

Petrakis, P.E.; Stamatakis, D.

Conference Paper

Human capital, growth and convergence traps: Implications from a cross-country analysis

Proceedings of the German Development Economics Conference, Kiel 2005, No. 26

Provided in Cooperation with:

Research Committee on Development Economics (AEL), German Economic Association

Suggested Citation: Petrakis, P.E.; Stamatakis, D. (2005) : Human capital, growth and convergence traps: Implications from a cross-country analysis, Proceedings of the German Development Economics Conference, Kiel 2005, No. 26, Verein für Socialpolitik, Ausschuss für Entwicklungsländer, Hannover

This Version is available at:

<https://hdl.handle.net/10419/19819>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.

Human capital, growth and convergence traps: Implications from a cross-country analysis

D. Stamatakis¹ and P.E. Petrakis²

Abstract

This article, adapted from Tamura's theoretical proposition, empirically investigates capital convergence in three country groups belonging to significantly different development categories: G7, developed and developing. Human capital evaluation, in this context, goes beyond enrolment and/or attainment rates. In addition to enrolments and government spending, alternative factors determining human capital effectiveness synthesize an idea of enhanced human capital proxy. Empirical results indicate moderate evidence of convergence among the three-country groups when conventional variables are included. The convergence "picture" is quite different when additional variables are empirically examined, implying the existence of a "convergence trap" caused by initial endowments on human capital.

Keywords:

Regional: advanced (OECD), developed (OECD), developing (world)
Country specific: USA, Mexico, Mauritius (as examples of each of the above)
Others: human capital, convergence, growth, cross country, development level

¹ Author, PhD Course Instructor, Athens National and Kapodistrian University, Division of Economic Development, 5, Stadiou Str., Athens 10562, Greece, Tel: +302103689383, Fax: +302103689352, e-mail: stamatd@hotmail.com

² Correspondence author, Athens National and Kapodistrian University, Associate Professor, Department of Economics, Division of Economic Development, 5, Stadiou Str., Athens 10562, Greece, Tel: +302103689353, Fax: +302103689352, e-mail: ppetrak@cc.uoa.gr

1 Introduction

A current key economic issue is whether poor countries tend to grow faster than rich ones and converge over time to some level of per capita income. In Tamura's (1991) theorization, human capital being the unique determinant of growth – which is a claim best suited to well developed economies – per capita income convergence arises from human capital convergence. Consequently, one could speculate that the absence of strong human capital convergence in less developed countries is manifested in the polarization of per capita incomes.

The present article extends from former studies by defining human capital in a more synthetic way and by performing a comparative analysis between country groups. It examines human capital convergence in a cross-section of 24 countries. Specifically, it comprises an empirical attempt to approximate conditional and unconditional growth convergence by measuring human capital. We examine the quantitative and qualitative evolution of human capital, based on three country groups that exhibit significantly different development: less developed, developed and advanced.

As in Petrakis and Stamatakis (2002), the advantage of the present methodology is twofold. First, it incorporates a more synthetic approximation to human capital or “enhanced human capital”. Thus, our measure of human capital includes not only the non-transferable dimension of human capital – years of education – but also the “public good” characteristics of the stock of knowledge found in books, media, blueprints and other documents and organizational structures. Hence, human capital can be perceived as the synergistic outcome of human and social capital with reference to the accumulated knowledge of a society and its forms of interaction, organization and culture (Georgi, 2002).

Secondly, the three-dimensional grouping of the countries in our sample, besides controlling for economic homogeneity, also implies structural proximity. As a result, the empirical inference can integrate issues beyond equilibrium-based growth theories, since the absence from the empirical procedure of initial variable levels (intercepts) provides a control for initial endowments which are merely a control of income levels.

The paper is organized as follows: section 2 presents a more synthetic definition of human capital and discusses the converging limitations of human capital. Section 3 provides an overview of existing evidence and prior attempts to evaluate convergence in human capital. Sections 4 and 5 describe the data set, and present and analyze the empirical findings. Section (6) discusses the implications of the empirical findings and offers some conclusions.

2 Enhanced human capital and convergence theory

2.1 Enhanced human capital

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 economic growth. In contrast, modern economists have shifted their attention, at least in regards to developed market economies, towards the role of human and social capital in the growth process. Nowadays, it is physical capital that has become the subject of conventional thinking.

Human capital is accepted as an important factor in group convergence and reinforced by empirical findings on the OECD domain. In contrast, Barro (1998; 2004) found that initial levels of schooling exhibited a positive relation to growth. In other words, human capital does not incorporate the diminishing properties of physical capital and offers therefore an explanation for the lack of growth convergence in a large group of countries. Moreover, Barro and Sala-i-Martin (2004) found that between 1950 and 1990 the average growth rate of developed countries significantly exceeded the corresponding growth rate for less developed countries (especially between 1950 and 1970), even though returns to physical capital were diminishing, a fact that reinforces the view of the non-diminishing productivity of human capital.

Romer (1986) claimed that technological competition between countries would lead to Pareto suboptimal growth rates, through patent rights that permit transitory monopoly profits; a motive for investment that leads to ongoing technological progress and innovation, and thus economic growth. Overall, if one acknowledges the synthetic disposition of human capital, measurability and data availability issues, in Redding's (1996) 'complementarity' context in which human capital, social capital and R&D identify an inseparable growth determinant; there is a concept of *enhanced human capital (EH)* that could be represented by a function of partial components of human capital (presented in Table 2).

$$EH = f(ENR, EXP, TEACH, BOOK, RPM) (1)$$

Expressed simply, equation (1) can be assumed to be a linear combination of equal weights:

$$EH_t = a_1ENR_t + a_2EXP_t + a_3TEACH_t + a_4BOOK_t + a_5RPM_t \quad (1a)$$

where, a_i are fixed parameters (*i.e.* $\sum a_i = 1 \quad \forall i = 1, 2, \dots, 5$).

