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Nadir Altinok

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Nadir ALTINOK

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Pôle AAFE – Esplanade Erasme – B.P. 26513 - F 21065 Dijon Cedex

Tél.+33 (0)3 80 39 54 50 - Fax +33 (0)3 80 39 54 79

iredu@u-bourgogne.fr- <http://www.u-bourgogne.fr/iredu>



Human Capital Quality and Economic Growth

Nadir ALTINOK*

IREDU/CNRS, University of Bourgogne, France

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Abstract

The estimation of the relationship between education and economic growth is marked by contradictions. These contradictions underline the lack of precision characterizing indicators of human capital. This paper constructs new indicators based on a pool of international surveys concerning pupil assessment. Thus, our new database, which includes 105 countries, makes it possible to confirm or not the positive relationship between education and growth. Taking into account the endogeneity of education, we measure a positive effect of qualitative indicators of human capital and the growth of countries between 1960 and 2000. The contribution of education to growth therefore appears significant, both from a quantitative and a qualitative point of view.

Keywords : Education Quality, Human Capital, Growth, Development.

J.E.L. Classification : H5, I2, O4.

* Electronic correspondance : Nadir ALTINOK (nadir.altinok@u-bourgogne.fr). The author would like to thank Mary Bouley (University of Bourgogne), Jean Bourdon (IREDU, CNRS, University of Bourgogne, France), Claude Diebolt (BETA, CNRS, University of Strasbourg, France), Marc Gurgand (PSE, CNRS, France), Geeta Kingdon (CSAE, Oxford University), Francis Kramarz (CREST, INSEE, France), François Leclercq (DIAL, University of Paris I, Unesco), Katharina Michaelowa (CIS, University of Zurich), Marie-Claude Pichery (LEG, CNRS, University of Bourgogne, France) and Alain Trannoy (EHESS, France), for their precious advice.

1 Introduction

The study of the determinants of economic growth has been one of the most important fields of research in economics since the mid 1980s. This field of research was spurred by the endogenous growth literature pioneered by the analysis of Paul Romer (1986) and Lucas (1988). Moreover, an important contribution came from the growth-empirics approach that began with the testing of the neoclassical convergence hypothesis (Baumol, 1986; Barro, 1991; Barro and Salt-I-Martin, 1992; Mankiw, Romer, and Weil, 1992). It is also necessary to underline the important contribution relating to the development of comparable cross-country data on GDP, productivity and human capital indicators (Summers and Heston, 1988; Barro and Lee, 1993, 1996, 2001).

Nevertheless, Lant Pritchett underlined the controversies surrounding the relationship between education and growth (Pritchett, 2001). Indeed, in spite of the large number of recent empirical studies carried out on data of international comparisons, the assumption of a clear and positive relationship between the investment in human capital and economic growth has been largely called into question. Let us note that in this paper, we consider education only as a component of human capital. Certain international comparative studies have shown that many educational variables are factors determining the growth of per capita GDP in a country (Barro, 1991; Mankiw and al, 1992). However, problems concerning data have led to serious limitations: educational variables such as schooling rates or the average number of school years are vague indicators of the measurement of human capital relating to education (Benhabib and Spiegel, 1994). Pritchett (2001) even wonders “where has all education gone?”.

This work suggests three main explanations to understand why the most robust econometric analyses do not make it possible to prove a stable and positive relationship between human capital and economic growth:

1. Individual wage increases can lead to a slowdown in the country if the new graduates move in mass towards unproductive sectors;
2. If, in spite of an increase in the educated population, the private sector does not need new skilled workers, an unexpected decrease in the yield of education can occur ex post. Thus, the contribution made by individual profit will be smaller than the yield ex ante would have predicted;
3. The quality of education may be so low that it does not produce the necessary skills to lead to economic growth.

The main thrust of by this paper takes into account this last assumption. According to the analysis of Hanushek and Kimko (2000), we start from the idea that one year of education in country i does not confer the same output as one year of education in country j . Thus, the studies which take into account only quantitative indicators of education will be skewed, owing to the fact that they regard human capital as a homogeneous factor of production.

Section 2 presents an overview of the principal studies undertaken on the relationship between education and economic growth. In section 3, we detail the data sources and general methodology used to obtain our database on the qualitative indicators of human capital. Section 4 estimates the contribution of the quality of education to economic growth. Lastly, section 5 concludes our analysis.

2 Review of literature

This section draws up a short review of the literature on the education-growth relationship, based essentially on the qualitative analyses of this relationship. For a complete review of literature, see Hanushek and Wossmann (2007).

2.1 Initial models

The idea according to which education contributes to growth constitutes at once the origin and the result of the theory of human capital. Theodore W. Schultz (1961) observes that education explains most of the Total Factor Productivity, that portion of growth that neither the physical capital nor the volume of labour manages to predict. Macroeconomic models estimated by accounting methods, then econometrics, take as a starting point the introduction of human capital into an aggregate production function, in addition to physical capital or the quantity of labour.

One can distinguish two approaches in terms of education (Aghion and Howitt, 1998):

1. Lucas (1988) shows that there are two sources of human capital accumulation: education and training by practice. This furthers the analysis by Becker (1964) in which growth is primarily determined by the accumulation of human capital (in terms of flows). This analysis is thus in accordance with those of Mankiw, Romer and Weil (1992) and Barro (1990).
2. The work of Nelson-Phelps (1966) show that the stock of human capital is the principal engine of growth and not the difference in rates: the variations in growth between countries are determined by the differences between their stocks of human capital and so by their respective capacities to generate technical progress.

The principal difficulty concerns the measurement of human capital. Indeed, in order to introduce human capital as a factor of production, it is necessary to have data in terms of stocks. However, as Mankiw, Romer and Weil (1992) show, one can use flows of investment, with the proviso of introducing a structural model of growth and supposing that these economies are close to their stationary equilibrium. The results of the two great classics of this literature, Barro (1991) and Mankiw, Romer and Weil (1992) are synthesized in table 1.

