Quality and Quantity of Education in the Process of Development*

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Abstract

We develop a theory of educational quality to study how quality could account for schooling decisions regarding higher education (secondary and above), and how the distribution of educational attainment and educational quality differ with the level of development. In a general equilibrium closed economy, higher education requires an extra investment of private resources, whereas primary education does not. The theory states that human capital accumulation depends on quality through two channels. The extensive channel refers to access to higher education. Even with perfect capital markets, relatively low quality could discourage opportunities to pursue education beyond primary school, since low quality decreases the returns from higher education. As a result, agents could get stuck at primary levels, and the economy ends up being poor. The intensive channel establishes that once individuals decide to participate in higher schooling, the higher the quality of educational system, the larger the investment made by each agent. Using cross-country data, empirical evidence shows that the proposed channels seem to be quantitatively important. Furthermore, the quality of education proves to be an important determinant of economic growth, especially when the quality of education is relatively high.

JEL classification: I21, O11, O15, O4.

Key words: Quality of education, human capital composition, economic growth.

1 Introduction

This paper seeks to understand what drives schooling decisions regarding higher education (that is, secondary and tertiary education), and how the distribution of educational attainment differs with

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the level of development. In particular, Table 1 shows how attainment levels in primary, secondary, and tertiary schools relate to per capita income. On the one hand, we observe that while the highest educational level attained by most of the population in low and middle-income countries is primary schooling (30 percent of the population in poor countries and 43 percent in middle-income economies), educational attainment in high income countries is concentrated in secondary levels.[1] On the other hand, secondary and tertiary schooling increase with income levels (i.e., about 23 percent of people in high-income countries had a tertiary degree, but less than 2 percent in low-income countries). However, there are not substantial differences in primary education attainment levels across income levels. Indeed, the share of individuals with no more than primary education was similar in poor and rich countries (30 percent in poor countries and 32 percent in rich economies).

One possible explanation for this evidence is that when borrowing is expensive and secondary and tertiary education are more costly than primary education –which seems to be the case since currently primary schooling is publicly provided in most countries– individuals with low wealth have limited access to the educational investment opportunities that are available to the rich (see, e.g., Galor and Zeira, 1993). Another possible explanation for the increased demand for educational attainment could be skill-biased technical change. The shift in production technologies causes information technologies to be complementary to employees with higher skill levels since it increases the returns to schooling, thereby creating an incentive for more people to attain higher schooling levels (see, for example, Galor and Moav, 2000).

In this paper, we analyze an alternative explanation that posits cross-country differences in the quality of the educational system to be a possible factor contributing to such patterns. As preliminary evidence of how important the quality of education may be, we plot enrollment rates in secondary education as a function of educational quality in each country.[2] The results are striking. Figure 1 shows an outstanding correlation between educational quality and enrollment rates in secondary schooling when the quality of education is relatively high —a correlation that disappears when the quality of the educational system is below a threshold level. Moreover, the upper and lower extremes in the figure also show that, on average, the countries with a high-quality educational system are mainly the high-income OECD economies, whereas those with low-quality educational systems are the less-developed countries.[3]

[1] In the year 2000, the share of population with secondary education as the highest level attained was 41.5 percent in rich countries, but just 11.26 percent in poor economies.

[2] We then measure the quality of the educational system through scores in internationally comparable tests taken from Hanushek and Kimko (2000). The enrollment rates in secondary education are taken from Barro and Lee (1994).

[3] A potential problem with these internationally comparable test scores is that they could measure innate abilities. First, it seems reasonable to assume that average ability of students does not vary across countries. Second, even assuming that high ability agents in developing countries would enter secondary schooling more often than low ability agents in these countries, and that the average ability level of secondary students would decline as secondary education expands, we would then expect a negative correlation between quality and enrollment rates across income levels. This would imply that Figure 1 is still robust to these assumptions. On the other hand, the relationship in both figures holds even when controlling for the level of financial development, the number of years of compulsory secondary education and if, instead of the 25^{th} percentile, we split the bottom of the quality distribution at the 20^{th} or 30^{th} percentile.

Table 1

	Attainment levels in education (%), year 2000		
Income	*Primary*	*Secondary*	*Tertiary*
Low	30.07	11.26	1.83
Middle	43.62	24.43	10.07
High	31.67	41.50	23.34

Note: Attainment levels refer to the population 25 years and above (Barro and Lee, 2001). The income classification is taken from the World Bank, 2007, which divides economies into income groups according to per capita gross national income.

Motivated by these observations, we develop an analytical theory to study how the quality of the educational system influences individuals' decisions to invest in higher education, which in turn affects the distribution of educational attainment and thus the country's level of per capita output. Specifically, the objective of this paper is to shed light on the following questions: Can educational quality account for schooling decisions in higher education? And if so, what are the channels through which educational quality operates? And how does the distribution of educational attainment and educational quality differ with a country's level of development?

To answer these questions, we construct a model of schooling decisions where growth results from the accumulation of physical and human capital. We find a simple closed-form solution, which allows us to identify the mechanisms at work and thus provides a theoretical foundation to check the results empirically. Our theory is based on the following assumptions. First, we differentiate between primary and higher education in a simple way: higher education requires then investment of private resources, whereas primary schooling does not, and is also compulsory. Agents decide whether or not to pursue higher education, and if so, how much to spend on it. The higher the investment, the higher the schooling level attained. Second, we assume the quality of the educational system to be an exogenous variable and, motivated by the evidence of Hanushek and Woessmann (2008), that it affects the returns on education. Finally, agents are heterogeneous in two dimensions; ability and inherited wealth, but capital markets are perfect. The essential implication of this assumption is that schooling decisions are independent of the current distribution of wealth levels. Although capital markets for education are far from perfect in reality, this assumption allows us to isolate and best illustrate the role played by education quality.

Our proposed theoretical model makes several predictions. It identifies two potential channels by which the quality of the educational system affects human capital accumulation. On the one hand, low educational quality decreases the returns from education and discourages access to higher education across a broader segment of the population. As a result, low quality could act as a barrier to pursuing higher education. We refer to this effect as the extensive channel. On the other hand, once individuals participate in higher education, high-quality educational systems raise the investments in schooling made by each person beyond primary school. We call this the intensive channel.

Apart from educational quality, general equilibrium forces also impact schooling choices through changes in prices, thereby reinforcing the effects of quality on schooling attainment. We show that as output per capita increases, agents have more incentives to invest in higher education. Greater per capita GDP affects the returns as well as the cost of education, since as wages increase, the marginal returns on education rise, while its opportunity cost —given by the interest rate— falls.

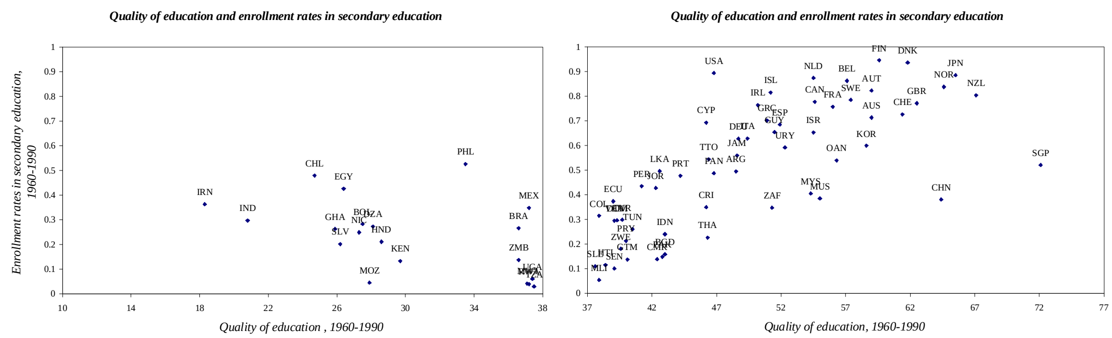

Figure 1: Quality of education and enrollment rates in secondary education

Over the course of a country's development, the extensive and the intensive channels are not acting always with the same strength. At low levels of educational quality, the extensive channel is at work, and here individuals would optimally decide to remain with primary education and only to invest in physical capital. As a result, aggregate output is low. This stage of development is called Regime I. As capital accumulates, and due to the general equilibrium effect, the economy could enter into Regime II, in which only the more intelligent agents invest in higher education. However, for agents with low abilities, the educational quality constraint remains binding and they stay with primary education instead. Along this transition from Regime I to Regime II, the output per capita is pushed onto a higher dynamic path. Economic growth increases the returns from investing in higher education relative to physical capital, raising the opportunities to pursue education beyond the primary level for less talented individuals, so that the economy enters Regime III. At this last stage of development, only the intensive channel is at work and the higher the quality, the larger the investment in higher education. Here, everyone makes the optimal investment, and the current gross interest rate equals the expected marginal product of higher education for each ability type.

The predictions of the model are tested on a broad sample of countries. One of the main difficulties in the empirical analysis is that the quality of schooling is difficult to measure, and data on schooling quality across countries is scarce. Our measures of the quality of education refer to students' cognitive performance in various international tests of academic achievement in math and science, were taken from Hanushek and Kimko (2000). The main advantage of this dataset is that it contains data for a broad number of countries including both developed and developing economies. However, the data are only available as an average over the period 1960-1990. Thus, as a robustness check of the results, we also use Barro and Lee's (2001) data, which includes observations of test scores for different years. The advantage of the latter is that, because it contains data over time, it allows us to account for the likely endogeneity of regressors. Finally, we measure university quality through international rankings that indicate universities' academic performance, taken from the Shanghai Jiao Tong University Academic Ranking of World Universities.

We find that the proposed channels through which educational quality affects attainment and investment rates in higher education are quantitatively important. In particular, our results reveal a statistically significant positive effect of educational quality on attainment levels in secondary and tertiary education. Moreover, even when controlling for the stock of human capital, countries with better educational quality are those with higher enrollment rates in secondary and tertiary education as well. Both results hold even when controlling for the initial level of development, a measure of current financial development, years of compulsory education, and several time-invariant variables that reflect cultural, geographical, and institutional characteristics of each country. Furthermore, consistent with the fact that primary education is publicly provided and compulsory in most parts of the world, the effect of educational quality barely influences primary schooling.

Moreover, the quality of education influences per capita income growth rates as well.[4] Whereas Hanushek and Kimko (2000) were the first to highlight the importance of the quality of education in promoting economic growth rates, the analysis in this paper goes one step further by testing some predictions of the model. On the one hand, consistent with our theory, the results show that quality does not affect economic growth in countries at the bottom end of the quality distribution, yet better educational quality has a clear positive influence on economic growth in the remaining economies. On the other hand, although both quality and investment in higher education are important determinants of economic growth in developing countries, our result show a predominant effect of quality of education over investment rates in more developed economies.

The paper is organized as follows. The next section discusses our research in the context of the existing literature. Section 3 presents the model under partial equilibrium. Section 4 analyses the economy in a general equilibrium context. Section 5 describes the data used in the empirical section as well as the econometric specification. Section 5 empirically examines the predictions of the theoretical model and Section 6 states the conclusions reached.

2 Relation to existing literature

Surprisingly, there is a continuing lack of theoretical and empirical work addressing the importance of the quality of education on the process of development.[5] However, there has been considerable recent research seeking to quantify the role of educational quality as an important determinant of cross-country income differences (see e.g., Erosa et al. 2006, Manuelli and Seshardri 2007, Schoellman

[4]For empirical studies that analyze the effect of education on promoting economic growth, see Barro (1991), Mankiw, Romer, and Weil (1992), De la Fuente and Doménech (2006) and Cohen and Soto (2007). For an overview of the puzzle involving the relationship between human capital and economic growth from the perspective of a growth accounting approach, see the evidence and thorough discussion by Pritchett (2001).

[5]Tamura's (2001) theoretical analysis was one of the first to include teacher quality in the production function of human capital in order to study the importance of teacher quality versus class size for growth.

2009, and Cordoba and Ripoll 2007).[6]

In two papers with a similar approach, Erosa et al. (2006) and Manuelli and Seshadri (2007) estimate the parameters of the production function of the human capital stock of a country rather than using the Mincer return.[7] In both models, the human capital production function includes both time inputs and goods inputs. The two variables, quantity and quality of the educational system, are decided at the individual level, and educational quality is captured by the total aggregate spending on education. When allowing for quality differences, both of the aforementioned papers find that effective human capital per worker varies substantially across countries and provides a large amplification mechanism for TFP differences across countries.[8] However, empirical evidence shows that increasing the amount of resources spent does not always translate into better learning among students or into increased labor quality (see, e.g., Hanushek, 1995; You, 2008). This issue motivates the inclusion of educational quality in our model as an exogenous parameter affecting the human capital production function, and specifically the returns on education.

We contribute to this branch of the literature in several ways. First, no study so far has analyzed how educational quality and schooling decisions regarding higher education are related in a theoretical framework. The present paper focuses on the channels by which quality affects schooling decisions about higher education. We show that through the extensive channel, the quality of the educational system could act as a barrier to educational investments beyond primary levels even with perfect capital markets. Consequently, it complements the literature on the existence of multiplicity of equilibria by providing an alternative theory centered on educational quality.[9] Second, from a theoretical and empirical perspective, our work focuses on human capital composition by differentiating between primary and higher education, although the former is modeled here in a reduced form.[10] This is so because primary schooling is publicly provided in most countries today.[11]

[6] Schoellman (2009) shows that the returns to schooling of US immigrants could be an appropriate estimate of education quality. Moreover, his accounting exercise demonstrates that quality adjusted schooling is very important in explaining income differences across countries. Cordoba and Ripoll (2007) calibrate the model to fit cross-country differences in demographic and educational variables, specifically, investment rates and schooling attainment. They find that demographic factors, in particular mortality rates, explain most of the differences.

[7] In contrast, Klenow and Rodríguez-Clare (1997) and Hall and Jones (1999) measure country-level human capital stocks by multiplying the mean years of schooling of the population by the estimated Mincer returns to schooling.