Even though, the above formulation exemplifies simplicity, it provides a synthetic measure of human capital that bridges quantity measures such as enrollment rates with the economic (or growth) importance of new technology creation, proxied by a country's dedication to research, as

well as the efficiency and aptitude in the production of human capital, merely captured by the qualitative dimension of students/teachers ratio, and by infrastructural issues such as book or library availability. Moreover, in support to the former discussion, the results of zero order correlation matrix between the above variables, including growth rates (table 1), on the one hand indicate a positive association between every variable and growth, and on the other, the complexity of human capital as implied by the pair-wise associations between the human capital proxy variables.

Regarding the synthetics of human capital, it should be noted that the present attempt completely ignores the health dimension, assuming that health improvements follow human capital advancement. Sab and Smith (2002) have explicitly measured convergence rates on health indicators versus human capital ones, indicating a significant interrelationship.

2.2 Towards a theory of human capital divergence

Furthermore, simplifying the value function initially set forth by Tamura (1991), the resulting value function (V) (from the Ramsey model) is an explicit function of a country's consumption and next period's ($t+1$) stock of human capital relative to the mean level of human capital over n countries (i.e. $i = 1, 2, \dots, n$):

$$V(EH_{it}, EH_t) = \max\{c_{it}/\sigma + bv[EH_{t+1}, \text{avg}(EH_{t+1})]\} \quad (2)$$

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

$$c_{it} = EH_{it}(1-\tau_{it}) \quad (3),$$

where τ represents the i th country's effort directed towards human capital enlargement.

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

$$EH_{t+1, i} = \Phi(EH_{t, i}/EH_{t, i}^{\text{th}})^{\delta} EH_{t, i} \tau_{it}^{(1-\delta)}, \text{ for } \forall \delta \geq 0 \quad (4)$$

where, EH^{th} could denote a threshold level of human capital, below which (when $\delta > 0$) the converging effect of human capital is reversed, as empirically found by Barro and Sala-i- Martin (2004), which merely implies the position that "some" minimum level of human capital is required to facilitate a country's productive capacity effectively; 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 be partly financing the extraordinary rate of human capital accumulation in advanced countries, since human capital investment would exceed the optimum level under perfect competition. This in return will

help them maintain their leading positions and induce the vicious circle of a “convergence trap”, since, even if growth occurs and poverty levels decrease, overall growth convergence will fail due to diverging trends in human capital.

One could summarize the above position by reducing it to an aggregate Cobb Douglas production function endogenous, only, with respect to human capital:

$$Y_i = A_i \{EH_{it}\}^\beta (EH_{t-1,i}/EH^{th})^\delta \quad (5)$$

where A captures the remaining factors which, by the present analysis, are assumed to be less important, and therefore exogenous. Including physical capital, meanwhile, technology is incorporated in the enhanced human capital. It should be underlined that the spillover 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 a reflection and therefore an approximation of the average level of human capital (over i), by taking the logs:

$$\ln Y_i = \ln \Phi_i + \beta \ln EH_{t,i} + \delta [\ln EH_{t-1,i} - \ln(\text{avg} EH_{t-1})] \quad (6)$$

then by taking the total differential and rearranging:

$$1/Y dY = \beta(1/EH_{t,i})dEH_{t,i} + \delta[1/(EH_{t-1,i}) - 1/(\text{avg} EH_{t-1})] d(EH_{t-1,i} - \text{avg} EH_{t-1}) \quad (7)$$

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.

Consequently, if one assumes homogeneity of degree one (or greater) in the production process (i.e. $\beta + \delta \geq 1$), divergence in human capital would imply growth divergence. 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.

Moreover, if one assumes cross-country uniformity in the marginal product of human capital (i.e. β constant across i), then the i th country’s convergence speed can be approximated by estimating the time path of human capital deviations from the mean in such a way that which ever sample the mean is calculated from would determine the territory of convergence – club, group, world etc. In other words, by taking the

$$EH_{it} - \text{avg} EH_t = \gamma [EH_{t-1,i} - \text{avg} EH_{t-1}] + u_{it} \quad (8)$$

where (γ) captures the i th 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.

Overall, if the preceding function (5) exhibits CRTS technology (e.g. $\beta + \delta = 1$), assuming patent right barriers and acknowledging the lengthy time requirements for the growth “metamorphosis” of human capital investment, then the absence of human capital convergence, in the case of substantial initial endowment gaps and reinforced by the current exponential technology change rates, coincides with asymptotic growth between poor and wealthy economies.

Of course, all of the above assume cultural and political proximity; a rather important assumption. For example, the post World War II Marshal Plan contributed to the political and merely cultural homogeneity of OECD countries – a statement that explains the evident convergence among OECD countries. On the other hand, the ongoing growth miracle of China is fostered by a mostly non-democratic political environment, yet its cultural individuality is governed by an austere (but stable) political regime, providing an “exceptional” foundation for economic advancement.

3 Empirical findings and former attempts to approximate educational convergence

3.1 Trends in human capital accumulation

Maddison (1989), regarding US productivity 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, labour productivity was falling while educational attainment was growing.