The estimates are carried out on a hundred countries and the explained variable is the per capita GDP growth between 1960 and 1985. The authors measure human capital investment by means of the gross enrolment ratios (GER). Barro makes a distinction between primary and secondary education and retains the value for 1960, while Mankiw, Romer and Weil use an average of the GER of secondary schooling over the time-period studied. The effects are significantly positive (however, they are only significant with 10% significance level for the OECD countries studied).

Directly inspired by the arbitration between education and immediate income of the labour force proposed by Becker (1964), Lucas (1988) considers human capital as an assimilation between physical capital and the labour force (Bourdon, 1999). Like investment in physical capital, educational investment leads to an increase in a factor of production, namely human capital. This accumulation allows for the creation of direct outputs for those who are best equipped; but its distribution and its concentration must be analysed, because as for physical investment, cases of thresholds or externalities exist which can modify the level and the forms of appropriation of the output.

Thus, one of the lessons of Lucas's work is that to invest in primary education, to choose a "rectangular" approach, i.e. based on mass education, can encourage growth in a country, allowing it to escape the trap of underdevelopment. However, we will see that these specifications have their limitations.

2.2 Some contradictions

The principal limit in Lucas (1988), Barro (1991) and Mankiw and al. (1992) is the implicit assumption that education exerts an identical effect on all individuals, as the capital factor does. The marginal product of education can remain indefinitely positive, over the entire population. However, this assimilation of human capital to "traditional" capital seems to contradict the facts.

Another limit is related to the fact of the endogeneity of education. In cross section analysis, there are structural differences between countries (institutional, political...) which can explain the variations in growth and even in the accumulation of human capital (Gurgand, 2000). The specifications of authors who measure education in terms of flows would then allocate to human capital the effect on income of these intrinsic characteristics.

Lastly, the authors suppose that economies converge towards their standing point and are not very distant from it. For this to be true, the rate of savings would have to be constant over the period 1960-1985, which would amount to supposing that developing countries are precisely not under-developed.

Other authors have tried to directly estimate aggregate production functions, so as to produce robust results with economic assumptions relating to equilibrium. Various authors (Kyriacou 1991, Lau, Jamison and Louat 1991, Lau, Bhalla and Louat 1991, Barro and Lee 1993 and Nehru, Swanson and Dubey 1995) have tried to constitute data on human capital stock allowing international comparisons over a long period. This approach, gravitating around the pioneering article by Nelson and Phelps (1966), was based on these data

in stocks, better adapted to the theory. Indeed, here the assumption of proximity to stationary equilibrium can be slackened. And if one assumes that the endogeneity of education can be treated in terms of fixed effects (non-observed country characteristics, correlated with education, are essentially invariant over time), the estimate of growth rate directly removes the skew of endogeneity.

In these terms, the study of Pritchett (2001) is a very interesting example. Using two recently created cross-national time-series data sets (Barro and Lee, 1993, Nehru and al. 1995), Pritchett estimates the growth rate of per worker educational capital. From these estimates of years of schooling of the labour force, he creates a measure of educational capital from the microeconomic specification of earnings used by Mincer (1974). In the regression, the dependent variable is growth in GDP per worker from PWT5 (Penn World Tables, version 5). The results of estimates of the growth-accounting equation for the entire sample of countries are reported in table 2. Surprisingly, the estimate of the impact of growth in educational capital on growth in per worker GDP is negative (-0.049) and insignificant ($t=1.07$). Other studies report similar results (for example, Benhabib and Spiegel, 1994, Islam, 1995).

Thus, when the most robust econometric methods are used, particularly in the correction process for selection bias, it becomes impossible to reveal a positive relationship between human capital and economic growth, whatever the economic specification selected (Gurgand, 2000). The analyses of Pritchett (2001), Benhabib and Spiegel (1994) and Islam (1995) highlight this absence of relationship between growth and education. More surprising, these models show that education acts negatively on aggregate income and sometimes in a very significant way.

2.3 The Human Capital Quality

As underlined above, Pritchett suggested three main explanations for the difficulty of finding a positive relationship between human capital and growth. One of the explanations proves to be the necessary distinction between quantity and quality in education. Indeed, most studies use strictly quantitative indicators of human capital. Few studies take into account, even partially the quality of education.

Hanushek and Kimko (2000) concerned with finding a better measurement of the quality of human capital, measure it using scores obtained from students participating in international assessments in science and mathematics. Starting from these test scores, they construct a unique (normalized) labour force quality measure for 31 countries covering the period from 1960 to 1990. They computed a quality measure for each country's labour force using quality measure using the weighted average over all harmonized test scores where each country's weight is calculated as the normalized inverse of its standard error. They then performed a cross-country regression for the 31 countries over the 1960-1990 period. The authors used the investigations of the IEA (International Association of the Evaluation of Educational Achievement) and of the IEAP (International

Assessment of Educational Progress). In total, twenty-six series of educational performances were taken into account (by distinguishing according to age, the field of competence, namely mathematics and sciences, and year). The authors then proceeded to a regression of the average annual growth rate on the initial (1960) per capita income, the quantity of schooling, the average rate of population growth, the quality of the labor force and a constant. Their estimate reveals a negative and significant coefficient on the initial per capita income variable; a positive but insignificant one on the quantity of schooling variable; a positive and highly significant coefficient on the labour force quality variable; and a negative but insignificant coefficient on the rate of population growth. After testing for causality, they conclude that there is a significant and positive causal relationship between the quality of the labor force (in other words better productivity) and the growth rate of the economy.