[8] Manuelli and Seshadri (2007), using a frictionless Ben-Porath framework, calibrate the human capital technology to match life-cycle earnings in the US. Erosa et al. (2006) by contrast, using a heterogeneous agent Bewley framework, calibrate the human capital technology to match cross-sectional heterogeneity in schooling and earnings in US data.

[9] For theoretical literature dealing with the impact of human capital investments under credit market restrictions and multiple steady states and poverty traps, see Galor and Zeira (1993), Mookherjee and Ray (2003) and Mookherjee and Napel (2006) among others. In contrast to these, Hidalgo (2009) shows that when credit market imperfections are endogenized, poverty traps may be avoided and intergenerational mobility may increase. Other papers that obtain multiple equilibria without assuming credit market restrictions include Galor and Tsiddon (1997), Moav (2002), or Castelló-Climent and Doménech (2008).

[10] In Manuelli and Seshadri (2007) human capital accumulaltion differs between early childhood and subsequent schooling. Erosa et al. (2006) distinguish cross-sectional heterogeneity in schooling in US data to restrict the parameters of the time share and returns to scale of the human capital production function.

[11] We abstract from modeling primary education decisions by assuming that it is compulsory and exogenously provided to individuals. Our results would not change qualitatively if primary education were financed publicly, since larger output would imply higher public resources to primary education.

Educational quality is liekely to be a factor influencing the distribution of human capital, and thus the level of development. And third, the predictions of our theory are tested on a broad sample of countries using regression analysis rather than quantitative analysis, which allows us to empirically test the channels and to control for other factors affecting the quantity and quality of education, thus minimizing omitted variables bias. While these two views can be seen as being at odds with each other, they are not mutually exclusive; in fact, both help us to understand the role of education quality on the development process.

Most of the empirical literature examining the potential effect of school quality on the quantity of education has focused on natural experiments and retrospective studies in a particular country. It has also been common to use input measures to assess the quality of schooling, that is, resources spent on schools and teacher and school characteristics (see e.g., Glewwe and Jacoby, 1994; Case and Deaton, 1999; Duflo, 2001; Hanushek et al., 2008). On the contrary, in this paper we directly measure quality as an outcome and not as a input, since the aim of any resources spent on schools is to improve the cognitive performance of students. Moreover, we use aggregate data on several countries at different stages of development to examine whether increases in the quality and quantity of education have the same effect at the initial levels of development as they do at later stages. As far as we know, we are the first to take a macroeconomic perspective to test the effect of the quality of schooling on the quantity of education at different levels of schooling, that is primary, secondary and tertiary schooling. In line with our theory, we find that our proposed channels through which quality affects the quantity of higher education may be quantitatively important. Furthermore, our results also suggest that the effect of quality and quantity on growth depends on the specific stage of development of the country.

3 The Model

We study a model in which growth dynamics result from physical capital accumulation as well as from human capital accumulation in a context where the quality of the educational system is an exogenous parameter. Our economy consists of one sequence of overlapping generations that live for two periods. In the first period, agents have primary education which is compulsory and exogenously provided. Moreover, they can invest in higher education by spending private resources, and there is a perfect capital market for human capital accumulation. In the second period, agents work and earn an income consistent with their human capital investment in the first period.

3.1 Production

In every period, the economy produces a single homogeneous good that can be used for consumption and investment, using the following production function

$$Y_t = K_t^{\alpha} H_t^{1-\alpha} = H_t k_t^{\alpha}, \tag{1}$$

where K_t, H_t are quantities of physical and human capital (measured in efficiency units) and employed in production at time t, k_t is the capital-labor ratio and $\alpha \in (0, 1)$. The production function is strictly monotone increasing, strictly concave and satisfies the neoclassical boundary conditions that assure the existence of an interior solution to the producers' profit-maximization problem.[12]

Producers operate in a perfectly competitive environment. Given the wage rate per efficiency unit of labor, and the rate of return to capital, in period t producers choose the level of employment of capital K_t and the efficiency units of labor H_t so as to maximize profits. The producers' inverse demand for factors of production is therefore given by

$$\begin{aligned} r_t &= f'(k_t) = \alpha k_t^{\alpha-1}, \\ w_t &= f(k_t) - f'(k_t)k_t = (1-\alpha)k_t^{\alpha}, \end{aligned} \tag{2}$$

where r_t is the rate of return to capital and w_t is the wage rate per efficiency unit of labor. For simplicity, we assume that capital depreciates fully on use $\delta = 1$, and thus $R_{t+1} = 1 + r_{t+1} - \delta = r_{t+1}$.

3.2 Individuals

In every period a generation, consisting of a continuum of individuals of measure 1, is born. Each individual has a single parent and a single child. Individuals are identical in preferences, within as well as across generations, but they differ in inherited wealth as well as in abilities. We denote ability type as a_j with $j = H, L$. Agents can be of a high ability type a_H, which occurs with probability γ or of a low ability a_L type, with probability $1 - \gamma$.

Agents live for two periods. In the first period of their lives, individuals devote their entire time to the acquisition of human capital, which is measured in efficiency units. The first period of their lives, which is a period in which they make decisions on whether or not to acquire higher education, agents receive primary education. Higher education requires private investments in education instead. Thus, even in the absence of expenditures, all individuals acquire some efficiency units of basic labor skills, which we interpret as primary education. We motivate this interpretation with the evidence that most societies publicly finance primary education and make it compulsory.

In the second period of their lives (adulthood), individuals supply their efficiency units of labor and allocate the resulting wage income, along with their inheritance and capital income, between consumption c_{t+1}^i and bequest to their children, b_{t+1}^i where the upper index i refers to the individual. The preferences of individual i are given by[13],

$$u_t^i = (1-\beta)\ln c_{t+1}^i + \beta \ln b_{t+1}^i,$$

where $\beta \in (0,1)$. The budget constraint is given by,

$$c_{t+1}^i + b_{t+1}^i \leq y_{t+1}^i.$$

Notice that by using FOC, a fixed fraction β of total income is saved $b_{t+1}^{i*} = \beta y_{t+1}^i$ and the remaining income is consumed $c_{t+1}^{i*} = (1-\beta) y_{t+1}^i$, such that the indirect utility function can be

[12] For models where growth is given by physical and human capital accumulation and educational attainment increase with income, see Galor and Moav (2004) and Galor et al. (2008).

[13] This "joy-of-giving" altruism is the common form discussed in the literature on income distribution. It is supported empirically by Altoniji et al. (1997).

written as

$$U_t^i = \ln(1-\beta)^{1-\beta}\beta^\beta y_{t+1}^i.$$

3.3 Formation of human capital

We allow each level of schooling to have a different return, depending on whether the level of schooling corresponds to primary or to higher levels of education. If agents choose to invest in higher education, they need to decide what level of expenditures to make, which in our model is given by the variable I_t. We assume that the higher this investment, the higher the quantity of higher education per person.[14]

Higher education schooling formation of human capital is modeled in a reduced form, since the production function of secondary and tertiary education is given by equation (3). Differences between these two levels of schooling are due to differences in the investments in education, such that the higher I_t, the higher the schooling level attained. Alternatively, we can introduce investments in time spent on schooling in the production function of human capital. We have chosen the first formulation to stress that even with perfect capital markets, educational quality may play a crucial role in schooling decisions.[15] The production function for higher education is given by

$$h_{t+1,j}^{high} = \theta a_j I_t^\varepsilon \text{ with } j = H, L \text{ and } 0 < \varepsilon < 1. \quad (3)$$

The parameter ε measures the degree of concavity of the production function with respect to the amount of resources invested. The human capital production function also depends on the quality of the educational system, which is exogenous and measured by θ, and the level of ability a_j. Although the marginal return to schooling diminishes with the level of schooling, rising school quality shifts the marginal return to schooling upward over all educational levels.[16] Clearly, talented individuals have higher total and marginal returns on higher education than less talented ones.

The efficiency units of labor suplied by the agent with primary education are given by

$$h_{t+1,j}^{pri} = \theta a_j \mu^\varepsilon \text{ with } j = H, L,$$

such that in absence of expenditures, agents supply their primary efficiency units of education.

The aggregate stock of efficiency units of human capital will be the sum of primary and higher levels of education.

[14] Using data from Education at a Glance (2009), the correlations between public and private expenditures on secondary and tertiary educational institutions as a percentage of GDP in the year 1995 and enrollment rates in secondary and tertiary education are 0,516 and 0,575, respectively.

[15] If time were the input in the production of human capital, the qualitative results would not be affected, as long as the time invested in the formation of human capital increases with the capital labor ratio.

[16] Some studies provide evidence on the impact of test performance on earnings, using nationally representative datasets for the US (e.g., Mulligan 1999, Murnane et al. 2000, Lazear 2003). Even controlling for the quantity of schooling, the experience of workers and other factors that can influence earnings, these studies find that higher quality —as measured by cognitive test scores— has a clear impact on earnings. See Hanushek and Woessman (2008) for an overview of this literature.

3.4 Investment decisions

We assume that capital markets are perfect. While this assumption is far from reality, we assume it to emphasize the role of the quality of the educational system.[17] The main implication of this assumption is that when agents decide to invest beyond primary education, everybody makes the optimal investment such that the current gross interest rate equals the expected marginal product of human capital so as to maximize expected income irrespective of one's initial wealth. Consequenlty, the allocation of productive capital between agents is independent of the current distribution of wealth levels, and what really matters is aggregate wealth.

The individual's optimization can be done backwards in two stages: after the decision on how to allocate the second period income between consumption and bequest, the individuals decide whether to purchase higher education or not. Therefore when agents decide whether or not to invest in higher education, they solve the following maximization problem for a given level of wages and interest rate

$$Max_{\{I_t\}} \quad y^i_{t+1} = w_{t+1}h^{high}_{t+1,j} - R_{t+1}(I_t - b^i_t).$$

Notice that in the presence of the log utility function and perfect capital markets, efficient human capital accumulation decisions are those that maximize the lifetime income of the individual. The optimal amount of higher education, I_t equates the marginal return to physical capital and human capital,

$$w_{t+1}\theta\varepsilon I_t^{\varepsilon-1}a_j = R_{t+1}. \tag{4}$$

This FOC tells us that the optimal investment is given when the opportunity cost of investing in higher education (R_{t+1}) is equal to the marginal returns thereof. The following equation gives us the optimal level of investment in higher education

$$I^*_{t,a_j} = (\frac{w_{t+1}\theta\varepsilon a_j}{R_{t+1}})^{\frac{1}{1-\varepsilon}}. \tag{5}$$

Notice that the optimal level of investment in higher education needs to satisfy $I^*_{t,a_j} > \mu$, such that once spending exceeds a certain level —here set equal to the primary level of education μ—, the individual accumulates higher schooling, that is $h^{high}_{t+1,j} > h^{pri}_{t+1,j}$ —although with diminishing returns since $\varepsilon < 1$.

The optimal level of higher education is increasing with ability, such that talented individuals choose longer schooling periods. Indeed, consistent with empirical evidence, a positive relationship exists between cognitive ability and college attendance for all family income and wealth levels in both the NLSY79 and NLSY97 (see Carneiro and Heckman, 2002, and Belley and Lochner, 2007). As expected, the optimal investment is increasing with the wage rate and decreasing with the opportunity cost of the educational investment. Notice that education quality is a force that causes higher educational investment to increase. Since the quality of the educational system positively affects the returns on education, investments in higher education increase with quality. Note that the optimal investment in higher education is independent of inherited wealth in the context of perfect capital markets.

[17] Adding imperfections in the capital markets would reinforce our results.

Individuals make the optimal schooling choice that maximizes their indirect utility, and thus choose higher education over primary education when the following condition holds,

$$U_t^i(\textit{higher education}) \geq U_t^i(\textit{primary education}),$$

$$\ln(1-\beta)^{\beta}\beta^{1-\beta}\{w_{t+1}\theta I_{t,a_j}^{*\varepsilon}a_j - R_{t+1}(I_{t,a_j}^{*} - b_t^i)\} \geq \ln(1-\beta)^{\beta}\beta^{1-\beta}\{w_{t+1}\mu^{\varepsilon}a_j + R_{t+1}b_t^i\},$$

$$\theta \geq \widetilde{\theta}_j = \frac{\mu^{1-\varepsilon}}{a_j\varepsilon(1-\varepsilon)^{\frac{\varepsilon}{1-\varepsilon}}}\left(\frac{R_{t+1}}{w_{t+1}}\right). \tag{6}$$

Let us denote the threshold level of quality by $\widetilde{\theta}_j$. As is clear from the expression above, this level depends on the type of individuals through differences in ability. In particular, it decreases with ability since talented agents have more incentives to invest in higher education. This critical value of education quality is increasing in the opportunity cost of higher education R_{t+1}. That is, an increase in the interest rate tightens the constraints on higher investment. On the other hand, when the wage per efficiency unit of labor increases, the constraint on education loosens since with higher wages the returns on investments in higher education are higher as well. Finally, it is independent of inherited wealth due to the assumption of perfect capital markets.

The next proposition summarizes the optimal decisions on levels of education for the agents when the variables w_{t+1}, R_{t+1} are given. It states that education quality is a crucial variable in determining educational choices and thus human capital composition.

Proposition 1 *[Human capital composition and educational quality]. For a given level of* w_{t+1}, R_{t+1}, *the composition of human capital depends on the quality of the school system in the following way.*

Regime I) If $\widetilde{\theta}_{a_H} > \theta$ *holds, that is when the quality is relatively low, all agents invest in primary education.*

Regime II) If $\widetilde{\theta}_{a_L} > \theta \geq \widetilde{\theta}_{a_H}$ *holds, only talented agents invest in higher education, while low ability agents get primary schooling.*

Regime III) If $\theta \geq \widetilde{\theta}_{a_L}$ *holds, that is when the quality is high enough, all agents invest in higher education.*

Proof. *It follows from the maximization problem of the individual described above.*

In short, the next proposition explains the channels through which quality affects education. On the one hand, high educational quality expands access to higher education to more people. And conversely, relatively low educational quality discourages investments in higher levels of education since it decreases the returns on higher education. As a result, people could get stuck at the primary level. We refer to this as the extensive channel. On the other hand, educational quality also affects the intensity of human capital formation beyond primary school, since a high-quality educational system raises the schooling level attained by each agent. We call this the intensive channel.

