the long run. They also reject the second assumption of the neoclassical model: firms are assumed to compete in a monopolistically competitive environment. Endogenous growth theories also drop the last neoclassical assumption that technological progress could be adopted at no cost by all countries. This implies that the location of research and development (R&D) activity may have an impact on the long-run growth rate.

The literature regarding convergence reviewed above leads to several tentative conclusions. First, whether absolute convergence is found in the data depends on the sample. Samples including relatively homogeneous economies, such as the countries of the OECD or the states of the United States, typically yield evidence of absolute convergence. Yet more diverse samples lead to different results. In large samples of countries, a country's initial level of income per person is not correlated with its subsequent growth rate, but after adding other explanatory variables on the right side

there is a strongly negative relation between initial income and the subsequent growth rate, which is conditional convergence.

Second, the neo-classical model does not necessarily predict convergence in an absolute sense (MRW 1992). That is, if countries have different steady states then rich countries may remain rich, and poor countries may remain poor. The neo-classical model predicts that each economy converges to its own steady state, which in turn is determined by its saving rate, population growth rate, human capital, and so on.

Finally, endogenous growth models with more than one sector also imply conditional convergence although no convergence of any kind exists in the one sector model.

B. Life Expectancy and Growth

There are several empirical studies examining the impact of life expectancy on economic growth. In these studies, researchers typically have employed a variety of estimation techniques, various model specifications and different data. In this section I review the literature that examines the effect of life expectancy on growth.

Barro and Lee (1994) obtain data on real output, the investment rate, etc., from the Summers-Heston data set and the World Bank, and use Barro and Lee's (1993) data on school attainment and U.N. numbers for life expectancy at birth. Their empirical equation relates real per-capita growth to two kinds of variables: first, the initial levels of state variables, such as the stock of physical capital and the stock of human capital in the forms of educational attainment and life expectancy at birth; and second, control or environmental variables such as the ratio of government consumption to GDP, the ratio

of domestic investment to GDP, the fertility rate and so on. They then estimate the coefficient of life expectancy in two sub-periods – 1965-75 (with 85 countries) and 1975-85 (with 95 countries) – using the Seemingly Unrelated Regressions estimator allowing for country-specific time-invariant random effects, and find that the coefficient of health capital has a strong and positive effect on growth (the estimated coefficient is 0.073). That is, if life expectancy at birth is 50 years, then holding other variables constant, an additional year of life expectancy at birth raises the growth rate by 0.14 percentage points per year; if life expectancy at birth is 70 years, then an extra year of life expectancy increases the growth rate by 0.1 percent.¹

Knowles and Owen (1995) use the data set used by MRW (1992), Barro and Lee's (1993) data on educational capital stock and data from the World Bank on life expectancy. They augment the basic Solow model by including health and education as separate factors of production, and estimate the coefficient of life expectancy in low-income developing countries, high-income countries and the full sample using OLS. They find that the effect of life expectancy on growth is positive and significant in low-income developing countries (0.310) and in the full sample (0.346), and slightly positive but not statistically significant in high-income countries (0.012).

Barro (1996) also uses data from Summers-Heston (Penn World Tables), Barro and Lee (1993) and the *International Country Risk Guide*. His empirical framework consists of three different equations, where the dependent variables are the growth rate of real per capita GDP (Gross Domestic Product) for 1965-1975, 1975-1985 and 1985-1990 respectively. The independent variables are male schooling; life expectancy; the rule-of-law index; the inflation rate; a terms-of-trade variable, which is the growth rate over each

¹ The health capital variable enters the equation in log (life expectancy) form.

period of the ratio of export to import prices; and so on. He examines the impact of life expectancy on economic growth using three-stage least squares with random effects, using lagged values of some regressors such as the five-years earlier value of log (GDP) (for example, for 1970 in the 1975-85 equation), the actual value of schooling, life expectancy, the rule of law and the terms-of-trade variable as instruments. He finds that the estimated coefficient of life expectancy at birth is 0.0423 and statistically significant, which means if life expectancy at birth is 50 years, then an additional year of life expectancy at birth raises the growth rate by 0.08 percentage points per year, holding other variables constant; if life expectancy at birth is 70 years, then an extra year of life expectancy at birth increases the growth rate by 0.06 percent.² As he explains, life expectancy may proxy not only health status but more broadly the quality of human capital such as the productivity of workers. Also, using a graph he shows that the partial relation between health status and subsequent growth is strongly positive and almost linear in the log of life expectancy.

Caselli, Esquivel, and Lefort (1996) criticize the random effects model used by Barro and Lee (1994), pointing out that this model fails to explain correlated individual effects, leading to inconsistent estimates. They suggest the Generalized Method of Moments (GMM) as an alternative estimation method to eliminate the sources of inconsistency. They augment the Solow Model by including health capital and educational capital. For the latter they use data on a country's secondary-enrolment rate provided by Barro and Lee (1994). They find that the coefficient of life expectancy is

² Again life expectancy enters the equation in log form.

negative and statistically insignificant (-0.00118), implying that there is no impact of life expectancy on economic growth.

Knowles and Owen (1997) reformulate the Solow model by incorporating health and education as labour augmenting, rather than as separate factors in the production function. Their cross-section data are from MRW (1992), Barro and Lee (1993) and the World Bank. They estimate their equation using OLS and find that there is a strong positive partial relation between the health proxy (life expectancy at birth) and output per worker. The estimated coefficient of life expectancy is 0.308 in their full sample (77 countries), which means that if life expectancy at birth is 50 years, then an additional year of life expectancy with raises the growth rate by 0.6 percentage points per year, holding other variables constant; if life expectancy at birth is 70 years, then an extra year of life expectancy increases the growth rate by 0.43 percent.³ Also, the estimated coefficient of life expectancy is 0.284 in their sample of less developed countries (55 countries), which can be interpreted as implying that if life expectancy at birth is 50 years, then an additional year of life expectancy raises the growth rate by 0.5 percentage points per year. If life expectancy at birth is 70 years, then an extra year of life expectancy increases the growth rate by 0.4 percent. However, they find that education does not have a significant effect on growth in a model that includes health, physical capital and initial output per worker.

Bloom and Sachs (1998) extend the Solow Model by including liquid liabilities, the area in the tropics, openness, human capital (e.g., years of schooling), public health (e.g., life expectancy at birth) and so on. Their data set is compiled from the World Bank, the United Nations (1996) and Statistics Canada (1997). Using OLS with cross-section

data from 1965 to 1990 they show that the coefficient of life expectancy is 0.040, which means that each extra year of life expectancy causes output per capita to rise by 0.08 percent and 0.057 percent when life expectancy at birth is 50 years and 70 years respectively.

Bloom, Canning and Sevilla (2001) derive a model in which growth in output is decomposed into four parts: the growth of world total factor productivity (TFP), the growth of inputs, a catch-up term, and an idiosyncratic shock to the country's TFP. They construct a panel of countries observed every 10 years from 1960 to 1990. Their data are obtained from Summers and Heston (1994) (output and capital stock), International Labour Office (1997) (labour supply), United Nations (1998) (life expectancy at birth), Barro and Lee (2000) (schooling) and Knack and Keefer (1995) (institutional quality). They then estimate the equation using the Instrumental Variables (IV) technique to remove the causal effect from output growth to input growth, which would result in a tendency to overstate the contribution of inputs to growth. They find that each extra year of life expectancy causes an increase of 4 percent in output, but they also find that the coefficient of schooling is small and insignificant, similar to Knowles and Owen's (1997) finding.⁴

Bhargava, Jamison, Lau and Murray (2001) compile their data set from Summers and Heston (1991), the World Bank and Barro and Lee (1996). Their empirical framework relates the growth rate of real per capita GDP over 5-year intervals during the period 1965-1990 to geographical variables (the area in the tropics); openness; the fertility rate; the adult survival rate lagged 5 years, which is a proxy for health capital; the

³Again life expectancy enters the equation in log form.

⁴Their regression model is a log-linear functional form; the life expectancy variable enters in a linear form.

interaction between the lagged adult survival rate and GDP; GDP lagged 5 years and so on. Using a panel-data approach, they find that there is a significant and positive effect of health capital on economic growth, equal to 0.181, in the case of a sample of 92 countries from Summers and Heston data set; and 0.192, in the case of 73 countries from the data set of World Development Indicators. However, they argue that a model of the growth rate should allow some form of non-linearity since, for countries at low levels of GDP, increases in the adult survival rate are likely to have significant effects on economic growth because they increase the contribution of labour during prime working years, while for middle and high income countries the effect on growth is likely to be insignificant because an increase in the adult survival rate beyond a certain threshold will simply increase the proportion of the elderly in the economy. They reformulate the model to examine the net effect of a change in the adult survival rate on the growth rate, and they find a significant positive impact of the adult survival rate on the growth rate until GDP is approximately \$907 in 1985 international dollars. They indicate that, for the poorest countries, a 1 percent change in the adult survival rate is associated with an increase of approximately 0.05 percent in the growth rate.

Webber (2002) extends Solow's growth model by adding educational capital and health capital, proxied by calories per head in 1990 for the flow of health capital and the average intake of calories per head over the period 1960-1990 for the average flow of health capital, to the Cobb-Douglas production function, and shows that economic growth can be written as a function of the rate of accumulation of physical capital and either the long-run average flows or stocks of health and educational capital. His data set is obtained from the World Bank, the United Nations, Barro and Lee (1993) and

Summers and Heston (1991). Using Ordinary Least Squares (OLS) with cross-sectional data for 46 countries over a period from 1960 to 1990, he finds that the estimated coefficient of health capital ranges from 0.03 to 0.39 but is not statistically significant in all cases.

McDonald and Roberts (2002) augmented a Solow model by including educational capital and health capital, proxied by life expectancy at birth and infant mortality. Their data set is acquired from Summers and Heston (1991), the World Bank and Nehru et al. (1995). Their dependent variable is the level of income per capita at the end of each 5-year period. They then construct three sub-samples: an OECD sample (22 countries); an LDC sample (55 countries), which consists of the countries that remain after extracting OECD countries; and an LDC2 sample (39 countries), which is the LDC sample excluding Latin American countries. They run a regression based on a panel data approach with two-way fixed effects including time-specific and country-specific effects. Their results show that the coefficients of health capital are positive and significant for the full sample (0.12), LDC countries (0.106), and LDC2 countries (0.331), but slightly negative and insignificant for OECD countries (-0.006).

So far, I have reviewed a number of empirical papers, and find that there are several issues that economists have raised. First, with some exceptions, most of the papers have shown that life expectancy has a positive and statistically significant effect on economic growth. That is, an increase in life expectancy (or health status) generally gives rise to an increase in economic growth.

Second, there is the possibility of a causal relationship between health status and economic growth and the omission of important explanatory variables such as openness,

the area in the tropics, corruption etc. in the estimating equations used by most studies. Simultaneity and omitted variables cause the coefficient estimates to be inconsistent. To solve the simultaneity problem, economists suggest using the IV method, but they agree that it is very hard to say whether the chosen instrumental variables, which should be correlated with the independent variables and uncorrelated with the error term in the regression equation, are valid or not. Those who have attempted this method include Barro (1996) and Bloom, Canning and Sevilla (2001). To solve the problem of omitted variables, most papers summarized above have added several possible variables that might have an impact on growth, but this solution also results in problems such as strong correlations between the pre-existing explanatory variables and the additional one.

Finally, when life expectancy is added to the model, some of the studies show that the education coefficient becomes negative or zero rather than strongly positive (Knowles and Owen 1997, and Bloom, Canning and Sevilla 2001) and there has been no clear interpretation of this result so far. Economists just try to explain this symptom by suggesting that there must be a discrepancy between the theoretical human capital variable in the production function and the actual variable used in regression model, or that multicollinearity among the variables causes this unexpected result.

Thus far, I have summarized several literatures dealing with convergence and the determinants of growth, especially health capital. My paper first takes the concept of convergence for granted; that is, it starts from the MRW augmented Solow model and further augments it by adding human capital: educational capital and health capital. Knowles and Owen (1995) were the first to do this. However, their research only concentrates on the cross-section approach. I further develop my model based on

Knowles and Owen (1995) into a panel-data approach following Islam (1996), who does not include health capital in his model. My paper combines these two previous approaches, that is, I augment the MRW model by including educational and health capital and estimate it using a panel data approach. My paper differs from other research in terms of dealing with, first, convergence analysis and then, the determinants of growth including health capital.

3. Growth Regressions as Dynamic Panel Data Models

Mankiw, Romer, and Weil (1992) extend the basic Solow model, and Knowles and Owen (1995) further augment MRW's model by adding health capital. Like Knowles and Owen (1995), I start with a Solow model including both health capital and educational capital as components of human capital.

After extending the MRW production function by adding educational and health capital, I obtain this form for the production function:

$$(1) \quad Y_t = K_t^\alpha S_t^\beta H_t^\gamma (A_t L_t)^{1-\alpha-\beta-\gamma}, \quad 0 < \alpha+\beta+\gamma < 1,$$

where Y is real output, K the stock of physical capital, S the stock of educational capital, H the stock of health capital, L the labour input, and A the labour-augmenting level of technology. Each capital stock evolves as follows:

$$(2) \quad \begin{aligned} \dot{K}_t &= s_k Y_t - \delta K_t, \\ \dot{S}_t &= s_s Y_t - \delta S_t, \end{aligned}$$

$$\dot{H}_t = s_h Y_t - \delta H_t,$$

where s_k , s_s , s_h are the savings rates for physical, educational and health capital, respectively. Physical, educational and health capital are assumed to depreciate at the same rate, δ , for simplicity. As MRW assume $0 < \alpha + \beta < 1$, in their paper I assume that $0 < \alpha + \beta + \gamma < 1$, which implies decreasing return to scale for all capital. Also, MRW assumed that

$$(3) \quad L_t = L(0) e^{nt}$$

$$(4) \quad A_t = A(0) e^{gt},$$

where n and g are the exogenous rates of growth of the labour force and technology

respectively, which are assumed to be constant across countries ($n = \frac{\dot{L}_t}{L_t}$, $g = \frac{\dot{A}_t}{A_t}$).

