HUMAN CAPITAL AND GROWTH IN OECD COUNTRIES: THE ROLE OF PUBLIC EXPENDITURE ON EDUCATION

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1. Introduction

The argument that a knowledge-based economy with a high capacity to innovate necessitates a highly skilled labour force is very appealing and often brought up today, as is the recommendation to some governments that they should increase spending on education. Indeed, most governments have traditionally been heavily involved in the formation of human capital. Total expenditure on educational institutions expressed as a percentage of the collective GDP of the 29 OECD countries amounts to almost 6% each year. On average, public funding accounts for 90% of these educational expenditure.

Recent empirical estimations of growth equations have all included a variable measuring the accumulated stock of human capital. The underlying idea is that the stock of human capital affects subsequent growth by influencing a country's ability to adopt new technologies. Most empirical research of this kind has confirmed the existence of a positive relationship between the initial stock of human capital and subsequent growth. However, the results are often derived from samples that are dominated by developing countries. The same conclusions do not necessarily hold for the sub-sample of OECD countries, see for example Englander and Gurney (1994).

A shortcoming common to most empirical work on human capital and growth is that the quality of human capital is insufficiently accounted for. Resources devoted to education and the organisation of educational systems both differ across countries and these differences have an impact on the quality of human capital (Hanushek and Kim, 1995; Lee and Barro, 2001). Several variables have been suggested to measure various qualitative aspects of educational systems, such as public expenditure on education, pupil-teacher ratios or the distribution of educational attainment

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(Dessus, 2000). Such variables should be included in cross-country growth regressions to control for differences in the quality of human capital.

The purpose of this paper is twofold. On the one hand, it aims to reassess the relationship between the stock of human capital and economic growth in the long run. On the other hand, it aims to find out whether differences resources allocated to education contribute to cross-country differences in economic growth. Panel data regressions will be applied to a sample consisting of 20 OECD countries, covering the period from 1970 to 2000. Concentrating on OECD countries only offers the advantage that policy conclusions with direct relevance to the OECD can be drawn. In addition, improved data for OECD countries on the educational attainment of the adult population have been constructed by de la Fuente and Domenech (2000) and by Bassanini and Scarpetta (2001), whereas data on the physical capital stock can be found in the OECD economic outlook database.

2. The role of human capital in growth models

2.1 Review of the literature

How does human capital or the educational attainment of the labour force affect the growth of an economy? One approach is to treat human capital as an ordinary input in the production function. The seminal work of Mankiw, Romer and Weil (1992) is in this tradition. They augmented the neo-classical Solow model by adding human capital as a production factor and showed that the model could be made more consistent with cross country data this way. The augmented Solow model succeeded in explaining 80% of the cross-country variability in per capita income. However, it was not able to account for much of the observed cross-country variation in income per capita when restricting the sample to OECD countries.

Recent empirical research which continues to build on the Mankiw-Romer-Weil model has used panel data approaches instead of cross-country regressions and improved measures of the educational attainment of the adult population. Panel data approaches allow for the inclusion of country-specific effects that reflect technological and institutional differences between countries (Islam, 1995; Hill and Jones, 1997). Recent papers following this approach tend to point to a positive relationship between human capital and per capita GDP growth (Dessus, 2000; Bassanini and Scarpetta, 2001; Andrés, Doménech and Molinas, 1996), although the coefficient may not be very stable (Andrés, Doménech and Molinas, 1996). In contrast, the coefficient turned out to be negative in Islam (1996). The only paper of the four mentioned above with an application to OECD countries was Bassanini and Scarpetta (2001).

An alternative approach associated with endogenous growth theory, is to model technological progress or the growth of total factor productivity as a function of the stock of human capital. According to this approach, the level of human capital directly affects total factor productivity through two channels. Romer (1990) postulated that human capital may directly influence total factor productivity by enhancing the capacity of nations to innovate with respect to new technologies and products. In addition, Nelson and Phelps (1966) developed a model in which human capital affected the speed of technological catch-up and diffusion. In other words, the ability to adopt and implement new technology from abroad is a function of the stock of human capital. Combining the insights provided by these models implies that growth rates may differ across countries for a long time due to differences in levels of human capital stocks (Benhabib and Spiegel, 1994). Moreover, it predicts that the country with the highest stock of human capital will always eventually emerge as the technological leader nation and maintain its leadership as long as its human capital advantage is maintained.