Proposition 2. *[Channels through which quality affects the quantity of education]. The quality of the educational system affects schooling decisions through two different channels: a) the extensive channel since, other things being equal, higher quality increases the number of people with higher education, creating a broader segment of the population with a higher education. Indeed, for relatively low levels of educational quality, that is $\theta < \widetilde{\theta}_{a_H}$, educational quality acts as a barrier to investment in higher education, and b) the intensive channel since, other things being equal and once people decide to invest in higher education, quality affects the depth of human capital formation beyond primary school. That is, high-quality educational system raises the schooling level attained per person,* $\frac{\partial I^*_{t,a_j}}{\partial \theta} > 0$.

Proof. *See Proposition 1 and equation (5)*

We will check whether these two channels are supported by the empirical data.

4 General Equilibrium

Up to now, we have analyzed partial equilibrium, showing that quality is an important variable explaining the human capital composition. This is so because first, educational quality below a threshold would imply that some agents would prefer to remain with primary education, and second better educational quality implies a larger level of investment in higher schooling per person. In general equilibrium, both results are reinforced since higher quality would entail a change in prices that provides incentives for agents to invest in higher education.

4.1 The economy's output accumulation path

Proposition 1 shows that the human capital composition depends on the level of education quality, and thus, among other factors, on the rate of return to capital R_{t+1}, and the wage rate w_{t+1}, which in turn depends on the stock of capital per capita k_{t+1}. As we show in this section, the economy's capital accumulation path depends on the educational decisions of the agents. Therefore, taking proposition 1 into account, we distinguish three different paths for the economy.

Regime I) If $\theta < \widetilde{\theta}_{aH}$

If the above inequality holds, all agents obtain primary education, and the growth process is driven by the accumulation of physical capital. Since we assume a closed economy and $\delta = 1$, the aggregate capital stock at $t+1$ comes from aggregate savings, which are given by the aggregate level of bequest

$$K_{t+1} = \gamma \int_0^\infty b_t^i dG(b_t^i) + (1-\gamma) \int_0^\infty b_t^i dG(b_t^i) = B_t = \beta Y_t,$$

where $G(b_t^i)$ is the distribution function of bequest, the fraction of the population with current wealth below b_t^i. The aggregate stock of human capital is given by

$$H_{t+1} = \gamma h_{t+1}^{i,pr} + (1-\gamma) h_{t+1}^{i,pri} = \gamma \theta a_H \mu^\varepsilon + (1-\gamma) \theta a_L \mu^\varepsilon.$$

And the capital-labor ratio is as follows

$$k_{t+1} = \frac{\beta Y_t}{\theta \overline{a} \mu^{\varepsilon}} = k^I(Y_t, \theta),$$

where $\overline{a} = \gamma a_H + (1-\gamma) a_L$. The law of motion of the capital-labor ratio can be written as $k_{t+1} = k^I_{t+1}(Y_t, \theta)$.

Aggregate output per capita is given by

$$Y_{t+1} = (\beta Y_t)^{\alpha} (\theta \overline{a} \mu^{\varepsilon})^{1-\alpha}. \tag{7}$$

The law of motion of output per capita under Regime I is $Y_{t+1} = Y^I(Y_t, \theta)$, and its steady state is unique and given by $Y^I_{ss} = \theta \mu \overline{a} \beta^{\frac{\alpha}{1-\alpha}}$. Notice that the steady state is increasing with the aggregate stock of human capital as well as with the marginal propensity to save β.

Regime II) If $\widetilde{\theta}_{aL} > \theta \geq \widetilde{\theta}_{a_H}$

Under this regime, only talented individuals invest in higher education. The aggregate stock of capital is given by,

$$K_{t+1} = \gamma \int_0^{\infty} (b^i_t - I^*_{t,a_H}) dG(b^i_t) + (1-\gamma) \int_0^{\infty} b^i_t dG(b^i_t) = B_t - \gamma I^*_{t,a_H} = \beta Y_t - \gamma I^*_{t,a_H}$$

Here, we are summing up the total savings among all members of the economy: the high ability type, which occurs with probability γ, and the low ability type, which occurs with probability $1-\gamma$. We remove I^*_{t,a_j} from the integral, since it is independent of bequest.

We add across people using the population share in each schooling category to obtain an aggregate measure of human capital

$$H_{t+1} = \gamma h^{high}_{t+1} + (1-\gamma) h^{pri}_{t+1} = \gamma \theta a_H I^{*\varepsilon}_{t,a_H} + (1-\gamma) \theta a_L \mu^{\varepsilon}.$$

Notice that the optimal level of investment depends on the capital-labor ratio, k_{t+1}, through the rate of return to capital and the wage rate per efficiency units of labor. Using equation (2) we can rewrite the optimal investment which is increasing in the stock of physical capital per efficiency unit, k_{t+1} and takes the form,

$$I^*_{t,a_j} = (\frac{\theta \varepsilon (1-\alpha) a_j}{\alpha} k_{t+1})^{\frac{1}{1-\varepsilon}} \text{ with } j = H, L, \tag{8}$$

where k_{t+1} is given by the following capital-labor ratio is

$$k_{t+1} = \frac{\beta Y_t - \gamma I^*_{t,a_H}}{\gamma \theta a_H I^{*\varepsilon}_{t,a_H} + (1-\gamma) \theta a_L \mu^{\varepsilon}} = k^{II}(Y_t, \theta).$$

The capital-labor ratio is a function of the following variables $k_{t+1} = k^{II}(Y_t,\, k_{t+1},\, \theta)$, since I^*_{t,a_j} is strictly increasing in k_{t+1} (see equations 5 and 2), therefore $k_{t+1} = k^{II}(Y_t,\, \theta)$. It is easy to check that $\partial K_{t+1}/\partial k_{t+1} < 0, \partial H_{t+1}/\partial k_{t+1} > 0$ and $\partial k_{t+1}/\partial \theta < 0$, $\partial k_{t+1}/\partial Y_t > 0$, $\partial k_{t+1}/\partial a_j < 0$.

Aggregate output per capita is given by

$$Y_{t+1} = (\beta Y_t - \gamma I^*_{t,a_H})^{\alpha}(\gamma\theta a_H I^{*\varepsilon}_{t,a_H} + (1-\gamma)\theta a_L \mu^{\varepsilon})^{1-\alpha}. \tag{9}$$

The law of motion under Regime II of the aggregate output is $Y_{t+1} = Y^{II}(Y_t, \theta)$.

Regime III) If $\theta \geq \widetilde{\theta}_{a_L}$

If the above inequality holds, all agents invest in higher education. Thus, aggregate capital stock under the path of Regime III is given by the following expression

$$K_{t+1} = \gamma \int_0^{\infty} (b^i_t - I^*_{t,a_H}) dG(b^i_t) + (1-\gamma)\int_0^{\infty} (b^i_t - I^*_{t,a_L}) dG(b^i_t) = B_t - \gamma I^*_{t,a_H} - (1-\gamma) I^*_{t,a_L} = \beta Y_t - \gamma I^*_{t,a_H} - (1-\gamma) I^*_{t,a_L}.$$

The aggregate stock of human capital is given by

$$H_{t+1} = \gamma h^{high}_{t+1} + (1-\gamma) h^{high}_{t+1} = \gamma\theta a_H I^{*\varepsilon}_{t,a_H} + (1-\gamma)\theta a_L I^{*\varepsilon}_{t,a_L}.$$

Notice that the optimal level of investment depends on the capital-labor ratio, k_{t+1}, through the rate of return to capital and the wage rate per efficiency units of labor. The capital-labor ratio k_{t+1} is given by the following equation

$$k_{t+1} = \frac{\beta Y_t - \gamma I^*_{t,a_H} - (1-\gamma) I^*_{t,a_L}}{\gamma\theta a_H I^{*\varepsilon}_{t,a_H} + (1-\gamma)\theta a_L I^{*\varepsilon}_{t,a_L}}. \tag{10}$$

The capital-labor ratio is a function of the following variables $k_{t+1} = k^{III}(Y_t,\, k_{t+1},\, \theta)$, since I^*_{t,a_j} is strictly increasing in k_{t+1} (see equation 5 and 2), therefore $k_{t+1} = k^{III}(Y_t,\, \theta)$.

Aggregate output per capita is given by

$$Y_{t+1} = (\beta Y_t - \gamma I^*_{t,a_H} - (1-\gamma) I^*_{t,a_L})^{\alpha}(\gamma\theta a_H I^{\varepsilon}_{t,a_H} + (1-\gamma)\theta a_L I^{\varepsilon}_{t,a_L})^{1-\alpha}.$$

The next proposition explains the dynamics of aggregate output per person and shows that there exists a unique, stable steady-state equilibrium.

Proposition 3 *[Stability of Regime III]. Under Regime III, the aggregate output per worker is given by the following law of motion $Y_{t+1} = Y^{III}(Y_t,\, \theta)$. The value Y^{III}_{ss} is given by a unique and locally stable equilibrium.*

Proof. *See Appendix.*

The next proposition states that under Regime III, all agents choose the optimal level of higher education and output per capita is maximized. Moreover, this aggregate output per capita depends on the quality of the system in two different ways: in a direct way, through the aggregate level of human capital, and in an indirect way, through the optimal level of education, $I^*_{t,aj}$. However, the next corollary shows that due to the envelope theorem, the indirect effect disappears.

Proposition 4. *Under Regime III the output per capita is maximized.*

Proof. *See Appendix.*

Corollary 1. *[Comparative statics of quality on aggregate output per capita]. An increase in the quality of the educational system, moves the path of the economy upwards under Regime III solely through the direct effect of quality on the stock of human capital of higher education.*

The proposition and the corollary that follows compare the output per worker in the three regimes.

Proposition 5. *[Comparing Regime I and III]. The economy under Regime III yields a higher physical and human capital accumulation and a higher output per worker than the economy under Regime I. Moreover, for a given Y_t, $Y_{t+1}^{III} > Y_{t+1}^{I}$* for every t *and hence it implies that $Y_{ss}^{III} \geqq Y_{ss}^{I}$ also holds.*

Proof. *See Appendix.*

Corollary 2. S*ince Regime II is the mixed regime between Regime I and Regime II, then $Y_{t+1}^{III} \geqq Y_{t+1}^{II} \geqq Y_{t+1}^{I}$ holds at any t.*

4.2 Endogenous wages and interest rates

The interest rate and the wage per efficiency unit of education are functions of the aggregate output per capita, since k_{t+1} is a strictly increasing function of Y_t,

$$\begin{aligned} r_{t+1} &= \alpha(k_{t+1})^{\alpha-1} = r(Y_t), \\ w_{t+1} &= (1-\alpha)(k_{t+1})^{\alpha} = w(Y_t), \end{aligned} \tag{11}$$

The last proposition shows that the quantity of higher education is determined by educational quality, as well as by equilibrium prices.

Proposition 6. *[General Equilibrium Price Effect]. Other things equal, the optimal amount of resources spent on higher education is affected by prices through general equilibrium effects, which in turn depend on the aggregate level of per capita output $I_{t,a_j}^* = I_{t,a_j}^*(\theta, Y_t)$. In particular, it is increasing with Y_t.*

Proof of Proposition 6. *See equation 5 and 10.*

Substituting equation 2 into the value of the threshold level of quality of the educational system, we obtain

$$\widetilde{\theta}_{a_j} = \frac{\mu^{1-\varepsilon}}{a_j(1-\varepsilon)\varepsilon^{\frac{\varepsilon}{1-\varepsilon}}(1-\varepsilon)}\left(\frac{\alpha}{(1-\alpha)k_{t+1}}\right) \tag{12}$$

Clearly $\widetilde{\theta}_{a_H} < \widetilde{\theta}_{a_L}$ and the threshold is decreasing with k_{t+1}. Figure 2 shows the dynamics of the critical values for talented and untalented individuals as a function of per capita output. The threshold level of education quality varies systematically with the level of development. In particular, it is decreasing with Y_t since as output per capita increases, the equilibrium prices change since the interest rate decreases and wages increases. As a result, the threshold $\widetilde{\theta}_{a_j}$ is relaxed as the economy develops.

[*Insert Figure* 2]

Since k_{t+1} is a strictly increasing function of Y_t, we can write the critical value $\widetilde{\theta}_{aj}$ as a function of Y_t , that is, $\widetilde{Y}_{aj}(\cdot)$, which is the threshold level of per capita output above which the agent with ability j invest in higher education. From Figure 2, we need to consider the three following cases: a) **Regime I:** $\theta \leq \widetilde{\theta}_{a_H} < \widetilde{\theta}_{a_L}$ (or similarly $Y_t \leq \widetilde{Y}_{a_H} < \widetilde{Y}_{a_L}$), with all agents with primary education, b) **Regime II:** $\widetilde{\theta}_{a_H} < \theta < \widetilde{\theta}_{a_L}$ (that is, $\widetilde{Y}_{a_H} < Y_t < \widetilde{Y}_{a_L}$), with only talented individuals with higher education and c) **Regime III:** $\widetilde{\theta}_{a_H} < \widetilde{\theta}_{a_L} \leq \theta$ (or similarly $\widetilde{Y}_{a_H} < \widetilde{Y}_{a_L} \leq Y_t$), where all agents have higher education.

The optimal level of investment in higher education needs to satisfy $I^*_{t,a_j} > \mu$. By substituting equation (5) into the inequality $I^*_{t,a_j} > \mu$, it becomes $\theta > \widetilde{\widetilde{\theta}}_{a_j} = \frac{\mu^{1-\varepsilon}}{a_j \varepsilon}\left(\frac{R_{t+1}}{w_{t+1}}\right)$, with $\widetilde{\widetilde{\theta}}_{a_j}$ monotonically decreasing with Y_t.