Dividing equation (1) by $A_t L_t$, which is effective units of labour, results in

$$(5) \quad \frac{Y_t}{A_t L_t} = \frac{K_t^\alpha S_t^\beta H_t^\gamma (A_t L_t)^{1-\alpha-\beta-\gamma}}{A_t L_t} = \left(\frac{K_t}{A_t L_t} \right)^\alpha \left(\frac{S_t}{A_t L_t} \right)^\beta \left(\frac{H_t}{A_t L_t} \right)^\gamma.$$

After defining $\hat{Y}_t = Y_t / A_t L_t$, $\hat{S}_t = S_t / A_t L_t$, $\hat{H}_t = H_t / A_t L_t$ and

$\hat{K}_t = K_t / A_t L_t$, I obtain following equation:

$$(6) \quad \hat{Y}_t = \hat{K}_t^\alpha \hat{S}_t^\beta \hat{H}_t^\gamma.$$

The rate of accumulation of physical capital, educational capital, and health capital is calculated from $\hat{k}_t = \dot{K}_t / A_t L_t$, $\hat{s}_t = \dot{S}_t / A_t L_t$ and $\hat{h}_t = \dot{H}_t / A_t L_t$ as follows:

$$\begin{aligned}
 (7) \quad \hat{k}_t &= \frac{\dot{K}_t (A_t L_t) - K_t (\dot{A}_t L_t + A_t \dot{L}_t)}{(A_t L_t)^2} \\
 &= \frac{\dot{K}_t}{A_t L_t} - \frac{K_t}{A_t L_t} \frac{(\dot{A}_t L_t + A_t \dot{L}_t)}{A_t L_t} \\
 &= \frac{s_k Y_t - \delta K_t}{A_t L_t} - \frac{K_t}{A_t L_t} \left(\frac{\dot{A}_t}{A_t} + \frac{\dot{L}_t}{L_t} \right) \\
 &= s_k \hat{y}_t - \delta \hat{k}_t - \hat{k}_t (g+n) \\
 &= s_k \hat{y}_t - (n + g + \delta) \hat{k}_t \\
 &= s_k \hat{k}_t^\alpha \hat{s}_t^\beta \hat{h}_t^\gamma - (n + g + \delta) \hat{k}_t,
 \end{aligned}$$

$$\begin{aligned}
 (8) \quad \hat{s}_t &= \frac{\dot{S}_t (A_t L_t) - S_t (\dot{A}_t L_t + A_t \dot{L}_t)}{(A_t L_t)^2} \\
 &= \frac{\dot{S}_t}{A_t L_t} - \frac{S_t}{A_t L_t} \frac{(\dot{A}_t L_t + A_t \dot{L}_t)}{A_t L_t} \\
 &= \frac{s_s Y_t - \delta S_t}{A_t L_t} - \frac{S_t}{A_t L_t} \left(\frac{\dot{A}_t}{A_t} + \frac{\dot{L}_t}{L_t} \right) \\
 &= s_s \hat{y}_t - \delta \hat{s}_t - \hat{s}_t (g+n) \\
 &= s_s \hat{y}_t - (n + g + \delta) \hat{s}_t \\
 &= s_s \hat{k}_t^\alpha \hat{s}_t^\beta \hat{h}_t^\gamma - (n + g + \delta) \hat{s}_t,
 \end{aligned}$$

$$\begin{aligned}
(9) \quad \hat{h}_t &= \frac{\dot{H}_t (A_t L_t) - H_t (\dot{A}_t L_t + A_t \dot{L}_t)}{(A_t L_t)^2} \\
&= \frac{\dot{H}_t}{A_t L_t} - \frac{H_t}{A_t L_t} \frac{(\dot{A}_t L_t + A_t \dot{L}_t)}{A_t L_t} \\
&= \frac{s_h Y_t - \delta H_t}{A_t L_t} - \frac{H_t}{A_t L_t} \left(\frac{\dot{A}_t}{A_t} + \frac{\dot{L}_t}{L_t} \right) \\
&= s_h \hat{Y}_t - \delta \hat{h}_t - \hat{h}_t (g + n) \\
&= s_h \hat{Y}_t - (n + g + \delta) \hat{h}_t \\
&= s_h \hat{k}_t^\alpha \hat{s}_t^\beta \hat{h}_t^\gamma - (n + g + \delta) \hat{h}_t,
\end{aligned}$$

where s_k , s_s and s_h are the fractions of income invested in physical capital, educational capital, and health capital, respectively, and δ is the rate of depreciation.

MRW assume that one unit of consumption can be transformed without cost into one unit of physical capital or one unit of educational capital. In addition, MRW assume that educational capital depreciates at the same rate as physical capital. Like MRW, I assume that consumption can be transformed into health capital costlessly, and that health capital depreciates at the same rate as physical and educational capital. Although these assumptions seem to be unrealistic, I make them in order to make the analysis simpler.

It is assumed that \hat{k}_t , \hat{s}_t and \hat{h}_t converge to their steady state value \hat{k}^* , \hat{s}^* and \hat{h}^* which means that in the steady state the rate of accumulation is zero ($\hat{k}_t = \hat{s}_t = \hat{h}_t = 0$). Therefore, one can write $s_k \hat{k}_t^\alpha \hat{s}_t^\beta \hat{h}_t^\gamma - (n + g + \delta) \hat{k}_t = 0$, $s_s \hat{k}_t^\alpha \hat{s}_t^\beta \hat{h}_t^\gamma - (n + g + \delta) \hat{s}_t = 0$, $s_h \hat{k}_t^\alpha \hat{s}_t^\beta \hat{h}_t^\gamma - (n + g + \delta) \hat{h}_t = 0$. Solving these three equation in terms of

\hat{k}^* , \hat{s}^* and \hat{h}^* , then I get

$$(10) \quad \hat{k}^* = \left(\frac{s_k^{1-\beta-\gamma} s_s^\beta s_h^\gamma}{n+g+\delta} \right)^{\frac{1}{1-\alpha-\beta-\gamma}}$$

$$(11) \quad \hat{s}^* = \left(\frac{s_k^\alpha s_s^{1-\alpha-\gamma} s_h^\gamma}{n+g+\delta} \right)^{\frac{1}{1-\alpha-\beta-\gamma}}$$

$$(12) \quad \hat{h}^* = \left(\frac{s_k^\alpha s_s^\beta s_h^{1-\alpha-\beta}}{n+g+\delta} \right)^{\frac{1}{1-\alpha-\beta-\gamma}}$$

The procedures to obtain (10), (11) and (12) are indicated in Appendix 2. As do Knowles and Owen (1995), I substitute (4), (10), (11), and (12) into (6) and take logs to obtain the following expression for steady-state income per capita,

$$(13) \quad \ln \left(\frac{Y_t}{L_t} \right) = \ln A(0) + g t - \frac{\alpha + \beta + \gamma}{1 - \alpha - \beta - \gamma} \ln(n+g+\delta) \\ + \frac{\alpha}{1 - \alpha - \beta - \gamma} \ln s_k + \frac{\beta}{1 - \alpha - \beta - \gamma} \ln s_s + \frac{\gamma}{1 - \alpha - \beta - \gamma} \ln s_h$$

This equation shows how income per capita depends on labour force growth and the accumulation of physical, educational, and health capital under the assumption that countries are currently in their steady state.

Also, income per capita can be expressed as a function of the steady-state “level” of educational and health capital instead of the accumulation of educational and health

capital. Solving (11) and (12) in terms of s^* and h^* , and substituting these into (13) gives

$$(14) \quad \ln \left(\frac{Y_t}{L_t} \right) = \ln A(0) + g t - \frac{\alpha}{1-\alpha} \ln(n+g+\delta) \\ + \frac{\alpha}{1-\alpha} \ln s_k + \frac{\beta}{1-\alpha} \ln s^* + \frac{\gamma}{1-\alpha} \ln h^*$$

This equation describes how income per capita relies on labour growth, the accumulation of physical capital and the steady-state “level” of educational and health capital. MRW note that although in this equation (14) $\ln A(0)$ appears to be just a constant, in fact, “the term reflects not just technology but resource endowments, climate, institutions, and so on; it may therefore differ across countries” [p. 411]. They therefore postulate that

$$\ln A(0) = a + \varepsilon$$

where a is a constant and ε is the country-specific shift term. After substituting this term into equation (14) and subsuming $g t$ into a , they proceed with Ordinary Least Squares (OLS) estimation of the equation under the assumption that ε is independent of the explanatory variables, which is a necessary condition for using OLS.

However, in general, the country-specific (technology) term ε must be correlated with the included explanatory variables such as the saving, population growth rates, school years, and so on experienced by that country, and therefore under this situation OLS is invalid. To solve this problem, Islam (1996) argues that the panel data framework provides a better and more natural setting to control for this country-specific (technology)

term, and this can be better indicated by considering the equation describing out of steady state behaviour. Now following Islam (1996), I further derive the equation describing out of steady state behaviour from equation (14).

Let \hat{Y}^* be the steady state level of income per effective worker, and let \hat{Y}_t be its actual level at any time t . Approximating around the steady state, the pace of convergence is indicated by

$$(15) \quad \frac{d \ln \hat{Y}_t}{d t} = \lambda [\ln \hat{Y}^* - \ln \hat{Y}_t] ,$$

where $\lambda = (n + g + \delta) (1 - \alpha - \beta - \gamma)$ is the speed of convergence parameter.⁵ This equation implies that

$$(16) \quad \ln \hat{Y}_{t_2} = (1 - e^{-\lambda \tau}) \ln \hat{Y}^* + e^{-\lambda \tau} \ln \hat{Y}_{t_1} ,$$

where \hat{Y}_{t_1} is income per effective worker at some initial point of time and

$\tau = (t_2 - t_1)$. Subtracting $\ln \hat{Y}_{t_1}$ from both sides yields,

$$(17) \quad \ln \hat{Y}_{t_2} - \ln \hat{Y}_{t_1} = (1 - e^{-\lambda \tau}) \ln \hat{Y}^* - (1 - e^{-\lambda \tau}) \ln \hat{Y}_{t_1} .$$

⁵ This equation is derived in Mankiw (1995, Appendix).

From equation (14), I obtain $\ln \hat{Y}^*$ to be

$$(18) \quad \ln \hat{Y}^* = -\frac{\alpha}{1-\alpha} \ln(n+g+\delta) + \frac{\alpha}{1-\alpha} \ln s_k + \frac{\beta}{1-\alpha} \ln s^* + \frac{\gamma}{1-\alpha} \ln h^*$$

Finally, substituting $\ln \hat{Y}^*$ into equation (17) gives

$$(19) \quad \begin{aligned} \ln \hat{Y}_{t_2} - \ln \hat{Y}_{t_1} &= (1 - e^{-\lambda\tau}) \frac{\alpha}{1-\alpha} \ln s_k - (1 - e^{-\lambda\tau}) \frac{\alpha}{1-\alpha} \\ &\ln(n+g+\delta) + (1 - e^{-\lambda\tau}) \frac{\beta}{1-\alpha} \ln s^* + (1 - e^{-\lambda\tau}) \frac{\gamma}{1-\alpha} \ln h^* \\ &- (1 - e^{-\lambda\tau}) \ln \hat{Y}_{t_1} \end{aligned}$$

The correlation between the unobservable $\ln A(0)$ and the observed included variables is not apparent in equation (19) since it has been formulated in terms of income per effective worker. Now I reformulate equation (19) in terms of income per capita.

Since

$$\hat{Y}_t = \frac{Y_t}{A_t L_t} = \frac{Y_t}{A(0) e^{gt} L_t}$$

thus I obtain

$$(20) \quad \ln \hat{Y}_t = \ln \left(\frac{Y_t}{L_t} \right) - \ln A(0) - gt$$

$$= \ln y_t - \ln A(0) - g t,$$

where Y_t is income per capita.

Substituting equation (20) into equation (19) finally yields,

$$(21) \quad \begin{aligned} \ln y_{t_2} - \ln y_{t_1} &= (1 - e^{-\lambda\tau}) \frac{\alpha}{1-\alpha} \ln s_k - (1 - e^{-\lambda\tau}) \frac{\alpha}{1-\alpha} \\ &\ln(n+g+\delta) + (1 - e^{-\lambda\tau}) \frac{\beta}{1-\alpha} \ln s^* + (1 - e^{-\lambda\tau}) \frac{\gamma}{1-\alpha} \ln h^* \\ &- (1 - e^{-\lambda\tau}) \ln y_{t_1} + (1 - e^{-\lambda\tau}) \ln A(0) + (g t_2 - e^{-\lambda\tau} g t_1) \end{aligned}$$

We can see that the above equation represents a dynamic panel data model with

$(1 - e^{-\lambda\tau}) \ln A(0)$ as the time-invariant individual country-effect term. I add one more assumption that g is also constant across time as well as countries, which ensures that $(g t_2 - e^{-\lambda\tau} g t_1)$ is constant across countries and time periods. Following Islam (1996), I use the conventional notation of the panel data literature:

$$(22) \quad Y_{it} - Y_{i,t-1} = \omega Y_{i,t-1} + \sum_{j=1}^4 \beta_j x_{it}^j + \eta + \mu_i + v_{it},$$

where

$$Y_{it} = \ln y_{t_2}$$

$$Y_{i,t-1} = \ln y_{t_1}$$

$$\omega = - (1 - e^{-\lambda\tau})$$

$$\beta_1 = (1 - e^{-\lambda\tau}) \frac{\alpha}{1-\alpha}$$

$$\beta_2 = - (1 - e^{-\lambda\tau}) \frac{\alpha}{1 - \alpha}$$

$$\beta_3 = (1 - e^{-\lambda\tau}) \frac{\beta}{1 - \alpha}$$

$$\beta_4 = (1 - e^{-\lambda\tau}) \frac{\gamma}{1 - \alpha}$$

$$x_{it}^1 = \ln s_k$$

$$x_{it}^2 = \ln (n + g + \delta)$$

$$x_{it}^3 = \ln s^*$$

$$x_{it}^4 = \ln h^*$$

$$\mu_i = (1 - e^{-\lambda\tau}) \ln A(0)$$

$$\eta = (g t_2 - e^{-\lambda\tau} g t_1)$$

Like Islam (1996) I assume that v_{it} is a transitory error term, which varies across countries and time periods, with a mean of zero. In the words of Islam (1996), equation (22) is

based on approximation around the steady state and ...is going to catch the dynamic process toward the steady state... this panel data approach allows us, after controlling for the individual country effects, to make an integration of the process of convergence occurring over several continuous time intervals and create a clearer picture for the relationship between the measurable and included economic variables and unobserved term (p. 12).

My empirical analysis is based on equation (22).

4. Estimation Method and Data

A. Fixed Versus Random Effects

Many methods are available for the estimation of panel data models with individual effects, and one common estimation issue that must be considered is whether the individual effects are to be thought of as “fixed” or “random.” In the random effects case the effects are assumed to be uncorrelated with the exogenous variables in the model. However, because, as I mentioned earlier, there is likely to be a correlation between the unobservable variable representing the country-specific effect and other observable variables included in the model, the random effects model is not suitable (Islam 1996).

The fixed effects model can be used for my analysis because it allows us to have an individual-specific constant term and permits the individual effects to be correlated with the other included explanatory variables. I use the Least Squares with Dummy Variables (LSDV) estimator, which allows different intercepts across countries. In this case the LSDV estimator is unbiased and consistent, since we eliminate the omitted variable problem that arises when we use OLS without dummy variables, that is, when we put the unobservable country-specific effect into the error term. However, one problem is that the existence of a lagged dependent variable on the right-hand side of the estimating equation makes LSDV an inconsistent estimator when asymptotics are considered in the direction of N . However, Amemiya (1967) shows that when the asymptotic properties of the estimators are considered in the direction of T , LSDV

estimation is consistent and asymptotically equivalent to Maximum Likelihood estimation.

B. Data and Samples

I construct a panel of countries observed over five-year intervals from 1965 to 1995; consequently, there are 6 observations for each country. Although most studies use income per capita I use income per worker ($\ln y$) obtained from the Penn World Tables 6.1 (Heston, Summers and Aten 2002) instead of income per capita because income per worker takes into account the fact that some fraction of the labour force is unemployed. This variable gives a more reasonable and precise performance for my analysis. The data for income per worker is measured in 1996 international purchasing power parity dollars (chain index). The average saving rate s_k at time t , proxied by the ratio of real domestic investment to Real GDP, is calculated as an average over the five years preceding t using the Penn World Tables 6.1.

