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A Macroeconomic Estimation of the Education Production Function

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Abstract

The aim of this paper is to test the existence of an education production function based on data resulting from international surveys of pupil assets. The results of the estimates, using first the total sample, and then making distinctions according to the economic level of the country, show significant differences concerning the relationships between educational inputs and outputs. Thus, inconsistencies found in former analyses in terms of estimating the education production function can partially be explained by the fact that they failed to take into account the economic level of the countries analysed.

Keywords : Education Quality, Human Capital, Public Expenditure.
J.E.L. classification: E61 ; H52 ; I22 ; I28.

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1 Introduction

This study aims to check for the existence of an education production function by carrying out international comparisons, based on results drawn from international investigations into the strengths of pupils. It thus falls into the line of work of international comparisons based on explaining scholastic performances by using variables which document school resources and organization. The existence of an education production function supposes from the start the opportunity of enacting stable relationships between the resources allocated to education (educational inputs) and the performances of the pupils (educational outputs).

Schools can be regarded as manufacturing units on the offer side, but, short of some exceptions, they are not-for-profit institutions. To think of schools as providing an education service leads to an analysis in terms of education production function (EPF). Pritchett and Filmer (1999) show that the analysis of the education system in terms of EPF requires modifications to the traditional analysis of a company. They suggest that schools be treated as organizations which try to maximizeadded value, which could be, for example, acquisition by the pupils of a knowledge base, all of this within the limits of their budget. In a general way, the output of the EPF can be measured as a level of qualification observed by means of investigations into the assets of pupils.

Recent analyses of international differences concerning economic growth have emphasised the role of human capital. International comparative studies have revealed that many educational variables are factors determining the GDP per capita growth of a country (Barro, 1991; Mankiw and al., 1992). However, problems of information have seriously limited the interest of these studies: educational variables, such as schooling rates or the average number of schooling years are vague indicators of the measurement of human capital (Benhabib and Spiegel, 1994; Pritchett, 2001). In this way, they are more a quantitative measurements of the resources allocated to education than a measurement of the skills developed in school.

On a more profound level, the quality of education can be measured by the performance of the pupils. Two types of indicators may be used. First of all, the qualitative value of schooling can be measured by performance on the labour market, such as the additional profits gained, in the sense defined by the Mincer model, or the policies of recruiting skilled workers. Another indicator may be pupil results obtained on international proficiency tests. In the framework of our study, we chose this second option. Several former studies, carried out on the personal level, showed that the results of studies of cognitive skills are good indicators of the future income of the pupils (Boissiere, Knight and Sabot, 1985; Birshop, 1989, 1992; Moll, 1998). Other studies, more macroeconomic in scope, also show that the results on these proficiency tests are strongly correlated with the economic performance of the referenced country. For example, Hanushek and Kimko (2000) and Barro (2001) found that results on tests in mathematics and sciences are positively correlated to the economic growth of the per capita GDP in regressions of international comparison. The quality of education can thus be considered an important component of human capital.

In this work, we try to determine the factors which account for education quality, measured from results of comparable assessments of pupil skills. The principal contribution of the present study is the sample size of countries for which we have data. Our large sample confers the possibility of distinguishing countries according to their economic level and thus of checking if there is a different education production function for each level. In this way, the inconsistencies found in preceding studies could be explained by one specific fact: failure to take into account the economic level of the countries in the estimate of the EPF. To each level of development could thus correspond a different production function.

In section 2, we present a review of the literature centred on the major existing estimates of the education production function. We then detail the methodology used to build our data on education quality (which we call "qualitative indicators of human capital" or QIHC) and other indicators of input. Section 4 presents the modelization and the empirical results. Section 5 concludes and an annex contains the principal data of the study.

2 A Brief Review of the Literature

Although many studies have estimated the relationship between pupil proficiency levels and educational input, they are generally based on microeconomic analyses. International comparisons are rare and difficult because easily available, consistent data is lacking.

The relationship between educational input and output can be analyzed by an EPF which connects a variety of input types to a given output. This function can be defined as:

$$Q = Q(F, R) + \varepsilon \qquad (1)$$

where Q represents the quality of education; F, family factors; R, factors of resources; and ε represents unmeasured factors influencing school quality.

Two major studies (Hanushek and Kimko, 2000; Lee and Barro, 2001) used aggregate data in determining the relationship between educational variables and results on tests. Thereafter, Al Samarrai (2002) carried out a review of literature while producing additional results. Without testing the data of international investigations, Gupta, Verhoeven and Tiongson (2002) demonstrated the need to distinguish countries according to their economic level in the estimate of EPF. Lastly, Hanushek and Luque (2003) looked further into the analyses resulting from Hanushek and Kimko (2000). The text below is inspired from Leclerq (2005), where we can find a more complete review.