Another contribution to the field of study which directly includes the measurement of the quality of education in a model of growth is that of Barro (2001). These data come from the same sources as those of Hanushek and Kimko. Barro however builds different indicators according to skill, namely mathematics, sciences and reading. These indicators are available for one period only and are introduced into a panel regression used in a previous article (Barro, 1997). Because of the restricted number of countries for which qualitative indicators of education are available, the sample is smaller and involves only 43 countries. The method of estimate used includes three equations in which the dependent variable is the real growth rate of the GDP per capita in purchasing power parity over the periods 1965-75, 1975-85 and 1985-90. Barro then uses many control variables such as an index of justice (rule-of-law index), an indicator of international trade, an indicator of inflation or fertility, etc. In order to avoid possible problems of endogeneity, the author uses the method of the triple-little-squares to solve a model with three simultaneous equations. Barro's results suggest that the quality of education is much more important than the quantity as measured by average secondary and university levels of attainment. In line with Hanushek and Kimko's results, Barro finds that the coefficient on the quantity of schooling variable is positive but insignificant, while that of the quality of schooling variable has a strong and significant predictive power.

3 Data and methodology

This section describes the nature of the data used to obtain the qualitative indicators of human capital (*QIHC*). Thereafter, we present the general methodology used to homogenize these data and to use them directly in the regressions.

3.1 Data used

The cognitive levels of pupils can be measured using the results on international investigations into pupil assets. These investigations set up specific procedures to measure qualification levels in mathematics, sciences and reading. The ques-

tionnaires were administered to several thousand pupils per country and were at once adapted to the local context and appropriate for international comparison (international standardization of the tests). Thus, these investigations, insofar as their sampling is adequate, can measure the international variations in pupils' cognitive attainment and thus distinguish differences in quality in the future labour force.

We used the most recent results from 6 groups of different international investigations (IEA, PISA, SACMEQ, PASEC, LABORATORIO and MLA). For the significance of these abbreviations, see appendix. Note that contrary to Barro (2001), our study does not adopt a panel approach. It thus has more in common with the approach of Hanushek and Kimko (2000), but distinguishes each field of skill (mathematics, science and reading) and increases the number of countries studied. The choice of these investigations calls for explanation. Preceding analyses used investigations carried out from 1961 to 1995, without considering their quality. For example, Barro used the success rates on all tests available between these two dates, for all skills. Hanushek and Kimko accounted for the quality of the data by balancing the rough results by the standard errors. But their re-scaling of the data was only based on the American national survey of school evaluation (NAEP - National Assessment of Evaluational Progress). They therefore supposed that the results of this investigation were dependable enough to assume a total anchoring of the data.

Certain investigations have been carried out in developing countries and have sought to measure the quality of education in countries which are generally not included in the evaluations carried out by major initial international investigations. Although the standard level for these investigations is more open to criticism than the investigations of the IEA or OECD, they represent an essential data source to include very poor countries in international comparisons. The quality of the investigations led by the IEA was highly criticized by the OECD, insofar as the questionnaires administered to the pupils were based too much on the American curricula. The launching of PISA by the OECD testifies to the fact that, in spite of the progress made these past years in sampling procedures, such investigations remain vague in their measurement of human capital. Thus, it remains clear that international investigations alone cannot explain the quality of human capital. However, they are a unique source for comparison of education systems, going beyond the simple quantitative indicators such as the completion rate of a school cycle.

The set of investigations used and the principal information relating to them are summarized in table 3. For a thorough description of these investigations, see in particular Beaton and al. (1999).

It should be noted that the investigations used do not always refer to the same educational level. While certain investigations measure pupils' skills at the secondary level (IEA-TIMSS, PISA, IEA), others are carried out at the primary level (IEA-PIRLS, LABORATORIO, PASEC, SACMEQ, MLA). More generally, the investigations measuring pupils' attainment in the rich countries are those which concentrate on the secondary level, while the other investigations prefer to measure skills at the primary level. Another difference arises

from the fact that certain evaluations group pupils by age (PISA), while others group pupils by school level (IEA, LABORATORIO, PASEC, MLA). This difference results in different country classifications according to the extent to which the practice of repeating a school year (which may be considerable in the developing countries) is used. Nevertheless, these limits modify the procedure of re-adjustment little insofar as the majority of countries having taken part in the PISA investigation also participated in the IEA reference investigation.

3.2 Methodology

Our study is in the prolongation of the work of Hanushek and Kimko and that of Barro. In order to improve our understanding of the impact of human capital on economic growth, we used 7 groups of international investigations of pupil attainment. We carried out an adjustment of these investigations to a common scale. The method used takes into account those countries which took part in several investigations simultaneously. By means of these results, we effected an anchoring of the investigations relative to each other. We find in Mingat (2003) a rather similar methodology of anchoring of the data relating to the investigations of pupil assets in sub-Saharan Africa. As a result of these procedures, we obtain qualitative indicators of human capital (*QIHC*) for three fields of competence (mathematics, sciences, reading).

In an appendix, we detail the methodology used to build our database. The totality of the data is present in Altinok and Murseli (2007).

4 Model and results

This section draws up the estimates carried out concerning the education-growth relationship. In the first paragraph, we consider a simple model, following by a model integrating control variables. In the second paragraph, we take into account the possible endogeneity of education by adopting a system of simultaneous equations.