MRW measure n as the rate of growth of the working age population. Since it is difficult to obtain panel data on the labour force, I depend on population growth rates computed also as an average over the five years preceding t from the total population figures of the Penn World Tables 6.1. Following Mankiw, Romer, and Weil, I take $(g+\delta)$ to be equal to 0.05 and assume that this value is the same for all countries and years.⁶ For the level of educational capital stock I use Barro and Lee's (2000, Appendix Table A.2) measure, defined as the average number of years of schooling (at all levels) achieved by the population aged 15 years and over. For health capital one possible approach is to

⁶ MRW suggest that in U.S. data the capital consumption allowance is about 10 percent of GNP, and the capital-output ratio is about three, which implies that δ is about 0.03, and also growth in income per capita

proxy it by the fraction of income spent on health investment. However, a given level of health spending can be associated with widely differing actual outcomes across different countries, even after controlling for levels of income and schooling (World Bank 1993, 53-54), so I follow the alternative approach of using life expectancy at birth as a proxy for the level of health capital stock, although this measure depends on mortality rates rather than morbidity. However, Murray and Lopez (1997) mention that higher life expectancy is generally thought to be associated with better health status and lower morbidity.

Since it is difficult to obtain life expectancy data at 5-year intervals I construct the data set using six different sources.⁷ I first obtain life expectancy data from the U.S Census Bureau site, but their data set has a lot of missing years. To fill in these missing years, next I use the Demographic Yearbook, which was published by the United Nations from 1970 to 1998. To fill in some missing data for OECD countries I use the data set from the Korean Institute for Health and Social Affairs web site, which provides life expectancy data for the period 1960-2000 in most cases. Since it provides life expectancy for OECD countries in terms of males and females separately, I simply calculate life expectancy at birth for both sexes by taking a simple average of male and female life expectancies. I use the UNICEF web site and the World Bank Group site, which provide life expectancy data for 1970 and 1980, respectively, in order to fill in some missing values in 1970 and 1980. Finally, to fill in the remaining data cells I use data from the site of the United Nations Population Division, but because they just provide the 5 year average of life expectancy for periods such as 1980-85 and 1985-90, I use simple math to

averages 2 percent in their sample, which suggest that g is about 0.02.

⁷ Complete details on the data sources for life expectancy can be found in Appendix 1.

extrapolate the single year value. For example, to obtain 1985 data I add the 1980-85 data to the 1985-90 data and divide it by 2.

Furthermore as do Knowles and Owen (1995), I proxy $\ln h^*$ by $-\ln(\text{80-life expectancy})$, adopting the transformation used by Anand and Ravallion (1993), where **(80-life expectancy)** is the shortfall of average life expectancy at birth from 80 years.

To choose countries, I use the World Bank classification site, which divides them into five groups on the basis of level of Gross National Income (GNI) per capita: low-income economies (64 countries), lower-middle-income economies (54 countries), upper-middle-income economies (34 countries), high-income economies (56 countries) and high-income OECD members (24 countries), which is a subset of the high-income countries. First, I choose 100 countries for which data exist in the Barro–Lee (2000) school attainment data set, and then I choose 91 countries for which a life expectancy series can be constructed using the six different sources discussed above. Next, I further exclude 13 countries that are members of OPEC or oil-producing countries based on the Appendix Table of MRW (1992), since the bulk of recorded GDP for these countries reflects the extraction of existing resources (MRW 1992). Then I exclude 11 countries which do not have enough data on RGDP per worker or the ratio of investment to RGDP from the Penn World Table. Thus, finally I get 67 countries for the full sample with observations for 1970, 1975, 1980, 1985, 1990 and 1995.⁸ I further subdivide the countries into three new categories: low-income countries (17 countries) from the low-income economies in the World Bank classification, middle-income countries (27 countries), which is the combination of lower-middle-income economies (18 countries)

⁸ I do not include China since it does not have schooling data for 1970.

and upper-middle-income economies (9 countries) in the World Bank classification, and high-income countries (23 countries), which consists of OECD (21 countries) and high-income economies (2 countries) in the World Bank classification. The reason I divide the countries into three groups on the basis of level of income per capita is, first of all, to test for absolute convergence among homogenous countries and conditional convergence among heterogeneous countries (i.e. low-income and high-income countries combined), and, second, to investigate the different impact of several explanatory variables on economic growth in each group. I believe that such an analysis would assist policymakers in solving the problem of how to share limited resources between different capital sectors, all of which induce economic growth, in order to attain growth without losing efficiency. For example, suppose that the estimated coefficient of health capital on economic growth is larger than that of educational capital in low-income countries. Then the policymaker should concentrate more on investing in health capital than educational capital in order to achieve faster economic growth without loss of efficiency.

Appendix 1 provides the list of countries and details regarding the data sources. Since some of the variables do not have a single value in each year I replace it with the closest year's value or average year's value (the specific year is indicated in the parentheses of Appendix 1). Although I can obtain these single missing values by extrapolating from the site of the United Nations Population Division, because I believe that an extrapolating method is less reliable I replace these missing values with the closest year's value or average year's value from U.S census bureau site and Demographic Yearbook of the United Nations if these data are available.

In table 1, I provide basic statistics about the data in periods 1970-1995. The descriptive statistics are computed using the pooled time-series cross-section data.

[Insert Table 1 about here]

Table 1 shows that the means of average years of schooling and life expectancy are 2.3468 years and 48.889 years, respectively, in low-income countries. These results indicate that most workers have not graduated from elementary schools in low-income countries. In middle-income countries, the means of average years of schooling and life expectancy are 5.1543 years and 65.121 years, respectively. In high-income countries, the means of average years of schooling and life expectancy are 8.2496 years and 74.239 years, respectively. The means of average years of schooling and life expectancy at birth seem to increase with the mean of income per worker across groups as one moves from low-income countries to high-income countries, and this fact suggests that the higher is income per capita, the greater is investment in educational and health capital. That is, there is the possibility of a causal relationship between the dependent variable (income per worker) and the independent variables (educational and health capital). The Min and Max values also can be used to compare groups. In low-income countries, the minimum value of life expectancy is approximately 28 years and the maximum value is 67 years. That is, the maximum value of life expectancy in low-income countries is 3 times larger than the minimum value of life expectancy. On the other hand, the maximum value of life expectancy is approximately 1.7 and 1.3 times larger than the minimum value in middle- and high-income countries, respectively. As we move from high-income countries to low-income countries, this difference between minimum and maximum values also

becomes larger in other variables such as income per worker and the average years of schooling.

Now, I plot the five-year average for each variable for each sample. Figures 1, 2, 3, 4 and 5 show how the five-year averages for each variable vary at each year.

[Insert Figures 1, 2, 3, 4 and 5 about here]

Figures 1, 2 and 3 show that the sample averages of income per worker, average years of schooling and life expectancy at birth for each group increases over the 1970-1995 period, with the exception of average of income per worker and average of life expectancy at birth in low-income countries. This fact can be interpreted as suggesting that there may be reverse causality. That is, although economists measure the contribution of inputs such as human capital to the growth of income per worker, the growth of income per worker may also have a reverse causal effect on inputs. For example, economic growth may stimulate investments in physical capital as well as human capital by facilitating increased schooling or improving people's health (Bloom, Canning and Sevilla 2001). Figures 4 and 5 present the sample averages of the average saving rate, proxied by the average of the ratio of real domestic investment to Real GDP, and the average of $(n+g+\delta)$ for each sample over the periods: 1970-1995. In contrast to Figures 1, 2 and 3, Figure 4 shows that the average saving rate for middle-income and high-income countries has fluctuated and, for low-income countries, it displays a decreasing trend from 1975. In Figure 5, the average of $(n+g+\delta)$ for high-income countries and the full sample displays large fluctuations, while for low-income and middle-income countries the fluctuations have been small.

5. Estimation Results and Interpretation

I consider the period 1960-1995 with six data (time) points for each country: 1970, 1975, 1980, 1985, 1990 and 1995. When $t=1975$, for example, $t-1$ is 1970, saving and population growth variables are averages over 1970-1975, and the average years of schooling and life expectancy at birth are the 1975 levels. These data are used for all the regressions I run in this paper.

Before I discuss the estimation results, I provide an overview of my estimation and testing strategy. First, I test for absolute convergence within each homogenous group (i.e., low-income countries, middle-income countries and high-income countries) and different combinations of groups (i.e., low- and middle-income countries, low- and high-income countries, middle- and high-income countries and the full sample). To test for absolute convergence, I examine the simple correlation between the initial level of income per worker and the subsequent rate of growth of income per worker, as is customary in studies of the neoclassical growth model (e.g., MRW 1992). The reason I test for absolute convergence in each group and combined groups is that neoclassical growth models assume that absolute convergence occurs if economies are similar with respect to preferences and technology. Since countries within each group have a similar level of income per worker (this value is calculated in terms of purchasing power parity) their preferences and technology are likely to be similar. Also, because countries in combined groups have different levels of income per worker their preferences and technology are likely to be different. Thus, I want to show that absolute convergence occurs in each homogenous group, but not in each heterogeneous combined group.

Second, I test for conditional convergence. Plenty of previous studies show that after adding variables that represent the determinants of growth, there is conditional convergence even in the wider sample of countries (Barro 1991; MRW 1992; Barro and Sala-i-Martin 1992). Thus, I wish to see if there is convergence (in the conditional sense) after adding the savings rate and $(n+g+\delta)$ into the model, even in each heterogeneous group. Finally, I analyze the impact of human capital (including educational capital) on economic growth within each homogeneous group (i.e., low-income countries, middle-income countries and high-income countries) by estimating equation (22). For this equation I use pooled OLS with fixed effects using five-year span data; the equations estimated prior to this are estimated using pooled OLS without fixed effects. Since I want to see how the impact of human capital (including educational capital) on economic growth differs in each of the three groups, the only combination of groups used to estimate this equation is the full sample. Thus, in total I use three equations to test for absolute convergence and conditional convergence and to examine the impact of educational and health capital.

I also test each equation for heteroskedasticity, specification error and normality of the errors. To test for heteroskedasticity I use the Breusch-Pagan-Godfrey test and the modified test proposed by Koenker (1981). Ramsey's RESET test is used to test for specification error and the Jarque-Bera test is used to test for normality of the errors.⁹ The presence of heteroskedasticity leads to inaccurate results for t and F tests since the usual estimator of the variance-covariance matrix of the OLS estimates is no longer correct. However, using White's heteroscedasticity-consistent covariance matrix one can make

⁹ Three RESET test statistics are reported: one for the inclusion of \hat{y}^2 ; one for the inclusion of \hat{y}^2 and

asymptotically valid statistical inferences. Thus I use White's heteroscedasticity-consistent covariance matrix to perform valid statistical tests if I find heteroskedasticity. The existence of specification error in the case of excluding a relevant variable leads to biased and inconsistent coefficient estimates and is likely to result in misleading conclusions from hypothesis testing procedures. On the other hand, specification errors that take the form of the inclusion of an irrelevant variable still yield unbiased and consistent estimates of the coefficients and result in valid hypothesis testing (there are also other types of specification errors such as adopting the wrong functional form and errors of measurement).

Finally, if the assumption of normally distributed errors is violated t and F tests are not strictly valid in small samples – they are valid only asymptotically. Therefore, before discussing the estimation results for each equation, I discuss the results of the diagnostic tests, since hypothesis tests are not valid if an equation fails some of the diagnostic tests I mention above.

A. The Evidence for Convergence

I first examine absolute convergence. The results can be seen in Table 2.¹⁰

[Insert Table 2 about here]

In this equation, the log of initial income per worker appears alone on the right-hand side.

The normality test indicates that the errors are not normal for all groups except low-income countries and middle-income countries. However, most economists still use F -tests in spite of detecting non-normality of the error terms, since they argue that the F -test is more conservative than large sample hypothesis tests.

\hat{Y}^3 ; and one for the inclusion of \hat{Y}^2 , \hat{Y}^3 , and \hat{Y}^4 , where \hat{Y} is the predicted value from OLS estimates.
¹⁰ Results are obtained using Shazam version 8.0 and 9.0.

Heteroskedasticity is found in the high-income subsample, the low- and high-income subsample, the middle- and high-income subsample and the full sample, at the 5 percent level of significance, but the results are ambiguous in the low- and middle-income group at the 10 percent level of significance. The strong evidence that there is heteroskedasticity within the high-income subsample, but not the low- and middle-income subsamples, is not surprising because over the period between 1970 and 1995, income per worker in low-income countries and middle-income countries changed only slightly. Their variation in income per worker over the period is not large. However, although average income per worker in the high-income group increased gradually, income per worker in some countries (South Korea, Austria, Italy, Singapore, Japan, Italy and Ireland) increased dramatically over this period (it more than doubled). That is, these seven countries actually had a very low level of income per worker in 1970, as compared to other countries in the high-income sample in 1970. However, by 1995 income per worker was quite similar across all countries. The rapid growth in income per worker in the seven countries mentioned above is likely responsible for the finding of heteroskedasticity in high-income countries and in any sample that includes the high-income countries. To deal with heteroskedasticity, I report White's heteroskedasticity-consistent standard errors for the high-income subsample, the low- and high-income subsample, the middle- and high-income subsample and the full sample.

The specification error tests in Table 2 show that except in the high-income group, the low- and middle-income group, and the low- and high- income group, there are no specification errors in any of the samples at the 5 % level of significance.

However, the RESET (4) test statistic is significant only at the 10% level of significance for the low- and middle-income sample.

In the low-income, middle-income, high-income and middle- and high-income samples the coefficient on the initial level of income per worker is negative and statistically significant at $\alpha=5\%$. On the other hand, in the low- and high-income sample the coefficient on the initial level of income per worker is positive and statistically significant and in the low- and middle-income subsample and the full sample the coefficient on the initial level of income per worker is statistically insignificant: that is, there is no tendency for poor countries to grow faster on average than rich countries in these combined groups' case. Surprisingly, the coefficient is negative and statistically significant when middle- and high-income countries are pooled, which means that absolute convergence can be found even in some combined groups' case. The adjusted R^2 is very low or essentially zero for all samples except high-income countries (0.2628).

MRW (1992) obtain similar results for the adjusted R^2 and the sign of the slope coefficient. They show that a significantly negative relation between initial income per worker and the subsequent growth rate is found in their OECD sample, which is almost the same as the sample of high-income countries I use in this paper. Also, the adjusted R^2 is relatively high in the OECD sample (0.46). The above results are also almost consistent with the findings of Barro and Sala-i-Martin (1992), who indicated that there is strong evidence of absolute convergence in homogenous groups such as the states of the U.S., but no absolute convergence occurs in diverse samples such as a sample of 98 countries.

In the low-income, middle-income, high-income, and middle- and high-income samples the respective implied values of the rate of convergence parameter λ are 0.0164, 0.021, 0.031 and 0.0064 respectively, and all are statistically significant at the 5 percent level. It is difficult to compare these results with those MRW (1992) since only one of their samples, the OECD sample, is similar to any of mine. I compare the implied λ for my high-income sample with their value of λ for OECD countries. MRW (1992) get a value of 0.015887, which is smaller than my estimate of 0.031. To explain this result, I rely on Dalgaard's (2003) economic argument and Islam's (1996) statistical argument. Dalgaard (2003) explains that due to the mean-reversing nature of the business cycle, decreasing the period length could result in making the rate of convergence faster. Islam (1996) illustrates this fact using the formula: $\lambda = (1/\tau) \ln(\gamma)$, where γ is the estimated coefficient of initial income per worker and $\tau = t_2 - t_1$. Since $t_2 - t_1$ is usually larger for the cross-section approach than for the panel-data approach, the estimated convergence rate obtained using panel data must be larger. Although MRW examine a different time period (from 1960 to 1985), my faster convergence rate seems to be very reasonable in these senses.