Hanushek and Kimko (2000) built a worldwide database of the results on international test scores for a sample of 39 countries (see for methodology, Hanushek and Kim, 1995). They took into account the results on international tests by the IEA (International Association for the Evaluation of Educational

Achievement) and from the IAEP (International Assessment of Educational Progress). Tests were administered to pupils belonging to different cohorts in 1965, 1970, 1981 and 1985 (IEA), 1988 and 1991 (IAEP) in 11, 17, 17, 17, 17, 6 and 19 countries, respectively. 39 countries contributed at least once, while the United States and Great Britain took part in the entire six series of tests. By using 67 to 70 observations in a regression of international comparison, they stress that proper measures of education (such as the pupil-teacher ratio at the primary level, current public expenditure per pupil, and total expenditure on education as a fraction of GDP) do not have a significant effect on the results obtained on international tests. Thereafter, Hanushek and Kimko carry out an analysis in terms of average over the period 1965-1991 in order to check the impact of school variables on the indicator of quality of the labour force which they compiled from the international surveys. They conclude that school resources are once again not correlated to the quality of education.

Lee and Barro (2001) sought the determinants of school quality in a panel database which included measurements of input and output of education for a greater number of countries. The authors took into account results in mathematics, sciences and reading for pupils of different ages who had participated in the same investigations as Hanushek and Kimko. The data used was gathered from 1964 to 1991. Thus, they built a panel database of 214 observations by combining the issues of the tests with variables of input. They based their study on their previous work concerning a database on the quantity and quality of education between 1960 and 1990, with a 5 year interval between each data set (Barro and Lee, 1996). This data set includes both educational attainment by sex for the population aged 15 and above and indicators of the quality of school input (teacher/pupil ratio, spending per pupil, teacher salaries, the share of students repeating grades or dropping out of school, each available for both primary and secondary schooling except for teacher salaries and drop out rates, available only for the primary level), and includes full data for 105 countries and partial data for 21 more. In contrast with Hanushek and Kimko, they demonstrate that school resources, including teacher salaries, have a significant impact on test scores, while the pupil-teacher ratio has a negative and significant impact on test success. In addition, the use of the repetition rate and the drop out rate as alternative variables of schooling quality reveals a positive relationship between the pupil-teacher ratio and each of these two variables. In two regressions out of four, teachers' salary is correlated negatively and significantly with the quality of human capital.

Al Samarrai (2002) carries out a review of literature concerning the relationships between school resources and educational performance. He concludes that there is no clear relationship between these two variables: while certain studies tend to confirm the conclusions of Hanushek and Kimko (Colclough and Lewin, 1993; Schultz, 1995), others confirm those of Lee and Barro (Gupta and al, 2002; Wossmann, 2000), while others give opposite results (McMahon, 1999; Al Samarrai, 2002). The Al Samarrai study uses the data of 1996 from UNESCO. It again uses quantitative variables (primary-school gross and net enrolment rate) and proxy measures of education quality (survival rate to grade 5 and net enrolment rate). Its sample includes respectively 90, 79, 69 and 33 observations, because of differing availabilities of data depending on the variable'. The explanatory variables include public expenditure on primary education, expressed as a proportion of the GNP, educational expenditure per pupil, the pupil-teacher ratio at the primary level and other control variables (Gini coefficients, per capita GNP, urbanization rate, proportion of Muslim Population, regional dummies). OLS results widely suggest insignificant or «incoherent» relationships, which are confirmed by alternative specifications and estimation techniques (including an instrumentation of school resource variables using the secondary school pupil teacher ratio, total education spending as a share of GNP and the length in years of the primary cycle).

Gupta, Verhoeven and Tiongson (1999) examine the impact of government spending on education and health care. The originality of their paper is to estimate 50 developing and transition countries, where other studies often concentrate on developed nations. Instead of using proficiency test results, they base their measurement of education quality on enrolment rates and the retention of pupils in school until grade four, which they regard as an appoximate endpoint in school achievement. Their results show that total spending on education hardly affects retention rates, but that the share of primary and secondary education spending to total spending has a significant and positive impact. Moreover, it is the share of resources dedicated to elementary schools that seems to affect their action ; total resources are too rough a measure to be relevant.

The study by Hanushek and Luque (2003) relies on that of Hanushek and Kimko (2000). The authors use the data of the IEA survey, particularly the TIMSS survey (The Third International Maths and Science Survey), of 1995 conducted in more than 40 countries, for pupils aged 9, 13 and 17. Hanushek and Luque consider the determinants of achievement focusing on the class-level average of mathematics for pupils aged 9 and 13, by extracting two samples of 300 observations for each country. For each age group, they estimate country regressions of the test score on different school and family variables. They base their reflection on the comparison between the variables which show or fail to show a relevant relationship, positive or not on success on test scores. The results show that all the coefficients associated with school characteristics are insignificant, and are split between positive and negative relationships. Only two and three countries for pupils of 9 and 13 years old, respectively, show coherent and significant results between achievement and the pupil-teacher ratio. Nonetheless, no country shows a positive and significant relationship between school completion and teachers education or their experience. This important finding explains the difficulty in estimating an education production function independent of the socio-economic context of the pupils studied.

3 Data and Methodology

The qualitative indicators of human capital (QIHC) can be regarded as an alternative to strictly quantitative variables of education, such as schooling rates.