There may also be positive externalities from human capital. Where the average level of human capital is high, the incidence of learning from others will be higher, and it is likely that there are greater productivity gains to be derived from exchanging ideas (Lucas, 1988). Human capital also tends to flow to countries that already have large amounts of such capital (the ‘brain drain’), raising the level of human capital and hence the level of output.

Several empirical studies have found that the educational attainment of the adult population or labour force contributes positively and significantly to subsequent economic growth (Barro, 1991; Easterly and Rebelo, 1993; Levine and Renelt, 1992; Benhabib and Spiegel, 1994). However, these results are based on samples dominated by developing countries and it is not clear that these results are applicable to OECD countries. In an interesting exercise, Englander and Gurney (1994) re-estimated growth equations based on four influential papers including Barro (1991), but restricting the sample to the OECD. Three of the four equations included variables for human capital, typically primary and secondary school enrolment rates. These variables turned out to have some explanatory power, but their estimates were not robust.

2.2 The measurement of human capital

Earlier studies by Mankiw, Romer and Well (1992) and Barro (1991) used a proxy for human capital defined as the secondary school enrolment rate multiplied by the fraction of the working age population that is of school age (they used the age group 15-19). This variable alone is likely to underestimate the true variation across OECD countries in the educational achievements of the working age population as it ignores primary and most importantly tertiary education. Moreover, changes in enrolment rates are likely to have an impact on GDP per capita and labour productivity growth only with a long time lag. Due to relatively short time series, there are limits to the number of lags that can be included in any regression model. Finally, measures of educational achievements based on enrolment rates are sensitive to the problem of reverse causality. The causality may indeed run from GDP per capita to enrolment, with an increase in per capita GDP prompting an increase in school enrolment in response to the higher returns on schooling produced by economic growth.

Barro and Lee (1993, 1996) have constructed an alternative set of estimates of the educational attainment of the adult population for 129 countries, covering the period 1960-85 at five-year intervals. They estimated the average years of schooling of the population of working age (25-64) using census data on school attainment from individual governments, as compiled by UNESCO and other sources. Adults can be classified into seven different groups according to their highest level of attainment:

(1) no formal education,

(2) incomplete primary education,

(3) complete primary education,

(4) first cycle of secondary education,

(5) second cycle of secondary education,

(6) incomplete higher education, and

(7) complete higher education. Information by country about the typical duration of each level of schooling then allowed them to compute the

number of years of attainment achieved by the average person in each country. To estimate attainment levels for years in which census data are not available, they applied a perpetual inventory method which makes use of gross enrolment ratios at various levels of schooling and the age composition the population. The basic idea is that the enrolled population is the flow that adds over time to the prior human capital stock to determine the subsequent stock.

This dataset has subsequently been revised and updated by De la Fuente and Domenech (2000) and Basemen and Scarpetta (2001) for OECD countries only. The contributions of the former paper consisted in using previously unexploited resources to estimate net enrolment rates and in removing sharp breaks in the data series that seem to reflect changes in classification criteria. The authors thus significantly improved the quality of the data contained in Barro and Lee for the OECD countries. The latter paper constructed a series of annual data on the average years of schooling of the adult population of age 15 to 64 for 21 OECD countries covering the period 1971-1998, which will be used in this paper.

Data on the average years of schooling of the adult population are better suited to investigate the effects of schooling, and have been widely used in empirical work since the mid 1990s. In addition, as pointed out by Temple (2000), the problem of reverse causality is less severe when using the average years of schooling of the working age population instead of enrolments rates as a measure of the human capital stock.

However, the measure also has its shortcomings. First of all, institutional aspects such as the hours spent in school each day, the length of educational cycles or the mandatory age until which young people have to attend school differ between countries and are likely to affect the average number of years that an adult has spent in school with no significant impact on the skills of a worker. Secondly, not all fields of education / specialisation contribute equally to the skill formation needed to facilitate the adoption or innovation of new technologies, yet they receive the same weight in the computation. Finally, the measure does not account for adult training and lifelong learning, although it is widely recognised that these types of learning are increasingly important in an environment of rapid technological progress.

