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Convergence on Alternative Human Capital Proxy Variables: A Cross Country Empirical Investigation

D. Stamatakis[1]

***Abstract**:*

This article conducts an empirical investigation comparing human capital convergence in three country groups of significantly different development levels: G7, developed and less developed. The contribution of this work is that Human capital evaluation surpasses enrolment and/or attainment rates.

In addition to enrollment rates and government spending, alternative factors that determine the contribution of human capital are incorporated, such as book availability, researchers per capita and students per teacher. The results indicate moderate evidence of convergence among the three-country groups when "traditional" variables are included.

Nevertheless, the convergence "picture" becomes remarkably transformed in reference to unconventional human capital proxies; indicating the incapacity of traditional variables to capture the complexity of human capital creation, implying the existence of a "convergence trap" that emphasizes on 'more' qualitative variables -ignored by traditional variables, suggesting a possible scenario of worldwide polarization, ultimately reinforced by political factors.

Key Words: *Economic Development, Growth, convergence, Developing Country, Developmental State, Innovation, Least Developed Country, human capital, education*

JEL Classification: *O3, O31, O33*

[1] *Assistant Professor Athens National and Kapodistrian University, Division of Economic Development. 8 Pesmatzoglou st. suite 302, Athens 105 59 Greece, email: dstamatakis3@gmail.com*

Introduction

A key economic issue currently is whether poor countries tend to grow faster than rich ones and converge over time to some steady state of per capita income. Instead of evaluating convergence based on a specific growth model, the present article considers the factors of production. Specifically, it constitutes an attempt to empirically evaluate and interpret convergence on human capital variables, providing a compliment to former studies regarding education and growth (e.g. Petrakis and Stamatakis, 2002; McMahon, 1998; Barro and Lee, 1993). Thus, implications are obtained from the intersection between former findings on enrollment rates and the, hereby empirical outcome, that incorporates an augmented set of human capital proxies; stocks and flows.

We examine quantitative and qualitative variables of human capital, based on three country groups that exhibit significantly different development levels: less developed, developed and advanced. The developed and advanced groups pertain to OECD countries, while the less developed group corresponds to poor nations outside the OECD.

The advantage of the present methodology is therefore twofold. On the one hand, it goes beyond enrollment rates; a rather simplistic measure of human capital that gets exhausted in modern economics. Ultimately, the present work incorporates a more synthetic approximation to human capital; one that implicitly emphasizes on measures of educational quality and overall effectiveness. Meanwhile, the three-dimensional grouping provides a control for economic homogeneity and implies structural proximity. As a result, the empirical inference can be stretched to integrate issues beyond equilibrium-based growth theories.

The empirical section utilizes Ben-David's (1993; 1995) technique, in the context of a stochastic model that evaluates all country-group combinations. The remainder of this article is developed as follows: Section 2 attempts a more synthetic definition of human capital and provides an overview of existing evidence and prior attempts to assess human capital convergence. Sections 3 and 4 describe the data set, the stochastic procedure and carry out the estimation process. The final section (5) discusses the empirical findings and the resulting implications.

An Overview of Empirical Findings and Former Attempts to Approximate Educational Convergence

Classical economics underlined the importance of capital stock and its formation process in relation to economic advancement, focusing primarily on its tangible dimension. In a period of primacy, land and natural resources were perceived as the key determinants of endogenous growth. In contrast, modern economists have shifted their attention -at least in regards to developed market economies- towards the intangible role of human and social capital. Nowadays, it is physical capital that has become the subject of conventional thinking.

Adam Smith and Marshall (1920), had predicted the evolving importance of human capital, where capital included Law, Church, Literature, Art and Education, among several other factors. In Irving Fishers (1906) formulation, capital is all-inclusive and includes human capital, specialized human capital and social organizational forms. Becker (1962; 1975), set forth the basic theory of human capital as it is used today in labor economics, influencing the flow growth literature, ranging from Arrow (1962; 1973) to Romer (1986; 1990), Lucas (1988; 1990), Mankiw *et al.* (1992) and Hanushek and Kym (1995).

