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Quality and Quantity of Education in the Process of Development*

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Abstract

We develop a theory of human capital investment to study through which channels students react to school quality when deciding about their investment in higher education (secondary and above) and how educational quality affects the growth process of an economy. In a dynamic general equilibrium closed economy, higher education requires an extra investment of private resources, whereas primary education is mandatory. The theory states that human capital accumulation raises with quality through two main effects: larger quality increases the number of people with higher education (extensive channel), and it increases the volume of investment in higher schooling per individual (intensive channel). That is, 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. The intensive channel establishes that once individuals decide to participate in higher schooling, the larger the quality of educational system, the larger the investment made by each agent. Educational quality may allow for different steps of development and that depending on quality the economy may follow different paths. Using cross-country data, empirical evidence shows that the proposed channels seem to be quantitatively important and that the effect of quality and quantity of education on growth depends on the stage of development.

JEL classification: I21, O11, O15, O4.

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

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1 Introduction

This paper seeks to understand what drives schooling decisions regarding higher education (that is, secondary and tertiary education), and why the distribution of educational attainment greatly differs with the level of development. In particular, Table 1 shows how attainment levels in primary, secondary, and tertiary schools relate to per capita income. We can observe two clear patterns. First, if we compare among all three attainment levels, agents in developing countries have at most primary schooling. Second, 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).[1]

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 and higher education is essentially non-mandatory– 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 and a measure of educational quality in each country.[2] The results are striking. Figure 1 shows a positive 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]

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

[1] However, the share of individuals with maximum primary education was similar in poor and rich countries (30 percent in poor countries and 32 percent in rich 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 (2001).

[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 and the number of years of compulsory secondary education.

Table 1

	Highest education level attained (%), 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

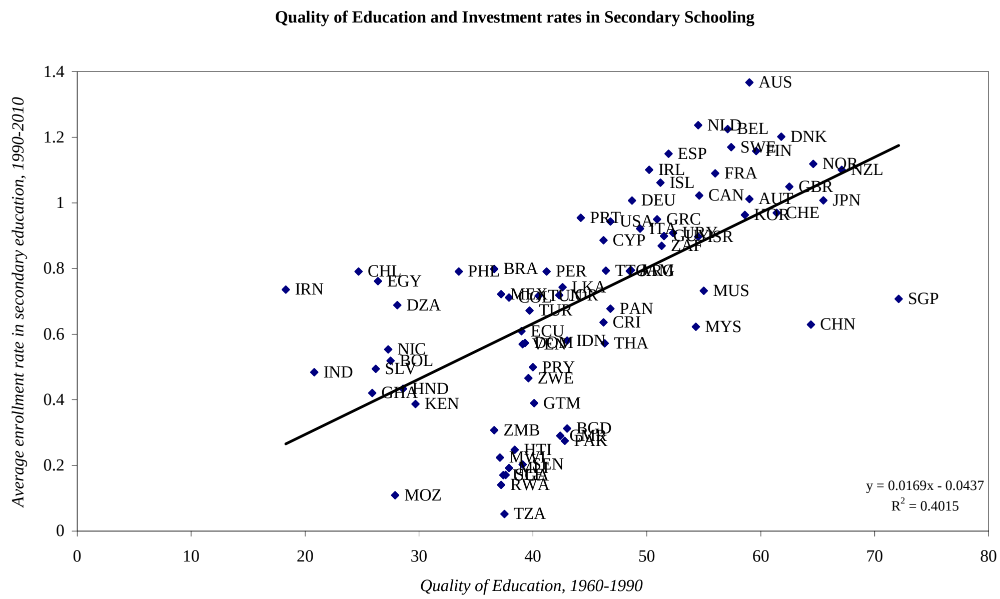
Note: Attainment levels refer to the population 25 years and above (Barro and Lee, 2001). The income classification is taken from the World Bank, 2007, which divides economies into income groups according to per capita gross national income.

affects the distribution of educational attainment and allows for different path of development. Specifically, the objective of this paper is to shed light on the following questions: Can educational quality account for higher education which are essentially an non-mandatory education? And if so, what are the channels through which educational quality operates? And how educational quality may affect the long run income level?

To answer these questions, we present 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: every individual is assumed to have the elementary skills which are taught in primary school, but there is an opportunity to continue on in education, which is a private choice. Specifically, higher education requires investment of private resources. Agents decide whether or not to pursue higher education, and if so, how much to spend on it. Accordingly, our focus is on the evolution of secondary education, under the assumption that the goal of universal basic literacy has already been met. Second, we assume the quality of the educational system to be an exogenous variable and, motivated by the evidence of Hanushek and Woessmann (2008), 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.[4]

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

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



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, 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.

Educational quality allows for different steps of development because the extensive and the intensive channels are not acting always with the same strength over the course of a country's development. 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. As a result, the economy is at the maximum possible income level in the steady state.

The level of educational quality determines the long-run income level, and depending on quality the economy may follow different paths. In one extreme, when quality is relatively high, the economy gradually develop towards the maximum possible income level in the steady state, with the full population investing in higher education. In the other extreme, when education quality is relatively low, the economy will find itself in a sort of poverty trap with no one going to secondary schooling.

The predictions of the model are tested on a broad sample of countries. Our measures of the quality of education refer to students' cognitive performance in various international tests of academic achievement in math and science, taken from Hanushek and Kimko (2000), Hanushek and Woessmann (2009) and Barro and Lee (2001). We measure university quality through international rankings that indicate universities' academic performance, taken from the Shanghai Jiao Tong University Academic Ranking of World Universities.

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 2009, and Cordoba and Ripoll 2007).[5] However, our paper concentrates on the effect of education quality on the process of development. Therefore, this paper analyses the dynamic relationship between educational quality, the distribution of educational attainments and economic growth. Surprisingly, there is a continuing lack of papers addressing this issue and we contribute to this literature in several aspects.[6] On the theoretical side, first no study so far has analyzed how educational quality affects schooling decisions regarding higher education. We show that, due to the extensive channel, educational quality could become a barrier to investments beyond primary levels. Consequently, we complement the literature of multiplicity of equilibria by providing an alternative theory generating this type of results.[7] Second, our work focuses on human capital composition by differentiating between primary and higher education, which in turn affects the process of development.[8] On the empirical side, the predictions of our theory are tested on

[5] Erosa et al. (2006) and Manuelli and Seshadri (2007) follow a similar approach and estimate the parameters of the production function of the human capital stock of a country that includes both time 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. Nevertheless, empirical evidence shows that increasing the amount of resources spent does not always translate into better learning among students (see, e.g., Hanushek, 1995; You, 2008). This issue motivates the inclusion of educational quality as a parameter that varies across countries and is exogenous to the individuals deciding about higher education.

[6] 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.

[7] 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-Cabrillana (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).

[8] 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. Nevertheless, their objective, which is different from us, is to explain income differences across country through cross-country human capital differences.

a broad sample of countries using regression analysis rather natural experiments and retrospective analysis in a particular country (see e.g., Glewwe and Jacoby, 1994; Case and Deaton, 1999; Duflo, 2001; Hanushek et al., 2008). As far as we know, we are the first to take a macroeconomic perspective by testing the effect of the quality of schooling on primary, secondary and tertiary schooling, and by using 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.[9] 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, 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.

In addition, we also find that the proposed channels through which educational quality affects secondary and tertiary 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, 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. 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. We show these results are not due to omitted variable bias, they hold 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. Results are also robust against outliers and are unlikely to be driven by reverse causation. In addition to analyzing the effect that the lagged value of the quality of schooling has on the future decisions to invest in higher education, we also correct for potential endogeneity bias by using instrumental variables.

