Externalidades de capital humano e o crescimento econômico[*]

Carolina Arteaga Cabrales

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Classificação JEL: J24, O11, O40, Y40.

Palavras chave: crescimento econômico, capital humano, externalidades.

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Palabras clave: crecimiento económico, capital humano, externalidades.

Human Capital Externalities and Growth[*]

Carolina Arteaga Cabrales

This paper provides evidence of positive externalities in human capital that help to explain divergences in development worldwide. We estimate the supply and demand for human capital using a five-year panel involving 60 countries, covering the period 1980-2000, and found that there exists positive externalities in human capital accumulation close to one. This translates into increasing returns to scale and increasing marginal returns in human capital.

JEL classification: J24, O11, O40, Y40.

Keywords: Economic growth, human capital, externalities.

I.   INTRODUCTION

International evidence on economic growth reveals large differences across countries, indicative of the persistence of structural divergences in patterns of development. These disparities demonstrate that poor countries have not grown sufficiently fast enough to achieve the level of most developed countries. According to Azariadis and Drazen (1990), during the last century, high-income countries had higher growth rates than poor countries. Pritchett (1997) likewise finds that the ratio of per capita income between the richest and the poorest countries increased by a factor of five. This evolution contrasts with the findings of neoclassical models,[1] wherein differences in income per capita across countries that have similar access to technology only respond to dissimilar initial conditions, conditions that vanish as time goes by and do not give rise to persistent differences in income levels. Indeed, in spite of the fact that the neoclassical theory predicts conditional convergence, a great part of the empirical literature dealing with this issue finds that there is no conditional convergence (Acemoglu and Dell, 2009; Quah, 1996), or at least not to the extent predicted by the theory (Romer, 1994).

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1 The neoclassical growth theory is essentially the sum of the Ramsey (1928), Koopmans (1965) and Cass (1965) models, and the Solow (1956) and Swan (1956) models. Mankiw, Romer and Weil (1992), and Barro and Sala-i-Martin (1995) carry out empirical exercises in support of the neoclassical growth theory.

Another empirical regularity that contrasts with the neoclassical model's prediction is the absence of substantial capital flows from rich to poor countries. Lucas (1990) compared the United States with India, and found that, based on the differences in capital stock between the two economies; the return in capital in India should be 58 times greater than in the United States. In reality, based on the actual data, the differential in interest rates is not of that magnitude —it is possible that diminishing marginal returns to capital does not exist. In spite of the United States' physical capital stock, its return is not significantly lower than those for countries with scarcely any physical capital stock. Moreover, in labor and human capital, whereas the neoclassical theory predicts flows from rich countries to poor countries, the exact opposite happens. Given that the convergence result is not corroborated by the data, and that human capital does not flow from rich to poor countries, it is necessary to evaluate the validity of certain neoclassical theory assumptions.[2]

Mankiw, Romer and Weil (1992) proposed a Solow model extended to include human capital, which corrected some of the empirical problems of the initial model. However, their new proposal replicated the 1956 Solow model's main results, among them, the conditional convergence hypothesis.

Some scholars have explored the consequences of eliminating the assumption of constant returns to scale in the production function. Romer (1986a) proposes a model where increasing returns in investment in capital are combined with diminishing returns and positive externalities in the creation of knowledge. Uzawa (1965) and Lucas (1988) set a model in which human capital is accumulated with increasing marginal returns; the investment in human capital is what creates the externality, through technological inventions arising from that process.

Other authors find differences in the factor shares of production, in such ways that they lead to equal marginal productivities without necessarily a corresponding leveling of stocks. Caselli and Freyer (2007) point out that capital marginal productivity is equal among countries once non-reproducible capital is deducted and the efficiency and costs related to the use of a particular factor are taken into account. According to Zuleta (2008a, 2008b) and Sturgill (2009), the leveling of marginal productivity occurs through adjustments in the factors' respective participations in

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2 Other authors, such as Alfaro, Kalemli-Ozcan and Volsovych (2003), and Beanhabib and Spiegel (1994), have also addressed this issue.

production, as functions of time and a country's development, but not necessarily through the flows of factors. These authors show that the participation of physical and human capital positively correlates with levels of income and negatively correlates with the participation of unskilled workers and natural capital.