4.1 Baseline regression with control variables

To evaluate the contribution of education to economic growth, two main approaches can be declined. The first approach assumes education plays the same role as physical capital in production: the stock of accumulated capital determines the possibilities of production at a given time. Consequently, the growth rate of the economy is affected by the growth rate of school attainment (Benhabib and Spiegel, 1994; Pritchett, 2001). The second approach suggests that the activities of research and development (R&D), by accumulating an immaterial stock of ideas and knowledge, make it possible to increase the effectiveness with which it is possible to produce wealth from capital and work (Romer,

1990). By raising the level of education and therefore the number of very qualified workers who can take part in this accumulation of knowledge, the rate of discoveries is increased, and thus the potentialities for growth in the economy. Education can play another role which is to support, not the technological innovation, but its adaptation. Nelson and Phelps (1966) very early suggested that the most powerful technologies are adopted and implemented more quickly by those economies richest in human capital. From this viewpoint, it is the level of education which raises the growth rate of the economy, by accelerating the assimilation of technical progress. Consequently, if a country devotes, in any one year, more resources to education and thus increases its stock of human capital, the result will be an increase in the growth rate of the economy. According to the ideas of Nelson and Phelps, it may be that education also increases the capacity to carry out strictly economic choices, in particular suitable allocation of resources. This second approach thus supposes that the output of education is all the higher as there are major opportunities for technological imitation and adaptation in an unstable universe. In their recent report for the French Council of Economic Analysis, Aghion and Cohen (2004) articulate these two mechanisms by distinguishing economies of imitation from economies of innovation. The first group of economies must invest primarily in the school levels supporting the imitation and implementation of new techniques, that is to say, primary and secondary education. This group includes countries with low and middle incomes. In order to encourage a growth, the second group of countries must contribute to technological innovation and have at their disposal a large mass of skilled labour. This justifies a major investment in higher education supporting economic growth. The developed countries belong to this second group of economies.

We chose this second type of approach to measure the impact of education on growth, because it fitted with the analysis of Nelson and Phelps (1966) which we also used to build our data. We introduced a quantitative educational variable (S) representing the average number of years of schooling between 1960 and 2000 for each country. In order to control for the effect of economic convergence, we introduced the GDP per capita in 1960 ($Y60$, or for the nearest year available). In the following estimates, we introduced successively the population growth rate ($DEMO$) and the qualitative indicator of human capital ($QIHC$) for the three fields of study. In order to allow for the possibility of specific constants according to skill, we introduced dummy variables whose values are not published. We obtained a database distinguishing each subject of study. In order to check for the possible colinearity between the explanatory variables (among which the two education variables), we carried out the Variance Inflation Factor (VIF) using STATA software. A value lower than 10 indicates that the colinearity between the variables is tolerable. In the totality of our estimates, colinearity seems unlikely to skew the model.

The results presented in table 2 show stable coefficients according to specifications and are of the expected sign for all of the variables. Initial income has a negative impact on annual growth rate, which confirms the assumption of convergence of economies. When the population growth rate is introduced, we

note that an increase of one percentage point decreases the annual growth rate by approximately 0,7 point. There is certainly a double relation of causality at work here, in the sense that the richer a country is the easier it can adopt a policy of birth rate control. The two educational indicators (S and $QIHC$) have significant and positive impacts on the annual growth rate (column 3). The inclusion of $QIHC$ increases in a notable way the explained value of the general model by increasing it from 40 to 56% between columns (1) and (3) and from 48 to 58% between columns (2) and (4). Comparatively, these conclusions are in accordance with those obtained by Hanushek and Kimko (2000) and Barro (2001). We cannot directly compare the explained variances of our model with that of Hanushek and Kimko (2000) or that of Barro (2001), because the databases are different. Indeed, we include a much larger number of countries (105 countries compared to 31 in the first study and 43 in the second). Concerning the quantitative variable of education, the two principal studies found positive but insignificant coefficients, while in our study the coefficients are positive and significant. This finding can be explained by the fact that we included a great number of countries, especially developing countries. This widening of the number of countries thus notably reinforces the relationship between education and growth, viewed from both the quantitative and qualitative perspective.

In order to assure comparability between the coefficients, we used the variations in standard deviation. The calculation of the impact of an increase in the standard deviation of an indicator on the average annual growth rate is made by multiplying the coefficient obtained for the indicator by the standard deviation of this indicator in the whole sample. See Wooldridge (2006, p.195). An increase by one standard deviation of $QIHC$ (approximately 17 points) involves an increase in approximately 0.9 percentage point of the average annual growth rate. Thus, the difference in growth between South Korea and Greece (3.18% annual growth for Greece versus 6.08% for South Korea) can in particular find its explanation in the quality of education: where $QIHC$ for Greece is only 82.8, that of South Korea is 96.3. Comparatively, an increase by one standard deviation of the quantity of education (2.3 years) increases growth rate by one percentage point. Consequently, it is not only the number of years of schooling that has an impact on growth, but also the quality of education which exercises as important an influence. It is necessary here however to moderate the amplitude of these coefficients, for at least two reasons. First of all, if education creates positive externalities, then the coefficient associated with our indicators may be over-estimated. Because of omitted variables, the coefficient associated with the educational indicators may include other factors. We try to check this assumption in table 5. In addition, as Bils and Knelow (2000) note, there may be a double relation of causality between education and growth: if education certainly has an impact on economic growth, such growth also probably has a return effect on education. In this case, the coefficient found could explain an opposite relation of causality between education and growth. We take this assumption into account in the following paragraph.

The inclusion in estimate (4) of the demographic variable does not modify the significance of the coefficients and maintains a considerable influence of $QIHC$.

With the introduction of a qualitative indicator of education, the quantitative effect of education decreases by approximately 50%. Certain countries boasting an important “stock” of education (for example the United States, Australia, the Netherlands) may have bypassed strong economic growth because of their relatively low quality education, while in others the contrary seems true (Singapore, Hong-Kong, South Korea). It remains natural however to think that other factors may have determined these growth differentials.

The relatively higher quality of human capital in South and East Asian countries undoubtedly explains their success in terms of economic growth (World Bank, 1995). This difference in economic growth may also be explained by an economic phenomenon of convergence, as reported in the work by Solow. In estimate (5), we therefore introduced a dummy variable relating to the continent of South and East Asia. The coefficient associated with this variable is significant and positive. Thus, all things being equal, countries on this subcontinent had an average annual growth rate between 1960 and 2000 which was higher by 0.67 points than that of other areas. The educational variables remain significant. We can conclude that the growth of the Asian countries is not completely due to an “Asian value” (defined by cultural and religious characteristics, see Stevenson, 1992, 1993) but also to the powerful education systems in these countries. When we introduce the dummy variable relating to sub-Saharan Africa (column 6), the coefficient is negative, but insignificant: thus the weak growth in certain African countries may in particular be explained by the weakness in the quality of their education systems.