In general, the underlying consequence — from “structural” to “equilibrium” theories and from Adam Smith and Abramovitz to formal contemporary economists such as Solow, Romer and Lucas, is that human capital investment produces an increasing effect on economic growth. According to Schumpeter (1991; 1942) and Schultz (1993; 1961), human resources are a far more important factor of production than natural resources, and most importantly, they provide the basic elements of entrepreneurship. Consequently, according to many other economists, human capital can be perceived as a dominating factor in growth convergence; especially in the case of OECD countries (DeLong, Mansoorian and Michelis, 2004).

Trends in Human Capital Accumulation

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

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

Wolf (2000) presented findings on human capital formation, 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 among the countries in this group. Meanwhile, secondary education increased to 94% in 1991 (from 54% in 1950) and to 97% in Industrialized Market Economies (IMEs). Most importantly, the coefficient of variation fell from 0.26% to 0.15% in OECD nations, and from 0.20% to 0.11% in IMEs.

Naturally, the greatest variation in OECD members, is located with respect to higher education: whereas in 1965 United States obtained a 40% enrollment rate (the highest) Turkey's was 4% (the lowest), meanwhile, 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) generated estimates for the mean years of schooling of the labor force, between the years 1965 and 1985, by using as base estimates those of the mid-1970s which are then backdated or postdated for either period. In this attempt, both France and Denmark exhibit an increase in mean years of schooling for the period between 1965 and 1975, and then a decline for the following decade. Meanwhile, in Germany, schooling levels are reported to have declined from 1965 to 1975.

In the work of Barro and Lee (1993), on the other hand, human capital is represented by stocks instead of flows. The method is similar to that of Kyriacou's, the data set refers to enrollment rates for the total population older than the age of 25 and the results indicate a continuous rise in enrollment rates rose from 1960 to 1980, yet lower than that of Kyriacou's.

Maddison (1987; 1991), in regard to average years of schooling between the years 1950 and 1989, for a sample of six well-developed market economies (G7 members), 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, which was to a certain extent a consequence of the country group (homogeneous).

In general, two stylized facts can be extracted in regards to educational trends (levels and/or flows) for OECD countries, despite data sources and methodological procedures; the results show an almost continuous upward trend in schooling years for the years 1965 and 1975. Dispersion seems to decline for the years 1965–80, and then rises between the years 1980 and 1985 (it should be noted though that the country sample changes over time).

Prior Attempts to Measure Human Capital Convergence

Departing from the role of human capital in the evolution of economic growth, Albin (1970), employing a sort of cost–benefit analysis, focused on the value of education, arrived at a rather pessimistic conclusion; poverty classes will be absorbed into advancing sectors, only if investment in education becomes worthwhile at some point in time. Initially, the poor are caught in a "vicious circle" in which their poverty implies that they are faced with relatively high rates of external finance and, consequently, internal discount rates high enough to forbid sizeable investment in human capital.

O'Neill (1995), in order to explain the time evolution of growth convergence, adapted an educational variance approach for a large country sample that incorporates countries of all development levels for the years 1967–85. The results reflect the frequently expressed opinion of many economists (and other social scientists) that our world is one of growing inequality. The noted variances, as indicators of global income inequality, indicate a significant betterment in regards to developed market economies (OECD countries), while less developed countries exhibit a relative worsening. O'Neill's contribution, in the present context, can be located in his effort to deconstruct the convergence patterns based on the positions of Romer (1989) and Tamura (1991), that convergence is powered by human capital and technology flows from the leading countries to the lagging ones.

The empirical results of O'Neill's work indicate that the total variation in income distribution comprises the separate contributions of education quantities, education prices and residual changes. One very important finding is that, in developed European countries, education played a major role in the overall reduction of income inequality. In contrast, the results for less developed countries are quite different, since the total change in income variation is positive, implying a deterioration of income distribution. In general the results establish a converging trend in regard to educational attainment, but the rates of acquired education have diverged. This divergence is greater in less developed countries, to such a degree that the converging effect of education gets cancelled out and, as a result, the overall variation in income becomes increased, mainly due to qualitative and structural factors that foster education effectiveness.