Denison (1989) reported similar results for OECD countries between 1973 and 1981 and Benhabib 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, proxied by the percentage of the population enrolled at each educational level, indicated that at the primary educational level there is an almost 100% enrolment 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 (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% enrolment rate (the highest) Turkey’s was 4% (the lowest). Moreover, in the same study when enrolment rates were replaced by attainment 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) generated estimates for the mean years of schooling of the labour force between the years 1965 and 1985, and found an increase for the period between 1965 and 1975, and then a decline for the following decade.

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

Maddison (1987; 1991), 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 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 the empirical results refer, mostly, to OECD countries. Regrettably, less developed countries are not included in the preceding discussion, mainly due to the lack of data.

3.2 A review of 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, and arrived at a rather pessimistic conclusion; poverty classes will be absorbed into advancing sectors, by means of a “vicious circle”, in which poverty leads to relatively high rates of external finance and similarly, high enough internal discount rates 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 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, into specific components resulting from changes in the distribution of characteristics across countries (a quantity effect) and changes in the valuation of these characteristics (a price effect). O'Neill asserts that changes in human capital establish a reliable predictor of the temporal 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. The modeling adapts a production function in log-linear format in which the parameters are allowed to vary over time.¹

The resulting 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, 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 cross country variation in income becomes increased, mainly due to qualitative and structural factors that foster education effectiveness.

In the same context, Ram (1995) investigated the inter-country inequalities in school enrolment rates in a large international data set of 88 less developed countries² for 1960, 1970, 1980 and 1986. He establishes a Bourguignon (1979) weighted inequality index³ for enrolment rates. Ram's findings (1960–86) 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, meanwhile, the inter-country convergence⁴ estimation showed evidence of convergence at all educational levels.

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 Gini-coefficient computations, using the Barro and Lee data set on attainment rates.⁵ Their results indicated a significantly negative effect of cross-country human capital inequality on growth.

Adapting Barro's traditional methodology, Sab and Smith (2002), in a sample of 84 countries between 1970-90, provide evidence of unconditional convergence on health variables, meanwhile, the output with respect to enrollment rates indicates conditional convergence, determined by *ceteris paribus* factors.

Lastly, Gradstein and Nikitin (2004), in an attempt to evaluate educational expansion, they indicated convergence and decreasing trends for coefficients of variation regarding schooling years, among different regions, but interestingly enough, these converging movements did not apply to per capita income.

4 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 here is to uncover convergence-rate differences in human capital variables. More specifically, the empirical section will evaluate and compare the speed of convergence within individual groups, between any two groups and among all three groups. This will, merely, test for 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).

4.1 The estimation model

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 Durlauf (1995), showed that the conventional approach was 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:

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

Taking the difference from the mean on both sides and by replacing human capital by “enhanced human capital ($\sum_i EH$ for every t and $t-1$):

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

We obtain equation (8) from section 2, that captures the time evolution of the sample’s deviation from its own mean over the examined time period where $avg(EH_t^j) = 1/n \sum_{i=1}^n$ and (i,t) represent the mean value of the human capital variable over $(i=1,2,...24)$ countries at year (t) . meanwhile (j) represents the group (or groups) that was used to calculate the average value of EH (i.e. $j=1,2,...7$).

In the present case of pooling, the intercept term (α) 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, merely, controls for income levels, 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.

One shortcoming of the preceding model is its strictly 'calculative' nature, since it ignores other factors, such as policy variables, that potentially affect human capital convergence. Undoubtedly, policy 'matters', especially the long term consistency of a given policy; given the substantial time lags that characterize the association between human capital and growth, the present study focuses on an insufficient time period to incorporate policy variables.

4.2 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). See Table 2. Consequently, the selection of the sample is non-random and could be criticized for selection bias, but it serves the purpose of comparative analysis between non-homogeneous country groups, where homogeneity is confined on an 'intra' level (i.e. within the group).

The country data is divided into three groups: "advanced" economies, "developed" economies and "less developed" economies. The "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 economies⁶ 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 has either recently entered the developed stage or is approximately within that group.

Once the grouping has been completed, Ben David's (1995) method provides an empirical starting-point for the establishment of a stochastic model which is evaluated by a GLS procedure. For each variable, the regressions are run separately for every possible combination between the three different groups of countries (*i.e. j = 7 regressions for each variable*), and the Gamma coefficients of each regression are then compared between the different regressions.

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 (2003). The educational variables that will provide the input for the estimation process are listed in Table 2.

5 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.

5.1 Econometric procedures and properties

The estimation process employs the Least Squares regression, with cross-section weights (by country), run for balanced samples (*i.e. WLS*). 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 is of autoregressive in nature, it becomes a nuisance to test for multi-collinearity.

5.1.1 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:

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

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.

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.

5.1.2 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 variables⁷ 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.

5.2 Enrolment rates (ENR)

The deviation from the mean of the gross enrolment 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. It should be stated that values greater than 100% (table 4) result because enrollment rates refer to gross rates.

The stochastic equation for each group or combination of groups will be the following:

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

5.2.1 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 (except the one between advanced and developed). Of course, 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. As a result, one should not expect dramatic changes or trends in the deviation of primary education. The estimated γ -coefficients above do not indicate robust evidence of convergence nor divergence, since the estimated values, although less than one, approximate one. Thus the evolution in the mean deviation of the enrolment rates in primary education merely exhibits stationarity (if not elements of divergence) – at least in the examined time period, which coincides with the last decade.

