Human Capital Convergence and Economic Growth: Another Look at the "Four Tigers"

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Abstract

In this paper, we propose an empirical study of cross-country convergence of human capital and economic growth. Following Barro, Mankiw, and Sala-i-Martin (1995), we apply the model proposed by Coulombe and Tremblay (2000) to investigate the role of human capital in economic growth across the " Four Tigers" and six other developed industrial countries.

There are many approaches to interpreting the rapid economic growth in the " Four Tigers". This study suggests that human capital accumulation in these economies is a key factor to explain the miracle. The study indicates that the selected indicators of human capital (relative levels of the percentage who have attained various levels of schooling in a given population) did converge through time. Some of the estimated speeds of convergence of human capital indicators are equal, from a statistical point of view, to the estimated speed of convergence of per capita GDP. The estimates of human capital's share in per capita GDP for higher education are between 0.27 and 0.33. All six indicators of human capital can be used to explain a substantial part of the growth of per capita GDP across ten countries from 1960 to 1990.

Key Words: Convergence, Human Capital, Economic Growth, the "Four Tigers"

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I. Introduction

In the neo-classical growth framework, convergence to a steady state is an important theoretical prediction regarding economic growth patterns and this prediction has received more and more empirical support recently. Barro and Sala-i-Martin in their across-country analyses showed that the growth rate of per capita GDP tends to be higher in poor countries than in rich countries in the post-WWII period (Barro and Sala-i-Martin, 1995).

For poor countries, the convergence process is the catching-up process. During this process, the "Asian Miracle" and the "Four Tiger Story" (South Korea, Taiwan, Hong Kong and Singapore) have been highlighted and have been the subject of a lot of studies. These countries did catch up to the rich ones in the past decades. But there are various approaches to explain how and why they could catch up. In this paper, I want to show that a big part of the growth of per capita GDP can be explained by the convergence of indicators of the stock of human capital. This paper is a direct application of the empirical analysis of Coulombe and Tremblay (2000) to the convergence process of ten countries. In their analysis, they tested the open economy growth model of Barro, Mankiw and Sala-i-Martin (1995) in the case of the ten Canadian provinces during the 1951-1996 period. In this paper, ten countries, the "Four Tigers" and six advanced industrial countries, are analysed. The six advanced industrial countries selected include Asian, American and European countries, which can represent the main advanced countries. Furthermore, I selected these countries since the data are available and ten countries (the "Four Tigers" and six advanced industrial countries) are relatively easy to be analysed for me.

Section II introduces the background of economic growth in the "Four Tigers". Section III

discusses the theoretical model. Section IV focuses on the data set and econometric issues. Since some empirical studies have shown that there are some problems in most human capital data sets, I will compare the Barro and Lee data set with other available data sets. In section V, we present the main results and analysis. The empirical analysis closely follows the one proposed by Coulombe and Tremblay (2000). First, σ convergence and β convergence will be shown. Then we compare the estimated convergence speeds of various indicators of human capital. After the analysis of the speed of convergence of per capita GDP and six indicators of human capital, we can estimate the share of human capital in GDP. Furthermore, we regress the growth rate of GDP on the initial level of human capital to get a more direct observation of economic growth and human capital accumulation. Finally, I will compare the results of this study with the results of Coulombe and Tremblay (2000). In section VI, a brief conclusion and some further discussion will be presented.

II. Economic Growth in the "Four Tigers"

1. Sustained economic growth with social progress

From 1960 to 1990, the "Four Tigers" experienced a remarkable period of sustained economic growth. The growth rates of per capita GDP for these economies are generally better than for any other countries of the world. Real per capita GDP increased more than four times in the "Four Tigers" between 1960 and 1985 (World Bank, http://www.worldbank.org/wbi/edimp/eastasia/ea.html).

Table 2.1 Average Growth Rates of the "Four Tigers" (1960-1984)

Economies	Population (%)	Employment (%)	GDP Per Capita (%)	GDP Per Worker (%)
South Korea	2.0	2.9	6.1	5.2
Taiwan	2.4	3.6	6.6	4.9
Hong Kong	2.3	3.5	6.4	5.7
Singapore	1.9	3.2	7.0	4.3

Source: The data are adapted from Harry T. Oshima, 1988, "Human Resource in East Asia's Secular Growth". *Economic Development and Culture Change,* V36 n3, Page 104.

Since 1960, the growth rate of per capita GDP in the "Four Tigers" was more than twice that of the rest of East Asia, about three times that of Latin America and South Asia. Among the countries with the greatest change in GDP per capita in the world (1960-1985), Taiwan, Hong Kong, Singapore and South Korea ranked 2nd, 4th, 5th and 6th respectively (World Bank, 1993).

Furthermore, the rapid sustained economic growth was accompanied by good progress in

social development. In three decades (1960-1990), the average years of schooling of the labor force, adult literacy, life expectancy, and the percentage of females in the labor force improved in the "Four Tigers".

Table 2.2 Socio-economic Improvements in the "Four Tigers"

Economies	Schooling Years (Years)		Adult Literacy (Per cent)		Life Expectancy Males / Females (Years)		Female Labor Force (Per cent)	
	1960	1990	1960	1990	1980	1990	1980	1990
Hong Kong	4.82	8.37	69.2	84.3	71.6 / 77.9	74.6 / 80.3	45.3	46.8
South Korea	3.23	9.25	43.1	89	62.4 / 65.0	67.7 / 75.7	42.8	47.0
Singapore	3.54	5.47	45.7	70.6	69.8 / 74.7	73.1 / 77.6	34.5	40.2
Taiwan	3.32	7.44	53.4	83.6	NA	NA	NA	NA

Sources: The data on average Schooling Years (in the population of 25-years and over) and Adult Literacy (here defined as '1 – No Schooling' in the population of 25-years and over) are from the Barro and Lee data set, www.worldbank.org/research/growth/ddbarle2.htm; the data of Life Expectancy and Female Labor Force are from United Nations Economic and Social Commission for Asia and the Pacific (ESCAP), http://unescap.org/stat/statdata/apinfig.htm.

2. The common characteristics of rapid growth

"Dynamic agricultural sector, rapid growth of exports, rapid demographic transition, high investment and saving rates and high investments in human capital" (World Bank, www.worldbank.org/wbi/edimp/eastasia/growth.html) are the common characteristics of the rapid growth of the "Four Tigers". These characteristics interacted and pushed the traditional economies into the modern industrial economies.

In the past three decades (1960-1990), agricultural output and productivity grew rapidly and

the share of agriculture in GDP declined sharply in the four economies. The agricultural labor force in Taiwan, Hong Kong, Singapore and South Korea declined to 13%, 2%, 2% and 19% respectively of the total labor force in the 1980s. Meanwhile, with the rapid growth of exports, merchandise production in these four economies experienced a sharp increase. The combined share of world manufacturing exports of the "Four Tigers" has increased from 1.5% to 8% between 1960 and 1990 (World Bank, 1993).

Table 2.3 Ratio of Total Trade to GDP of the "Four Tigers"

Economies	1970	1980	1985	1988
South Korea	0.32	0.63	0.66	0.66
Taiwan	0.53	0.95	0.82	0.90
Hong Kong	1.5	1.52	1.78	2.82
Singapore	2.12	3.70	2.77	3.47

Source: The data are from World Bank, 1993, *The East Asian Miracle*: *Economic Growth and Public Policy*, Oxford University Press, Page 39.

The population growth rate fell with the rising standard of living. The relatively large reduction in fertility in the "Four Tigers" led to a larger reduction of population growth than in other developing countries. World Bank (1993) showed, for example, that the rate of population growth declined from 2.6% a year in 1960-70 to 1.1% in 1980-90 in South Korea and from 2.5% to 1.4% in Hong Kong.

From 1960 to 1990, both savings and investment increased rapidly in the "Four Tigers". Both the traditional cultures and the governments of these economies encourage domestic savings. In the early years of their development, Korea and Taiwan once set some strict limits on

exports of capital to guarantee their domestic investment. Therefore, domestic savings and investment in the four economies is significantly higher than in other economies. Savings rates for the "Four Tigers" averaged over 30% of GDP in the past three decades (1960-1990), "while the saving rate in Sub-Saharan Africa was 15%, in Latin-America and the Caribbean, 19%, and in the high-income economies, 20%" (World Bank, www. worldbank.org/wbi/edimp/eastasia /save. html).

3. Human capital accumulation

As mentioned before, the factors of dynamic agricultural change, rapid growth of exports, rapid demographic transition and high investment and saving rates interacted over the "Four Tigers" industrialising process, and these factors were based on human capital. For example, the rapid growth of exports required more and more skilled workers; the change from a rural population into an urban population required improvements in basic education to adapt to the transition; and the rapid demographic transition (reduction in fertility) accompanying the modern life style needed better educated parents.

On the other hand, rapid economic growth and declining population growth in the "Four Tigers" has allowed expenditures on education to rise rapidly. According to the World Bank (1993), for example, from 1970 to 1989, "real expenditure per pupil at the primary level rose by 355 percent in Korea. In Mexico and Kenya, expenditures rose by 64 and 38 percent respectively" (World Bank, 1993, Page 45). Some studies show that countries with rapid economic growth have relatively high rate of human capital accumulation.

Furthermore, with the accumulation of human capital, the skilled labor force can easily

absorb and master the imported technologies. Although GDP growth was very high, the "Four Tigers" have not experienced rapid technical progress [1]. The reason may be that the cost of R&D is more than that of importing similar technologies. Hence, the quality of labor (human capital) is very important since it contributes to the effectiveness of the importation, absorption, dissemination, and adaptation of technological progress.

4. Explanations of the miracle

There are a lot of approaches to explaining the successful growth of the "Four Tigers". The current dominant model is "market-friendly development". This model suggested the following key factors of economic growth: "macroeconomic stability, human capital formation, openness to international trade, and an environment that encourages private investment and competition" (World Bank, 1993, Page 84-85).

Another explanation of the "Four Tigers" experience is "state-directed industrial development". This model emphasis the importance of government. In fact, government interventions can be easily found in the development process of the "Four Tigers", especially in the early years (Pack and Wesphal, 1986). For example, Taiwan once encouraged public departments to invest in exporting industries, especially in small and medium-scale companies. In South Korea, some industries such as heavy industries were controlled with credit, and new

[1] Many studies found that technical progress in the rapid economic growth of East Asian economies is "less significant than in the high income industrialized economies". World Bank reported: "A recent study, which explicitly estimated a production function more general than that typically assumed in growth accounting studies, found that the data do not reject the hypothesis that technical progress was zero" (www.worldbank.org/wbi/edimp/eastasia/prod.html) in the "Four Tigers" from about 1960 to 1990.

competitors in these industries were constrained (World Bank, 1993).

Some researchers proposed that the rapid growth rates were associated with U.S. aid, the destruction of the old order, a sense of political and economic urgency, a plentiful labour force, the Japanese Model, the Industrial New-Confucianism and other traditional cultural factors. [2] (Vogel, 1991).

The successful story of the "Four Tigers" did not provide a general model of rapid growth for their future development and for other developing countries. However, the accumulation of physical capital and human capital and integration into the world economy have been considered the basic factors for economic growth by most researchers.

[2] Since the "Four Tigers" all share the Confucian heritage, some researchers who emphasis traditional culture suggested that their rapid growth is the success of the Confucianism. See Ronald P. Dore (1988) and Hung-chao Tai (1989).

III. Theoretical Model

Following Barro, Mankiw and Sala-i-Martin (1995) and the application of Coulombe and Tremblay (2000), there are two key assumptions in this model. The first is perfectly mobile physical capital across the open countries [(3)]; second, there is a binding constraint on the financing of human capital. So in the cross-country convergence process, the accumulation of physical capital will be driven by the accumulation of human capital.

Introducing human capital provides a solution to the problem encountered by the traditional Solow-Swan model (Mankiw, 1995). The problem is that the contribution of capital to economic growth is underestimated and there is a discrepancy between the theoretical predictions of the Solow-Swan model and the international data (for more discussion of this topic please see Mankiw, 1995 and Coulombe and Tremblay, 2000, section 2.1). The broader capital concept increases the capital share, and we can get a modified Cobb-Douglas production function (Barro, Mankiw and Sala-i-Martin, 1995):

$$Y = A K^{\alpha} H^{\eta} (Le^{gt})^{(1-\alpha-\eta)}$$

where α and η are the elasticities of output Y with respect to physical and human capital. Since physical capital is perfectly mobile, the marginal product of K is a constant that is determined by the exogenous world interest rate. Consequently, we can derive a new modified production

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[(3)] One method of testing this assumption is to estimate the correlation coefficient between domestic saving and investment of an economy (Feldstein and Horioka, 1980). If the correlation coefficient is not significantly different from 0 at a given confidence level, then it is said that there is perfect capital mobility; otherwise, there is not perfect capital mobility in the economy. See Coulombe and Tremblay (1999, Appendix) for a discussion of the problem (Working paper version of the 2000 paper).

function, which just includes the human capital variable (Barro, Mankiw and Sala-i-Martin, 1995):

$$y = B\,h^{\eta/(1-\alpha)} \qquad (I)$$

where y is the per capita output; B is a constant exogenous variable; and h is the human capital / labour ratio.