Developing economies, despite the noticeable improvement in educational attainment, still remain at the lower end of overall educational distribution. Therefore, factors that have a substantial effect on productivity, such as skilled labor, favor the developed economies in a disanalogous manner and naturally at the expense of the less developed. Hence, in relation to the advanced economies, when a country is very far behind it can only get further back. The modeling adapts a production function in log-linear format in which the parameters are allowed to vary over time.[i]

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[ii] for 1960, 1970, 1980 and 1986. He establishes a Bourguignon (1979) weighted inequality index[iii] for enrollment rates. Ram's findings in regard to the overall change (1960–86) indicate a worsening of global educational equality at the higher level of education. Meanwhile, inequality seems to be diminished in regard to primary and secondary education. The evolution pattern of the *L-index* is similar to preceding studies in that an initially noted improvement (1960–80) declines in the 1980s.

Moreover, the inter-country convergence[iv] estimation showed evidence of convergence at all educational levels. However the corresponding speeds are higher for primary and secondary education. In addition, when *L-index* is calculated on an inter-level basis (i.e. measuring inequality across the three educational levels), the results suggested a relative deficiency of less developed countries; an ongoing worsening in the acquisition of education at all levels.

Finally, Castello and Domenech (2001), in an effort to introduce inequality measures in stochastic growth equations performed on a cross-section sample, employed human capital inequality variables, obtained by Ginni-coefficient computations, using the Barro and Lee data set on attainment rates.[v] Their results indicated a significantly negative effect of human capital inequality on growth.

Methodology and Data

In the next section, a comparative empirical investigation will be attempted between three alternative country groups that exhibit significantly different development levels; advanced, developed and less developed. The aim is to uncover convergence-rate differences in human capital variables, within individual groups, between any two groups and among all three groups. This will test 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 merely modifying 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)*:

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

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

$$c_{it} = HC_{ti}(1-\tau_{ti}) \tag{2}$$

where (τ) 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:

$$HC_{t+1,\,i}= \Phi(HC^{th}/HC_{t,i})^{\delta}\, HC_{t,i}\ \tau_{ti}^{(1-\delta)},\quad for\ \forall\,\delta\geq 0 \tag{3}$$

Where, HC^{th} denotes a threshold level of human capital, below of which (when $\delta>0$) the converging effect of human capital is reversed as empirically found by Barro & Sala I 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:

$$Y_i = \Phi_i \{HC_{ti},^{\beta} (HC_{t-1,i}/HC^{th})^{\delta}\} \tag{4}$$

Where *(Φ)* 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 countries*), then by taking the logs:

$$lnY_i = ln\Phi_i + \beta lnHC_{ti} + \delta ln(HC_{t-1,i}\text{-}avgHC_{t-1}) \tag{5}$$

…and the total differential,

$$1/Y\ dY = \beta(1/HC_{ti})dHC_{ti} + \delta[1/(HC_{t-1,i}\text{-}avgHC_{t-1})]\ d(HC_{t-1,i}\text{-}avgHC_{t-1}) \tag{6}$$

Where growth (*1/Y dY*) is determined by the marginal product of human capital *(β)*, the *spillover* effect *(δ)* and the *relative* percentage changes in human capital[vi]. Moreover, if cross-country uniformity in the marginal product of human capital is assumed, then one can approximate the *ith* country's convergence rate by estimating the time path of human capital deviations from the overall country mean, in such way, that the particular sample that the mean is calculated from, determines the territory of convergence (i.e. club, group, world, etc).

$$HC_{ti} - avgHC_t = \gamma\ [HC_{t-1,i} - avgHC_{t-1}] + u_{ti} \tag{7}$$

Where (γ) captures the *ith* country's speed of convergence towards the group in question, meanwhile, (γ) 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.

Therefore, in terms of a stochastic function with respect to human capital *(HC),* this could be expressed by the following equation:

$$HC^{j}_{i,\,t}=a + \gamma HC_{i,,\,t-1} + e_{i,\,t} \tag{1a}$$

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

$$HC_{i\,t}- avg(HC^{j}_{t})=\gamma[HC_{t-1} - avg(HC^{j}_{t-1})] + u_{it} \tag{2a}$$

we obtain equation *(2a)* 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*.

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 model ignores the income level effect, 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

Since the aim here is to identify differences among three distinct groups of countries, 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 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[vii].