More innovative research has attempted to measure the quality of the adult population more directly by using a country's average score on international mathematics and science tests taken at the 4th and 8th grade

(Hanushek and Kim, 1995). Their results support the idea that education has an important effect on growth. This approach will not be followed in this paper, but it would be worthwhile to examine the robustness of their results in a sample restricted to OECD members in future research.

2.3 Methodology

This paper uses a standard growth accounting framework with a constant returns production function which does not include human capital as a separate input. The production function is written in intensive form and in first differences:

$$\Delta(q_{it}) = \Gamma_0 + (1-\alpha)\Delta(a_{it}) + \alpha\Delta(k_{it}) + \eta_t + \mu_i + \epsilon_{it} \quad (1)$$

where $q_{i\,t}$ is output per worker in country i at time t, k the stock of physical capital employed by the business sector per worker, and a the Solow residual per worker. Note that the measure of the physical capital stock does not include the public capital stock (infrastructure, public buildings...) or the residential capital stock. Data on the business capital stock, total employment and gross domestic product are all taken from the OECD Economic Outlook database. All monetary variables are expressed at constant prices of 1995 using the appropriate deflator, and converted into dollars using 1995 purchasing power parities. Dummy variables are added to capture fixed time (η_t) and country (μ_i) effects. Time dummies are included to control for temporal shocks that may be responsible for productivity slowdowns or accelerations and that are common to most OECD countries. Country dummies pick up permanent cross-country differences in productivity levels that presumably reflect differences in R&D investment and other omitted variables.

In the simplest possible specification as suggested by the endogenous growth theory, the change in the Solow residual depends on the stock of human capital per worker, $h_{i\,t}$:

$$\Delta(a_{it}) = g(h_{it})$$

More in particular, countries with higher levels of human capital per worker will experience faster technological progress. This is so because human capital enhances the ability to innovate. The average level of human capital per worker is proxied in this paper by the average years of schooling of the adult population aged 15 and over at the beginning of each period. Assuming that technological progress is a logarithmic function of human capital, equation (1) can be written as:

$$\Delta(q_{it}) = \Gamma_0 + \beta\log(h_{i\ t-1}) + \alpha\Delta(k_{it}) + \eta_t + \mu_i + \epsilon_{it} \qquad (2)$$

However, as can be seen from Table 1, countries with a highly educated adult population need not always be the high growth countries. In fact, countries where the average years of schooling of the adult population was already high in 1971 (USA, Canada, Australia, Switzerland and New Zealand) grow on average considerably slower during the period 1971-2000 than countries with a lower initial average educational attainment of the adult population (Ireland Finland, Spain and Japan). This can be explained by the catch-up factor which causes laggards to grow faster than leaders during a transitional period of time. This effect has been strengthened by the process of EU enlargement, the creation of the single European market, and closer integration of OECD economies. Based on the work of Nelson and Phelps (1966), Bils and Klenow suggest that the growth rate of technology for a country i may be written as:

$$\Delta(a_{it}) = \beta\log(h_{it}) - \gamma\log(q_{i\ t-1}/q_{US\ t-1})$$

and interpreted as follows: the growth rate of technological progress will be higher the larger the productivity gap with the highest productivity country (the US in this sample). In addition, countries will bridge the productivity gap more rapidly when they are rich in human capital. This results in an alternative specification of the growth regression (2):

$$\Delta(q_{it}) = \Gamma_0 + \beta\log(h_{i\ t-1}) + \alpha\Delta(k_{it}) + \gamma\log(q_{i\ t-1}/q_{US\ t-1}) + \eta_t + \mu_i + \epsilon_{it} \qquad (3)$$

The paper uses pooled data at 5 year intervals starting in 1971 and ending in 2000. The appropriate length of the time span is of course subject to some debate. Time spans of just one year are technically feasible, but often deemed too short for studying growth behaviour as short term disturbances may loom too large (a possible alternative may be to use annual data based on trend measures). Time spans longer than 5 years may be superior though not feasible given the lack of long time series. As a result, most studies have opted for 5 year intervals.