5.2.2 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 γ -coefficient implies moderate indications of convergence between the combined groups, especially between advanced-developed and poor countries.⁸

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).

5.2.3 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 enrolment rates.⁹ Similarly, the three-group union indicates, at least, stationarity in higher education enrolment 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, enrolment 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 enrolments. 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 *H*₀: $\gamma = \gamma + 0.1$ 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, enrolment-rate interpretation should be done with skepticism, especially if the intention is to make inferences about human capital. Undoubtedly, enrolments 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.

5.3 Public expenditure on education (EXP)

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:

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

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. See Tables 6 and 7.

The mean deviation from the group(s) mean 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 countries 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 enrolment 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.

5.4 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.

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

for every country or country-group combination.

The following subsections refer to Tables 8 and 9 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.

5.4.1 Secondary education

Table 8 demonstrates a different situation from the preceding findings in this section, since the mean number of students per teacher exposes substantial deviations among the three groups. For instance, the figure for advanced economies is almost one half the corresponding value for the less developed countries. Naturally, the ratio of students/teachers has a reverse relationship with the level of development.

The regression output of Table 9 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.¹⁰ Furthermore, the corresponding statistics display a high level of significance in regards to both; specification (*R-sq*, *F-value*) and estimation (*t*- values).

5.4.2 Higher education

In Tables 8 and 9, even though the mean deviations of Table 8 demonstrate rather insignificant differences between the groups, 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.¹¹

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.

5.5 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.

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

Tables 10 and 11 present the descriptive statistics and the corresponding estimation output for each country group and group combination.

The preceding results signify the enormous level difference 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).¹² 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).

5.6 Researchers per capita (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.

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

Tables 12 and 13 present the descriptive statistics and corresponding estimation output for each country group and group combination.

Table 12 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), 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.¹³ 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 countries, 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,¹⁴ their difference in absolute terms will continue to increase.

5 Concluding remarks and implications

Thus far, concerning human capital, empirical studies were performed mainly on enrolment and/or attainment rates of educational levels. The results, for the most part, suggested evidence of cross-country convergence. Similarly, regarding enrolment flows, the current study indicated 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 enrolment rates, and revealed in some cases signals of divergence, especially in connection with LDC economies. Meanwhile, in other instances (i.e. when the initial gap was immense), the outcomes implied neither convergence nor divergence, but stationarity; in other words prolongation of the existing status quo.

Furthermore, by employing the simplicity of equation (1a) the above discussion is strengthened, since the combined convergence rate of the “enhanced” human capital (EH) in reference to the last country group ($j=7$; *DEVELOPED, ADVANCED AND LDC*)¹⁵ is less than one:

$$\gamma_{j=7}^{HH} = 1/5[\gamma_{j=7}^{ENR} + \gamma_{j=7}^{EXP} + \gamma_{j=7}^{TEACH} + \gamma_{j=7}^{BOOK} + \gamma_{j=7}^{RPM}] = \underline{\underline{0.9367 < 1.}}$$

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 a 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, further strengthened by the findings of Gradstein and Nikitin (2004), that indicate cross country convergence on schooling years, but not on income levels.

Intuitively, higher education (e.g. graduate and postgraduate) and research 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, especially post graduate, in order to be economically effective – assuming an extension for increased research efforts – requires increased funding and often the contribution of the private 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. 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 enrolment rates increase, at the primary and secondary level. In addition, adapted from the work of Gradstein and Nikitin (2004), figure 1 implies the existence of three-level convergence clubs on schooling years that discretely separates the countries of their sample, with respect to human capital accumulation, into three groups that converge towards a notably disparate level of human capital.

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, where lagging countries buy patent protected technology from leading ones and through suboptimal pricing, they finance a faster human capital accumulation on advanced countries. Meanwhile, in many cases, when the existing human capital is inferior to ‘*some*’ threshold level, it does not permit lagging countries to benefit – at least not directly- in the accumulation of human capital, even though they realize an income benefit.

Consequently, by the time the additional income finds its way to human capital investment, leading countries will be farther ‘ahead’ in a repetitive cycle -assuming that the present condition will persist or *ceteris paribus*- of diverging human capital accumulation, in which the superiority of leading countries would be merely financed by lagging ones.