Next, I examine conditional convergence. Table 3 presents the estimation results. In this table I add my measures of the rates of investment and population growth to the right-hand side of the regression.

[Insert Table 3 about here]

The test for normality indicates that the error terms are normally distributed only in the three relatively homogenous groups. Although I find non-normality of errors in

each heterogeneous group I still use F-tests to test joint hypotheses since the F-test is the most conservative test method.

As in Table 2, in Table 3 I find heteroskedasticity in the high-income sample, the low- and high-income sample, the middle-and high-income sample and the full sample at the 5 percent level of significance. As noted earlier, this heteroskedasticity can be explained by the fact that the variation in income per worker over the period (1970-1995) in some countries in the high-income group is much larger than in other countries in the same group. I also use White's heteroscedasticity-consistent standard errors to correct for heteroskedasticity in the high-income sample, the low- and high-income sample, the middle-and high-income sample and the full sample.

The RESET test shows that after adding variables specification errors seem to be corrected in the low- and high-income sample at the 5 and 10 percent levels of significance. However, in the low- and middle-income sample and the full sample, the log of the savings rate and $\ln(n+g+\delta)$ seem to introduce a specification error that was not previously there.

In all seven samples the coefficient on the initial level of income per worker is now significantly negative, which means that there is strong evidence of convergence in conditional terms after controlling for those variables which according to the Solow model determine the steady state. This result is consistent with those of Barro (1991), Barro and Sala-i-Martin (1992) and MRW (1992), who show that if they include additional variables, then the partial relation between the growth rate and the log of initial income per worker becomes more negative in homogenous groups and becomes negative in heterogeneous groups. Also, the inclusion of the rate of investment (or the savings

rate) and the rate of population growth improves substantially the fit of regression in all seven groups, which is also observed by MRW (1992). The convergence rate also increases in all samples except high-income countries, whose convergence rate slightly decreases. Overall, the impact of the additional variables on the convergence rate is greatest for low- and high-income countries (0.0267 in table 3 vs. -0.00325 in table 2), the most heterogeneous group. The impact is the largest for the full sample (0.026 in table 3 vs. -0.000784 in table 2), which is the second heterogeneous group, and least important for the high-income countries. This result is also similar to those of Barro and Sala-i-Martin (1992) and MRW (1992). Barro and Sala-i-Martin (1992) explain this result by pointing out that, first, additional variables help to hold constant cross-sectional differences in the long-run values, and, second, the ranking of the extent of these differences goes from the most heterogeneous group to most homogenous group.

The coefficient of the savings rate is significantly positive in all samples at the 5% level of significance except in middle-income countries, which is similar to most empirical results (i.e., MRW 1992 and Islam 1996). The sign of the coefficient of $\ln(n+g+\delta)$ in low-and middle income countries and middle-and high-income countries is negative and statistically significant at the 5% level of significance, but the sign of $\ln(n+g+\delta)$ is not statistically significant in the remaining samples. An F-test of the null hypothesis that the coefficient of $\ln s_k$ and $\ln(n+g+\delta)$ sum to zero shows that except in low-income and high-income countries it can be rejected at the 5% level of significance. The p-value of the implied λ shows that in all cases it is significantly different from zero at $\alpha=5\%$. The F-test for the null hypothesis that the coefficients of $\ln s_k$ and $\ln(n+g+\delta)$ are jointly zero indicates that this hypothesis can be rejected in all samples at $\alpha=5\%$.

The above results are almost consistent with the findings of Barro and Sala-i-Martin (1992) and MRW (1992), who indicate that there is strong evidence of absolute convergence in homogenous groups such as the states of the U.S. or the OECD, but that in diverse samples, convergence occurs only after including other explanatory variables in the model (see also Barro 1991, and Islam 1996).

B. The Effect of Educational and Health Capital

Now I examine the impact of health status on economic growth using the LSDV method. I begin by estimating equation (22) under the assumption that each country has a different country effect leading to a different intercept term. I examine the case of low-income countries (17 countries with 6 time points), middle-income countries (27 countries with 6 time points), high-income countries (23 countries with 6 time points) and the full sample (67 countries with 6 time points). The results are reported in Table 4.

[Insert Table 4 about here]

The test for normality indicates that the error terms are normally distributed in the low-income and high-income groups, but not in the other groups. Using either heteroskedasticity test, at the 5% level of significance one cannot reject the null hypothesis of homoskedasticity for low income countries and high-income countries, but one can reject it for middle-income countries and the full sample. In the case of middle-income countries, heteroskedasticity appears after adding human capital and the dummy variables, but the reverse happens in the case of the high-income countries. Given these results in Table 4, I use White's heteroskedasticity-consistent covariance matrix for the middle-income and full samples.

I check the RESET test statistics to see whether there are specification errors in each sample. No specification errors are found in the low-income sample. For high-income countries two out of three RESET tests imply no specification errors at the 5% level of significance. On the other hand, the results show that there may be specification errors in the middle-income and full samples. However, when I consider another test of specification errors, the FRESETS test, generally the results suggest no specification errors at the 5 and 10 percent level of significance, so overall this version of the model seems to suffer less from specification error.¹¹ Also, it is interesting that although the specification of the estimating equation changes, there never seem to be specification errors in the low-income sample.

Now I discuss the coefficient estimates and their implications. In all cases the coefficient of initial income per worker is statistically significant at the 5 percent level. The coefficient of the savings rate in all samples is significantly positive at the 5 percent level of significance, a result which is found in most empirical studies (i.e., Barro and Lee 1994; Knowles and Owen 1995; Caselli, Esquivel, and Lefort 1996; McDonald and Roberts 2002; Webber 2002). The coefficient of $\ln(n+g+\delta)$ in all samples is insignificantly negative or positive; these results are not consistent with most empirical studies.

Next, I examine the coefficient of educational capital in all samples. The coefficient of average years of schooling in the low-income group has a negative sign and is statistically significant at the 5 percent level. This result is slightly different from that

¹¹ 0.0511 (0.95), 0.1137 (0.97), 0.1871(0.98) in low-income sample, 2.3769 (0.097), 2.177 (0.295), 1.485 (0.437) in middle-income sample, 2.429 (0.093), 1.2495 (0.295), 0.9891 (0.437) in high-income sample and 0.2877 (0.75), 0.9235 (0.451), 0.9622 (0.451) in full sample (P-values are in parentheses). SHAZAM computes three versions of the FRESETS test proposed by DeBenedictis and Giles (1998). They find their tests to be at least as powerful as the RESET test in most cases examined.

of McDonald and Roberts (2002). Although their estimate of the coefficient of schooling is negative, it is insignificant. This unexpected result can be interpreted as implying that the quality and quantity of schooling in low-income countries is so low that it does not contribute to growth at all. Put another way, in low-income countries, the quality of education must be very low and the change in their average school years over the period is within the elementary school level. Thus, schooling in low-income countries does not have any positive impact on economic growth. In middle-income countries, average years of schooling has a positive but not statistically significant effect, which is consistent with the results of Islam (1996) and McDonald and Roberts (2002), but not with the results of Knowles and Owen (1995, 1997) who find that it is positive and significant.¹² Barro and Lee (2001) attempt to construct a measure of educational capital that takes quality into account by pointing out that the quality of education would be reflected in the performance of students and graduates rather than the quantity of education. However, their data series are not long enough to be used in panel data estimation, so economists using this approach still use educational attainment.

In the case of high-income countries, the impact of schooling is positive and statistically significant at the 5 percent level, a result which is consistent with McDonald and Roberts (2002). This result may suggest that increasing the quantity of educational capital up to the level found in high-income countries would contribute to economic growth. In the full sample, the coefficient of educational capital is slightly negative but insignificant. This result is consistent with most other empirical studies (Barro 1996;

¹² Their list of middle-income countries also includes low-income countries.

Knowles and Owen 1997; Bloom, Canning and Sevilla 2001; McDonald and Roberts 2002).

Finally, I examine the impact of life expectancy on economic growth. In the case of low-income countries the contribution of health status is positive (0.13852) but not statistically significant, which is similar to the results of McDonald and Roberts (2002), but different from the results of Knowles and Owen (1995). The latter authors found that the impact of health capital on growth is significantly positive. In middle-income countries the coefficient of health is negative but statistically insignificant, a result which differs from those of Knowles and Owen (1997) and McDonald and Roberts (2002), both of whom use a sample similar to mine which consists of a combination of poor and intermediate income countries and whose results are significantly positive. In high income countries the coefficient of life expectancy is positive and statistically significant (0.0389) at the 5% level. However, this result differs from those of previous studies such as Knowles and Owen (1995) who obtain insignificant estimate of 0.012, and McDonald and Roberts (2002) who get insignificant estimate of -0.06 in the OECD sample. The results for the full sample – a coefficient of 0.048 – are positive and significant, consistent with most empirical studies (Barro and Lee 1994; Knowles and Owen 1995; Barro 1996; Knowles and Owen 1997; Bloom and Sachs 1998; Bloom, Canning and Sevilla 2001; Bhargava, Jamison, Lau and Murray 2001; McDonald and Roberts 2002).

One interpretation of these inconsistent results is that although life expectancy is an appropriate indicator of health capital, because life expectancy estimates are based on the overall length of life computed from mortality data they do not take into account the quality of life. People do not live all those years in perfect health. At some point in their

lives, most people have some level of disability or illness. WHO (2000), a press release about health-adjusted life expectancy, finds that the lowest levels of health-adjusted life expectancy were found in Africa, where the HIV-AIDS epidemic is rampant. The countries at the bottom of the list were Sierra Leona, with 25.9 years of healthy life for babies born in 1999; Niger, with 29.1 years; Malawi, with 29.4 years; Zambia, with 30.3 years; Botswana, with 32.3 years; Uganda, with 32.7 years; Rwanda, with 32.8 years; Zimbabwe, with 32.9 years; Mali, with 33.1 years; and Ethiopia, with 33.5 years. These values are much lower than those of life expectancy for the countries included in my low-income sample. Thus, there must be a discrepancy between life expectancy, which I use, and the ideal measure of health capital, health-adjusted life expectancy. From this reason, especially in low-income countries, there is a possibility of obtaining unexpected results.

In table 4, I present several different F-tests. An F-test for the null hypothesis that the coefficients of $\ln s_k$ and $\ln (n+g+\delta)$ sum to zero shows that the log of the savings rate and the log of $(n+g+\delta)$ have similar magnitude and opposite sign in all samples, as equation (21) implies. The F-test of overall significance shows that the dependent variable (the growth rate) is linearly related to all explanatory variables in all samples.

Table 4 also shows the means, maximum values, and minimum values of the estimated coefficient of country-specific shift terms. The panel data approach with country-specific effects that I use in my paper allows each country to have a different production function. The maximum values of the country-specific effect are approximately 12%, 23%, 17% and 30% larger than minimum values of those in each sample. In the full sample (the most diverse sample) the difference between maximum and minimum is much larger than those in other samples. Thus, this result suggests that

we should allow each country to have different production function as the panel data approach does. An F-test to determine whether the coefficients of all the dummy variables are the same indicates that, in all samples, they are not. This result also implies that each country has a different intercept term, which means that at least one country must have a different country-specific effect. The estimated coefficient of every country-specific shift term is positive and statistically significant at the 5% level (the range of p-values is from 0.0000 to 0.0002).

My results on the determinants on growth such as health capital are consistent with those found in most empirical studies; that is, health capital generally does contribute to economic growth. However, my conclusions in the case of middle-income and high-income countries are not consistent with other studies. In the case of middle-income countries I can explain this difference by pointing out that the actual data I use differs in terms of countries and periods (number of observation) from other data sets, so that different results are possible. Also, my sample includes three countries (South Korea, Israel and Singapore) which displayed dramatic increases in life expectancy at birth over the period 1970-1995; most previous studies do not include these three countries in their OECD group. Furthermore, I examine a different time period, so different results might be possible in comparison with other studies (most previous studies use almost the same sample and time periods as MRW (1992)). However, for the full sample, my results are consistent with other previous studies.

Although the augmented Solow model seems to explain the determinants of economic growth very well in the case of the high-income group, it does not seem to explain them as well in the case of low-income countries and middle-income countries.

This argument can be supported by looking at the adjusted R^2 and tests for specification errors in homogenous groups in Tables 2, 3 and 4. In Table 2, the adjusted R^2 in high-income countries is relatively higher than those in low-income and middle-income countries, although there are serious specification errors in high-income countries, but not in low-income and middle-income countries. In Table 3, the adjusted R^2 increases in all three homogenous groups. Again it is highest in high-income countries even though there are still specification errors in the high-income sample, but not in the other two homogenous groups. In Table 4, however, according to the RESET (4) test specification errors disappear in the high-income sample but appear for the first time in the middle-income sample after adding educational and health capital to the Solow model. Also, the adjusted R^2 increases dramatically for high-income countries. In all three tables, the adjusted R^2 for high-income countries is much larger than those for the other groups. The substantially larger adjusted R^2 for high-income countries and the disappearance of specification errors after the addition of human capital leads to the conclusion that the augmented Solow model gives a very good explanation of economic growth in high-income countries, but not in developing countries.

6. Conclusion

In this paper I used OLS to study convergence and the determinants of growth. The analysis was carried out using several variants of an augmented Solow model that included explanatory variables measuring the inputs of physical, educational and health capital. Education was measured by average years of schooling and health was measured by life expectancy at birth. The results show that there is strong evidence of absolute convergence in all homogeneous samples, and conditional convergence in heterogeneous samples. These results are consistent with most previous convergence studies. Furthermore, health capital has a positive and significant impact on economic growth in high-income countries and the full sample.

However, using life expectancy as a proxy for health status may not provide an appropriate test of the model because life expectancy is not the best measure of health status. Even though there are several possible alternatives (such as Health-Adjusted Life Expectancy) it is hard to get enough data on them to run a panel data regression, which provides a better and more natural setting to control for the country-specific (technology) effect in comparison to the cross-section data approach. In addition, growth theory does not seem to explain why there is no impact of human capital on economic growth in developing countries, and this fact can lead to the possibility that there may be another variable such as social infrastructure and political stability that we have to consider in explaining economic growth. Also, to get a more precise result I could use different types of econometric techniques such as GMM. Future work should focus on finding variables which are able to provide a better explanation of economic growth in developing countries.