In the framework of Barro, Mankiw and Sala-i-Martin (1995), human capital accumulation determines the dynamic evolution of the economic variables of economies and so leads to long-run equilibrium in the evolution process. They suggested that the convergence speed of per capita GDP (or income) should be equal to the convergence speed of human capital, and countries (or regions) originally with less achievement in human capital should grow faster than rich ones.

There are two types of convergence. "σ Convergence" implies that the dispersion of indicators in the cross-section distribution will decrease during the transitory period. We can look for σ convergence by comparing the standard deviations of indicators of human capital. "β Convergence" is said to occur if "the poor economies grow faster than rich ones" (Barro and Sala-i-Martin, 1995). In this empirical study, the analysis is based on the hypothesis of absolute convergence, which means that the economies converge to the same steady state.

According to Barro and Sala-i-Martin, we can estimate the convergence speed of per capita GDP using the following form:

$$\text{Ln } y_{i,t} = e^{-\beta 1 t}\,\text{Ln } y_{i,0} + (1 - e^{-\beta 1 t})\,\text{Ln } y_i^* \qquad (II)$$

where $y_{i,t}$, $y_{i,0}$ and y_i^* are per capita GDP for economy i at time t, time 0 and its steady state value; β_1 is the convergence speed of per capita GDP. As in Coulombe and Tremblay (2000),

from (I) and (II), we obtain:

$$\text{Ln } h_{i,t} = e^{-\beta 2t} \text{Ln } h_{i,0} + (1 - e^{-\beta 2t}) \text{Ln } h_i^* \qquad \text{(III)}$$

where $h_{i,t}$, $h_{i,0}$ and h_i^* are the human capital / labour ratio for economy i at time t, time 0 and its steady state value; β_2 is the convergence speed of the human capital / labour ratio. According to Barro, Mankiw and Sala-i-Martin (1995), β_2 in equation (III) should be equal to β_1 in equation (II), which implies the same speed of convergence for y and h. From (II) and (III), we can estimate and compare the convergence speed of the per capita GDP with those speeds of the various indicators of human capital.

The next step of the analysis is to compare the output level with the stock of human capital, and so to estimate the share of human capital in output. From (I), we obtain:

$$\text{Ln } y_{i,t} = [\eta / (1- \alpha)] \text{ Ln } h_{i,t} \qquad \text{(IV)}$$

Using this equation we can estimate $[\eta / (1- \alpha)]$, and for given α, the implied η can be computed. η is both the elasticity of output to human capital and the share of human capital. According to Coulombe and Tremblay (2000), α (the share of physical capital) can be "measured from non-wage income in the national accounts" . Barro, Mankiw and Sala-i-Martin (1995) suggested that the benchmark of this share is about 0.33 based on international data.

Finally, the relationship between the growth rate of per capita GDP and the initial level of human capital will examined more directly by estimating the following form (Coulombe and Tremblay, 2000):

$$\text{Ln } (y_{i,t} / y_{i,0}) = C \text{ Ln } h_{i,0} \qquad \text{(V)}$$

This is a modified convergence equation. β convergence implies that the parameter C should be negative.

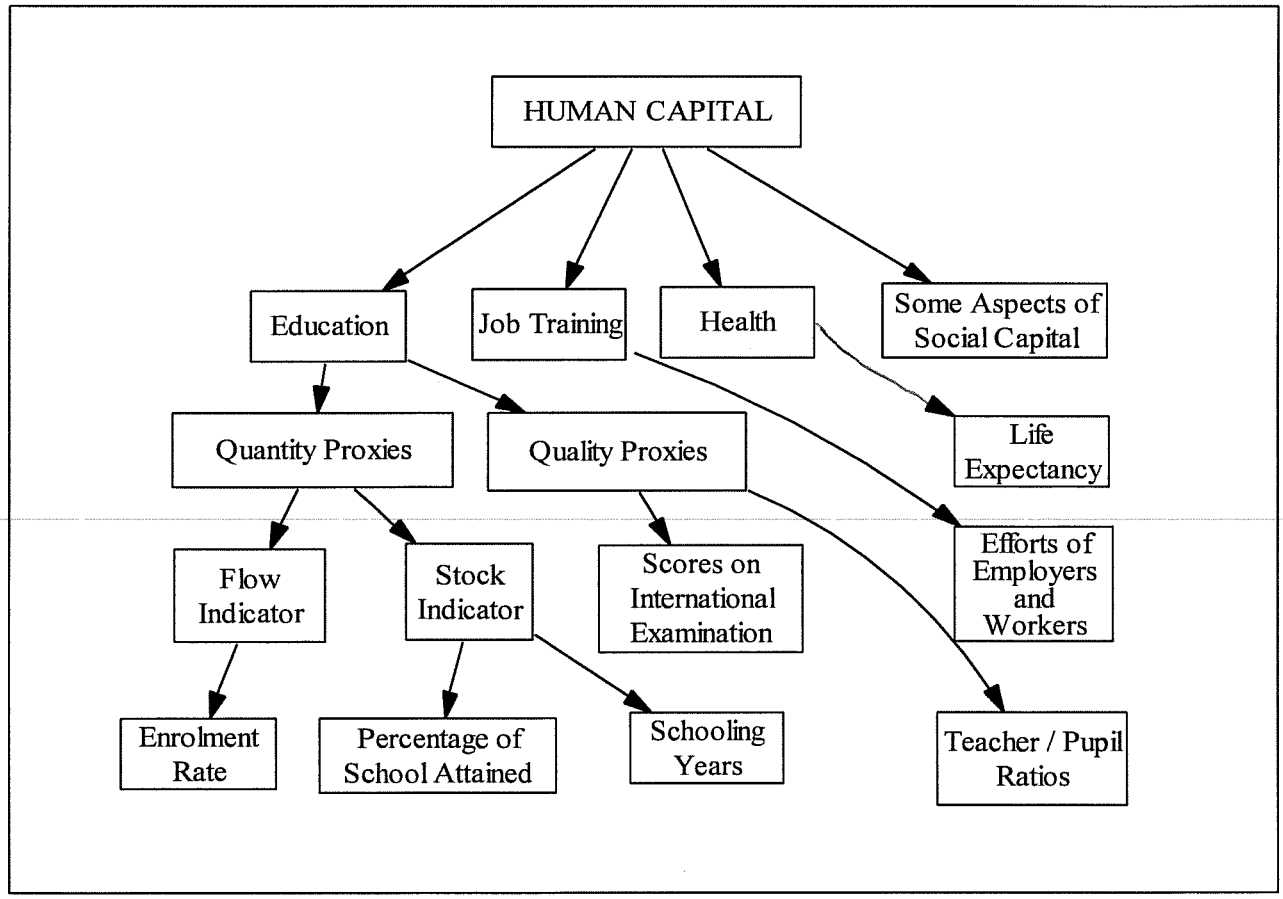
In summary, this model includes two key assumptions (perfect mobility of physical capital and a binding constraint for the financing for human capital) and the equations from (I) to (V).

IV. Human Capital Data Set and Econometric Issues

1. How to measure human capital

As Table 4.1 shows, in the theoretical field, we should consider education, job training, health, and some "social capital" when we measure human capital. Since most of these aspects are not openly exchanged as physical capital in markets, it is very difficult to find suitable proxies for human capital. For example, although on-the-job-training has become more and more important in recent years, the training efforts of employers and workers are difficult to measure.

Table 4.1 Human Capital Proxy Structure



The health situation of the population, especially of the labor force, and other aspects of social capital are important for human capital formation, but these indicators are also difficult to measure. Hence, most of the recent studies about human capital focus on education.

Many indicators are proposed by researchers to measure educational achievement. These indicators can be divided into two types. One is quantitative indicators, for example, schooling years (which is average years of schooling of the given population), the enrolment rate and the percentage of (certain level) school attained (which is the percentage who have attained various levels of schooling in the given population); another type is qualitative indicators, for example, scores on international examinations. De La Fuente and Domenech (2000) discussed quantitative indicators in more detail. They analyzed the difference between the flow indicator (enrolment rate at various levels in the given population) and stock indicator (for example, the percentage who have attained various levels of schooling in adult population). Barro and Lee (1993, 1996) and Barro (2000) discussed qualitative indicators of educational achievement in more detail. Hanushek and Kim (1995) found that scores on international examinations work better to explain the economic growth than years of schooling. Barro (2000) used average years of schooling as indicators of quantity of education and "scores on internationally comparable examinations" as indicators of the quality of education.

2. Available international education data sets

The original data on education are from various statistical reports and many kinds of censuses. For example, the World Bank, UNESCO, and other international organizations often report some educational surveys. Using these surveys and other available sources, many

researchers constructed international data sets of educational achievement. In their recent study, De La Fuente and Domenech (2000) divided available international education data sets into two groups according to "whether they make use of both census attainment data and enrolment series or only the latter" (Page 4): the first group includes Kyriacou (1991) and Barro and Lee (1993; 1996); the second group includes Louat, Jamison and Louat (1991), Lau, Bhalla and Louat (1991) and Nehru, Swanson and Dubey (1995).

De La Fuente and Domenech (2000) discussed various possible measurement errors in these data sets. They also compared the OECD data set with Barro and Lee's. Since the Barro and Lee data set covered 138 countries and provided data on males and females with various levels of educational attainment, it is widely used by researchers, although some problems in it have been observed.

Because the treatment of vocational education and apprenticeship programs is different, it is often found that secondary school attainment in the OECD data set is generally higher than in the Barro and Lee's. "The difference exceeds forty points in Austria, Germany, Finland, Denmark, Norway and the UK, and is quite important for a number of other European countries and for Japan" (De La Fuente and Domenech, 2000, 10). Moreover, it has been observed that there are some sharp breaks within the Barro and Lee data set.

In a recent paper, Barro discussed this problem. He argued: "The OECD categories are below upper secondary, upper secondary, and tertiary. We believe that the first OECD category would correspond roughly to the sum of our first three categories [4]. However, this approximation is satisfactory only if the OECD's concept of upper secondary attainment

[4] The first three categories are no schooling, primary school attained and secondary school attained.

corresponds closely to the U.N. concept of complete secondary attainment" (Barro, 2000, 5).

Furthermore, Barro (2000,5) proposed that the OECD classification probably "counts as upper secondary many persons whom the U.N. ranks as less than complete secondary" .

Although there are problems such as sharp breaks, some measurement errors, and mistakes from original censuses in the Barro and Lee data set (for more discussion see De La Fuente and Domenech, 2000), it covers most countries of the world, especially the developing countries. It is widely used for international educational research.

3. Indicators in this study

As mentioned before, this empirical study will test if human capital convergence can explain the rapid economic growth of the "Four Tigers". Since qualitative data on education for these economies is difficult to get, I focus on the available quantitative data set. In the following discussion, we simply use the percentage who have attained at least secondary school and higher school in a given population [5] as the index of education achievement in an economy and so as the index of human capital.

The Data Set is taken from Barro and Lee (1996). Although there are some disadvantage in the data set as we discussed before, I selected these data just because it is impossible to find another better international data set for this empirical study.

The Barro and Lee data set (1996) provided two groups of variables (over 15 years of age

[5] "The Percentage of Secondary (or Higher) School Attained" in the Barro and Lee data set means "the percentage who have attained secondary (or higher) school in the given population". "Schooling Years" in the Barro and Lee data set means "average years of schooling in the given population".

and over 25 years of age), but here we just consider the population over 25 years of age. First, we consider two benchmark levels of education: at least secondary school and higher school (for more detail on the classification please see Barro and Lee, 1993). We exclude those of no more than secondary school since there is little difference of the percentage of who have attained this level of education among ten countries in this study. Second, we want to see if there is a gender difference in the human capital accumulation process, so we consider data for the total population, the male population and the female population. Therefore, we used six indexes as the proxy of human capital: the Percentage who have attained at least Secondary school in the Total Population over 25 years of age (SAP); the Percentage who have attained at least Secondary school in the Male Population over 25 years of age (SAM); the Percentage who have attained at least Secondary school in the Female Population over 25 years of age (SAF); the Percentage who have attained Higher school in the Total Population over 25 years of age (HAP); the Percentage who have attained Higher school in the Male Population over 25 years of age (HAM); the Percentage who have attained Higher school in the Female Population over 25 years of age (HAF). The per capita GDP index is also based on the Barro and Lee Data Set (PPP adjusted).

The selected countries include the "Four Tigers" and six advanced industrial countries. They are Canada (CA), France (FR), Great Britain (GB), Hong Kong (HK), Japan (JP), South Korea (KO), Taiwan (OA), Singapore (SG), Sweden (SW) and United States (US). As we mentioned in Section I, the six advanced industrial countries selected include Asian, American and European countries. I hope that they represent main advanced countries in the world. Meanwhile, the data on these countries are available and ten countries (the "Four Tigers" and six

advanced industrial countries) are easy for me to analyse me. Once again, the purpose of the empirical study is to show if human capital convergence can explain the output convergence across the "Four Tigers" and the advanced industrial countries.

The sample period is 1960 to 1990.