2.4 Results

Panel estimates (pooled OLS with time-specific effects and country specific effects) are provided in Table 2 for the two specifications of the model. In a first specification, the catch-up effect is solely determined by the initial level of human capital at the beginning of each 5 years period. In a second specification, relative productivity levels (GDP per worker) relative to those in the US at the beginning of each period are added to better capture the catch-up effect. Earlier empirical research (Barro, 1991; Benhabib and Spiegel, 1994) had found a positive effect for human capital, at least when initial productivity levels were also controlled for.

The coefficient on the initial level of human capital per adult worker comes out to be negative and significant in both specifications, and more strongly when initial relative productivity levels are not controlled for. This result is not very surprising. Given that the initial level of human capital is correlated with the initial productivity level, the former picks up the catch-up effect with its predicted negative sign when the latter is not included in the growth regression. Adding initial productivity levels to the model attenuates the negative effect somewhat, but does not lead to a sign reversal.

It needs to be pointed out that previous studies were based on cross-section regressions – that is one observation per country for the entire period – and samples that included developing countries. When the regressions were re-estimated for the smaller sample of OECD countries only, the coefficient on human capital became insignificant (Englander and Gurney, 1994; Benhabib and Spiegel, 1994). However, a recent study by Domenech and De La Fuente pointed to a positive role for human capital in growth regressions after the existing data had been meticulously revised; in particular the growth in the average years of schooling per adult contributed positively to GDP per worker growth.

It is also a common finding that, when researchers attempt to incorporate the temporal dimension of human capital variables into growth regressions, the coefficient on human capital becomes either insignificant or strongly negative (Islam, 1996). In our sample of OECD countries, some countries experienced rapid growth in their transition to EU membership (Ireland, Spain, Finland, and to a lesser extent Sweden) or during their earlier stages of industrialisation (Japan, most European countries during the 70s). These growth rates gradually fell back to a lower level until a turning point was reached in the early or mid 90s. At the same time, the educational attainment of the adult population continued to rise as young people invested more in education (possibly in anticipation of higher returns). Since panel data methods rely more on within country variation, this negative temporal relationship surfaces more forcefully in panel

Table 1

Average growth of GDP per worker, years of schooling and resources devoted to education

	1971-2000 Average growth of GDP per worker (percentage)	1971 Average years of schooling	1970-1995 Average public education expenditure (percentage of GDP)	1970-1995 Average public education expenditure corrected for demographic patterns (percentage of GDP)	1970-1995 Average expenditure per student for all levels of education (percentage of GDP per capita)	1970-1995 Average ratio of students to teachers for primary education
Australia	1.6	11.1	5.4	4.9	24.2	20.3
Austria	2.4	9.8	6.2	6.7	29.7	15.0
Belgium	2.3	8.3	6.0	6.6	25.4	16.3
Canada	1.1	11.4	7.7	7.0	28.3	17.3
Denmark	1.6	9.9	7.4	8.1	36.1	12.2
Finland	2.6	8.7	6.6	6.9	30.8	17.4
France	2.0	9.0	5.5	5.6	22.3	20.0
Greece	2.0	7.5	2.5	2.6	13.2	n.a.
Ireland	3.6	8.0	6.5	5.3	24.0	28.5
Italy	2.2	6.8	5.0	5.3	26.2	15.7
Japan	2.5	9.6	5.3	5.5	24.9	23.5
Netherlands	1.6	9.1	6.4	6.4	26.5	22.2
New Zealand	1.0	10.3	5.9	5.1	21.4	20.3
Norway	2.4	9.9	7.1	7.4	32.8	15.5
Spain	2.5	5.8	2.9	2.9	11.9	28.3
Sweden	1.7	9.2	7.6	8.7	38.6	14.3
Switzerland	0.7	10.6	4.8	5.5	25.8	n.a.
United Kingdom	1.9	9.2	6.1	6.4	29.8	21.0
United States	1.4	11.6	6.7	6.2	25.9	15.0

Sources: UNESCO, OECD.