References

- Amemiya, Takeshi (1967) "A Note on the Estimation of Balestra- Nerlove Models," Technical Report No. 4, Institute for Mathematical Studies in Social Sciences, Stanford University.
- Anand, Sudhir, and Martin Ravallion (1993) "Human Development in Poor Countries: On the Role of Private Incomes and Public Services," *Journal of Economic Perspectives*, Vol. 7, No. 1, 133-150.
- Banks Arthur S. (1979) "Cross-National Time-Series Data Archive," Center for Social Analysis, State University of New York at Binghamton.
- Barro, Robert J. (1991) "Economic Growth in a Cross Section of Countries," *Quarterly journal of Economics*, Vol. 106, No. 2, 407-443.
- ____ (1996) "Determinants of Economic Growth: a Cross- Country Empirical Study," NBER Working Paper 5698.
- Barro, Robert J., and Lee, Jong-Wha (1993) "International Comparisons of Educational Attainment," *Journal of Monetary Economics*, 32, 363-394.
- ____ (1994) "Sources of Economic Growth," *Carnegie-Rochester Conference Series on Public Policy* 40, 1-46.
- ____ (2000) "International Data on Educational Attainment: Updates and Implication," Centre for International Development at Harvard University (CID) working paper No. 42.
- ____ (2001) "Schooling Quality in a Cross- Section of Countries," *Economica*, Vol. 68, No. 272, 465-488.
- Barro, Robert J., and Xavier Sala-i-Martin (1992) "Convergence," *Journal of Political Economy*, Vol. 100, No. 2, 223-51.
- Beck, Nathaniel, and Jonathan N. Katz (1995) "What to do (and not do) with Times-Series Cross-Section Data," *American Political Science Review* 89(3):634-647.
- Bhargava, Alok, Dean T. Jamison, Lawrence J. Lau and Christopher J. L. Murray (2001) "Modelling the Effects of Health on Economic Growth," *Journal of Health Economics* 20, 423-440.
- Bloom, David E., Canning, David. Canning and Jaypee Sevilla (2001) "The Effect of Health on Economic Growth: Theory and Evidence," NBER Working Paper No.

8587.

- Bloom, David E. and Sachs, Jeffrey D. (1998) "Geography, Demography, and Economic Growth in Africa," *Brooking Papers on Economic Activity* 2, 1-67.
- Caselli, F., Esquivel, G. and Lefort, F. (1996) "Reopening the Convergence Debate: a New Look at Cross-country Growth Empirics," *Journal of Economic Growth*, Vol.1, 369-389.
- Cass, David (1965) "Optimum Growth in an Aggregate Model of Capital Accumulation," *Review of Economic Studies*, Vol. 32, No. 3, 230- 40.
- Dalgaard, Carl-Johan (2003) "The Augmented Solow Model Revisited," Institute of Economics, University of Copenhagen,
<http://www.econ.ku.dk/dalgaard/growth/handout/augmented.pdf>.
- DeBenedictis, L. F. and D. E. A. Giles (1998) "Diagnostic Testing in Econometrics: Fourier approximations," in A. Ullah and D. E. A. Giles (eds.), *Handbook of Applied Economic Statistics*, New York: Marcel Dekker, 383-417.
- Greene, William H. (2003) *Econometric Analysis*, Upper Saddle River, N.J.: Prentice Hall.
- Hamoudi, Amar A. and Sachs, Jeffrey D. (1999) "Economic Consequences of Health Status: A Review of the Evidence," CID Working Paper No. 30.
- Hanushek, Eric A. (1995) "Interpreting Recent Research on Schooling in Developing Countries," *World Bank Research Observer*, Vol. 10, No. 2, 227-246.
- Heston, A. and R. Summers (1988) "A new set of international comparisons of real Product and price levels for 130 countries, 1950-1985," *Review of Income and Wealth*, Vol. 34, No. 1, 1-25.
- _____ (1991) "The Penn World Table (Mark 5): an expanded set of international comparisons, 1950-1988," *Quarterly Journal of Economics*, Vol. 106, No. 2, 327-68.
- _____ (1994) "Penn World Tables version 5.6," available from the National Bureau of Economic Research, Cambridge MA, <http://pwt.econ.upenn.edu/>.
- Heston, A., R. Summers., and Bettina, Aten (2002) *Penn World Tables version 6.1*, Center for International Comparisons at the University of Pennsylvania (CICUP), <http://datacentre2.chass.utoronto.ca/pwt>.
- Islam, Nazrul (1995) "Growth Empirics: a Panel Data Approach," *Quarterly Journal of Economics*, Vol. 110, No. 4, 1127-1170.

- Knack, Stephen and Philip Keefer (1995) "Institutions and Economic Performance: Cross-Country Tests Using Alternative Institutional Measures," *Economics and Politics*, Vol. 7, No. 3, 207-227.
- Knowles, S. and Owen, P. D. (1995) "Health Capital and Cross-Country Variation in Income per Capita in the Mankiw- Romer- Weil Model," *Economics Letters* 48, 99- 106.
- _____ (1997) "Education and Health in an Effective-Labour Empirical Growth Model," *Economic Record*, Vol. 73, 314-328.
- Koenker, R. (1981) "A note on Studentizing a test for heteroscedasticity," *Journal of Econometrics*, Vol. 17, 107-112.
- Koopmans, T.C. (1965) "On the Concept of Optimal Economic Growth," Cowles Foundation Paper 238, Yale University, 225-230.
- Korean Institute for Health and Social Affairs,
http://healthguide.kihasa.re.kr/eng/sub_frame6.html.
- Lucas, R. E. (1988) "On the Mechanics of Development," *Journal of Monetary Economics* 22, 3-42.
- Maddala, G. S. (1971) "The Use of Variance Components Model in Pooling Cross-Section and Time Series Data," *Econometrica*, Vol. 39, No.2, 341-58.
- Mankiw, N. Gregory (1995) "The Growth of Nations," *Brookings Papers on Economic Activity*, Vol. 1, 275-310.
- Mankiw, N. G., Romer, D. and Weil, D. N. (1992) "A Contribution to the Empirics of Economic Growth," *Quarterly Journal of Economics*, Vol. 107, No. 2, 407-37.
- Mark Bilal, Mark and Klenow, Peter J. (2000) "Does Schooling Cause Growth?" *American Economic Review*, Vol. 90, No. 5, 1160- 1183.
- McDonald, S. and Roberts, J. (2002) "Growth and Multiple Forms of Human Capital in an Augmented Solow Model: A Panel Data Investigation," *Economics Letters*, Vol. 74 (2), 271-6.
- Murray, C. J. L., and A. D. Lopez (1997) "Regional Patterns of Disability-Free Life Expectancy and Disability Adjusted Life Expectancy: Global Burden of Disease Study," *Lancet* 349, 1347-52.
- Nehru, V., E. Swanson, and A. Dubey (1995) "A new database on human capital stock In developing and industrial countries: sources, methodology and results,"

Journal of Development Economics, Vol. 46, 379-401.

Nonneman, Walter, and Patrick Vanhoudt (1996) "A Further Augmentation of the Solow Model and the Empirics of Economic Growth for OECD Countries," *Quarterly Journal of Economics*, Vol. 111, No.3, 943-953.

PRS group (2004) *International Country Risk Guide*,
<http://www.prsgroup.com/icrg/icrg.html>.

Ramsey, Frank P. (1928) "A Mathematical Theory of Saving," *Economic Journal*, Vol. 38, No. 152, 543-559.

Rebelo, S. (1991) "Long Run Policy Analysis and Long Run Growth," *Journal of Political Economy*, Vol. 99, No.3, 500-521.

Romer, Paul (1986) "Increasing Returns and Long Run Growth," *Journal of Political Economy*, Vol. 94, No. 5, 1002-1037.

_____ (1989a) "Capital Accumulation in the Theory of Long-Run Growth," in *Modern Business Cycle Theory*, Robert J. Barro, ed. (Cambridge, MA: Harvard University Press).

_____ (1989b) "Human Capital and Growth: Theory and Evidence", NBER Working Paper No. 3173, Cambridge.

Schultz, T. Paul (1993) "Mortality Decline in the Low- Income World: Causes and Consequences," *American Economic Review*, Vol. 83, No. 2, 337-342.

Solow, Robert M. (1956) "A Contribution to the Theory of Economic Growth," *Quarterly Journal of Economics*, Vol. 70, No. 1, 65-94.

Statistics Canada (1997) *World Trade Analyzer*, Data on CD-ROM.

Strauss, John, and Duncan Thomas (1998) "Health, Nutrition, and Economic Development," *Journal of Economic Literature*, Vol. 36, No. 2, 766-817.

Temple, Jonathan R. W. (1998) "Robustness Tests of the Augmented Solow Model," *Journal of Applied Econometrics*, Vol. 13, No. 4, 361-375.

UNICEF, <http://www.unicef.org/infobycountry/index.html>.

United Nations (1996) *World Population Prospects 1950-2050 (The 1996 Revision)* New York: United Nations, Computer diskettes.

United Nations (1998) *Demographic Indicators 1950-2050*, New York.

United Nations Population Division, <http://esa.un.org/unpp/index.asp?panel=2>.

United Nations, *Demographic Yearbook*, New York, 1970-1998 years.

U.S. Census Bureau, <http://www.census.gov/ipc/wwwIDB/IDBidbprint.html>.

Webber, Don J. (2002) "Policies to Stimulate Growth: Should We Invest in Health or Education?" *Applied Economics*, Vol. 34, No. 13, 1633-1643.

World Bank classification site,
<http://www.worldbank.org/data/countryclass/classgroups.htm>.

World Bank Group,
<http://www.worldbank.org/depweb/english/modules/social/life/datanot.html>.

World Health Organization (2000), Press Releases 2000
<http://www.who.int/inf-pr-2000/en/pr2000-life.html>

APPENDIX1. The List of Countries and the Data Sources for Life Expectancy in each year

N O	COUNTRY	SAMPLE L I H	1970	1975	1980	1985	1990	1995
1	Benin	1	UNICEF	UN	IDB	IDB	IDB	IDB
2	Cameroon	1	UNICEF	IDB (1974-76)	IDB	IDB	IDB	IDB
3	Ghana	1	IDB	IDB	IDB	IDB	IDB	IDB
4	India	1	UNICEF	IDB	IDB	IDB	IDB	IDB
5	Kenya	1	UNICEF	IDB (1974)	IDB	IDB	IDB	IDB
6	Malawi	1	UNICEF	UNPD	IDB	IDB	IDB	IDB
7	Mali	1	UNICEF	UN (1976)	UNPD	UNPD	IDB	IDB
8	Mozambique	1	UNICEF	UNPD	IDB	IDB	IDB	IDB
9	Nepal	1	UNICEF	IDB	IDB	IDB	IDB	IDB
10	Nicaragua	1	IDB (1971)	IDB	IDB	IDB	IDB	IDB
11	Pakistan	1	UNICEF	IDB (1976)	IDB (1981)	IDB	IDB	IDB
12	Papua New Guinea	1	UNICEF	UNPD	IDB	IDB	IDB	IDB
13	Sierra Leone	1	UNICEF	IDB	IDB	IDB	IDB	IDB
14	Togo	1	UNICEF	UNPD	IDB (1981)	IDB	IDB	IDB
15	Uganda	1	IDB	IDB	IDB	IDB	IDB	IDB
16	Zambia	1	UNICEF	UNPD	IDB	IDB	IDB	IDB
17	Zimbabwe	1	UNICEF	UNPD	UNPD	IDB	IDB	IDB
18	Argentina	1	UNICEF	UN	IDB	IDB	IDB	IDB
19	Bolivia	1	IDB	IDB	IDB	IDB	IDB	IDB
20	Brazil	1	IDB	IDB	IDB	IDB	IDB	IDB
21	Chile	1	UNICEF	UN	TWBG	IDB	IDB	IDB
22	Costa Rica	1	UNICEF	UN	TWBG	IDB	IDB	IDB
23	Dominican, Rep	1	UNICEF	UN	IDB	IDB	IDB	IDB
24	Ecuador	1	UNICEF	UNDP	UNDP	UN	IDB	IDB
25	El Salvador	1	IDB (1970-72)	IDB	IDB	IDB	IDB	IDB
26	Fiji	1	UNICEF	IDB (1976)	UNDP	IDB	IDB	IDB
27	Guatemala	1	IDB	IDB	IDB	IDB	IDB	IDB
28	Guyana	1	UNICEF	UNDP	IDB	IDB	IDB	IDB
29	Jamaica	1	IDB	UNDP	UNDP	IDB	IDB	IDB
30	Jordan	1	UNICEF	UNDP	IDB	IDB	IDB	IDB
31	Malaysia	1	IDB	UN	IDB	IDB	IDB	IDB
32	Mauritius	1	UNICEF	UN	TWBG	IDB	IDB	IDB
33	Mexico	1	IDB	UN	IDB	IDB	IDB	IDB
34	Panama	1	UNICEF	IDB	IDB	IDB	IDB	IDB
35	Paraguay	1	UNICEF	IDB	IDB	IDB	IDB	IDB

36	Peru		1	UNICEF	UNDP	IDB (1981)	IDB	IDB	IDB
37	Philippines		1	IDB	UNDP	IDB	IDB	IDB	IDB
38	South Africa		1	UNICEF	UNDP	IDB	UNDP	IDB	IDB
39	Sri Lanka		1	UNICEF	UNDP	IDB (1981)	IDB	IDB	IDB
40	Syria		1	UNICEF	UN	IDB (1981)	IDB	IDB	IDB
41	Thailand		1	UNICEF	UN (1974-75)	UNDP	UN (1985-86)	IDB	IDB
42	Trinidad & Tobago		1	UNICEF	UN	IDB	IDB	IDB	IDB
43	Tunisia		1	UNICEF	UNPD	IDB (1981)	IDB	IDB	IDB
44	Uruguay		1	UNICEF	UN (1974-76)	TWBG	IDB	IDB	IDB
45	Australia		1	IDB (1970-72)	IDB (1975-77)	IDB	IDB	IDB	IDB
46	Austria		1	UNICEF	KIHASA	KIHASA	KIHASA	IDB	IDB
47	Belgium		1	UNICEF	KIHASA	KIHASA	KIHASA	IDB	IDB
48	Canada		1	UNICEF	UN (1975-77)	IDB (1980-82)	UN (1984-86)	IDB	IDB
49	Denmark		1	UNICEF	KIHASA	KIHASA	KIHASA	IDB	IDB
50	Finland		1	UNICEF	KIHASA	IDB	IDB	IDB	IDB
51	France		1	UNICEF	IDB	IDB	KIHASA	IDB	IDB
52	Greece		1	IDB	UNDP	IDB	UNDP	IDB	IDB
53	Ireland		1	UNICEF	UNDP	KIHASA	UN (1985-87)	IDB	IDB
54	Israel		1	UNICEF	UN	TWBG	IDB	IDB	IDB
55	Italy		1	UNICEF	IDB (1974-77)	KIHASA	KIHASA	KIHASA	IDB
56	Japan		1	UNICEF	KIHASA	IDB (1980-81)	IDB (1984-85)	IDB	IDB
57	Korea, Rep		1	UN	UN (1975-80)	TWBG	KIHASA	IDB	IDB
58	Netherlands		1	UNICEF	KIHASA	KIHASA	KIHASA	IDB	IDB
59	New Zealand		1	IDB (1970-72)	IDB	IDB	KIHASA	IDB	IDB
60	Norway		1	UNICEF	KIHASA	KIHASA	KIHASA	IDB	IDB
61	Portugal		1	IDB	IDB	IDB (1979-82)	KIHASA	KIHASA	IDB
62	Singapore		1	IDB	UNDP	IDB	UN	IDB	IDB
63	Spain		1	IDB	IDB	IDB	KIHASA	KIHASA	IDB
64	Sweden		1	UNICEF	KIHASA	IDB	IDB	IDB	IDB
65	Switzerland		1	UNICEF	KIHASA	IDB	IDB	IDB	IDB
66	United Kingdom		1	UNICEF	UN	KIHASA	KIHASA	KIHASA	IDB
67	United States		1	IDB	IDB	IDB	IDB	IDB	IDB

Notes: 1. In sample menu, L, I and H represent low-income country, intermediate (middle-income) country and high-income country respectively.