In order to better understand the optimal decisions of the individuals under each regime, it is important to know the order of the parameters $\widetilde{\theta}_{a_j}$ and $\widetilde{\widetilde{\theta}}_{a_j}$. Clearly $\widetilde{\theta}_{a_L} > \widetilde{\theta}_{a_H}$ and $\widetilde{\widetilde{\theta}}_{a_L} > \widetilde{\widetilde{\theta}}_{a_H}$ always holds. Furthermore, since $\frac{1}{(1-\varepsilon)^{\frac{\varepsilon}{1-\varepsilon}}} > 1$ the following inequality holds $\widetilde{\theta}_{a_j} > \widetilde{\widetilde{\theta}}_{a_j}$ too. Therefore, we can have the following possibilities: either $\widetilde{\theta}_{a_L} > \widetilde{\widetilde{\theta}}_{a_L} > \widetilde{\theta}_{a_H} > \widetilde{\widetilde{\theta}}_{a_H}$ or $\widetilde{\theta}_{a_L} > \widetilde{\theta}_{a_H} > \widetilde{\widetilde{\theta}}_{a_L} > \widetilde{\widetilde{\theta}}_{a_H}$.

We assume that the parameters satisfy the following inequality

$$\frac{1}{(1-\varepsilon)^{\frac{\varepsilon}{1-\varepsilon}}} < \frac{a_H}{a_L} \tag{13}$$

Under $A1$ the following order of the parameters holds: $\widetilde{\theta}_{a_L} > \widetilde{\widetilde{\theta}}_{a_L} > \widetilde{\theta}_{a_H} > \widetilde{\widetilde{\theta}}_{a_H}$ (or similarly $\widetilde{Y}_{a_L} > \widetilde{\widetilde{Y}}_{a_L} > \widetilde{Y}_{a_H} > \widetilde{\widetilde{Y}}_{a_H}$).[18]

Under Regime I since the expression $\widetilde{\theta}_{a_H} > \theta$ holds, all agents obtain only primary education. We can distinguish two cases in Regime I. The first case is when the quality of the educational system takes the lowest possible value, specifically $\widetilde{\theta}_{a_L} > \widetilde{\widetilde{\theta}}_{a_L} > \widetilde{\theta}_{a_H} > \widetilde{\widetilde{\theta}}_{a_H} > \theta$. Since $\widetilde{\widetilde{\theta}}_{a_H} > \theta$ also implies that $\widetilde{\widetilde{\theta}}_{a_L} > \theta$ holds, then for all agents $\widetilde{\widetilde{\theta}}_{a_j} > \theta$. This last expression is equivalent to $I^*_{t,a_j} < \mu$. Substituting equation (5), this last inequality translates into the expression $w_{t+1} a_j \varepsilon \theta \mu^{\varepsilon-1} < R_{t+1}$, which is the FOC at the limit when $I_{t,a_j} = 0$ (see equation 4). As a result, all agents would optimally invest just in physical capital. Furthermore, $I^*_{t,a_j} < \mu$ implies that the indirect utility is higher under primary schooling (i.e. $\widetilde{\theta}_{a_j} > \theta$) such that low and high ability agents choose primary education.

In the second case of Regime I, that is when $\widetilde{\theta}_{a_H} > \theta > \widetilde{\widetilde{\theta}}_{a_H}$ holds, the argument of case one at Regime I remains for low ability agents since $\widetilde{\theta}_{a_L} > \widetilde{\widetilde{\theta}}_{a_L} > \widetilde{\theta}_{a_H} > \theta$ holds. For high ability agents, on the other hand the inequality $\widetilde{\theta}_{a_H} > \theta$ is equivalent to $U_{t,a_H}(higher) > U_{t,a_H}(primary)$ —see equation 6. However, the inequality $\theta > \widetilde{\widetilde{\theta}}_{a_H}$ means that $I^*_{t,a_H} > \mu$. The reason of why high ability agents prefer primary education despite the fact that $I^*_{t,a_H} > \mu$ holds, is that at low levels of development the capital labor ratio would be relatively low, which in turn would imply that the optimal level of investment in human capital would be relatively low as well (i.e. $I^{*'}_{t,a_H}(k_{t+1}) > 0$). As a result, the first best level of investment is not enough to compensate the cost of repaying the debt of the loan $R_{t+1} I^*_{t,a_H}$ (notice that even if I^*_{t,a_H} is low, interest rates R_{t+1} are high since $R^{'}_{t+1}(k_{t+1}) < 0$). Consequently, when comparing primary and higher education, high ability agents optimally choose the option of obtaining just primary education.

[18] By assuming the following order $\widetilde{\theta}_{a_L} > \widetilde{\theta}_{a_H} > \widetilde{\widetilde{\theta}}_{a_L} > \widetilde{\widetilde{\theta}}_{a_H}$, the results would not change qualitatively.

Under Regime II since $\widetilde{\theta}_{a_L} > \theta \geq \widetilde{\theta}_{a_H}$ holds, only talented agents invest in higher education and low ability agents only obtain primary schooling. That is, since $\theta > \widetilde{\theta}_{a_H}$ holds, high ability agents prefer to invest in higher education, and the optimal amount of investment in higher education satisfies $I^*_{t,a_H} > \mu$.

For low ability agents we can distinguish two cases under Regime II. In the first case, education quality is in the range $\widetilde{\theta}_{a_L} > \widetilde{\widetilde{\theta}}_{a_L} > \theta \geq \widetilde{\theta}_{a_H}$. The condition $\widetilde{\widetilde{\theta}}_{a_L} > \theta$ is equivalent to $I^*_{t,a_L} < \mu$, which in turn becomes, $w_{t+1}a_L\varepsilon\theta\mu^{\varepsilon-1} < R_{t+1}$, which is the FOC at the limit when $I_{t,a_L} = 0$. Moreover the condition $\widetilde{\widetilde{\theta}}_{a_L} > \theta$ implies that $\widetilde{\theta}_{a_L} > \theta$ holds, which means that low ability agents would optimally choose primary schooling.

The second case is when $\widetilde{\theta}_{a_L} > \theta > \widetilde{\widetilde{\theta}}_{a_L}$ holds. The inequality $\theta > \widetilde{\widetilde{\theta}}_{a_L}$ is equivalent to $w_{t+1}a_L\varepsilon\theta\mu^{\varepsilon-1} > R_{t+1}$. But at the same time $\widetilde{\theta}_{a_L} > \theta$ means that low ability agents prefer primary education. The argument applied under Regime I for high ability agents now is applied to less able agents. Specifically, the first best level of investment is not enough to compensate the cost of repaying the debt of the loan $R_{t+1}I^*_{t,a_L}$ (notice that even if I^*_{t,a_L} is low, interest rates R_{t+1} are high since $R'_{t+1}(k_{t+1}) < 0$). Consequently, when comparing primary and higher education, low ability agents optimally choose the option of getting just primary education.

Under Regime III since $\theta \geq \widetilde{\theta}_{a_L} > \widetilde{\widetilde{\theta}}_{a_L} > \widetilde{\theta}_{a_H} > \widetilde{\widetilde{\theta}}_{a_H}$ holds, low and high ability agents choose higher education and invest the optimal amount. That is, since $\frac{1}{(1-\varepsilon)^{\frac{\varepsilon}{1-\varepsilon}}} > 1$ holds, $\theta \geq \widetilde{\theta}_{a_j}$ implies that the optimal level of investment always satisfies $I^*_{t,a_j} > \mu$.

5 The Evolution of Output per Worker

5.1 The dynamics of output per worker

In this section, we discuss the most interesting equilibrium dynamics paths. The dynamic path of output per worker is not unique since it will depend upon the initial output per worker, Y_0, and on how the variables $\widetilde{Y}_{a_H} < \widetilde{Y}_{a_L}$ and Y^{III}_{ss}, Y^{II}_{ss}, Y^{I}_{ss} are related. From the analysis above, we know that $Y^{III}_{ss} > Y^{II}_{ss} > Y^{I}_{ss}$ and that $\widetilde{Y}_{a_H} < \widetilde{Y}_{a_L}$ holds.

[*Insert Figure* 3, 4]

Let us consider the following order of the parameters:

A. $\widetilde{Y}_{a_H} < \widetilde{Y}_{a_L} < Y^{I}_{ss} < Y^{II}_{ss} < Y^{III}_{ss}$.

We assume that the initial output per worker Y_0 is below the value $\widetilde{Y}_{a_H}$, such that the economy is in Regime I, characterized by a low level of aggregate output. At this stage of development, growth is due only to the investment in physical capital, and agents optimally attend only primary education. As output per worker increases, the threshold level of educational quality decreases, and thus, it becomes feasible for high ability agents to invest in secondary education. Consequently, the economy is entering Regime II where less talented individuals remain with primary education and others progress to higher levels. Along this transition from Regime I to Regime II, the output per capita is pushed up to a higher dynamic path. Higher output increases the returns from investment in education while its cost gets reduced, such that low ability agents reallocate their resources toward investments in higher education. As a result, the economy achieves the last stage of development, Regime III, where all its agents make the first-best investment in higher levels of schooling. It is worth noting that at this last stage of development, the amount invested in higher education per agent is higher than in Regime II. This is because higher output increases the investment in higher education through the general equilibrium price effect. Moreover, once the economy reaches Regime III and all agents are investing the optimal amount in higher education, it will remain in this regime thereafter. As a result, we could interpret the investment in higher education in Regime II as secondary education, and the one in Regime III as tertiary education.

Clearly, Figure 3 shows us the interdependence among economic growth, the distribution of educational attainment, and the quality of the educational system. It occurs because the stock of human capital increases as we move along the three development paths, since first more people access to higher education —extensive channel—, and second since each agent attains a higher level of schooling, due to the general equilibrium price effect —intensive channel—.

We can analyze how an exogenous variation in quality affects the economy. Its effects depend on the stage of the development process. When the quality of the educational system is in the range $\theta < \widetilde{\widetilde{\theta}}_{a_j}$ —that is, when the rate of return to human capital is lower than the rate of return to physical capital for agent j—, an increase in education quality changes prices —specifically wages increase and interest rates decrease— through an increase in output per capita. A similar effect occurs under Regime III. However, if the economy is in the region $\widetilde{\widetilde{\theta}}_{a_j} < \theta < \widetilde{\theta}_{a_j}$ then an increase in quality could imply that either low or high ability agents would decide to seek higher education as well. As a consequence, at this stage of development, apart from changes in prices we could also have a more efficient reallocation of resources since the increase in output could further increase the incentives to invest in higher education.

B. $Y_{ss}^{I} < \widetilde{Y}_{a_H} < Y_{ss}^{II} < \widetilde{Y}_{a_L} < Y_{ss}^{III}$

We assume that the initial output per worker Y_0 is below the value Y_{ss}^{I}. In this case the economy has reached the steady state level of output per worker before the output per worker reaches the value $\widetilde{Y}_{a_H}$. As a result, for any level of aggregate output below $\widetilde{Y}_{a_H}$ the economy converges to the low stable steady state Y_{ss}^{I}, where agents obtain only primary education. The second stable steady state is associated with Regime II and for any level of output between the thresholds $\widetilde{Y}_{a_H}$ and $\widetilde{Y}_{a_L}$, the economy converge to Y_{ss}^{II}. Finally, for any level of output above $\widetilde{Y}_{a_L}$ the economy converges to the highest stable steady state under Regime III, Y_{ss}^{III}.

It is interesting to analyze the conditions under which the dynamic of B prevails, which basically means analyzing the conditions under which Y_{ss}^{I} and $\widetilde{Y}_{a_H}$ are far away from one another. This may occur when the marginal propensity to save is low, since it would imply that Y_{ss}^{I} would be very low as well and that $\widetilde{Y}_{a_H}$ is independent of β. The reason is clear: since the driving force of growth under Regime I is physical capital accumulation, economies with a low savings rate will accumulate physical capital, and thus per capita output at a lower rate. Another possibility is a low quality educational system θ. It could trap the economy at a low level of development since with an initially very low quality of the educational system, the level of Y^I_{ss} will be very low and the value of $\widetilde{Y}_{a_H}$ will be high (see Figure 2).

This paper therefore, suggests that low educational quality could adversely affect a country's process of development. In the following, we will text empirically whether educational quality affects the growth process, distinguishing among critical values for educational quality.

5.2 Results to be tested

i) Channels through which quality affects human capital composition:

$H1$: Other things being equal, in countries with relatively low quality the proportion of people with completed secondary schooling is low — extensive channel. Moreover, as output increases quality becomes less important as a barrier to investment in higher levels of education —general equilibrium effect.

$$\theta \gtreqless \widetilde{\theta}_j = \frac{\mu^{1-\varepsilon}}{a_j \varepsilon (1-\varepsilon)^{\frac{1-\varepsilon}{\varepsilon}}} \frac{R_{t+1}}{w_{t+1}} = \widetilde{\theta}_{a_j}(\underset{-}{Y_t}).$$

$H2$: Others things being equal and once people decide to invest in higher education, (a) higher quality increases the investment rates in higher education –intensive channel, (b) higher output increases the investment rates in higher education —general equilibrium effect:

$$I^*_{t,a_j} = \left(\frac{w_{t+1}\theta\varepsilon a_j}{R_{t+1}}\right)^{\frac{1}{1-\varepsilon}} = I(\underset{+}{\theta}, \underset{+}{Y_t}...).$$

ii) Effect of quality and quantity on output:

$H3$: Other things being equal, in countries with relatively high quality, the level of output is going to be higher.

$$Y_{t+1} = \begin{cases} Y^I(Y_t, \theta) & if \quad Y_{t+1} < \widetilde{Y}_{a_H} \text{ or } \theta < \widetilde{\theta}_{a_H,t} \\ Y^{II}(Y_t, \theta) & if \quad \widetilde{Y}_{a_H} \leq Y_{t+1} < \widetilde{Y}_{a_L} \text{ or } \widetilde{\theta}_{a_H,t} \leq \theta < \widetilde{\theta}_{aL,t} \\ Y^{III}(Y_t, \theta) & if \quad \widetilde{Y}_{a_L} \leq Y_{t+1} \text{ or } \widetilde{\theta}_{a_L,t} \leq \theta. \end{cases}$$

$H4$: Other things being equal and once all agents invest in higher education and maximize income, the dynamic of output per worker is explained by educational quality —direct effect, since the indirect effect of quality through educational quantity disappears. In particular,

$$Y_{t+1} = Y^{III}(Y_t, \theta, \underbrace{I^*_{t,a_j}(\theta)}_{=0}).$$

6 Data and econometric model

6.1 Data

The predictions of our theoretical model regarding the influence of schooling quality on the quantity invested in education and its influence on the process of development are analyzed empirically for a broad sample of countries. One of the main drawbacks in this regard is that quality of schooling is difficult to measure, and data on educational quality across countries is scarce. The existing data on educational quality for a broad sample of countries comes from two main sources. The first includes measures of schooling inputs, such as expenditures per student, teacher-pupil ratio, and teachers´ salaries, among others. The second refers to direct measures of output or cognitive skills. In this paper, we use the second since it directly measures the knowledge acquired while in school. In fact, several papers conclude that more resources spent in school do not always improve students' performance (see, e.g., Hanushek, 1995).