Lastly, in column 7, we combine the quantitative indicator of education S and $QIHC$ (S_{QIHC}). In this way, we test whether the readjustment of the average number of school years by the quality of education can improve our measurement of education, by supposing that one school year in a considered country is not identical to the same year in another country. The value obtained by calculating $QIHC/100 \times S$ can thus be regarded as an average number of school years adjusted by the quality of education. The result is that the coefficient associated with this variable is positive and significant. An increase by one standard deviation of this indicator (that is to say approximately 0.83 school years corrected by $QIHC$) leads to an increase of 1.5 points in the annual growth rate. This effect is more important than the sole effect of the indicator of quantity of education: the adjustment of a quantitative indicator of education by $QIHC$ can make it possible to improve the impact of education on growth. As underlined above, it is nonetheless essential to remain rather prudent when considering the amplitude of this coefficient.

In the tradition of Levine and Revelt (1992), we introduce into the specification a variety of other common economic measurements in order to check that the coefficients associated with $QIHC$ do not include variables omitted in preceding specifications. Table 3 includes in our analysis of growth a series of other explanatory indicators included in preceding analyses (see Aghion and Howitt, 2000). The additional indicators are : the ratio between expenditure on defense and on education expressed as a percentage of GNP ($DEFENCE$),

the rate of private investment expressed as a percentage of *GNP* (*PRIINV*), and the rate of openness of the economy measured by the share of international trade expressed as a percentage of *GNP* (*TRD*). As indicated previously, the relationship of causality between these factors and growth is questionable. Nevertheless, our principal interest is the sensitivity of our qualitative indicator of education with the introduction of these key variables (see Levine and Revelt, 1992, Levine and Zervos, 1993). We reproduce in column (1) the original estimate with *QIHC*. The introduction of key variables certainly modifies the amplitude of *S* and *QIHC* on growth, but both remain positive and significant. Indeed, the coefficient associated with *QIHC* is divided by two when control variables are introduced: consequently, an increase by one standard deviation in the quality of education induces a variation in the annual growth rate of approximately 0.6 points, which still remains very high. The three indicators *DEFENSE*, *PRIINV* and *TRD* have the expected signs and are significant.

An interesting finding is illustrated in column 7. When the combination of quantity and quality of education is effected (*S_{QIHC}*), we observe a significant increase in the education-growth relationship: a variation by one standard deviation of *S_{QIHC}* (approximately 2.32 years) increases the average annual growth rate by 0.72 points; conversely, an increase in only the quantitative indicator of education increases growth by 0.36 points (column 4).

4.2 Human Capital Endogenization

Growth makes it possible to increase the resources of a State, and a share of those resources may be directed towards investment in human capital. Thus, the previously estimated relationships may over-estimate the causal impact of the quality of education on the growth rate.

Let us consider the following system:

$$g_i = X_i\beta + \gamma QIHC_i + \epsilon_i \quad (1)$$

$$S_i = W_i\alpha + \eta g_i + \rho QIHC_i + \tau_i \quad (2)$$

$$QIHC_i = Z_i\Psi + \chi g_i + v_i \quad (3)$$

The growth (g_i) of a nation is determined by the quality of its education (*QIHC*) and a series of other factors (*X*) [equation 1], while growth also acts, with other factors *W*, to directly determine the quantity of education (*S*) [equation 2] and the quality of education (*QIHC*) [equation 3]. However, if resources combined with other factors (*Z*) determine the quality of education [equation 3], then the simple estimate of equation 1 will not provide the true impact of the quality of education on growth (γ). This equation alone may just as easily reflect the impact of growth on the quality of education. The reasoning is similar for the quantity of education. Consequently, the endogeneity of education

would make it possible to see whether we are in fact measuring the impact of education on growth, and not the reverse.

In equation 2, we consider that growth has a direct impact on the quantity of education. In addition, the quality of education can also contribute to increasing the quantity of education: better schools can appreciably increase the number of years of schooling in a population, by increasing the demand for education and in particular by decreasing the dropout rates. Other factors also play into the determination of the quantity of education. We chose potential factors such as the educational expenditure for primary education (*DEPPRI*), the net enrolment ratio at primary level (*NERPRI*) and the pupil-teacher ratio in primary education (*TEAPRI*).

Equation 3 considers in a similar way that the growth rate can directly explain the quality of education. In addition, a series of factors likely to improve the quality of education is here introduced. They are the same as those used in equation 2, with the addition of the dropout rate (*DROPPRI*) and the retention rate in primary school (*REPPRI*), two factors likely to notably influence the quality of education.

We first check for the endogeneity of schooling indicators. We used the Hausman test between the OLS and Instrumental models. In order to confirm the results, we tried to see whether the variables *S* and *QIHC* were quite endogenous in the above specifications. To do so, we regressed one by one these variables with the other variables (including those in equations 2 and 3). We then regressed the traditional OLS estimate by adding to the specification residuals resulting from the preceding estimate. If the coefficient associated with these residuals is significant, then the variable in question is potentially endogenous. The two variables *S* and *QIHC* produced results confirming their probable endogeneity. See Wooldridge (2006, p532) for the method used.

Then we undertook the estimate of a system with three simultaneous equations. The terms of errors $\varepsilon, i = g, S, QIHC$ are distributed according to a normally and identically distributed variance σ_i^2 . A correlation of error terms is probable between the equation of the growth rate and those of the educational indicators. Taking account of the correlation between the error terms requires a recourse to the estimation method of three-stage least squares (TLS). This estimation method consists in an estimate of each equation by the two-stage least square with a correlation of error terms (it uses the residuals of the first stage to estimate the correlations between the various equations, Grenne, 2005, p.391).