Table 2

The impact of human capital on growth

Dependent variable: Growth of real GDP per worker

	(a)	(b)
Growth rate of business sector capital stock	0.288*** (5.86)	0.248*** (4.89)
Log of initial human capital stock	–0.44*** (3.28)	–0.302** (2.12)
Initial GDP per worker relative to US		–0.207** (2.45)
Time fixed effects	Yes	Yes
Country fixed effects	Yes	Yes
R^2	0.625	0.646

Note: t-values in parentheses.
* significant at 10%, ** significant at 5%, *** significant at 1%.

estimates. Moreover, in this case, the negative temporal relationship is strong enough to outweigh the positive cross-sectional relationships found in earlier studies. Some recent studies (Dessus, 2000) have used a varying parameter method instead, with better results.

There are probably some other factors biasing the temporal relationship between human capital and economic growth. For example, the average educational attainment of the adult population (aged 15-64) is likely to understate the average educational attainment of the workforce because low educated workers are less likely to participate in the labour market. In some OECD countries; skill-based employment growth has been particularly strong, causing older and generally less educated workers to be pushed out before the age of 64 by younger and better educated ones.

More importantly, the measure used does not account for the quality of education. Quality differences are likely to be important though, because school systems are known to vary widely across countries in terms of management, organisation, resources provided and the preparation of students coming to school. It often happens that fast growing countries witness rapid increases in the educational attainment of the workforce, but that increased enrolment rates are not matched by an equally large expansion of school resources. In this case, quantitative improvements are achieved at the expense of quality, and the growth of the human capital stock is overstated when looking exclusively at the average years of schooling. In contrast, some mature economies where the educational attainment of the adult population is already high may further expand their human capital stock mainly by upgrading the quality of education. It may therefore be useful to employ a richer specifications of the growth regression with respect to human capital, including quantitative as well as qualitative measures. This will be discussed in a next point.

3. The role of public expenditure on education

3.1 The quality of human capital: the role of public expenditure on education

In the richest possible specification, the stock of human capital would be modelled as a function of the quantity of schooling, the school resources, family background and other socio-economic factors, and ability. This paper is less ambitious and will focus on a subset of variables contributing to the performance of school systems. These include the resources invested in education, the organisational structure of the education system (such as the length of the school year, the use of computers in school, opportunities to combine with apprenticeships) and the regulation of education. Financial resources are mainly provided by the public sector, although private funding plays an increasing role in a number of countries (US, Japan, Australia) at the tertiary level. Given the lack of internationally comparable quantitative indicators of several aspects of education quality (such as the organisation and regulation of an education system), indicators on public funding allocated to education will be used as a proxy for education quality in this paper.

Expenditure on education consists of capital expenditure (less than 10% on average in OECD countries) and current expenditure (more than 90% on average in OECD countries). Current expenditure are dominated by teachers' salaries. The higher a teacher's salary is relative to average earnings, the easier it becomes to attract better qualified and more productive teachers. The relationship between expenditure on education and the quality of the future labour force is therefore expected to be positive.

Public expenditure on education expressed as a fraction of GDP is commonly used as an indicator to compare how much of their wealth different countries invest in education. However, this indicator needs to be interpreted in the light of a number of inter-related supply and demand factors, including

(1) the demographic structure of the population,

(2) the enrolment rates at different levels of education,

(3) per capita income,

(4) the length of educational programs,

(5) the national price level for educational resources.

Moreover, the indicator may obscure decisions about the allocation of funds which influence the quality of instruction such as relative expenditure on teachers' salaries which depends on the generosity of compensation and pupil-teacher ratios, or the conditions of educational facilities. Another allocative decision is related to the division of resources between pre-primary, primary, secondary and tertiary education.

This paper attempted to correct the above indicator for demographic differences between countries. First, the fraction of young persons of school age (age groups 0 to 25) in the total population is computed for each country and period, and then the average is taken for all countries and time periods pooled together. Next, the share of GDP devoted to education for each country and time period is multiplied by the average fraction of people of school age in the total population and divided by the corresponding fraction for the country and time period. This results in an indicator that measures how much of its wealth each country would devote to education if the relative size of the population of school age did not vary with time and/or between countries. Whereas public spending on education, expressed as a fraction of GDP, tends to decrease over time, this declining trend is weakened or over reversed after demographic structures have been accounted for.