4. Econometric issues in this study

First, we use relative levels to replace real levels because real levels of education are not very useful as the indicators of human capital when we compare them across countries. For example, educational institutions and traditional culture are different in different countries. In some countries you can obtain a university degree in three years but in other countries you must spend four years to get it. However, this study focuses on the convergence process instead of the change of real levels of education. As Coulombe and Tremblay (2000, section 3.1) pointed out: "most of the problems associated with the imperfect measure of human capital are then overturned" by using a relative level indicator of human capital. In this case, we use RGDP, RSAP, RHAP, RSAM, RHAM, RSAF and RHAF to represent the relative levels for a country with respect to the average over the ten countries of GDP, SAP, HAP, SAM, HAM, SAF and HAF respectively.

Second, in the sample period (1960 to 1990), we use 5-year intervals since the base data of the Barro and Lee data set is presented as 5-year intervals and the complete time series are not available. Furthermore, we use 5-year intervals rather than 10-year intervals (or other intervals) since the sample in this study will be too small if use the latter.

Third, we use the pooled time series cross-section estimation technique suggested by

Coulombe and Lee (1995) to increase the degrees of freedom since this empirical study involves a small sample. So there are six five-year sub-periods and ten cross-section observations, resulting in a sample of 60 panel observations.

Since the model is estimated using relative variables, equations (II)-(V) in section III must be modified as follows:

$$\text{Ln}\left(\text{RGDP}_{i,\,t+p} / \text{RGDP}_{i,\,t}\right) = -\left(1 - e^{-5\beta y}\right) \text{Ln}\left(\text{RGDP}_{i,\,t}\right) + U_{i,\,t+p} \qquad (1)$$

$$\text{Ln}\left(\text{RHX}_{i,\,t+p} / \text{RHX}_{i,\,t}\right) = -\left(1 - e^{-5\beta hx}\right) \text{Ln}\left(\text{RHX}_{i,\,t}\right) + U_{i,\,t+p} \qquad (2)$$

$$\text{Ln}\left(\text{RGDP}_{i,\,t}\right) = [\eta / (1-\alpha)] \text{Ln}\left(\text{RHX}_{i,\,t}\right) + U_{i,\,t+p} \qquad (3)$$

$$\text{Ln}\left(\text{RGDP}_{i,\,t+p} / \text{RGDP}_{i,\,t}\right) = C \text{Ln}\left(\text{RHX}_{i,\,t}\right) + U_{i,\,t+p} \qquad (4)$$

where p is the length of period (5 years in this case). RHX represents the indicator of human capital, which may be any one of the six indicators mentioned before. β_y and β_{hx} are the speeds of convergence of per capita GDP and various indicators of human capital . Ui is the error term. Since all variables are computed as deviations from the sample means, the intercept (constant term) is zero.

To estimate the coefficients of equations (1) – (4), we use the GLS (Cross Section Weights)[6]. The " Technical Note " in *EView 3.1 Help System* shows that "Cross-section weighted regression is appropriate when the residuals are cross-section heteroskedastic and

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[6] All the estimations in this paper are done using Eviews 3.1. " If you select Cross Section Weights, EViews will estimate a feasible GLS specification assuming the presence of cross-section heteroscedasticity." (For more discussion on this topic , see "Pooled Time Series and Cross-Section Data", *EView 3.1 Help System*). Cross-section weighted regressions are used in this paper since the residuals are expected to show cross-section heteroskedasticity. Using this approach made the empirical analysis robust.

contemporaneously uncorrelated." These assumptions are made in this study. After estimating the coefficients, we can compute β. Furthermore, following Coulombe and Tremblay (2000), we iterate to convergence in the estimation process.

Finally, we use Wald statistics to compare the convergence speeds of various indicators. The Wald statistics is computed by the following form:

$$W = (\beta_1 - \beta_2)^2 / [Var(\beta_1) + Var(\beta_2)]$$

Since $\beta = f(c) = Ln (1+ c) / (- 5)$ in this case, and c is the estimated coefficient of logarithm of indicators, we can compute the W as following form:

$$W = (c_1 - c_2)^2 / [Var(c_1) + Var(c_2)]$$

Therefore, we can directly compute the W from the estimated coefficients and their standard deviations [7].

[7] It is possible that the Wald test result based on β might be different from that based on c since Wald tests are known to be sensitive to the functional form of the test statistic. See Lafontaine and White, "Obtain any Wald Statistic You Want", *Economics Letters* 21 (1986), 35-40.

V. The Main Results and Analyses

1. A look at the data on the relative level of per capita GDP and the relative level of human capital

In general, from table 5.1, we can see that countries with lower per capita GDP - Korea, Taiwan, Singapore and Hong Kong - tend to have a lower percentage of school attained (RSAP and RHAP), while the rich countries with higher per capita GDP - United States, Canada, Great Britain and Sweden - tend to have a good educational achievement. However, France has a higher per capita GDP with lower educational achievement and Japan has higher educational achievement but lower per capita GDP in the first ten years. For Japan, the reason may be the impact of WWII. For example, the physical capital in Japan needed the time to recover from the war damage, but its human capital was less affected by the war. But for France, as we discussed in section IV, the reason may be a problem with the data. In the OECD data set, the level of educational achievement in France is higher than in the Barro and Lee data set (for some indicators by more than 40%!).

2. σ convergence of human capital

(Insert Figure 1, Figure 2 and Figure 3)

We can find a clear σ convergence pattern in Figures 1 to 3. During the 30 year period, the dispersion of all six indicators of human capital tended to decrease. However, the patterns of decrease differed. From Figure 1, the standard deviation across the 10 countries of the

Table 5.1 Relative Levels of Per Capita GDP and Relative Levels of Human Capital

(Countries' Average=1)

Countries	Canada (CA)	France (FR)	Great Britain (GB)	Hong Kong (HK)	Japan (JP)
1960RGDP	1.5792	1.2960	1.4104	0.4815	0.6449
1960RSAP	1.6915	0.3184	0.8723	0.7297	1.2338
1960RHAP	2.2279	0.3571	0.3061	0.7993	1.0714
1990RGDP	1.3128	1.0499	0.9847	1.0862	1.1175
1990RSAP	1.3861	0.6847	0.8709	0.8958	1.0919
1990RHAP	1.2313	0.7365	0.7998	0.6099	1.2198

Countries	Korea (KO)	Taiwan (OA)	Singapore (SG)	Sweden (SW)	United State (US)
1960RGDP	0.1913	0.2945	0.3582	1.6262	2.1179
1960RSAP	0.4478	0.5041	0.8292	1.3731	2.0000
1960RHAP	0.4422	0.7143	0.0000	1.2755	2.8061
1990RGDP	0.5029	0.6416	0.8257	1.0921	1.3867
1990RSAP	1.1185	0.8293	0.5983	1.0354	1.4891
1990RHAP	0.7710	0.7020	0.2704	1.0587	2.6007

percentage who have attained at least secondary school in the total population (SDRSAP) declined from about 56% to 35% with a sharp break in 1975 [8]. In fact, from 1975 to 1980, there is an increase in the standard deviation of this indicator. For the level of higher education, from Figure 2, the standard deviation for the total population (SDRHAP) declined from about 90% to 70% over the three decades.

For both levels of educational attainment, the standard deviations of the indicators for the female population (SDRSAF and SDRHAF) are higher in the initial year and decreased faster than the indicators for the male population (SDRSAM and SDRHAM).

In Figure 3, we find an interesting pattern: while the standard deviations of the indicators for at least secondary education decreased from 1970 to 1975, the standard deviations of the indicators for higher education increased. In the real world, we find that while the developed countries were improving investment in higher education in this period, the "Four Tigers" were improving investment in secondary education.

(Insert Figure 4, 5, 6, 7, 8, 9)

In Figure 4 and Figure 6, we can easily find a clear convergence pattern of human capital indicators . The relative levels of the percentage who have attained at least secondary school in the total population (RSAP) and in the female population (RSAF) showed a perfect convergence pattern across the ten countries over the 30 year period. But in Figure 5 (the relative levels of the percentage who have attained at least secondary school in the male population, or RSAM),

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[8] As we discussed in section IV, sharp breaks exist in the Barro and Lee data set. In this case, there are three countries (Canada, Sweden and U.S.A.) in which the percentage who have attained secondary school in the total population in 1975 is significantly less than in 1970.

Figure 7 (the relative levels of the percentage who have attained higher school in the total population, or RHAP), Figure 8 (the relative levels of the percentage who have attained higher school in the male population, or RHAM) and Figure 9 (the relative levels of the percentage who have attained higher school in the female population, or RHAF), we find the convergence pattern not so significant as in Figure 4 and Figure 6. However, in general, we can observe that the countries who have initially less educational achievement seem to reach closer to the average (relative level = 1) over the 30 year period, and the countries who have initially better educational achievement also tend to come back to the average (relative level = 1).

3. β Convergence of human capital

We estimate the speeds of convergence of all six indicators using equation (2). The results are presented in Table 5.2.

First, we can reject the null hypothesis that $\beta=0$ which means no convergence, for all six indicators at the 1 percent level. So, human capital in countries originally with less achievement grew faster than human capital in countries with higher levels of achievement during 1960-1990.

Another finding from Table 5.2 is that the estimated speeds of convergence of indicators for at least secondary education achievement are greater than for higher education achievement. According to the theoretical prediction, the estimated speed of convergence of per capita GDP and human capital should be from 0.014 to 0.035 (Barro, Mankiw and Sala-i-Martin, 1995). In this case, we found one estimated convergence speed of human capital indicators for at least secondary education (in male population) is bigger than the upper number, but all the other estimated speeds are within the interval.

Table 5.2 Human Capital Convergence in 10 Countries

	Human Capital Indicators			
	Relative Levels of the Percentage who have attained at least Secondary School		Relative Levels of the Percentage who have attained Higher School	
	A	B	A	B
Total	-0.1565	**0.0340**	-0.1514	**0.0328**
	0.0226		0.0358	
	0.4309		0.2175	
Males	-0.2322	**0.0528**	-0.1313	**0.0281**
	0.0422		0.0407	
	0.2693		0.1450	
Females	-0.1511	**0.0328**	-0.1322	**0.0284**
	0.0135		0.0262	
	0.6674		0.2686	

Observations: 60 panel in all the 3 cases for at least secondary education (RSAP, RSAM and RSAF) ; 59 panel in two cases for higher education in the total population and the male population (RHAP and RHAM); 58 panel for higher education in the female population (RHAF). The reason for the unbalanced observations is that some data for Singapore in the data set are zero.

Estimating Equation: equation (2)

Note: The numbers in column A are the estimated coefficients, the standard errors of coefficients, and the adjusted R squared, respectively. The numbers in column B are the estimated annual convergence speeds.

Table 5.3. Wald Statistics for the comparison of the estimated Convergence Speed between at least Secondary and Higher Education

Total:	0.014	(A1)
Males:	2.961	(A1)
Females:	0.411	(A1)

A1: Can not Reject the Null Hypothesis that the speed of convergence for at least education is equal to the speed of convergence for higher education at confidence of 95%

Note: The critical values of the Wald statistics are 3.84 (at 95% confidence level) and 6.63 (at the 99% confidence level)

Table 5.4 Wald Statistics for the comparison of the estimated Convergence Speed between Males and Females

at least Secondary Education	3.3504	(A1)
Higher Education	0.0003	(A1)

A1: Can not Reject the Null Hypothesis that the speed of convergence in the male population is equal to the speed of convergence in the female population at confidence of 95%

Note: The critical values of the Wald statistics are 3.84 (at 95% confidence level) and 6.63 (at the 99% confidence level).

Now let us compare the estimated convergence speeds for at least secondary education and higher education using the Wald Statistics. From Table 5.3, the null hypothesis of equality would not be rejected in all 3 cases at the 5 percent level, which means that there is no significant difference in estimated convergence speeds between at least secondary and higher education in the total population, the male population and the female population.

From Table 5.4, we can not reject the null hypothesis of equality at the 5 percent level. Therefore, there is no significant difference between the estimated speeds of convergence of males and females, both for at least secondary and higher education. However, the gender difference of convergence speeds in at least secondary education is greater than in higher education.

In the "Four Tigers", in the early part of the period (about 1960-1975), secondary education was more heavily emphasized than higher education since the opportunity cost for higher education is greater than that for secondary education. For example, a person who pursues higher education could alternatively earn money in the labor force, but a child who goes to secondary school may have difficulty finding a job. For families, the investment in a university student is much greater than the investment in a secondary school student. However, in the convergence process, with the GDP increasing, government and families could offer more investments in higher education, especially in 1980s. Therefore, in the whole catching-up process (1960-1990), there is no significant difference in the estimated convergence speed between at least secondary education and higher education. But we should note that the Wald statistic for the male population (2.961) is bigger than the other two numbers (0.014 for the total population and 0.411 for the female population).

Let us consider another phenomenon in the "Four Tigers". The traditional culture in these economies emphasized the male's education more than the female's education, especially in the early part of the development process. However, as the economy and society became more open in the catching-up process, these countries recognized the importance of the female's education and improved the level of investment in it. Therefore, in the whole catching-up process (1960-1990), there is no significant difference between the male convergence speed and the female convergence speed across the ten countries. But we should note that the Wald statistic for at least secondary education (3.3504) is bigger than that for higher education (0.0003).

