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The human capital convergence fallacy: A cross country empirical investigation

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This article adapts a modification of Tamura's theoretical proposition and conducts a cross-country empirical investigation in an attempt to evaluate convergence on two different human capital proxies; namely enrollment rates and per capita researchers. The analysis considers three country groups at significantly different development levels: Advanced, developed and less developed countries. The hypothesis of convergence is rejected when alternative, to enrollment rates, approximations to human capital are used, merely implying the existence of a "convergence trap" for countries with significantly lower endowments of human capital. The results provide circumstantial evidence of within group convergence and between group divergences when enrollment in education is considered, but no convergence/divergence when research effort is considered. This last finding suggests the possibility of a "convergence trap", since initial human capital endowment could drive a process of worldwide polarization.

Key words: Advanced (OECD-G7), developed (OECD), less developed (world), USA, Mexico, Mauritius, human capital, convergence, growth, cross country, development level.

INTRODUCTION

A key economic issue currently is whether poor countries tend to grow faster than rich ones and converge over time to some level of per capita income. Drawing on Tamura's (1991) theorization, where human capital is the unique determinant[1] of growth: income "convergence arises from human capital convergence …" By the same token, one could speculate that the absence of strong human capital convergence in less developed countries and with advanced countries is manifested in the polarization of per capita income.

Former empirical studies on human capital, emphasize on, and analyze, mainly, the behavior of enrollment rates as a proxy of human capital. Consequently, and merely due to the variable characteristics, they fail to accurately describe the complexity of its economic significance; a concept compatible with educational quality rather than quantity[2]. Ultimately, most of these studies indicate evidence of convergence; meanwhile the income convergence picture is 'somewhat' different.

In contrast to most previous studies, this paper considers, in addition to enrollment rates, a more synthetic approximation to human capital; one that implicitly incorporates aspects of the economic effectiveness of education[3]. The number of researchers per million populations serves adequately this intention, since a country's dedication to research could be an indication of the economic exploitation of human capita

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(i.e. patent rights, etc.). Moreover, the three-dimensional grouping of countries adopted implies proximity on the exogenous factors that determine the level of the steady state (leisure, savings rate etc.), in addition to controlling for economic homogeneity. The present methodology, as an alternative to prior studies that used one single data set, attempts to approximate conditional and unconditional human capital convergence within and between three homogeneous country groups of different development level, namely less developed, developed and advanced[4]. As a result, one could compare and evaluate the convergence hypothesis among different proxies of human capital and make inferences that can be stretched to integrate issues beyond equilibrium-based growth theories.

The remainder of this article is as follows: Section 2 provides an overview of existing evidence and prior attempts to valuate convergence in human capital across countries. A section 3 and 4 describe the data set, the modeling and presents the empirical findings. The final section discusses the empirical findings and the resulting implications.

FORMER ATTEMPTS TO APPROXIMATE EDUCATIONAL CONVERGENCE

Trends in human capital accumulation

In studying US productivity from 1970 to 1979, Maddison (1989) reported that the national per capita income decreased by 0.2%, whereas increases in educational attainment contributed 0.6% to the growth of National Income per Person (NIPP). In other words, labor productivity was falling while educational attainment was growing.

Denison (1989) reported similar results for OECD countries between 1973 and 1981. Using Kyriacou's series, Behebid and Spiegel (1994) found no statistical significance for educational attainment when regressed on economic growth, when the model included a catch-up term.

Wolff (2000) presented findings on human capital, proxied by the percentage of the population enrolled at each educational level. He indicated that at the primary educational level there is an almost 100% enrollment ratio and, consequently, there is no significant variation. Meanwhile, secondary education increased to 94% in 1991 (from 54% in 1950) and to 97% in industrialized market economies. Most importantly, the coefficient of variation fell from 0.26% to 0.15% in OECD nations, and from 0.20% to 0.11% in industrialized market economies.

Naturally, the greatest variation in OECD members regards higher education: whereas in 1965, the United States obtained a 40% enrollment rate (the highest) Turkey's was 4% (the lowest). In the same study when attainment rates replaced enrollment rates, the coefficient of variation declined over the same time period for all educational levels. The greatest improvement is noticed with respect to secondary and higher education, even though the corresponding standard deviations increased in both secondary and tertiary education.

Kyriacou (1991) claimed that the mean years of schooling of the labor force between the years 1965 and 1985, demonstrate an increase for the period between 1965 and 1975, and then a decline for the following decade.

The work of Barro and Lee (1993), regarding attainment rates, indicate a continuous rise in schooling years from 1960 to 1980, yet lower than that of Kyriacou's.

