

Human Capital and Growth

The Recovered Role of Education Systems

Sébastien Dessus

When investments in education in developing countries do not produce higher growth, the problem may be the quality of the schooling—of the education infrastructure, of the initial endowment in human capital, and of the system's ability to equitably distribute educational services. The consensus to support and emphasize public primary education for all (rather than secondary education for the few)—typically found in the most egalitarian societies—is most likely to increase the contribution of human capital accumulation to growth.

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Summary findings

Recent empirical studies question conventional wisdom about the importance of education to growth. These results partly reflect how international differences in the quality of education systems—defined by the systems' ability to produce one marginal unit of productive human capital—are not taken into account.

Dessus estimates neoclassical growth models on panel data in which the elasticity of human capital depends stochastically on different characteristics of the education system. Among characteristics that explain differences in quality are education infrastructure, the initial endowment of human capital, and the ability to

distribute educational services equally among potential students.

Giving priority to primary education for all rather than secondary education to a few is more likely to foster growth (for the same fiscal burden). But parallel actions are also probably needed – for example, promoting institutions that motivate skilled workers to spend time on growth-promoting activities and encouraging the inflow of foreign technologies to maximize the social return to public investment in education.

This paper—a product of the Social and Economic Development Group and Social Development Group, Middle East and North Africa Region—is part of a larger effort in the region to better understand the role that education has on human capital accumulation and growth. Copies of the paper are available free from the World Bank, 1818 H Street NW, Washington, DC 20433. Please contact Krisztina Mazo, room H10-102, telephone 202-473-9744, fax 202-477-0432, email address kmazo@worldbank.org. Policy Research Working Papers are also posted on the Web at <http://econ.worldbank.org>. The author may be contacted at sdessus@worldbank.org. July 2001. (21 pages)

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Human Capital and Growth: the Recovered Role of Educational Systems

Sébastien Dessus*

The World Bank

West Bank and Gaza Resident Mission. P.O. Box 54842 Jerusalem

Tel./Fax/E-mail: (972 2) 236 65 49/236 65 43/sdessus@worldbank.org

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I. Introduction

Recent empirical studies based on international comparisons question the conventional development wisdom on the importance of education for growth. Using panel data to correct inherent shortcomings of cross-country estimates of neo-classical growth models, Caselli, Esquivel and Lefort (1996) do not find robust evidence to support the view that investing in human capital necessarily produces growth, as suggested earlier by Mankiw, Romer and Weil (1992). Casual comparative observations in a number of developing economies confirm this statement: improvements in the educational attainment of the labor force do not always have a positive impact on the rate of growth of output per worker (Pritchett, 1996). The author even wonders “where has all the education gone?”, or in other words, what is the utility of schooling expenditures?

A plausible explanation may come from the fact that the quality of educational systems evolves at different pace from one country to another. Indeed, analysis from Hanushek and Kim (1995) shows the significance of labor force quality as an explanatory of international differences in per capita growth rates. Since it has also been shown by Lee and Barro (1996) that labor force quality was correlated with educational infrastructures, one might think that simply introducing the latter into the neo-classical growth model would reconcile cross-country and panel data estimates. Unfortunately, multiplying the measure of human capital with an indicator of quality to account for differences in the quality of educational systems does not significantly change the picture.

Nevertheless, this result is not sufficient to reject the hypothesis that human capital accumulation has a positive impact on economic growth. In this paper, we propose an alternative specification of the impact of educational systems on growth. We assume that the differences in the quality of educational systems lie in their respective capacity to produce one marginal unit of productive human capital, where a unit is defined as productive if it permits an increase in GDP. It directly follows that international differences need to be taken into account in average factor productivity, as well as the elasticity of GDP with respect to human capital. The estimation bias originating from ignoring these

differences may then well explain why a negative role is conferred to human capital in growth models estimated using panel data.

We test this assumption on a panel of 83 countries for the period 1960-1990. After having reproduced results similar to those reported by Caselli *et al.* (1996) and Islam (1995), we observe the presence of a significant bias of estimation originating from the lack of considering differences in educational systems. By correcting the bias, a positive impact of human capital accumulation on growth reappears. Then, we try to identify statistically the source of heterogeneity using a varying parameter method. Our results suggest that differences in educational infrastructures explain significantly differences in human capital marginal productivity across countries. Moreover, the capacity of a school system to distribute educational services equally within the population enhances the contribution of human capital accumulation to growth. Finally, the initial endowment in human capital has a significant impact on the quality of education. Even though this last result is difficult to interpret because it may capture many theoretical channels through which the availability of human capital influences the quality of educational services, it is fully consistent with the existence of poverty traps observed by Azariadis and Drazen (1990) and Cohen (1996).

