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***LEVEL AND GROWTH EFFECTS OF HUMAN CAPITAL:
A Cross-Country Study of the Convergence
Hypothesis***

BY

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LEVEL AND GROWTH EFFECTS OF HUMAN CAPITAL:
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ABSTRACT

This paper examines the role of human capital in explaining the inability of some developing countries to "catch up" with more advanced countries. I construct a new proxy for human capital stock, namely the estimated years of schooling in the labor force and reproduce the findings of several cross-country studies that the initial human capital levels are positively related to future output growth. Then, I estimate a cross-country Cobb-Douglas production function for the 1970-1985 period and find that the growth of human capital is not related to the growth of output, contrary to what the Lucas (1988) model would lead us to expect. Two possible explanations are offered for why levels matter and not growth: First, that the output elasticity of human capital is positively related to the human capital level, and second that the level of average human capital is a proxy for the growth of technology.

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1. Introduction

Neoclassical growth theory predicts that countries with similar preferences should tend to converge in productivity and per capita income levels because of diminishing returns to capital and because of diffusion of technology. Samples of developed or industrialized countries do, indeed, display convergence. However, the phenomenon of convergence is not universal. More inclusive samples do not provide any support for the convergence hypothesis.

The main issue examined in this paper is the role of education and the associated accumulation of human capital stock in explaining the inability of some developing countries to "catch up" with more advanced countries. To examine the question, a new index of human capital stock is constructed, namely the estimated years of schooling in the labor force.

I first build on Barro's (1991) and Barro and Sala i Martin's (1990) work. A regression of the countries' per capita income growth rates is run on the initial per capita income and the initial human capital levels. The coefficients of initial per capita income are negative and significant and for the initial human capital stock are positive and significant. The first result of this paper conforms with that of the existing literature and suggests that laggard countries cannot converge to the economically more advanced countries unless they have relatively abundant levels of initial human capital stock.

I then estimate a cross-country Cobb-Douglas production function with physical capital, labor, and human capital. Both inputs and output are measured in growth rates for the 1970-1985 period. The results from these regressions are puzzling: the coefficient of human capital is insignificant.¹ This is despite the abundant evidence in the literature supporting the hypothesis that education contributes significantly to growth.² Furthermore,

¹ Similar results are obtained using a growth accounting approach, in which the total factor productivity growth (adjusted for quality of labor) is found to be negatively related to the growth of the years of schooling embodied in the labor force (Kyriacou 1991).

² Many studies, mainly country specific, provide overwhelming evidence that education affects economic growth and productivity through its positive effect on individuals' ability to perform tasks, to receive, process, and diffuse information, to communicate, and to adjust to a changing economic

this result seems to be inconsistent with the first result obtained, and an explanation is needed to resolve the puzzle: why is it that only the level and not the growth of human capital affects the GDP growth?

Two possible explanations are offered. One explanation is that the output elasticity of human capital is positively related to the human capital level. This could be interpreted as evidence that there are threshold externalities to education, as in Azariadis and Drazen (1990). In other words, a country cannot have a significant positive contribution of education to growth unless it has already attained a certain threshold level of human capital stock. The second explanation relates to an omitted variable problem, specifically the omitted variable of technological growth. If one considers the initial level of human capital endowments to be a proxy for technological growth, as in Romer (1990), then there is a theoretical justification for introducing the level of human capital in the growth rate regressions.

The structure of the paper is as follows: In the second section, I summarize the literature on convergence. Then, I briefly present the data used in this work giving more emphasis on the estimation of the human capital index. In the fourth section, building on Barro (1991) and Barro and Sala i Martin (1991) I examine the role of the initial human capital level in explaining why the convergence hypothesis does not hold true universally, using the constructed index of human capital. In the fifth section I present the aggregate production function approach and the puzzling results of the growth rate regressions. The two proposed explanations of the puzzling results are presented in the sixth section. Finally, a summary and some concluding remarks are presented in the last section.

2. The Convergence Hypothesis

According to neoclassical theory, all countries should be expected to converge to a unique growth path: Because of diminishing returns to capital, countries with higher level of capital, that is, richer countries, should tend to have lower marginal products of capital and thus less investment and lower

environment. Comprehensive surveys with evidence on the role of education on economic growth can be found in Bowman (1980), Psacharopoulos (1984), and Tilak (1989).

per capita growth rates. Furthermore, with a some degree of free trade in existence, capital would tend to migrate toward the poorest countries where its marginal product is higher. In addition, technology, which is to a great extent a public good, should be accessible to some degree to all countries. Therefore, in principle the more technologically backward a country is the more it can benefit from applying or imitating modern technology from the technological leaders. This is the so called "advantages of backwardness" hypothesis. In short, neoclassical theory predicts that countries should tend to converge to a unique growth path, and if they have similar preferences and technology should tend to converge in productivity and income levels, and become similar to each other over time.

Indeed, certain samples of countries do display convergence and the countries included in these samples become similar over time. Several studies of samples, which mainly include developed countries, for example, Madison (1982), and Baumol (1986), support this so called convergence or catching up in productivity hypothesis.

However, more inclusive samples provide weaker or no support to the convergence hypothesis:³ Many developing countries are unable to catch up in productivity and income levels with the more advanced countries. Their growth rates are lower than those of many developed countries and, as a result, the per capita income gap between them and the developed countries is widening. There are even extreme cases where poor developing countries have negative growth rates. For example, according to the Summers-Heston (1988) data set, Zaire, Guyana, and Venezuela had negative average growth rates of their per capita income for the 1950-1985 period. In addition, fifteen countries, mostly African, had negative growth rates of their per capita income for the 1960-1985 period.⁴

Can economic theory explain the inability of some developing countries to catch up with more advanced countries? There are, some economic factors suggested in the literature that could explain to a certain extent why the

³ See, for example, Baumol (1986), De Long (1988), Barro (1991), Barro and Sala i Martin (1990), Benhabib and Jovanovic (1991).

⁴ Angola, Benin, Burundi, Central African Republic, Chad, Ghana, Madagascar, Mali, Somalia, Zaire, Zambia, Guyana, and Venezuela.

convergence hypothesis does not hold true universally. For example, human capital, R&D spillovers, specialization, openness to trade, and financial intermediation are factors that are claimed to determine the long-term economic growth because they can, in general, introduce increasing returns to scale at the economy-wide level. A comprehensive survey of this literature can be found in Easterly and Wetzer (1989).