In this paper, we estimate the human capital externalities that arise from aggregate levels of human capital in a panel of countries. We identify the marginal return for human capital, and find that there are increasing returns to scale and increasing marginal returns that may lead to higher human capital return in those economies with higher levels of this particular factor.

By estimating human capital externalities, this paper helps to explain evidence of a growth divergent path in the presence of human capital externalities. Countries with an abundance of human capital may have increasing marginal returns, and thus an incentive to continue accumulating human capital; conversely, poor countries with low returns on human capital will find it difficult and non-profitable to do so. In this way, externalities block the channels of a conditional convergence. Such a result is only possible when poor and developing countries invest more in human capital (stock and quality) than what is profitable at the given level of accumulation.

Human capital is a broad, multidimensional concept, and incorporates many different forms of investment in human beings. Healthcare and nutrition are certainly important aspects of such an investment, especially in developing countries, where respective deficiencies may severely limit a population's capacity to participate in productive activities. This paper, however, only takes into account the key factors of human capital that affect labor force knowledge and competency; such capital is accumulated through schooling, continuous formation and experience useful in the production of goods and services, and in the acquisition of new knowledge (De la Fuente, 2004).[3]

Hanushek and Wosseman (2008) describe the channels through which human capital contributes to growth. First, human capital increases physical capital and labor productivity. Second, human capital accumulation increases the capacity of innovation (Aghion and Howitt, 1998; Lucas, 1988; Romer, 1990). Third, higher levels

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[3] Ignoring possible health and nutrition effects may generate bias. Nevertheless, these variables generally correlate to education. In light of this fact, in the exercise performed here, we may overestimate the role of education, even if not human capital as a whole.

of human capital facilitate the diffusion and adoption of new technologies (Barro, 2001; Benhabib and Spiegel, 1994; Nelson and Phelps, 1966). Forth, upon reaching a certain level, the acquisition of human capital becomes easier (Azariadis and Drazen, 1990; Jones, 2008). Finally, human capital accumulation helps improve health and national security (Acemoglu and Angrist, 1999). Identifying the importance of each of those channels goes beyond the objectives of this paper. Here, we seek to know the marginal return on human capital and to evaluate the existence of externalities in firms' respective individual production such as would result from the interaction of all or some of the abovementioned channels.

The paper consists of five sections, inclusive of this introduction. The second section presents the data used and some stylized facts supporting the paper´s central hypothesis. The third section explains the economic model and the econometric strategy used to evaluate the existence of positive externalities in human capital. The fourth section shows the econometric results. The fifth section concludes.

II.   DATA AND FACTS

A.   DATA

This paper uses information from several different sources. The key database used was Freeman and Oostendorp's (2005) "Occupational Wages around the World" (OWW), which standardizes and groups data from a survey conducted annually by the International Labor Organization. This database contains information on 139 countries, for the period 1983-2003, and includes 161 occupations. Based on this data, occupations were classified as being either skilled or unskilled, according to the level of human capital. This enabled us to obtain an average salary for both low and high human capital level occupations (see the appendix for the list of occupations).

For human capital, we used Barro and Lee's (2000) database "International Data on Educational Attainment," which has five-year data for the period 1960-2000, for eighty countries. This information was based on censuses conducted mainly by UNESCO.[4] High level human capital or skilled labor is defined as males who

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4 For observations on information that was not available, the authors used a combination of interpolation of the existing census data and a perpetual inventory method.

have completed higher education.[5] Education Gini coefficient data were taken from Castelló and Doménech (2002), who calculate this coefficient based on the information contained in Barro and Lee (2001). Data on the labor force, population, public education expenditures, and unemployment levels vis-à-vis educational levels, and infant vaccination was obtained from the World Development Indicators (WDI), from the World Bank. For data on institutions, we used the Governance Index calculated by the World Bank, based on data taken from the *International Country Risk Guide* (ICRG). Total factor productivity data were taken from Daude and Fernández-Arias (2010).[6] Interest rate data were taken from the International Financial Statistics of the International Monetary Fund. Using this information, we built an unbalanced panel containing five-year data for sixty countries[7] for the period 1980-2000.