Maddison (1989; 1995) found that average years of schooling for G7 members between the years 1950 and 1989, uncovered a substantial increase in educational attainment in the post-World War II era (starting from 1950), meanwhile, the dispersion remained relatively constant over the examined period due to group homogeneity.

In general, two stylized facts can be extracted in regards for OECD –regarding enrollment and/or attainment rates- countries despite data sources and methodological procedures;

A. The results show an almost continuous upward trend in schooling years for the years 1965 and 1975, and
B. Dispersion seems to decline for the years 1965–80, and then rises between the years 1980 and 1985.

Nevertheless, an inevitable deficiency of the above review is that empirical results refer, mostly, to OECD countries. Regrettably, less developed countries are less frequently included in similar studies[5].

A review of prior attempts to measure human capital convergence

In an attempt to evaluate the impact of human capital on growth, Albin (1970), in the context of cost-benefit analysis, concluded that the increased value (cost) of education (due to productivity enhancement); the resulting large discount rates of educational investment would forbid poverty classes to acquire higher education. As a result lower income endowment classes will be absorbed in advancing sectors at lower income positions, contributing to a 'vicious cycle' scenario.

O'Neill (1995), in order to explain the time evolution of growth convergence, adapted an educational variance approach on enrollment rates for a large sample of countries of all development levels for the years 1967–1985. The procedure used deconstructs the variation in income over time based on the positions of Romer (1989) and Tamura (1991); convergence is powered by human capital and technology flows from the leading countries to the lagging ones. O'Neill (op. cit.) asserts that changes in human capital establish a reliable predictor of the tempo-

ral patterns in the process of income convergence among developed economies and claims that the same method can be advantageous in uncovering the inferior performance of less developed countries in comparison with the developed ones[6].

The resulting human capital variance estimates –as indicators of cross country income variability- indicate a significant betterment in regards to developed market economies (OECD), while less developed countries exhibit a relative worsening. In other words, even though the increase in educational attainment had a significant effect on the reduction of global income inequality, the existing or evolved variation in the value of education — an issue of the overall productive effectiveness of educational attainment — increased at a faster rate.

In general, the results establish a converging trend in regard to educational attainment and/or enrollments, but the actual content of education; the quality and thus the economic effectiveness of education have diverged. This divergence is greater in less developed countries, to such a degree that the converging effect of education attainment gets cancelled out and, as a result, the overall cross country variation in income increases, mainly due to qualitative and structural factors that foster education effectiveness.

In the same context, Ram (1995) investigated the inter-country inequalities in school enrollment rates in a large international data set of 88 less developed countries[7] for 1960, 1970, 1980 and 1986. He establishes a Bourguignon (1979) weighted inequality index[8] for enrollment rates. Ram's findings (1960–1986) indicate a worsening of cross-country educational equality at the higher level of education. Meanwhile, inequality seems to be diminished in regard to primary and secondary education, on the other hand, the inter-country convergence[9] estimation showed evidence of convergence at all educational levels.

Finally, Castello and Domenech (2002), in an effort to introduce inequality measures in stochastic growth equations performed on a cross-section sample, employed human capital inequality variables, obtained by Gini- coefficient computations, using the Barro and Lee data set on attainment rates.[10] Their results indicated a significantly negative effect of cross-country human capital inequality on growth.

Overall, the above studies –among many others- indicate human capital convergence based on alternative methodological procedures performed on enrollment or attainment rates data sets. In the meantime, they constitute a starting and benchmark point for further analysis in the spectrum of alternative variable sets, methodologies and techniques.

METHODOLOGY AND DATA

In this section, a comparative empirical investigation was attempted between three alternative country groups that exhibit significantly different development levels; advanced, developed and less developed. The aim here is to uncover convergence-rate differences in human capital variables, within individual groups, between any two groups and among all three groups. This tested the theoretical validity about group convergence; conditional on the domain of each development group that indirectly implies overall proximity (infrastructure, political, market, institutional etc.), and across heterogeneous groups (e.g. developing versus advanced).

Tamura revisited

The empirical model results by simplifying (and merely altering) the value function *(V)* , initially set forth by Tamura (1991), based on which, *value* is an explicit function of a country's consumption *(c_{it})* and next period's *(t+1)* stock of human capital *(HC_{t+1})* relative to the mean level of human capital over n countries *(i.e. i=1,2,…n)*:

$$V(HC_{ti}, \quad HC_t) = max\{c_{it}/ + bv[HC_{t+1}, avg(HC_{t+1})]\}$$

$$(2)$$

Meanwhile, consumption becomes an implicit function of human capital investment at time t by the following time allocative restriction:

$$c_{it} = HC_{ti}(1 - {}_{ti}) \qquad (3),$$

Where *( )* represents the *ith* country's effort directed towards human capital enlargement.