The factor emphasized in this paper is education and the associated accumulation of human capital. How is education related to the convergence hypothesis? To what extent does it improve productivity and to what extent is it a catalyst to the diffusion of technological knowledge? Are there externalities to education? These are the types of questions addressed.

3. The Data

This section briefly describes how some of the variables used in the empirical tests are estimated, specifically human capital, physical capital, and labor force. More emphasis is given to the construction of the human capital stock index.

As already mentioned, in contrast to the existing literature which uses mainly school enrollment ratios or literacy rates, I use the estimated years of schooling in the labor force as an index of human capital stock. The average years of schooling is thereafter indicated by h , and the total by H . The index h is estimated for the years 1965, 1970, 1975, 1980, and 1985 by using information available in the Psacharopoulos and Arriagada (1986) data set and data on lagged school enrollment ratios from various issues of the Unesco's Statistical Yearbook.

Psacharopoulos and Arriagada (1986) compile and present data on the educational composition of the labour force for many countries. More specifically, they provide one observation on the average years of schooling in the labour force, h , for ninety-nine countries and two or more observations for thirty-three countries. These observations come from published censuses and special labour force surveys and cover different years, mostly from the sixties, seventies, and early eighties. Note that the reported data refer to years of formal education only. On the job training as well as vocational training, which can contribute to the improvement of the human capital stock,

are not accounted for. Furthermore, quality of schooling cannot be captured by this measure.

As mentioned, the enrollment ratio data are from various issues of the Unesco's Statistical Yearbook. An enrollment ratio for a given schooling level is defined as the ratio of total number of students enrolled in this level to the total number of persons in the corresponding age group. The data used refer to enrollment ratios in primary and secondary schooling as well as higher education.

The estimation procedure for h is as follows: data on h in the mid seventies, specifically the years 1974, 1975, 1976, or 1977, are provided in Psacharopoulos and Arriagada (1986) for forty-two countries. These countries and their corresponding values of h are presented in table A.1 of the data appendix A. It is then assumed that this human capital index is related to lagged school enrollment ratios. In fact, there is a strong relationship between average years of schooling in the labor force in the mid 70's and lagged enrolment ratios of the following form:

$$(3.1) \quad H75 = 0.052 + 4.439*PRIM60 + 2.665*SEC70 + 8.092*HIGH70$$

(t=4.48) (t=1.72) (t=2.62)

$R^2 = .82$

where,

H75 = average school years in the labor force (mid 70's)
 PRIM60 = enrolment ratio, 1960, primary education.
 SEC70 = enrolment ratio, 1970, secondary education.
 HIGH70 = enrolment ratio, 1970, higher education.

Assuming that this relationship remains more or less constant over time and across countries, we can use it to estimate the average years of schooling in the labor force for several years (1965, 1970, 1975, 1980, 1985) and for many countries since, as mentioned, the lagged enrollment ratios needed are largely available in various issues of the Unesco Statistical Yearbook. The values of h estimated with the method described above are presented in table A.2 of the data appendix A. The number of observations for the 1970 levels and 1970-1985 growth rates of human capital is significantly larger, approximately ninety.

The assumption that the relationship between h and the lagged enrollment ratios remains constant over time and across countries implies that there are no differences among countries and over time in the length of each schooling

level, the dropout ratios and the number of class repeaters. Even though these assumptions might be rather restrictive, the estimated values of h seem reasonable according to table A.3 of the data appendix A. This table compares the values of h estimated in this study with the values of h presented in Psacharopoulos and Arriagada (1986) for the same or adjacent years, whenever such comparison is possible. The correlation coefficient is 0.85.

The growth of capital stock for the 1970-1985 period is estimated from the Summers and Heston (1988) data set: Assuming that investment grows exponentially from time minus infinity to time t at a constant growth rate g , that is, $I(t) = I(-\infty) e^{gt}$, then the capital stock in 1970 is: $K(1970) = I(1970)/(g+\delta)$,⁵ where g is estimated from the investment series available prior to 1970 and δ is the capital depreciation rate assumed to take the values $\delta_1=8\%$ and $\delta_2=10\%$. The 1985 value of capital is estimated using the perpetual inventory method.

The labor force variable is constructed by using the time series data on population from the Summers and Heston data set along with data on the labor force participation (LFP) rates in many countries from different issues of the World Development Report. These rates refer to the percentage of people of 14 to 65 years of age who are in the labor force. For a few countries the LFP rates are not available and therefore population growth rates are used instead of labor force growth rates. This does not seem to have affected the results in any significant way, since the countries with population rather LFP rates do not come out as outliers in the subsequent regressions.

4. Growth and the Initial per Capita Human Capital Level

The question of how human capital is related to the convergence hypothesis has been addressed in the literature mostly by examining the relation between a country's initial human capital level and its subsequent growth of its per capita income. For example, Barro and Sala i Martin (1990)

⁵ This implies that the countries are at the steady state, which is probably not true. However, this is one feasible alternative to roughly estimate the capital stock at a benchmark year (1970). Note that, for most countries, there are no sufficient data on investment prior to 1970 that would allow one to estimate the capital stock in this year using a weighted average of lagged investments.

consider the following regression:⁶

$$(4.1) \quad 1/T \log(Y_t^i/Y_{t-T}^i) = \alpha + \beta \log(Y_{t-T}^i) + \gamma h_{t-T}^i + u_t^i$$

where, h_{t-T}^i is a human capital index, namely school enrolment ratios, for country i at initial period $t-T$, and Y_t^i is the per capita income of country i at time t . They use data from 114 countries for the 1960-1985 period, and they run the regression both with and without the human capital term. They find that the coefficient of initial level of per capita output is positive and insignificant when h is not included in the regression, but becomes negative and significant when it is included. The coefficient of human capital is positive and significant. This result suggests that poorer countries tend to grow faster than richer countries only if they have initial human capital levels that are similar to those of the richer countries.