Bibliography

- Abramovitz, M.A. (1986). "Catching Up, Forging Ahead, and Falling Behind," *Journal of Economic History* 66.
- Abramovitz, M.A. (1994). "The Origins of the Postwar Catch-up and Convergence Boom." In J. Fagerberg, B. Verspagen, N. Von Tunzelmann (eds), *The Dynamics of Trade, Technology and Growth*. Aldershot: Edward Elgar (1994), pp. 21–52.
- Abramovitz, M.A. and P.A. David. (1996). "Convergence and Deferred Catch-up: Productivity Leadership and the Waning of American Exceptionalism." In R. Landau, T. Taylor and G. Wright (eds), *The Mosaic of Economic Growth*. Stanford: Stanford University Press, pp. 21–62.
- Albin, P. (1970). "Poverty, Education and Unbalanced Economic Growth," *Quarterly Journal of Economics* 84, 69–84.
- Amparo, C. and D. Rafael. (2002). "Human Capital Inequality and Economic Growth: Some New Evidence," *The Economic Journal* 112, 187–200.
- Arrow, K.J. (1962). "The Economic Implications of Learning by Doing," *Review of Economic Studies* 29 (June), 155–173.
- Arrow, K.J. (1973). "Higher Education as a Filter," *Journal of Public Economics* 2, 87–106.
- Barro, R.J. and J.W. Lee. (1993). "International Comparisons of Educational Attainment," *Journal of Monetary Economics* 32, 363–394.
- Barro, R.J. and X. Sala-i-Martin. (1992). "Convergence," *Journal of Political Economy* 100, 223–251.
- Barro, R.J. and X. Sala-i-Martin, X. (2004). *Economic Growth*. 2nd edition.
- Barro, R.J. (1991). "Economic Growth in a Cross Section of Countries," *Quarterly Journal of Economics* 106(2), 407–444.
- Baumol, W.J. (1986). "Productivity Growth, Convergence, and Welfare: What the Long Run Data Show," *American Economic Review* 76, 1072–1085.
- Becker, G.B. (1975). *Human Capital: A Theoretical and Empirical Analysis, with Special Reference to Education*. Chicago: University of Chicago Press.
- Becker, G.S. (1962). "Investment in Human Capital: A Theoretical Analysis," *Journal of Political Economy* 70, 9–49.
- Ben-David, D. (1993). "Equalizing Exchange: Trade Liberalization and Income Convergence," *Quarterly Journal of Economics* 108, 653–679.
- Ben-David, D. (1995). "Measuring Income Convergence: An Alternative Test." Foerder Institute for Economic Research. Working Paper No. 41/95. Tel Aviv: Tel Aviv University.
- Benhabib, J. and M.M. Spiegel. (1994). "The Role of Human Capital in Economic Development: Evidence from Aggregate Cross Country Data," *Journal of Monetary Economics* 34, 143–173.
- Bernard, A.B. and S.N. Durlauf. (1991). "Convergence of International Output Movements." NBER Working paper 3629, February.
- Bernard, A.B. and S.N. Durlauf. (1995). "Convergence in International Output," *Journal of Applied Econometrics* 10 (1995), 97–108.
- Bourguignon, F. (1979). "Decomposable Income Inequality Measures," *Econometrica* 47, 901–920.
- Byung-Joo, L. (2000). *Eviews and Econometrics*. <http://www.ByungJoo.Lee.81@nd.edu> (2000).
- DeLong, J.B. (2004). *Economic Growth*, ch 5. Unpublished textbook.
- DeLong, J.B., A. Mansoorian and L. Michelis. (2004). *Macroeconomics*. Toronto: McGraw Hill.
- Denison, E.F. (1985). *Trends in American Economic Growth, 1929–1982*. Washington, DC: Brookings.
- Fisher, I. (1906). *The Nature of Capital and Income*, New York and London: Macmillan.
- Georgi, B.P. (2002). "The Role of Human and Social Capital in Growth: Extending Our Understanding," *Cambridge Journal of Economics* 26, 461–479.
- Gradstein and Nikitin (2004). "Educational expansion: Evidence and Interpretation", *World Bank Policy Research Working Paper* 3245.
- Hanushek, E. and D. Kym (1995). "Schooling, Labor Force Quality and Economic Growth." NBER Working Paper 5399, Cambridge, MA.
- Kocenda, E. and J. Hanousek. (1998). "Integration of Emerging Equity Markets," *Korean Economic Review* 14, 99–114.
- Kyriacou, G.E. (1991). "Level and Growth Effects of Human Capital: A Cross Country Study of the Convergence Hypothesis." Unpublished paper. New York: New York University Press.