2. The name of countries is listed alphabetically in each group.

3. I calculate life expectancy at birth on both sexes by adding male to female and dividing it by 2 in case that there just exists life expectancy at birth on male and female.

4. I use a simple math skill to extrapolate the single year value in case of data from United Nations Population Division. For example, for obtaining 1985 data I add the 1980-85 data to the 1985-90 data and divide it by 2.

5. Unless otherwise indicated, life expectancy data are obtained from each source for the year indicated at the top of the column.

Data sources

1. IDB : IDB data of U.S census bureau site, <http://www.census.gov/ipc/www/idbprint.html>
2. UN : Demographic Yearbook of United Nations (1970-1998)
3. UNICEF : Information by country on UNICEF site, <http://www.unicef.org/infobycountry/index.html>
4. TWBG : Life Expectancy data from The World Bank Group, <http://www.worldbank.org/depweb/english/modules/social/life/datanot.html>
5. KIHASA : Health Guide on Korean Institute for Health and Social Affairs, http://healthguide.kihasa.re.kr/eng/sub_frame6.html
6. UNPD : United Nations Population Division, <http://esa.un.org/unpp/index.asp?panel=2>

Appendix 2.

From $s_s \hat{k}_t^\alpha \hat{s}_t^\beta \hat{h}_t^\gamma = (n + g + \delta) \hat{s}_t$, I obtain \hat{s}_t such that

$$\begin{aligned}\hat{s}_t^{\beta-1} &= \left(\frac{n + g + \delta}{s_s} \right) \hat{k}_t^{-\alpha} \hat{h}_t^{-\gamma} \\ \hat{s}_t &= \left(\frac{s_s}{n + g + \delta} \right)^{\frac{1}{1-\beta}} \hat{k}_t^{\frac{\alpha}{1-\beta}} \hat{h}_t^{\frac{\gamma}{1-\beta}} \quad \text{--- (1)}\end{aligned}$$

From $s_h \hat{k}_t^\alpha \hat{s}_t^\beta \hat{h}_t^\gamma = (n + g + \delta) \hat{h}_t$, I also obtain \hat{h}_t such that

$$\begin{aligned}\hat{h}_t^{\gamma-1} &= \left(\frac{n + g + \delta}{s_h} \right) \hat{k}_t^{-\alpha} \hat{s}_t^{-\beta} \\ \hat{h}_t &= \left(\frac{s_h}{n + g + \delta} \right)^{\frac{1}{1-\gamma}} \hat{k}_t^{\frac{\alpha}{1-\gamma}} \hat{s}_t^{\frac{\beta}{1-\gamma}} \quad \text{--- (2)}\end{aligned}$$

Now, I substitute (2) into (1) to remove \hat{h}_t term.

$$\begin{aligned}\hat{s}_t &= \left(\frac{s_s}{n + g + \delta} \right)^{\frac{1}{1-\beta}} \hat{k}_t^{\frac{\alpha}{1-\beta}} \left(\left(\frac{s_h}{n + g + \delta} \right)^{\frac{1}{1-\gamma}} \hat{k}_t^{\frac{\alpha}{1-\gamma}} \hat{s}_t^{\frac{\beta}{1-\gamma}} \right)^{\frac{\gamma}{1-\beta}} \\ &= \left(\frac{s_s}{n + g + \delta} \right)^{\frac{1}{1-\beta}} \hat{k}_t^{\frac{\alpha}{1-\beta}} \left(\frac{s_h}{n + g + \delta} \right)^{\frac{\gamma}{(1-\gamma)(1-\beta)}} \hat{k}_t^{\frac{\alpha\gamma}{(1-\gamma)(1-\beta)}} \hat{s}_t^{\frac{\beta\gamma}{(1-\gamma)(1-\beta)}}\end{aligned}$$

I rearrange this equation for \hat{s}_t

$$\begin{aligned}\hat{s}_t^{\frac{1-\beta-\gamma+\beta\gamma-\beta\gamma}{(1-\beta)(1-\gamma)}} &= \left(\frac{s_s}{n + g + \delta} \right)^{\frac{1}{1-\beta}} \hat{k}_t^{\frac{\alpha}{1-\beta}} \left(\frac{s_h}{n + g + \delta} \right)^{\frac{\gamma}{(1-\gamma)(1-\beta)}} \hat{k}_t^{\frac{\alpha\gamma}{(1-\gamma)(1-\beta)}} \\ \hat{s}_t^{\frac{1-\beta-\gamma}{(1-\beta)(1-\gamma)}} &= \left(\frac{s_s}{n + g + \delta} \right)^{\frac{1}{1-\beta}} \hat{k}_t^{\frac{\alpha}{1-\beta}} \left(\frac{s_h}{n + g + \delta} \right)^{\frac{\gamma}{(1-\gamma)(1-\beta)}} \hat{k}_t^{\frac{\alpha\gamma}{(1-\gamma)(1-\beta)}} \\ \hat{s}_t &= \left(\frac{s_s}{n + g + \delta} \right)^{\frac{1-\gamma}{1-\beta-\gamma}} \hat{k}_t^{\frac{\alpha(1-\gamma)}{1-\beta-\gamma}} \left(\frac{s_h}{n + g + \delta} \right)^{\frac{\gamma}{1-\beta-\gamma}} \hat{k}_t^{\frac{\alpha\gamma}{1-\beta-\gamma}} \quad \text{--- (3)}\end{aligned}$$

I also substitute (1) into (2) to remove \hat{s}_t term.

$$\hat{h}_t = \left(\frac{s_h}{n + g + \delta} \right)^{\frac{1}{1-\gamma}} \hat{k}_t^{\frac{\alpha}{1-\gamma}} \left(\left(\frac{s_s}{n + g + \delta} \right)^{\frac{1}{1-\beta}} \hat{k}_t^{\frac{\alpha}{1-\beta}} \hat{h}_t^{\frac{\gamma}{1-\beta}} \right)^{\frac{\beta}{1-\gamma}}$$

$$= \left(\frac{s_h}{n + g + \delta} \right)^{\frac{1}{1-\gamma}} \hat{k}_t^{\frac{\alpha}{1-\gamma}} \left(\frac{s_s}{n + g + \delta} \right)^{\frac{\beta}{(1-\beta)(1-\gamma)}} \hat{k}_t^{\frac{\alpha\beta}{(1-\beta)(1-\gamma)}} \hat{h}_t^{\frac{\gamma\beta}{(1-\beta)(1-\gamma)}}$$

Rearranging this equation into \hat{h}_t , then

$$\begin{aligned} \hat{h}_t^{\frac{1-\beta-\gamma+\beta\gamma-\beta\gamma}{(1-\beta)(1-\gamma)}} &= \left(\frac{s_h}{n + g + \delta} \right)^{\frac{1}{1-\gamma}} \hat{k}_t^{\frac{\alpha}{1-\gamma}} \left(\frac{s_s}{n + g + \delta} \right)^{\frac{\beta}{(1-\beta)(1-\gamma)}} \hat{k}_t^{\frac{\alpha\beta}{(1-\beta)(1-\gamma)}} \\ \hat{h}_t^{\frac{1-\beta-\gamma}{(1-\beta)(1-\gamma)}} &= \left(\frac{s_h}{n + g + \delta} \right)^{\frac{1}{1-\gamma}} \hat{k}_t^{\frac{\alpha}{1-\gamma}} \left(\frac{s_s}{n + g + \delta} \right)^{\frac{\beta}{(1-\beta)(1-\gamma)}} \hat{k}_t^{\frac{\alpha\beta}{(1-\beta)(1-\gamma)}} \\ \hat{h}_t &= \left(\frac{s_h}{n + g + \delta} \right)^{\frac{1-\beta-\gamma}{1-\beta-\gamma}} \hat{k}_t^{\frac{\alpha(1-\beta)}{1-\beta-\gamma}} \left(\frac{s_s}{n + g + \delta} \right)^{\frac{\beta}{1-\beta-\gamma}} \hat{k}_t^{\frac{\alpha\beta}{1-\beta-\gamma}} \quad \text{--- (4)} \end{aligned}$$

Now, I substitute equation (3) and (4) into $s_k \hat{k}_t^\alpha \hat{s}_t^\beta \hat{h}_t^\gamma - (n + g + \delta) \hat{k}_t$. That is,

$s_k \hat{k}_t^\alpha$ (equation (3)) ^{β} (equation (4)) ^{γ} = $(n + g + \delta) \hat{k}_t$. Thus,

$$\begin{aligned} s_k \hat{k}_t^\alpha &\left(\left(\frac{s_s}{n + g + \delta} \right)^{\frac{1-\gamma}{1-\beta-\gamma}} \hat{k}_t^{\frac{\alpha(1-\gamma)}{1-\beta-\gamma}} \left(\frac{s_h}{n + g + \delta} \right)^{\frac{\gamma}{1-\beta-\gamma}} \hat{k}_t^{\frac{\alpha\gamma}{1-\beta-\gamma}} \right)^\beta \\ &\left(\left(\frac{s_h}{n + g + \delta} \right)^{\frac{1-\beta}{1-\beta-\gamma}} \hat{k}_t^{\frac{\alpha(1-\beta)}{1-\beta-\gamma}} \left(\frac{s_s}{n + g + \delta} \right)^{\frac{\beta}{1-\beta-\gamma}} \hat{k}_t^{\frac{\alpha\beta}{1-\beta-\gamma}} \right)^\gamma = (n + g + \delta) \hat{k}_t \end{aligned}$$

$$\begin{aligned} s_k \hat{k}_t^\alpha &\left(\frac{s_s}{n + g + \delta} \right)^{\frac{\beta(1-\gamma)}{1-\beta-\gamma}} \hat{k}_t^{\frac{\alpha\beta(1-\gamma)}{1-\beta-\gamma}} \left(\frac{s_h}{n + g + \delta} \right)^{\frac{\beta\gamma}{1-\beta-\gamma}} \\ \hat{k}_t^{\frac{\alpha\beta\gamma}{1-\beta-\gamma}} &\left(\frac{s_h}{n + g + \delta} \right)^{\frac{\gamma(1-\beta)}{1-\beta-\gamma}} \hat{k}_t^{\frac{\alpha\gamma(1-\beta)}{1-\beta-\gamma}} \left(\frac{s_s}{n + g + \delta} \right)^{\frac{\beta\gamma}{1-\beta-\gamma}} \hat{k}_t^{\frac{\alpha\beta\gamma}{1-\beta-\gamma}} = (n + g + \delta) \hat{k}_t \end{aligned}$$

Rearranging this equation for \hat{k}_t yields,

$$s_k \hat{k}_t^{\alpha + \frac{\alpha\beta(1-\gamma)}{1-\beta-\gamma} + \frac{\alpha\beta\gamma}{1-\beta-\gamma} + \frac{\alpha\gamma(1-\beta)}{1-\beta-\gamma} + \frac{\alpha\beta\gamma}{1-\beta-\gamma} - 1} \left(\frac{s_s}{n + g + \delta} \right)^{\frac{\beta-\beta\gamma+\beta\gamma}{1-\beta-\gamma}}$$

$$\left(\frac{s_h}{n + g + \delta} \right)^{\frac{\beta\gamma+\gamma-\beta\gamma}{1-\beta-\gamma}} = (n + g + \delta)$$

$$s_k \hat{k}_t^{\frac{\alpha-\alpha\beta-\alpha\gamma+\alpha\beta-\alpha\beta\gamma+\alpha\beta\gamma+\alpha\gamma-\alpha\beta\gamma+\alpha\beta\gamma-1+\beta+\gamma}{1-\beta-\gamma}} \left(\frac{s_s}{n + g + \delta} \right)^{\frac{\beta}{1-\beta-\gamma}}$$

$$\left(\frac{s_h}{n + g + \delta} \right)^{\frac{\gamma}{1-\beta-\gamma}} = (n + g + \delta)$$

$$s_k \hat{k}_t^{\frac{\alpha+\beta+\gamma-1}{1-\beta-\gamma}} \left(\frac{s_s}{n+g+\delta} \right)^{\frac{\beta}{1-\beta-\gamma}} \left(\frac{s_h}{n+g+\delta} \right)^{\frac{\gamma}{1-\beta-\gamma}} =$$

$$(n+g+\delta)$$

$$\hat{k}_t^{\frac{\alpha+\beta+\gamma-1}{1-\beta-\gamma}} = \left(\frac{s_k}{n+g+\delta} \right)^{-1} \left(\frac{s_s}{n+g+\delta} \right)^{-\frac{\beta}{1-\beta-\gamma}} \left(\frac{s_h}{n+g+\delta} \right)^{-\frac{\gamma}{1-\beta-\gamma}}$$

Therefore, I finally get this,

$$\hat{k}_t^* = \left(\frac{s_k}{n+g+\delta} \right)^{-\left(\frac{1-\beta-\gamma}{\alpha+\beta+\gamma-1}\right)} \left(\frac{s_s}{n+g+\delta} \right)^{\left(\frac{1-\beta-\gamma}{\alpha+\beta+\gamma-1}\right) \left(\frac{-\beta}{1-\beta-\gamma}\right)}$$

$$\left(\frac{s_h}{n+g+\delta} \right)^{\left(\frac{1-\beta-\gamma}{\alpha+\beta+\gamma-1}\right) \left(\frac{-\gamma}{1-\beta-\gamma}\right)}$$

$$= \left(\frac{s_k}{n+g+\delta} \right)^{\left(\frac{1-\beta-\gamma}{1-\alpha-\beta-\gamma}\right)} \left(\frac{s_s}{n+g+\delta} \right)^{\left(\frac{\beta}{1-\alpha-\beta-\gamma}\right)}$$

$$\left(\frac{s_h}{n+g+\delta} \right)^{\left(\frac{\gamma}{1-\alpha-\beta-\gamma}\right)}$$

Which is the same as $\hat{k}^* = \left(\frac{s_k^{1-\beta-\gamma} s_s^\beta s_h^\gamma}{n+g+\delta} \right)^{\frac{1}{1-\alpha-\beta-\gamma}}$. \hat{s}^* and \hat{h}^* also can be obtained by same procedure I have done.