Similar results are obtained when, instead of enrolment ratios, the estimated average years of schooling in the labor force are used as a proxy for human capital. These results are presented in table 1:

Table 1

OLS regressions of income growth on initial income and human capital levels
dependent variable: per capita income growth rates 1970-85.
Heteroskedasticity-consistent covariance matrices

	(1)	(2)	(3)	(4)
Constant	0.0106 (3.11)	-0.0024 (-0.58)	0.0112 (4.36)	-0.0078 (-1.44)
Y70pc	0.0011 (1.45)	-0.0045 (-3.25)		
lnY70pc			0.0047 (2.44)	-0.0090 (-2.43)
h70		0.0067 (4.60)		0.0062 (4.09)
Obs.	111	89	111	89
R ²	0.0113	0.2124	0.0373	0.1695

- t-statistics in parentheses

⁶ They also consider the case where the level of initial per capita income, rather than the its logarithm, is in the RHS of the regression. The results are similar.

Table 1 presents the results of a regression similar to (4.1), when either the level of initial per capita income or its logarithm are included in the RHS. The growth rates are for the 1970-1985 period, and h_{70} is the mean years of schooling in the labor force in 1970. As in Barro and Sala i Martin (1990), the coefficient of initial per capita income when h is not included in the regression is positive but becomes negative and significant when it is included. The coefficients of human capital are positive and significant.⁷

There are two potential problems in these tests. The first is a possible endogeneity problem, that stems from the fact that the human capital level might depend on the expected growth of future output. The second is that the model is incomplete: there are other variables affecting the per capita income growth not included in the regression. Therefore, it might be the case that, because of either of these problems, the estimates from the previous regressions are biased. These problems are addressed in Kyriacou (1991) and neither seems to affect considerably the results of table 1.⁸

Overall, the evidence suggests that a poorer country tends to grow faster than a richer one when they have similar human capital levels, or more generally when the poorer country has abundance of human capital relative to its per capita income. In this sense, relative abundance of initial per capita human capital endowments in laggard countries seems to be a prerequisite for the convergence hypothesis to hold true. In the next section, I examine the role of human capital in the convergence of per capita income in a different way, specifically, using an aggregate cross-country production function approach.

5. Human Capital in an Aggregate Production Function

As mentioned earlier, there is abundant evidence in the literature emphasizing the importance of education and human capital in productivity and growth. Along with the evidence presented in the previous section, there are

⁷ Similar results are obtained when the OPEC members are excluded from the sample.

⁸ Levine and Renelt (1990), however, find that the coefficients of the initial level of school enrolment ratios are not very robust when other variables incorporated in the regression.

numerous studies, mainly country specific, that provide strong support to the hypothesis that education and human capital contribute significantly to growth. In this section, an aggregate production function that incorporates human capital is used to test the significance of the contribution of human capital to economic growth at an aggregate cross-country level. Any externalities to education should in principle be reflected in the estimated human capital coefficients and, if present, they would indicate that initial conditions do matter for long-run growth and, in the absence of any intervention, countries with insufficient human capital would be doomed to be permanently underdeveloped. The possible presence of externalities to education might therefore be an explanation of why the convergence hypothesis does not hold true universally. (See Lucas 1988)

Consider a Cobb-Douglas production function that allows for externalities to human capital, that is,

$$(5.1) \quad Y = A K^\alpha L^\beta H^\gamma \bar{H}^\delta$$

where Y is the output level, K is the capital stock, L is the labor force, and H is the total years of schooling in the labor force used as a proxy or an index for the total human capital stock in the economy. \bar{H} is intended to capture the external effects of human capital. The state of technological knowledge is indicated by A and is assumed to be exogenous and disembodied.⁹ Taking the logarithms and then differentiating (5.1) with respect to time, we get the following equation:

$$(5.2) \quad \dot{Y}/Y = \dot{A}/A + \alpha \dot{K}/K + \beta \dot{L}/L + (\gamma + \delta) \dot{H}/H$$

where the dot indicates a time derivative. Some growth rate regressions corresponding to equation (5.2) are run, and the results are presented in

⁹ This production function, treats the human capital variable (H) as a separate input in the production process. Another way to incorporate human capital in the production function is to use, as Grilliches (1970) and Lucas (1988) do, the average years of schooling, that is, to treat capital as a labor augmenting technological change, that transforms labor into efficiency units.

table 2.¹⁰ This table refers to the case where the capital stock is estimated under the assumption that it depreciates at a constant rate of 8% and the sample excludes the OPEC members. Similar results are obtained when depreciation is 10% and the OPEC members are included. Columns (1) and (3) refer to the periods 1970-1985 and column (2) refers to the period 1965-1985. The difference between columns (1) and (3) is that the later uses more reliable but also more scattered data on labor force growth from different issues of the ILO Statistical Yearbook. In columns (1) and (2) L represents population between the ages of 14 to 65, and in column (3) it represents population included in the labor force broadly defined as the employed plus the unemployed who search for a job.

Table 2

OLS Results, using growth rates, depr.= 8%
 Dependent variable: growth of total output
 Heteroskedasticity-consistent covariance matrices
 Sample excludes OPEC members

Variable	Coefficient	1970-1985 whole sample (1)	1965-1985 sample (2)	1970-1985 ILO sample (3)
c		0.0009 (0.27)	0.0099 (2.52)	0.0023 (0.54)
K growth	α	0.5548 (9.41)	0.4620 (7.08)	0.5220 (6.89)
L growth	β	0.3428 (0.90)	-0.0347 (-0.13)	-
L growth (ILO)	β	-	-	0.1896 (1.80)
H growth	$\gamma + \delta$	-0.1122 (-1.29)	0.1535 (1.10)	0.0659 (0.78)
Obs.		80	39	40
R ²		0.6278	0.6061	0.7831

- t-statistics in parentheses.

Several observations can be made from table 2. In column (1), the

¹⁰ Some logarithms of the levels regressions can also be run by taking the logs of the variables in equation 5.1. However, the growth rate regressions have a significant advantage over the logarithms' regressions, namely that of at least partially eliminating differences in measurements of variables across countries, if these differences remain more or less constant over time.

coefficient of labor is small and insignificant,¹¹ and the coefficient of human capital, is negative and insignificant. As compared to column (1), in column (2) the coefficient of capital becomes slightly stronger and more significant and the coefficient of labor becomes even weaker. Even though not quite significant, the human capital coefficient appears with a positive sign, and a value of 0.15. Similarly, in column (3) the human capital coefficient again appears positive with a value of 0.07, but it is statistically insignificant. An additional observation from table 2 is that all the regressions indicate decreasing returns to scale: the sum of the coefficients is less than one.