- Levin, A. and Chien-Fu Lin. (1992). "Unit Root Tests in Panel Data: Asymptotic and Finite-Sample Properties." University of California-San Diego Discussion Paper No. 92-23.
- Lucas, R.E. (1988). "On the Mechanics of Development Planning," *Journal of Monetary Economics* 22, 3–42.
- Lucas, R.E. (1990). "Why Doesn't Capital Flow from Rich to Poor Countries?" *American Economic Review* 80, 92–6.
- McMahon, W.W. (1998). "Education and Growth in East Asia," *Economics of Education Review* 17, 159–172.
- Maddison, A. (1989). *The World Economy in the 20th Century*. Paris: OECD Development Centre.
- Maddison, A. (1995). *Monitoring the World Economy 1820–1992*. Paris: OECD Development Centre.
- Mankiw, N.G. (1995) "The Growth of Nations," *Brookings Papers on Economic Activity* 1, 275–310.
- Mankiw, N.G., D. Romer and D.R. (1992). "A Contribution to the Empirics of Economic Growth," *Quarterly Journal of Economics* 107 (199), 407–438.
- Marshall, A. (1920). *Principles of Economics*, 8th edn. London: Macmillan.
- Marx, K. and F. Engels. [1847] 2000. *Manifesto of the Communist Party*.
- O'Neil J. (1995). "Endogenous Human Capital Accumulation and Intertemporal Substitution in the Aggregate Labor Market." PhD, Binghamton: State University of New York.
- OECD (2003). *Education at a glance: OECD indicators*. Paris, OECD.
- OECD (2003). *Historical statistics*. Paris, OECD.
- OECD (1998). *Human capital investment*. Paris, OECD.
- OECD (2003). *Trends in developing countries*. Paris, OECD.
- Petrakis, P. and D. Stamatakis. (2002). "Growth and Educational Levels: A Competitive Analysis," *Economics of Education Review* 21, 513–521.
- Psacharopoulos, G. (1989). "Time Trends in the Returns to Education: Cross-National Evidence," *Economics of Education Review* 8, 225–231.
- Psacharopoulos, G. (1994). "Returns to Investment: A Global Update," *World Development* 22, 1325–1343.
- Ram, R. (1995). "Intercountry and Intracountry Inequalities in School Enrolments: A Broad International Perspective," *Economics of Education Review* 14, 363–372.
- Roemer, J. (1982). *A General Theory of Exploitation and Class*. Cambridge, MA: Harvard University Press.
- Romer, P.M. (1986). "Increasing Returns and Long Run Growth," *Journal of Political Economy* 94, 1002–1037.
- Romer, P.M. (1990). "Endogenous Technical Change," *Journal of Political Economy* 98, 571–593.
- Romer, P.M. (1993). "Idea Gaps and Object Gaps in Economic Development," *Journal of Monetary Economics* 32, 543–573.
- Romer, P.M. (1994). "The Origins of Endogenous Growth," *Journal of Economic Perspectives* 8(1).
- Sab, R. and Smith, S. C. (2002). "Human Capital Convergence: A joint Estimation Approach", *IMF Staff Papers* 49, 200-211.
- Schultz, T.W. (1961). "Investment in Human Capital," *American Economic Review* 51, 1–17.
- Schultz, T.W. (1993). *Origins of Increasing Returns*. Oxford: Blackwell.
- Schumpeter, J.A. (1942). *Capitalism, Socialism and Democracy*. New York: Harper and Bros.
- Schumpeter, J.A. (1991). *The Economics and Sociology of Capitalism*. An anthology of his works edited by R. Swedberg, Princeton, NJ: Princeton University Press.
- Smith, A. [1776] (1937). *An Inquiry into the Nature and Causes of the Wealth of Nations*. New York: Modern Library.
- Solow, R. (1956). "A Contribution to the Theory of Economic Growth," *Quarterly Journal of Economics* 70, 65–94.
- Tamura, R. (1991). "Income Convergence in an Endogenous Growth Model," *Journal of Political Economy* 99, 522–540.
- Tilak, B.G. (1989). "Education and Its Relation to Economic Growth, Poverty and Income Distribution: Past Evidence and Further Analysis." Discussion Paper No. 46, The World Bank (March).
- UNDP (2001). *Human development report*. New York, Oxford University Press.
- UNESCO (1999). *Statistical Yearbook*. Paris, UNESCO and Bernan Publishing
- Wolff, E.N. (2000). "Human Capital Investment and Economic Growth: Exploring the Cross Country Evidence," *Structural Change and Economic Dynamics* 11, 433–472.

Table 1 The zero order correlation matrix between the variables, resulting from the complete data set; all three country groups simultaneously including growth rates*.

| | <i>Growth rate</i> | <i>R&D</i> | <i>ENR</i> | <i>BOOK</i> | <i>EXP</i> | <i>TEACH</i> |
|--------------------|--------------------|----------------|--------------|--------------|--------------|--------------|
| <i>Growth rate</i> | 1.000 | 0.113 | 0.297 | 0.299 | 0.233 | 0.247 |
| <i>R&D</i> | 0.113 | 1.000 | 0.504 | 0.589 | 0.515 | 0.268 |
| <i>ENR</i> | 0.297 | 0.504 | 1.000 | 0.473 | 0.262 | 0.244 |
| <i>BOOK</i> | 0.299 | 0.589 | 0.473 | 1.000 | 0.778 | 0.312 |
| <i>EXP</i> | 0.233 | 0.515 | 0.262 | 0.778 | 1.000 | 0.337 |
| <i>TEACH</i> | 0.247 | 0.268 | 0.244 | 0.312 | 0.337 | 1.000 |

* The procedure was calculated on the mean values of the variables for the examined time period, meanwhile enrollments are taken from secondary education only.

Table 2 The three groups of countries for which data was compared

| <i>Advanced (OECD)</i> | <i>Developed (OECD)</i> | <i>Less developed (world)</i> |
|------------------------|-------------------------|-------------------------------|
| 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 |

Table 3 Description of the data set: variables, years, variable definitions and sources

| <i>Var.</i> | <i>Years</i> | <i>Definition</i> | <i>Source</i> |
|--------------------|--------------|--|---|
| 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 <i>Statistical Yearbook</i> , 1999 For the years 1998–2001: OECD's <i>Education at a Glance</i> , 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 <i>Statistical Yearbook</i> , 1999 For the years 1998–2001: OECD's <i>Education at a Glance</i> , 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: <i>Education Online Database</i> , 2003 |
| BOOK | 1990–97 | The total number of books (volumes) in public libraries divided by the total number of registered users | UNESCO's <i>Statistical Yearbook</i> , 1999 |
| RPM | 1990–97 | Number of researchers per million population | UNESCO's <i>Statistical Yearbook</i> , 1999 |

Table 4 Group descriptive statistics for the variable $[ENR_{i,t} - avg(ENR^j_t)]$.

| Primary education | | | | | |
|--------------------------------|-------------|---------------|------------------|-----------------------|-------------|
| <i>Country group (j)</i> | <i>Mean</i> | <i>Median</i> | <i>Std. dev.</i> | <i>Cross sections</i> | <i>Obs.</i> |
| 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 |

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

| Primary education | | | | | |
|-----------------------------|--|----------------|--------------------------|----------------|--------------|
| <i>Country group (j)</i> | <i>γ-coefficient</i> | <i>t-value</i> | <i>R²-adj</i> | <i>F-value</i> | <i>DW***</i> |
| 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** | 0.989 | 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 |

| 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 AR terms. As a result, the reported DW value on the table is of the final regression (corrected when necessary).