The studies by Hanushek and Kimko (2000) and Lee and Barro (2001) previously undertook this kind of readjustment. It is strictly speaking a question of quantifying on a scale from 0 to 100 the quality of education, more precisely, the success rates of representative samples by various countries on international investigations into pupil assets. We take into account 7 various international tests. The data were taken from Barro and Lee (2000) for the investigations prior to 1995 and from official reports for the other investigations. Below, we present a general methodology. For complete details on the investigations used and for further information relating to our methodology, see Altinok and Murseli (2007).

The method used is based on the examination of countries which simultaneously took part in several investigations. By means of their results, we carry out a comparative anchoring of the various investigations. The database obtained is in the shape of a panel and extends from 1964 to 2005. We carry out a compilation of the whole of the investigations relating to the measurement of pupil assets at the primary and secondary levels. Two groups of tests can be distinguished: those in which the United States took part and which allow an anchoring with a specific test (test series A) and those in which the United States did not take part (test series B). For the first series of A investigations, we use an anchoring on an American investigation NAEP (National Assessment of Educational Progress) similar to that used by Hanushek and Kimko (2000). The NAEP is the principal measuring instrument of the assets of American pupils starting from 1969. The IAEP (International Assessment of Educational Progress) is the international equivalent of the NAEP. Thus, the evaluation procedure is based on the American results. At different periods since 1970, in the United States, pupils of 9, 13 and 17 years old were tested on their assets in sciences and mathematics. These tests can provide a measurement of absolute reference for the proficiency level of the United States. In order to process at the same time the data from the IEA and IAEP investigations, Hanushek and Kimko (2000) used the results of the United States as "doubloons ". They thus modified the averages of the IEA investigations in order to harmonize them with those of the NAEP which were closest (in terms of age, year and field of competence). Unlike Hanushek and Kimko, we did not correct the scores a second time for measurement errors in order to obtain indicators comparable to those obtained from the B test series,. For the B test series - those in which the United States did not take part - we carried out an anchoring of the investigations based on the results of countries which took part in at least two different investigations. In the end, we obtain 56 series of investigations for all the age groups (9, 10, 13, 14, 15 and the last year of secondary school). In order to obtain data comparable in terms of time and of corresponding educational variables, we did not take into account the test series for pupils in their last year of secondary school or the pretests, which reduced the number of investigations to 42 series. In a final stage, since certain series roughly relate to the same year and the same school level (primary or secondary), regrouping them led finally to 26 test series spread out between 1964 and 2005 and for three fields of proficiency (mathematics, sciences and reading).

In addition to the qualitative variables of education built and explained above, an entire set of educational and economic variables were used to estimate the education production function. For the data collected from 1960 to 1990, the database of Barro and Lee (1996) was mobilized. The following variables are included: primary teachers' salaries expressed as a percentage of the per capita GDP (SHSALP variable), pupil-teacher ratios at the primary and secondary levels (TEAPRI and TEASEC variables respectively for the pupil-teacher ratios at the primary and secondary levels), public expenditure on education per pupil according to the educational level expressed as a percentage of the per capita GDP (SHPUPP and SHPUPS variables, respectively for the primary and the secondary levels). Since these data are available only until 1990, we carried out an actualization with, in particular, data from UNESCO and the World Bank (see UNESCO, 2004, 2005 and World Bank, 2002). Concerning the SHSALP variable, we carried out an estimate based on the data available in UNESCO databases and then completed missing data from World Bank (2002) information. The share of teacher salaries in per capita GDP of the countries studied was calculated by dividing the total sum paid out to teachers over one year by the number of teachers during the year considered. By juxtaposing this sum with the per capita GDP, the SHSALP variable was obtained. The variables of public expenditure on education per pupil were brought up to date using data extracted from the Institute for Statistics of the UNESCO: this concerns public expenditure on education per pupil expressed as a percentage of the per capita GDP, declined according to the corresponding school level. The variable concerning the average number of school years of people aged 25 or older (variable ADEDU) was extracted from Barro and Lee (2000). As the sample of countries available in this database is rather limited, the ADEDU variable was approximated by the expectancy of years of schooling available in the UNESCO databases (see UNESCO, 2004, 2005). Indeed, these two variables are extremely dependent on a delay effect: in general, expectancy of years of schooling in young people is higher than that of adults because the first variable takes into account evolutions in the schooling of young people. Lastly, data relating to per capita GDP (variable GDPPC) were extracted from Heston et al (2002). Table 1 lists the sources of the variables used.

4 Model and empirical results

This section attempts to estimate the education production function. In the first paragraph, we carry out a general estimate. The following paragraph makes a distinction according to educational level. Lastly, we distinguish the countries according to their economic level.

4.1 Model

The education production function (EPF) was estimated on the basis of qualitative indicators of human capital (QIHC). The FPE counts indicators of input and indicators of output. Since we adopt the database of Barro and Lee (1996), we use the same variables in the estimate of EFP. We did not use the variable number of school days in the year, considering that this variable is very difficult to measure, in particular for the least developped countries.

The family factors considered are the log of real per capita GDP (GDPPC), considered here as a proxy for parental income and the log of average schooling years of adults aged 25 and over (ADEDU), variable considered as expressing the education of parents from a macro-economic point of view. Measurements of school resources included the pupil-teacher ratio in the primary and secondary levels (respectively TEAPRI, TEASEC), the log of the public educational spending per pupil expressed as a ratio of per capita GDP (SHPUPP, SHPUPS) and the share of the log of real salary per primary school teacher expressed as a ratio of per capita GDP (SHSALP). The SHSALP, SHPUPP and SHPUPS variables are not closely correlated with the income variable, because they are all expressed as multiples of the per capita GDP.