Table 2 raises two questions: The first is the negative, albeit insignificant, coefficient of H in column (1). The second is the change of this coefficient from negative to positive in columns (2) and (3). The following observation might lead to a possible explanation of this puzzle: a significant difference among the above samples is that the one of column (1) is considerably larger than those of columns (2) and (3), and as table 3 shows, countries included in the second and third samples have in general higher levels of average years of schooling in the labor force in 1970. Specifically, the mean of h is 4.046 for the whole sample (excluding OPEC), as opposed to 5.463 for the 1965-1985 sample, and 5.252 for the 1970-1985 ILO sample. This suggests that it could be the case that the growth of H matters only when the levels of h are sufficiently high. This point is examined in more detail in the next section where the production function is modified to conform with this hypothesis.

Table 3

Summary statistics of the level of h in 1970, for the samples in table 2.

	1970-1985 whole sample (1)	1965-1985 sample (2)	1970-1985 ILO sample (3)
Mean	4.046	5.463	5.252
Standard Deviation	2.647	2.288	2.588
Minimum	0.158	1.692	0.862
Maximum	10.39	10.39	10.39
Countries with h < 1	13	0	1
Total number of countries	80	39	40

¹¹ Similar results are often obtained in cross-country studies, for example, Romer 1987.

The results from this section do not suggest the existence of externalities to education that would support its role in the convergence hypothesis. On the contrary, at this aggregate level, the results do not even seem to attribute any significance to education as a direct input in the production process. The coefficients of human capital are insignificant (and even with a negative sign). This is despite the abundant evidence in the literature, that strongly suggests, that education contributes significantly to growth.

The next section offers two possible explanations to this puzzling result. As mentioned earlier, one observation from this section gives a direction leading to one possible explanation: when the regressions of the Cobb-Douglas production function are run for two smaller samples (one covering the 1965-1985 period, and one using ILO data for labor force participation for the 1970-1985 period) the results are relatively more supportive of the importance of H as an input in the production process. Albeit insignificant, the coefficients of H become positive with values of 0.15 and 0.07 respectively. As mentioned, the countries in these smaller samples have higher initial levels of average years of schooling in the labor force in 1970.

6. Possible Explanations for the Puzzling Results.

The last observation can lead to an explanation of the puzzling results: It could be the case that the levels of initial human capital stock enter into the production function in a way that is not captured by the simple Cobb-Douglas production function. Two possible cases are examined: The first is that the growth of human capital is more effective the higher its average level, that is, there might exist threshold levels of h beyond which investments in education become more productive. The second is that there is an omitted variable problem in the analysis of the previous section, specifically that of technological growth. Therefore, the initial level of h could enter in the production function as a proxy for technological growth,

as in Romer (1990).¹²

The first possible explanation implies that the elasticity of H is higher the higher the level of h is. Therefore, countries with low per capita human capital endowments tend to have a lower contribution of H to output growth. There are several arguments to support this explanation. The first is that at low values of h , it is conceivable to expect that high fixed costs in the production of H are borne by the countries, for example to establish an educational system from scratch, to train the first teachers, or to build the first schools.¹³ A second possibility is that countries with such a low h are most likely agricultural in which children are, in general, productive workers in the family farms. Therefore, there might exist a high opportunity cost in sending these children to school. Finally, another argument is that there are transaction, interaction, communication and other costs involved when educated workers have to perform tasks in an illiterate or poorly educated environment.

Two additional forms of production functions are tested to allow for the elasticity of H to change with the level of h . The first formulation tested is as follows:

$$(6.1) \quad Y = K^{\alpha} L^{\beta} H^{\gamma+6h}$$

As pointed out above, this production function has the characteristic that output elasticity of H is not constant, but depends on the levels of h and H . In particular,

¹² Another possible explanation of the puzzling result could be related to the fact that the human capital index used, that is, the years of schooling in the labor force, captures the quantity but not the quality of schooling. The evidence suggests that there is a negative relationship between the growth of quantity and the growth of quality of schooling as measured by the public expenditure on education per student, and the teacher-student ratio. Therefore, ignoring the variable for the quality of schooling causes the regression to give a coefficient of human capital that is downward biased. However, preliminary attempts to include proxies of quality of schooling in the regressions do not support this hypothesis. (see Kyriacou, 1991)

¹³ For example, Psacharopoulos (1980) examined data from 83 developing countries and found that average costs in higher education are inversely proportional to the enrolment ratios in higher education, indicating the existence of fixed costs.

$$\epsilon_{HY} = \gamma + \delta(1+\ln H)h$$

The second formulation tested is as follows:

$$(6.2) \quad Y = K^\alpha L^\beta H^\gamma e^{\delta h}$$

The output elasticity of H is not constant, but depends on the level of h. In contrast, to the previous case, however, this formulation gives a monotonically increasing elasticity with respect to h (for $\delta > 0$). In particular,

$$\epsilon_{HY} = \gamma + \delta h$$

The production functions in (6.1) and (6.2) give the following equations in terms of growth rates:

$$(6.1') \quad \frac{dY}{Y} = \alpha \frac{dK}{K} + \beta \frac{dL}{L} + \gamma \frac{dH}{H} + \delta h(1+\ln H) \frac{dH}{H}$$

$$(6.2') \quad \frac{dY}{Y} = \alpha \frac{dK}{K} + \beta \frac{dL}{L} + \gamma \frac{dH}{H} + \delta h \frac{dH}{H}$$

Since we are not dealing with small changes, but changes over 15 years, a more appropriate way to derive the growth rate equations is using differences of the logarithms between the initial, and final periods. In this way we get:

$$(6.1'') \quad \ln\left(\frac{Y_2}{Y_1}\right) = \alpha \ln\left(\frac{K_2}{K_1}\right) + \beta \ln\left(\frac{L_2}{L_1}\right) + \gamma \ln\left(\frac{H_2}{H_1}\right) + \delta \ln\left(\frac{H_2^{h_2}}{H_1^{h_1}}\right)$$

$$(6.2'') \quad \ln\left(\frac{Y_2}{Y_1}\right) = \alpha \ln\left(\frac{K_2}{K_1}\right) + \beta \ln\left(\frac{L_2}{L_1}\right) + \gamma \ln\left(\frac{H_2}{H_1}\right) + \delta (h_2 - h_1)$$

Both production functions are estimated and the results are presented in table 4. Capital depreciation is assumed to be 8%. Similar results are obtained when depreciation is assumed to be 10%. The sample excludes OPEC members. Similar results are obtained when these countries are included.