The results of the various estimates are presented in table 4. The main finding is that the two indicators of education have positive significant coefficients.

The estimate in column (1) does not take into account the endogeneity of education and reprints the results of table 2. In column (2), we took into account only equations (1) and (2), in order to test whether the quantitative indicator had an impact on growth: the coefficient associated with this variable is positive and significant. The estimates in columns (3) and (4) include the three equations. It will be noted that when the quality of education is taken into account, the effect of the quantity of education decreases by approximately 30%.

Consequently, the quantity of education plays a role in explaining growth, but the quality of education systems plays an equally explanatory role. In addition, this effect is all the higher as the educational factors are endogenised. We can explain this finding by the fact that in equation (2), whatever the specification used, the associated value of the coefficient is negative and significant. The annual growth rate would then seem to have a negative and significant impact on the average number of years of schooling, when other control variables are taken into account (namely quality of education, public expenditure on primary education, the net enrolment rate in primary education and the teacher-student ratio in primary school). As the object of this study is not to estimate an education production function, the results of the estimates of equations 2 and 3 are not presented in the present paper. This surprising finding can be compared with that reported by Pritchett (2001): not having taken into account the double causality between education and growth, the negative coefficient found in his estimates is comparable to the result which we obtain when we estimate the contribution of the growth rate on the quantity of education. On the contrary, the growth rate of the economy has a positive and significant impact on the qualitative indicator of education. Thus, an increase by one standard deviation in the quality of education (approximately 17 points) increases by approximately 1 point the average annual growth rate between 1960 and 2000, when the effect of the growth rate on the quality of education is taken into account.

The other indicators are of the expected sign and are significant, except for the variable of population growth and that associated with expenditure on defence and education in columns (3) and (4), which are not significant.

In column (5), we combined the two educational variables, namely S and $QIHC$, in order to see whether, when we correct the average number of school years by the quality of the education system (S_{QIHC}), the effect of education on growth was modified or not.

The system then becomes:

$$g_i = X_i\beta + \gamma S_{QIHC,i} + \varepsilon_i \quad (4)$$

$$S_{(QIHC,i)} = W_i\alpha + \eta g_i + \nu_i \quad (5)$$

The coefficient associated with the variable S_{QIHC} is positive and significant. Precisely, its amplitude is higher than that S of alone : thus, when the quality of education is taken into account, the effect of education on growth increases by approximately 50%: an increase by one year of the average number of school years adjusted to the quality of education leads to an increase of approximately 0.7 points in the annual growth rate (column 5).

5 Conclusions

Among all the explanations for economic growth, one generally accepted explanation concerns the level of human capital. The seeming obviousness of the idea however, has met with inconsistencies in the existing literature. The most robust macro-economic analyses reveal contradictions in the relationship between education and growth. Pritchett (2001) showed that very often the impact of education on growth is negative and significant. However, the majority of these studies ignored the qualitative dimension of human capital, recognizing only the purely quantitative indicators.

Using national or international surveys into the pupil assets in mathematics, sciences and reading make it possible to fill this gap in qualitative measurement. Hanushek and Kimko (2000) and Barro (2001) used qualitative variables, but did not exploit all of the international investigations or all the countries surveyed (36 countries in the first study and 43 countries in the second). In this research study, we used a method which enabled us to obtain qualitative indicators of human capital (QIHC) for approximately 105 countries, and for each academic subject (mathematics, sciences, reading). Consequently, our sample includes more developing countries than the two principal existing studies in this field.

The estimate of the relationship between education and growth reveals the positive roles played at once by the quantity and by the quality of education: when the QIHC are taken into account, the quantitative effect decreases, but remains significant. Whatever the specifications selected (with or without variables of control), the qualitative effect of education is always positive and significant on the growth rate of the economy.

An important problem had to be addressed: as economic growth also plays a part in explaining the quality of education systems, it was necessary to make use of a simultaneous equations model. Taking account of the possible endogeneity of education - via the two educational indicators - made it possible to distinguish the possible double causal relationship between education and growth. With this endogenization, the effect of education on growth is maintained, from the quantitative point of view as well as the qualitative. Education thus has a real effect on the growth rate of an economy.

Nevertheless, the estimated effect of the quality of education on growth seems over-estimated: indeed, our results show that an increase by one standard deviation in the quality of education brings with it an increase by a single point in the average annual growth. As Hanushek and Kimko (2000) indicated, there is no direct and clear relationship between differences in productivity in the profits of individuals of different nations and the economic growth of those nations. It is highly possible that the quality of education generates positive externalities and thus encourage a nation into a higher cycle of growth. This argument underlines the possibility of variables omitted in the equations of growth, but we have little information on their nature. By including a certain number of them (expenditure on defence, rate of trade, rate of private investment), the qualitative and quantitative effects of education were reduced, but remained positive.

It is thus necessary to proceed cautiously in measuring the magnitude of the effect of education on growth. However, by confirming preceding analyses which used qualitative indicators, we can conclude from our study that the quality of education is an important factor in growth. It now remains to determine the factors likely to improve the quality of education and thus to encourage economic growth of countries.

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6 Appendix

This appendix describes the methodology used to calculate the qualitative indicators of human capital only for the cross country database. We present here the procedure for mathematics. A general presentation of this methodology is included in Altinok and Murseli (2007).

As there are eight international surveys analysing children's learning achievement, our study tried to gather those surveys on a common scale in order to allow an international comparison of children's learning achievement across countries. These surveys are SACMEQ (Southern and Eastern Africa Consortium for Monitoring Educational Quality) , MLA (Monitoring Learning Achievement), PASEC (Programme on Analysis of Education Systems), LLCE (Latin American Laboratory for Assessment of the Quality of Education), PISA (Programme for International Student Assessment), TIMSS (Third International Mathematics and Science Study), PIRLS (Progress in International Reading Literacy Study). For more informations on these surveys, see Beaton et al. (1999).