The paper is organized as follows. Section 2 presents the model under partial equilibrium. Section 3 analyses the economy in a general equilibrium context. Section 4 describes the data. Section 5 empirically analyzes the channels through which quality influences the quantity of schooling. Section 6 examines the link between education and growth, and Section 7 states the conclusions reached.

2 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 exogenous.

[9] Hanushek and Kimko (2000), Hanushek and Woessmann (2008, 2009, 2010) analyze from a macroeconomic perspective the influence of the quality of education on the growth rates. For a detail analysis of these papers see Section 7.2.

Our economy consists of one sequence of overlapping generations that live for two periods. Agents have primary education which is compulsory and also have the opportunity to 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.

2.1 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.[10]

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, $\delta = 1$ and thus $R_{t+1} = 1 + r_{t+1} - \delta = r_{t+1}$.

2.2 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. Agents 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 $j = H, L$ and 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, while in the second periods agents supply their efficient units of education. Primary education is compulsory so that every individual is assumed to have the elementary skills which are taught in primary school.[11] Higher education requires private investments in education instead. Thus, in the first period of their lives, agents make decisions on whether or

[10] 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).

[11] Introducing a tax to finance primary schooling does not change the results qualitatively.

not to acquire higher education, so that even in the absence of expenditures, all individuals acquire primary education. Accordingly, our focus is on the evolution of secondary education, under the assumption that the goal of universal basic literacy has already been met.

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^i_{t+1} and bequest to their children, b^i_{t+1} where the upper index i refers to the individual. The preferences of individual i are given by[12],

$$u^i_t = (1-\beta)\ln c^i_{t+1} + \beta \ln b^i_{t+1},$$

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

$$c^i_{t+1} + b^i_{t+1} \leq y^i_{t+1}.$$

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

$$U^i_t = \ln(1-\beta)^{1-\beta}\beta^\beta y^i_{t+1}.$$

2.3 Formation of human capital

If agents choose to invest in higher education, they need to decide what level of private expenditures to make, which in our model is given by I_t. Alternatively, we can introduce investment 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.[13] The production function for higher education is

$$h^{high}_{t+1,j} = \theta a_j \mu (1+\theta I_t)^\phi \text{ with } j = H, L \text{ and } \phi < 1, \tag{3}$$

The human capital production function also depends on the quality of the educational system, which is exogenous and measured by θ, and on the level of ability a_j. When $I_t = 0$, the acquired level of human capital is primary schooling, $h^{pri}_{t+1,j} = \theta a_j \mu$ with μ being an exogenous investment made by the government. Although the marginal returns to investment in higher schooling diminishes with the real resources invested, rising school quality shifts the marginal returns upward over all educational levels.[14] Talented individuals have higher total returns and marginal returns on higher education than less talented ones. Notice that the marginal returns to quality in equation 3 are

[12] 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).

[13] 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.

[14] 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.

increasing. Entering in this way is important to be consistent with the empirical evidence showing us that quality affects educations decisions – for example figure 1.

Notice that the production function of secondary and tertiary education is given by equation (3). Due to this simple set up, 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, and thus the quantity of higher education per person.[15]

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

2.4 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. The main implication of this assumption is that when agents decide to invest beyond primary education, everybody makes the optimal investment to maximize expected income irrespective of one‘s initial wealth. Consequently, the allocation of productive capital between agents is independent of the current distribution of wealth levels, and what really matters is aggregate wealth.

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. 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

$$Max_{\{I_t \geq 0\}} \quad y^i_{t+1} = w_{t+1} h^{high}_{t+1,j} - R_{t+1}(I_t - b^i_t).$$

The optimal interior solution, I_t, equates the marginal return to physical capital and human capital,

$$w_{t+1}\theta^2\phi(1+\theta I_t)^{\phi-1}a_j = R_{t+1}. \tag{4}$$

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, which is given by

$$I^*_{t,a_j} = (\frac{w_{t+1}\theta^2\phi a_j}{R_{t+1}} - 1)^{\frac{1}{1-\phi}}. \tag{5}$$

Since the quality of the educational system positively affects the returns on education, education quality is a force that increases investment. We call this effect the *intensive channel*; the larger the quality, the larger the investment made per person. In the next sections, we will show that this effect is reinforce under general equilibrium, and that the date is in favor of this channel. The optimal level of higher education is increasing with ability and 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

[15] 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.

and NLSY97 (see Carneiro and Heckman, 2002, and Belley and Lochner, 2007). As expected, the optimal investment is increasing with the wage rate, decreasing with the opportunity cost of the educational investment and, due to perfect capital markets, independent of inherited wealth.

Since $\lim_{I_j \to 0} \frac{\partial h^{high}_{t+1,j}}{\partial I_j} < \infty$, we can find a θ low enough such that the FOC becomes $w_{t+1}\theta^2\phi a_j \mu < R_{t+1}$ and individuals optimally remains with primary, $I^*_{t,a_j} = 0$. Let's define the threshold level of educational quality in which agents are indifferent between investing in higher education or not

$$\widetilde{\theta}_j = (\frac{1}{a_j \phi \mu}\left(\frac{R_{t+1}}{w_{t+1}}\right))^{\frac{1}{2}}. \tag{6}$$

This equation identifies what we call the *extensive channel* of educational quality on decisions to access higher education. It states that only when quality is above a threshold, individuals enter higher schooling. By contrast when quality is below it, educational quality becomes a barrier to enter higher schooling. In the next sections, we will check if there is evidence in support of this channel.

This threshold depends on individuals, not through inherited wealth since capital markets are perfect, but through differences in ability. In particular, it decreases with ability since talented agents have more incentives to invest in higher education. It is increasing in the opportunity cost of higher education R_{t+1}, so that an increase in the interest rate tightens the constraints on higher investment. If 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.

The next proposition summarizes the optimal educational investment decisions under partial equilibrium. It states that education quality is a crucial variable in determining educational choices and thus human capital composition.

Proposition 1 *[Human capital composition and the extensive channel]. For a given level of* w_{t+1}, R_{t+1}, Y_t *and* θ *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 receive 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.*

3 General Equilibrium

Up to now, we have analyzed partial equilibrium, showing that educational quality becomes crucial explaining the composition of human capital. This is so because first, educational quality below a threshold would imply that some agents would prefer to remain with primary education–extensive channel–, and second better educational quality implies a larger level of investment in higher schooling *per person* –intensive channel. We will show that in general equilibrium, both results are reinforced since as the economy develops, higher output would entail a change in prices that provides incentives for agents to invest in higher education.

3.1 The economy's output accumulation path

In this section, we first analyze the threshold level of educational quality under general equilibrium, which distinguish the different stages of development. And second, we show that in every period the economy, as an aggregate, is entirely characterized by the aggregate output per worker or per capita, Y_t. Finally, we study its law of motion at each stage and along the process of development in order to understand the dynamics implications of the model for the composition of human capital, output and educational quality.