Table 4

Various formulations of the production function, OLS regressions, depr.=8%
 Dependent variable: growth rates of total output, 1970-1985.
 Heteroskedasticity-consistent covariance matrices
 Sample excludes OPEC members

Variable	Coefficient	(1)	(2)	(3)	(4)
Constant		-0.0066 (-1.36)	-0.0041 (-1.07)	-0.0063 (-1.37)	-0.0032 (-0.87)
K7085	α	0.5346 (10.12)	0.5339 (10.04)	0.5331 10.14)	0.5363 (9.98)
L7085	β	0.1579 (0.52)	0.3297 (1.18)	0.0684 (0.22)	0.3488 (1.25)
H7085	γ	-0.0224 (-0.23)	-0.1237 (-1.45)	-0.0431 (-0.46)	-0.1730 (-1.99)
h70(1+lnH70) dH/H	δ	0.0200 (2.90)			
ln(H85 ^{h85} /H70 ^{h70})	δ		0.0249 (3.27)		
h70 dH/H	δ			0.0654 (3.06)	
h85 - h70	δ				0.0735 (2.98)
Obs.		80	80	80	80
R ²		0.6630	0.6702	0.6681	0.6677

- t-statistics in parentheses

The first two columns of table 4 refer to equations (6.1') and (6.1'') respectively. The last two columns refer equations (6.2') and (6.2'') respectively. The evidence from this table supports the hypothesis that the output elasticity of H depends positively on the level of h. In all regressions the δ coefficients are significant and the t-statistics are around three. Therefore, these results suggest that the lower the level of h, the lower the output elasticity of H, and the lower the contribution of education to growth.¹⁴

One interesting question to examine is how these threshold levels of h are related with the labor shares across countries. These labor shares are

¹⁴ As table 3 of the previous section shows, there are many countries with very low h in 1970. For example, there are 13 countries in the sample examined with less than one years of schooling in the labor force in 1970. The large number of countries with low h in 1970 should be the reason why the simple Cobb-Douglas production function for the whole sample gives a negative and insignificant coefficient for H.

the sums of the shares of raw labor and of human capital embodied in raw labor. A limiting factor in giving a complete analysis of the issue is that the labor coefficients are in general negative and insignificant.¹⁵ Still, however, one interesting observation can be made concerning the labor shares and human capital endowments, namely the positive relationship between h and labor shares. This is presented in table 5.

Table 5

Correlation Coefficient between labor shares and average years of schooling in the labour force

Year	Correlation Coefficient	Number of Countries
1970	0.68	62
1975	0.72	75
1980	0.72	79
1985	0.70	56

The source of the data on labor shares is the UN National Accounts and Statistics (1988). The labor share is defined as the portion of GNP (net of indirect taxes) that is paid as compensation to employees and includes both the returns to human capital and raw labor. The other main cost components of GNP are depreciation, indirect taxes, and operating surplus. The operating surplus defined as the excess of GNP over and above the cost components mentioned above and includes rents and profits. Table 5 shows that there is a very high correlation between labor shares and the average years of schooling in the labor force. This fact is consistent with the first hypothesis tested in this section, that the higher h is, the higher the elasticity of H .

Overall, the evidence so far seems to support the first possible explanation of the puzzle: countries with low initial per capita human capital endowments tend to have an insignificant contribution of human capital on growth. On the other hand, countries with high initial per capita human capital endowments tend to have higher output elasticities with respect to

¹⁵ This result, often obtained in cross country studies, for example Romer (1987), could be due to poor data on labor or as Benhabib and Jovanovic (1991) pointed out, it could be due to that physical capital is correlated with the disturbance term thus creating a downward bias on the coefficient of labor.

human capital. This result is consistent with the observed differences in labor shares across countries, that is, countries with higher level of h , have higher share of labor. It is also consistent with the recent findings of a study at the World Bank which reports that the output elasticity of the mean years of schooling in developing countries in 1985 varies across regions: the higher the region's level of h , the higher the elasticity (Lau, Jamison and Fouat, 1991).

The second possible explanation for the puzzling result of section 5, is the following: Romer (1990), among others, suggests that the rate of technological change in a country depends on its human capital endowments. Therefore, under this assumption, in equilibrium, the growth of output should be equal to the growth of technological change which is determined by the levels of h . Romer differentiates between two types of human capital, H_1 used in the final goods sector, and H_2 used in the research sector that produces technology. He then argues that the aggregate stock of knowledge evolves according to:

$$(6.3) \quad \dot{A}_t = \delta A_t H_2 \quad \text{or} \quad \dot{A}_t / A_t = \delta H_2 \quad \text{where } \delta > 0.$$

Therefore, the more the human capital level is devoted to research, the higher the growth of technology. For a developing country which does not produce new technology, H_2 could be interpreted as the human capital devoted to imitating and adopting technology from other economically more advanced countries.

Incorporating this idea into (5.2) we get:

$$(6.4) \quad \frac{dY}{Y} = \alpha \frac{dK}{K} + \beta \frac{dL}{L} + (\gamma + \delta) \frac{dH}{H} + g(h)$$

Table 6

OLS regressions, depr.=8%
 Dependent variable: growth rates of total output, 1970-1985.
 Heteroskedasticity-consistent covariance matrices
 Sample excludes OPEC members

Variable	Coefficient	(1)	(2)	(3)	(4)
Constant		-0.0169 (-1.83)	-0.0145 (-1.58)	-0.0232 (-2.09)	-0.0176 (-1.62)
K7085	α	0.5401 (10.03)	0.5467 (9.89)	0.5298 (9.72)	0.4893 (8.89)
L7085	β	0.2396 (0.80)	0.4331 (1.58)	0.2707 (1.03)	0.3645 (1.35)
H7085T	γ	0.0984 (0.66)	-0.0070 (-0.06)	0.0718 (0.56)	0.0721 (0.66)
ln(h70)	η	0.0081 (2.31)			
h70	η		0.0019 (2.01)	0.0071 (2.54)	0.0072 (2.90)
h70sqr	θ			-0.0005 (-2.37)	-0.0006 (-2.87)
REVCoup					-0.0198 (-2.57)
Obs.		80	80	80	80
R ²		0.6528	0.6411	0.6553	0.6954

t-statistics in parentheses

The OLS results for some variations of equation (6.4) are presented in table 6. In column (1) the function $g(h)$ is assumed to be equal to $\eta \ln h$, where h is the value of the average years of schooling in the labor force in 1970. The coefficient for capital is positive, statistically significant and at the same levels as in the previous regressions. Labor is again insignificant. The coefficient for the growth of H is positive and statistically insignificant, and the coefficient for $\ln h$ is positive and significant. In column (2), where the production function $g(h)$ is assumed to be equal to ηh , the results are similar. In the third column $g(h)$ takes the form $\eta h + \theta h^2$. The coefficient of h is 0.0071 and statistically significant, and the coefficient of h^2 is -0.0005 and also statistically significant. This result supports the hypothesis that human capital endowments contribute to economic growth through their effect on technological progress. Furthermore, the contribution of human capital endowments increases at a decreasing rate.