Hanushek and Kimko (2000) is the first attempt to compile measures of quality of schooling across countries based on students' cognitive performance in various international tests of academic achievement in math and science. Originally, only 39 countries participated in international tests of academic achievement. Hanushek and Kimko (2000) extended these original measures to other countries by imputing missing values from international test score regressions. By combining all available information, these authors computed a single measure for 90 countries averaged over the period 1960-1991.[19]

We also use Barro and Lee's (2001) dataset, which compiles scores on the examinations in science, mathematics, and reading for students of different age groups in various years in 58 countries. In particular, the data refer to 13-14 year-old students' test scores in math and science available for the years 1964, 1982-1983, 1988, 1990-1991, and 1993-1998 for the math test, and for the years 1970-1972, 1984, 1988, 1990-1991, and 1993-1998 for the science test. The use of math and science and not the reading scores is derived from the idea that research activities and the creation of new ideas are important sources of growth (e.g., Romer, 1990).

While the aforementioned measures refer to students who are likely to be attending secondary education, there are no similar data available across countries for older students of university age. As an alternative, we measure university quality through international rankings that indicate universities' academic performance. The Shanghai Jiao Tong University Academic Ranking of World Universities (the Shanghai ranking) aggregates six different indicators of research performance at the university level, such as alumni and staff winning Nobel Prizes, highly cited researchers, and articles indexed in major citation indices.[20] The resulting academic rankings of the top 500 institutions are available annually since 2003. Although the weights used to compute the rankings are somewhat arbitrary, one of the advantages of the indexes is that they are computed from publicly available information. However, the main drawback is that they do not take into account countries' population and, therefore, they do not correct for a possible scale effect. To solve this problem, we use the methodology suggested by Aghion et al. (2007, 2009), which transforms the original index into a measure that can be interpreted as a fraction of the United States per capita performance.[21]

[19] Throughout the paper we use the quality variable QL2 taken from Table C-1 in Hanushek and Kimko (2000).

[20] The indicators of research performance include the number of alumni from the university winning Nobel Prizes in physics, chemistry, medicine, and economics, and Fields Medals in mathematics; the number of university faculty winning Nobel Prizes in the same fields; the number of articles (co-) authored by university faculty published in *Nature* and *Science*; the number of articles (co-) authored by university faculty published in the Science Citation Index Expanded and the Social Science Citation Index; the number of highly cited researchers from the university in 21 broad subject categories, and the academic performance with respect to the size of the university.

[21] For example, to compute the measure of Top 100, Aghion et al. (2007) take the best university in the top 100 of

We report the results using the transformed index of the top 100 and top 500 institutions.

Data on the quantity of education is taken from two different sources. As a measure of the stock of human capital, we use the share of individuals with a given level of schooling, proxied by data on the share of population aged 25 and above for whom primary, secondary, and tertiary is the highest level of school attained, as compiled by Barro and Lee (2001) from 1960-2000. The investment in education is proxied by enrollment rates in primary, secondary, and tertiary education, taken from Barro and Lee (1994) and updated with UNESCO data. As additional controls we add public spending on education as a share of GDP, taken from the World Development Indicators and Barro and Lee (1994), the share of total population living in urban areas, from Easterly and Sewadeh (2002), and several variables that will be discussed in detail in the next subsection.

For the estimation of the growth equation, we use data on real per capita GDP, the physical capital investment rate, the government share of real GDP, and exports plus imports divided by real GDP, all taken from the PWT 6.2. Finally, the inflation rate, measured as the annual growth rate of consumer prices, is taken from Easterly and Sewadeh (2002).

6.2 Econometric model

According to our theory, the quality of the educational system may affect the quantity of education via two channels. The first of these, the extensive channel, tells us that low educational quality may act as a barrier to investment decisions in higher education. We would therefore expect that, other things being equal, countries with a higher-quality educational system will be those with a greater proportion of individuals with education beyond primary school, that is, with a greater stock of secondary and tertiary education. Thus, we estimate several variants of the following equation:

$$Education_{i,t} = \alpha_0 + \alpha_1 \ln y_{i,t-\tau} + \alpha_2 Quality^h_{i,t-\tau} + \alpha_3 FD_{i,t-\tau} + \alpha_j X_{j,i,t-\tau} + \nu_{i,t}$$

where $Education_{\mathrm{i,\ t}}$ is measured as the share of population 25 years and above with secondary and tertiary education as the highest level of school attained, i stands for the country, t for the time, and τ for the lag. The explanatory variables include the initial per capita income ($\ln y$), since, according to our theory, in general equilibrium, the level of development influences investment decisions through factor prices, and a measure of the quality of education ($Quality^h$). Thus, controlling for the level of development, we will test whether the quality of the educational system influences the share of population with higher schooling.

Given that there may be alternative mechanisms that can also act as a barrier to educational decisions, we control for the presence of credit market constraints, which prevent capable individuals with no collateral from investing in human capital acquisition. Due to the lack of data on credit market constraints for a sufficient number of countries and periods, the literature has commonly used financial development as a proxy for credit constraints (see, e.g., Flug et al. 1998, Iyigun and Owen 2004). Following this literature, we also measure credit market restrictions through

the Shanghai ranking and give it a score of 100, the next best university is given a score of 99, and so on. Then they compute the sum of the top 100 universities in each country and divide the sum by the country's population. Finally they compute a relative score compared to the United States by dividing each country score by that of the US.

the variable (*FD),* which equals the private credit provided by deposit money banks and other financial institutions, divided by GDP. The variable is taken from the latest version of the Financial Development and Structure Database by Beck and Demirgüç-Kunt (2009). Although the variable of financial development does not measure the imperfections in credit markets directly, we expect there to be less restriction to access credit since the financial system is more developed.

The length of compulsory education can also explain differences in human capital investment across countries. Thus, we could find two countries that are similar in levels of development and other characteristics, one of which has higher attainment levels in secondary education, not because the quality of education is higher, but because the length of compulsory education at the secondary level is longer. To control for the number of years that are compulsory at the secondary level, we take data on duration of compulsory education from UNESCO. The main drawback of the data is that they are only available from 2000 onwards. Nevertheless, we expect the laws regarding a country's educational system to remain stable over a long period of time.

The fact that most of the data on the quality of education is available mainly for a cross-section of countries, and that finding appropriate instruments is a difficult task, the strategy we follow to control for possible endogeneity problems and omitted variable bias is the following. Whereas our model suggests that causality goes from quality to quantity of education, it is possible that a society's level of development and education influence the resources devoted to schools and the production of human capital. For example, more developed and educated societies may demand a higher-quality educational system. Hence, governments cannot directly affect outcomes, but they can increase the resources spent on education or promote policies that improve the quality of schooling. Thus, in the set of explanatory variables, we control directly for the quantity of resources governments spend on education and some characteristics of the educational system that may reflect the value that governments and society ascribe to education, such as the number of school days per year. Nevertheless, we also check the robustness of the results with Barro and Lee's (2001) data set, since the temporal dimension of the data allows us to include lagged values of the educational quality measure and, therefore, minimize possible problems of endogenous variables.[22]

Moreover, we also directly control for specific characteristics of countries that can influence both the quality and quantity of schooling and whose omission could bias the estimated coefficients. In particular, the time-invariant variables refer to cultural, political, and geographic characteristics of countries. The cultural characteristics are proxied by the share of the population professing a religion (taken from La Porta et. al 1999), the number of school days per year (Barro and Lee 2001) and a dummy for East Asian countries. In fact, the high value people in East Asian countries place on education may explain why these economies score high on international tests and have higher levels of schooling than other countries with similar levels of development. Political institutions are proxied by a dummy for democratic countries, taken from Papaioannou and Siourounis (2008). Finally, geographical characteristics are measured with a dummy for countries located in tropical areas taken from Easterly and Sewadeh (2002).

[22] An alternative strategy is to instrument for education quality with its lags. However, this option is unfeasible in this context since the reduced available data restricts the sample to only 20 observations.

On the other hand, the quality of the educational system may also affect the quantity of schooling through the intensive channel; that is, once individuals decide to invest in education beyond primary school, quality also affects the depth of human capital formation since the higher the quality, the higher their investment in schooling will be. Moreover, through the general equilibrium effect, higher levels of education increase with output. Thus, we estimate several variants of the following equation:

$$\dot{h}_{i,t} = \beta_0 + \beta_1 \ln y_{i,t-\tau} + \beta_2 Quality^h_{t-\tau} + \beta_3 Education_{i,t-\tau} + \eta_{i,t} \tag{14}$$

where $\dot{h}$ stands for the accumulation of higher education, measured through the enrollment rates in secondary and tertiary levels of education. The explanatory variables include the initial level of development and the quality of education. Moreover, to test whether once individuals have decided to invest in education, a better-quality educational system implies a higher investment in schooling, we also control for the initial stock of secondary and tertiary education.

7 Empirical Results

7.1 Channels through which quality influences the quantity of education

The data on educational quality is taken from Hanushek and Kimko (2000), which is available for a broad set of countries. Specifically, the available data is averaged over the period 1960-1990. After combining the observations on quality with the other variables included in the estimation, we arrive at a total of 72 countries in the sample, which includes developed and developing economies. Columns (1-6) in Table 2 display the results of the effect of schooling quality on attainment levels in secondary education, measured as the share of the population 25 years and older with secondary schooling. Controlling for the initial level of development, measured as the log of real GDP per capita in 1960, the results in column (1) show that a higher-quality educational system has a positive and statistically significant effect on attainment levels in secondary schooling. The estimated coefficient suggests that an increase in one standard deviation in the quality indicator (11.9) increases attainment levels in secondary schooling by 0.059 points. This effect is significant considering that during this period, the average attainment level in secondary schooling in Sub-Saharan African countries was 0.060. The importance of the quality aspect of education is also reflected in its explanatory power, since the initial level of development and the quality of schooling alone explain about 64 percent of the variation across countries in secondary schooling attainment levels. Moreover, the positive and statistically significant effect of the quality of education on attainment levels in secondary schooling is not the result of atypical observations. Column (2) includes a dummy variable that controls for outliers, since their residuals exceed more than two times the estimated standard error of the residuals.[23] The estimated coefficient of the quality of schooling does not change, which implies that previous results are not driven by atypical observations.

[23] Countries whose residuals exceed more than two times the estimated standard error of the residuals include Ghana, United States, Sri Lanka, and Austria.

A greater quantity of education may also have an impact on the quality of schooling; that is, as the economy develops and individuals acquire more education, it is possible that demands on the government to increase the quality of the educational system will increase as well. Governments may respond to these demands by providing more computers and schooling materials, by increasing the number of teachers, by increasing teachers' salaries, etc. Thus, column (3) controls for the share of public spending on education, which comprises all of the aforementioned items.

On the other hand, since access to school may be easier in urban areas than in rural ones, we also control for the share of population living in urban areas. Moreover, access to skilled jobs is lower and prospects for the future less favorable in rural areas, which may also discourage individuals living in these areas from making investments in higher education. Results show that higher spending on education and a greater share of population living in urban areas are related to higher attainment levels in secondary education. However, even when controlling for any of these variables, the positive, statistically significant effect of educational quality on attainment levels in secondary schooling still holds.[24]

Results do not change either if we control for a proxy of restrictions in the credit market, which has been the channel analyzed most frequently in the literature to explain underinvestments in education. As stated above, the lack of available data on credit constraints for a sufficient number of countries and periods has forced researchers to use indicators of financial development instead. Thus, column (4) controls for private credit provided by deposit money banks and other financial institutions as a share of GDP. Results show that economies with a better financial system also have higher attainment levels in secondary education. However, controlling for a proxy of credit constraints does not change the positive and statistically significant coefficient of the quality of schooling.

It may also be possible that countries with a higher-quality educational system are also those in which governments ascribe high importance to education. Thus, it could be that instead of quality, we are picking up the higher number of years of compulsory secondary education in these countries. To rule out this possibility, in column (5) we control for the number of years of education that are compulsory at the secondary level. The estimated coefficient of this variable is positive, although not statistically significant at the standard levels. Nevertheless, our results show that controlling for this variable does not change the coefficient and significance of the measure of quality of schooling.

Finally, we directly control for specific characteristics of countries, such as cultural, political, and geographical factors that may influence the quality and quantity of schooling. In fact, cultural and religious features may affect individuals' values and attitudes towards education. For example, Guiso et al. (2003) find that religious beliefs are associated with economic attitudes. Thus, to eliminate the possibility that the coefficient of quality of schooling is picking up an East Asian effect, since these countries perform well in international tests and have high attainment levels, and to control for countries' cultural characteristics, we include in the set of controls an East Asian dummy and

[24] Results do not change if we control for other inputs determined by the government that directly affect secondary schooling, such as the pupil-teacher ratio in secondary school and the share of government educational expenditures per pupil at the secondary level, taken from Barro and Lee (2001).

the share of population professing Muslim, Catholic, or Protestant religious beliefs. In addition, cultural values are also taken into account through the number of school days per year in primary school, since this can reflect the importance society ascribes to education.[25] Furthermore, political institutions and geographical characteristics are controlled for through a dummy for democratic countries and a dummy for countries in tropical regions.[26] Our results —displayed in column (6)— show a positive and statistically significant coefficient of the East Asian dummy, which reflects cultural and other specific characteristics of this region relating to the importance of education. On the contrary, Muslim countries, on average, have lower attainment levels than countries in which the majority of the population profess a different religion. Our results also show that whereas democratic countries have a larger share of the population with secondary schooling, being located in tropical areas seems to discourage educational attainment. Nevertheless, controlling for all of these specific country characteristics does not change the positive and statistically significant effect that the quality of education has on the number of individuals who attain higher levels of education; the coefficient of the quality of education continues to be positive and statistically significant at the 1 per cent level.