Table 1. Descriptive statistics, 1970-1995

	N	MEAN	ST.DEV	MIN	MAX
Low-Income: 17 countries					
Income per Worker	102	3663.1	2380	942	14434
Average Saving Rate	102	0.10341	0.076758	0.011	0.421
n+g+ δ	102	0.076956	0.00701	0.0513	0.103
Average Years of Schooling	102	2.3468	1.2113	0.2	5.42
Life expectancy	102	48.889	7.1075	27.92	67.09
Middle-income: 27 countries					
Income per Worker	162	13672	5553.8	3710.0	29120
Average Saving Rate	162	5.1733	7.6149	0.052	28.600
n+g+ δ	162	2.5877	3.3204	0.0439	8.1900
Average Years of Schooling	162	5.1543	1.4526	1.4800	8.4600
Life expectancy	162	65.121	6.0276	45.100	76.400
High-Income: 23 countries					
Income per Worker	138	34679	9032.6	7595.0	56065
Average Saving Rate	138	25.334	6.3773	15.900	49.700
n+g+ δ	138	5.8283	0.68419	4.2800	8.4000
Average Years of Schooling	138	8.2496	1.9860	2.6000	11.890
Life expectancy	138	74.239	2.9198	60.000	79.530
Full sample: 67 countries					
Income per Worker	402	17088	13902	942.00	56065
Average Saving Rate	402	9.1950	12.127	0.011	49.700
n+g+ δ	402	2.5916	3.0192	0.0439	8.4000
Average Years of Schooling	402	5.2757	2.7951	0.20000	11.890
Life expectancy	402	64.132	11.175	27.920	79.530

Figure 1.

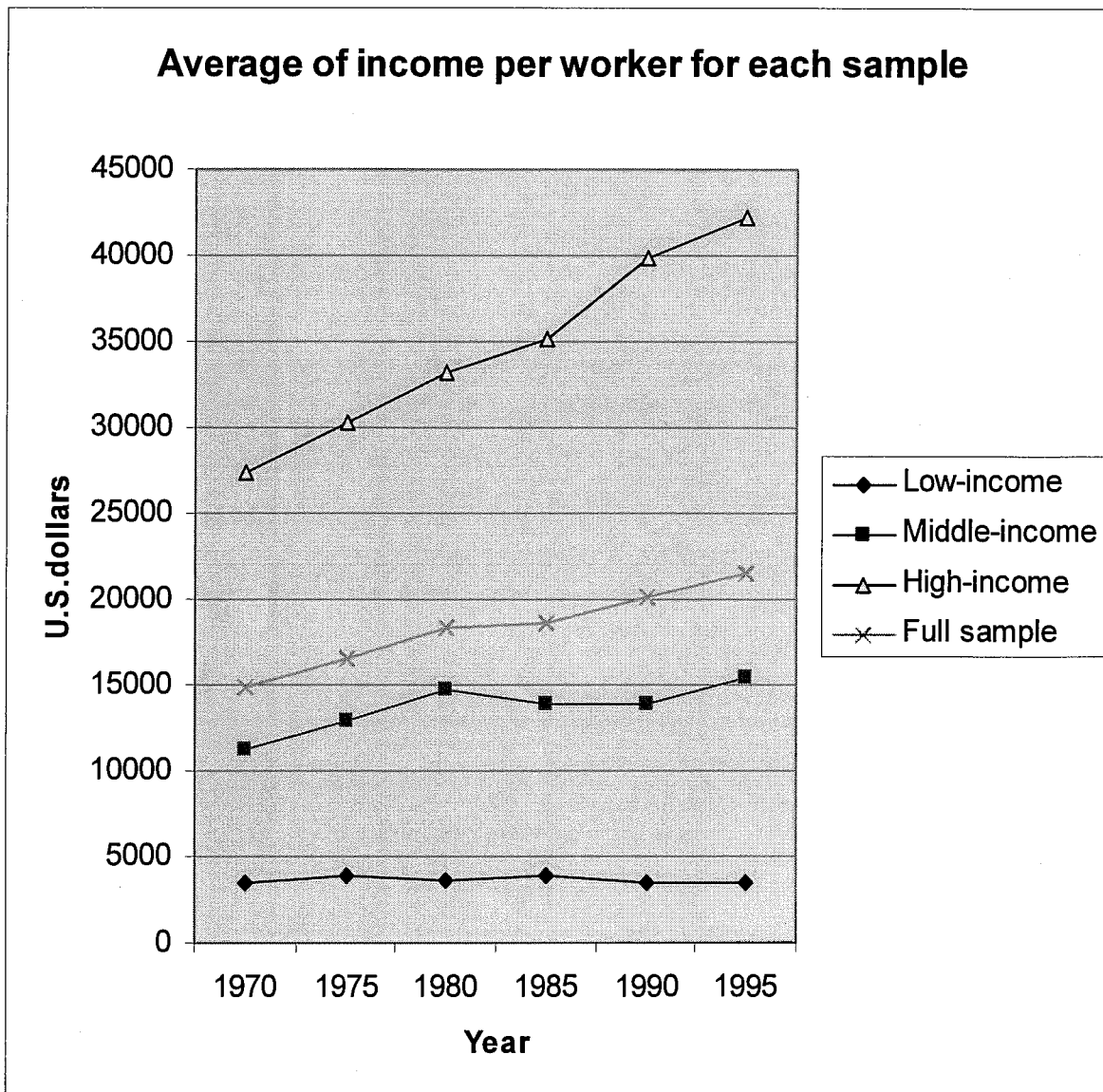


Figure 2.

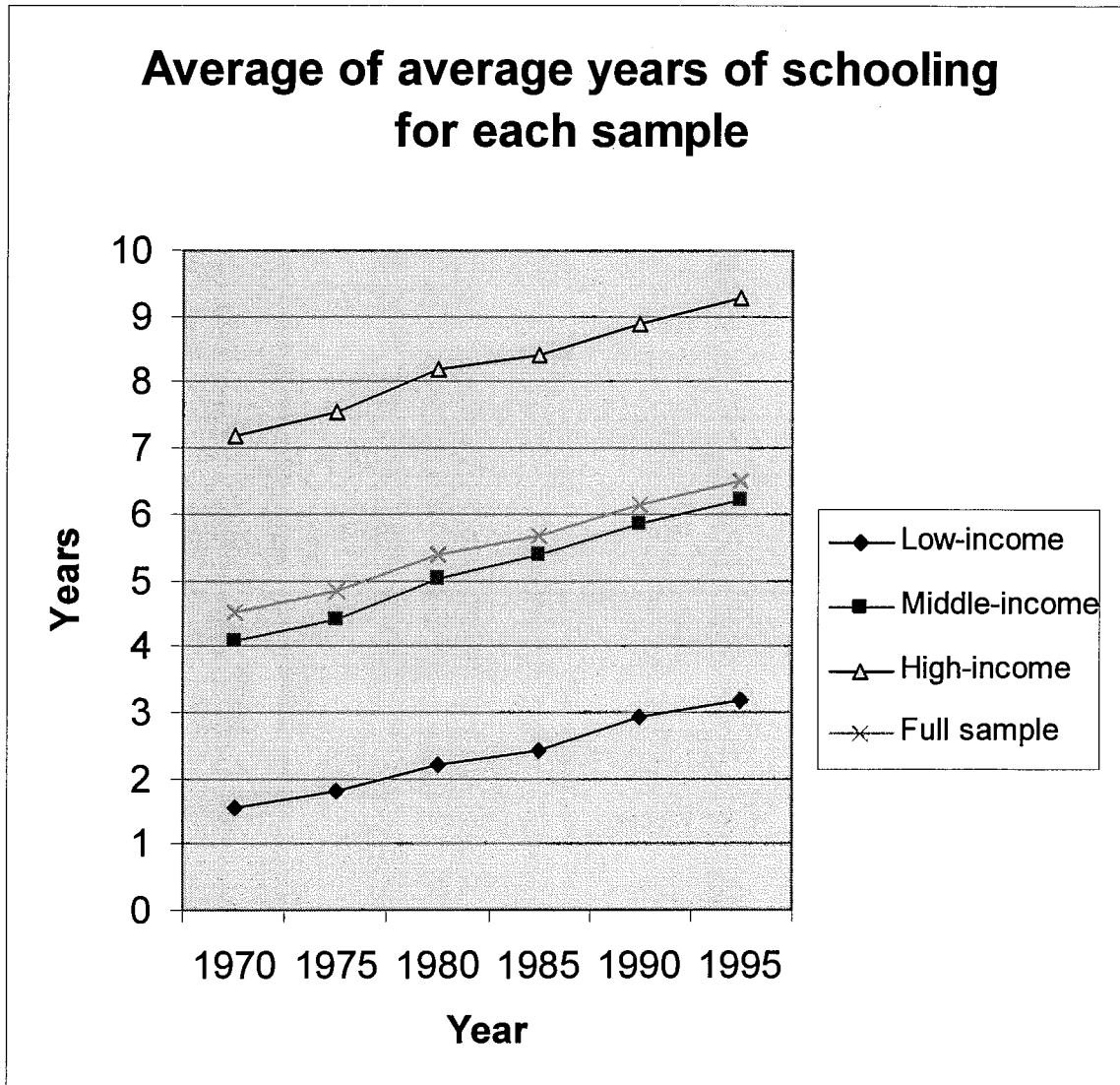


Figure 3.

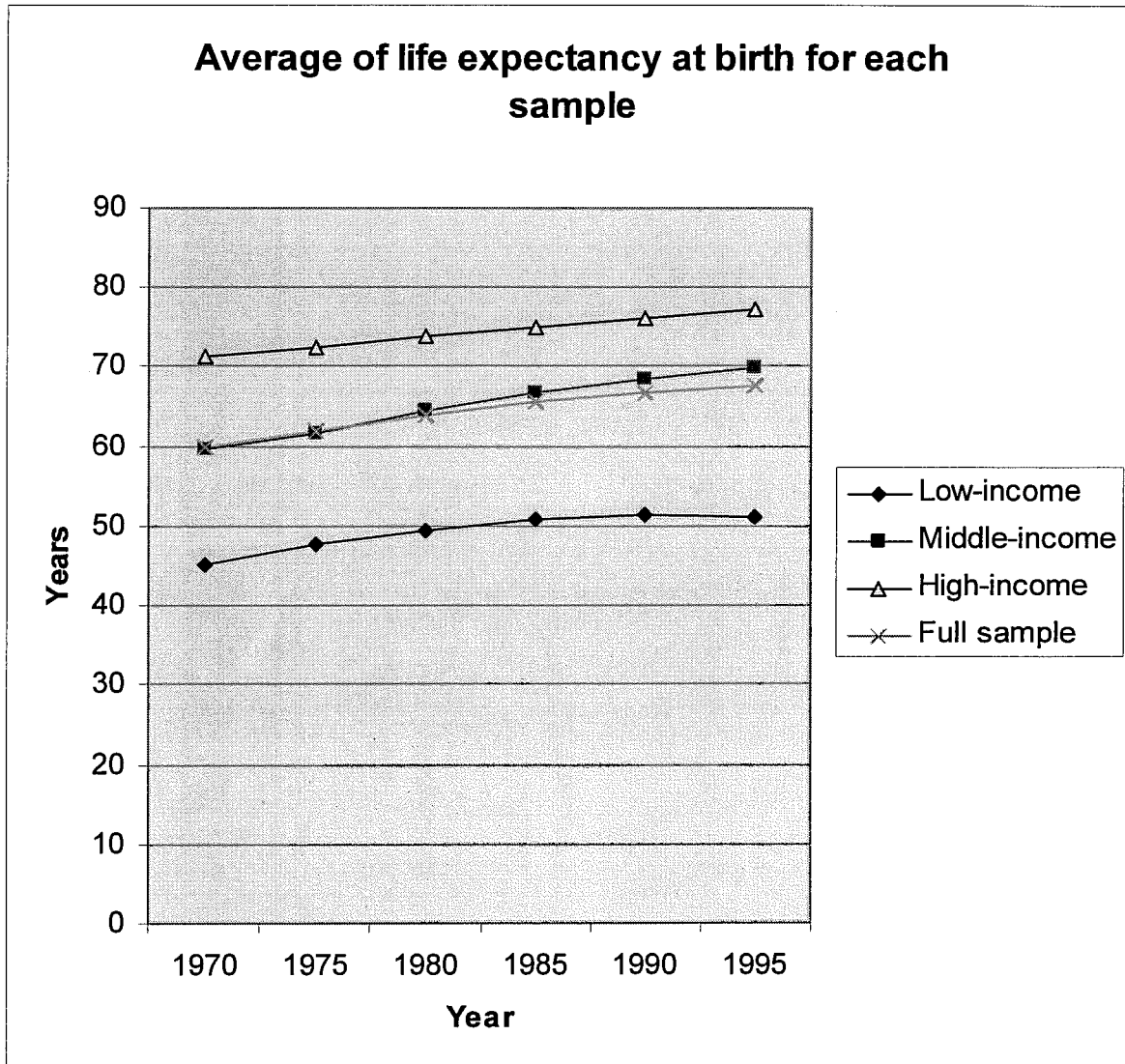


Figure 4.

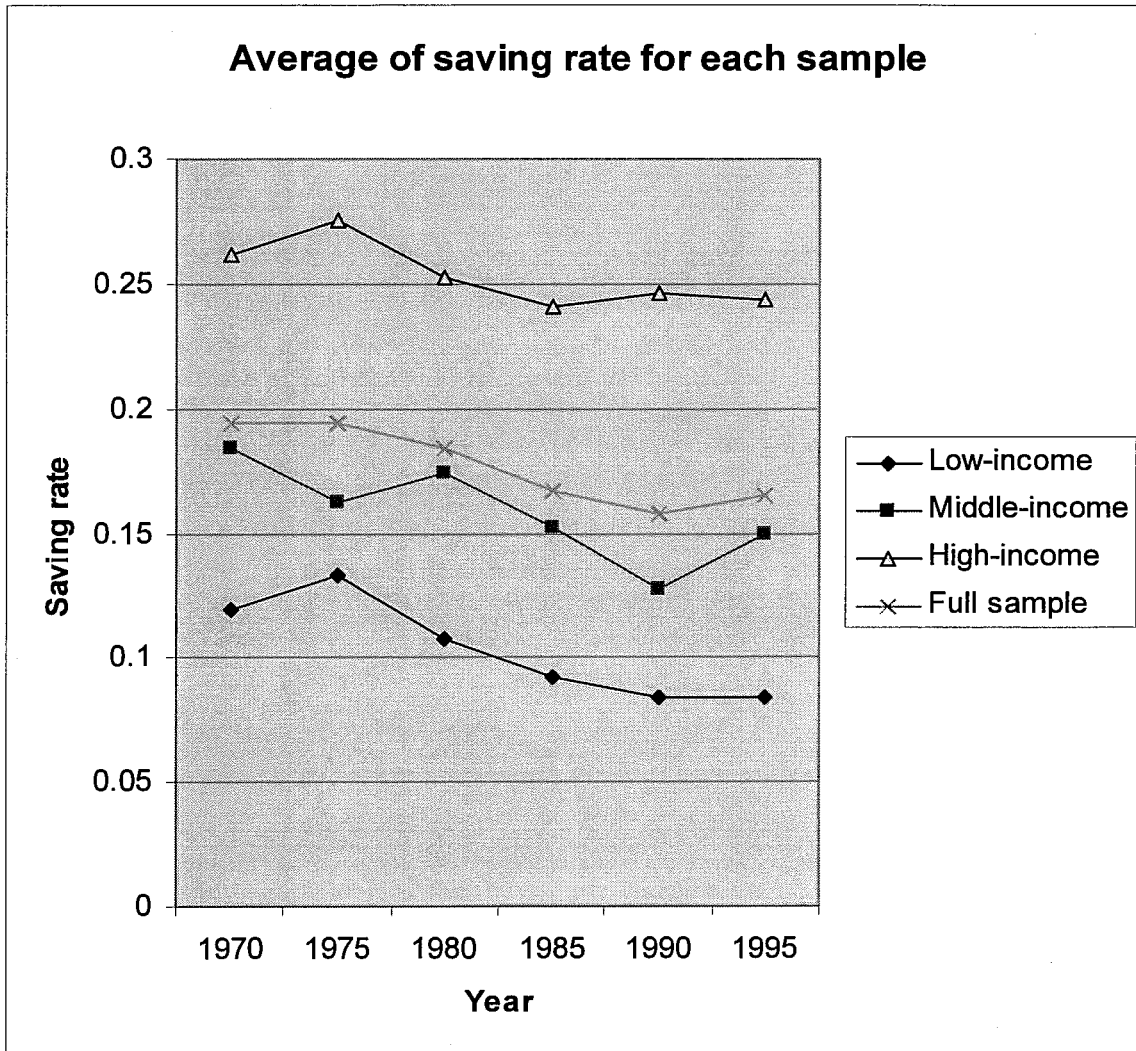


Figure 5.