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

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

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: *Description of the data set: variables, years, variable definitions and sources*

Var.	*Years*	*Definition*	*Source*
ENR^j	1990–2001	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 *Education at a Glance*, 2002
EXP	1990–2001	Total and current public expenditure on j-th educational level, expressed as a percentage of the gross national product in all educational levels combined	For the years 1990–97: UNESCO's *Statistical Yearbook*, 1999. For the years 1998–2001: OECD's *Education at a Glance*, 2002
$TEACH^j$	1990–2001	The number of teaching staff of the j-th educational level divided by the number of students enrolled in the j-th educational level	OECD: *Education Online Database*, 2003
BOOK	1990–97	The total number of books (volumes) in public libraries divided by the total number of registered users	UNESCO's *Statistical Yearbook*, 1999
RPM	1990–97	Number of researchers per million population	UNESCO's *Statistical Yearbook*, 1999

The Convergence Estimation Model

In the existing literature of economic growth, there are numerous articles that address — among other things — the issue of convergence. Convergence in explanatory variables of importance can be researched by several methods. Baumol (1986), Barro (1991) and Barro and Sala-I-Martin (1991; 1992) pioneered the conventional approach by examining, in a cross-section country set, the evolution over time of the per capita growth rate, in reference to its initial level.

Later research by Bernard and Durfauf (1995) showed that the conventional approach was very simplistic, and valid only under strong assumptions. The methodology that will be adopted here has been used in several studies; it utilizes a pooled data set and relies on weaker assumptions. Ben-David (1995; 1996) adapted this approach in a growth study of real per capita income in numerous countries. Kocenda and Hanousek (1998) applied this methodology to study convergence paths of macroeconomic variables in European and Asian economies. The convergence analysis will start by modeling the time path of educational variable for a group of *i* individual countries, with observations taken from *t* time periods, in the context of an autoregressive process, expressed by the following equation:

$$ED^{j}_{i,t} = a + \gamma ED^{j}_{i,,t-1} + e_{i,t} \quad (1)$$

where $ED^{j}_{i,t}$ represents a human capital variable, or a component (i.e. the *j-th* level of education at the *i-th* country at time *t*. Taking the difference from the mean on both sides ($\sum_i ED$ for every *t* and *t-1*):

$$ED^{j}_{i\,t} - avg(ED^{j}_{t}) = \gamma(ED^{j}_{t-1} - avg(ED^{j}_{t-1}) + u_{it}, \quad (2)$$

We obtain an estimation equation that captures the time evolution of the sample's deviation from its own mean over the examined time period where $avg(ED^{j}_{t}) = 1/n\ \Sigma^{n}_{i=1}$ and *(i,t)* represent the mean value of the educational level *(j)* over *(n)* countries at year *(t)*. In this 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 effects at $(t\text{-}t_0)$, in the convergence process. As a result, the preceding model is a strict calculation procedure, measuring the relative degree or speed of educational convergence regardless of starting positions. It provides no information on the acting component(s) — within the education variable (this would be possible only if the human capital variable was expressed implicitly by a function, and consequently, the right-hand variables could be checked for convergence).

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.

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 that employed more accurate 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 (see below).

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) is of an auto-regressive nature, 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:

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

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.

Once heteroscedasticity was detected, in addition to cross-section weights, another countermeasure was taken. White's heteroscedasticity-consistent covariance method of correction was used, also being applied to the calculation of the standard errors and the t-statistics. After the correction, heteroscedasticity could not be detected by White's test.

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 (Byung-Joo 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[x] 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 term until the DW was statistically different than the above-mentioned critical values.

Enrollment rates (ENR^j)

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 (γ) both in an intra-group and inter-group context. The stochastic equation for each group or combination of groups will be the following:

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

for every country or country-group combination, where, *j = primary (p), secondary (s), higher (h).* As a result, for every country group there will be three alternative regressions; one for every educational level.

The following subsections refer to the tables below that contain the output from the estimation process and are organized based on country group(s) and for secondary and higher educational levels, one with descriptive statistics and one with the regression results.