The test scores we used are available separately by subject: mathematics, science, and reading; by the age group of the students tested; and by the year of the test. Each test has a varying number of observations, depending on the number of countries that participated in the project. In our estimation, we do not use the test scores for the students in the final year of secondary education because some measures of secondary input are not present at this level.

Because the input measures are available for five-year intervals from 1960 to 1990, we matched the input measures with test scores in the nearest year for which the score is available. For instance, we refer the test score of 1964 to the input measures of 1965, the test scores of 1991 to the input measures of 1990, and so on.

The education production function, which relates the test scores to input over a broad panel of countries, can be represented as follows:

$$Q_{ijt} = \alpha_{ijt} + \beta_1 \times F_t + \beta_2 \times R_t + \varepsilon_{ijt} \qquad (2)$$

where Q_{ijt} denotes the test scores of subject i (mathematics, science, and reading) for students of age group j (9 or 10 years old on the one hand and 13 or 15 years old on the other hand) in year t (1964,1970-72, 1982-83, 1984, 1990-91, 1995, 1999, 2000, 2001, 2002, 2003); F_t indicates family factors in year t (income and schooling of parents); R_t indicates school resources (pupil-teacher ratio, education expenditure per pupil and average teacher salary) and ε_{ijt} indicates the error. All the explanatory variables except for the pupil-teacher ratio are log-linearized.

The panel is composed of a system of 26 equations, organized according to the field of competence, the school level and the year. The system is estimated by the seemingly-unrelated-regression (SUR) technique. This procedure allows for different error variances in each equation and for correlation of these errors across the equations. We include a different constant term in each equation and thereby allow for differences in the level of difficulty of each test. Estimation by a panel method would make it possible to differentiate the errors for each test series, but would suppose that they are independent. Thereafter, in order to control for the assumption of variations within countries, we carry out a fixed effects estimation. Indeed, it could be that the previous relations refer only to differences between countries. Lastly, we test the idea of endogeneity of the income variable, potentially able to skew the coefficients, by the instrumental variables method.

This panel database is not balanced because of differences in observations according to years. It contains approximately 490 directly exploitable observations with the educational input. Compared to the work of Lee and Barro which took into account only 214 observations and a very limited number of countries with intermediate and low incomes, our database takes into account a more marked heterogeneity and may thus produce results which contradict those found in previous studies.

Table 3 presents the principal results of the EPF including all skills and all the countries in the sample. We have set the coefficients to be equal in each skill and for the two educational levels (primary and secondary). This last assumption is slackened in paragraph 4.3. Below, we discuss our principal conclusions.

4.2 Empirical results of the general estimation

Family factors. The system includes two variables relating to family factors (income and education of parents). The impact of parents' incomes on the assessment results is positive and significant (coefficient 1.906; standard error 0.406). Thus, the income variable has a positive and significant effect on success in proficiency exams. The coefficient relating to parents' education is positive and significant (coefficient 5.242; standard error 0.778). This conclusion confirms that the success of a pupil is conditioned by the human capital of his/her own parents. We regard here the adults' school years as being an approximation of the parents' education, but it may also represent the teachers' qualification level.

School resources. We also introduce three factors involving school resources (teachers' salaries, educational expenditure and pupil-teacher ratio). The salary levels of teachers have a negative and significant effect on the international tests (coefficient -1.770; standard error 0.555). This finding may appear surprising, but is probably explained by the inclusion of developing country in the sample: indeed, the poorest countries (especially those of SubSaharan Africa) tend to pay their teachers better (relative to their per capita GDP) than the richest countries. This point is analyzed in paragraph 4.4. The index of educational expenditure has a positive and significant effect on the results on the international tests (coefficient 1.735; standard error 0.512).

The analysis of the impact of the pupil-teacher ratio seems to stress that the size of the class does not have a significant effect on proficiency test success. Indeed, the coefficient of the pupil-teacher ratio is negative but insignificant (coefficient -0.055; standard error 0.038). This variable is difficult to interpret in the absence of an indicator of dispersion within countries. Indeed, the analysis of international comparison carried out here assumes that class size is identical within a given country. It would be interesting in and of itself to test the variability of class size on the qualification level of the pupils, but this type of indicator is unfortunately not available. Nevertheless, we tried to determine whether the pupil-teacher ratio effect was not more quadratic than linear: the estimate in column (2) takes into account this assumption. This reveals that the pupil-teacher ratio is connected significantly when this quadratic variable is introduced: thus there seems to be a threshold beyond which the pupil-teacher ratio has a positive effect (higher than the level of 35 pupils commonly accepted). This finding may be explained by the existence of major differences in class sizes between countries: while the pupil-teacher ratio is rather low in developed countries (an average of 16 pupils in primary classes and 13 pupils in secondary classes), it is very high in countries with low incomes (an average of 42 pupils in primary classes and 26 pupils in secondary classes). Consequently, there may exist opposite effects which are underlined here by the quadratic form. We will analyze this point in paragraphs 4.3. and 4.4.