II. The Analytical Framework of Conditional Convergence: Theory and Empirical Evidence

The conditional convergence model developed by Mankiw *et al.* (1992) is directly derived from the textbook Solow model (1956), augmented with an argument of human capital in the neo-classical production function. It is written as the reduced form of a constant returns to scale production function and a capital law of motion, such that:

$$y_t = k_t^a h_t^b \text{ and } \begin{cases} \dot{k} = sk y - (n + g + \delta)k \\ \dot{h} = sh y - (n + g + \delta)h \end{cases} \quad (1)$$

with y , k and h being respectively the income, the physical capital stock and the human capital stock per unit of efficient labor; sh and sk the investment rates in physical and human capital stocks; n the population growth rate, δ the physical capital depreciation rate, and g the growth rate of exogenous technical progress. The transitional phase of growth of an economy towards its steady state can be written as:

$$\begin{aligned} \ln y_t - \ln y_{t-1} = & + (1 - e^{-\lambda}) \frac{a}{1 - a - b} (\ln sk - \ln(n + g + \delta)) \\ & + (1 - e^{-\lambda}) \frac{b}{1 - a - b} (\ln sh - \ln(n + g + \delta)) \\ & - (1 - e^{-\lambda}) \ln y_{t-1} \end{aligned} \quad (2)$$

with $\lambda = (1 - a - b)(n + g + \delta)$

First designed to test the assumption of per capita income convergence across countries, this specification has rapidly been adopted as a means of identification of long-run growth determinants. The initial estimations of conditional convergence equations on cross-sectional data were then criticized on two fronts. On the one hand, Caselli *et al.*, (1996) show that ignoring country-specific individual effects is a major source of bias and justifies the use of panel data. On the other hand, (Islam, 1995) questions the choice of using school enrolment measures to capture the investment in human capital, on the basis that the law of motion of human capital formation remains largely unknown. Islam then suggests directly using the stock of human capital in conditional convergence equations, the latter taking the form:

$$\ln y_{i,t} - \ln y_{i,t-1} = -\beta \ln y_{i,t-1} + \alpha \ln sk_{i,t} / (n_{i,t} + \delta + g) + \lambda \ln h_{i,t} + \mu_t + \eta_i + \varepsilon_{i,t} \quad (3)$$

where t denotes the period and i the country. The capita income growth rate depends on the initial position of the economy (the convergence effect), as well as on the variables defining the steady state towards which the economy is converging. The investment rate, sk , is one of those variable, once deflated by the sum of the population growth rate, the physical capital depreciation rate, and the growth rate of exogenous technical progress.¹ The steady state is equally defined by a country-specific fixed effect, η_i ,² and a period-specific fixed effect, μ_t , in order to capture temporal shocks common to all countries. Finally, steady state per capita income is defined by introducing the human capital stock, h , which is justified if the latter is statistically exogenous to the growth process. The estimated coefficient λ is a multiplicative factor of the elasticity of GDP with respect to human capital.³

¹ The sum $\delta + g$ is conventionally fixed to five percent (Mankiw *et al.*, 1992). Sensitivity analysis shows that this arbitrary choice does not significantly modify the estimates of the structural parameters of the production function.

² Fisher tests for a common intercept across countries reject this null hypothesis, in conformity with Caselli *et al.* (1996).

³ The elasticity of GDP with respect to physical capital is theoretically equal to $\alpha / (\beta + \alpha)$. The estimated

This model is estimated by using different econometric methods to test the validity of the results obtained by Islam (1995) and Caselli *et al.* (1996), who observe that human capital accumulation contributes negatively to growth. In conformity with these studies, data are taken from Barro and Lee (1994). The sample is balanced, with six five-year periods from 1960-65 to 1985-90 and 83 countries. Per capita incomes are expressed at purchasing power parities, in international dollars for the year 1985. The investment rate is coherent with the measure of income, and the human capital stock represents the average schooling years in the total population over age 25 (see Appendix).

Table 1 reports the econometric estimation of Equation (1) using four different econometric methods to address the problem of inconsistency in dynamic equations with individual effects first publicized by Nickell (1981). Nickell shows that estimating dynamic equations with individual effects (random or deterministic) using ordinary least squares produces asymptotically biased estimators, as long as the number of periods is finite. This bias originates in the asymptotic correlation between residuals and the lagged endogenous variable. The Hausman test of specification⁴, and the exhaustive nature of the sample justify the deterministic (rather than stochastic) character of the individual effects. We also verify the exogenous nature of the human capital stock.⁵

The first column of Table 1 presents the estimation performed without correction of the bias mentioned above. Three methods are then alternatively employed to correct the bias: the method of Chamberlain (1984), used by Islam (1995); the generalized method of moments (GMM) suggested by Arellano and Bond (1991) and used by Caselli *et al.* (1996); and the method of Balestra-Nerlove suggested by Sevestre and Trognon (1996).

Advantages and disadvantages of the first two methods have been largely discussed in the convergence literature. Chamberlain's method does not require the imposition of restrictive assumptions on the residuals' distribution, the initial income or the fixed effects. It bears, on the other hand, a very high cost in terms of estimation, since one needs to estimate a very large number of parameters and to resolve numerically equations of high degree, which in turn severely reduces the

coefficient of human capital must also be divided by $(\beta + \alpha)$ to obtain the elasticity of GDP with respect to human capital.