In short, columns (1) to (3) indicate that the effect of the level of human capital, which can be represented by shifts of the aggregate production function, is positive and significant.

In contrast to the significant effect of the level of h on growth, the output elasticity of output elasticity is small and insignificant. Interpreting the results as in Romer (1990), this suggests that the effect of human capital in the final goods sector is insignificant, whereas its effect as an input in the intermediate goods sector, which is the engine for technological growth, is significant.

In addition to the hypothesis that technological growth depends on human capital endowments one can test the hypothesis that other factors affect technological growth as well. For example, it could be the case that the political instability in a country might discourage the introduction, adaptation or diffusion of new technology. This is tested in column (4) of table 6, where an index of political instability from Barro and Wolf (1989) data set is introduced in the regression. This variable, REVCoup, is a measure of the average number of revolutions and coups for the 1960-1985 period, or a sub-period. The coefficient of this variable is negative and significant. The inclusion of this variable in the regression does not affect the coefficients of the human capital variables.

Overall, the evidence seems to support the hypothesis that human capital endowments contribute to economic growth through their effect on creation, adaptation, and diffusion of technological progress. The effect of this contribution can be represented by an upward shift in the aggregate production function.

7. Summary and Conclusions

Human capital has been cited in the literature as a possible factor related to the inability of some developing countries to catch up with the economically more developed ones. Indeed, as it is shown in this and several other cross-country studies, the initial level of human capital is positively correlated to future growth. Furthermore, holding the per capita human capital constant, the convergence hypothesis holds true.

This paper examines the question in another way as well, using an

aggregate production function approach. Specifically, a cross-country Cobb-Douglas production function is estimated for the 1970-1985 period. The results from this exercise are puzzling. The coefficient of human capital (years of schooling in the labor force) is negative and insignificant, despite the abundant evidence in the literature that supports the hypothesis that education contributes significantly to growth. Two possible explanations are proposed.

The first explanation is related to the particular functional form of the aggregate cross-country production function assumed, that is, the simple Cobb-Douglas production function. Since the "correct" form of the production function is not known but assumed, two additional forms are tested. The common feature of these production functions is that they allow the output elasticity of H (total years of schooling in the labor force), to vary with the per capita level of human capital, h (average years of schooling in the labor force).

Both production functions give results that support the hypothesis that the output elasticity of H depends positively on the level of h . Therefore, the lower the level of h , the lower the output elasticity of H , and the lower the contribution of H to growth. Possible explanations for this could be the presence of high fixed costs in the production of H , high opportunity costs for acquiring education in countries with low h , and the existence of transaction, interaction, communication and other costs when educated workers have to operate in a poorly educated environment. This explanation is consistent with the fact that country labor shares are positively related to the level of average years of schooling in the labor force.

The second possible explanation relates to the link between human capital endowments and the subsequent growth of technology. Specifically, if human capital endowments determine the rate of growth of technology as in Romer (1990), then the initial level of the average years of schooling can be used as a proxy for technological growth in the growth rate regressions. The results of this work seem to support this hypothesis, that is, the per capita human capital endowments contribute to economic growth through their effect on creation, adaptation, and diffusion of technological progress. The effect of this contribution can be represented by an upward shift in the aggregate

production function that is related to the level of the average human capital endowments of a country.

Both explanations conform with the diverging patterns of per capita income observed in the real world: the convergence hypothesis holds true only if sufficient levels of per capita human capital stock have been accumulated.

Furthermore, these explanations shed some light onto the question of why the level and growth effects of human capital on economic growth are different.

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APPENDIX A (data appendix)

Table A.1

List of countries with available data on the average years of schooling in the labor force, h, in the mid-seventies.

	Country	Year	h
1	Algeria	1977	4.0
2	Cameroon	1976	2.2
3	Egypt	1976	3.3
4	Lesotho	1976	4.3
5	Liberia	1974	1.3
6	Malawi	1977	2.9
7	Mali	1976	0.5
8	Mauritius	1975*	5.9
9	Morocco	1975*	1.8
10	Senegal	1976	2.9
11	Swaziland	1976	4.4
12	Tunisia	1975	2.2
13	India	1975*	1.5
14	Iran	1976	2.7
15	Japan	1975*	8.9
16	Jordan	1975	5.6
17	Korea, Rep.	1975*	6.1
18	Malaysia	1975*	5.9
19	Pakistan	1975	1.2
20	Singapore	1974	5.3
21	Sri Lanka	1975*	6.7
22	Syria	1975	4.1
23	Thailand	1974	4.1
24	Belgium	1975*	8.2
25	Greece	1975*	5.7
26	Netherlands	1975	9.1
27	Canada	1975*	10.4
28	Guatemala	1975*	3.3
29	Honduras	1974	3.0
30	Mexico	1975*	4.4
31	Panama	1975*	5.7
32	USA	1975*	11.6
33	Argentina	1975*	7.1
34	Bolivia	1976	5.4
35	Brazil	1975*	4.8
36	Chile	1975*	7.0
37	Colombia	1975*	4.9
38	Paraguay	1975*	4.7
39	Peru	1975*	6.1
40	Uruguay	1975*	6.7
41	Venezuela	1975*	5.9
42	Fiji	1976	8.3

Source: Psacharopoulos and Arriagada (1986).

* Values estimated through simple interpolation or extrapolation.