We then estimated the same model, this time introducing a variable relating to the average economic growth rate between 1960 and 2000, that is to say approximately the period covered by the QIHC database. In column (3), the introduction of this variable is positive and significant which may notably be interpreted as the assumption of a stable convergence on the part of developing countries. All things being equal, those countries experiencing strong economic growth between 1960 and 2000 boast education systems of higher quality than those in the other countries.

4.3 Fixed effects and endogenous regression techniques

The estimates referred to in Table 3 are estimates with random effects, which make it possible at error term to correlate them over time for a given country. Thus, the previous relationships may only reflect differences in ressources between large groups of countries, or between the countries themselves (between effects).

In column (1) of Table 4 we tried to control for the EPF using regional dummies. The first finding is that the fact of integrating regional dummies decreases the value of the majority of the coefficients - except for that relating to parents' economic level. However, these variables remain significant and retain the same sign. Thus, regional specificity alone does not explain the determinants of pupil performance on international tests. As shown above, the indicator relating to the economic level of the parents (measured by the logarithm of the per capita GDP) has a positive and significant sign. It should be noted that this taking into account of regional specificity makes teachers' wages insignificant. Thus, the negative relationship found in column 1 is explained in particular by regional differences. It is also to be noted that the dummy variable relating to East and South-east Asia is positive but not significant. The lack of significance of this indicator calls into question the existence of an «Asian value», referring specifically to the culture and the existing religion in these countries (Stevenson, 1992; Stevenson and al., 1993).

Column 2 shows the results of a fixed effects regression. This estimate includes dummy variables in order to capture the differences in skills and school levels. The sample covers only those countries for which we have two or more observations in the proficiency tests. Consequently, the mass of the countries which took part in only one round (that is to say very often low income countries) are not taken into account in this estimate. The sample is thus reduced to 341 observations. The taking into account of fixed effects does not change the sign of the coefficients found. Income and parental education play positively on education quality (coefficients 2.600 and 3.102 respectively). These coefficients are significant at 10% significance level In addition, educational expenditure is also correlated positively and its coefficient is significant with the threshold of 1% (coefficient 2.347). The variable relating to teacher salaries remains negative and significant with the threshold of 5% (coefficient -1.671): thus, even when controlling the model with fixed effects, this variable remains negatively correlated with the quality of education. Lastly, it should be noted that the pupil-teacher ratio is correlated positively and significantly with the test results (coefficient 0.124; standard error 0.065). This finding confirms that revealed in the preceding table, namely the existence of differences in threshold in the effect of pupil-teacher ratio on pupils' performance. When one takes into account the intra-country variations, the effect of the pupil-teacher ratio on education quality is positive. The fact that certain variables are significant only with the threshold of 10% in the estimate for fixed effects regression thus supposes that the relationships found in the previous estimates reflect at the same time variations between countries as well as intra-country effects. Nonetheless, since all these variables are of the expected sign and significant, the estimates cannot be fully explained by unobserved country factors.

It could be that the previous estimates are skewed because of the possible endogeneity of certain variables, among which that relating to income. Indeed, if a higher income can cause an increase in education quality, an increase in education quality can in turn mean an increase in income. Under this assumption of a double causal relationship, the possible endogeneity of the income variable can result in a skewing of all the coefficients in the model. In order to check the accuracy of this assumption, we turned to an estimate with instrumental variables. Given the difficulty in finding instruments in panel data, we resorted to the share of investment in the real per capita GDP (INV) and to the average annual growth rate of the population for each 5 year interval (POP), variables taken from the Penn World Tables (Heston and al., 2002). These two indicators are strongly correlated with the income variable, and it is supposed that they are not correlated with the error of the model. We introduced a series of dummies in order to control for probable differences between skills, school levels or year of the tests. Without these dummies, the Hausman test indicates the rejection of the assumption of endogeneity of the income variable (the addition of the dummies gives a similar but strongly constrained result to the coefficients of the model because of their great number). It therefore follows that the relationships found in the preceding columns do not suffer from endogeneity of the income variable. For information, we reproduced the results of this estimate in column 3. All of the coefficients are of the expected sign and the majority remain significant. The test of endogeneity of the other variables would undoubtedly have revealed new information, but for lack of available instruments, we could not test this assumption.

4.4 Distinction concerning the level of education

Table 3 allows for a distinction between school levels, but the estimate is constrained by the equality of the coefficients. The relaxation of this constraint of equality of the coefficients enables us to see whether there is a distinction in the EPF according to the school level. Table 5 presents the results obtained. The number of observations falls when the school levels are separated, but remains sufficiently large to obtain significant relationships. It will be noted that all the variables which were significant in the general model remain so when the school levels are separated

Family factors. The parents' income level has a more substantial impact at the primary education stage than at the secondary level (the coefficient is 1.972 for the primary level and only 1.308 at the secondary). On the other hand, parents' education has a decidedly higher impact (almost double) on the QIHC at the secondary level (coefficient of 3.506 for primary education, compared to 7.730 for secondary education). Thus, quality at the secondary level would seem more influenced by family factors than at the primary level.