Overall, our results show a quite robust and positive effect of the quality of education on the proportion of the population with secondary schooling. Next, we show that, given a stock of education, higher quality increases the investment rates in higher education as well.

By measuring educational investment rates through enrollment rates in secondary schooling, column (7) shows that countries with higher-quality educational systems also have higher enrollment rates in secondary education. Specifically, an increase of one standard deviation in the quality of education (11.9) is related to an annual increase of 0.107 points in enrollment rates.[27] Likewise, as stated by the general equilibrium effect, countries with higher per capita income in 1960 also have higher average enrollment rates over the period 1960-1990. Furthermore, as shown in column (8), the positive influence of the quality of schooling on enrollment rates in secondary education is not driven by atypical observations.[28]

Once individuals decide to invest in higher education, whether or not a higher-quality educational system implies higher investment in education is tested in column (9). Specifically, the attainment levels in secondary schooling are included in the set of controls. The findings reveal that even when controlling for the stock of human capital, a higher-quality educational system is associated with higher investment rates in secondary schooling; the coefficient of the quality indicator is positive and statistically significant at the 1 percent level. Finally, instead of controlling directly for the stock of education, column (10) includes the broad set of variables that have been suggested to influence the attainment levels. The results show that controlling for all the determinants of attainment levels,

[25] This variable, taken from Barro and Lee (2001), is not available for higher levels of schooling. A more informative variable might be the number of school hours per year. However, information on this measure is only restricted to a small number of countries.

[26] Sachs and Warner (1997) find that being located in tropical areas is a geographical disadvantage for development.

[27] As a reference, the mean and standard deviation of secondary enrollment rates in the sample is 0.399 and 0.263, respectively.

[28] Countries whose residuals exceed more than two times the estimated standard error of the residuals include Ghana and Sri Lanka.

as displayed in column (6), the estimated coefficient of the quality of schooling is reduced, although it remains positive and statistically significant at the 1 percent level.

In order to minimize endogeneity problems, we test the robustness of the previous results with alternative measures of quality compiled by Barro and Lee (2001). The advantage of this dataset is that it includes observations of test scores for different years, which allows us to include explanatory variables lagged five years. However, this comes at the cost of reducing the number of countries by almost half.[29] Broadly, using Barro and Lee's (2001) data set produces similar results to those found for a broader set of countries with cross-sectional data. Table 3 shows that even when controlling for the initial level of development, atypical observations, the share of public spending on education, the share of individuals living in urban areas, the degree of financial development, the years of compulsory education in secondary education, and other cultural, institutional, and geographical characteristics specific to a given country, a higher quality of schooling is related to higher attainment levels in secondary education. Likewise, for a given stock of human capital, higher quality also implies higher investment in education, reflected in higher enrollment rates.

To test for tertiary education, we study the impact of educational quality on the attainment levels and enrollment rates at the university level. One of the problems of existing data on the quality of schooling is that the quality of secondary education is not always related to quality at the tertiary level. For instance, according to the international test scores compiled by Hanushek and Kimko (2000), the quality of secondary education in the United States is lower than that in other countries with similar or lower levels of development (see Figure 1). However, when it comes to tertiary education, American universities are by far the best in the world. Whereas there is not a similar measure of scores in internationally comparable tests at the university level, we can proxy the quality of tertiary education with international rankings of the performance of universities, taken from the Shanghai Jiao Tong University Academic Ranking of World Universities, as detailed in the previous section.[30]

Table 4 shows the results of the effect of university quality, measured by the performance of the top 500 universities in year 2003, on attainment levels and enrollment rates in tertiary education.[31] Column (1) shows that higher per capita income is positively and significantly related to higher attainment levels in tertiary education. Moreover, even controlling for the level of development, countries with a higher number of universities in the top 500 also have a higher share of the population with university education. In quantitative terms, the effect implies that an increase of one standard deviation in the quality indicator (0.44) is associated with an annual increase of 0.23 points in attainment levels in tertiary education. This effect is huge, since the attainment levels in tertiary

[29] The results displayed in Table 3 refer to test scores in science, for which there are a few more observations available than for test scores in math. Nevertheless, the results do not change with the use of math scores.

[30] The correlation of the quality measure taken from Hanushek and Kimko (2000) with the transformed measure of university performance taken from the Shanghai ranking is 0.417 for the top 100 institutions and 0.570 for the top 500 institutions.

[31] We are forced to use data on university quality from 2003 because the rankings are only available from 2003 onwards. Nevertheless, in spite of some changes over the last 40 years, the quality of university and the great predominance of American institutions has remained quite stable over the years.

education in Latin American countries in the year 2000 are 0.12, in East Asian countries 0.16, and in the high-income OECD economies 0.23.

As displayed in columns (2-4), the results are not influenced by atypical observations and are robust to controlling for the share of public spending on education, the share of population living in urban areas, and an indicator of financial development. Moreover, although controlling for country-specific characteristics reduces the estimated coefficient of the quality indicator (column (5)), it continues being high in absolute value and statistically significant at the 1 percent level. Furthermore, columns (6-9) show that the positive influence of university quality on the quantity of investment in tertiary education is also reflected in enrollment rates; higher university quality is related to higher enrollment rates in tertiary education. This result holds even when controlling for the initial level of development and the initial percentage of individuals with tertiary education.

On the other hand, in our model we assume that the primary level of education is given and that individuals' decisions to invest in education mainly refer to higher schooling. The reason is that in most countries, primary education is compulsory and financed by the government. In fact, according to UNESCO data, in the year 2000 primary education was compulsory in every country in the world. Therefore, we would expect that any effect of higher-quality education on the quantity of education should be stronger in secondary and tertiary education than in primary education.

One of the main drawbacks in testing the influence of quality on the quantity of education at the primary level is that there are not available data on quality of primary education for a broad number of countries and periods. Nevertheless, to have a first approximation of this relationship, we use the measure of quality of education from Hanushek and Kimko (2000). Results concerning primary education are presented in Table 5. In general, the estimated coefficient and the explanatory power of quality is much lower in primary than in secondary education. Moreover, available data on UNESCO show that in year 2000 primary education was compulsory in all countries in the world. Thus, we would expect educational quality not to have any effect on the primary enrollment rates in that year. And indeed, columns (5-6) show that when enrollment rates are measured in year 2000, the positive and statistically significant effect of the quality of education on the primary enrollment rates disappears.[32]

Overall, in line with the predictions of the theoretical model, our results suggest that the quality of the educational system is an important determinant of the quantity of resources invested both in higher education and, to a lesser extent, in primary schooling. Other things being equal, a higher-quality educational system is associated with a higher share of the population and higher enrollment rates at the secondary and tertiary levels.

[32] Clearly, our results do not imply that quality does not matter in primary education. In fact, quality at the primary level is also a concern in some developing economies, as reflected by teacher absenteeism and teacher negligence in schools (see Kremer et al. 2005). Indeed, we found a strong negative correlation between the probability of dropouts at the primary level and educational quality. However, since in our theory quality affects the returns and not the probability of dropouts, we refrain from analyzing this question in detail.

7.2 Education and growth

In this section, we analyze the effect of the quality of education on the process of development. In particular, we will test whether the quality of education has influenced the economies' growth rates of real per capita GDP. The first hypothesis we want to test is whether the quality of education has a differential effect in countries with a low-quality educational system and those with a high-quality system. According to our theory, relatively low educational quality discourages peoples's investments to increase their levels of education since it decreases the returns from higher education. As a result, agents get stuck at the primary level, and the economy ends up being poor. By contrast, relatively high quality raises opportunities to pursue education beyond primary school, and thus output is high.

We test this hypothesis in Table 6, in which the average growth rate of per capita income for the period 1960-1990 is regressed on the initial per capita income to reflect convergence in incomes across countries, and other standard determinants of growth, such as the physical capital investment share, the public spending share, the imports plus the exports divided by GDP and the inflation rate. We use Hanushek and Kimko's (2000) data on the quality of education since the variable is available for a broad number of countries, including those with low and high educational quality, as well as those with very low and very high income levels. Therefore, we estimate a cross-sectional equation by OLS.[33] The effect of the quality of education on the per capita income growth rates is examined in column (1). Results show a positive and statistically significant coefficient of the quality indicator, suggesting that, other things being equal, countries with a better-quality educational system have experienced, on average, higher growth rates in the per capita income. However, according to our model, the positive effect of the quality of education on the growth of income should be observed only when the quality of education is above a threshold level. Thus, in order to test whether there is a differential effect of quality on growth at low and high levels of quality, we multiply the quality indicator by a dummy variable that takes the value 1 if the quality indicator is below the 25^{th} percentile in the distribution of quality of schooling, and zero otherwise. We do the same for countries with the quality indicator above the 25^{th} percentile value in the distribution of quality. Our results, displayed in column (2), show that whereas the estimated coefficient of the quality of education is not significant in countries with quality at the bottom of the distribution, higher-quality educational systems have a positive statistically significant effect in most of the economies.[34]

When all agents maximize income, the dynamic of output per worker in the model is explained by educational quality since the effect of quality on the private investment in education disappears due to the envelope theorem —see corollary 1. This result is difficult to test since knowing whether a country is at its steady state is not straightforward. Nevertheless, as an approximation, we assume

[33] Using Barro and Lee's (2001) dataset, we have also tried to estimate a dynamic panel data model that controls for country-specific effects with the system GMM estimator. However, even using a low number of lags in the set of instruments, the reduced number of observations makes this estimator less reliable, as reflected by the specification tests.

[34] Results are similar if, instead of the 25^{th} percentile, we make the partition at the 20^{th} or 30^{th} percentile in the distribution of quality.

that rich countries are more likely to be closer to their steady state than poorer economies. Thus, we would expect that the quality of the educational system is more important than the investment in the quantity of education in high-income economies, which should be closer to their steady state. We start by testing the effect of investment in education, measure by the enrollment rates in secondary schooling, on growth rates. our results, displayed in column (3), show that higher enrollment rates are positively and statistically significantly related to higher growth rates in per capita income over the period 1960-1990. Moreover, the effect is stronger in economies that were relatively poor than in countries with per capita incomes in the top 25^{th} percentile of the distribution of income in 1960 (column (4)).[35] In addition, once we control for the quality of education (column (5)), the coefficient of the enrollment rate in the top-income economies stops being statistically significant, whereas the estimated coefficient of the enrollment rates in the bulk of lower-income economies continues being significant.[36]

In line with Hanushek and Kimko (2000), columns (6-7) show that once the quality of education is taken into account, the influence of average years of schooling on growth disappears. Nevertheless, even controlling for the average years of schooling, the differential effect of quality in low- and high-educational-quality countries remains unchanged; although both coefficients are positive, only the one in countries with high educational quality countries is statistically significant at the standard levels (column (8)). This finding reveals that in order for the quality of education to encourage growth, quality has to be above a minimum level. Moreover, when we differentiate the effect of average years of schooling between the top income economies and the rest of the economies, columns (9-10) also show that controlling for the quality of education makes the coefficient of years of schooling become statistically insignificant only in the top income countries.

Overall, whereas higher-quality educational systems are related to higher growth rates in real per capita GDP, the effect is mainly found when the quality of education is relatively high or above a minimum level. Moreover, when the joint effect of educational quantity and educational quality is analyzed, findings reveal that in economies at the top end of the income distribution, increases in the quality of education matter more than increases in the quantity of education for economic growth.

8 Conclusions

So far, most of the theoretical and empirical literature on human capital and development has focused mainly on the quantity of schooling. This paper reconsiders the role of human capital by emphasizing the importance of the qualitative aspects of education and their effect on schooling decisions about higher education, and thus human capital composition and output. Our proposed

[35] The dummy for high-income countries takes the value of 1 if the real GDP per capita is higher than $6142.51, which is the value of the 75^{th} percentile in the distribution of real GDP per capita income in 1960, and zero otherwise.

[36] If instead of measuring quantity of education with enrollment rates as suggested by result H4, we measure quantity with the attainment levels in secondary education, our results still hold. Moreover, the results are also robust to the cutoff point of top-income countries. The results are similar if the split is made with the top 20^{th} or top 10^{th} percentile of high-income economies in 1960.

theory shows that, when primary schooling is compulsory and publicly provided, educational quality may affect economic growth by increasing the extensiveness —expanding access to more agents—, as well as the intensiveness —increasing the investment made by each agent— of the accumulation of human capital beyond primary education. Our results further suggest that educational quality plays a central role in the composition of human capital and thus in the development process.

Using cross-country data, the paper presents empirical evidence showing that the extensive and intensive channels are important factors in the accumulation of human capital beyond primary schooling. In particular, countries with a higher quality educational system are those with higher attainment levels and higher investment rates in secondary and tertiary education. In contrast, consistent with the fact that primary education is publicly provided and compulsory in most parts of the world, higher quality scarcely affects primary attainment levels and primary enrollment rates.

According to our theory, the positive influence of the quality of education on economic growth is mainly found in countries in which the quality of education is relatively high. We also find that when quality and quantity are included as potential determinants of growth rates in real per capita GDP, both variables are statistically significant in developed countries, but in the top income economies our results show a predominant effect of quality over quantity of schooling.