Let's find the analytical solution under general equilibrium of the lower bound of the threshold of quality– that is $\widetilde{\theta}_{a_{H,t}}$. By Proposition 1, we know that if quality is relatively low, i.e. $\theta < \widetilde{\theta}_{a_{H,t}}$ holds, all agents receive primary education and the aggregate capital stock at $t+1$ is as follows:

$$K_{t+1} = B_t = \beta Y_t,$$

Since capital depreciates at rate $\delta = 1$, the aggregate capital stock at $t+1$ comes from aggregate savings, which are given by the aggregate level of bequest. The aggregate stock of human capital is given by

$$H_{t+1} = \gamma h_{t+1}^{i,pr} + (1-\gamma) h_{t+1}^{i,pr}.$$

And the capital-labor ratio is as follows

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

with $\overline{a} = \gamma a_H + (1-\gamma) a_L$ being the average ability, and k_{t+1} being increasing in Y_t and decreasing in θ. Taking into account this capital-labor ratio and equations (2) and (6), the threshold level of education quality for high ability agents is

$$\widetilde{\theta}_{a_{H,t}} = \frac{\overline{a}\alpha}{\beta Y_t a_H \phi (1-\alpha)}. \tag{7}$$

The upper bound of the threshold of quality is given by $\widetilde{\theta}_{a_L}$. If $\theta > \widetilde{\theta}_{a_L}$ holds, all agents invest in higher education and thus, the aggregate capital stock is given by

$$K_{t+1} = \beta Y_t - \gamma I_{t,a_H}^{*} - (1-\gamma) I_{t,a_L}^{*}.$$

The aggregate stock of human capital is

$$H_{t+1} = \gamma h_{t+1}^{high} + (1-\gamma) h_{t+1}^{high} = \gamma \theta a_L \mu (1 + I_{t,a_L}^{*})^{\phi} + (1-\gamma) \theta a_H \mu (1 + I_{t,a_H}^{*})^{\phi}.$$

Since I_{t,a_j}^{*} is strictly increasing in k_{t+1} (see equation 2 and 5), after some calculation the capital-labor ratio is given by

$$k_{t+1} = \frac{(\beta Y_t + \frac{1}{\theta})^{1-\phi}}{\theta^{1+\theta} \widetilde{a}^{1-\phi} \mu (\frac{1-\alpha}{\alpha} \phi)[1 + \frac{\alpha}{(1-\alpha)\phi}]^{1-\phi}} = k^{III}(Y_t, \theta), \tag{8}$$

with $\widetilde{a} = \gamma a_L^{\frac{1}{1-\phi}} + (1-\gamma)a_H^{\frac{1}{1-\phi}}$ and k_{t+1} being increasing in Y_t and decreasing in θ.[16] Considering this capital-labor ratio and equations (3) and (6), the threshold level of education quality for low ability agents is

$$\widetilde{\theta}_{a_{L,t}} = \frac{\alpha\widetilde{a} + (1-\alpha)\phi(\widetilde{a} - a_L^{\frac{1}{1-\phi}})}{\beta Y_t a_L^{\frac{1}{1-\phi}}\phi(1-\alpha)}. \tag{9}$$

For a given Y_t, $\widetilde{\theta}_{a_{H,t}} < \widetilde{\theta}_{a_{L,t}}$ holds[17]. The thresholds level of education quality varies systematically with the level of development. Figure 2 shows the dynamics of the *extensive channel* as a function of per capita output. In particular, it is decreasing with Y_t since as output per capita increases, the equilibrium prices change because the interest rate decreases and wages increases. As a result, the constraints on quality are relaxed as the economy develops.

$[Insert\ Figure\ 2]$.

We can define the threshold level of per capita output $\widetilde{Y}_{aj}(\cdot) = (\widetilde{\theta}_{aj})^{-1}$. From Figure 2, we need to consider the three following cases: a) **Regime I:** $\theta \leq \widetilde{\theta}_{a_{H,t}} < \widetilde{\theta}_{a_{L,t}}$(or similarly $Y_t \leq \widetilde{Y}_{a_H} < \widetilde{Y}_{a_L}$), with all agents with primary education, b) **Regime II:** $\widetilde{\theta}_{a_{H,t}} < \theta < \widetilde{\theta}_{a_{L,t}}$ (that is, $\widetilde{Y}_{a_H} < Y_t < \widetilde{Y}_{a_L}$), with only talented individuals with higher education and c) **Regime III:** $\widetilde{\theta}_{a_{H,t}} < \widetilde{\theta}_{a_{L,t}} \leq \theta$ (or similarly $\widetilde{Y}_{a_H} < \widetilde{Y}_{a_L} \leq Y_t$), where all agents have higher education.

Under **Regime I)** If $\theta < \widetilde{\theta}_{aH,t}$, the aggregate output per capita is given by

$$Y_{t+1} = (\beta Y_t)^{\alpha}(\theta\overline{a}\mu)^{1-\alpha}. \tag{10}$$

with $Y_{t+1} = Y^I(Y_t, \theta)$.

Under **Regime II)** $\widetilde{\theta}_{a_{H,t}} < \theta < \widetilde{\theta}_{a_{L,t}}$,only talented individuals invest in higher education. The aggregate stock of physical capital is,

$$K_{t+1} = \beta Y_t - \gamma I^*_{t,a_H}$$

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

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

The capital-labor ratio is

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

Notice that I^*_{t,a_j} is strictly increasing in k_{t+1}. This equation implicitly define $k_{t+1} = k^{II}(Y_t,\, \theta)$. It is easy to check that $\partial k_{t+1}/\partial\theta < 0$, $\partial k_{t+1}/\partial Y_t > 0$.

[16] We need $1 > \varepsilon + \phi$ for k_{t+1} be increasing with Y_t.

[17] This is so, because $\frac{\overline{a}}{a_H} < 1$ and $\frac{\widetilde{a}}{a_L^{\frac{1}{1-\phi}}} > 1$ always hold.

The aggregate output per capita is given by

$$Y_{t+1} = (\beta Y_t - \gamma I^*_{t,a_H})^\alpha(\gamma\theta a_L\mu + (1-\gamma)\theta a_H\mu(1+I^*_{t,a_H})^\phi)^{1-\alpha}. \tag{11}$$

with $Y_{t+1} = Y^{II}(Y_t, \theta)$.

Under **Regime III)** $\widetilde{\theta}_{a_{H,t}} < \widetilde{\theta}_{a_{L,t}} \leq \theta$, the aggregate output per capita is given by

$$Y_{t+1} = (\beta Y_t - \gamma I^*_{t,a_L} - (1-\gamma)I^*_{t,a_H})^\alpha(\gamma\theta a_L\mu(1+I^*_{t,a_L})^\phi + (1-\gamma)\theta a_H\mu(1+I^*_{t,a_H})^\phi)^{1-\alpha} \tag{12}$$

with $Y_{t+1} = Y^{III}(Y_t, \theta)$.

In short, the evolution of output per worker is given by the following expression

$$Y_{t+1} = \begin{cases} Y^{III}(Y_t,\theta) & if \quad \widetilde{Y}_{a_L} \leq Y_t \text{ or } \widetilde{\theta}_{a_L,t} \leq \theta \\ Y^{II}(Y_t,\theta) & if \quad \widetilde{Y}_{a_H} \leq Y_t < \widetilde{Y}_{a_L} \text{ or } \widetilde{\theta}_{a_H,t} \leq \theta < \widetilde{\theta}_{a_L,t} \\ Y^{I}(Y_t,\theta) & if \quad Y_t < \widetilde{Y}_{a_H} \text{ or } \theta < \widetilde{\theta}_{a_H,t} \end{cases} \tag{13}$$

In the next section, we discuss the most interesting equilibrium dynamics paths.

3.2 The dynamics of output per worker

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. Intuitively, because under Regime III all agents maximize income, output per worker is the highest. Since Regime II is the mixed regime between Regime I and Regime II, then $Y^{III}_{t+1} \geqq Y^{II}_{t+1} \geqq Y^{I}_{t+1}$ holds at any t. 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]

Let us consider the following order of the parameters:

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

The dynamics of output per capita is depicted in figure 3. 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, agents optimally attend only primary education. As output per worker increases, due to physical capital accumulation, 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 schooling levels. Along this transition 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. Once the economy reaches Regime III and all agents are investing the optimal amount in higher education, it will remain in this regime thereafter. 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. 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.