Moreover, Tamura's spillover (or converging) effect on human capital accumulation can be altered as follows:

$$HC_{t+1, i} = (C^{th}/HC_{t,i}) \quad C_{t,i} {}_{ti}{}^{(1-)}, \quad for \; \forall \; \geq 0 \quad (4)$$

Where, HC^{th} denotes a threshold level of human capital, below of which (when >0) the converging effect of human capital is reversed as empirically found by Barro and Martin (2004), merely implying the position that 'some' minimum level of human capital is required to effectively facilitate a country's productive capacity; create infrastructures, attract foreign investment, utilize available technologies and participate in innovation.

On the other hand a country that possesses superior endowments of human capital can receive 'monopoly type' profits from lagging ones, by exploiting its advancement (i.e. edge productive technology, patents, etc). As a result, countries with inferior human capital would, partly, finance the extraordinary rate of human capital accumulation in advanced countries, since human capital investment would exceed the optimum level under perfect competition.

One could abridge the above position by reducing it to an aggregate Cobb Douglas production function *(Y)* endogenous, only, with respect to human capital:

$$Y_i = {}_i (HC_{ti}, (HC_{t-1,i}/ C^{th})) \qquad (5)$$

Where *( )* captures the remaining factors that by the present analysis are assumed less important and, therefore exogenous. It should be underlined that the *spillove*r term of human capital above represents the proportion of total production that was carried out by the extraordinary investment in human capital that resulted from suboptimal conditions in period *t-1*. Furthermore, if the minimum threshold level is an approximation of the average level of human capital (over *i*), then by taking the logs:

$$lnY_i = ln \; {}_i + lnHC_{ti} + ln(HC_{t-1,i}-avg \; C_{t-1}) \qquad (6)$$

…and the total differential,

$$1/Y \; dY = (1/HC_{ti} \;)dHC_{ti} + [1/(HC_{t-1,i}-avg \; C_{t-1})] \; d(HC_{t-1,i}-avg \; C_{t-1}) \qquad (7)$$

Table 1. The three groups of countries for which data was compared.

Advanced (OECD)	Developed (OECD)	Less developed (world)
USA	Mexico	Mauritius
Canada	Belgium	Paraguay*
Japan	Greece	Sri Lanka
Germany	Spain	Chile*
Great Britain	Korea	Zambia*
France	Netherlands	Indonesia
Denmark	Portugal	Nigeria*
Sweden	Turkey	India

*On some occasions due to lack of data, these countries were replaced by others of the same continent and of similar development UNDP ranking.

Where growth ($1/Y \, dY$) is determined by the marginal product of human capital *( )*, the *spillover* effect *( )* and the *relative* percentage changes in human capital[11].

Moreover, if one assumes cross-country uniformity in the marginal product of human capital, then he can approximate the *ith* country's convergence rate by estimating the time path of human capital deviations from the mean, in such way, that over what sample the mean is calculated from, would determine the territory of convergence; club, group, world, etc.

$$HC_{ti} - avgHC_t = [HC_{t-1,i} - avgHC_{t-1}] + u_{ti} \qquad (8)$$

Where *( )* captures the *ith* country's speed of convergence towards the group in question, meanwhile, *( )* could also represent the rate of convergence between groups of countries, as in the present article.

Versions of the above stochastic model has been used in several studies on an *ad hoc* basis; (Ben-David 1993,1995; Kocenda and Hanousek, 1998) They derived the former model (8) by modeling the time path of a variable for a group of *i* individual countries, with observations taken from *t* time periods, in the context of an autoregressive process.

In terms of a human capital variable *(HC)* this could be expressed by the following equation:

$HC^j_{i,t} = a + \gamma HC_{i,,t-1} + e_{i,t}$ (1),

And by taking the difference from the mean on both sides (HC for every *t* and *t-1*):

i

$HC_{i\,t} - avg(HC^j_t) = \gamma[HC_{t-1} - avg(HC^j_{t-1})] + u_{it,}$

we obtain equation (8) from above, that captures the time evolution of the sample's deviation from its own mean over the examined time period where $avg(HC^j_t) = 1/n \, \Sigma^n_{i=1}$ and *(i,t)* represent the mean value of the human capital variable over *(i=1,2,..n)*; countries at year *(t)*.meanwhile *(j)* represents the group (or groups) that was used to calculate the average value of *HC* (i.e. *j=1, 2,…7*).

In the present case of pooling, the intercept term (a) drops out, since by construction the differential has a zero mean over all the countries and time periods, a fact which eliminates the model's capacity to capture initial endowment. As a result, the preceding model controls for income, and measures the relative degree or speed of educational convergence regardless of starting positions.