Table A.2

Estimated Average Years of Schooling in the Labor Force
in 1965, 1970, 1975, 1980, 1985

S-H#	Country	h65	h70	h75	h80	h85
1	Algeria	1.409	1.704	2.541	3.599	4.657
2	Angola		0.875	1.224	2.457	3.690
3	Benin			1.347	1.841	2.335
4	Botswana	1.100	1.370	2.130	2.831	3.533
5	Burkina Faso			0.437	0.585	0.733
6	Burundi			0.920	1.327	1.734
7	Cameroon	1.272	1.911	3.218	4.323	5.429
8	Central Afr.	0.611	0.931	1.614	2.587	3.561
9	Chad	0.151	0.306	0.815	1.320	1.825
10	Congo			2.059	2.932	4.158
11	Egypt			4.530	5.113	5.696
12	Ethiopia		0.172	0.397	0.768	1.140
13	Gabon	1.872	2.804	4.907	6.460	8.013
14	Gambia					1.552
15	Ghana	1.572	2.606	3.029	3.444	3.859
16	Guinea/Bis.	0.327	0.607	1.779	2.039	2.299
17	Ivory Coast	0.469	0.929	2.460	3.287	4.113
18	Kenya		1.642	2.443	2.944	3.445
19	Lesotho	3.258	3.582	3.955	4.420	4.884
20	Liberia	1.295	1.665	1.741	2.484	3.228
21	Madagascar	1.681	1.946	2.734	3.521	4.307
22	Malawi	1.721	1.692	2.926	2.446	1.967
23	Mali	0.345	0.490	0.645	1.044	1.444
24	Mauritania					1.029
25	Mauritius	4.654	5.185	5.598	5.951	6.303
26	Morocco	1.155	1.692	2.606	3.046	3.485
27	Mozambique	1.171	1.762	3.388	2.745	2.102
28	Niger	0.149	0.158	0.301	0.566	0.831
29	Nigeria	0.895	1.361	1.797	1.901	2.006
30	Rwanda	1.437	2.773	2.297	2.767	3.237
31	Senegal	0.572	0.920	1.638	2.059	2.480
32	Sierra Leone	0.633	0.862	1.353	1.668	1.983
33	Somalia	0.214	0.387	0.590	0.708	0.825
34	South Africa					
35	Sudan	0.784	0.906	1.445	1.767	2.089
36	Swaziland	1.474	2.151	3.181	4.292	5.402
37	Tanzania	0.682	1.010	1.391	1.617	1.843
38	Togo	1.082	1.463	2.232	3.282	4.332
39	Tunisia	1.976	2.758	3.829	4.742	5.655
40	Uganda	1.346	1.793	2.427	2.680	2.933
41	Zaire			3.012	3.671	4.331
42	Zambia	1.602	1.852	2.535	3.183	3.830
43	Zimbabwe			4.670	4.762	4.854
44	Afghanistan					
45	Bahrain					
46	Bangladesh			2.831	3.156	3.482

Table A.2 (continued)

Average Years of Schooling in the Labor Force
in 1965, 1970, 1975, 1980, 1985

S-H#	Country	h65	h70	h75	h80	h85
47	Burma			3.275	4.107	4.939
48	Hong Kong		4.063	5.597	6.699	7.801
49	India	1.931	2.420	4.034	4.393	4.751
50	Iran	1.713	1.927	3.010	4.380	5.749
51	Iraq	1.789	2.552	3.828	4.190	4.552
52	Israel	6.151	7.014	6.900	8.467	10.034
53	Japan	7.227	7.680	8.318	8.894	9.469
54	Jordan	2.901	4.434			7.470
55	Korea	4.792	5.422	5.983	6.959	7.936
56	Kuwait			7.189	7.054	6.919
57	Malaysia	3.962	4.466	5.349	5.539	5.729
58	Nepal		0.560	0.853	1.439	2.025
59	Oman					
60	Pakistan	1.847	2.170	1.943	2.241	2.540
61	Philippines		6.628	7.203	8.036	8.868
62	Saudi Arab	0.303	0.559	0.962	1.957	2.951
63	Singapore		6.074	6.747	6.818	6.889
64	Sri Lanka			5.725	5.879	6.032
65	Syria	3.088	3.730	4.694	5.658	6.623
66	Taiwan					4.669
67	Thailand	3.901	4.083	4.354	4.933	5.513
68	Un. Arab Emir.					
69	Yemen					
70	Austria			7.578	8.076	8.574
71	Belgium		8.014	8.491	8.921	9.351
72	Cyprus					
73	Denmark	6.533	7.233	8.610	7.758	6.907
74	Finland			7.486	9.157	10.828
75	France	8.672	8.984	10.020	9.780	9.539
76	Germany	9.105	9.010	8.799	9.565	10.332
77	Greece	6.383	7.150	7.644	8.022	8.400
78	Iceland			7.521	8.039	8.558
79	Ireland	6.256	7.235	8.132	8.481	8.830
80	Italy	6.642	7.333	7.956	8.544	9.132
81	Luxembourg	4.568	5.044	7.009	6.956	6.902
82	Malta			7.430	7.127	6.823
83	Netherlands		7.929	8.289	8.882	9.475
84	Norway			8.815	9.026	9.237
85	Portugal	3.884	5.303	8.033	7.274	6.516
86	Spain	4.136	4.927	7.147	8.423	9.699
87	Sweden	6.690	7.244	8.052	8.844	9.635
88	Switzerland			5.722	6.160	7.378
89	Turkey	2.698	3.052	4.613	5.470	6.327
90	United King.	7.004	7.771	7.355	7.927	8.498
91	Barbados			6.308	7.159	8.009
92	Canada	8.018	9.039	9.227	9.605	9.984

Table A.2 (continued)