B.   FACTS

Within the framework of a Mankiw et al. (1992) production function, we get:

$$Y_t = A_t K_t^{\alpha} H_t^{\beta} L_t^{1-\alpha-\beta} \tag{1}$$

Where Y_t is the product, A_t the technology level or total factor productivity, K_t the capital stock, H_t the human capital stock or skilled labor stock, and L_t is the unskilled labor. To set the profit maximization problem, we set w_h as the value of human capital marginal productivity, w_t the value of unskilled labor marginal productivity, and r_t as the return to investment in physical capital.

The firm's maximization problem becomes:

$$\max_{\{k_t, h_t, l_t\}} \Pi_{t_t} = A_t K_t^{\alpha} H_t^{\beta} L_t^{1-\alpha-\beta} - r_t K_t - w_{h,t} H_t - w_{l,t} L_t \tag{2}$$

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5 In our econometric approach, we use two additional definitions of human capital in order to guarantee the robustness of our results.

6 Although we recognize that there are problems in using a variable that includes human capital in its calculation, we still believe that this is the best approach for measuring total-factor productivity (TFP). The use of *proxy s* for this variable as a tendency or *dummy* per year was rejected, as this would eliminate a dimension of the panels.

7 See the appendix for a list of the countries.

The first order conditions for H and L are:

$$H : \beta A K^{\alpha} H^{\beta-1} L^{1-\alpha-\beta} = W_h \tag{3}$$

$$L: (1-\alpha-\beta) A K^{\alpha} H^{\beta} L^{-\alpha-\beta} = W_l \tag{4}$$

Solving the firm's problem, we get:

$$\frac{\beta L}{(1-\alpha-\beta)H} = \frac{w_h}{w_l} \tag{5}$$

The coefficients found in the literature for the production function are: for α, the participation of physical capital, a value close to one-third; and for β, the human capital coefficient, a value ranging between one-third and one-half (De la Fuente and Doménech, 2001; Gollin, 2002 Mankiw, Romer and Weil, 1992). Based on the above, we set two possible values for the parameters:

$\alpha = \frac{1}{3}$, $\beta = \frac{1}{3}$; consequently, equation (5) yields:

$$\frac{w_h}{w_l} = \frac{L}{H} \tag{6}$$

Additionally, $\alpha = \frac{1}{3}$, $\beta = \frac{1}{2}$; therefore, it follows from equation (5) that:

$$\frac{w_h}{w_l} = \frac{2L}{H} \tag{7}$$

That is to say, the relative return on human capital with respect to unskilled labor $\left(\frac{w_h}{w_l}\right)$ must be proportional to the relative abundance of unskilled labor in relation to human capital $\left(\frac{L}{H}\right)$.

According to the data in Tables 1 and 2, it is evident that, despite the fact that the data follows a pattern of higher relative remuneration when human capital is scarcer, as predicted by theory, differences in the scales between that asserted by the neoclassical model and that existing in reality are substantial. The second columns in Tables 1 and 2 show the relative abundance of unskilled labor relative to skilled labor. The third columns indicate the relationship between the salaries for the two types of labor. For example, in Table 1, although the trend predicted by the theory is correct —i.e., there is higher relative remuneration when there is greater scarcity (3.5 versus 2), the

difference should be much greater. If $\alpha = 0.33$ and $\beta = 0.33$, then the return on human capital should not be 3.5 times that of unskilled labor, but rather 38 times. According to theory, and based on the values we assume for α and β, these two columns should be equal. However, the data shows that that is not the case and that the values suggested for α and β are implausible. Additionally, the disparity increases when income levels fall, implying that, mainly for low-income countries, the neoclassical theory does not properly explain the dynamics of factor remuneration.