Convergence, in the preceding framework, is indicated if the differential of change in education becomes smaller over time. This,

based on the above modeling, will be manifested in $\gamma < 1$ and statistically significant. Alternatively, $\gamma > 1$ would be an indication of divergence. Prior work has established that a subunity convergence coefficient is robust evidence of convergence, and vice versa. Ben-David (1995) performed 10,000 simulations for each of the three possible outcomes: convergence, divergence and neutrality. His simulations provided evidence of convergence and divergence, according to the preceding γ-value requirements and consistent with the specific convergence scenario that the simulation process portrayed. When neutral data was used, with no strong indication either way, the calculated γ-value approached unity.

Data

The focus here is on identifying differences among three distinct groups of countries. Hence it is vital to group the data into subgroups of adequate similarity in terms of development level. The level of industrialization meets this requirement as a criterion for capital stock and economic advancement, which in most ways are synonymous with economic development. The categorization is based on GDP, physical capital stock and the composite index of development found in UNDP (2001). The intent here was to group countries, on the one hand based on their UNDP index proximity, and on the other hand, to include countries from all continents; if possible. As a result, each group's relative positioning on the UNDP list is significantly different than the one of the other groups, and by choosing countries from different regions; the possibility of sample bias due to geographical proximity is reduced[12] (Table 1).

The country data is divided into three groups: advanced economies, newly developed economies and less developed economies. The newly developed group is taken from the OECD's developed market economies, but its average level of capital stock is significantly lower than that of the advanced group, while the less developed group consists of non-developed market economies[13] with low levels of capital stock and ones that are found at the bottom of the UNDP's list. It should be noted that the term "developed" is somewhat vague; the

Table 2. Description of the data set: variables, years, variable definitions and sources

Var.	Years	Definition	Source
ENR^j	1992–2003	Total number of students enrolled in j-th educational level, regardless of age expressed as a percentage of the population of the corresponding age group	For the years 1990–97: UNESCO's *Statistical Yearbook*, 1999. For the years 1998–2001: OECD's *Statistics*, 2004
RPM	1990–1998	Number of researchers per million population	UNESCO's *Statistical Yearbook*, 1999

purpose though is to define a group that approximates a 'midpoint' between the 'advanced' and 'less developed'. Therefore it contains countries from both 'ends' of the middle subgroup of the UNDP list[14].

The empirical part in the following section uses a pooled data set obtained from the records of UNESCO (1999), while more recent data on particular variables was acquired from OECD (2004). The educational variables that will provide the input for the estimation process were chosen based on quantitative factors (i.e. availability) (Table 2).

THE CONVERGENCE ESTIMATION PROCESS

This section will combine the methodology discussed above with the data set obtained in an empirical process. The significance of the estimated coefficients and their corresponding *t-values* will be based on common t-tables, in contrast to other studies (i.e. Ben-David, 1995; Kocenda and Hanousek, 1998), that use adjusted critical values from the Levin and Lin (1992) tables, generated by Monte Carlo simulations. The reason for this is that the estimation results exhibit substantial magnitudes on *t-values* and, therefore, common tables are sufficient.

Econometric procedures and properties

The estimation process employs the Least Squares regression technique, with cross-section weights (by country), run for balanced samples. This constitutes a variation of the least squares method. This procedure first divides the weight series by its mean and then multiplies all of the data for each cross section by the scaled weight series in such a way as to normalize the data set. Meanwhile the "balanced" option implies that the data set is balanced with respect to data availability for the different cross sections. These do not affect the parameter estimation but make the weighted residuals more comparable to the unweighted ones. This procedure is quite common, especially when heteroscedasticity of a known form is a problem. It is also permissible to use it in combination with other correction methods for heteroscedasticity.

Since the regression procedure is of one variable and the specification of the model (in a way, the model measures auto-correlation, with t-1) on panel data, it becomes a nuisance to test for multi-collinearity.

Heteroscedasticity: To test for heteroscedasticity, White (1980) developed a test that regresses the squares of the regression residuals to the explanatory variable and their squares:

$$u_i^2 = b_1[HC_{t-1} - avg(HC_{t-1}^j)] + b_2 [HC_{t-1} - avg(HC_{t-1}^j)]^2 + e_{j,t}$$

The null hypothesis is that all coefficients are equal to zero ($b_1 = b_2 = 0$); that is, the absence of heteroscedasticity, while the calculated statistic could be either an F or chi-square. Naturally, White's heteroscedasticity-consistent covariance method of correction was used, also being applied to the calculation of the standard errors and the t-statistics.