Table 6 Group descriptive statistics for the variable $[EXP_{i,t} - avg(EXP^j)]$

| Country group (j) | Mean | Median | Std. dev. | Cross sections | Obs. |
|-----------------------------|-------|--------|-----------|----------------|------|
| ADVANCED | 0.59 | 0.545 | 0.156 | 8 | 96 |
| DEVELOPED | 0.43 | 0.450 | 0.102 | 8 | 96 |
| LDC | 0.268 | 0.275 | 0.152 | 8 | 92 |
| ADVANCED AND LDC | 0.43 | 0.410 | 0.213 | 8 | 96 |
| DEVELOPED AND LDC | 0.391 | 0.358 | 0.084 | 16 | 192 |
| DEVELOPED AND ADVANCED | 0.51 | 0.49 | 0.154 | 16 | 192 |
| DEVELOPED, ADVANCED AND LDC | 0.43 | 0.435 | 0.184 | 24 | 288 |

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

| Country group (j) | 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).

Table 8 Group descriptive statistics for the variable [$TEACH_{i,t} - avg(TEACH'_{i,t})$]

| Secondary education | | | | | |
|--------------------------------|-------------|---------------|------------------|-----------------------|-------------|
| <i>Country group (j)</i> | <i>Mean</i> | <i>Median</i> | <i>Std. Dev.</i> | <i>Cross sections</i> | <i>Obs.</i> |
| ADVANCED | 13.34 | 14.05 | 3.12 | 8 | 64 |
| DEVELOPED | 16.26 | 16.21 | 5.53 | 8 | 64 |
| LDC | 21.99 | 21.16 | 6.67 | 8 | 64 |
| ADVANCED AND LDC | 15.53 | 14.74 | 6.11 | 8 | 128 |
| DEVELOPED AND LDC | 16.91 | 15.78 | 6.83 | 16 | 128 |
| DEVELOPED AND ADVANCED | 15.46 | 15.43 | 6.69 | 16 | 128 |
| DEVELOPED, ADVANCED AND LDC | 16.21 | 15.45 | 7.02 | 24 | 192 |
| Higher education | | | | | |
| ADVANCED | 14.84 | 15.14 | 7.23 | 8 | 64 |
| DEVELOPED | 16.08 | 16.93 | 6.09 | 8 | 64 |
| LDC | 15.55 | 14.71 | 5.31 | 8 | 64 |
| ADVANCED AND LDC | 15.81 | 15.71 | 5.10 | 8 | 128 |
| DEVELOPED AND LDC | 15.81 | 14.92 | 5.70 | 16 | 128 |
| DEVELOPED AND ADVANCED | 15.46 | 15.44 | 6.69 | 16 | 128 |
| DEVELOPED, ADVANCED AND LDC | 15.49 | 14.96 | 6.25 | 24 | 192 |

Table 9 The output of the pooled least squares estimation, corrected for heteroscedasticity by White's consistent standard errors and covariance methodology

| Secondary education | | | | | |
|--------------------------------|--|----------------|---------------|----------------|--------------|
| <i>Country group (j)</i> | <i>γ-coefficient</i> | <i>t-value</i> | <i>R2-adj</i> | <i>F-value</i> | <i>DW***</i> |
| 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).

Table 10 Group descriptive statistics for the variable $[BOOK_{i,t} - \text{avg}(BOOK^j_t)]$

| <i>Country group (j)</i> | <i>Mean</i> | <i>Median</i> | <i>Std. dev.</i> | <i>Cross sections</i> | <i>Obs.</i> |
|-----------------------------|-------------|---------------|------------------|-----------------------|-------------|
| ADVANCED | 0.379 | 0.382 | 0.239 | 8 | 64 |
| DEVELOPED | 0.202 | 0.165 | 0.173 | 8 | 64 |
| LDC | 0.056 | 0.009 | 0.083 | 8 | 64 |
| ADVANCED AND LDC | 0.218 | 0.181 | 0.240 | 8 | 128 |
| DEVELOPED AND LDC | 0.129 | 0.077 | 0.154 | 16 | 128 |
| DEVELOPED AND ADVANCED | 0.290 | 0.243 | 0.226 | 16 | 128 |
| DEVELOPED, ADVANCED AND LDC | 0.212 | 0.173 | 0.219 | 24 | 192 |

Table 11 The output of the pooled least squares estimation, corrected for heteroscedasticity by White's consistent standard errors and covariance methodology

| <i>Country group (j)</i> | <i>γ-coefficient</i> | <i>t-value</i> | <i>R²-adj</i> | <i>F-value</i> | <i>DW***</i> |
|-----------------------------|--|----------------|--------------------------|----------------|--------------|
| 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).