⁴ This test rejects at the one percent level the null hypothesis of random individual effects.

⁵ The Hausman of specification test cannot reject the null hypothesis of exogeneity, for which the risk to be

choice of specifications and the number of periods. GMM is, on the other hand, easier to implement and produces consistent estimates whatever assumption is retained regarding fixed effects. The third method, less employed in the convergence literature, consists of projecting the endogenous lagged variable on a set of instruments consisting of all the exogenous variables at each period, and then using its predictor to estimate the structural equation. This last method has the advantage of being less consuming in terms of degrees of freedom than the two previous ones. It is also easier to combine with the requirements of a varying parameter method which is used in Section IV. Therefore, after having compared the estimates of Equation (3) using the three methods, we will use alternatively Balestra-Nerlove or GMM methods depending on the nature of the specification (with or without varying parameters).

<< TABLE 1 >>

We can observe in Table 1 that human capital accumulation — as it is specified in the Solow model — exerts a negative role on growth whichever estimation method is retained. These results confirm previous ones from the authors cited above, and motivate us to explore other hypotheses for a better understanding of the nature of the relationship between human capital accumulation and growth.

A first attempt consists of correcting human capital with an index of quality. For Islam (1995), this “anomalous” result could indeed be the consequence of a measurement error. The author suggests that the average years of schooling is a poor measure for what it is attempts to capture, since the quality of schooling is not included. Therefore, the statistical relationship between human capital and growth may be imperfectly measured in countries where the quality of education has evolved rapidly. In order to test this assumption, we estimate a conditional convergence equation in which the actual human capital Ω may be written for the period t as:

$$\Omega_t = h_t^\omega I_t^\nu \quad (4)$$

where I_t is a quality index. The conditional convergence equation thus becomes:

$$\ln y_{i,t} - \ln y_{i,t-1} = -\beta \ln y_{i,t-1} + \alpha \ln s_{i,t} / (n_{i,t} + \delta + g) + \lambda \omega \ln h_{i,t} + \lambda \nu I_{i,t} + \mu_t + \eta_i + \varepsilon_{i,t} \quad (5)$$

wrongly rejected exceeds 80 percent.

The quality index must contain temporal information, otherwise the quality effect cannot be distinguished from the country fixed effect. This condition seriously limits the available number of variables able to capture the international differences in the quality of schooling. We retain two indicators for this purpose, (i) the pupil-teacher ratio in primary school (*PTI*) and (ii) the share of schooling expenditures in GDP (*EY*). These two indicators may be interpreted as measures of the efforts made by countries to improve the quality of their educational systems.

One may notice that the elasticity of GDP with respect to human capital is no longer identifiable in Equation (5). This specification enables us, however, to observe if the introduction of quality indexes modifies the estimated relationship between human capital accumulation and growth. Results are reported in Table 2.

<< TABLE 2 >>

Adding the quality indexes does not modify the nature of the relationship between human capital accumulation and growth, which remains negative and significant in the augmented Solow model. The estimated coefficient for *PTI* presents the expected sign, but is not significantly different from zero. The estimated coefficient for *EY* presents the wrong sign, and is insignificant.

III. Testing the Augmented Solow Model: the Crucial Issue of Heterogeneity

The interest in convergence issues originates from the postulate that all the economies are characterized by the same technology. In the absence of such an assumption, the idea of convergence vanishes, since heterogeneous technologies mechanically generate country-specific transitional and steady state paths. This assumption may be justified in the original Solow model, in which the physical capital is the only factor of production. Admittedly, financial market imperfections preclude marginal productivities from being equalized instantaneously. Nevertheless, one may accept that the elasticity of GDP with respect to physical capital is comparable from one country to another: equipment goods are produced in a few countries and are highly tradable; in addition capital may rapidly be declared obsolete in case of technological revolution.

These arguments are not necessarily valid for human capital. As underlined by Galor (1996), human capital is to a large extent country-specific, non-tradable, and slowly depreciates, so that it is difficult

to postulate *a priori* that the elasticity of GDP with respect to human capital is universal.⁶ Relaxing this assumption of homogeneity has very important consequences: ignoring this new source of heterogeneity produces biased coefficients in the estimation of conditional convergence equations. As a matter of fact, arguing that slope heterogeneity — under classical conditions of random distribution and exogeneity — is not a problem as long as we are only interested in the estimation of the average slope is not valid with dynamic specifications (Pesaran and Smith, 1995). In this case, imposing a common slope will bias the estimators. We illustrate the origin of the bias in the following paragraphs. Assume a random variable defined by:

$$y_{i,t} = \phi y_{i,t-1} + \gamma_i x_{i,t} + \varepsilon_{i,t} \quad (6)$$

where x is strictly exogenous and ε a random variable with classical properties of distribution and independence. Imposing the slope homogeneity will generate implicitly the following model:

$$y_{i,t} = \phi y_{i,t-1} + \gamma x_{i,t} + v_{i,t} \quad \text{and} \quad v_{i,t} = (\gamma_i - \gamma)x_{i,t} + \varepsilon_{i,t} \quad (7)$$