Average Years of Schooling in the Labor Force
in 1965, 1970, 1975, 1980, 1985

S-H#	Country	h65	h70	h75	h80	h85
93	Costa Rica	4.466	5.457	5.917	7.072	8.226
94	Dominican R.	3.185	4.526	5.451	6.051	6.652
95	El Salvador	2.654	3.385	4.448	4.335	4.221
96	Guatemala	2.054	2.383	2.618	3.147	3.676
97	Haiti	1.257	1.911	2.302	2.482	2.662
98	Honduras	1.904	2.656	3.532	4.588	5.643
99	Jamaica	6.217	6.477	5.709	5.804	5.899
100	Mexico	3.309	3.867	4.667	5.864	7.062
101	Nicaragua	2.511	3.552	3.906	4.965	6.023
102	Panama	5.239	5.885	5.929	6.959	7.989
103	Trin.&Tob.	6.206	6.765	4.753	5.335	5.916
104	USA	9.821	10.398	11.952	12.019	12.086
105	Argentina	6.002	6.492	6.521	7.272	8.024
106	Bolivia	2.395	3.350	4.205	4.785	5.365
107	Brazil	3.491	4.112	5.401	5.468	5.536
108	Chile	5.156	5.851	6.690	6.826	6.963
109	Colombia	3.176	3.813	4.471	5.496	6.521
110	Ecuador	3.509	4.199	5.068	6.915	8.762
111	Guyana			6.269	6.240	6.211
112	Paraguay	4.756	5.163	5.203	5.684	6.166
113	Peru	4.246	4.261	5.458	6.701	7.944
114	Suriname			6.036	6.060	6.085
115	Uruguay	6.338	6.724	7.307	7.483	7.659
116	Venezuela	3.666	4.346	6.359	6.629	6.898
117	Australia	6.912	7.388	7.806	8.264	8.722
118	Fiji	3.983	4.260	4.804	5.720	6.637
119	Indonesia					
120	New Zealand	7.972	7.937	8.306	8.790	9.275
121	Papua New G.			1.726	2.263	2.799

Table A.3

Comparison of average years of schooling in the labor force (h) between this study and Psacharopoulos & Arriagada (1986).

SH#	Country	This study		Psacharopoulos & Arriagada (1986)	
		h	year	h	year
1	Algeria	2.5	1975	4.0	1977
4	Botswana	1.4	1970	2.0	1971
7	Cameroon	3.2	1975	2.2	1976
11	Egypt	4.5	1975	3.3	1976
12	Ethiopia	0.8	1980	2.6	1978
17	Ivory Coast	3.3	1980	3.2	1978
18	Kenya	2.9	1980	3.5	1980
19	Lesotho	4.0	1975	4.3	1976
20	Liberia	1.7	1975	1.3	1974
22	Malawi	2.9	1975	2.9	1977
23	Mali	0.6	1975	0.5	1976
25	Mauritius	5.2	1970	4.5	1972
		6.3	1985	6.7	1983
26	Morocco	1.7	1970	1.2	1971
		3.0	1980	2.9	1982
27	Mozambique	2.7	1980	1.2	1980
29	Nigeria	0.9	1965	0.8	1967
30	Rwanda	2.8	1980	2.2	1978
31	Senegal	1.6	1975	2.9	1976
35	Sudan	1.4	1975	5.5	1974
36	Swaziland	3.2	1975	4.4	1976
39	Tunisia	3.8	1975	2.2	1975
42	Zambia	1.6	1965	3.3	1963
43	Zimbabwe	3.2	1980	5.5	1979
46	Bangladesh	3.2	1980	2.4	1981
48	Hong Kong	6.7	1980	8.8	1981
49	India	4.4	1980	1.9	1981
50	Iran	3.0	1975	2.7	1976
52	Israel	10.0	1985	11.3	1983
53	Japan	7.7	1970	7.6	1969
		8.9	1980	9.8	1979
55	Korea	5.4	1970	3.9	1969
		7.0	1980	8.0	1980
56	Kuwait	7.0	1980	4.5	1979
57	Malaysia	4.0	1965	5.0	1967
		5.5	1980	6.5	1980
60	Pakistan	1.9	1975	1.2	1975
		2.2	1980	2.5	1981
61	Philippines	8.0	1980	7.0	1980
63	Singapore	6.7	1975	5.3	1974
		6.8	1980	6.0	1980
64	Sri Lanka	5.9	1980	7.5	1981
65	Syria	4.7	1975	4.1	1975
66	Taiwan	4.7	1985	8.4	1983
67	Thailand	4.4	1975	4.1	1974
		4.9	1980	4.6	1980
71	Belgium	8.0	1970	8.1	1970
		8.5	1975	8.3	1977
73	Denmark	7.8	1980	8.6	1981
		6.9	1985	10.8	1983
74	Finland	9.2	1980	8.5	1980
75	France	9.8	1980	6.2	1982
76	Germany	9.6	1980	10.4	1982
77	Greece	7.2	1970	4.3	1971
		8.0	1980	7.9	1981

Table A.3 (continued)

Comparison of average years of schooling in the labor force
between this study and Psacharopoulos & Arriagada (1986).

		This study		Psacharopoulos & Arriagada (1986)	
SH#	Country	h	year	h	year
83	Netherlands	8.3	1975	9.1	1975
84	Norway	9.0	1980	11.3	1980
85	Portugal	7.3	1980	4.5	1981
86	Spain	8.4	1980	6.2	1981
88	Switzerland	6.2	1980	11.0	1980
89	Turkey	5.5	1980	5.1	1980
92	Canada	9.6	1980	11.7	1981
93	Costa Rica	5.9	1975	6.4	1973
96	Guatemala	2.1	1965	1.7	1964
		2.6	1975	3.0	1973
97	Haiti	2.5	1980	1.6	1982
98	Honduras	3.5	1975	3.0	1974
99	Jamaica	5.8	1980	6.9	1978
100	Mexico	3.9	1970	4.2	1970
		4.7	1975	4.5	1977
101	Nicaragua	3.6	1970	4.4	1971
102	Panama	5.9	1970	4.8	1970
103	Trinidad & Tobago	5.3	1980	6.6	1980
104	USA	10.4	1970	10.6	1969
		12.0	1980	12.6	1981
105	Argentina	7.3	1980	7.4	1980
106	Bolivia	4.2	1975	5.4	1976
107	Brazil	5.5	1980	5.6	1980
108	Chile	5.9	1970	5.9	1969
		6.8	1980	8.1	1981
109	Colombia	3.2	1965	2.8	1964
		4.5	1975	4.8	1973
		5.5	1980	5.0	1978
110	Ecuador	6.9	1980	6.5	1982
111	Guyana	6.2	1980	6.8	1982
112	Paraguay	5.2	1970	4.3	1972
		5.7	1980	5.6	1982
113	Peru	6.7	1980	7.0	1981
115	Uruguay	6.3	1965	5.1	1963
		7.3	1975	6.7	1975
116	Venezuela	6.6	1980	6.2	1979
117	Australia	8.3	1980	11.1	1981
118	Fiji	4.8	1975	8.3	1976
120	New Zealand	8.8	1980	11.7	1981