Table 1
Relative Abundance versus Relative Return

Income Level	L/H	Wh/Wl
High	3.30	1.94
Middle	10.79	2.63
Low	38.05	3.50

Data in constant dollars for the period 1980-2000.
Source: Author's calculations based on Barro and Lee's (2000), and Freeman and Oostendorp's (2005); OWW.

Table 2
Relative Abundance versus Relative Return

Income Level	2L/H	Wh/Wl
High	6.60	1.94
Middle	21.58	2.63
Low	76.10	3.50

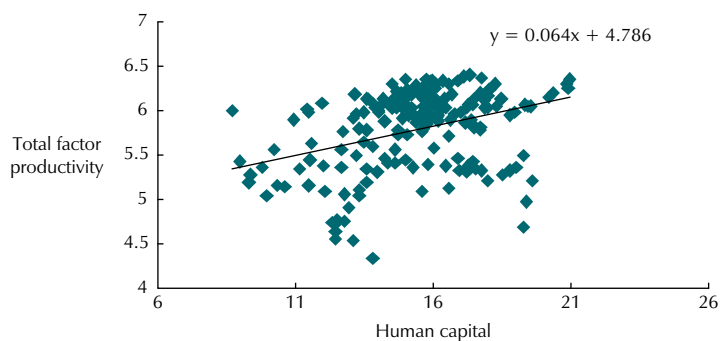Data in constant dollars for the period 1980-2000.
Source: Author's calculations based on Barro and Lee's (2000), and Freeman and Oostendorp's (2005); OWW.

An alternative way of looking for positive externalities in human capital accumulation is to examine its relationship with total factor productivity (TFP). This is because estimates of this variable usually do not take into account the possibility of increasing returns in productive factors. If there are externalities related to human capital levels then they would be included in the Solow residual, and not in the human capital share. Hence, if the externality is a function of the aggregate level of human capital, the TFP will correlate with human capital because when human capital increases, the externality becomes larger–this is captured by the TFP estimates. Graph 1 shows that, in fact, human capital and TFP exhibit a positive relationship.

Graph 2 shows the relationship between the relative abundance of unskilled labor and the relative salary of human capital. According to the graph, the relationship between these two ratios is far from the expected behavior based on neoclassical theory. The dotted line shows the average relationship of the variables, whereas the shadowed

space between the black and green lines shows the expected relationship based on the neoclassical model. Given the presence of the positive externalities captured in the salary, which the neoclassical model does not consider, a possible explanation for this behavior is that there has been an undervaluation of human capital marginal productivity in countries where that factor is abundant, and an overvaluation where that factor is scarce.

Graph 1
Total Factor Productivity and Human Capital

$y = 0.064x + 4.786$

Source: Author's calculations based on Barro and Lee's (2000) and Daude and Fernandez-Arias (2010). The data is for the period 1980-2000.

Graph 2
Relative Salaries (*Wh/Wl*) versus *L/H*
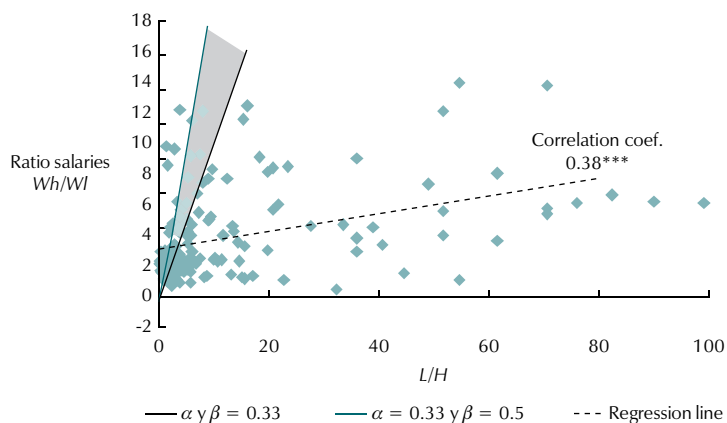
Correlation coef. 0.38***

—— α y β = 0.33   —— α = 0.33 y β = 0.5   - - - Regression line

Data in constant dollars for the period 1980-2000.
Source: Author's calculations based on Barro and Lee's (2000), and Freeman and Oostendorp's (2005); OWW.