From this paper we can derive some interesting policy implications. First, when seeking to promote human capital formation, policy makers usually focus on expanding access to education, while paradoxically forgetting the qualitative aspects. According to our theoretical and empirical results, working to improve educational quality could be an extremely powerful and effective policy approach since the effect of quality on the stock of human capital formation is driven by two differentiated effects; in addition to the indirect effect of increasing incentives to invest in higher education (quality enhances the stock of human capital of higher education due to both the extensive and the intensive channels), we also find that the quality of education has a direct effect that is distinct from the indirect one. That is, quality is good in itself since it reveals the degree of effectiveness of accumulating human capital. It should be noted that we are not claiming that a generalization of education is not a legitimate policy aim in and of itself. Rather, we are emphasizing the importance of the quality of the educational system.

Second, the existence of quality in higher education remains a major challenge in the developing world, and its implementation requires a long term perspective, implying changes in educational institutions, laws, and policies. A possible short-term solution for local communities could be to promote programs in which prestigious foreign educational institutions open branches in developing countries with a growing demand for higher education but lacking educational systems of adequately high quality. Renowned universities and higher educational institutions operating beyond their own borders could help such developing countries to increase human capital formation and work their way out of poverty.

A logical extension of this work would be to analyze the determinants of educational quality by endogenizing the quality of the educational system. In this context, it would be interesting to analyze the policy implications of increasing educational quality in detail. This would be crucial if the goal is to identify ways to stimulate development in poor economies. In sum, there appears to exist enormous potential for researchers and policy makers to focus on the qualitative aspects of education, and with this paper, we are only scratching the surface.

9 References

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10 Appendix

Proof of Proposition 3. *The function* Y_{t+1}^{III} *is strictly concave:* $\frac{\partial Y_{t+1}^{III}}{\partial Y_t^{III}} = \alpha k_{t+1}^{\alpha-1}\beta = R_{t+1}\beta > 0$, $\frac{\partial^2 Y_{t+1}^{III}}{\partial Y_t^{III2}} = \beta R_{t+1}\frac{\alpha-1}{k_{t+1}} < 0$ since $0 < \alpha < 1$. *In order to show that output increases monotonically, converging to a unique locally stable steady state equilibrium, we need to show that the next condition hold, that is* $\lim_{Y\to\infty}\frac{\partial Y_{t+1}^{III}}{\partial Y_t^{III}} = \alpha\beta\frac{1}{k_{t+1}^{1-\alpha}}$ *since and* $k_{t+1}\to\infty$ *if* $y_t\to\infty$ *we have* $\lim_{Y\to\infty}\frac{1}{k_{t+1}^{2}} = \frac{1}{\infty} =$

0. *This is so because by equation (5)* I^*_{t,a_j} *is strictly increasing in* k_{t+1}*, therefore* $k_{t+1} = k^{III}_{t+1}(Y_t, \theta)$, and $\frac{\partial k^A_{t+1}}{\partial Y^A_t} > 0$.

Proof Proposition 4. *Under Regime III the output per worker is given by* $Y^{III}_{t+1} = (\beta Y_t - \gamma I^*_{t,} - (1-\gamma) I^*_t)^\alpha (\gamma\theta I^{*\varepsilon}_{t,j} a_H + (1-\gamma)\theta I^{*\varepsilon}_{t,j} a_L)^{1-\alpha}$.

It is easy to check that $I^*_{t,a^j} = \arg\max Y^{III}_{t+1}$*, since the FOC are*

$$\frac{\partial Y^{III}_{t+1}}{\partial I^*_{t,j}} = \alpha K^{\alpha-1}_{t+1} H^{1-\alpha}_{t+1}(-1) + (1-\alpha) K^{\alpha}_{t+1} H^{-\alpha}_{t+1} \{\theta\varepsilon I^{*\varepsilon-1}_t\} = 0.$$

Taking into account equation (2), the expression $\frac{\partial Y^{III}_{t+1}}{\partial I^*_{t,j}} = 0$ *can be rewritten as*

$$R_{t+1} = w_{t+1} a_j \theta\varepsilon I^{*\varepsilon-1}_{t,j}, \text{ for any } a_j \text{ with } j = H, L$$

which is the FOC of the efficient level of investment in education. Notice that if there where under-investment, that is if $I_t < I^*_t$*, then* $R_t < w_t\theta\varepsilon I^{\varepsilon-1}_t$ *holds, and* $\frac{\partial Y^{III}_{t+1}}{\partial I^*_{t,j}} > 0$*. On the contrary, when there were overinvestment, that is* $I_t > I^*_{t,j}$*, then* $R_t > w_t\theta\varepsilon I^{\varepsilon-1}_t$ *holds, and* $\frac{\partial Y^A_{t+1}}{\partial I^*_{t,j}} < 0$.

Proof of Corollary 1. *If we take the derivative of* Y^{III}_{t+1} *with respect to educational quality we have*

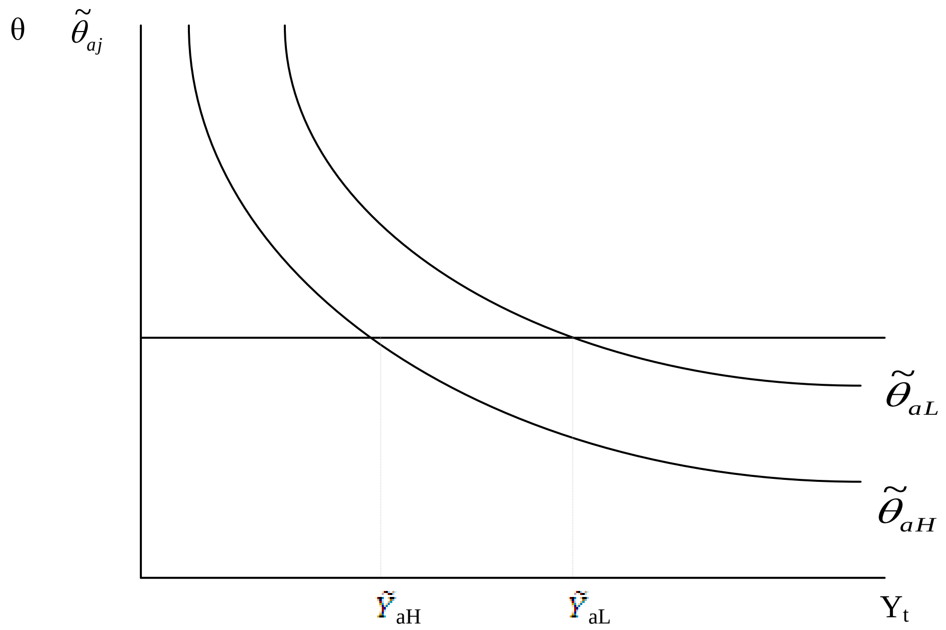
$$\frac{\partial Y^{III}_{t+1}}{\partial \theta} = \frac{\partial Y^{III}_{t+1}}{\partial \theta} + \frac{\partial Y^{III}_{t+1}}{\partial I^*_{t,j}} \frac{\partial I^*_{t,j}}{\partial \theta} > 0 \text{ for any } a_j \text{ with } j = H, L$$

it is clear that the indirect effect, which is given by the second term, is equal to zero since $I^*_{t,j}$ *is maximizing income for all agents in the economy. Moreover,* $\frac{\partial Y^{III}_{t+1}}{\partial \theta} = \frac{\partial H^{III}_{t+1}}{\partial \theta} > 0$

Proof of Proposition 5. *Notice that when the economy is under Regime III,* $\theta > \widetilde{\theta}_{a_L}$ *holds which means that all agents prefer the invest in higher education. That is, by Proposition 4, we know that* $I^*_{t,a^j} = \arg\max Y^{III}_{t+1}$*, for any* a_j *with* $j = H, L$*. which implies that the optimal level of investment in higher education is characterized by equalizing marginal returns to investment in higher education to the interest rate among all agents in the economy. As a result, aggregate output is higher under Regime III than under Regime I; comparing the output per worker under the two economies we obtain that* $Y^{III}_{t+1} = (K_{t+1})^\alpha (H_{t+1})^{1-\alpha} > Y^I_{t+1} = (K_{t+1})^\alpha (H_{t+1})^{1-\alpha}$ *and thus* $Y^{III}_{ss} > Y^I_{ss}$ *always holds.*

We can also show that under Regime III $H^{III}_{t+1} > H^I_{t+1}$ *holds for every* t*. This is the case since when the economy enters into Regime III, we have that* $I^*_{t,a_j} > \mu$ *which implies that* $\gamma\theta I^{*\varepsilon}_{t,a_H} a_H + (1-\gamma)\theta I^{*\varepsilon}_{t,a_L} a_L > \gamma\theta\mu^\varepsilon a_H + (1-\gamma)\theta\mu^\varepsilon a_L \Leftrightarrow H^{III}_{t+1} > H^I_{t+1}$ *holds.*

Finally, according to our model, the only way to accumulate human capital is by transforming physical capital into human capital. Therefore if $H^{III}_{t+1} > H^I_{t+1}$ *holds, the inequalilty* $K^{III}_{t+1} > K^I_{t+1}$ *holds as well.*



Regime I	**Regime II**	**Regime III**
$Y_t < \tilde{Y}_{aH}$	$\tilde{Y}_{aH} < Y_t < \tilde{Y}_{aL}$	$Y_t > \tilde{Y}_{aL}$
$\theta < \tilde{\theta}_{aH}$	$\tilde{\theta}_{aH} < \theta < \tilde{\theta}_{aL}$	$\theta < \tilde{\theta}_{aL}$