In summary, Figure 3 shows us the interdependence among economic growth, the distribution of educational attainment, and the quality of the educational system. As we move along the three development paths, output per worker increases, which in turn, due to general equilibrium effects, increases the future capital-labor ratio changing the equilibrium prices. Specifically, larger output per worker increases the wage per efficient unit and decreases the interest rate–see equation 2– so that agents get incentives to invest in higher education. Consequently, as output increases, more people could enter into higher schooling –the constraint on quality relaxed (see figure 2)– and, once agents decided to invest in higher education, the investment per person also increases. Both effects, due to the general equilibrium price changes, en up fostering the accumulation of human capital.

The next proposition summarizes the equilibirum and some of its properties.

Proposition 2: *If the aggregate output per worker is given by the law of motion in equation (11) and if* $\widetilde{Y}_{a_L} < Y_{ss}^{I}$ *holds,* Y_{ss}^{III} *is the unique and locally stable equilibrium. Moreover, it is the highest possible steady state.*

Proof. *See Appendix.*

Clearly, because under Regime III all agents maximize income, output per worker is maximized. The implication of the proposition above is the following corollary.

Corollary 1. *[Comparative statics of educational quality on aggregate output per capita]. An increase in educational quality moves the path of output per worker upwards under Regime III solely through the direct effect of quality on the human capital production function, and not through the indirect effect of quality on the investment in higher education.*

Countries like South Korea, or Taiwan in the 40's were doing enormous initial investment in education to implement its strong educational reforms, and both countries move to a higher steady state.

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}. Since $Y_{ss}^{I} < \widetilde{Y}_{a_H}$ holds, the economy converges to the low stable steady state Y_{ss}^{I}, where agents only have primary education. For any level of output between the thresholds $\widetilde{Y}_{a_H}$ and $\widetilde{Y}_{a_L}$, the economy converge to Y_{ss}^{II}. And 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 country can be stuck at the low steady state where agents only have primary education. This may occur when the marginal propensity to save is low, since Y_{ss}^{I} is increasing with β and $\widetilde{Y}_{a_H}$ is decreasing instead. In our model more education is given by transforming physical capital into human capital. Therefore, economies with a low savings rate will accumulate less physical capital, and thus per capita output at a lower rate. Similarly, when θ is very low, it could trap the economy at a low level of development since with an initially very low quality of the educational system, the extensive channel becomes effective, so that

$\widetilde{Y}_{a_H}$ will be relatively high and Y_{ss}^I will be relatively low.

In short, this paper suggests that low educational quality could adversely affect a country's process of development through the extensive and the intensive channels. In the following, we will text empirically whether educational quality affects the growth process.

4 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.[18]

Hanushek and Woessmann (2009) extend previous measures to improve direct comparisons of student knowledge over time, across tests and across age groups.[19] The new data set provides measures of test scores for 77 countries as an average over the period 1964-2003. However, in spite of its improvement in comparability terms and the effort to include more countries, for many of the new countries there are not data on per capita GDP for the period 1960-2004 (e.g. the new data set includes 15 former communist countries). As a result, when combined Hanushek and Woessmann's (2009) data with other data sets the number of observations in the sample is highly reduced.

We also use Barro and Lee's (2001) data set, 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, we use data of 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).

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

[19] Tests are performed mainly in students at the secondary level of education, usually from age 9 to age 15.

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 ranking 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] 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. The source is the latest Barro and Lee's (2010) data set available from 1950 to 2010. 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. The time span for enrollment rates is from 1960 to 2008.

To avoid the results to be biased by omitted variables, we control for an array of measures that could influence the decisions of individuals to invest in higher education as well as other variables that are related to both the quantity and quality of schooling. Next we define the additional controls and in the next section we discuss in detail why these variables should be included in the analysis.

We control for the degree of credit market imperfection. 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 variable (*FD),* which equals the private credit provided by deposit money banks, 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

[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 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 imperfections in credit markets directly, we expect there to be less restriction to access credit since the financial system is more developed.

To control for the number of years that are compulsory at the secondary level, we take data on duration of compulsory education from UNESCO.[22] 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). Geographical characteristics are measured with a dummy for countries located in tropical areas taken from Easterly and Sewadeh (2002). Finally, 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), and the share of total population living in urban areas, from Easterly and Sewadeh (2002).

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).

5 Empirical results on the effect of quality on quantity of education

5.1 Hypothesis to be tested

5.1.1 Extensive channel [H1]

Proposition 1 shows that only when quality is above a threshold level, individuals decide to invest in secondary schooling, creating a broader segment of the population with a higher education. One cross-country implication of this Proposition is that we would expect that in countries where educational quality is larger, the stock of people with secondary schooling will be larger too. To check this hypothesis, our empirical strategy would be the following:

$$\begin{aligned} Education_{i,t} &= \alpha_0 + \alpha_1 Quality^h_{i,t-\tau} + \alpha_2 \ln y_{i,t-\tau} \\ &\quad + \alpha_3 FD_{i,t-\tau} + \alpha_4 YearsC_{i,t-\tau} + \alpha_4 X_{i,t-\tau} + \nu_{i,t}, \end{aligned} \tag{14}$$

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 and t for the time. To minimize reverse causation all explanatory variables are lagged τ periods. This channel

[22] The main drawback of the data on years of compulsory education is that they are only available from 2000 onwards.

states that the higher the quality of education ($Quality^h$) the higher the number of individuals that will decide to enter secondary schooling. Hence, we expect $\alpha_1 > 0$ and statistically significant.

In general equilibrium, the investment in higher education is also determined by equilibrium prices, which in turn depend on the aggregate level of per capita output. Specifically, it increases with aggregate output per capita. To avoid the coefficient of quality is also picking up the general equilibrium effect, we need to control for the initial level of per capita income ($\ln y$). We also include other mechanisms that can influence the decision to invest in higher education such as the number of compulsory years in secondary schooling ($YearsC$), and the existence of credit market constraints, proxied by the degree of financial development (FD). As detailed below, other controls also include time invariant variables to account for cultural, political and geographical characteristics that may influence both the quality and the quantity of education.

5.1.2 Intensive channel [H2]

The model shows that once people decide to enter higher education, the larger the quality the larger the investment rates will be

$$I^*_{t,a_j} = I(\underset{+}{\theta}, \underset{+}{Y_t}...) \tag{15}$$

Since the seminal work by Mankiw et al. (1992) it has been common in the empirical literature to use the secondary school enrollment rate as a proxy for human capital investment. Using this measure as the dependent variable, we test the intensive margin with the following econometric specification:

$$\dot{h}_{i,t} = \beta_0 + \beta_1 Quality^h_{t-\tau} + \beta_2 \ln y_{i,t-\tau} + \beta_3 Education_{i,t-\tau} + \mu_{i,t} \tag{16}$$

where $\dot{h}$ stands for the accumulation of higher education, measured through the enrollment rates in secondary schooling. As before, the specification also accounts for the general equilibrium effects by including per capita income in the set of controls. Once individuals have decided to invest in education, a better-quality educational system implies a higher investment in schooling. Thus, controlling for the initial stock of secondary education ($Education$), we expect $\beta_1 > 0$ and statistically significant.

5.2 Empirical Results

We start by testing H1 and H2 using Hanushek and Kimko's (2000) data set on quality since it contains a greater number of countries, including several developing economies, as compared to other available data sets. Nevertheless, in the next subsection we show the results are robust to alternative measures of educational quality.

In order to correct for potential endogeneity bias we measure the explanatory variables lagged several years. Specifically, given the variable on educational quality is available as an average over the period 1964-1991, we split the whole sample into two sub periods and measure the explanatory variables from 1960 to 1990 and the dependent variable from 1990 to 2010. Table 2 displays the results for the extensive margin in columns (1-6) and those for the intensive channel in columns (7-9).