Table 3: *The output of the pooled least squares estimation, corrected for heteroscedasticity of unknown form, by White's consistent standard errors and covariance methodology*

Secondary education (j = 2)					
Country group	*γ-coefficient*	*t-value*	*R^2-adj*	*F-value*	*DW****
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
Higher education (j = 3)					
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 AR terms. As a result, the reported DW value on the table is of the final regression (corrected when necessary).*

Secondary Education

The results of the descriptive statistics on the raw data set 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.

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 *γ-coefficient* implies moderate indications of convergence between the combined groups, especially between advanced-developed and poor countries.[xi]

In reference to the above table, 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.[xii] 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 (compared with the other two) of the “developed” group; it incorporates countries like Turkey and Mexico that have recently entered the developed world, versus Denmark, 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 *γ-coefficient* with high accuracy. For instance, the hypothesis testing $Ho: \gamma = \gamma + 0.1$ 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 *γ-value* of 0.9, $\gamma \leq 1.0$, 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 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.

Public Expenditure on Education (EXP^j)

The second variable that will be empirically investigated refers to total government expenditure *(EXP)* in the public educational sector as a percentage of total income. Adapting equation (2) from above, the estimation equation becomes:

$$EXP_{i\,t} - avg(EXP_t) = \gamma[EXP_{t-1} - avg(EXP_{t-1})] + u_{it},$$

for every country or country-group combination. The process will be carried for all educational levels combined, examining in this way, apart from the additions to human capital, the overall policy reflection, or a country’s dedication to educational advancement.

Table 4:*The output of the pooled least squares estimation, corrected for heteroscedasticity of unknown form, by White’s consistent standard errors and covariance methodology*

Country group	*γ-coefficient*	*t-value*	*R2-adj*	*F-value*	*DW****
ADVANCED	1.020	76.342	0.980	4335.6	1.68
DEVELOPED	0.900	22.926	0.856	519.9	1.97
LDC	0.991	46.249	0.947	1554.5	1.43

ADVANCED AND LDC	0.999	106.248	0.986	12381.7	1.59
DEVELOPED AND LDC	0.917	27.967	0.885	1352.1	2.05
DEVELOPED AND ADVANCED	0.980	62.756	0.955	3691.9	1.98
DEVELOPED, ADVANCED AND LDC	0.988	99.552	0.971	8795.3	1.86

***Significant at the 99% level.*
**** For DW = 0.00, or DW = 4.00 autocorrelation was assumed and the process was repeated with AR terms. As a result, the reported DW value on the table is of the final regression (corrected when necessary).*

The mean deviation from the group(s) means demonstrate rather small values, indicating the nature of the variable; government policy in regards to education is by definition a very long-term decision variable. This can also be verified by the minimal standard deviations. Nonetheless, the greater numbers are attached to the least homogeneous groups; between advanced and poor and the all three groups combination.

The estimation output, aside from the significant regression statistics, indicates a case of divergence among developed countries, underlining once again the diversity in this group that nevertheless is constituted by developed market and OECD economies. Moreover, elements of divergence are located in the union of DEVELOPED AND LDC countries. The absence of divergence is only evident in the ADVANCED group, while the summation of developed and poor countries shows significant evidence of divergence, and the world as a whole (all three groups) indicates a gamma value less than one at a significance level of 70% (the standard error for that regression is 0.0099). Similarly, the rest of the *γ-values*, except for the one between ADVANCED and LDC, demonstrate failure to reject the null hypothesis of $\gamma < 1$ at a significance level between 70% and 80%. Surprisingly, when rich counties are combined with poor, the hypothesis that the *γ-coefficient* is significantly different than one ($\gamma \neq 1$), is rejected at the 95% level of significance.

Overall, public expenditures, as implied by the above results, contain less evidence of convergence, compared to enrollment rates. The proportion of an economy's output invested in education, implicitly, incorporates a qualitative dimension in addition to quantity, and goes beyond 'numbers of students stacked in a classroom'; it says something about the classroom.

Number of Students per Teacher (TEACH)

The next variable that will be tested refers to the ratio of students to teachers. This specific measure incorporates qualitative as well as quantitative dimensions attached to human capital, since the number of teachers assigned to a standardized number of students captures merely the degree of a country's dedication to effective educational provision.

$$TEACH_{i\,t} - avg(TEACH_t) = \gamma[TEACH_{t-1} - avg(TEACH_{t-1})] + u_{it},$$

for every country or country-group combination.