First, we selected countries which participated in at least two different surveys so as to establish a comparison between the surveys. The IEA surveys were chosen as reference surveys as they cover the largest number of countries and as the economic levels of the participating countries are the most heterogeneous. We will present the general methodology as applied to mathematics.

Note that we only used tests dated after 1995, because we wanted to obtain qualitative indicators for the most recent year. Therefore, to include as many countries as possible, we had to use several IEA surveys and not only the TIMSS 2003 survey. In order to assure a better comparison with the other surveys, we

decided to use only data from grade 8. We have therefore used three surveys in IEA mathematics (TIMSS1995, TIMSS1999, and TIMSS2003).

All the surveys were then adjusted to a 0-100 scale, with 100 as the highest possible score.

$$\left(x_{ij}^k\right)_{adjusted} = \frac{x_{ij}^k}{\max(x_{ij}^k)} \times 100 \quad (6)$$

Where $\left(x_{ij}^k\right)_{adjusted}$ represents the adjusted results of survey i for country j in subject k .

Note that index i includes seven groups of surveys (SACMEQ, MLA, PASEC, LABORATORIO, PISA, TIMSS, PIRLS). Index j includes all the countries participating in the different surveys. Index k refers to the subject measured (mathematics, science, reading). Equation (6) therefore shows that the adjusted result $\left(x_{ij}^k\right)_{adjusted}$ is obtained by dividing each result of the initial survey x_{ij}^k by the maximum value of this survey $\max(x_{ij}^k)$, multiplied by 100.

Note that we did not adjust survey variance because we wished to allow for a possible difference in variance between surveys. While Hanushek and Kimko (2000) adjusted surveys in order to have a mean of 50 and pondered them by a (normalized) standard error, Lee and Barro (2001) preserved absolute means, without pondering tests with any variance indicator. In our methodology, we were faced with two options: if we chose a standardisation of surveys by variance indicators, we would suppose that all surveys between 1964 and 2005 had the same mean and the same variance ; on the contrary, if we did not standardise tests, we would suppose that mean and variance of tests can vary over time. We chose the second hypothesis because the number and the nature of the countries which participated in the tests vary greatly among tests. It will be noted that, despite this absence of standardization by variance of tests, we nonetheless have comparable results, due to the methodology of matching with “doublon countries”.

Starting from the TIMSS indexes, we tried to track countries which had participated in the TIMSS and at least one other survey. It will be noted that all the surveys include countries which participated in the TIMSS and at least one other survey. (Except for the PASEC survey which does not include the countries of the TIMSS survey).

We then proceeded to a matching based on the means of those countries which participated in at least two surveys (called “doublons”); each survey was re-adjusted according to how closely it fitted with the IEA survey which was taken as a reference.

$$\bar{x}_{i,doublings_n}^k = \frac{\sum_{i=1}^n \tilde{x}_{i,doublings_n}^k}{n} \quad (7)$$

Equation (7) records the operation used to obtain the mean of the doublings for each survey, which is noted $\bar{x}_{i,doublings_n}^k$.

This was accomplished by calculating the mean of the results of the “doubling countries”, namely those which participated in both the IEA reference survey and the survey we wanted to adjust.

$$\bar{x}_{IEA,Country_n}^k = \frac{\sum_{i=1}^n x_{IEA,Country_n}^k}{n} \quad (8)$$

Equation (8) highlights the same operation as that performed on the IEA reference survey. We calculated the mean of the results for the “doubling countries” of the IEA survey. In the next step, we calculated the transfer index from survey to the adjusted survey according to the IEA reference survey. This calculation was made by dividing the mean of the reference survey $\bar{x}_{IEA,Country_n}^k$ by the mean of the adjustment survey $\bar{x}_{i,doublings_n}^k$.

$$Index_{IEA,i}^k = \frac{\bar{x}_{IEA,Country_n}^k}{\bar{x}_{i,doublings_n}^k} = \frac{\sum_{i=1}^n x_{IEA,Country_n}^k}{\sum_{i=1}^n x_{i,doublings_n}^k} \quad (9)$$

Finally, we proceeded to the calculation of the values of the initial survey, now re-adjusted according to the reference survey. This was done by multiplying the initial result of country j in survey i for subject k : x_{ij}^k by the corresponding reference index, namely $Index_{IEA,i}^k$.

$$\hat{x}_{ij}^k = \left(x_{ij}^k\right)_{adjusted} \times Index_{IEA,i}^k \quad (10)$$

As a result of these procedures, we were able to obtain all the re-adjusted results in mathematics referenced to the TIMSS survey. Moreover, for each country which provided adjusted results in several surveys, the mean of those results was calculated (see Equation 11).

$$\bar{x}_{ij}^k = \frac{\sum_{i=1}^n \hat{x}_{ij}^k}{n} \quad (11)$$

The same type of procedure was used with regard to the measurement of skills in science and reading. In order to obtain a synthetic indicator of the quality of human capital, the arithmetic mean of the scores in the three fields was calculated. The whole of the data is available on request.

Table 1: **Data source (Page 1/2)**

<i>Variables</i>	<i>Abreviation</i>	<i>Source</i>
Initial Income in 1960 (constant prices of 2000, chain series)	<i>Y60</i>	Penn World Tables 6,1 ; Heston, Summers and Aten (2002)
Average annual growth rate of economy	<i>GDP</i>	Penn World Tables 6,1 ; Heston, Summers and Aten (2002)
Average population growth rate	<i>DEMO</i>	Penn World Tables 6,1 ; Heston, Summers and Aten (2002)
Quantitative variable of education : average years of schooling of people aged between 15 and 25.	<i>S</i>	Barro and Lee (2001) and Unesco (2004)
Qualitative variable of education : Qualitative Indicators of Human Capital	<i>QIHC-M</i> <i>QIHC-S</i> <i>IQCH-L</i>	Altinok and Murseli (2007) M=Math. S=Science L=Literacy
Ratio of real government spending on defence and on education to real GDP	<i>DEFENSE</i>	Easterly and Rebelo (1993)
Average ratio of private investment relative to GDP	<i>PRIINV</i>	Barro and Lee (1994) [INVWB-INVPUB]
Ratio of total trade to GDP	<i>TRD</i>	King and Levine (1993)
Total public expenditure on education as % of GDP	<i>DEPEDU</i>	Unesco (2004), Unesco (2005)
Teachers' salaries expressed as a percentage of per capita GDP	<i>SHSALP</i>	Barro and Lee (2001), Unesco (2004), Unesco (2005)

Note: Continue on next page.