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 the subsequent 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 6 percent. This 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 dummy variables that control 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. 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 explain about 60 percent of the variation across countries in secondary schooling attainment levels.

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. For example, 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]

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 (4) 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

[23] Countries whose residuals exceed more than two times the estimated standard error of the residuals include Ghana and Sri Lanka, with a positive value and New Zealand with a negative one.

[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).

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.

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. Thus, column (5) controls for private credit provided by deposit money banks 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.

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 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 that 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.

Overall, our results show a quite robust and positive effect of the quality of education on the subsequent 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.

The intensive margin is tested in columns (7-9), where the educational investment rates are proxied 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 0.08 points in enrollment rates. Likewise, countries with higher per capita income in

[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.

1960 also have higher average enrollment rates over the period 1990-2010. 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.[27]

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.

5.3 Robustness of the results

5.3.1 Alternative measures of the quality of education

We test the robustness of the previous results with alternative measures of quality compiled by Barro and Lee (2001). The advantage of this data set is that it includes observations of test scores for different years, which allows us to include explanatory variables lagged five years to minimize endogeneity concerns. However, this comes at the cost of reducing the number of countries by almost half.[28] 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. The upper part of Table 3 shows the estimated coefficient of the quality of education in each specification is similar to that obtained with Hanushek and Kimko's data. Moreover, the estimated coefficient of quality is statistically significant in almost all specifications.

Results also hold with the measure of quality updated by Hanushek and Woessmann (2009), which is a clear improvement in terms of comparability over time, across tests and across students age group. However, when combined with the other data sets the number of observations when using this measure reduces to only 45 economies. The results, displayed in panel B, show that the previous findings using Hanushek and Kimko´s data are not a product of measurement error bias. The use of the improved data set that ensures a better comparability across countries also shows a clear positive and significant effect of a better quality of education on the share of individuals with secondary schooling. Likewise, once controlling for the stock of secondary education, higher quality also boosts the investment rates in education, as reflected by the higher enrollment rates.

However, since the data on quality of Hanushek and Woessmann (2009) is computed as an average up to the year 2003, it is more difficult to control for endogeneity in this scenario. In line with Pritchett (2000) and Krueger and Lindalh (2001), who use Nerhu et al (1995) and Kyriacou's (1991) schooling data, respectively, as an instrument for Barro and Lee's (2003) measures on years of schooling, at the bottom part of Table 3 we follow an instrumental variable approach an use the

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

[28] The results displayed in Panel A 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.

measure of Hanushek and Kimko (2000) as an instrument for the quality measure of Hanushek and Woessmann (2009). The correlation among both variables is high (0.71), and the quality variable of Hanushek and Kimko (2001) should not influence attainments levels and enrollment rates directly except as an instrument for the quality of education. Furthermore, the high value of the F-test in the first stage regression suggests the results do not suffer from a weak instrument problem. Findings reveal that the positive effect of the quality of education on the quantity of schooling continues being positive and significant. In fact, the estimated coefficient of quality is now higher than its OLS counterpart in Panel B. Nevertheless, in quantitative terms the impact on attainment levels is similar to that found in Table 2. According to column (1), a one standard deviation increase in the quality of schooling (0.592) increases the secondary attainment levels by 5 percent.

5.3.2 Alternative measures of the quantity of education

In Section 2 we modelize higher education in a reduced form, as we do not differentiate between secondary and tertiary education. However, in the empirical analysis we can check whether the extensive and intensive channels can be found at the university level. 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.[29]

The upper part of 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, averaged over the period 2000-2010.[30] 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 increase of 2.6 percent in attainment levels in tertiary education. This effect is high since the average attainment levels during the period 2000-2010 is 11.5 percent in the sample

[29] 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.

[30] We are forced to use data on university quality from 2003 because the rankings are only available from 2003 onwards.

that includes all countries and 2.3 percent in the Sub-Saharan African region. As displayed in columns (2-6), 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, an indicator of financial development and cultural, political and geographical variables. Furthermore, column (9) shows that once individuals decide to enter tertiary education, that is, controlling for the stock, the higher the quality of universities the higher the investment rates in tertiary education.

In our model we assume that the primary level of education is publicly provided by the government 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). Not surprisingly, the lower part of Table 4 shows no effect of the quality of education on the share of individuals with primary education and the investment rates in primary schooling; the coefficient of quality is close to zero in almost all specifications.

6 Education and growth

6.1 Hypothesis to be tested

6.1.1 Effect of the quality of education on development [H3]

Proposition 2 shows that under Regime III, that is, when quality is sufficiently high $\theta > \widetilde{\theta}_{a_L,t}$, all agents maximize income and thus output per worker is maximized. One implication of this proposition will be that when quality exceeds a threshold, the larger the educational quality, the larger the rate of growth of a country.

Our identification strategy would be to differentiate among high and low quality countries to test whether the quality of education has influenced the economies' growth rates of real per capita GDP. Specifically:

$$\begin{aligned} \Delta \ln y_{i,t} \quad = \quad & \gamma_0 + \gamma_1 Quality^h_{i,t-\tau} * dummy^{LOW}_{QLTi} + \\ & \gamma_2 Quality^h_{i,t-\tau} * dummy^{HIGH}_{QLTi} + \\ & \gamma_3 \ln y_{i,t-\tau} + \gamma_4 X_{i,t-\tau} + \mu_{i,t} \end{aligned} \qquad (17)$$

where $\Delta \ln y$ is the growth rate of per capita income and the explanatory variables include standard determinants of growth. To pick up a differential effect of low and higher educational quality we interact the quality measure with low and high quality dummies. The low quality dummy is equal to one if the value of quality is lower than the mean of the OECD countries minus 2 times its standard deviation, and zero otherwise. The dummy of high quality countries is equal to one if the quality value is higher than this threshold level. Thus, we would expect a negligible effect when quality is below a threshold level, that is $\gamma_1 \approx 0$, and a positive effect when quality is above that level, $\gamma_2 > 0$.

6.1.2 Effect of quality and investment rate in education on development [H4]

Corollary 1 shows that when output is relatively high, the positive impact of changes in quality on output per worker is only due to the direct effect of quality on the human capital production function, and not through the indirect effect of quality on the investment in higher education.

$$Y_{t+1} = Y^{III}(Y_t, \theta, \underbrace{I^*_{t,a_j}(\theta)}_{=0}) \tag{18}$$

We would expect that once the quality and quantity of schooling are included as explanatory variables in a standard growth regression, the effect of quantity would depend on the country's stage of development. In our model, given that capital markets are perfect, when countries are on their steady state the level of investment is maximized and the indirect effect of quality on output disappear. This hypothesis is difficult to test since knowing whether a country is at its steady state is not straightforward. Nevertheless, as an approximation, we assume that rich countries are more likely to be closer to their steady state than poorer economies. Thus, we would expect that in high-income economies, the quality of the educational system is more important than the investment in the quantity of education. Empirically we test H4 with the following econometric specification:

$$\begin{aligned} \Delta \ln y_{i,t} \quad = \quad & \rho_0 + \rho_1 \dot{h}_{i,t-\tau} * dummy^{LOW}_{Yi} + \\ & \rho_2 \dot{h}_{i,t-\tau} * dummy^{HIGH}_{Yi} + \rho_3 Quality^h_{i,t-\tau} \\ & \rho_4 \ln y_{i,t-\tau} + \rho_5 X_{i,t-\tau} + \mu_{i,t} \end{aligned} \tag{19}$$

where $dummy^{LOW}_{Yi}$ is equal to one if the real GDP in 1960 is lower than the 75th percentile of the income distribution in that year and zero otherwise. Likewise, $dummy^{HIGH}_{Yi}$ is equal to one if the real GDP per capita in 1960 is within the top 25 percentile of the income distribution, and zero otherwise. We should expect a positive effect of the quality of education on growth ($\rho_3 > 0$). On the other hand, the effect of the investment rate in education should be higher in those countries that are further to their steady states, $\rho_1 > 0$ and $\rho_2 \approx 0$.