Expenditure per student at 1995 constant prices and expressed in equivalent US dollars is an indicator which is corrected for both differences in the relative size of the population of school age and enrolment rates. This amount can be thought of as the weighted average of the amounts spent per student at the different levels of education, with the weights given by the corresponding fraction of students enrolled at that level. This implies that the measure is pushed upwards in countries where a large fraction of students participates in tertiary education (due to broad accessibility to and a high demand for tertiary education) because the cost per student increases with the level of education (see OECD Education at a Glance, various issues). Given that teachers' salaries tend to increase with per capita income, a better indicator of the importance attached to a young person's education can be obtained by dividing the average amount spent per student by per capita income.

It would be misleading to equate lower expenditure per student in general with lower quality of education because the efficiency with which education is provided also needs to be accounted for. In fact, average spending per student can be further decomposed into the average amount spent per teacher (= teachers' salaries) and the number of teachers relative to the number of students. The reverse of the latter, that is the ratio of students to teachers at a specific level of education has also been used as an indicator of quality. It needs to be pointed out that student-teacher ratios do not translate directly into class size because the relationship is complicated by many factors that vary between countries: the length of a school year, the number of hours for which a student attends class each day, the length of a teacher's working day, and many more. Still, student-teacher ratios are a good approximation of class size, especially at the primary level. The student-teacher ratio is expected to be negatively correlated with schooling quality because students can learn more rapidly by having more frequent interactions with teachers in smaller classes.

There has been a tendency in most OECD countries for the student-teacher ratio in primary education (no data available on secondary education) to drop over time until the beginning of the 90s. However, this decline may merely reflect a lag in the response of educational systems to demographic changes, adding little to the quality of education.

3.2 Alternative specifications of the model corrected for the quality of human capital

A first specification consists of correcting human capital measured by the quantity of schooling by an index of quality. For Islam (1995), the negative correlation between human capital and growth could be the consequence of a measurement error, caused by excluding the quality of education from the measure for human capital. One solution may be to multiply the average years of schooling (h) by an indicator of quality:

$$H_{it} = h^{\omega}_{it}\, I^{\upsilon}_{it}$$

which results in the following specification of the growth equation:

$$\Delta(q_{it}) = \Gamma_0 + \beta\omega\log(h_{i\,t-1}) + \beta\omega\log(I_{i\,t-1}) + \alpha\Delta(k_{it}) + \\ + \gamma \log(q_{i\,t-1}/q_{US\,t-1}) + \eta_t + \mu_i + \epsilon_{it} \qquad (4)$$

The quality index must contain temporal information, otherwise it cannot be distinguished from other country specific effects. This condition seriously limits the available number of variables able to capture international differences in the quality of schooling. Four indicators were retained for this purpose:

(1) the share of public education expenditure in GDP,

(2) the share of public education expenditure in GDP corrected for variations in the relative size of the population of school age over time and between countries,

(3) average public expenditure per student relative to per capita income,

(4) pupil-teacher ratio in primary education.

Data on public expenditure on education, number of students and number of teachers were taken from the UNESCO database which goes back to 1970. Where possible, these indicators were measured as the average of the 5 years preceding the beginning of each period. For each country, spending on education was converted in constant prices of 1995 using the deflator of government consumption and subsequently converted into $ using purchasing power parities. Due to the German reunification in 1991, no long series were available for Germany so this country had to be omitted. Data on the deflator of government consumption, purchasing power parities, and GDP are obtained from the OECD economic outlook database, whereas information on the size of the population and the composition thereof were taken from the UN demographic database.

One weakness of the quality indicators is that they are related to persons in school, which will be added to the future human capital stock. They are therefore at best a proxy of the quality of the current human capital stock. A larger lag for the quality indicators may seem advisable, but needs to be balanced against the resulting loss of observations. Given the current paucity of data, no additional lags were introduced.