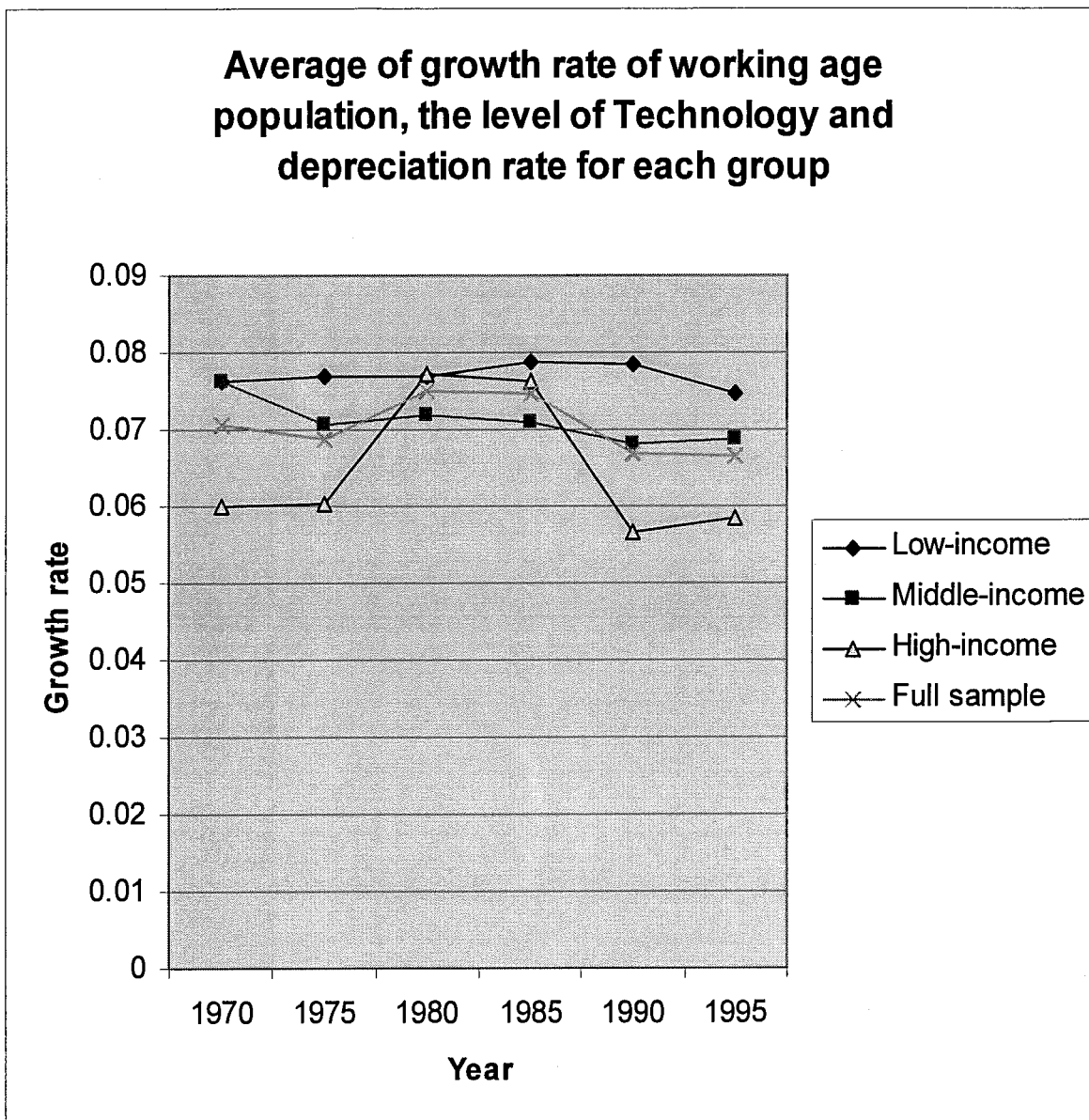


Table 2
Test for Absolute Convergence
Dependent Variable: $\ln Y_{it} - \ln Y_{i,t-1}$

Sample:	Low-Income	Middle-Income	High-Income	Low and High-Income	Low and Middle-Income	Mmiddle- and High-Income	Full Sample
	102	162	138	240	264	300	402
Constant	0.6566 (0.26)	1.008 (0.248)	1.5967 (0.4206)	-0.8465 (0.08155)	0.14238 (0.1143)	0.3923 (0.111)	0.03292 (0.07525)
$\ln Y_{it} - \ln Y_{i,t-1}$	-0.0789 (0.0326)	-0.0995 (0.0263)	-0.1449 (0.0404)	0.0164 (0.008127)	-0.010286 (0.0129)	-0.0315 (0.0109)	0.003942 (0.00773)
p-value	0.018	0.000	0.000	0.044	0.428	0.004	0.61
R^2	0.0457	0.0754	0.2628	0.012	-0.014	0.0175	-0.0019
Specification Error Test							
1. Reset(2) Test	0.00343	0.34441	4.5517	0.2406	0.55611	1.3878	0.009148
p-value	0.953	0.558	0.035	0.0624	0.457	0.24	0.924
2. Reset(3) Test	0.67821	0.47745	4.1651	8.9568	3.4527	1.1359	1.4211
p-value	0.51	0.621	0.018	0.0000	0.033	0.32	0.243
3. Reset(4) Test	0.52898	0.3545	2.9718	6.3603	2.4846	1.1757	1.1233
p-value	0.663	0.786	0.034	0.0000	0.061	0.31	0.339
Heteroskedasticity Test							
1. Koenker test	0.103	0.002	52.11	17.757	2.097	16.714	17.773
p-value	0.7479	0.96149	0.0000	0.0003	0.1476	0.0004	0.00002
2. B-P-G test	0.130	0.003	88.47	36.646	3.22	26.312	30.399
p-value	0.7189	0.95653	0.0000	0.0000	0.07276	0.0000	0.0000
Normality of errors test							
Jarque - Bera test	3.8906	2.1142	13.9815	54.4967	20.106	16.6926	41.5482
p-value	0.143	0.347	0.0001	0.0000	0.000	0.000	0.0000
Implied λ	0.0164	0.021	0.031	-0.00325	0.00206	0.0064	-0.000784
-p-value	0.02249	0.00048	0.00119	0.0419	0.47	0.005	0.609

Note: 1. Heteroskedasticity test is based on Chi-Square statistics with Degree of Freedom=1. 2. Reset test is based on F-Statistics. 3. Jarque -Bera test is based on Chi-Square statistics with Degereec of Freedom=2. 5. Standard errors are in parentheses.

Table 3
Test for Conditional Convergence¹

Dependent Variable: $\ln Y_{it} - \ln Y_{i, t-1}$

Sample:	Low-income	Middle-income	High-income	Low- and High- Income	Low- and middle- Income	Middle- and high-income	Full Sample
No of observation:	102	162	138	240	264	300	402
Constant	0.98177 (0.5567)	1.2359 (0.277)	1.3725 (0.409)	1.156 (0.2331)	0.358 (0.1558)	0.9549 (0.139)	0.5319 (0.111)
$\ln Y_{i, t-1}$	-0.11655 (0.03226)	-0.12299 (0.029)	-0.13672 (0.0358)	-0.1251 (0.02485)	-0.033 (0.0147)	-0.0923 (0.0142)	-0.051 (0.0119)
-p-value	0.000	0.000	0.0000	0.0000	0.027	0.000	0.000
$\ln sk$	0.0949 (0.0247)	0.0118 (0.012)	0.10972 (0.035)	0.1014 (0.02209)	0.042 (0.0114)	0.032 (0.0103)	0.0481 (0.0126)
-p-value	0.000	0.328	0.002	0.0000	0.000	0.002	0.000
$\ln(n+g+\delta)$	-0.0842 (0.1928)	0.00365 (0.0129)	-0.12021 (0.07)	-0.0503 (0.0312)	-0.026 (0.01211)	-0.0098 (0.0117)	-0.027 (0.0142)
-p-value	0.662	0.777	0.093	0.108	0.034	0.0403	0.059
R^2	0.1553	0.1059	0.3133	0.2573	0.0585	0.1279	0.1075
Specification Error Test ²							
1. Reset(2) Test	0.449	0.07374	2.9997	0.36834	16.113	2.143	26.897
-p-value	0.504	0.786	0.086	0.544	0.000	0.144	0.0000
2. Reset(3) Test	0.2655	0.03672	2.0117	0.2929	8.2907	2.925	14.367
-p-value	0.767	0.964	0.138	0.746	0.000	0.055	0.0000
3. Reset(4) Test	0.23214	0.11937	4.7693	0.2962	5.605	2.048	9.5537
-p-value	0.874	0.949	0.003	0.828	0.001	0.107	0.0000
Heteroskedasticity ³ Test							
1. Koenker test	1.907	1.016	44.225	29.18	3.25	19.089	26.007
-p-value	0.591	0.79742	0.000	0.000	0.3547	0.00026	0.00001
2. B-P-G test	2.456	1.333	59.276	56.88	5.07	31.56	45.1
-p-value	0.4832	0.72139	0.000	0.000	0.1665	0.0000	0.0000
Normality of errors test							
Jarque - Bera test ⁴	3.0217	2.1142	3.8556	39.75	19.65	21.3608	39.0272
-p-value	0.221	0.347	0.145	0.00	0.00	0.000	0.0000
F-test ⁵	0.0033	6.9441	0.0232	11.048	5.078	21.0045	18.4223
-p-value	0.954	0.00924	0.87908	0.00089	0.0242	0.000	0.00002
Implied λ	0.02672	0.02624	0.0294	0.02672	0.006671	0.01936	0.026
-p-value	0.001	0.00012	0.00056	0.0000	0.029	0.000	0.00003
F-test ⁶	7.488	3.733	5.208	25.026	7.7523	16.547	19.443
-p-value	0.00094	0.026	0.0063	0.000	0.00054	0.000	0.000

¹ Standard errors of the coefficient estimates are in parentheses

² Reset test is based on F-Statistics

³ Heteroskedasticity test is based on Chi-Square statistics with Degree of Freedom=3

⁴ Jarque - Bera test is based on Chi-Square statistics with Degree of Freedom=2.

⁵ H_0 : Coefficients of $\ln sk$ and $\ln(n+g+\delta)$ sum to zero. ⁶ H_0 : Coefficients of $\ln sk$ and $\ln(n+g+\delta)$ are jointly zero.

Table 4
 LSDV Estimation with Fixed Effects with educational and health capital¹

Dependent Variables: $\ln Y_{it} - \ln Y_{i, t-1}$

Sample:	Low-Income	Middle-Income	High-Income	Full sample
No of observation:	102	162	138	402
$\ln Y_{it}, t-1$	-0.3494 (0.09788)	-0.3304 (0.08568)	-0.358 (0.0454)	-0.28865 (0.0474)
-p-value	0.001	0.000	0.000	0.000
$\ln s_k$	0.151 (0.048)	0.1679 (0.068)	0.2423 (0.0507)	0.15594 (0.0353)
-p-value	0.003	0.000	0.000	0.000
$\ln(n+g+\delta)$	0.226 (0.235)	-0.1973 (0.229)	-0.1154 (0.0921)	-0.0326 (0.1286)
-p-value	0.338	0.39	0.213	0.8
$\ln s^*$	-0.0859 (0.055)	0.1649 (0.1184)	0.2107 (0.074)	-0.0467 (0.03014)
-p-value	0.0125	0.166	0.005	0.122
$\ln h^*$	0.1385 (0.1275)	-0.0728 (0.05885)	0.0389 (0.0198)	0.048 (0.0223)
-p-value	0.282	0.218	0.052	0.031
R^2	0.2772	0.2349	0.6121	0.3124
Specification Error Test ²				
1. Reset(2) Test	0.00645 (0.936)	0.32641 (0.569)	4.8296 (0.03)	0.0514 (0.821)
2. Reset(3) Test	0.2629 (0.77)	11.53 (0.000)	2.5248 (0.084)	3.802 (0.023)
3. Reset(4) Test	0.2199 (0.88)	10.298 (0.000)	1.8168 (0.148)	5.9351(0.001)
Heteroskedasticity Test ³				
1. Koenker test	29.32 (0.1063)	51.162 (0.01278)	33.08 (0.19443)	116.47 (0.00054)
2. B-P-G test	32.3 (0.054)	74.959 (0.00002)	28.43 (0.38896)	206.6 (0.000)
Normality of error test ⁴				
Jarque-Bera test	1.8412 (0.398)	12.3622 (0.002)	1.7214 (0.423)	95.3886 ^s
Implied λ	0.08596	0.0802	0.08864	0.0681
-p-value	0.00545	0.00213	0.000	0.000
F-test ⁶	1.8292	0.02608	1.613	1.088
-p-value	0.17623	0.87169	0.206	0.297
F-test ⁷	5.88	9.18	32.9	13.82
-p-value	0.00000	0.0000	0.000	0.000

Table 4 (continued)

Sample:	Low-Income	Middle-Income	High-Income	Full sample
The means of the country specific effect	4.314	2.563	2.846	2.921
The maximum values of the country specific effect	4.5641 (1.393)	2.828 (0.958)	2.9816 (0.4799)	3.5759 (0.6058)
the minimum values of the country specific effect	4.0083 (1.222)	2.1723 (0.8833)	2.5134 (0.4524)	2.5325 (0.5567)
F-test ⁸ -p-value	3.412 0.000014	2.8183 0.00006	7.51 0.0000	4.53 0.000

¹ Standard errors of the coefficient estimates and maximum and minimum country-specific effects are in parentheses.

² Reset test is based on F-Statistics (P-value is in parentheses).

³ Heteroskedasticity test is based on Chi-Square statistics with D.F=21 for Low-Income, 31 for intermediate-income and 27 for high-income countries (P-value is in parentheses).

⁴ Jarque - Bera test is based on Chi-Square statistics with Degree of Freedom=2 (P-value is in parentheses).

⁵ This value is for the Chi-Square goodness of fit test with degrees of freedom=14 since Shazam 8.0 and 9.0 cannot produce the Jarque - Bera test statistics for the model.

⁶ H_0 : Coefficients of $\ln s_k$ and $\ln(n+g+\delta)$ sum to zero. ⁷ F-test for overall significance test.

⁸ F-test for testing whether all dummy variables are equal.