6.2 Empirical results

We test H3 in Table 5, in which the average growth rate of per capita income for the period 1960-2004 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.[31] 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. Certainly, when we split the quality effect between low and high quality countries our results show that whereas the estimated coefficient of the quality of education is not significant in countries with quality at the bottom end of the distribution, higher-quality educational systems have a positive and statistically significant effect in most of the economies (column (2)).

On the other hand, hypothesis [H4] states 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, measured 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 1960-2004. Moreover, in line with the theoretical predictions, column (4) shows that 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.[32]

Finally, in column (5) we test H3 and H4 in the same specification. In line with the previous findings, results show that the effect of the quality of education on growth is positive and statistically significant only when quality is relatively high. Furthermore, once we control for the quality of education, 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.[33]

Hanushek and Kimko (2000) are the first to show that once the quality of education is taken into account the effect of the average years of schooling in an otherwise standard growth equation vanishes. In Table 6 we take Hanushek and Kimko (2000) results as a benchmark and show that the

[31] 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.

[32] 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.

[33] The results are robust to the cutoff point of top-income countries. Specifically, 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. Moreover, the results are also robust to the measure of quality by Hanushek and Woessmann (2009), although in this case the coefficient of the interaction term of the investment rate with the low income dummy lowers significance when we test H3+H4. Furthermore, if instead of measuring quantity of education with the enrollment rates, we measure quantity with the attainment levels in secondary education, our results still hold.

effect of quality and quantity of education on growth differs according to the degree of quality and the level of development of the economy. Columns (1) and (2) display similar results are those found by Hanushek and Kimko (2000), that is, the positive coefficient of the average years of schooling (column 1)) disappears once a measure of the quality of education is included in the set of controls (column 2)). Going one step further, column (3) shows that the positive effect of quality on growth is found only when quality is relatively high, which leads to the suggestion that quality is not growth enhancing unless students achieve a minimum level of knowledge. When including the effect of quality and quantity together –see column (5)– we find the influence of quantity is different in low and high income economies. When the effect of quality is accounted for, whereas the influence of quantity disappears in high income economies, we still find a positive influence of quantity on growth in lower income countries.

Overall, the results show that whereas Hanushek and Kimko's findings hold for the whole sample of countries, depending on the level of quality and the level of development of the economy several nuances can be made to this general result. Following the predictions of our theoretical model we find that in order the quality of education to increase the economic performance of the economies, quality has to be above a threshold level that guarantees that the individuals have reached a minimum level of knowledge. Second, in most of the economies not only an increase in the quality of education but also an increment in the quantity of schooling is associated to a higher income per capita growth rate. However, in countries at the top end of the income distribution increases in the quality of education are more growth enhancing than increases in the quantity of schooling.

7 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. Our proposed 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 higher education. 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. These results are not driven by omitted variables, are robust to several measures of educational quality and are not influenced by atypical observations.

This paper also extends Hanushek and Kimko (2000)'s results, who were the first to show that in the estimation of a standard growth equation, once a measure of quality is accounted for, the positive coefficient of the average years of education stops being statistically significant whereas the positive effect of the quality of schooling remains significant. In line with the predictions of the theoretical model, it is shown that the positive influence of the quality of education on economic growth is only found in countries in which the quality of education is relatively high, suggesting that for quality to be growth enhancing the individuals need to acquire a minimum level of knowledge. Moreover, when quality and quantity of education are included as potential determinants of growth, not only quality but also quantity is growth enhancing in the less developed countries, whereas the results show a predominant effect of quality over quantity in the top income countries.

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.

8 References

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9 Appendix

Proof of Proposition 2.

If $\widetilde{Y}_{a_L} < Y_{ss}^{I}$ *holds, it implies that the following order of the parameters* $\widetilde{Y}_{aH} < \widetilde{Y}_{a_L} < Y_{ss}^{I} < Y_{ss}^{II} < Y_{ss}^{III}$ *holds too, so that the only possible equilibrium is under the Regime III. First, we show that law of motion of* Y_{t+1}^{III} *is strictly concave. And second, we show that that the next condition holds:* $\lim_{Y\to\infty} \frac{\partial Y_{t+1}^{III}}{\partial Y_t^{III}} = 0$.

Substituting equation (8) into the law of motion of Y_{t+1}^{III}(see equation (12))*, we obtain after some maths the following expression*

$$Y_{t+1}^{III} = \left(\frac{(\beta Y_t\theta+1)\alpha}{\theta(\alpha+(1-\alpha)\phi)}\right)^{\alpha}\left(\widetilde{a}^{1-\phi}\theta\left(\frac{(\beta Y_t\theta+1)(1-\alpha)\phi}{\alpha+(1-\alpha)\phi}\right)^{\phi}\right)^{1-\alpha}$$

Takink derivatives $\frac{\partial Y_{t+1}^{III}}{\partial Y_t^{III}} = (\alpha+(1-\alpha)\phi)(\beta Y_t\theta+1)^{\alpha+(1-\alpha)\phi-1}\Delta > 0$, *with* Δ *being a strictly positive constant, and* $\frac{\partial^2 Y_{t+1}^{III}}{\partial^2 Y_t^{III}} < 0$ *since* $0 < \alpha < 1$. *Finally,* $\lim_{Y\to\infty}\frac{\partial Y_{t+1}^{III}}{\partial Y_t^{III}} = 0$, *because* $\alpha + (1-\alpha)\phi < 1$.

QED.

Proof Corollary 1. *Under Regime III the output per worker is given by*

$$Y_{t+1} = (\beta Y_t - \gamma I_{t,a_L}^{*} - (1-\gamma)I_{t,a_H}^{*})^{\alpha}(\gamma\theta a_L\mu(1+I_{t,a_L}^{*})^{\phi} + (1-\gamma)\theta a_H\mu(1+I_{t,a_H}^{*})^{\phi})^{1-\alpha}$$

If we take the derivative of Y_{t+1}^{III} *with respect to educational quality we have*

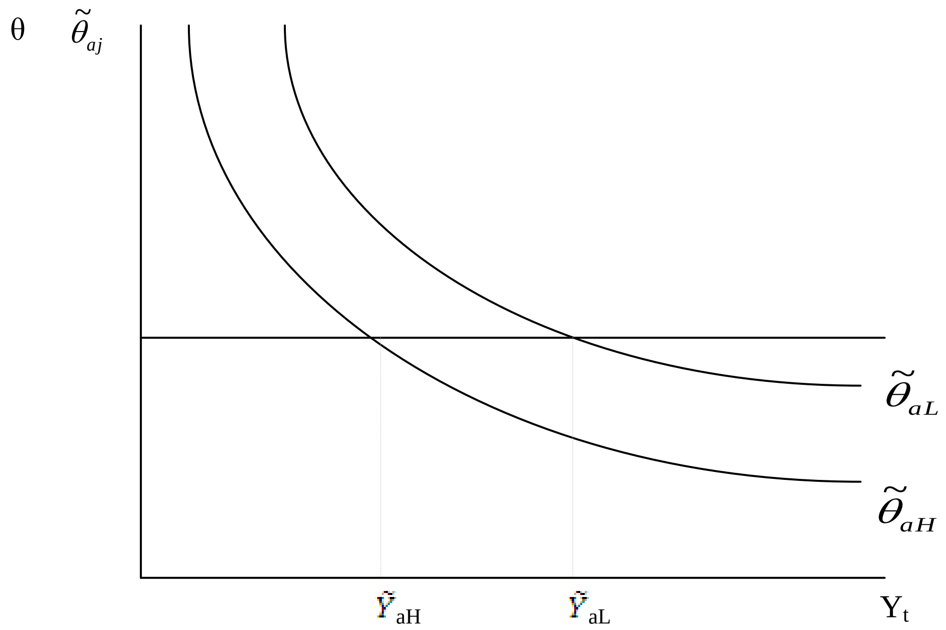
$$\frac{\partial Y_{t+1}^{III}}{\partial\theta} = \frac{\partial Y_{t+1}^{III}}{\partial\theta} + \frac{\partial Y_{t+1}^{III}}{\partial I_{t,j}^{*}}\frac{\partial I_{t,j}^{*}}{\partial\theta} > 0 \text{ for any } a_j \text{ with } j = H, L$$