Figure 2: The evolution of the thresholds

Figure 3: Possible dynamic of aggregate output per worker

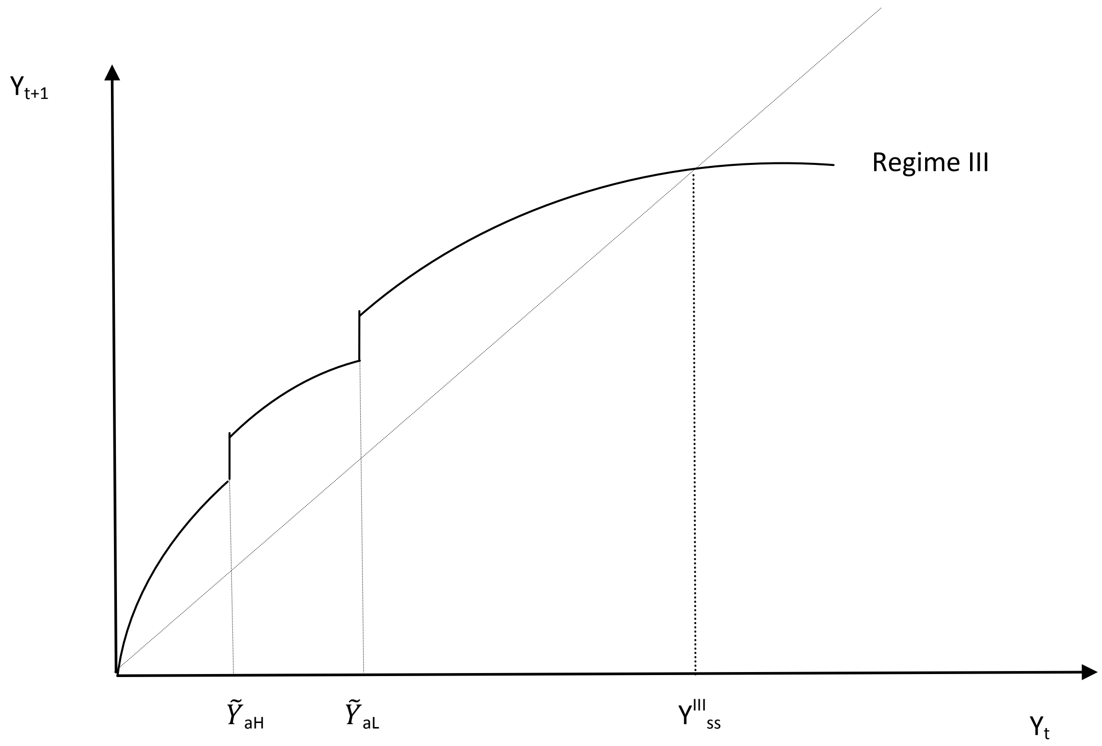


Figure 4: Possible dynamic of aggregate output per worker

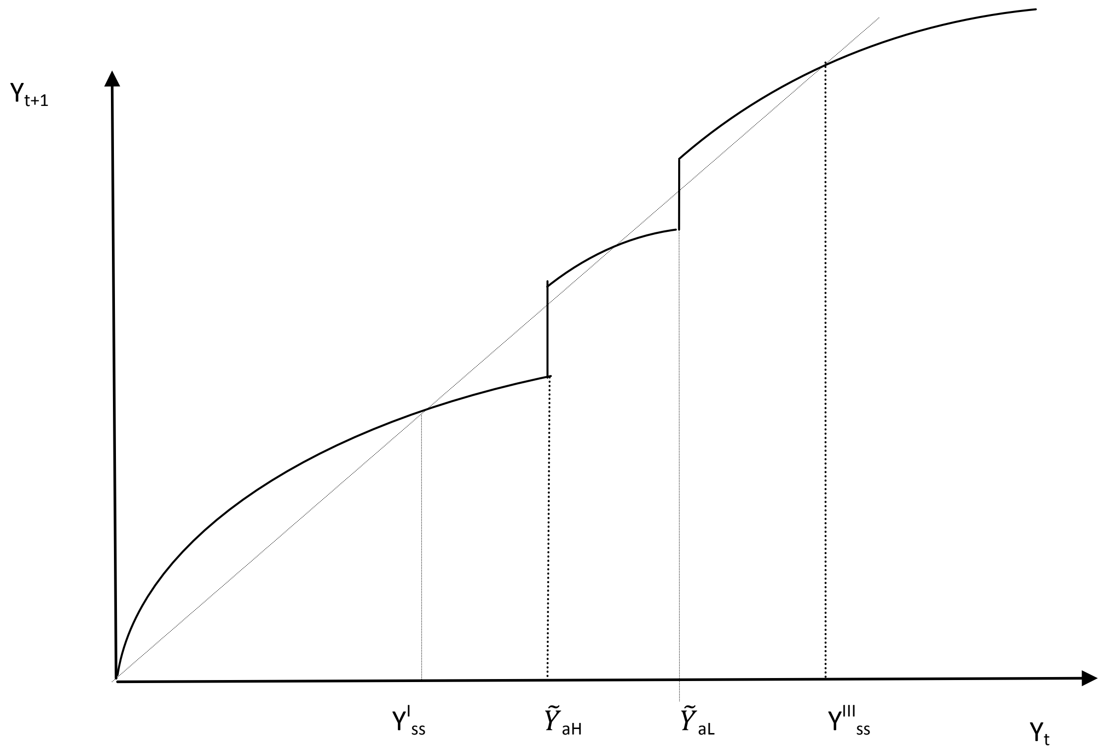


Table 2

Dependent variable: Education at the secondary level

	Attainment level ($Education^{SEC}_{60-90}$)						Enrollment rates ($\dot{h}^{SEC}_{60-90}$)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
$Quality^{HK}_{60-90}$	0.005^a	0.005^a	0.005^a	0.004^a	0.004^a	0.003^a	0.009^a	0.009^a	0.008^a	0.004^b
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)
lny_{60}	0.065^a	0.068^a	0.044^b	0.055^a	0.052^b	0.020	0.164^a	0.182^a	0.173^a	0.036
	(0.015)	(0.012)	(0.019)	(0.020)	(0.020)	(0.018)	(0.020)	(0.018)	(0.026)	(0.041)
d_+		0.200^a	0.186^a	0.188^a	0.184^a	0.173^a		0.328^a	0.314^a	0.198^a
		(0.009)	(0.017)	(0.017)	(0.020)	(0.018)		(0.034)	(0.052)	(0.067)
$Education^{SEC}_{60}$									0.234	
									(0.181)	
$PSEduc_{60-90}$			0.012^c	0.011	0.011	0.014^c				0.019
			(0.007)	(0.007)	(0.008)	(0.007)				(0.014)
$lnurb_{60-90}$			0.028	0.025	0.024	0.034^b				0.098^a
			(0.017)	(0.017)	(0.018)	(0.015)				(0.028)
FD_{60-90}				0.033	0.036	-0.024				0.053
				(0.051)	(0.052)	(0.052)				(0.072)
$Years\ compulsory^{SEC}$					0.002	-0.006				-0.002
					(0.005)	(0.004)				(0.008)
East Asia						0.056^c				0.106
						(0.032)				(0.084)
Muslims						-0.068^b				-0.127^c
						(0.029)				(0.069)
Catholics						0.021				0.020
						(0.030)				(0.084)
Protestants						0.020				0.109
						(0.042)				(0.073)
School Days						0.076^c				0.065
						(0.044)				(0.083)
Institutions						0.056^b				0.077^c
						(0.023)				(0.042)
Tropical						-0.082^a				-0.182^a
						(0.018)				(0.040)
Constant	-0.568^a	-0.605^a	-0.548^a	-0.589^a	-0.572^a	-0.413^a	-1.255^a	-1.404^a	-0.135^a	-0.550^b
	(0.100)	(0.069)	(0.083)	(0.100)	(0.112)	(0.153)	(0.148)	(0.123)	(0.199)	(0.239)
R^2	0.640	0.760	0.772	0.783	0.784	0.856	0.739	0.777	0.796	0.903
Countries	71	71	66	64	64	64	72	72	69	64

Note: OLS estimation. Robust standard errors in parenthesis. a, b and c stand for significance level at 1, 5 and 10 per cent respectively. Dependent variable is the share of population 25 years and above with secondary education (columns 1-6) and enrollment rates in secondary education (columns 7-10). Quality of education is measured through scores in international comparable test, taken from Hanushek and Kimko (2000).

Table 3

Dependent variable: Education at the secondary level

	Attainment level ($Education_t^{SEC}$)						*Enrollment rates* ($\dot{h}_t^{SEC}$)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
$Quality_{t-5}^{BL}$	0.005^b	0.006^a	0.005^c	0.006^b	0.006^b	0.004	0.007^b	0.007^b	0.007^b	0.009^b
	(0.002)	(0.002)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)
lny_{t-5}	0.090^a	0.084^a	0.055	0.039	0.041	0.029	0.187^a	0.177^a	0.168^a	0.013
	(0.025)	(0.024)	(0.036)	(0.035)	(0.035)	(0.042)	(0.025)	(0.024)	(0.027)	(0.057)
d_+		0.243^a	0.192^a	0.184^a	0.176^a	0.206^b		0.484^a	0.483^a	0.458^a
		(0.032)	(0.040)	(0.048)	(0.050)	(0.087)		(0.033)	(0.035)	(0.049)
d_-		-0.226^a	-0.206^a	-0.249^a	-0.254^a	-0.193^a		-0.386^a	-0.406^a	
		(0.023)	(0.052)	(0.058)	(0.059)	(0.055)		(0.026)	(0.039)	
$Education_{t-5}^{SEC}$									0.085	
									(0.121)	
$PSEduc_{t-5}$			0.013	0.014	0.015^c	0.010				-0.000
			(0.008)	(0.009)	(0.009)	(0.011)				(0.012)
$lnurb_{t-5}$			0.045	0.046	0.056	0.073				0.124^c
			(0.049)	(0.050)	(0.056)	(0.059)				(0.071)
FD_{t-5}				0.067^c	0.065^c	0.048				0.101
				(0.034)	(0.034)	(0.041)				(0.063)
Years compulsory^{SEC}					-0.005	-0.005				-0.001
					(0.008)	(0.010)				(0.010)
East Asia						0.199^a				-0.044
						(0.056)				(0.080)
Muslims						0.021				-0.116
						(0.097)				(0.086)
Catholics						0.024				0.107
						(0.043)				(0.064)
Protestants						0.058				0.092
						(0.052)				(0.060)
School Days						-0.054				-0.365^b
						(0.093)				(0.154)
Institutions						0.078^b				-0.069
						(0.035)				(0.049)
Tropical						-0.156^a				-0.175^b
						(0.044)				(0.075)
Constant	-0.642^a	-0.611^a	-0.557^a	-0.483^b	-0.525^b	-0.380	-1.267^a	-1.168^a	-1.087^a	0.402
	(0.200)	(0.186)	(0.192)	(0.189)	(0.199)	(0.299)	(0.251)	(0.233)	(0.238)	(0.494)
Time dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
R^2	0.408	0.515	0.506	0.573	0.577	0.681	0.648	0.815	0.816	0.892
Countries	40	40	35	35	35	35	38	38	38	33
Obs.	84	84	73	68	68	68	78	78	78	63

Note: OLS estimation. Robust standard errors in parenthesis. a, b and c stand for significance level at 1, 5 and 10 per cent respectively. Dependent variable is the share of population 25 years and above with secondary education (columns 1-6) and enrollment rates in secondary education (columns 7-10). Quality of education is measured through scores in international comparable test in science in students 13-14 year old, taken from Barro and Lee (2000).

Table 4

Dependent variable: *Education at the university level*

	Attainment level ($Education_t^{TER}$)					*Enrollment rate* ($\dot{h}_t^{TER}$)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$Quality^{univ\ ranking}$	0.052^a	0.042^a	0.041^a	0.041^a	0.035^a	0.085^a	0.083^a	0.040^a	0.072^a
	(0.006)	(0.005)	(0.005)	(0.006)	(0.006)	(0.013)	(0.009)	(0.009)	(0.012)
lny_{t-5}	0.032^a	0.029^a	0.026^a	0.027^a	0.020^a	0.079^a	0.071^a	0.054^a	0.051^a
	(0.002)	(0.001)	(0.003)	(0.004)	(0.004)	(0.004)	(0.003)	(0.004)	(0.009)
d_+		0.204^a	0.195^a	0.193^a	0.193^a		0.320^a	0.214^a	0.302^a
		(0.013)	(0.013)	(0.013)	(0.013)		(0.020)	(0.020)	(0.023)
d_-							-0.209^a	-0.160^a	-0.209^a
							(0.011)	(0.012)	(0.020)
$Education_{t-5}^{TER}$								0.846^a	
								(0.084)	
$PSEduc_{t-5}$			0.000	0.001	0.000				0.002^b
			(0.000)	(0.000)	(0.000)				(0.001)
$lnurb_{t-5}$			0.006^c	0.012^b	0.016^a				0.005
			(0.003)	(0.005)	(0.005)				(0.010)
FD_{t-5}				-0.003	-0.003				0.038^c
				(0.011)	(0.011)				(0.020)
East Asia					-0.007				0.063^a
					(0.013)				(0.020)
Muslims					-0.024^a				0.011
					(0.008)				(0.018)
Catholics					-0.013				0.082^a
					(0.010)				(0.016)
Protestants					-0.004				0.021
					(0.008)				(0.021)
School Days					0.021				0.023
					(0.013)				(0.023)
Institutions					0.004				0.020^c
					(0.005)				(0.011)
Tropical					-0.021^a				-0.050^a
					(0.005)				(0.010)
Constant	-0.239^a	-0.213^a	-0.211^a	-0.239^a	-0.224^a	-0.406^a	-0.369^a	-0.285^a	-0.377^a
	(0.014)	(0.011)	(0.014)	(0.020)	(0.040)	(0.036)	(0.030)	(0.029)	(0.076)
Time dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes
R^2	0.564	0.780	0.781	0.782	0.796	0.655	0.812	0.855	0.849
Countries	102	102	97	91	91	105	105	105	89
Obs.	769	769	588	436	436	726	726	705	410

Note: OLS estimation. Robust standard errors in parenthesis. a, b and c stand for significance level at 1, 5 and 10 per cent respectively. Dependent variable is the share of population 25 years and above with tertiary education (columns 1-6) and the enrollment rate in tertiary education (columns 7-9). Quality of tertiary education is measured as the fraction of the United States per capita performance for the Top 500 universities.

Table 5

Dependent variable: Education at the primary level

	Attainment level ($Education^{PRI}_{60-90}$)		Enrollment rates ($\dot{h}^{PRI}_{60-90}$)		Enrollment rates ($\dot{h}^{PRI}_{2000}$)	
		All controls		All controls		All controls
	(1)	(2)	(3)	(4)	(5)	(6)
$Quality^{HK}_{60-90}$	0.002	0.002	0.003[b]	0.002[c]	-0.001	0.001
	(0.002)	(0.002)	(0.002)	(0.001)	(0.002)	(0.001)
lny_{60}	0.065[a]	0.055	0.088[a]	0.017	0.052[c]	0.071[b]
	(0.022)	(0.050)	(0.029)	(0.034)	(0.030)	(0.035)
All controls: FD_{60-90}, PSE_{60-90}, $lnurb_{60-90}$, *East Asia, Muslims, Catholics, Protestants, School days, Institutions, Tropical*						
R^2	0.213	0.528	0.358	0.800	0.086	0.656
Countries	71	64	72	64	66	59

Note: OLS estimation. Robust standard errors in parenthesis. a, b and c stand for significance level at 1, 5 and 10 per cent respectively. Dependent variable is the share of population 25 years and above with primary education (columns 1-2) and enrollment rates in primary education (columns 3-6). Quality of education is measured through scores in international comparable test, Hanushek and Kimko (2000).

Table 6

Dependent variable: *Average Growth rate of real per capita GDP, 1960-1990*

	Test H3		Test H4			Hanushek and Kimko (2000)				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
lny_{60}	-0.0099[a]	-0.0103[a]	-0.0116[a]	-0.0095[a]	-0.0105[a]	-0.0116[a]	-0.0125a	-0.0132[a]	-0.0103[a]	-0.0111[a]
	(0.0021)	(0.0020)	(0.0029)	(0.0026)	(0.0027)	(0.0034)	(0.0030)	(0.0027)	(0.0034)	(0.0032)
$Quality_{60-90}$	0.0006[a]				0.0005[a]		0.0006[a]			0.0007[a]
	(0.0001)				(0.0001)		(0.0002)			(0.0002)
$Quality_{60-90} * dummy^{LOW}_{Quality}$		0.0003						0.0003		
(quality below 25^{th} percentile)		(0.0003)						(0.0003)		
$Quality_{60-90} * dummy^{HIGH}_{Quality}$		0.0005[a]						0.0005[a]		
(quality above 25^{th} percentile)		(0.0001)						(0.0002)		
$\dot{h}^{SEC}_{60}$			0.0324[a]							
			(0.0108)							
$\dot{h}^{SEC}_{60} * dummy^{HIGH}_{Income}$				0.0283[a]	0.0148					
($RGDP_{60}$ above 75^{th} percentile)				(0.0090)	(0.0096)					
$\dot{h}^{SEC}_{60} * dummy^{LOW}_{Income}$				0.0542[a]	0.0400[b]					
($RGDP_{60}$ below 75^{th} percentile)				(0.0192)	(0.0191)					
$Schooling^{years}_{60}$						0.0023[b]	0.0005	0.0009		
						(0.0009)	(0.0009)	(0.0009)		
$Schooling^{years}_{60} * dummy^{HIGH}_{Income}$									0.0022[b]	0.0005
($RGDP_{60}$ above 75^{th} percentile)									(0.0009)	(0.0010)
$Schooling^{years}_{60} * dummy^{LOW}_{Income}$									0.0038[a]	0.0021[b]
($RGDP_{60}$ below 75^{th} percentile)									(0.0010)	(0.0009)
Additional controls: $(I/GDP)_{60-90}$, $(G/GDP)_{60-90}$, $Trade_{60-90}$, $Inflation_{60-90}$										
R^2	0.600	0.612	0.549	0.594	0.644	0.488	0.594	0.604	0.514	0.621
Countries	72	72	71	71	71	68	68	68	68	68

Note: OLS estimation. Robust standard errors in parenthesis. a, b and c are 1, 5 and 10 per cent significance level respectively. Quality of education is measured through scores in international comparable test, taken from Hanushek and Kimko (2000).