4. GDP convergence and human capital convergence: the comparison of estimated speeds

Using equation (1), we can estimate the convergence speed of per capita GDP, which is about 0.027 (see results in Table 5.5). Note that this result falls in the theoretical interval (0.014 - 0.035). As Table 5.5 indicates, we can reject the null hypothesis of no convergence at the 1 percent level.

We can compare the estimated convergence speeds between per capita GDP and each indicator of human capital. Barro, Mankiw and Sala-i-Martin (1995) pointed out that the convergence speeds of per capita GDP and human capital should be equal.

Table 5.5 Convergence of Per Capita GDP in 10 Countries (1960-1990)

The estimated coefficient	-0.1257
The Convergence Speed β	0.0269
S.D.	0.014
Adjusted R squared	0.587

Observations: 60 panel

Estimating Equation: equation (1)

Note: The number in the first row is the estimated coefficient. Below it is the standard Deviation and the third row is the adjusted R squared.

From Table 5.6, the Wald statistics show that we can not reject the null hypothesis of equality at the 5 percent level for five of the six indicators, which means that there is no significant difference between the five convergence speeds (for all indicators of higher education and at least secondary education in the total population and in the female population) and the convergence speed of per capita GDP at the 95% level of confidence. Since the null hypothesis is rejected for only one indicator (for at least secondary education in the male population), we can say that this indicator may be not suitable to represent the whole level of human capital in this model.

Table 5.6. Wald Statistics for the comparison of the convergence speed of human capital and GDP

Measures of GDP and Human Capital Indicators		
	Relative Levels of the percentage who have attained at least Secondary School	Relative Levels of the percentage who have attained Higher School
Total	0.7685 (A1)	0.3287 (A1)
Males	4.5288 (R1)	0.0132 (A1)
Females	0.7122 (A1)	0.0300 (A1)

R1: Reject the Null Hypothesis of equality at confidence of 95%

A1: Can not Reject the Null Hypothesis of equality at confidence of 95%

Note: The critical values of the Wald statistics are 3.84 (at 95% confidence level) and 6.63 (at the 99% confidence level).

5. GDP Level and Human Capital Share

Using equation (3), we can estimate the human capital share in per capita GDP. The results are presented in Table 5.7. The physical capital share we used is the benchmark $\alpha = 0.33$.

The first interesting result is that all the estimated human capital shares in per capita GDP for at least secondary education are higher than for higher education. At the 95% confidence interval, the sum of η and α of some indicators will be near or bigger than 1. This result means that there were increasing returns when the poor countries invested in secondary education in the

catching-up process.

In the real world, the "Four Tigers" had a faster growth rate for secondary education in the early development period. As we discussed before, because there is a binding constraint for financing human capital, poorer countries had not more money to invest in higher education, especially in the early part of the convergence process (1960 to 1975 in this study). Since the opportunity cost of investing in secondary education is less than that in higher education, the strategy of emphasising secondary education in the early development period in the "Four Tigers" led to the accumulation of human capital (for example, the necessary labour skills for producing goods for exportation) in the short term. As we see in Table 5.7, the "Four Tigers" experienced the increasing returns on their investment in secondary education, especially in the male population.

In Mankiw's (1995) estimation, the human capital share is about 0.5. In Coulombe and Tremblay's (2000) study, the income (minus transfers) elasticity of human capital based on a university degree is between 0.42 and 0.59. In Table 5.7, the interesting finding is that the human capital share for higher education ranges from 0.27 to 0.33 and for at least secondary education ranges from 0.46 to 0.88 (based on 95% confidence intervals).

Now we can go back to see the problem encountered by the neo-classical growth model, which is the discrepancy between theoretical predictions and the international data. The reason may be that the neo-classical growth model just considers physical capital. If we consider the benchmark $\alpha = 0.33$, then the broader capital share will be α plus η, and from this empirical study the capital share is between 0.60 and 0.66 (just considering the higher education). According to Mankiw (1995), if we want to reconcile the neo-classical model with stylized facts,

the broader share of capital should be 0.8.

Table 5.7 Share of Human Capital in GDP in 10 Countries (1960-1990)

	Measures of GDP and Human Capital Indicators					
	Relative Levels of the Percentage who have attained at least Secondary School			Relative Levels of the Percentage who have attained Higher School		
	A	B		A	B	
Total	0.8862	0.5937		0.4631	0.3103	
	0.0315	0.5496	0.6377	0.0157	0.2883	0.3323
	0.9108			0.6971		
Males	1.1312	0.7579		0.4509	0.3021	
	0.0881	0.6344	0.8813	0.0205	0.2733	0.3308
	0.6907			0.5778		
Females	0.7329	0.4910		0.4407	0.2953	
	0.0255	0.4553	0.52673	0.0149	0.2744	0.3162
	0.9181			0.8009		

Observations: 70 panel
Estimating Equation: equation (3)
Note: The numbers in column A are the estimated coefficients of the logarithm of the human capital indicator. Below these are the standard deviations and the third row is the adjusted R-squared. The numbers in column B are the human capital share of GDP. Below these are the confidence intervals (95%) for the share of human capital. **(α = 0.33)**

6. GDP Growth and Human Capital Contribution

Now, let's take a more direct look at the relationship between GDP growth and human capital. Using equation (4), we can regress the growth rate of per capita GDP on the initial level of human capital. The results are presented in Table 5.8.

For all six coefficient estimates, we can reject the null hypothesis that coefficient estimates are equal to zero ($c = 0$) at the 5 percent level, which means that the growth rate of per capita GDP is significantly related to the initial level of these indicators of human capital.

Comparing Table 5.8 with Table 5.5, we find that the R-squares from the regressions of GDP growth rate on the initial level of human capital are about 60%-90% of the R-squared in Table 5.5. Therefore, the initial level of human capital explains less of the growth rate of GDP than does the initial level of GDP. Look back to our two key assumptions in this model: perfect mobility of physical capital and credit constraint on human capital. In real world, these assumptions are not so perfectly satisfied.

Table 5.8 Regression of the growth rate of GDP on the initial level of human capital

	Measures of GDP and Human Capital Indicators	
	Relative Level of the Percentage who have attained at least Secondary School	Relative Level of the Percentage who have attained Higher School
Total	-0.099 (R1)	-0.076 (R1)
	0.017	0.004
	0.363	0.553
Males	-0.100 (R1)	-0.085 (R1)
	0.024	0.005
	0.227	0.530
Females	-0.093 (R1)	-0.064 (R1)
	0.013	0.003
	0.475	0.578

Observations: 60 panel

Estimating Equation: equation (5)

Note: The numbers in the first row are the estimated coefficients of the logarithm of the human capital indicator. The numbers in the second row are standard deviations and the third row is the adjusted R-squared.

R1: Reject the Null Hypothesis that coefficient estimates are equal to zero (c = 0) at confidence of 95%

7. Comparison of this case with Coulombe and Tremblay's (2000) study

In section V.1 to V.6, we directly applied the empirical analysis of Coulombe and Tremblay (2000) to the convergence process of the "Four Tigers" and six other countries. Although their analysis is to test the open economy growth model of Barro, Mankiw and Sala-i-Martin (1995) across the ten Canadian provinces during the 1951-1996 period, most of the results of my case are very close to their study.

Table 5.9 Comparison of this case with Coulombe and Tremblay's (2000) study

Studies	Coulombe and Tremblay (2000)	This Study
Economies	10 Provinces of Canada	the "Four Tigers" and other six countries
Period	1951-1996	1960-1990
Indicators of Human Capital	"the percentage of the population (15-years and over, 15 to 24 years and 25-years and over, for males, females and population of both sexes) who have at least achieved two alternative benchmark levels of education: Grade 9 and a university degree" (Coulombe and Tremblay, 2000, Section 3.2)	the percentage of at least secondary school attained and higher school attained of the population (25-years and over, for males, females and total population)
Main Results (25-years and Over)	Convergence speed of income per person minus government transfers to persons: **0.020**	Convergence speed of per capita GDP: **0.027**
	Convergence speeds of human capital indicators: at least Grade 9 university degree Both: **0.030** **0.029** Males: **0.028** **0.025** Females: **0.029** **0.040**	Convergence speeds of human capital indicators: at least secondary higher education Both: **0.034** **0.033** Males: **0.053** **0.028** Females: **0.033** **0.028**

(Table 5.9 continued)

Main Results (25-years and Over)	Wald Statistics for the Comparison between Convergence speeds of human capital indicators and Personal Income (minus government transfers): at least Grade 9 university degree Both: **7** **2.9** Males: **3.3** **1** Females: **7** **16**	Wald Statistics for the Comparison between Convergence speeds of human capital indicators and per capita GDP: at least secondary higher education Both: **0.77** **0.33** Males: **4.53** **0.01** Females: **0.71** **0.03**
	Share of Human Capital in National Income (Personal Income minus government transfers): at least Grade 9 university degree Both: **1.01** **0.52** Males: **0.93** **0.51** Females: **0.96** **0.44**	Share of Human Capital in National Income (Per Capital GDP): at least secondary higher education Both: **0.59** **0.31** Males: **0.76** **0.30** Females: **0.49** **0.29**

Source: The data are taken from Coulombe and Tremblay (2000), Table 2, Table 6 and Table 7.

In general, from Table 5.9, we can see that the results of this study are very close to the results of Coulombe and Tremblay's (2000) study (here we just consider human capital indicators for the age group 25-years and over). First, most of the convergence speeds of per capita income (here we just consider the measures excluding government transfers to persons in the Canadian case) and human capital indicators in their study and this study lay in the theoretical interval (0.014- 0.035). Second, 3 human capital indicators used in their study and 5 of the indicators used in this study are consistent with the framework of Barro, Mankiw and Sala-i-Martin (1995), which proposed that there should be no significant difference between the

speeds of convergence of the income and human capital indicators. Third, both their study and this study concluded that there are some indicators (relating to secondary education) for which sum of the shares of human capital and physical capital is greater than 1. Although they suggested that "this does not mean however that increasing public investment in basic education will generate increasing returns to scale" (Coulombe and Tremblay, working paper version of the 2000 paper, 19) since today every Canadian can reach Grade 9, I think that this is not the case in the developing countries or in their development process. For example, as we mentioned before, the rapid economic growth in the "Four Tigers" actually benefited from the increased investment in secondary education, especially in the early part of the catching-up process.

Since Coulombe and Tremblay (2000) focused on the provinces of Canada but this study considers the international case, there are some differences in the basic conditions in the two studies. For example, migration (one type of human capital) across provinces in Canada is definitely easier than across the ten countries in this study. Furthermore, the difference in economic systems, language, culture and even the climate across provinces in Canada is less than across the ten countries in this study. These differences in the background in the two studies lead to the different impacts on the assumptions of the model and also affect the explanatory power of the model.

VI. Conclusion and Further Discussion

There is no miracle in Asia.

Any growth and development has its explanations and patterns. Human capital growth over the past decades is the most important driving force of the economic growth of the " Four Tigers". This empirical study indicates that human capital convergence between the four new industrial economies and six advanced industrial countries can explain a substantial part of the convergence of per capita GDP across these economies from 1960 to 1990.

In this study, we discussed the convergence patterns of six indicators of human capital and per capita GDP. We computed the various convergence speeds and found that 5 indicators satisfied Barro, Mankiw and Sala-i-Martin's framework (1995), which implies that the convergence speed of human capital is equal to the convergence speed of per capita GDP. The estimates of the human capital share in per capita GDP for higher education are between 0.27 and 0.33. By regressing the GDP growth rate on the initial level of human capital, we found that all six indicators of human capital can be used to explain the substantial part of the growth of per capita GDP across ten economies from 1960 to 1990.

From 1960 to 1990, the "Four Tigers" successfully finished the catching-up process for secondary education, and this should be the recipe for the "miracle" image. But the relatively slower convergence speed for indicators of attainment of higher education in these countries may affect them in the human capital race in the future. After the perfect convergence of secondary education, improving investment in higher education might be the driving force of economic growth for those new industrial countries.

The limit of this model is that it is difficult to measure human capital. As we discussed in Section IV, the simplified indicators (in this paper is the percentage of school attained) necessarily limit the explanatory power of this model. We excluded health indicators, on-the-job-training indicators and other relevant human capital indicators just because these indicators are difficult to obtain. But as mentioned before, these factors are very important and have become more and more important over time. For example, on-the-job-training is emphasized not only in developed countries but also in developing countries in recent years, and there are more and more investments in job training. For the "Four Tigers", since most technologies are imported from advanced countries in the catching-up process, we can say that on-the-job-training had a special importance for their economic development. Better health, lower fertility rates, and higher participation rate of women in the labor market also contribute to human capital in the "Four Tigers".

As many researchers suggested, quality indicators of education (for example, scores on international examinations) are very important measures of human capital. Since data on the quality of education is not available for the "Four Tigers", I ignored this variable in this study. However, we should consider that quality of education to be a factor affecting human capital formation.