School resources. The coefficient associated with teachers salaries shows more amplitude at the primary level than at the secondary level (coefficient of -1.855 for primary education, and -1.152 for secondary). Consequently, the quality of education at the secondary level is more an issue of organization and distribution of the resources than a simple question of the amount of expenditure. The impact of school expenditure is twice as high in primary education as in secondary (the coefficient is 2.278 for primary education but 1.035 for secondary education), which confirms the preceding finding. Lastly, it is interesting to note that the pupil-teacher ratio has an unfavourable and significant impact on the QIHC at the secondary level (coefficient -0.264; standard error 0.051), while the impact is insignificant at the primary level. Beyond the threshold effect, the insignificant relationship uncovered in the general specification may be partly explained by the aggregation of the educational levels. Once the distinction between grades is made, the pupil-teacher ratio shows a significant relationship to the quality of secondary education; however this impact must be put into perspective due to the wide variety of school organizations at the secondary level.

4.5 Distinction based on the economic level of the countries studied

In this paragraph, we separate the countries in our sample according to their level of economic wealth. This is done in order to test whether the input used in our study may have different influences according to the degree of economic development of the country. By using the World Bank classification, we separated the countries into three divisions: countries with high incomes (HIC), countries with intermediate incomes (MIC) and countries with low incomes (LIC). It is indeed interesting to ask the question whether the relationships presented in Table3 are not solely due to differences between the income levels of the different countries and not within groups of homogeneous countries Analyses including regional variables and the estimates for fixed effects made it possible to partly reject this idea. Separation according to the countries' income level may provide some indication concerning the possibility of distinct EPFs. Table 6 presents the results of the estimate. The principal observation that one can make is that there are major differences for all the coefficients, which thus testifies to the existence of a distinct EPF according to the income level of the country.

Family factors. The effect of family income, which was significant and positive in the general models, changes sign and loses its significance according to the GDP per capita level for each country. For the group of HIC, the impact is not significant, while it is negative and significant for the group of MIC. The results concerning the group of LIC show a high and positive coefficient for this variable (coefficient 6.123, standard error 2.455). One can thus note that the higher the income level of the country, the weaker the impact of the country's wealth on education quality. The variable representing parental education has a positive and significant impact in HIC and MIC. The value of the coefficients is higher for the MIC (coefficient 8.316; standard error 0.375), while it is very weak for the HIC (coefficient 1.993; standard error 0.860). The sign of the coefficients for the LIC is highly contradictory for the two data bases, since we observe a negative relationship between the education of the parents and the QIHC.

School resources. The sign of the coefficient relating to teachers' salaries is almost always negative, but it is significant only for the MIC and LIC. We note that this coefficient is all the higher in absolute value as the income level of the countries is low: the excessive wages in the least advanced countries can find here an argument relating to the need to redistribute educational expenditure in order to give priority to nonrecurring expenditure. These results underline the need to distinguish by the income level of the countries when analysing the sample: the remuneration of the LIC teachers is dispersed in the general sample, whereas inside each group of similar income countries, this dispersion is strongly reduced within each group. The analysis of the variable relating to the expenditure on education shows a positive relationship in the three specifications. It will be noted that the range of the coefficients differs according to the income level of the country: while it is weak for the HIC (coefficient 1.032; standard error 0.487), it is high for the MIC and the LIC (respectively: coefficient 3.250 and 3.108; standard error 0.728 and 1.882). The pupil-teacher ratio effect on the

QIHC also shows disparities according to the income level of the county. The impact of this variable is positive and significant for the HIC (coefficient 0.142; standard error 0.044), while it is negative and significant for the MIC (coefficient -0.280; standard error 0.056). The coefficient of this variable for the LIC is not significant although a negative relationship is observed.

5 Conclusion

The objective of this work was to build a new database of educational indicators and to check for the existence of an education production function. By using newer investigations than those used in previous analyses, we obtained a database on the qualitative indicators of human capital (QIHC). This database is shaped as a panel gathers a total of 490 observations for the QIHC from 1964 to 2005 and is directly exploitable using the school and family indicators available in Barro and Lee (1996). In addition, our sample covers more countries of intermediate and low incomes than the mass of previous samples. By carrying out estimates with the total sample first and then after separating the countries according to their income levels, we checked whether the relationships found in the estimate of the general educational production function persisted or not.

The results show that the existence of an education production function is partly demonstrated when the total sample is used: family factors (parental income and education) play a clear role in the total sample. Variables concerning educational resources (educational expenditure by pupil, teachers' salaries) also have an impact on test performance. In addition, only the variable of school organization (namely the pupil-teacher ratio) does not have an impact in the total sample. The estimate with fixed effects shows that only the variables relating to income and the pupil-teacher ratio have within country impact, the other variables showing more inter country relationships. Testing the possible endogeneity of certain variables – including those related to the income variable – induces a rejection: thus, the estimates carried out are not biased by the assumption of a double relation of causality.