Autocorrelation: The presence of autocorrelation is not significant in this specification, with a few exceptions, which demonstrate a moderate problem of autocorrelation. The testing procedure is a modification of the Durbin and Watson procedure as used by Baltagi and Li (1991). The test follows a Chi-square distribution and the critical value at the 95% significance level is: $X^2 = 1,0.05 = 3.4841$, while the corresponding values from the performed Durbin and Watson are approximately when DW = 0 and DW = 4 (Lee, 2000). It should also be kept in mind that the present model is not explanatory. In fact, for such a short time interval, it would be expected that the determinants of the trend in the deviations remained mainly the same, since the variables[15] heavily depend on structural characteristics that, usually, demonstrate extended time lags. Nevertheless, when serial correlation was detected the process was re-run with an auto-regressor (lagged at t-1, t-2, etc) term until the DW was statistically different than the above-mentioned critical values. Thus, the adjusted R-sq values take into consideration the total number of regression.

Enrollment rates (ENR)

The deviation from the mean of the enrollment rates variable (ENR) auto-regressive process was run separately for each individual country group, for every two group combination and for all three groups simultaneously, by estimating the convergence coefficient ( ) both in an intra-group and inter- group context. The stochastic equation for each group or combination of groups -for every educational level- will be the following:

Table 3   Group descriptive statistics for the variable [$ENR_{i,\,t}$- $avg(ENR^{j}_{t})$].

Primary education					
Country group (j)	**Mean**	**Median**	**Std. dev.**	**Cross sections**	**Obs.**
ADVANCED	1.03	1.02	0.40	8	96
DEVELOPED	1.07	1.05	0.93	8	96
LDC	0.98	1.06	0.18	8	96
ADVANCED AND LDC	1.04	1.30	1.35	16	192
DEVELOPED AND LDC	1.01	1.03	0.84	16	192
DEVELOPED AND ADVANCED	1.05	1.03	0.73	16	192
DEVELOPED, ADVANCED AND LDC	1.26	1.04	1.27	24	288
Secondary education					
ADVANCED	1.112	1.05	0.179	8	96
DEVELOPED	0.99	1.0	0.290	8	96
LDC	0.47	0.5	0.256	8	96
ADVANCED AND LDC	0.80	0.89	0.389	16	192
DEVELOPED AND LDC	0.73	0.72	0.374	16	192
DEVELOPED AND ADVANCED	1.06	1.05	0.248	16	192
DEVELOPED AND ADVANCED AND LDC	0.864	0.95	0.370	24	288
Higher education					
ADVANCED	0.54	0.50	0.166	8	96
DEVELOPED	0.40	0.44	0.163	8	96
LDC	0.084	0.07	0.052	8	92
ADVANCED AND LDC	0.315	0.275	0.263	8	96
DEVELOPED AND LDC	0.24	0.17	0.202	16	192
DEVELOPED AND ADVANCED	0.475	0.47	0.179	16	192
DEVELOPED, ADVANCED AND LDC	0.34	0.39	0.238	24	288

$$[ENR_{i,\,t}- avg(ENR^{j}_{t})] = \gamma[(ENR_{i,t-1} - avg(ENR^{j}_{t-1})] + u_{it},$$

Primary education

The results of the descriptive statistics (Table 3) indicate that the greatest difference from the mean is found in the last country combination when the whole sample is included. Similarly, the largest variability, as measured by the standard deviation, is found when the ADVANCED and LDC groups are combined, implying the absence of world equity and uniformity.

The output of the regression procedure (Table 4), as captured by *R-sq, t,* and *F* values, underlines the validity of the proposed specification. An exception is observed on the advanced and developed group, where the -value is insignificant, possibly due to the AR term. Nevertheless, large values of *R-sq* were expected since the model is of an auto-regressive nature. Nevertheless, it permits the safe interpretation of the estimated coefficients. It should also be kept in mind that in recent times, primary education has been mandatory in most countries. In the most parts of the world, children enroll, at least, in primary education. Consequently, one should not expect dramatic changes or trends in the deviation of

primary education, consistent with Wolf's (2000) claim; that in the 90's, enrollments in primary education reached 100%. The estimated *-coefficients* above do indicate evidence of convergence, since the estimated values are less than one; finding consistent with most prior studies. Thus the evolution in the mean deviation of the enrollment rates in primary education merely exhibits stationarity — at least in the examined time period, which coincides with the last decade.

Secondary education

Once again the descriptive statistics imply an increase in the variability as one moves towards the combined country groups, with the largest being the three-group combination. Moreover, in individual groups, the largest mean deviation is reported in wealthier countries, implying uniformity among the poorest countries, while their counterparts in the developed world demonstrate increased dynamism.

Similarly, the regression and coefficient statistics for secondary education demonstrate values that signify the merits of the simplistic specification. The *R-sq, t* and *F* values are significant beyond the 99% mark. The *-coeffi-*

Table 4. The output of the pooled least squares estimation, corrected for heteroscedasticity by White's consistent standard errors and covariance methodology.