In this case, estimating Equation (7) with the methods presented in the previous paragraphs will produce biased coefficients if the exogenous variable follows an auto-regressive process. The covariance between the lagged variable and the residual is indeed different from zero:

$$E(y_{i,t-1}, v_{i,t}) = \zeta + E(\phi(x_{i,t-1}, (\gamma_i - \gamma)x_{i,t})) \neq 0 \quad \text{for} \quad E(x_{i,t-1}, x_{i,t}) \neq 0 \quad (8)$$

This example illustrates that the heterogeneity bias is due to the simultaneous presence in the right-hand side of the equation of a lagged endogenous variable and an exogenous variable following an auto-regressive process. This is typically the case of conditional convergence equations, in which the lagged endogenous variable is associated with the human capital stock which follows by definition an auto-regressive process since it is the result of cumulative investments.

We test the presence of such a bias in the previous estimations. In order to do so, we compare the estimate of the average slope in case of slope heterogeneity to the constrained estimate, using Wald and Hausman tests. First, we estimate the following conditional convergence equation:

⁶ This concern of heterogeneity was actually already present in the first studies on convergence (Mankiw *et al.*, 1992). By distinguishing different groups of countries (non-petroleum countries, intermediate countries, OCDE countries), with significantly different speeds of convergence, the authors were implicitly giving credit to the idea that production functions could differ internationally in their elasticities.

$$\ln y_{i,t} - \ln y_{i,t-1} = -\beta \ln y_{i,t-1} + \alpha \ln s_{i,t} / (n_{i,t} + g + \delta) + \gamma_i \ln h_{i,t} + \mu_i + \eta_i + \varepsilon_{i,t} \quad (9)$$

The average slope of human capital is then defined by:

$$\hat{\gamma} = N^{-1} \sum_i^N \hat{\gamma}_i \quad \text{and} \quad \hat{V}(\hat{\gamma}) = N^{-2} \left[\sum_i^N \sum_j^N E(\hat{\gamma}_i, \hat{\gamma}_j) \right] \quad (10)$$

This last estimator of the average slope is consistent, but less efficient than the one estimated imposing common slopes. Comparing the two with Hausman test of specification thus enables us to test the presence of a heterogeneity bias. The Wald test allows measuring whether relaxing of the constraint of common slopes improves significantly the goodness of fit of the model. Table 3 reports the two estimations, with and without constraint.

<< TABLE 3 >>

Wald and Hausman tests both reject at the one percent level the null hypothesis of slope homogeneity. Relaxing this assumption has several consequences. Even though the implicit elasticity of GDP with respect to physical capital remains comparable to the previous estimates (about 0.3), the estimated elasticity of GDP with respect to human capital is significantly modified. From being negative and significantly different from zero, it becomes positive and not significantly different from zero. We thus recover a positive impact of human capital accumulation on growth after correction of the heterogeneity bias. This effect is not significantly different from zero, probably as a result of the great variance of the parameter.

IV. Seeking the Source of Heterogeneity: the Significance of Educational Systems

The preceding section has underlined that results reported in the literature about the negative relationship between human capital and growth come from the heterogeneity of production functions. The question is now whether the source of the heterogeneity may be identified, in a view to provide operational recommendations.

For this purpose, we propose an alternative view of the impact of educational systems on growth. We assume that the differences in the quality of educational systems lie in their respective capacity to produce one marginal unit of productive human capital. This unit is defined as productive if it permits

an increase in GDP. Therefore, the quality of educational systems is no longer defined with respect to the average productivity of available human capital, but with respect to its marginal productivity. We thus conceive an alternative specification to the one used previously when we corrected the human capital with a quality index. It consists in writing the productive human capital Ω as an exponential function of a quality index Z , as follows:

$$\Omega = h^z \quad \text{or} \quad \frac{\partial \Omega}{\partial t} = Zh^{z-1} \frac{\partial h}{\partial t} \quad (11)$$

In other words, the formation of a marginal unit of productive human capital depends on country-specific characteristics, which determine the real path of human capital accumulation. In this case, it is straightforward to observe that the elasticity of GDP with respect to human capital differs from one country to another, since the per capita production function now takes the form:

$$y_{i,t} = A_t e^{g t} k_{i,t}^{\bar{\alpha}} \Omega_{i,t}^{\bar{\lambda}} = A_t e^{g t} k_{i,t}^{\bar{\alpha}} h_{i,t}^{\bar{\lambda} Z_i} = A_t e^{g t} k_{i,t}^{\bar{\alpha}} h_{i,t}^{\bar{\gamma}_i} \quad (12)$$

In order to identify statistically the origin of these differences, we estimate conditional convergence equations in which the coefficient associated with human capital varies stochastically from one country to another depending on domestic characteristics:

$$\ln y_{i,t} - \ln y_{i,t-1} = -\beta \ln y_{i,t-1} + \alpha \ln s_{i,t} / (n_{i,t} + \delta + g) + \gamma_i \ln h_{i,t} + \mu_i + \eta_i + \varepsilon_{i,t} \quad (13)$$

$$\text{and} \quad \gamma_i = \lambda + \theta Z_i + u_i$$

This equation allows us to test the impact of several characteristics of the educational system on its quality. The variable Z_i is invariant in time, otherwise no degrees of freedom would be available.