Taking into account the economic level of the countries brings new information which partly explains former failures as regards the estimation of an education production function. It is shown in particular that as the economic level of the countries rises, the amplitude of the relationship between economic variables of education and test performance decreases. In addition, the impact of the pupil-teacher ratio differs according to whether one is in a country of high income or a country of median income. Indeed, while the class size effect is positive in countries with high incomes, it is negative in countries with median incomes and insignificant in countries with low incomes.

This international comparative study shows that the differences in education quality between countries are important and can be partially explained by quantitative explanatory variables. However, there remains a great deal of education quality which is not explained by these variables. Beyond the econometric and data problems, there we expect that a substantial share of education quality is determined by pedagocical activities and school organization. Of course at present we cannot effectively measure these influences in econometric estimates due to the lack of suitable variables.

In addition, the analysis of the variety of pupil assessments across international need to be studied more closely. We need to question whether this dispersion can explain the mean level and especially if this inequality is not also generated by certain inequalities such as those of income or in structural variables (geography, civil peace, transparency, etc.).

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

Indicator	Abbreviation	Period	Source
GDP per capita (in $2000 constant prices, chain series)	GDPPC	1960-2000	PWT 6.1 ; Heston, Summers and Aten (2002)
Education of parents (average schooling years of adults aged 25 years old)	ADEDU	1960-2000	BL (2000), Unesco (2004), Unesco (2005)
Pupil-teacher ratio at primary level	TEAPRI	1960-2002	BL (2000), Unesco (2004), Unesco (2005)
Pupil-teacher ratio at secondary level	TEASEC	1960-2002	BL (2000), Unesco (2004), Unesco (2005)
Public expenditure on primary education expressed as a % of GDP per capita	SHPUPP	1960-2002	BL (1996), Unesco (2006)
Public expenditure on secondary education expressed as a % of GDP per capita	SHPUPS	1960-2002	BL(1996), Unesco (2006)
Repetition rate at primary level (%)	REPPRI	1965-2002	BL (2000), Unesco (2004), Unesco (2005)
Repetition rate at secondary level (%)	REPSEC	1970-2002	BL (2000), Unesco (2004), Unesco (2005)
Teachers' salaries expressed as a % of per capita GDP	SHSALP	1960-2002	BL (2000), Unesco (2004), Unesco (2005)
Drop out rate in primary level (%)	DROP	1970-2002	BL (2000), Unesco (2004), Unesco (2005)

Note: BL = Barro and Lee, PWT = Penn World Tables.

Data source (Page 2/2)

Indicator	Abbreviation	Period	Source
School life expectancy (in years)	EXPEN	1998, 2002	Unesco (2004), Unesco (2005)
Average annual growth rate of population	POP	1960-2000	PWT 6.1. Heston, Summers and Aten (2002)
Investment share of Real GDP per capita in chain series	INV	1960-2000	PWT 6.1. Heston, Summers and Aten (2002)

Note: BL = Barro and Lee, PWT = Penn World Tables.

Table 2: **Tests of achievement used in the regressions**

Survey	Year	Field of Competence	Number of Countries	Age of pupils
IEA	1964	Mathematics	13	13, Fin. sec.
IEA	1970-72	Science	19	10,14, Fin. sec.
		Reading	15	10,14, Fin. sec.
IEA	1982-83	Mathematics	20	13, Fin. sec.
IEA	1984	Science	24	10,14, Fin. sec.
IAEP	1988	Mathematics	6	13
		Science	6	13
IEA	1991	Reading	31	9,14
IAEP	1990-91	Mathematics	20	9,13
		Science	20	9,13
IEA	1993-98	Mathematics	41	9,13, Fin. sec.
		Science	41	9,13, Fin. sec.
MLA	1992-1997	Mathematics	13	10
		Science	11	10
		Reading	11	10
LLCE	1997	Mathematics	11	10
		Reading	11	10
SACMEQ	1999	Reading	7	10
TIMSS	1999	Mathematics	38	14
		Science	38	14
PASEC	1995-2005	Mathematics	11	9,10
		Reading	11	9,10
PISA	2000	Mathematics	43	15
		Science	43	15
		Reading	43	15
PIRLS	2001	Reading	35	9,10
SACMEQ	2002	Mathematics	14	10
		Reading	13	10
TIMSS	2003	Mathematics	26,48	10,14
		Science	26,48	10,14
PISA	2003	Mathematics	41	15
		Science	41	15
		Reading	41	15

Note : Fin. Sec means Final Secondary.
For more detail concerning surveys, see text.

Table 3: **General Estimations of the Education Production Function**

	(1)	(2)	(3)
Regression	Panel SUR	Panel SUR	Panel SUR
Sampling	Full	Full	Full
Independent variable	QIHC	QIHC	QIHC
Number of equations	26	26	26
GDP per capita	1.906***	1.617***	2.742***
	(0.406)	(0.387)	(0.446)
Education of Parents	5.242***	5.905****	4.417***
	(0.778)	(0.741)	(0.765)
Salary of Teachers	-1.770***	-1.117**	-1.317**
	(0.555)	(0.55)	(0.493)
Education expenditures	1.735***	0.100*	1.317***
	(0.512)	(0.534)	(0.493)
Pupil-teacher ratio	-0.055	-0.355***	0.003
	(0.038)	(0.085)	(0.038)
Sq. of Pupil-teacher ratio		0.005***	
		(0.001)	
Av. annual growth rate			0.740***
			(0.185)
Constants			
Mathematics	27.532***	31.103***	16.672***
	(4.059)	(4.348)	(4.453)
Science	23.382***	27.097***	12.183***
	(5.93)	(3.922)	(4.403)
Reading	22.168***	25.686***	11.595***
	(5.83)	(3.752)	(4.257)
Rsq	–	–	–
Observations	490	490	449

Note : Due to the presence of 26 equations, Rsq. are not shown.
All explanatory variables except the last three variables are logged.
We present only the averages of constants by subject.
* 10 ** 5 *** 1 percent of significance level.