Furthermore, when we look back the two key assumptions in this model (perfect mobility of physical capital and credit constraint on human capital), we should consider that these assumptions are not perfectly satisfied. First, there were some limits on capital flows in the "Four Tigers" during the first ten years of the sample period (1960s). As we discussed in Section II, Korea and Taiwan placed strict limits on the export of capital when there was a shortage of

capital for local investment, and domestic savings and investment in the four economies is significantly higher than in other economies. Second, there is no perfectly binding constraint on human capital accumulation in these ten countries. As some researchers have proposed, U.S. aid to Korea and Taiwan are very important for their economic development. This aid includes some human capital flows (for example, technology training across countries, financing students of these countries to study in U.S., and foreign experts helps). Therefore, the two key assumptions in this model are not perfectly satisfied for this case study, and these limits also affected the results.

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Figure 1. SD Convergence of Relative Levels

(the Percentage who have attained at least Secondary School)

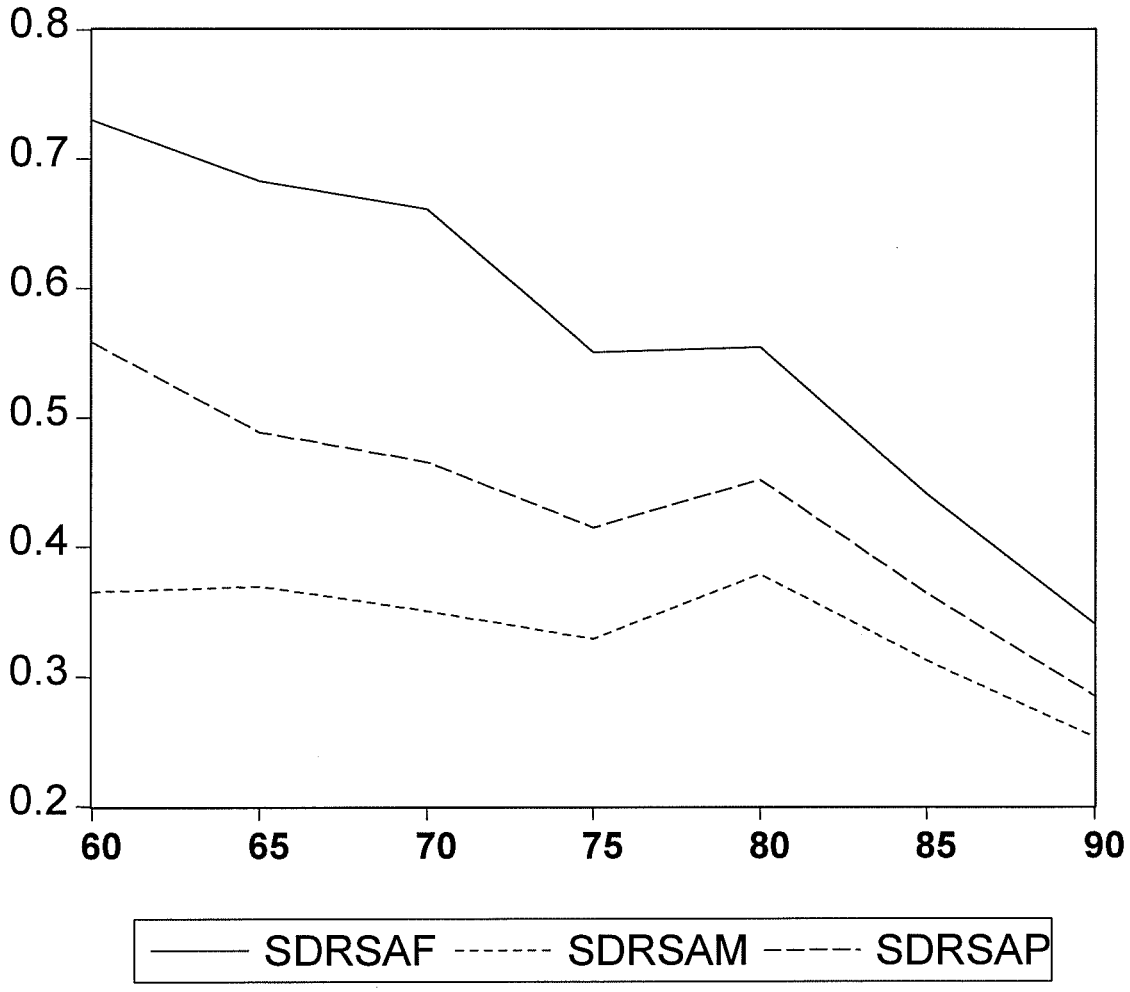


Figure 2. SD Convergence of Relative Levels

(the Percentage who have attained Higher School)

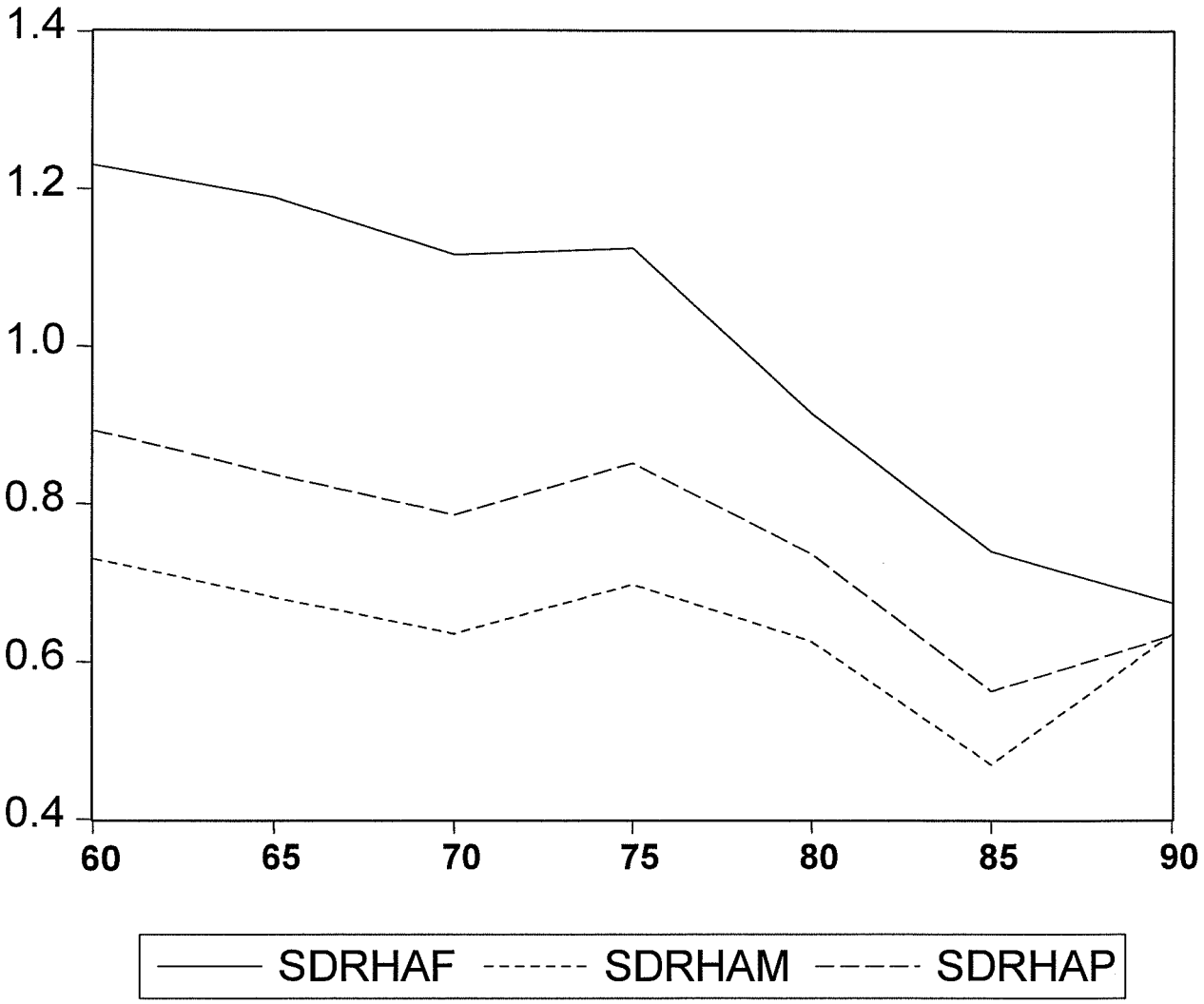


Figure 3. Comparison of SD Convergence Between at least Secondary and Higher School Attained Indicator

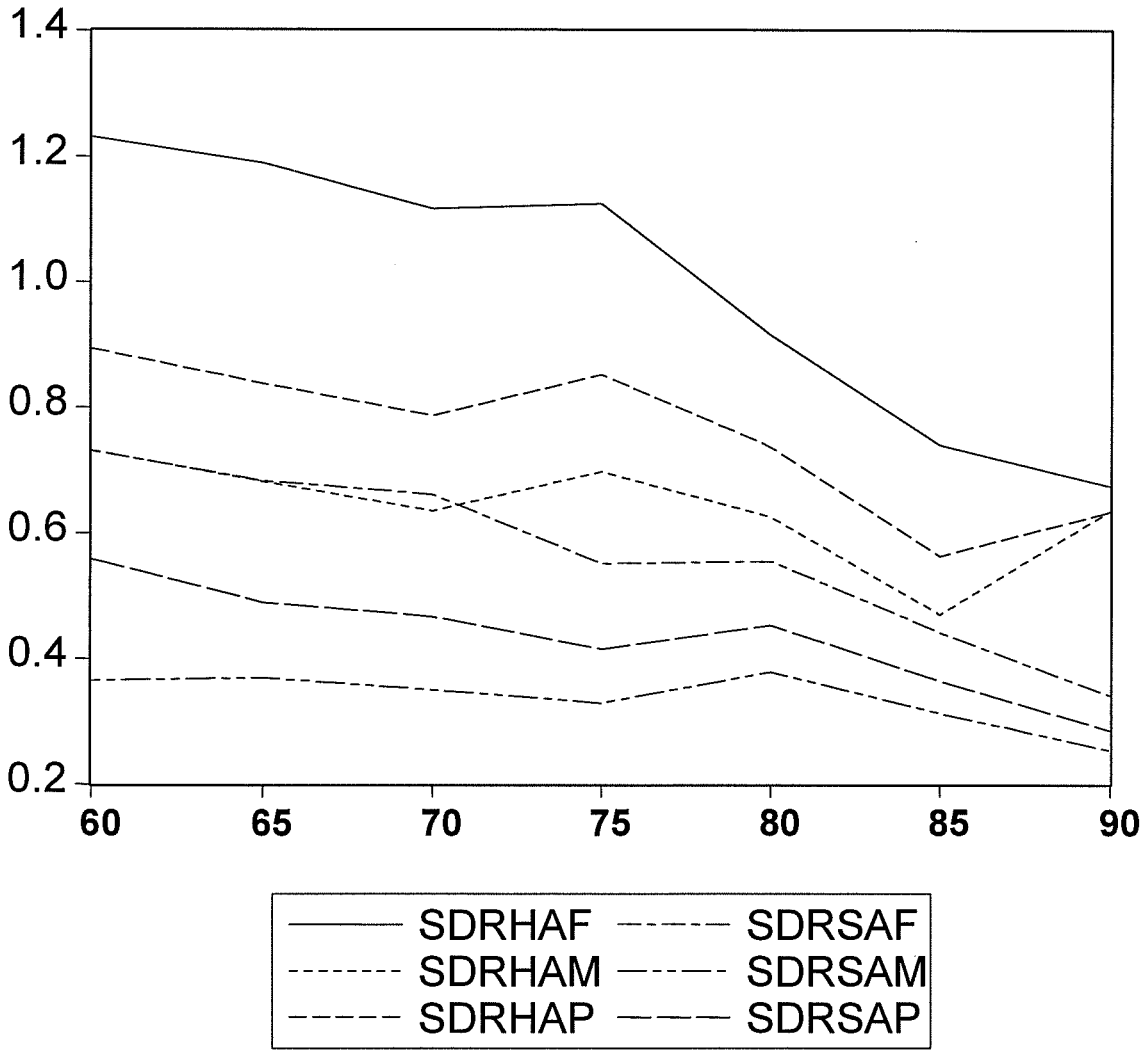


Figure 4. Convergence of Relative Levels
(the Percentage who have attained at least Secondary School in the Total Population)