We assume that ε and u are two random perturbations independently and identically distributed and which are independent from each other. However, as soon as γ_i is replaced by its expression in the convergence equation, it appears that the residuals are heteroscedastic for $h_{i,t}$ different from zero, which is obviously the case. In order to consider the stochastic nature of the human capital coefficient, we use the varying parameter method suggested by Amemya (1978) for this purpose. It consists of estimating equation (13) with generalized least squares, so as to take into account the heteroscedasticity using a consistent estimate of the variance-covariance matrix of residuals.

Two alternative sets of economic theories are tested. The first is inspired by works of Lucas (1988),

Azariadis and Drazen (1990) and Cohen (1996). All of these studies defend the idea that the production of one marginal unit of human capital depends on the amount of human capital already available. In the first study, the production of human capital depends on the human capital already available and the time devoted by the population to this activity. In the second, only the economies initially endowed with a sufficient level of human capital are able to produce a marginal unit of human capital. In the third, the main factor of the production function of human capital is the human capital accumulated in the past. This general idea may be understood intuitively: the more the country is endowed with teachers and know-how in productive activities, the greater its capacity to educate new students and train workers. This seems to be particularly relevant for developing countries, which have engaged in massive education plans to respond to demographic pressures without having a sufficient initial level of human capital. In these cases, the rapid increase in the years of schooling may actually mask the stagnation of the productive human capital.

To some extent, the second set of theory leaves off from the analytical framework used until now, since it necessitates disaggregating the human capital. Aggregated human capital is now defined as the sum of individuals' human capital, and the marginal impact of the aggregated human capital equals the sum of the marginal impacts of the individual's human capital. Therefore, it is assumed that the social return of education equals the private return of education. Works from Psacharopoulos (1994) suggest that the latter is generally decreasing with the number of years of schooling. Under these conditions, the social return of educational investment is higher when it is aimed at increasing the human capital of the less skilled, a proposition also emphasized recently by Shultz (1999). Moreover, the social marginal cost of education increases with the number of years of schooling: financing one year of university education is more expensive for society than one year of primary school. It is then relevant to test whether the distribution of education within the population affects the marginal productivity of aggregated human capital. The same average number of years of schooling may indeed mask very different distribution patterns of qualifications across countries. We thus test the assumption that the marginal productivity of human capital depends on the distribution of qualifications, for a given average number of years of schooling.

In order to test these theories, we use several indicators of the quality of the educational system and of the distribution of qualifications. None of them is a perfect indicator of what we want to describe. Moreover, as we will see below, it is difficult to say that any of the indicators describes exclusively one of the two theories mentioned in the previous paragraphs that the marginal production of human capital depends upon the human capital already in existence; and/or that the marginal productivity of human capital depends upon the distribution of qualifications. However, we believe the repeated observation of significant correlations will be a positive indication of the robustness and relevance of the theoretical relationships we are testing.

The two first indicators, the pupil-teacher ratio and the share of educational expenditures in GDP have already been discussed, but the difference with their use in section II is that we now use the average measure over the studied period for each country, denoted with the suffix *A*. We also test the impact of the number of students per teacher in secondary school, *PT2A*, for which the average is available for the period 1950-80. These three variables describe to what extent the country devotes financial and human resources to the activity of education. They are probably correlated among themselves, since a large share of educational expenditures is used to remunerate teachers. They are also probably correlated with the initial human capital stock, if we assume that the number of teachers is *ceteris paribus* a positive function of the available human capital stock. By also testing the impact of the latter (*h0*, the human capital stock in 1960) on the marginal productivity of human capital between 1960 and 1990, we therefore test directly the theory suggested by Azariadis and Drazen (1990) and Cohen (1996).

The measure of dispersion of qualifications is more delicate to build. Ideally the good measure would be a Gini index of education, for which the years of education of each individual would replace the traditional measure of income. To our best knowledge, this measure is unfortunately unavailable for international comparisons. We use instead a simpler measure of distribution of education, which is the share of the population who has never been to school (*NSCOLA*).