The first term, $\frac{\partial Y_{t+1}^{III}}{\partial\theta}$, *is what we call the direct effect, which is strictly positive. The indirect effect is given by* $\frac{\partial Y_{t+1}^{III}}{\partial I_{t,j}^{*}}\frac{\partial I_{t,j}^{*}}{\partial\theta}$ *and it cancels out because* $I_{t,a^j}^{*} = \arg\max Y_{t+1}^{III}$. *Consequently, the FOC are*

$$\frac{\partial Y_{t+1}^{III}}{\partial I_{t,j}^{*}} = \alpha K_{t+1}^{\alpha-1}H_{t+1}^{1-\alpha}(-1) + (1-\alpha)K_{t+1}^{\alpha}H_{t+1}^{-\alpha}\{\theta\varepsilon I_t^{*\varepsilon-1}\} = 0.$$

This is so because, taking into account equation (2)*, the expression* $\frac{\partial Y_{t+1}^{III}}{\partial I_{t,j}^{*}}$ *can be rewritten as* $R_{t+1} = w_{t+1}a_j\theta\varepsilon I_{t,j}^{*\varepsilon-1}$, for any a_j with $j = H, L$, *which is the FOC of the efficient level of investment in education.*

QED.



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

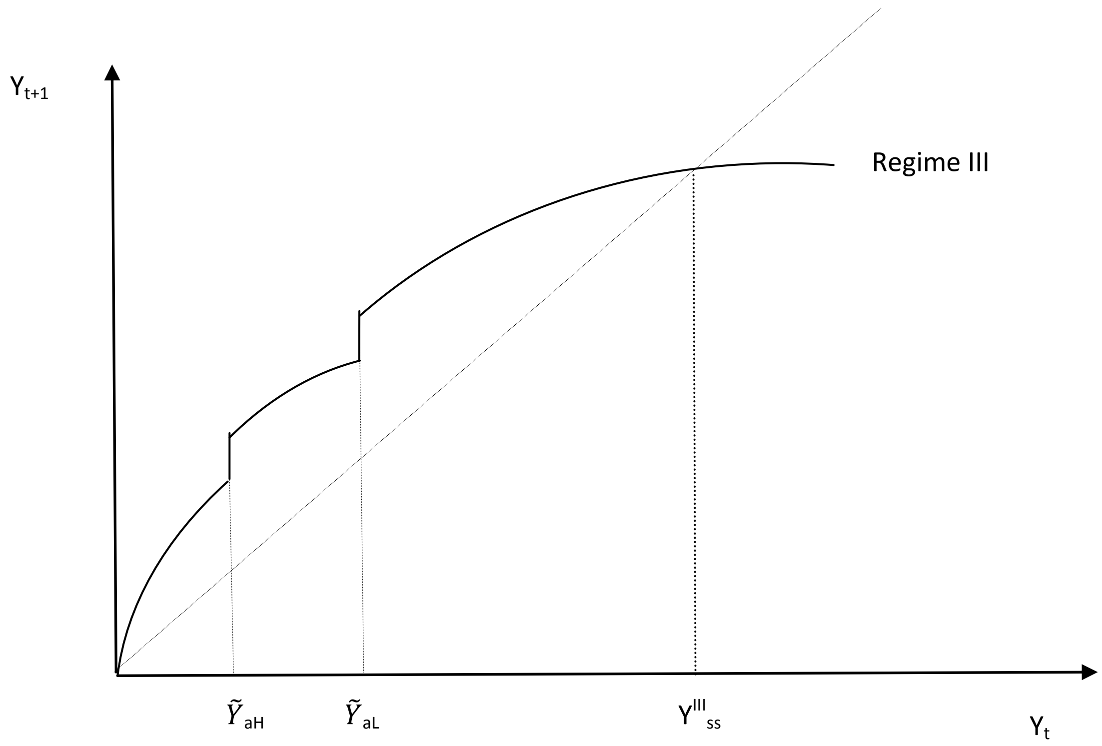


Table 2

Dependent variable: Education at the secondary level

	H1						H2		
	Attainment level ($Education^{SEC}_{1990-2010}$)						Enrollment rates ($\overset{\bullet}{h}{}^{SEC}_{1990-2010}$)		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$Quality^{HK}_{60-90}$	0.005^a	0.005^a	0.004^a	0.004^a	0.003^b	0.003^b	0.007^a	0.008^a	0.007^a
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)
lny_{60}	0.064^a	0.086^a	0.007	0.005	0.031	-0.016	0.222^a	0.219^a	0.201^a
	(0.022)	(0.020)	(0.029)	(0.030)	(0.030)	(0.024)	(0.028)	(0.028)	(0.031)
d_+		0.350^a	0.264^a	0.259^a	0.295^a	0.266^a		0.345^a	0.342^a
		(0.063)	(0.037)	(0.044)	(0.040)	(0.033)		(0.038)	(0.037)
d_-		-0.313^a	-0.275^a	-0.277^a	-0.264^a	0.264^a		-0.354^a	-0.335^a
		(0.027)	(0.027)	(0.027)	(0.036)	(0.041)		(0.026)	(0.028)
$Education^{SEC}_{60}$									0.324
									(0.215)
$PSEduc_{60-90}$			0.029^a	0.029^a	0.026^a	0.034^a			
			(0.008)	(0.009)	(0.009)	(0.009)			
$lnurb_{60-90}$			0.094^a	0.093^a	0.087^a	0.102^a			
			(0.023)	(0.024)	(0.023)	(0.020)			
$Years\ compulsory^{SEC}$				0.002	-0.001	-0.012^c			
				(0.008)	(0.007)	(0.006)			
FD_{60-90}					0.014	-0.064			
					(0.054)	(0.058)			
East Asia						0.041			
						(0.045)			
Muslims						-0.001^b			
						(0.000)			
Catholics						0.000			
						(0.000)			
Protestants						0.000			
						(0.000)			
School Days						0.001^c			
						(0.001)			
Institutions						0.060^c			
						(0.032)			
Tropical						-0.097^a			
						(0.030)			
Constant	-0.385^b	-0.590^a	-0.367^b	-0.355^b	-0.479^a	-0.336^c	-1.382^a	-1.384^a	-1.232^a
	(0.167)	(0.129)	(0.139)	(0.158)	(0.159)	(0.185)	(0.197)	(0.197)	(0.225)
R^2	0.428	0.603	0.677	0.677	0.698	0.783	0.719	0.754	0.762
Countries	72	72	66	66	63	63	71	71	71

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).