Likewise, Table 3 shows how the correlation between human capital's relative abundance and its relative return is weakened as the country development level decreases. In short, the data show that the behavior of human capital's marginal productivity does not evolve as predicted by the neoclassical theory.

Table 3
The Correlation of the Per Income Level Divided by the Relative Salary Ratio (*Wh/Wl*) versus *L/H*

Income Level	Correlation Coefficient
High	0.6***
Middle	0.45***
Low	-0.19

Note: Data in constant dollars for the period1980-2000. Asterisks indicate the statistical significance level: *** at 1%, **at 5% and * at 10%.
Source: Author's calculations based on Barro and Lee's (2000), and Freeman and Oostendorp's (2005); OWW.

This fact is confirmed by the migration movements of human capital; indeed, based on Beine, Docquier and Rapoport (2006) and Beine, Docquier and Schiff (2008) data, only 7% of skilled adults from a high income country migrate to a country belonging to the OECD, whereas 16% of skilled adults coming from poor countries do so.[8] This is explained, among other things, by the return differential on human capital, which is higher when abundant. According to Acemoglu (1996), this fact is particularly important if we take into account that low human capital stock in an economy generates a vicious circle in poor countries, given the impossibility of making good use of its increasing returns due to the low return rate. Put another way, the labor force's average human capital is not enough to generate a virtuous cycle whereby sufficient incentives exist to increase human capital.

Furthermore, when carrying out a descriptive regression (Table 4), we find that the return on human capital is greater for high and medium-high income levels and where human capital is relatively abundant. The positive and significant coefficient of human capital abundance contradicts the assumption of diminishing marginal returns, and does not allow for mechanisms giving rise to a conditional convergence. Graph 3 shows the positive relationship between human capital abundance and the

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8 Along the same line Medina and Posso (2009) find that Colombia and Ecuador are net exporters of human capital.

salary for skilled occupations or human capital, something confirmed by the estimate in Table 4.

Table 4
Estimate of Salary Determinants for Human Capital

Dependent Variable: ln(Human Capital Salary)	
Independent variables	
Public expenditure on education (%GDP)	0.36***
Ln human capital	0.11**
Income level (high or low)	0.34***
Institutions	0.20**
Percentage of population living in the tropics	0.006
Constant	6.2***
Observations	193
R2	0.45

Note: Data in constant dollars for the period 1980-2000. Asterisks indicate the statistical significance level: *** at 1%, **at 5% and * at 10%.
Source: Author's calculations based on Barro and Lee's (2000), and Freeman and Oostendorp's (2005) and World Bank (2009).

Graph 3
Human Capital Salary and Percentage of Population over
25 Years of Age Who Have Completed Higher Education
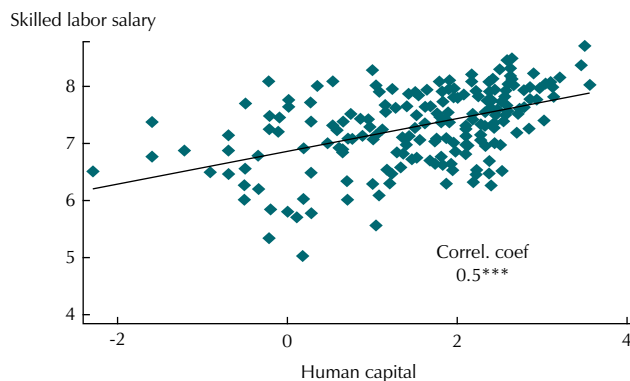
Data in constant dollars for the period 1980-2000.
Source: Author's calculations based on Barro and Lee's (2000), and Freeman and Oostendorp's
(2005), OWW, and Penn World Tables (2006).