Data source (Page 2/2)

<i>Variables</i>	<i>Abreviation</i>	<i>Source</i>
Public expenditure on primary education expressed as a percentage of per capita GDP	<i>DEPPRI</i>	Barro and Lee (1996), UIS-Unesco (2006)
Net Enrolment Ratio at primary level	<i>TNSPRI</i>	World Bank (2002)
Pupil-teacher ratio at primary level	<i>TEAPRI</i>	Barro and Lee (2001), Unesco (2004),
Drop out rate at primary level (%)	<i>DROP</i>	Barro and Lee (2001), Unesco (2004), Unesco (2005)
Repetition rate at primary level (%)	<i>REPPRI</i>	Barro and Lee (2001), Unesco (2004), Unesco (2005)

Table 2: **Baseline Regression**

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Explanatory Variables							
Y60	-1.58 (0.32)	-1.86 (0.31)	-1.54 (0.26)	-1.72 (0.27)	-1.55 (0.29)	-1.70 (0.27)	-1.46 (0.15)
DEMO		-0.73 (0.10)		-0.42 (0.11)	-0.50 (0.11)	-0.42 (0.11)	-0.55 (0.10)
S	0.70 (0.09)	0.59 (0.09)	0.38 (0.10)	0.37 (0.10)	0.31 (0.10)	0.36 (0.1)	
QIHC			0.06 (0.01)	0.05 (0.01)	0.05 (0.01)	0.05 (0.01)	
QIHC/100*S							1.70 (0.15)
Asia (=1)					0.65 (0.29)		
Africa (=1)						-0.16 (0.36)	
Constant	0.04 (0.26)	2.24 (0.39)	-2.39 (0.38)	-0.73 (0.62)	-0.19 (0.57)	-0.48 (0.91)	-5.01 (0.86)
Observations	191	191	192	192	192	192	192
Adjusted R sq	0.41	0.50	0.57	0.60	0.61	0.60	0.61
Test VIF S		3.24	4.46	4.47	5.14	4.68	
Test VIF QIHC			2.58	2.98	3.26	4.18	
Test Mean VIF		2.17	2.53	2.6	2.69	2.84	1.81

Note: Huber-White Standard error in parenthesis. For detail of regression see text.

Table 3: Regression with control variables

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Explanatory Variables							
Y60	-1.58 (0.32)	-1.86 (0.31)	-1.54 (0.26)	-1.72 (0.27)	-1.55 (0.29)	-1.70 (0.27)	-1.46 (0.15)
DEMO		-0.73 (0.10)		-0.42 (0.11)	-0.50 (0.11)	-0.42 (0.11)	-0.55 (0.10)
(S)	0.70 (0.09)	0.59 (0.09)	0.38 (0.10)	0.37 (0.10)	0.31 (0.10)	0.36 (0.10)	
QIHC			0.06 (0.01)	0.05 (0.01)	0.05 (0.01)	0.05 (0.01)	
QIHC/100*S							1.7 (0.15)
DEFENCE		-8.49 (1.64)		-5.54 (1.50)		-5.48 (1.54)	-4.77 (1.59)
PRIINV			13.59 (2.06)	14.05 (2.18)		14.70 (2.13)	10.90 (2.34)
TRD					1.33 (0.27)		0.68 (0.20)
Constant	0.04 (0.26)	2.24 (0.39)	-2.39 (0.38)	-0.73 (0.62)	-0.19 (0.57)	-0.48 (0.91)	-5.01 (0.86)
Observations	191	191	192	192	192	192	192
Adjusted R sq	0.41	0.5	0.57	0.6	0.61	0.6	0.61
Test VIF S		3.24	4.46	4.47	5.14	4.68	
Test VIF QIHC			2.58	2.98	3.26	4.18	
Test Mean VIF		2.17	2.53	2.6	2.69	2.84	1.81

Note: Huber-White Standard error in parenthesis. For detail of regression see text.

Table 4: **Regression with endogenization of human capital variables**

	(1)	(2)	(3)	(4)	(5)
Explanatory Variables					
Y60	-1.72 (0.27)	-2.21 (0.24)	-2.17 (0.28)	-1.71 (0.25)	-1.06 (0.14)
DEMO	-0.42 (0.11)	-0.73 (0.12)	-0.27 (0.25)	-0.12 (0.18)	-0.57 (0.11)
S	0.37 (0.10)	0.63 (0.11)	0.53 (0.17)	0.35 (0.14)	
QIHC	0.05 (0.01)		0.06 (0.04)	0.06 (0.03)	
QIHC/100*S					0.96 (0.27)
DEFENCE		-7.56 (1.90)	-2.57 (3.56)	-3.01 (2.73)	-7.11 (1.74)
PRINV				9.57 (2.26)	8.92 (1.81)
TRD		1.41 (0.24)	1.14 (0.28)		
Constant	-0.73 (0.62)	2.37 (0.68)	-2.4 (2.59)	-2.84 (1.81)	-1.95 (1.58)
Observations	192	157	152	153	138
Hausman Chi2		26.28(7)	21.93(6)	24.94(8)	35.75(7)

Note: Huber-White Standard Errors in Parenthesis. For detail of regression see text.