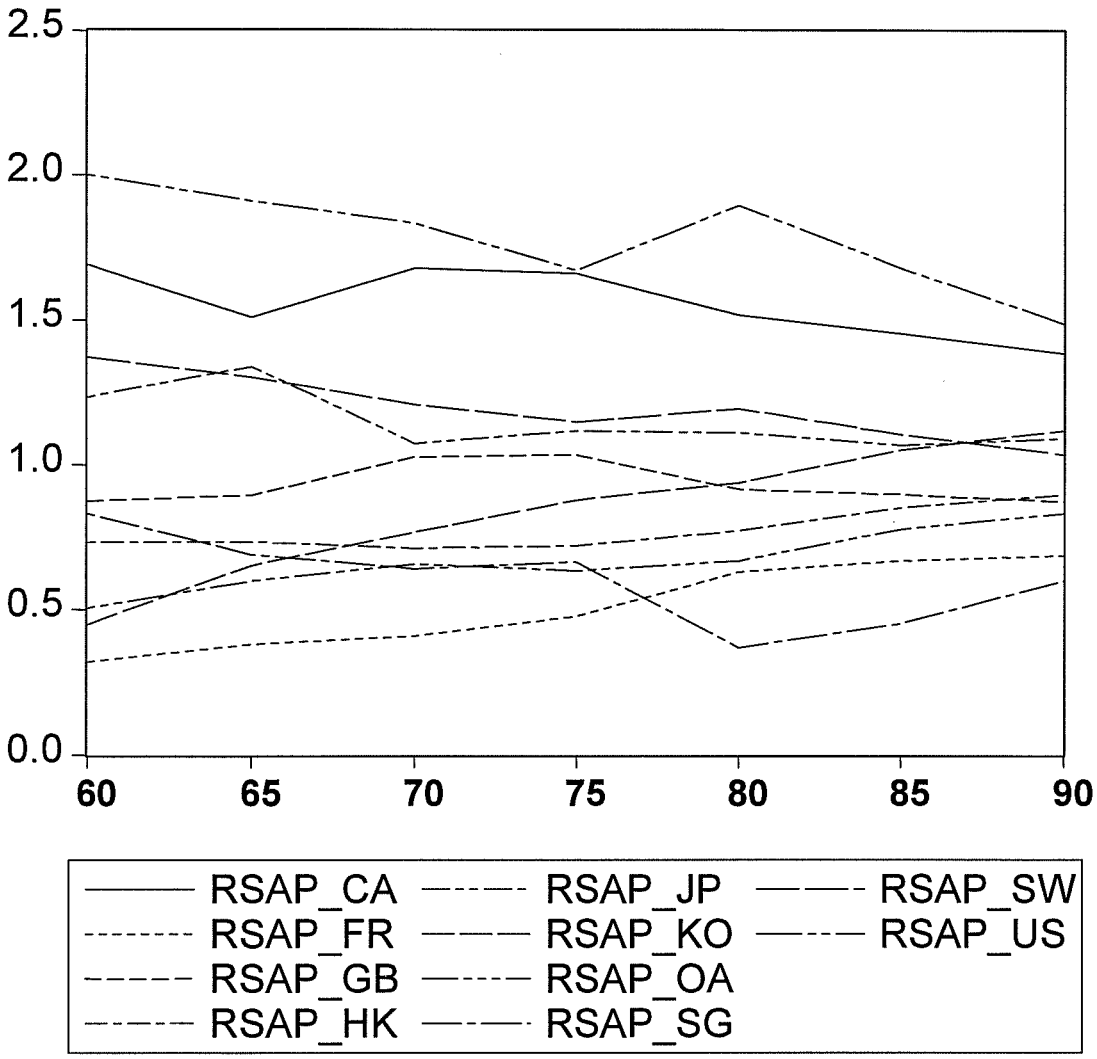


Figure 5. Convergence of Relative Levels
(the Percentage who have attained at least Secondary School
In the Male Population)

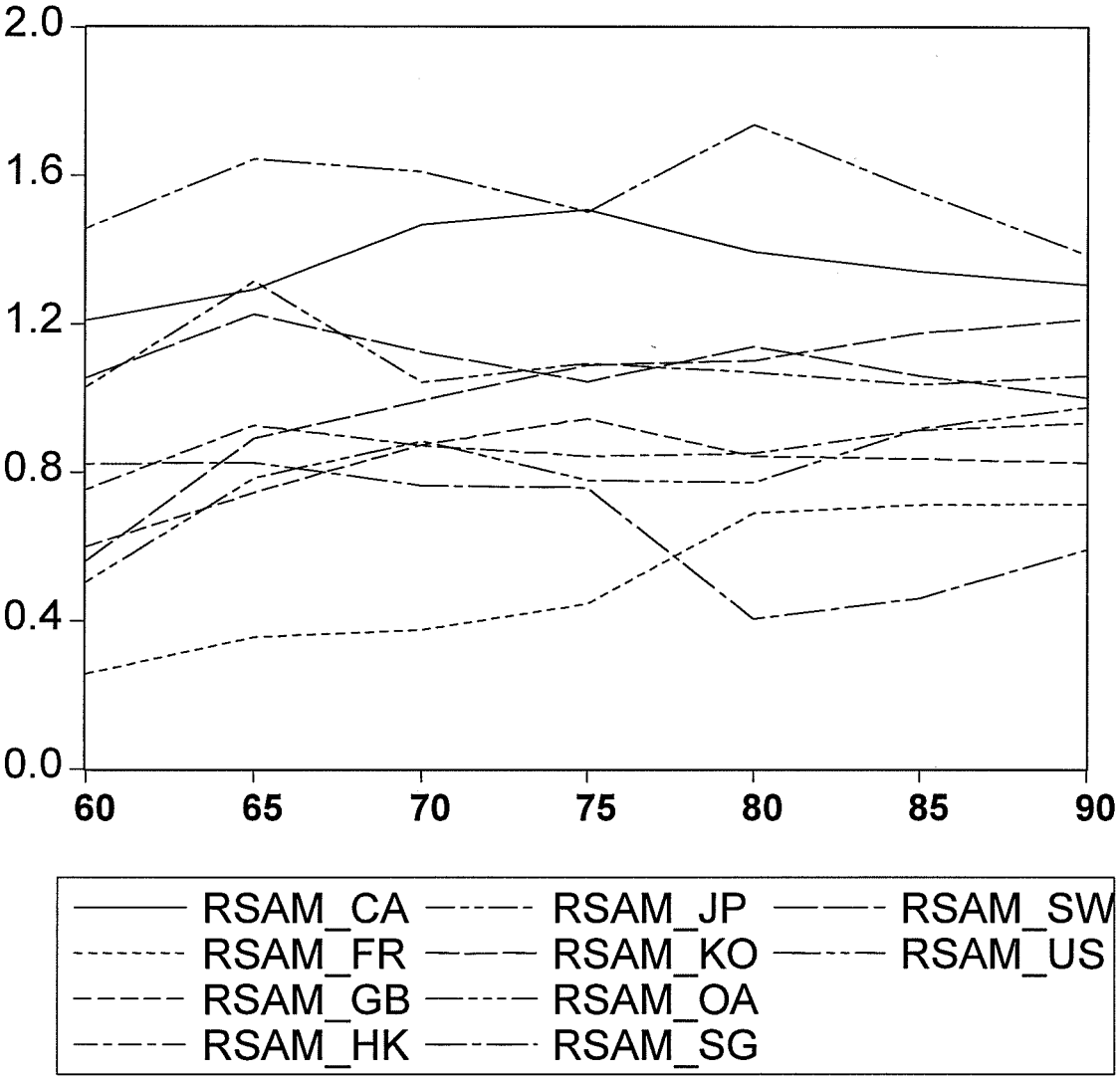


Figure 6. Convergence of Relative Levels
(the Percentage who have attained at least Secondary School
in the Female Population)

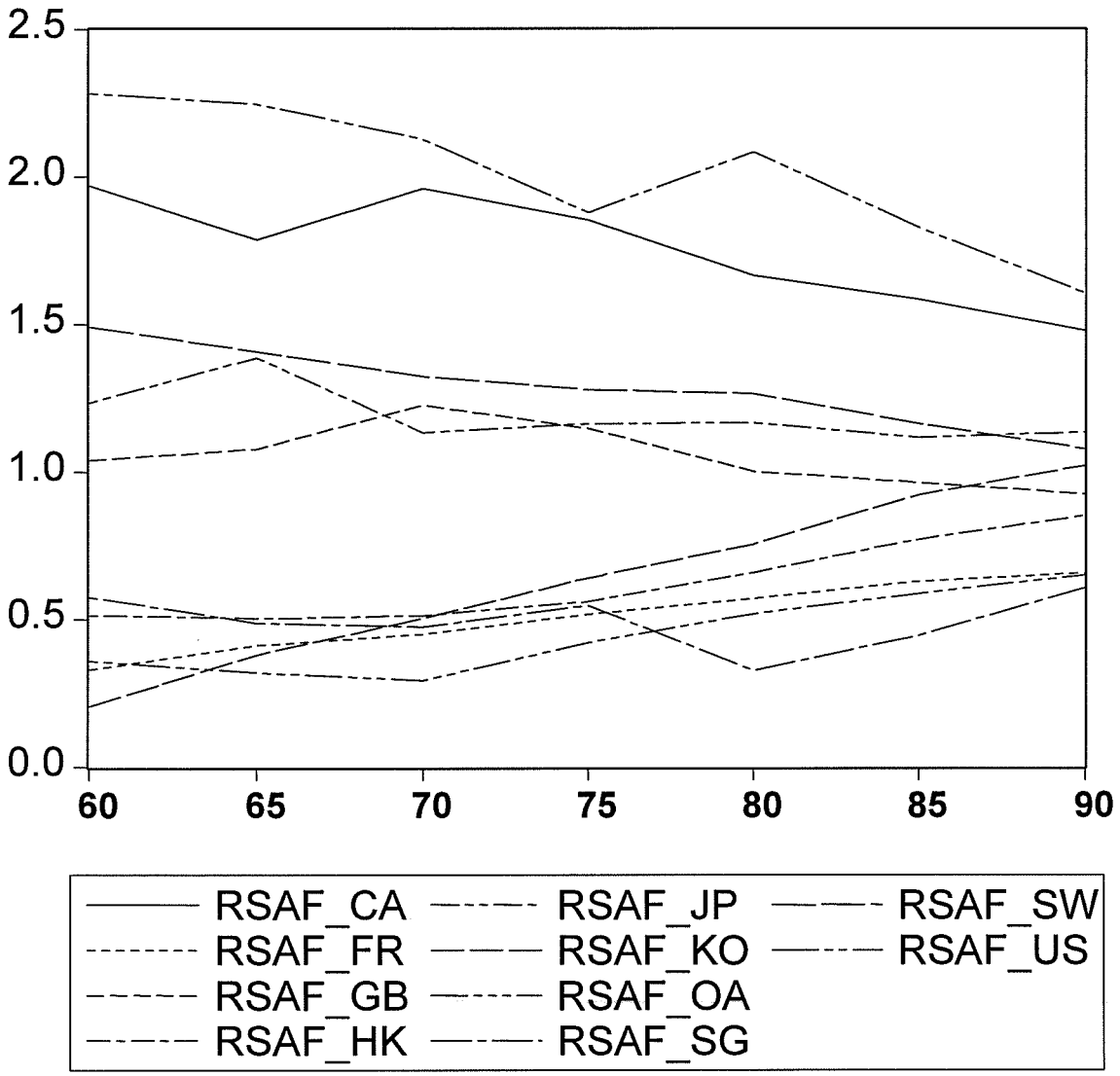


Figure 7. Convergence of Relative Levels

(the Percentage who have attained Higher School
in the Total Population)

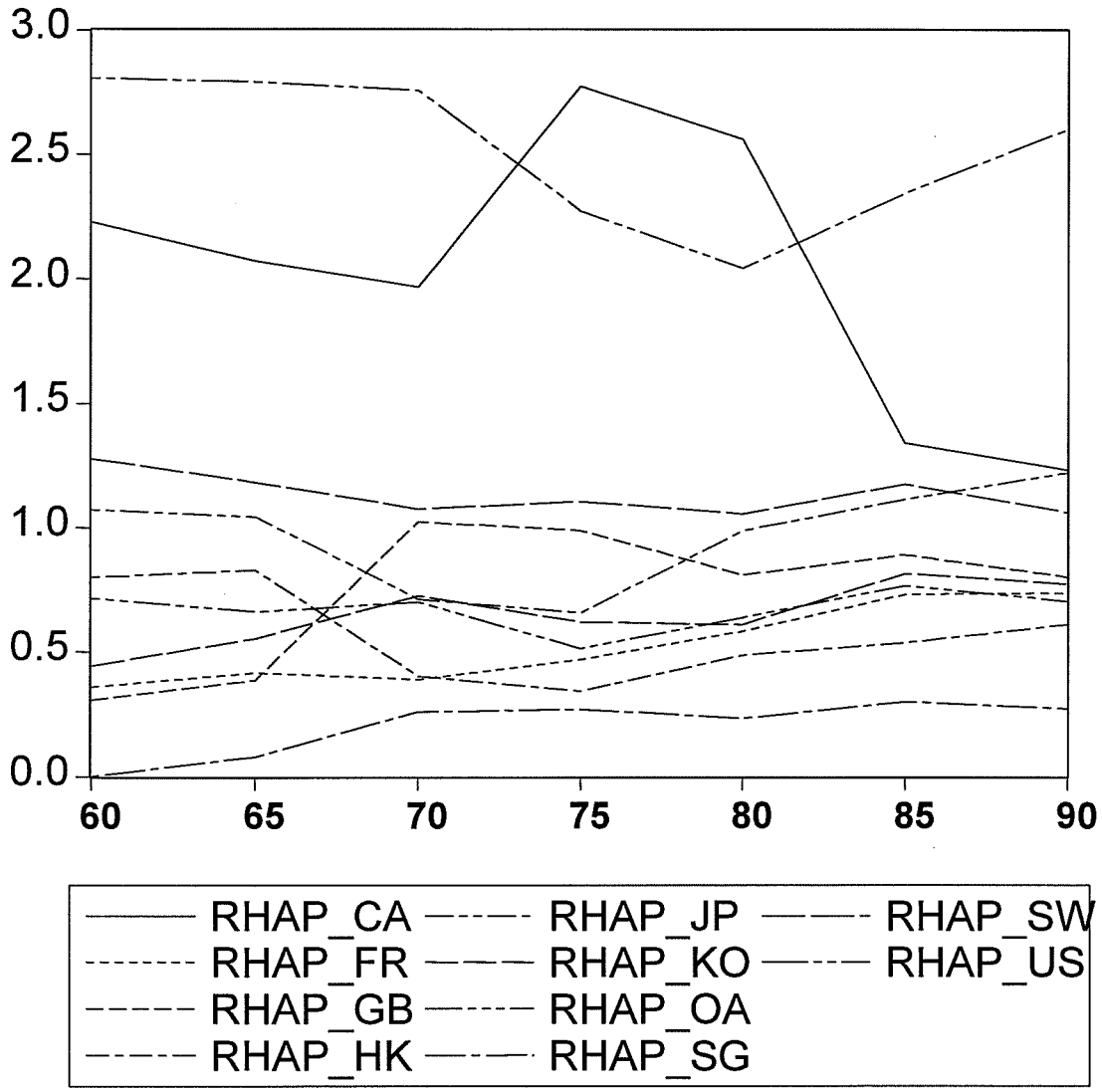


Figure 8. Convergence of Relative Levels

(the Percentage who have attained Higher School
in the Male Population)