The following subsections refer to the tables below that contain the output from the estimation process and are organized based on the country group(s) and for secondary and higher educational levels, due to their increased economic importance; one with descriptive statistics and one with the regression results.

Table 5: *The output of the pooled least squares estimation, corrected for heteroscedasticity of unknown form, by White's consistent standard errors and covariance methodology*

Secondary education					
Country group	*γ-coefficient*	*t-value*	*R2-adj*	*F-value*	*DW****
ADVANCED	0.977	38.714**	0.956	1192.7	1.63
DEVELOPED	0.959	51.707**	0.973	1947.1	1.91
LDC	1.045	49.768**	0.952	1070.6	1.34
ADVANCED AND LDC	1.051	19.025**	0.866	717.1	1.35
DEVELOPED AND LDC	1.01	24.274**	0.857	665.5	1.46
DEVELOPED AND ADVANCED	0.862	10.445**	0.812	476.2	2.10
DEVELOPED, ADVANCED AND LDC	0.928	13.842**	0.811	717.1	1.71
Higher education					
ADVANCED	0.765	7.495**	0.764	179.4	2.24
DEVELOPED	1.022	26.623**	0.935	787.5	1.95
LDC	0.942	12.989**	0.834	270.5	2.07
ADVANCED AND LDC	0.957	16.455**	0.863	612.9	2.01
DEVELOPED AND LDC	0.976	23.386**	0.877	784.05	2.09
DEVELOPED AND ADVANCED	0.863	10.446**	0.811	476.3	2.11
DEVELOPED, ADVANCED AND LDC	0.881	13.293**	0.814	731.1	2.07

*** Significant at the 99% level.*
**** For DW = 0.00, or DW = 4.00 autocorrelation was assumed and the process was repeated with AR terms. As a result, the reported DW value on the table is of the final regression (corrected when necessary).*

Secondary Education

The regression output of the above table contains mild elements of convergence in regards to secondary education on LDC, meanwhile the overall uniformity seems to be inhibited, mainly due to the DEVELOPED country group, which follows a diverging route from the mean trend of the ADVANCED and DEVELOPED groups.[xiii] Furthermore, the corresponding statistics display a high level of significance in regards to both; specification (*R-sq*, *F-value*) and estimation (*t-* values).

Higher Education

In Table 8, the regression output indicates evidence of divergence. It is emphatic to note the strong diverging dynamic within the advanced group, perhaps implying the absolute superiority of USA (and a couple of other countries) that polarize this country group. Most importantly, the γ-coefficient of the three-group combination — which in a way represents the world as a whole — designates a diverging trend since the 1990s.[xiv]

In relation to higher education, the evidence suggests significant elements of divergence, in contrast to secondary education. Secondary education, just like primary, eventually becomes standardized (to some degree) worldwide, whereas higher education is more peculiar in nature; far more dependent on infrastructure, and therefore it inherits stronger qualitative essentials.

Number of Books per Capita (BOOK)

The next variable that will be tested refers to the ratio of public libraries' total book volumes, to population. This variable incorporates public-good characteristics and demonstrates the social capital dimension of human capital. The imbedded assumption here is that individuals in the sample have the same propensity of using a library.

$$BOOK_{i\,t} - avg(BOOK_t) = \gamma[\,BOOK_{i,t-1} - avg(BOOK_{t-1})] + u_{it}\,,$$

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

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

Country group	*γ-coefficient*	*t-value*	*R2-adj*	*F-value*	*DW****
ADVANCED	1.009	128.52**	0.996	13318.9**	1.50
DEVELOPED	0.561	2.165	0.294	20.99**	2.76
LDC	1.006	27.437**	0.945	831.71**	1.92
ADVANCED AND LDC	1.003	157.49**	0.994	17082.1**	1.68
DEVELOPED AND LDC	0.720	3.511	0.505	99.71**	3.012
DEVELOPED AND ADVANCED	0.760	8.648**	0.643	175.79**	2.59
DEVELOPED, ADVANCED AND LDC	0.910	11.687**	0.815	645.94**	3.31

*** Significant at the 99% level.*
**** For DW = 0.00, or DW = 4.00 autocorrelation was assumed and the process was repeated with AR terms. As a result, the reported DW value on the table is of the final regression (corrected when necessary).*