Table 12 Group descriptive statistics for the variable $[RPM_{i,t} - \text{avg}(RPM^j_t)]$

| <i>Country group (j)</i> | <i>Mean</i> | <i>Median</i> | <i>Std. dev.</i> | <i>Cross sections</i> | <i>Obs.</i> |
|-----------------------------|-------------|---------------|------------------|-----------------------|-------------|
| 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 |

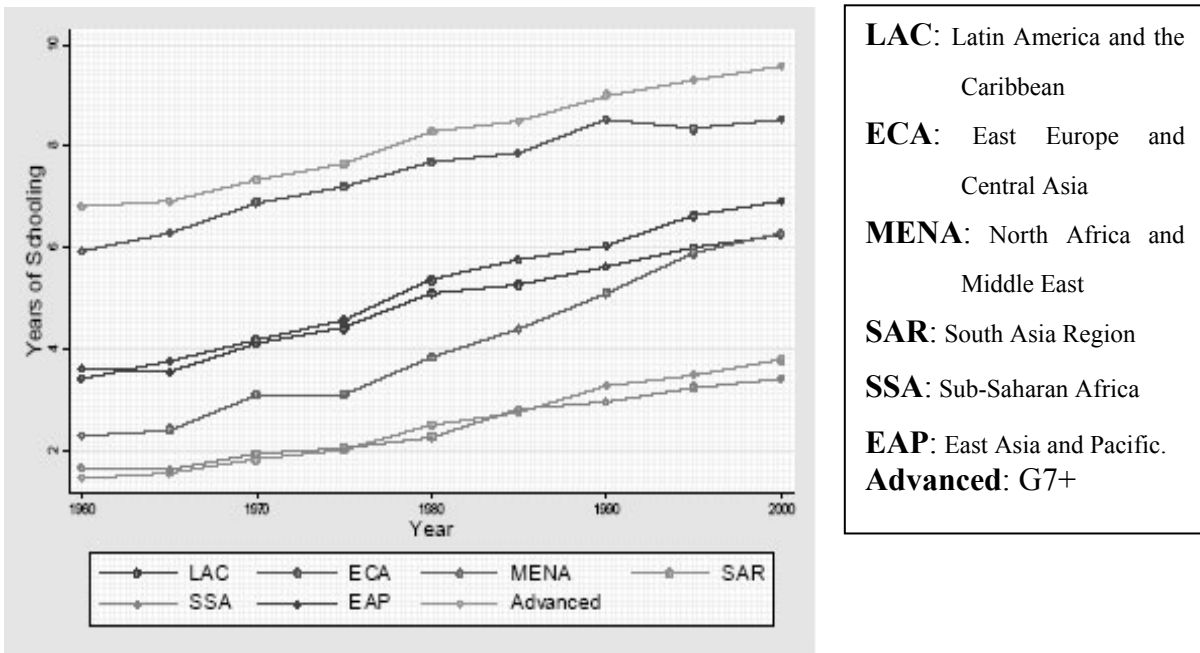
Table 13 The output of the pooled least squares estimation, corrected for heteroscedasticity by White's consistent standard errors and covariance methodology

| <i>Country group (j)</i> | <i>γ-coefficient</i> | <i>t-value</i> | <i>R²-adj</i> | <i>F-value</i> | <i>DW***</i> |
|-----------------------------|--|----------------|--------------------------|----------------|--------------|
| 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 AR terms. As a result, the reported DW value on the table is of the final regression (corrected when necessary).

Figure 1 Average years of schooling for population over 15 years old, 1960-2000: by World region.



LAC: Latin America and the Caribbean
ECA: East Europe and Central Asia
MENA: North Africa and Middle East
SAR: South Asia Region
SSA: Sub-Saharan Africa
EAP: East Asia and Pacific.
Advanced: G7+

Source: Gradstein and Nikitin (2004), “Educational expansion: Evidence and Interpretation”, World Bank Policy Research *Working Paper* 3245, page 4.

Notes

¹ The transformation is: $GDP_{i,t} = (a_0 + a_1H_{it} + a_2K + a_3L) + Hit(a_{it} - a_1) + [(U_{it} + (a_2 + K_{it} - a_2K_{it}) + (a_3L_{it} - a_3L) + (a_{0t} - a_0)]$, 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 labour, respectively, calculated across countries and over time. Thus, the estimation equation becomes: $VQt = Var(a_0 + a_1H_{it} + a_2K + a_3L)$.

² Advanced countries are included as one observation due to homogeneity.

³ $L = \sum p_i \ln(p_i/y_i)$ 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.

⁴ The stochastic model was: $\ln[ENR_{86}/ENR_{60}]_{ij} = a_j + b_j \ln(ENR_{60})_{ij} + U_{ij}$, where $[ENR_{60}]_{ij}$ and $[ENR_{86}]_{ij}$ denote enrolment rates at level j in country i for the years 1960 and 1980 respectively, and u_{ij} is the common disturbance term.

⁵ The Gini coefficient is defined as: $G^h = 1/[2avg(C^h)] \sum \sum [x_i - x_j] n_i n_j$ for $i, j = 0, 1, 2, 3$. The magnitude of G^h constitutes a direct analogy for educational inequality.

⁶ This classification refers to non-communist economies; communist economies are totally excluded from this study.

⁷ 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.

⁸ The hypothesis $H_0: \gamma = 1$ is not rejected at a significance level higher than 90% for all groups except ADVANCED AND LDC.

⁹ The hypothesis $H_0: \gamma = 1$ is rejected at significance level higher than 90% for all groups except DEVELOPED, ADVANCED AND LDC.

¹⁰ The hypothesis $H_0: \gamma = 1$ is rejected at significance level higher than 90% for groups DEVELOPED, LDC, ADVANCED AND LDC and DEVELOPED AND ADVANCED.

¹¹ The hypothesis $H_0: \gamma = 1$ is rejected at significance level higher than 90% for groups ADVANCED, DEVELOPED AND ADVANCED and DEVELOPED, ADVANCED AND LDC.

¹² The hypothesis $H_0: \gamma = 1$ 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.

¹³ The hypothesis $H_0: \gamma = 1$ 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.

¹⁴ For ADVANCED the mean rate of change is 17.1% and 16.7% for LDC.

¹⁵ From educational levels, only higher education was used