These different measures are not independent from each other, as we can observe in Table 4 where the correlation matrix is reported. A few remarks arise from this table. First, the average share of educational expenditures in GDP is not significantly correlated with the number of students per

teacher in primary and secondary school. This suggests that these variables are of very different nature. In particular, the system of remuneration for teachers may differ largely across countries (Pritchett, 1996), and so the differences in the share of educational expenditures in GDP may not actually reflect the efforts engaged by each country to promote education. Second, one may observe that the pupil-teacher ratio in secondary school is only correlated with its counterpart in the primary school, but not correlated with the other indicators. Third, the initial endowment in human capital, h_0 , is highly correlated with the other indicators (with the exception of *PT2A*), and particularly with the variable describing the effort of the nation to integrate the largest part of its population in the educational system, *NSCOLA*. Fourth, variables supposed to describe the quality of the educational system are equally highly correlated with the variable *NSCOLA*. Therefore, it will be difficult to attribute to any variable the ability to validate exclusively one single theory among the two tested.

<< TABLE 4 >>

Table 5 reports the estimations of the impact of different characteristics of the educational system on the marginal productivity of human capital, using the varying parameter method. Our results indicate that the indicators retained for the quality of educational systems explain significantly the differences across countries in the contribution of human capital accumulation to growth. The variables *PT1A*, *NSCOLA* and *EYA* are significantly different from zero at the 10 percent level and present expected signs. One standard deviation in the pupil teacher ratio translates in a 0.15-0.20 variation in the elasticity of GDP with respect to human capital. One standard deviation in the two other variables translates in a 0.10-0.15 variation of the same elasticity. These results suggest that investing in educational infrastructures is rewarded, and that the quality of education received affects positively the skills of each individual.

The coefficient for the pupil-teacher ratio in secondary school is neither significantly different from zero nor of expected sign. It probably illustrate the fact that in most of the sample's countries, the average years of schooling is less than six, which is generally the number of years necessary to complete primary school. Besides, the absence of a correlation with the other variables (cf. Table 4) could reflect the fact that in some countries the improvement of schooling conditions in secondary school has been achieved to the detriment of the primary school.

The initial endowment in human capital, h_0 , is the most significant among the variables tested in this study. The more the country was endowed with human capital in 1960, the more the increase in educational attainment between 1960 and 1990 has been productive. One standard deviation in the initial endowment translates in a 0.2 variation in the elasticity of GDP with respect to human capital.

<< TABLE 5 >>

This result tends to confirm the conclusions of Azariadis and Drazen (1990) and Cohen (1996). In addition, it is not subject to the criticism put forward by Pritchett (1996) on the basis of three points. The first point made by Pritchett is to notice that if the initial level of human capital influences the growth rate of GDP, then the growth rate of human capital should *also* influence the growth rate of GDP, a result for which the author cannot find robust empirical evidence. Our approach reconciles the two stylized facts, since we observe that the initial endowment of human capital determines to what extent the growth rate of GDP is influenced by the growth rate of human capital. The second point made by Pritchett is to observe that the fact that human capital affects growth *only* through externality effects (Azariadis and Drazen, 1990) is in contradiction with the empirical evidence which concludes that human capital positively affects individual remuneration (Psacharopoulos, 1994). Our specification only indicates that the scale of individual remuneration depends on the quality of the educational system, without any need to resort to externality effects. Finally, Pritchett (1996) questions the assumption of thresholds retained by Azariadis and Drazen (1990), which seems to contradict the empirical observation of a continuous concave relationship between the private return and the level of human capital (Psacharopoulos, 1994). Again, this observation is not questioned by our specification, which postulates a decreasing marginal productivity of human capital.

Obviously, one cannot attribute to this last result the ability to capture only the influence of educational systems on growth. There are other theoretical models that predict such an interactive effect without resorting to the educational system – for instance models with network externalities in the production function (Benhabib and Spiegel, 1994), or models in which the education level of the parents has a positive effect on student performance (Lee and Barro, 1998). However, it remains in practice difficult to distinguish the different theoretical channels, given the high degree of correlation between the initial endowment in human capital and the indicators of educational infrastructures (cf.

Table 4). Without feigning exclusivity, our results suggest that the difference in educational infrastructures may be one plausible explanation for the heterogeneity of production functions.

The analytical framework developed here does not however allow us to explain the paradox emphasized by Pritchett (1996): the observed poor impact of educational investment on growth in some countries seems to contradict the micro evidence, for which a huge literature indicates that more educated individuals receive higher wages, even in countries where the contribution of human capital accumulation to growth is close to zero. As suggested by Pritchett (1996), a potential explanation may be found by looking at differences in institutional frameworks across countries. Human capital can have only limited impact on economic growth if it is employed in socially unproductive activities, but nevertheless remunerative at the micro-level. Such misallocation may occur when distortions in the institutional framework make rent seeking activities more profitable than productive ones, thus providing incentives for skilled workers to turn to the former. Testing formally this assumption goes much beyond the scope of this paper, which tries to identify the impact of educational systems on social returns to human capital. But, if one admit that private and social returns may differ, a straightforward recommendation would be to implement a tax/subsidy scheme to fill the gap between social and private returns.