Country group (j)	-coefficient	t-value	R^2-adj	F-value	DW
Primary education					
ADVANCED	0.920	18.131**	0.831	429.04**	2.421
DEVELOPED	0.971	42.117**	0.960	2062.14**	1.953
LDC	0.943	43.340**	0.939	1351.58**	2.172
ADVANCED AND LDC	0.945	50.211**	0.935	58.68**	2.113
DEVELOPED AND LDC	0.954	63.720**	0.947	3106.14**	2.149
DEVELOPED AND ADVANCED	0.23	3.12	0.051	9.95	2.140***
DEVELOPED, ADVANCED AND LDC	0.953	65.507**	0.942	4263.99**	2.088
Secondary education					
ADVANCED	0.995	76.717**	0.9746	3357.7**	1.92
DEVELOPED	0.995	76.203**	0.975	3357.9**	1.91
LDC	0.987	113.553**	0.992	11313.3**	1.45
ADVANCED AND LDC	1.013	156.182**	0989	15926.6**	2.19
DEVELOPED AND LDC	1.004	137.366**	0.990	17039.5**	1.67
DEVELOPED AND ADVANCED	1.004	87.620**	0.961	4266.4**	1.84
DEVELOPED, ADVANCED AND LDC	1.009	174.321**	0.987	19.302.4**	1.73
Higher education					
ADVANCED	0.910	36.054**	0.973	3164.6**	1.48
DEVELOPED	1.036	67.749**	0.984	5422.1**	1.42
LDC	1.04	92.542**	0.993	11728.0**	1.24
ADVANCED AND LDC	0.994	96.049**	0.963	22809.7**	1.12
DEVELOPED AND LDC	1.043	147.636**	0.994	27232.7**	1.38
DEVELOPED AND ADVANCED	0.963	54.475**	0.978	7768.7**	1.26
DEVELOPED, ADVANCED AND LDC	1.004	106.764**	0.991	27471.2**	1.29

** Significant at the 99% level.
*** For DW=0.00, or DW=4.00 autocorrelation was assumed and the process was repeated with one AR term.

cient implies moderate indications of convergence within groups and elements of divergence between groups; especially, in the case of "advanced-developed and poor countries".[16]

In reference to Table 4, it should also be noted that secondary education "matters" more in LDC countries (Petrakis and Stamatakis, 2002; Psachropoulos, 1994).

Higher education

In regard to higher education, the average deviations from the group mean, is far smaller from those of the lower educational levels. Once again, the highest values for standard deviations are noted on the advanced and LDC and developed, advanced and LDC combinations of country groups.

Furthermore, the quality specification, as captured by the *R-sq, t,* and *F* statistics, allow for the safe interpretation of the estimated coefficients. The combination of "poor" and "advanced" countries shows moderate evidence of convergence, or at least, not a worsening of the existing status in enrollment rates.[17] Similarly, the three- group union indicates, at least, stationarity in higher education enrollment since 1990. One rather troubling coefficient is that of developed

countries, which implies the absence of convergence. An explanation for this could be provided by the elevated heterogeneity of the "developed" group (compared to the advanced and LDC), since it incorporates countries like Turkey and Mexico that have recently entered the developed world, versus Netherlands that has been a developed world member for a much longer period.

Overall, enrollment rates exhibit weak evidence of convergence at the secondary and higher level, or if one allows room for error, they do not demonstrate a worsening, at least in regards to enrollments. It is important to report that the magnitude of the *t and R-sq* values permits the interpretation of the *-coefficient* with high accuracy. For instance, the hypothesis testing *Ho:* = + *0.1* is rejected in most regressions at a significance level of 95%, since the corresponding standard errors are very minimal (large *t-values*). For example, it can be claimed that for a *-value* of *0.9, 1.0,* with 95% certainty.

Moreover, enrollment-rate interpretation should be done with skepticism, especially if the intention is to make inferences about human capital. Undoubtedly, enrollments are used as a proxy to human capital investment. Nevertheless, they fail to capture important quality aspects that determine the productive effectiveness of the education process which also

Table 5. Group descriptive statistics for the variable [RPM $_{i,t}$ - avg(RPM^j_t)]

Country group (j)	Mean	Median	Std. dev.	Cross sections	Obs.
ADVANCED	3222.1	2870	165.4	8	64
DEVELOPED	1242.2	1104	111.2	8	64
LDC	180.2	122	21.9	8	64
ADVANCED AND LDC	1701.1	1408	86.4	8	128
DEVELOPED AND LDC	711.8	295	59.0	16	128
DEVELOPED AND ADVANCED	2232.2	23.6	137.2	16	128
DEVELOPED, ADVANCED AND LDC	1548.2	1104	93.7	24	192

Table 6. The output of the pooled least squares estimation, corrected for heteroscedasticity by White's consistent standard errors and covariance methodology.