The raw data of the above regression indicates enormous level differences between advanced and poor countries. The mean value of the former is nearly sixfold that of the latter, also supported by the relative size of the three-group standard deviation; being the largest underlines the evolution of inequality as we move from wealthy to poor. Similarly, the regression results, even though trivial in a few cases, imply an increase in world inequity through the diverging coefficient of the overall sample (DEVELOPED, ADVANCED AND LDC).[xv] Additionally, pair wise and single group output indicates the existing diversity, within and across groups, except for the two extreme cases (i.e. LDC and ADVANCED). In other words, the relative positions of the country groups, in the best case, are to remain the same. Most, importantly, the *γ*-coefficient between the two extreme groups indicates stationarity, as a result of the immense level differences (or initial endowments in reference to the hereby examined time period).

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. 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.

$$RPM_{i\,t} - avg(RPM_t) = \gamma[\, RPM_{i,\,t-1} - avg(RPM_{t-1})] + u_{it}\,,$$

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

Table 7:*The output of the pooled least squares estimation, corrected for heteroscedasticity of unknown form, by White's consistent standard errors and covariance methodology*

Country group	*γ-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	1.005	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 AR terms. As a result, the reported DW value on the table is of the final regression (corrected when necessary).*

Similarly, the descriptive statistics of the preceding data set indicate 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*), one could say that the relative positions of the three groups remained the same and their deviations from the corresponding mean are not exhibiting any significant trends.[xvi] Furthermore, 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, and the extreme diversity of the developing countries that imply evidence of 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,[xvii] their difference in absolute terms will continue to increase.

Concluding Remarks and Implications

Thus far, concerning human capital, former empirical attempts were performed mainly 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 indicates moderate evidence of convergence.

On the contrary, when the focal point was turned towards alternative constituents of human capital, such as RPM, teachers and book availability, the results were inconsistent with those of enrollment rates, and implied, in some cases, signals of divergence, especially in reference to poor economies. Meanwhile, in other instances; when the initial gap was extremely large, the outcomes implied neither convergence nor divergence, but prolongation of the deviant status quo determined by initial endowments. 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 existence of a sort of "convergence trap."

Naturally, the converging inconsistency of the empirical findings among the different components of human capital may provide a source for skepticism. However, if the immaterial and qualitative dimension of human capital is considered; an argument could be made in favor of the latter, since the economic effectiveness of education is largely an issue of infrastructure and policy.

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 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 underline 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] The transformation is: $GDP_{i,t} = (a_0 + a_1H_{it} + a_2K + a_3L) + Hit\ (a_{1t} - a_1) + [(U_{it} + (a_2 + K_{it} - a_2K_{it}) + (a_3L_{it} - a_3L) + (a_{0t} - a_0)$, 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: $VQt = Var(a_0 + a_1H_{it} + a_2K + a_3L)$.

[ii] Advanced countries are included as one observation due to homogeneity.
[iii] $L = \Sigma p_i\ ln(p_i/y_i)$ 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.

[iv] 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 uij is the common disturbance term.

[v] The Ginni coefficient is defined as: $G^h = 1/[2avg(C^h)]\Sigma\Sigma[x_i\text{-}x_j]n_i n_j$ *for i, j = 0,1,2,3.* The magnitude of G^h constitutes a direct analogy for educational inequality.

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

[vii] 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.

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

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

[x] 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.

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

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

[xiii] The hypothesis Ho: $\gamma = 1$ is rejected at significance level higher that 90% for groups DEVELOPED, LDC, ADVANCED AND LDC and DEVELOPED AND ADVANCED.

[xiv] The hypothesis Ho: $\gamma = 1$ is rejected at significance level higher that 90% for groups ADVANCED, DEVELOPED AND ADVANCED and DEVELOPED, ADVANCED AND LDC.

[xv] The hypothesis Ho: $\gamma = 1$ for DEVELOPED, ADVANCED AND LDC cannot be rejected using a 95% level of significance, and can be rejected for DEVELOPED AND ADVANCED, and DEVELOPED AND LDC.

[xvi] The hypothesis Ho: $\gamma = 1$ 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.

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