Table 4: **Fixed-effects and IV estimations**

	(1)	(2)	(3)
Regression	SUR	Fixed-Effect	IV technique
Sampling	Full	Full	Full
Independent variable	QIHC	QIHC	QIHC
Number of equations	26	1	1
GDP per capita	2.662***	2.600**	4.578**
	(0.478)	(1.359)	(2.106)
Education of parents	3.186***	3.102*	5.087**
	(0.789)	(1.831)	(2.299)
Salary of teachers	-0.555	-1.671**	-0.566
	(0.555)	(0.810)	(0.856)
Education expenditures	1.350***	2.347***	1.757**
	(0.524)	(0.663)	(0.701)
Pupil-teacher ratio	-0.013	0.124*	0.143
	(0.038)	(0.065)	(0.091)
Sq. of Pupil-teacher ratio	-4.469***		
	(1.394)		
SubSaharan Africa	-4.469***		
	(1.394)		
East and South-east Asia	0.732		
	(0.749)		
Eastern Europe and Central Asia	3.264***		
	(0.735)		
Latin America	-3.203***		
	(0.764)		
Middle East and North Africa	-3.458***		
	(0.862)		
Constant		-3.517***	-23.67***
Mathematics	18.967***	(12.017)	(18.678)
	(4.966)		
Sciences	14.425***		
	(4.907)		
Reading	13.715***		
	(4.783)		
Tests dummies	No	Yes	Yes
Country dummies	No	Yes	No
R sq.	–	0.86	0.67
Hausman Chi Sq.			6.93***
			(0.22)
Observations	490	341	339

Note : Due to the presence of 26 equations, Rsq. are not shown.
All explanatory variables except pupil-teacher ratio and dummies are logged.
For column (1), we present only the averages of constants by subject.
* 10 ** 5 *** 1 percent of significance level.

Table 5: **Regression with distinction according to education level**

	(1)	(2)	(3)
Regression	Panel SUR	Panel SUR	Panel SUR
Sampling	Full	Primary level	Secondary level
Independent variable	QIHC	QIHC	QIHC
Number of equations	26	11	15
GDP per capita	1.906***	1.972***	1.308***
	(0.406)	(0.682)	(0.421)
Education of parents	5.242***	3.506***	7.730***
	(0.778)	(1.028)	(0.827)
Salary of teachers	-1.770***	-1.855*	-1.152**
	(0.555)	(1.059)	(0.584)
Education expenditures	1.735***	2.278**	1.035*
	(0.512)	(0.930)	(0.615)
Pupil-teacher ratio	-0.055	-0.006	-0.264***
	(0.038)	(0.060)	(0.051)
Constant			
Mathematics	27.532***	23.679***	32.307***
	(4.059)	(6.585)	(4.139)
Sciences	23.382***	20.980***	28.996***
	(5.930)	(6.709)	(3.940)
Reading	22.168***	16.555***	29.278***
	(5.830)	(6.510)	(3.755)
Observations	490	189	301

Note : due to the presence of 26 equations, Rsq. are not shown.
All explanatory variables except pupil-teacher ratio are logged.
We present only the averages of constants by subject.
* 10 ** 5 *** 1 percent of significance level.

Table 6: **Regression with distinction according to economic level of countries**

	(1)	(2)	(3)
Regression	Panel SUR	Panel SUR	Panel SUR
Sampling	HIC	MIC	LIC
Independent variable	QIHC	QIHC	QIHC
Number of equations	25	13	5
GDP per capita	-0.392	-0.888	6.123***
	(0.934)	(0.342)	(0.545)
Education of Parents	1.993**	8.316****	-2.386***
	(0.860)	(0.375)	(0.545)
Salary of Teachers	0.195	-2.705***	-13.281***
	(0.545)	(0.619)	(2.181)
Education expenditures	1.032**	3.250***	3.108*
	(0.487)	(0.728)	(1.882)
Pupil-teacher ratio	0.142	-0.280***	-0.046
	(0.044)	(0.056)	(0.058)
Constants			
Mathematics	44.905***	52.532***	72.604***
	(9.120)	(4.362)	(21.997)
Sciences	41.361***	46.091***	66.346***
	(9.129)	(4.046)	(22.182)
Reading	42.177***	45.713***	76.334***
	(9.106)	(3.649)	(22.182)
Rsq	–	–	–
Observations	260	150	41

Note : Due to the presence of several equations, Rsq. are not shown.
All explanatory variables except the last variable are logged.
* 10 ** 5 *** 1 percent of significance level.