Country group (j)	-coefficient	t-value	R^2-adj	F-value	DW
ADVANCED	0.940	15.19**	0.934	781.4**	2.93
DEVELOPED	0.989	39.88**	0.980	2766.2**	1.33
LDC	0.918	12.76**	0.839	288.1**	2.72
ADVANCED AND LDC	1.008	47.92**	0.987	8353.3**	2.92
DEVELOPED AND LDC	1.010	50.53**	0.985	7306.2**	1.75
DEVELOPED AND ADVANCED	0.988	37.52**	0.978	4936.9**	2.68
DEVELOPED, ADVANCED AND LDC	0.905	52.67**	0.986	12179**	2.68 ***

** Significant at the 99% level.
*** For DW = 0.00, or DW = 4.00 autocorrelation was assumed and the process was repeated with one AR term.

requires investment. These quality characteristics (organization, facilities, libraries, course material, teaching quality etc.) become increasingly crucial in post-secondary education, since, at this level, education becomes more specialized to provide the student with the required skills to enter the highly competitive and technology powered global economy. Nevertheless, aside from the preceding discussion, enrollment remain one of the most commonly used proxies, and since many convergence claims are based on these, it becomes interesting to compare them with other human capital proxies, such as researchers per million.

Number of researchers per million (RPM)

The final variable that will be tested refers to the research and development effort of each country group. Due to currency and exchange rate inconsistencies, especially for less developed economies, and since RPM expenditure is mainly expressed in terms of domestic currency, the uniform expression of RPM expenses in terms of a common currency would be devious due to different exchange rate regimes; especially in LDC countries with fixed exchange rate policies. Instead, the number of researchers per million people was chosen as a proxy of RPM, since its measurement units make it comparable across different countries.

$$RPM_{it} - avg\,(RPM^j_t) = \gamma[RPMi_{,t-1} - avg\,(RPM^j_{t-1})] + u_{it,}$$

The Tables 5 and 6 below present the descriptive statistics and corresponding estimation output for each country group and group combination.

The preceding table with the descriptive statistics indicates the immense superiority of advanced countries. The mean number of researchers is almost three times larger than the corresponding for developed countries, and nearly 20 times greater than that of the less developed ones.

Observing the estimation output, aside from the significant statistics (*R-sq, t* and *F*); it could be said that the relative positions of the three groups remained the same and their deviations from the corresponding mean are not exhibiting any significant trends.[18] Regrettably, some skepticism would be justified regarding the coefficient of the last regression (all three groups); possible explanations could be the heterogeneity resulting from the extreme differences on the initial endowments (starting values) and/or the correction process by adding an AR term. Even if the - value indicates convergence, it would take LDC countries more than thirty years to reach the current level of advanced countries; at the suggested 9.5% growth rate. Thus, if the 'advanced continue to advance', the convergence possibility becomes seriously weakened.

Interestingly, within the advanced and LDC groups there is evidence of divergence, underlining the supremacy of a few countries (e.g. USA) -even among advanced counties. Meanwhile, the immense gap with

respect to the developing countries, in addition to their economic exploitation by the 'strong' (through patent rights; negotiating power; commercial and military power, etc), could provide the main ingredients for polarization.

Overall, the existing enormous mean difference between advanced and LDC countries, reinforced by the absence of improvement—as noted by the above results—implies the incapacity of lagging nations to respond. As a result, and since the rates of change in new researchers are approximately the same,[19] their difference in absolute terms will continue to increase.

Concluding remarks and implications

Thus far, concerning human capital, empirical studies were performed exclusively on enrollment and/or attainment rates of educational levels. The results, for the most part, suggested evidence of cross-country convergence. Similarly, regarding enrollment flows, the current study indicated moderate evidence of convergence.

On the contrary, when the focal point was turned towards alternative approximations of human capital, such as RPM, the results were inconsistent with those of enrollment rates, and revealed no evidence of divergence nor convergence, especially in connection with poor economies. Alternatively, the favorable case would imply prolongation of the existing status quo and the acute disparity between rich and poor countries.

Based on the former, and on the assumption that the rate of human capital change will persist, the actual gap (in absolute terms) will be getting larger, implicating the vicious cycle of a "convergence trap". Of course, the converging inconsistency of the empirical findings among the different components of human capital may provide a source for skepticism. However, if the synthetic nature of human capital is considered, then an argument could be made in favor of the latter.