Table 3

Dependent variable: Education at the secondary level

	H1						H2		
	Attainment level ($Education_t^{SEC}$)						*Enrollment rates* ($\dot{h}_t^{SEC}$)		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
A- Measure of quality: Barro and Lee (2001), pooled OLS									
$Quality_{t-5}^{BL}$	0.006^b	0.004^c	0.003	0.002	0.005^c	0.003	0.007^b	0.007^b	0.006^b
	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)	(0.003)	(0.003)	(0.002)
lny_{t-5}	0.089^a	0.103^a	0.042	0.042	0.058^c	0.057	0.183^a	0.178^a	0.166^a
	(0.027)	(0.025)	(0.033)	(0.032)	(0.030)	(0.044)	(0.025)	(0.024)	(0.027)
R^2	0.392	0.485	0.548	0.564	0.608	0.681	0.655	0.792	0.795
Countries	40	40	37	37	35	35	40	40	40
Obs.	84	84	73	73	68	68	80	80	80
B- Measure of quality: Hanushek and Woessmann (2009), OLS									
$Quality_{64-03}^{HW}$	0.052^c	0.061^c	0.072^b	0.072^b	0.056	0.088	0.089^b	0.071^b	0.073^b
	(0.030)	(0.033)	(0.033)	(0.029)	(0.037)	(0.065)	(0.035)	(0.030)	(0.031)
lny_{60}	0.036	0.061^b	0.004	-0.002	0.013	0.013	0.162^a	0.149^a	0.157^a
	(0.027)	(0.029)	(0.036)	(0.036)	(0.034)	(0.058)	(0.022)	(0.021)	(0.023)
R^2	0.192	0.403	0.503	0.522	0.622	0.670	0.637	0.785	0.788
Countries	45	45	43	43	41	41	44	44	44
C- Measure of quality: Hanushek and Woessmann (2009), IV									
$Quality_{64-03}^{HW}$	0.084^c	0.124^a	0.120^b	0.116^a	0.093	0.184^c	0.177^a	0.177^a	0.187^a
	(0.045)	(0.044)	(0.045)	(0.041)	(0.073)	(0.098)	(0.048)	(0.043)	(0.050)
lny_{60}	0.026	0.031	0.012	0.008	0.023	0.092^c	0.135^a	0.124^a	0.131^a
	(0.027)	(0.021)	(0.036)	(0.035)	(0.036)	(0.054)	(0.021)	(0.020)	(0.019)
R^2	0.169	0.393	0.543	0.557	0.621	0.706	0.609	0.786	0.781
Countries	44	44	42	42	40	40	43	43	43
F-test first-stage	26.15	23.76	35.44	34.52	12.42	8.76	22.22	20.78	18.92
Additional Controls		d+-	col. 2 $PSEduc_{t-\tau}$ $lnurb_{t-\tau}$	col. 3 YearsComp	col. 4 $FD_{t-\tau}$	col. 5 FE		d+-	$Educ_{t-\tau}^{SEC}$

Note: 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). In panel A dependent variable is measured in period t and explanatory variables also include time dummies. In panel B and C dependent variable is measured as an average over the period 2000-2010.

Table 4

Dependent variable: Quantity of education, averaged 2000-2010

	H1						H2		
	Attainment level (*$Education_t$*)						*Enrollment rates* ($\dot{h}_t$)		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
				A- Measure of quantity: Tertiary Education					
$Quality_{2003}^{univ-ranking}$	0.061^b	0.062^b	0.065^b	0.064^b	0.063^b	0.059^c	0.082	0.112^a	0.085^b
	(0.026)	(0.024)	(0.025)	(0.026)	(0.027)	(0.030)	(0.053)	(0.032)	(0.035)
lny_{1960}	0.056^a	0.054^a	0.031^b	0.030^b	0.034^b	0.025	0.179^a	0.185^a	0.179^a
	(0.010)	(0.009)	(0.013)	(0.013)	(0.014)	(0.017)	(0.023)	(0.018)	(0.019)
R^2	0.502	0.724	0.738	0.739	0.738	0.756	0.648	0.814	0.816
Countries	82	82	75	75	73	73	71	71	70
				B- Measure of quantity: Primary Education					
$Quality_{64-03}^{HW}$	-0.001	-0.001	-0.001	0.000	0.000	-0.001	-0.001	-0.001^c	-0.001^c
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)
lny_{60}	-0.024	-0.034	0.034	0.044	0.057	0.061	0.028	0.020	0.013
	(0.024)	(0.023)	(0.041)	(0.042)	(0.051)	(0.053)	(0.023)	(0.015)	(0.017)
R^2	0.042	0.127	0.227	0.254	0.316	0.461	0.041	0.542	0.551
Countries	72	72	66	66	63	63	71	71	71
Additional		d+-	col. 2	col. 3	col. 4	col. 5		d+-	$Educ_{t-\tau}$
Controls			$PSEduc_{t-\tau}$	YearsComp	$FD_{t-\tau}$	FE			
			$lnurb_{t-\tau}$						

Note: 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). In panel A dependent variable is measured in period t and explanatory variables also include time dummies. In panel B and C dependent variable is measured as an average over the period 2000-2010.

Table 5

Dependent variable: *Average Growth rate of real per capita GDP, 1960-2004*

	H3		H4		H3-H4
	(1)	(2)	(3)	(4)	(5)
lny_{60}	-0.0090[a]	-0.0097[a]	-0.0108[a]	-0.0093[a]	-0.0099[a]
	(0.0018)	(0.0016)	(0.0021)	(0.0022)	(0.0018)
$Quality_{60-90}$	0.0005[a]				
	(0.0001)				
$Quality_{60-90} * dummy^{LOW}_{Quality}$		-0.0000			-0.0000
		(0.0000)			(0.0002)
		0.0003[b]			0.0002[c]
$Quality_{60-90} * dummy^{HIGH}_{Quality}$		(0.0001)			(0.0001)
$\overset{\bullet}{h}{}^{SEC}_{1960}$			0.0310[a]		
			(0.0091)		
$\overset{\bullet}{h}{}^{SEC}_{1960} * dummy^{LOW}_{Income}$				0.0483[b]	0.0300[c]
				(0.0184)	(0.0170)
$\overset{\bullet}{h}{}^{SEC}_{1960} * dummy^{HIGH}_{Income}$				0.0279[a]	0.0127
				(0.0081)	(0.0081)
Additional controls:					
$(I/GDP)_{60-90}$, $(G/GDP)_{60-90}$, $Trade_{60-90}$, $Inflation_{60-90}$					
R^2	0.560	0.613	0.534	0.569	0.653
Countries	72	72	72	72	72

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).

Table 6

Dependent variable: *Average Growth rate of real per capita GDP, 1960-2004*

	Hanushek and Kimko (2000)		H3	H4	H3-H4
	(1)	(2)	(3)	(4)	(5)
lny_{60}	-0.0102^a	-0.0102^a	-0.0106^a	-0.0092^a	
	(0.0026)	(0.0023)	(0.0020)	(0.0028)	
$Quality_{60-90}$		0.0005a			
		(0.0001)			
$Quality_{60-90} * dummy^{LOW}_{Quality}$			-0.0000		0.0000
			(0.0002)		(0.0002)
			0.0003^b		0.0003^b
$Quality_{60-90} * dummy^{HIGH}_{Quality}$			(0.0001)		(0.0001)
$H^{AverageYears}_{1960}$	0.0021^a	0.0008	0.0006		
	(0.0008)	(0.0008)	(0.0007)		
$H^{AverageYears}_{1960} * dummy^{LOW}_{Income}$				0.0018^b	0.0003
				(0.0007)	(0.0007)
$H^{AverageYears}_{1960} * dummy^{HIGH}_{Income}$				0.0028^a	0.0014^c
				(0.0008)	(0.0007)
Additional controls:					
$(I/GDP)_{60-90}$, $(G/GDP)_{60-90}$, $Trade_{60-90}$, $Inflation_{60-90}$					
R^2	0.490	0.567	0.616	0.503	0.635
Countries	72	72	72	72	72

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).