The following graphs show the relationship of the three production factors (physical capital, labor force and human capital) with per capita GDP. According to Graph 4, there is a lineal, increasing relationship between physical capital per capita and per

capita GDP. Each additional unit of physical capital per person is transformed into an additional unit of product.[9] With respect to labor, as expected, there is no relationship at all; according to the graph, there are no scale effects[10] on the labor force. In terms of per capita, an economy is not richer or poorer for having a larger or smaller labor force.

Graph 4
Physical Capital per Capita versus Per Capita GDP and Labor
Force versus Per Capita GDP
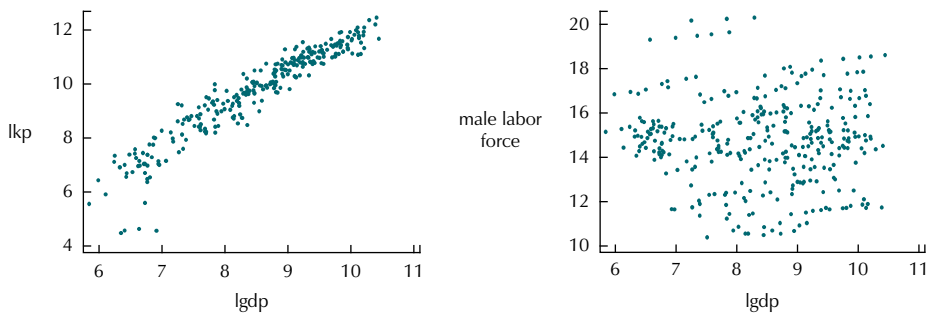
Data in logarithms for the period 1980-2000.
Source: Author's calculations based on Daude and Fernández-Arias (2010), and World Bank (2009).

Graph 5 shows the relationship between the percentage of population with higher education and per capita GDP. Here we observe an unusual or different kind of behavior. For the lower 50% of human capital value, per capita GDP seems invariable when faced with increases in the level of a population's education; however, for the upper 50%, there is a clearly increasing relationship, although with considerable variance. Graph 5 seems to indicate that human capital is important to development only when a determined human capital stock has been accumulated.[11] In the second panel of Graph 5, the sample is separated and two regression lines are fitted, one for countries with high levels of human capital (green line) and the other for countries with low levels (red line). According to the slopes, it is observed that increasing human capital in a country with a high human capital stock increases per capita

9 Given that there is no causality argument, it may also be stated that each additional product unit per capita produces an additional physical capital unit.

10 The scale effect refers to the relationship between the labor force size and economic development.

11 Then again, the relationship could be thought of as running in the opposite direction.

GDP to a greater extent than in a country with a low human capital stock. This also supports our hypothesis that there exist positive externalities resulting from an economy's human capital aggregate level. Whereas for physical capital, each additional unit of capital is transformed into a unit of product, with human capital, additional units are transformed into higher product levels, though only as a function of the human capital aggregate level.

Graph 5
Human Capital versus Per Capita GDP
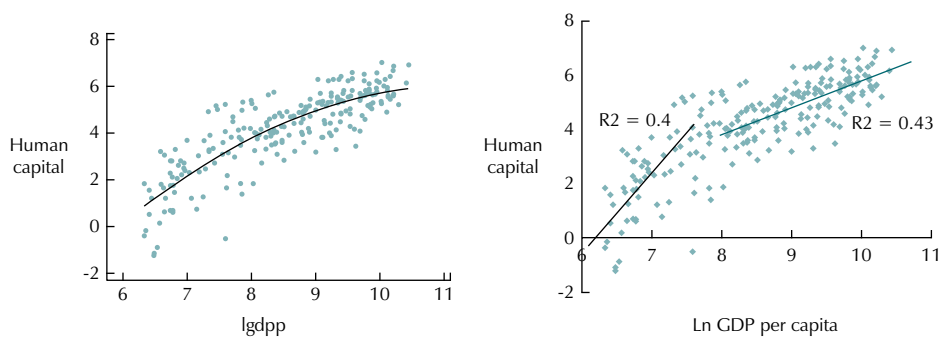
Data in constant dollars for the period 1980-2000.
Source: Author's calculation based on Barro and Lee's (2000), and World Bank (2009).