Finally, the fact that the elasticity of GDP with respect to human capital depends positively on the level of human capital is an obvious source of self-sustained growth. The more human capital is accumulated, the higher is its marginal productivity. There is no equilibrium since in the long run the marginal productivity of human capital becomes increasing and the system explodes. This effect of endogenous growth is, however, highly unrealistic: there is presumably a limit in the number of years of schooling that individuals may accumulate. This result— if one does not attribute too much credit to its predictive capacity (after all, it is obtained on the basis of only thirty years of observations)— is interesting, for it suggests a plausible explanation for the phenomenon of conditional divergence (a simultaneous convergence of inputs and divergence of incomes) observed by Cohen (1996).

V. Conclusion

The result reported by Pritchett (1996) and Caselli *et al.* (1996), that human capital accumulation would exert a negative influence on growth, suffers from a specification bias. This bias originates from ignoring the international differences in the quality of schooling systems, which is defined in this paper as the capacity to produce one marginal unit of productive human capital. Using a varying parameter method, we identify several characteristics that may explain these differences: the educational infrastructures, the initial endowment in human capital and the ability of the system to distribute equally educational services within the population.

These results explain to a large extent why investments in education in developing countries have not been rewarded by higher growth. Massive enrolments have been detrimental to the quality of education supplied; the unequal distribution of educational services has hampered the efficiency of public expenditures. These two effects have in turn most likely reduced the pace of schooling enrollment for two reasons: firstly, because the low private return of education has limited the demand for education; and secondly, because the unequal distribution of education has reduced the financing capacities of the public sector. Birdsall, Ross and Sabot (1995) observe in this respect that it is in the most egalitarian societies that the largest consensus to support public schooling for all is found. It would be interesting to go further in this direction of research, as well as in finding more precise indicators of the quality of educational systems.

Poverty traps resulting from these vicious circles are not inevitable. A priority given to primary education and access to all should produce, for the same fiscal burden, more positive effects in terms of growth than prioritizing secondary education for a few. Nevertheless, restricting the field of public actions solely to the educational system is most likely insufficient. Parallel actions could also be envisaged to promote institutional frameworks that would motivate skilled workers to devote their time to growth-promoting activities. Along the same lines, efforts to favor the inflow of foreign technologies in developing countries should be encouraged (Pissarides, 1993), in order to maximize the social return of public investment in education.

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Table 1: Estimation of the augmented Solow model with different methods (1960-90)

	Dependent variable: $\ln y_t$			
	(1)	(2)	(3)	(4)
$\ln y_{t-5}$	0.794 (18.3)	0.702 (19.3)	0.860 (14.8)	0.846 (13.1)
$\ln s / (n+g+\delta)$	0.151 (4.96)	0.207 (15.1)	0.100 (3.01)	0.141 (3.58)
$\ln h$	-0.085 (3.03)	-0.181 (13.1)	-0.081 (2.38)	-0.080 (2.19)
Adjusted R ²	0.99	-	0.98	0.98
Observations	498	498	415	498

Notes: (1) OLS Estimation with fixed effects (LSDV); (2) Estimation with the Chamberlain method (in this case, standard errors are measured using first derivatives of the Gauss-Newton algorithm); (3) Estimation with GMM (in this case the dependent variable is $\ln(y_t) - \ln(y_{t-5})$); (4) Estimation with the Balestra-Nerlove method; Statistics in parenthesis are T-Students. Adjusted R² in Column 3 is recalculated by substituting the variance of $\ln(y_t)$ to the variance of $\ln(y_t) - \ln(y_{t-5})$ to be compared to the other estimations. Cross section averages are removed from each variable so that it becomes useless to estimate period-specific effects. y : per capita GDP; s : investment rate; h : average schooling years in the total population over age 25.

Table 2: Estimation of the Solow model with quality indexes in education (1960-90)

	Dependent variable: $\ln y_t$	
	(1)	(2)
$\ln y_{t-5}$	0.801 (13.7)	0.758 (10.3)
$\ln s / (n+g+\delta)$	0.098 (2.81)	0.115 (2.85)
$\ln h$	-0.091 (2.52)	-0.079 (1.82)
$\ln PTI$	-0.041 (0.84)	
$\ln EY$		-0.017 (0.41)
Adjusted R ²	0.99	0.98
Observations	400	320

Notes: Estimation with GMM. Adjusted R² in Column 3 is recalculated by substituting the variance of $\ln(y_t)$ to the variance of $\ln(y_t) - \ln(y_{t-5})$ to be compared to previous estimations. Cross section averages are removed from each variable so that it becomes useless to estimate period-specific effects. Statistics in parenthesis are T-Students. PTI : pupil-teacher ratio in primary school. EY : ratio of schooling expenditures in GDP. These two variables are lagged ten years to account for the delay between the schooling period and the entry in professional activity.

Table 3: Estimation of the Solow Model with heterogeneous slopes for the human capital

	Dependent variable: $\ln y_t$	
	(1)	(2)
$\ln y_{t-5}$	0.846 (13.1)	0.443 (5.43)
$\ln s / (n+g+\delta)$	0.141 (3.58)	0.215 (4.63)
$\ln h$	-0.080 (2.19)	0.086 (0.89)
Adjusted R ²	0.98	0.99
Observations	498	498

Notes: Estimation with the Balestra-Nerlove method. (1) Estimation imposing common slopes for human capital. (2) Estimation with different slopes for human capital (see text). Cross section averages are removed from each variable so that it becomes useless to estimate period-specific effects. Statistics in parenthesis are T-Students.