An alternative is to argue that the contribution of educational systems lies in their capacity to produce one marginal unit of productive human capital. A country's ability to produce one marginal unit of human capital depends on the quantity of schooling at the beginning of each period as well as on the resources of a country invested in education. In other words, the contribution of a given educational attainment of the adult population towards growth will be larger the more a country invests in education. One way to test this hypothesis is to estimate a model in which the coefficient expressing the contribution of human capital to growth could be assumed to be increasing in the quality of education, as expressed by the various indicators mentioned above. This amounts to transforming the growth equation (3) as follows:

$$\Delta(q_{it}) = \Gamma_0 + \beta\log(h_{i\,t-1}) + \alpha\Delta(k_{it}) + \gamma\log(q_{i\,t-1}/q_{US\,t-1}) + \eta_t + \mu_i + \epsilon_{it} \qquad (5)$$

where: $\beta = \psi + \Phi Z_i + u_i$

The variable Z is invariant in time, otherwise no degrees of freedom would be available (Dessus, 2000). The same indicators are used, but the difference with the previous specification is that the average measure of the indicator over the entire period for each country is used. It is true that the indicators of education quality vary with time in each country, fluctuating counter-cyclically in the short run and reflecting changes in educational policies, demographic structure and enrolment patterns among others. However, there also appears to be a country-specific element here: some countries exhibit a stronger preference for education than others. The averages of each indicator over the entire period for each country are shown in Table 1. The countries with the lowest GDP per capita (Spain and Greece) allocate a significant lower fraction of their GDP or GDP per capita to education. In contrast, the Scandinavian countries have a strong preference for public spending on education.

Equation (5) can be measured by replacing β with the expression $\psi + \Phi Z$. Other empirical research has indicated that heteroscedasticity may arise in such specifications, therefore the White heteroscedasticity-consistent estimator will be used in this case.

3.3 Results

When the various indicators of investment in education are added in multiplicative form (Table 3), the estimations yield no significant results for three of the four indicators. Note that the coefficient of human capital has become insignificant as well in each of the specifications. These findings are consistent with those of Dessus (2000), who also found that the multiplicative specification didn't perform well. However, when public expenditure on education per student as a fraction of GDP per capita is used as an indicator of the quality of education, does a negative and significant coefficient appear. This result is counter-intuitive at first, but appears to be the result of multicollinearity. In particular, countries with low initial productivity levels relative to the US, are also countries with a low initial human capital stock in terms of both quantity and quality of schooling, while at the same time experiencing more rapid growth in the process of catching up with the richer OECD countries.

The alternative specification (Table 4) performs better. Although the coefficient on human capital becomes more significantly negative, the estimated coefficient of the interaction term involving human capital and a measure of the quality of education is positive and significant at the 1% level in the following three cases:

(1) when public expenditure on education relative to GDP is included,

(2) when the same indicator is used after correction for demographic structures,

(3) when expenditure per student relative to GDP per capita is included.

A percentage increase in the average years of schooling can be expected to have a positive effect on productivity growth if a country spends on average at least 5% of its GDP on education, or at least 6.4% of its GDP after differences in demographic patterns have been accounted for. Likewise, an increase in the quantity of schooling will raise productivity growth when expenditure per student expressed as a fraction of GDP per capita amounts to 30% or more on average. In contrast, the pupil-teacher ratio, though having the predicted sign, does not contribute to the explanation of productivity growth differences between countries.

Table 3

The impact of expenditure on education: first specification

Dependent variable: Growth in real GDP per worker

	(a)	(b)	(c)	(d)
Growth rate of business sector capital stock	0.224** (4.33)	0.218** (4.18)	0.206** (2.78)	0.214** (3.97)
Log of initial human capital	–0.164 0.98)	–0.138 –0.8	–0.063 (0.34)	–0.15 (0.88)
Initial GDP per worker relative to US	–0.255*** (2.78)	–0.271*** (2.89)	–0.358*** (3.31)	–0.323*** (3.06)
Public education expenditure	–0.035 (1.18)			
corrected for demographic		–0.042 (1.34)		
Expenditure per student for all levels of education			–0.008 (0.22)	
Ratio of students to teachers for primary education				–0.053 (1.67)
Time specific effects	Yes	Yes	Yes	Yes
Country specific effects	Yes	Yes	Yes	Yes
R^2	0.645	0.647	0.65	0.66

Note: t-values in parentheses.
 * significant at 10%, ** significant at 5%, *** significant at 1%.