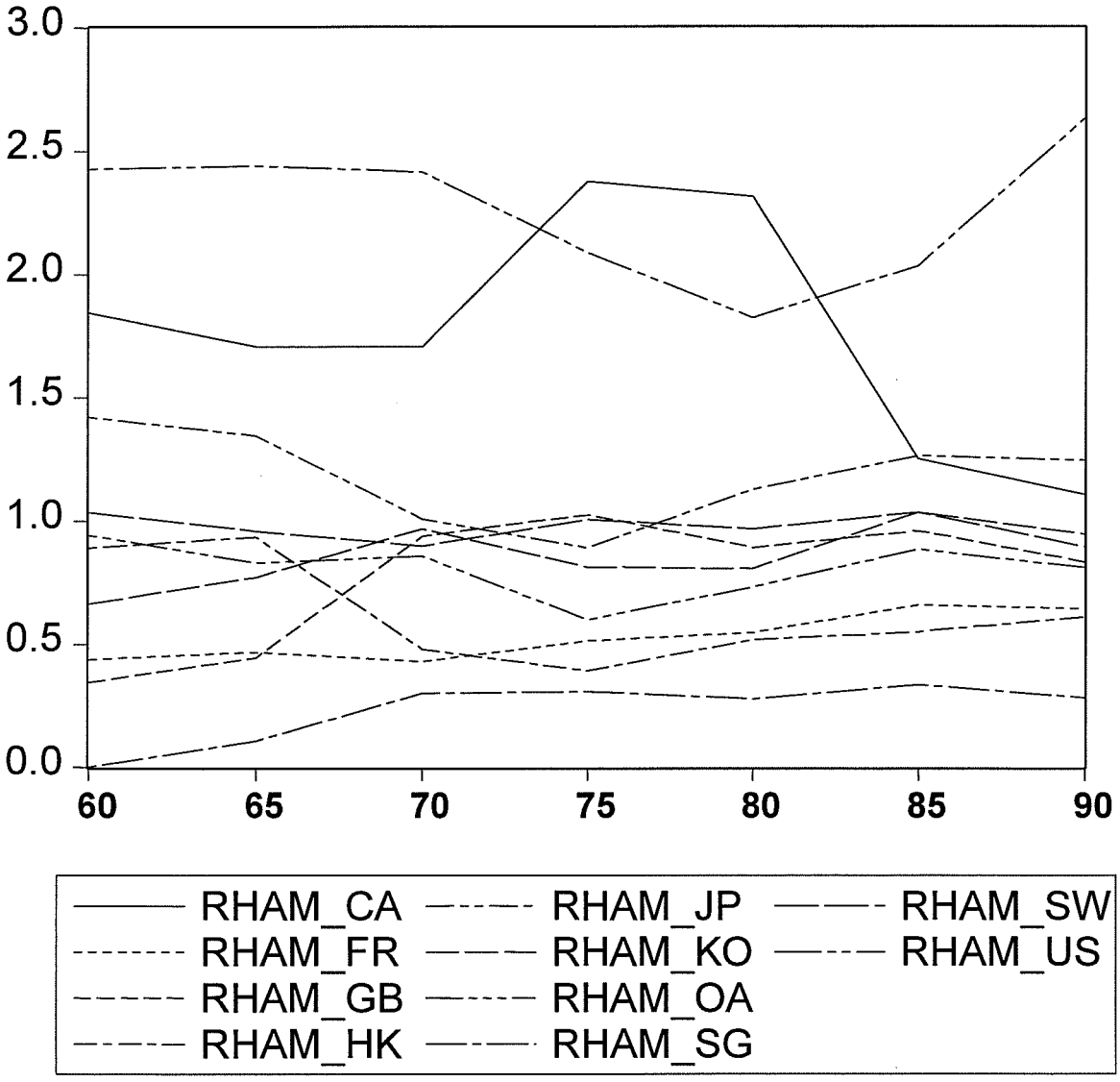


Figure 9. Convergence of Relative Levels

(the Percentage who have attained Higher School
in the Female Population)

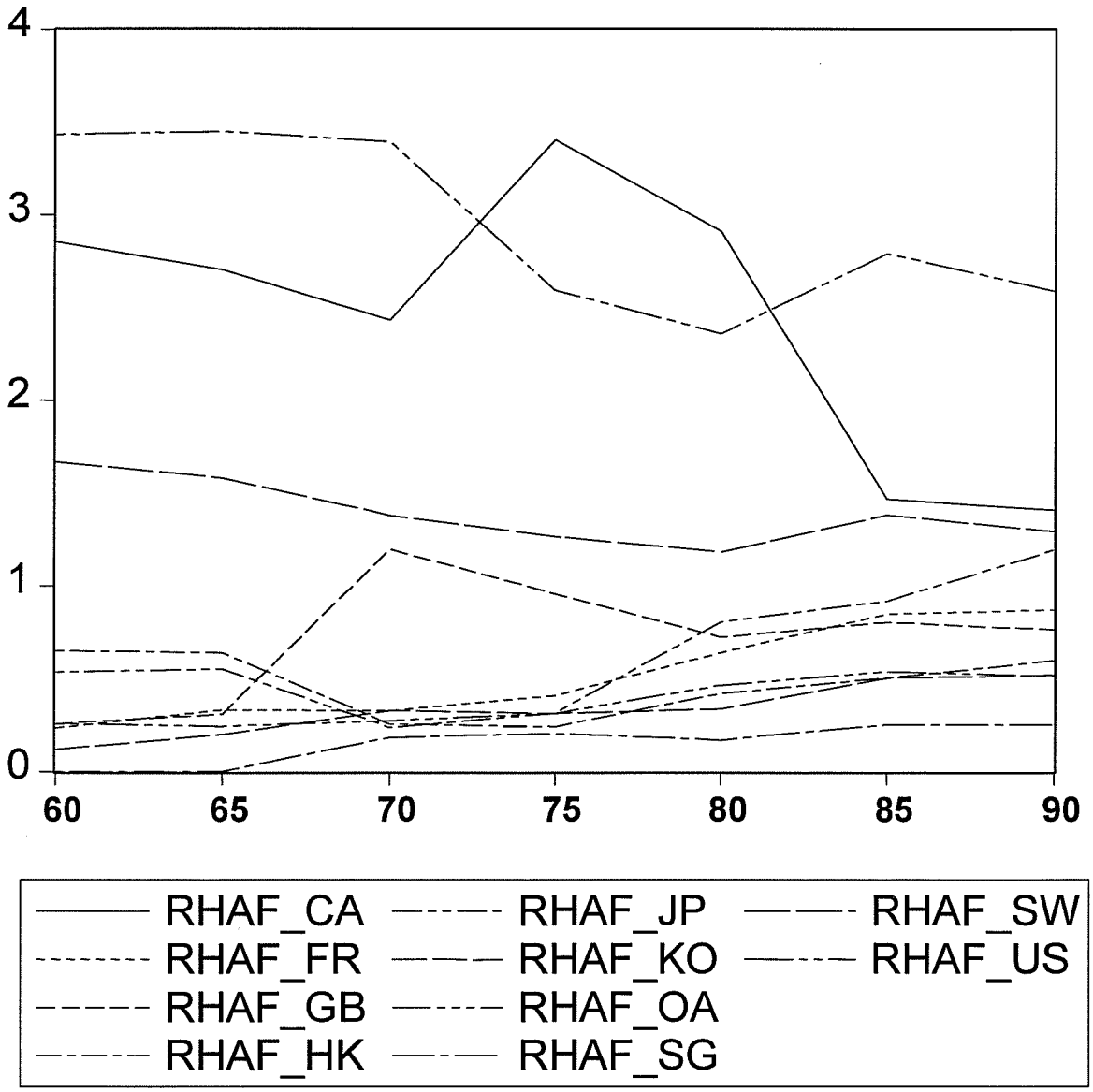
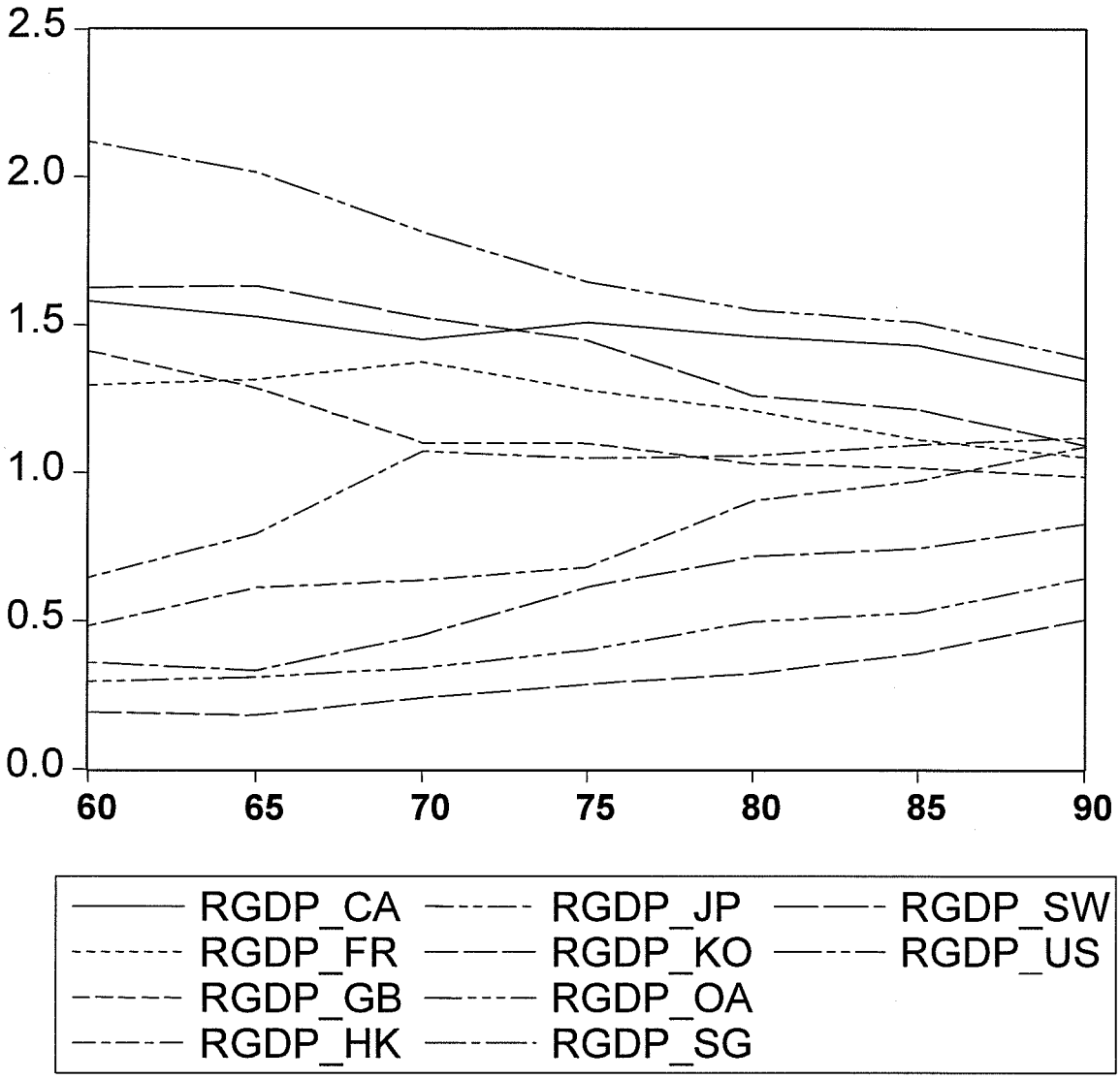