Table 4: Correlation matrix of different characteristics of the educational system

	$h0$	$PT1A$	$PT2A$	$NSCOLA$	EYA
$h0$	1.00				
$PT1A$	-0.63	1.00			
$PT2A$	-0.13	0.38	1.00		
$NSCOLA$	-0.88	0.62	0.08	1.00	
EYA	0.55	-0.29	0.08	-0.43	1.00

Notes: The correlation coefficients are calculated using the largest sample for each couple of variables (a maximum of 80 countries and a minimum of 62 countries). In bold are reported the correlation coefficients significantly different from zero at the 1 percent level. $h0$: average schooling years in the total population over age 25 in 1960 ; $PT1A$: Average pupil teacher ratio in primary school over the period 1950-80; $PT2A$: Average pupil teacher ratio in secondary school over the period 1950-80 ; $NSCOLA$: average share of the population who has never been to school over the period 1960-90; EYA : average share of schooling expenditures in GDP over the period 1950-80.

Table 5: Educational Systems and the marginal productivity of human capital

	Dependent variable: $\ln y_t$				
	(1)	(2)	(3)	(4)	(5)
$\ln y_{t-5}$	0.444 (5.45)	0.439 (5.26)	0.427 (5.31)	0.457 (5.60)	0.459 (5.53)
$\ln s / (n+g+\delta)$	0.214 (4.62)	0.209 (4.43)	0.211 (3.84)	0.214 (4.31)	0.220 (4.49)
varying parameter: $\ln h$					
<i>Intercept</i>	-0.175 (1.57)	0.714 (3.05)	-0.133 (0.45)	0.214 (1.84)	-0.351 (0.05)
<i>h0</i>	0.080 (2.96)				
<i>PT1A</i>		-0.018 (2.76)			
<i>PT2A</i>			0.013 (0.86)		
<i>NSCOLA</i>				-0.005 (1.85)	
<i>EYA</i>					0.111 (2.08)
Observations	498	480	420	450	444

Notes: Estimation method: varying parameter method (see text). Statistics in parenthesis are T-Students. R² are not reported because the model includes two random perturbations.

Appendix. Data.

Definition and sources of variables

<i>y</i> :	Per Capita GDP (international dollars 1985). Source: Summers and Heston (1991).
<i>s_K</i> :	GDP Share of investment. Source: Summers and Heston (1991).
<i>s_H</i> :	Secondary enrollment rate weighted by the share of population aged 15-19. Source: World Bank and United Nations.
<i>h</i> :	Average number of years of schooling of the population aged 25 and more in the beginning of the five-year period. Source: Barro and Lee (1993).
<i>n</i> :	Demographic growth rate. Source: World Bank.
<i>PT1</i> :	Pupil-teacher ratio in primary education. Source: UNESCO.
<i>PT1A</i> :	Average pupil-teacher ratio in primary education over the period 1950-1980. Source: UNESCO.
<i>PT2A</i> :	Average pupil-teacher ratio in secondary education over the period 1950-1980. Source: UNESCO.
<i>EY</i> :	GDP Share of public educational expenditures. Source: UNESCO.
<i>EYA</i> :	Average GDP Share of public educational expenditures over the period 1950-1980. Source: UNESCO.
<i>NSCOLA</i> :	Average percentage of "no schooling" in the total population over the period 1960-1990. Source: Barro and Lee (1993).

*Countries**

Algeria	Congo, Dem. Rep.	Peru	Cyprus
Cameroon	Zambia	Uruguay	Denmark
Egypt, Arab Rep.	Canada	Venezuela	Finland
Ethiopia	Costa Rica	Myanmar	France
Ghana	Dominican Republic	Indonesia	Germany
Côte d'Ivoire	Salvador	India	Greece
Kenya	Guatemala	Iran	Island
Madagascar	Haiti	Israel	Ireland
Malawi	Honduras	Japan	Italy
Mauritius	Jamaica	Jordan	Malta
Morocco	Mexico	Korea, Rep.	Netherlands
Niger	Nicaragua	Malaysia	Norway
Nigeria	Panama	Pakistan	Portugal
Rwanda	United States	Philippines	Spain
Senegal	Argentina	Singapore	Sweden
Sierra Leone	Bolivia	Sri Lanka	Switzerland
South Africa	Brazil	Syria	Turkey
Tanzania	Chili	Taiwan	United Kingdom
Togo	Colombia	Thailand	Australia
Tunisia	Ecuador	Austria	New Zealand
Uganda	Paraguay	Belgium	

* Some countries are excluded of some of the regressions in Table 2 (Columns 1,2) and Table 5 (Columns 2-5), because information on educational infrastructure is missing.

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