Table 4

The impact of expenditure on education: first specification

Dependent variable: Growth in real GDP per worker

	(a)	(b)	(c)	(d)
Growth rate of business sector capital stock	0.240***	0.235***	0.229***	0.206***
	(4.97)	(4.75)	(4.64)	(3.74)
Log of initial human capital stock	–0.596***	–0.529***	–0.545***	0.524***
	(3.40)	(2.93)	(2.94)	(2.62)
Initial GDP per worker relative to US	–0.290***	–0.258***	–0.251***	–0.254***
	(3.44)	(2.99)	(2.93)	(2.85)
Interaction term with different indicators of resources invested in education				
Average public education expenditure	0.119***			
	(3.62)			
Average public education expenditure corrected for demographic patterns		0.083***		
		(2.83)		
Average expenditure per student for all levels of education			0.018	
			(2.79)	
Average ratio of students to teachers for primary education				–0.007
				(0.78)
Time dummies	Yes	Yes	Yes	Yes
Country dummies	Yes	Yes	Yes	Yes
R^2	0.69	0.674	0.673	0.673

Note: t-values in parentheses.
* significant at 10%, ** significant at 5%, *** significant at 1%.

The above results suggest that countries with a relatively young population can expect more rapid productivity growth, as they experience a larger inflow of young, and generally better qualified, persons into the labour force. In addition, the results are a first indication that traditions regarding spending on education may help explain differences in the countries' abilities to produce one productive unit of productive human capital. It does not appear advisable to raise spending per student by lowering the number of students per teacher (in primary education) though. So the positive effect may be attributable to one or more of the following factors:

(1) high student enrolment, in particular in tertiary education,

(2) generous teachers' compensation which may help in attracting qualified teachers,

(3) high spending on items other than teachers' salaries which may be an asset in a rapidly changing society, in particular at higher levels of education.

Finally, the robustness of the outcomes was tested by running the same regressions on a sub-sample of countries. It turned out that the significance of the coefficients reflecting the average quality of education in the second specification were sensitive to the omission of the lowest income countries (Spain and Greece). It therefore appears that systematic differences between countries in the amounts invested in education do not explain productivity growth differences between the richest OECD countries.

4. Conclusions

The relationship between school resources, education quality and productivity growth is controversial. Hanushek and Kim (1995) concluded that the quality of education, measured by students average performance on standardized international tests in mathematics and science, contributed significantly and positively to productivity growth. However, they also argued that financial resources allocated to education have only a weak or insignificant impact on student performance on such tests. These findings were subsequently contested by Lee and Barro (2001), who showed that school resources are positively related to student performance.

The results presented in this paper suggest a small positive role for education policies, in particular government spending on education. Holding the average years of schooling constant, countries which on average invest more of their wealth in education appear to raise the productivity of their human capital. However, the results are not very robust, so the controversy whether or not a more generous public funding of educational systems improves a country's performance remains.

The studies of Hanushek and Kim (1995), Dessus (2000), and Barro and Lee (2001) all concluded that a lower ratio of students to teachers in primary education student performance and on economic growth. When concentrating on the richer countries only, this relationship appears to be weaker. Whereas some developing countries experience an increase of the class sizes as a result of increased enrolment during periods of high economic growth, most OECD countries saw a decrease as a result of the slowdown in population growth. These decreases in class size have not contributed much to the quality of education.

Finally, this paper did not find a positive link between the initial educational attainment of the adult population at the beginning of each five year period and the growth rate of GDP per worker over that period. This finding may be explained by the strength of the catch-up effect, which is determined by factors other than initial levels of human capital (for example, EU membership and the institutional reforms taking place within this context). Alternatively, it may be due to the specification of the model, the chosen estimation method or the quality of the data.

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