Higher education is behind the creation of new technology and multidisciplinary innovation in general. As a result, economic advancement could be merely viewed as the outcome of investment, infrastructure and policy regarding higher education. It is also a known fact that third-level education, in order to be economically effective — assuming an extension for increased research efforts — requires increased funding and often the contribution of the privet sector (i.e. the collaboration between tertiary education institutions and the business world). Consequently, in this framework of thinking, convergence in higher education -in addition to R&D and knowledge stocks (i.e. libraries, labs, etc) appears to be a necessary (but not sufficient) condition for growth convergence and global income equality. Alternatively, human capital convergence at the primary and secondary level is not enough to empower growth convergence. This observation is in accordance with the overall polarization of worldwide per capita income—and especially in the case of less developed countries—even though, poor countries demonstrate significant enrollment rates increase, at the primary and secondary level.

Interestingly, and as an extension to the preceding arguments, one could interpret the role of the lengthy time lag of educational attainment (until it becomes productively enforced), and the post-World War II extreme rate of technological advancement. An intuitive line of reasoning could be made that countries with significantly lower human capital endowments in the 1950s era, and in the absence of long-term policy dedication, would face a serious barrier to catching up. The later would be the natural consequence; on the one hand, of the faster rate of technological change than the productive enforcement of educational attainment, and on the other, of the necessity for very long-term and 'costly' policy dedication to increased human capital investment; a dependant to political stability. Thus, in some cases, growth rate polarization could be –to some degree- the manifestation of a '*convergence trap*' on the rate of human capital accumulation.

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Notes

[1] a claim best suited to well developed economies.

[2] Population growth, migration and other factors alter the magnitude of enrollments.

[3] For example R&D leads to the creation of new ideas, patents that can be exploited financially.

[4] Where this group consists the G7 group except Sweden and Denmark

[5] Barro, (1991), Barro and Lee, (1993) and Psacharopoulos (1994) are among the few that emphasize on developing countries.

[6] The transformation is: $GDP_{i,t} = (a_0 + a_1 H_{it} + a_2 K + a_3 L) + H_{it} (a_{1t} - a_1) + [(U_{it} + (a_2 + K_{it} - a_2 K_{it}) + (a_3 L_{it} - a_3 L) + (a_{0t} - a_0),$ where a_i is the average contribution over the t years of the sample (67 - 85) and K and L are the mean values of capital and labor, respectively, calculated across countries and over time. Thus, the estimation equation becomes: $VQt = Var(a_0 + a_1 H_{it} + a_2 K + a_3 L).$

[7] Advanced countries are included as one observation due to homogeneity.

[8] $L = \Sigma p_i \ln(p_i/y_i)$ where p_i and y_i are shares of the i-th country in total population and income, respectively and the sum is over the N countries of the sample.

[9] The stochastic model was: $Ln[ENR_{86} \backslash ENR_{60}]_{ij} = a_j + b_j \ln(ENR_{60})_{ij} + U_{ij,.}$ where $[ENR_{60}]_{ij}$ and $[ENR_{86}]_{ij}$ denote enrollment rates at level j in country i for the years 1960 and 1980 respectively, and u_{ij} is the common disturbance term.

[10] The Ginni coefficient is defined as: $Gh = 1/[2avg(Ch)] [x_i - x_j]n$ in j for i, j = 0,1,2,3. The magnitude of Gh constitutes a direct analogy for educational inequality.

[11] Consequently, if one assumes homogeneous of degree one (or greater) production technology (i.e. $+ \geq 1$), convergence in human capital would imply growth convergence. Interestingly enough, even in the case of diminishing marginal productivity in human capital (i.e. <1), a positive spillover effect (i.e. >0) would slow down the speed of convergence, and in the extreme case of > , the 'extraordinary' additions to human capital would totally offset the diminishing effect of marginal productivity.

[12] Often UNDP rankings, since they result from a large number of different indexes (e.g. schooling, infant mortality, income, etc.) are quite different than the income ranking; for example, Italy even though a member of the G7 has a rank of around 30th in the UNDP (2001) list.

[13] This classification refers to non-communist economies; communist economies are totally excluded from this study.

[14] The middle subgroup would result if the top ten and last ten countries from the UNDP list were excluded.

[15] This is mainly due to the nature of the variables. Education and in general human capital variables are used with time lags between 8 and 12 years.

[16] The hypothesis Ho: = 1 is not rejected at a significance level higher that 90% for all groups except ADVANCED AND LDC.

[17] The hypothesis Ho: = 1 is rejected at significance level higher that 90% for all groups except DEVELOPED, ADVANCED AND LDC.

[18] The hypothesis Ho: = 1 for developed, developed, advanced and ldc, developed and advanced, developed and ldc and advanced and ldc cannot be rejected using a 95% level of significance.

[19] For advanced the mean rate of change is 17.1% and 16.7% for LDC.