Figure 10. Convergence of Relative Level
(Per Capita GDP)



Appendix 1: Human Capital and Economic Growth Data Set

Source: Barro and Lee Data Set (1996)

obs	SP	HAP	SAP	SM	HAM	SAM	SF	HAF	SAF
CA-1	37.9	13.1	51	34.4	13.9	48.3	41.5	12.3	53.8
CA-2	35.5	13.5	49	32.4	14.6	47	38.6	12.3	50.9
CA-3	45	15.2	60.2	41.7	17.1	58.8	48.2	13.4	61.6
CA-4	36.6	30.9	67.5	33.7	33.4	67.1	39.4	28.5	67.9
CA-5	36.8	37.4	74.2	33.8	40.3	74.1	39.6	34.7	74.3
CA-6	59.5	19.3	78.8	56.5	21.7	78.2	62.3	17	79.3
CA-7	62	21.4	83.4	60.2	23.3	83.5	63.7	19.6	83.3
US-1	43.8	16.5	60.3	39.9	18.3	58.2	47.5	14.8	62.3
US-2	43.8	18.2	62	38.9	20.9	59.8	48.3	15.7	64
US-3	44.4	21.3	65.7	40.3	24.2	64.5	48.1	18.7	66.8
US-4	42.6	25.3	67.9	37.5	29.3	66.8	47.1	21.7	68.8
US-5	62.9	29.8	92.7	60.7	31.7	92.4	64.9	28.1	93
US-6	57.4	33.7	91.1	55.5	35.2	90.7	59.2	32.3	91.5
US-7	44.4	45.2	89.6	33.3	55.4	88.7	54.4	36	90.4
HK-1	17.3	4.7	22	23.4	6.7	30.1	11.2	2.8	14
HK-2	18.4	5.4	23.8	25.7	8	33.7	11.4	2.9	14.3
HK-3	22.3	3.1	25.4	30.1	4.8	34.9	14.7	1.4	16.1
HK-4	25.4	3.8	29.2	32	5.5	37.5	18.5	2	20.5
HK-5	30.5	7.1	37.6	36.2	9	45.2	24.3	5	29.3
HK-6	38.3	7.7	46	43.7	9.5	53.2	32.7	5.8	38.5
HK-7	43.3	10.6	53.9	46.8	12.8	59.6	39.6	8.3	47.9
JP-1	30.9	6.3	37.2	30.4	10.7	41.1	31.4	2.3	33.7
JP-2	36.7	6.8	43.5	36.3	11.5	47.8	37	2.5	39.5
JP-3	33	5.5	38.5	31.6	10.1	41.7	34.3	1.3	35.6
JP-4	38.1	7.3	45.4	36.1	12.5	48.6	40	2.6	42.6
JP-5	39.9	14.4	54.3	37.2	19.6	56.8	42.4	9.6	52
JP-6	41.9	16	57.9	38.4	21.9	60.3	45.2	10.6	55.8
JP-7	44.5	21.2	65.7	41.5	26.2	67.7	47.3	16.6	63.9
OA-1	11	4.2	15.2	13	7.1	20.1	8.7	1.1	9.8
OA-2	15.1	4.3	19.4	21.4	7.1	28.5	8	1.1	9.1
OA-3	18.1	5.4	23.5	26.8	8.6	35.4	7.7	1.5	9.2
OA-4	20	5.7	25.7	26.2	8.4	34.6	12.8	2.6	15.4
OA-5	23.3	9.3	32.6	28.3	12.7	41	17.6	5.5	23.1
OA-6	31	11	42	38.2	15.3	53.5	23.1	6.2	29.3
OA-7	37.7	12.2	49.9	45.3	17	62.3	29.5	7.1	36.6
KO-1	10.9	2.6	13.5	17.4	5	22.4	5.1	0.5	5.6

obs	SP	HAP	SAP	SM	HAM	SAM	SF	HAF	SAF
KO-2	17.5	3.6	21.1	25.8	6.6	32.4	9.9	0.9	10.8
KO-3	21.8	5.6	27.4	30.1	9.7	39.8	14	1.8	15.8
KO-4	28.7	6.9	35.6	37	11.4	48.4	20.8	2.6	23.4
KO-5	36.9	8.9	45.8	44.5	14	58.5	29.6	4	33.6
KO-6	45.3	11.7	57	50.6	17.9	68.5	40.3	5.8	46.1
KO-7	53.9	13.4	67.3	57.6	19.9	77.5	50.3	7.2	57.5
SG-1	25	0	25	32.8	0	32.8	15.7	0	15.7
SG-2	21.8	0.5	22.3	29.1	0.9	30	13.9	0	13.9
SG-3	20.9	2	22.9	27.6	3	30.6	13.9	1	14.9
SG-4	23.9	3	26.9	29.4	4.3	33.7	18.3	1.7	20
SG-5	14.6	3.4	18	16.7	4.8	21.5	12.5	2	14.5
SG-6	20.1	4.3	24.4	21	5.8	26.8	19.3	2.9	22.2
SG-7	31.3	4.7	36	31.9	5.9	37.8	30.7	3.5	34.2
FR-1	7.5	2.1	9.6	6.9	3.3	10.2	8	1	9
FR-2	9.6	2.7	12.3	8.9	4	12.9	10.2	1.5	11.7
FR-3	11.6	3	14.6	10.7	4.3	15	12.3	1.8	14.1
FR-4	14.1	5.2	19.3	12.6	7.2	19.8	15.5	3.4	18.9
FR-5	22.2	8.5	30.7	27.1	9.5	36.6	17.8	7.6	25.4
FR-6	25.6	10.5	36.1	30.1	11.4	41.5	21.6	9.8	31.4
FR-7	28.4	12.8	41.2	32.2	13.5	45.7	24.9	12.1	37
SW-1	33.9	7.5	41.4	34.3	7.8	42.1	33.5	7.2	40.7
SW-2	34.6	7.7	42.3	36.4	8.2	44.6	32.9	7.2	40.1
SW-3	35	8.3	43.3	36	9	45	34	7.6	41.6
SW-4	34.3	12.3	46.6	32.3	14.1	46.4	36.2	10.6	46.8
SW-5	43	15.4	58.4	43.7	16.8	60.5	42.3	14.1	56.4
SW-6	43	16.9	59.9	43.8	17.9	61.7	42.2	16	58.2
SW-7	43.9	18.4	62.3	45.2	18.8	64	42.7	18	60.7
GB-1	24.5	1.8	26.3	21.3	2.6	23.9	27.3	1.1	28.4
GB-2	26.5	2.5	29	23.3	3.8	27.1	29.3	1.4	30.7
GB-3	28.9	7.9	36.8	25.6	9.4	35	31.9	6.6	38.5
GB-4	31	11	42	27.6	14.4	42	34	8	42
GB-5	32.9	11.8	44.7	29.3	15.5	44.8	36	8.6	44.6
GB-6	35.7	12.8	48.5	32.1	16.6	48.7	38.9	9.3	48.2
GB-7	38.5	13.9	52.4	35.3	17.5	52.8	41.5	10.6	52.1

Sources: www.worldbank.org/research/growth/ddbarle2.htm

Note: (1) 1-7 represent 1960,1965,1970,1875,1980,1985 and 1990, respectively. (2) SP, SM and SF are the percentage of secondary school attained for the Total Population, Males and Females. HAP, HAM and HAF are the percentage of higher school attained for the Total population, Males and Females. SAP, SAM and SAF are the percentage of at least secondary school attained for the Total population, Males and Females.

Appendix 2: Result Reports Using EView

1. Relative level of Per capita GDP

Dependent Variable: YRGDP_?
Method: GLS (Cross Section Weights)
Date: 06/23/00 Time: 14:36
Sample: 1 6
Included observations: 6
Total panel (balanced) observations 60
Convergence achieved after 4 iteration(s)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOG(RGDP_?)	-0.125666	0.013712	-9.164898	0.0000

Weighted Statistics			
R-squared	0.587039	Mean dependent var	-0.004315
Adjusted R-squared	0.587039	S.D. dependent var	0.147337
S.E. of regression	0.094682	Sum squared resid	0.528917
Durbin-Watson stat	1.569259		

Note: YRGDP= Ln ($RGDP_{i, t+p}$ / $RGDP_{i, t}$)

2. Relative level of the percentage who have attained at least secondary school in the total population

Dependent Variable: YRSAP_?
Method: GLS (Cross Section Weights)
Date: 06/29/00 Time: 17:12
Sample: 1 6
Included observations: 6
Total panel (balanced) observations 60
Convergence achieved after 4 iteration(s)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOG(RSAP_?)	-0.156497	0.022566	-6.935167	0.0000

Weighted Statistics			
R-squared	0.430904	Mean dependent var	0.028941
Adjusted R-squared	0.430904	S.D. dependent var	0.160607
S.E. of regression	0.121160	Sum squared resid	0.866099
Durbin-Watson stat	1.904624		

Note:YRSAP= Ln ($RSAP_{i, t+p}$ / $RSAP_{i, t}$)

3. Relative level of the percentage who have attained at least secondary school in the male population

Dependent Variable: YRSAM_?
Method: GLS (Cross Section Weights)

Date: 06/29/00 Time: 17:15
Sample: 1 6
Included observations: 6
Total panel (balanced) observations 60
Convergence achieved after 6 iteration(s)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOG(RSAM_?)	-0.232271	0.042161	-5.509161	0.0000

Weighted Statistics			
R-squared	0.269370	Mean dependent var	0.055594
Adjusted R-squared	0.269370	S.D. dependent var	0.171807
S.E. of regression	0.146855	Sum squared resid	1.272417
Durbin-Watson stat	1.598713		

Note:YRSAM= Ln ($RSAM_{i, t+p}$ / $RSAM_{i, t}$)

4. Relative level of the percentage who have attained at least secondary school in the female population

Dependent Variable: YRSAF_?
Method: GLS (Cross Section Weights)
Date: 06/29/00 Time: 17:17
Sample: 1 6
Included observations: 6
Total panel (balanced) observations 60
Convergence achieved after 2 iteration(s)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOG(RSAF_?)	-0.151141	0.013510	-11.18696	0.0000

Weighted Statistics			
R-squared	0.667402	Mean dependent var	0.046714
Adjusted R-squared	0.667402	S.D. dependent var	0.241380
S.E. of regression	0.139207	Sum squared resid	1.143336
Durbin-Watson stat	1.748370		

Note:YRSAF = Ln ($RSAF_{i, t+p}$ / $RSAF_{i, t}$)

5. Relative level of the percentage who have attained higher school in the total population

Dependent Variable: YRHAP_?
Method: GLS (Cross Section Weights)
Date: 09/03/00 Time: 15:03
Sample: 1 6
Included observations: 6
Total panel (unbalanced) observations 59
Convergence achieved after 6 iteration(s)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOG(RHAP_?)	-0.151361	0.035850	-4.222019	0.0001

Weighted Statistics			

R-squared	0.217489	Mean dependent var	0.043173
Adjusted R-squared	0.217489	S.D. dependent var	0.287094
S.E. of regression	0.253962	Sum squared resid	3.740814
Durbin-Watson stat	2.121939		

Note:YRHAP= Ln ($RHAP_{i,t+p}$ / $RHAP_{i,t}$)

6.Relative level of the percentage who have attained higher school in the male population

Dependent Variable: YRHAM_?
Method: GLS (Cross Section Weights)
Date: 09/03/00 Time: 15:05
Sample: 1 6
Included observations: 6
Total panel (unbalanced) observations 59
Convergence achieved after 6 iteration(s)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOG(RHAM_?)	-0.131292	0.040680	-3.227462	0.0021

Weighted Statistics			
R-squared	0.145007	Mean dependent var	0.022640
Adjusted R-squared	0.145007	S.D. dependent var	0.247002
S.E. of regression	0.228393	Sum squared resid	3.025471
Durbin-Watson stat	2.068500		

Note:YRHAM= Ln ($RHAM_{i,t+p}$ / $RHAM_{i,t}$)

7.Relative level of the percentage who have attained higher school in the female population

Dependent Variable: YRHAF_?
Method: GLS (Cross Section Weights)
Date: 09/03/00 Time: 15:06
Sample: 1 6
Included observations: 6
Total panel (unbalanced) observations 58
Convergence achieved after 7 iteration(s)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOG(RHAF_?)	-0.132204	0.026204	-5.045169	0.0000

Weighted Statistics			
R-squared	0.268617	Mean dependent var	0.089608
Adjusted R-squared	0.268617	S.D. dependent var	0.375370
S.E. of regression	0.321020	Sum squared resid	5.874077
Durbin-Watson stat	2.087683		

Note:YRHAF= Ln ($RHAF_{i,t+p}$ / $RHAF_{i,t}$)