Until now, all that has been shown is the evidence supporting the hypothesis, according to which, positive externalities exist in human capital accumulation. The next step is to estimate these.

III.   THE MODEL AND ECONOMETRIC STRATEGY

We estimate a demand equation for human capital in order to evaluate the existence of externalities for this factor. The econometric estimation of demand is difficult in that observed data only show market equilibriums that correspond to the interaction between supply and demand. Although we may derive some equilibrium determinants from the results of a simple regression,[12] a good's supply and demand —in this case, a production factor— cannot be estimated. However, changes in those variables affecting only one of the curves generates equilibriums located all along

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12 As we did in Table 4.

the unaffected curve, thus enabling us to estimate it. In this fashion, movements of the human capital supply curve determinants enable us to deduce the demand curve. Given this analytical framework, both supply and demand must be estimated via simultaneous equations[13] if the point is to obtain a human capital demand equation.

A.   HUMAN CAPITAL SUPPLY

To find a human capital supply equation, it is necessary to understand the determinants of individual decisions related to the accumulation of education and experience. The literature has explored this matter deeply, on the basis of which, we have chosen those variables that best explain supply.

Decisions related to the accumulation of human capital have two dimensions: one dimension is related to each individual's own characteristics and his or her home; the other dimension reflects the characteristics of the society in which the individual lives. The first consists of the conditions corresponding to the individuals' homes, conditions which facilitate or work against learning, for instance, based on the provision of adequate nutrition and good healthcare. Also, parental academic assistance at home (parental involvement in children's academic education), examples of role models, and educational results are key variables when deciding upon the optimal human capital to accumulate (Hanushek, 1986).

The second dimension is related to the social environment and the individual's access to formal education. In particular, it depends on availability of schools and universities adequately equipped and easily accessible for potential students, likewise, on the equality or inequality with which they are distributed in a society. Institutional arrangements affecting education quality and its profitability are also a component of this second dimension. An inefficient distribution of human capital across low productive activities and rent-seeking activities, will not supply a high enough return on education, and human capital accumulation will be discouraged (Murphy, Shleifer and Vishny, 1991).

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13 In the literature, there is a consensus that there exists a simultaneity bias when aggregate data are used to estimate supply or demand, as salary must not be assumed as being exogenous. This happens differently compared to, for instance, the calculation of demand for a firm, wherein it can be assumed that salary is exogenous and that there are infinite bidders. For this estimation, there is more than one independent variable, both for supply and demand, whereby the system is over-identified and the estimation method encompasses instrumental variables.

According to Mejía and St-Pierre (2008), identical agents in terms of their cognitive and non-cognitive abilities may make different decisions regarding human capital accumulation if they have different factor endowments complementary to the process of human capital formation. These complementary endowments refer to a series of variables —the level of parents' education, access to formal education, and food during childhood, among others—which affect human capital formation. Given his or her complementary factor endowments, each individual decides if he or she should invest time and effort in human capital formation and to what extent. Individuals face different costs when accumulating human capital, as the sacrifice in devoting time to human capital formation is a function of complementary factor endowments. The agent problem is that the more human capital acquired, the higher the income; at the same time, his or her time in the labor force will be shorter.

Additionally, Castelló and Doménech (2002) model an economy where inequality in human capital distribution influences the accumulation process. The authors claim that human capital supply is a function of a population's average life expectancy and of the human capital accumulation made by the previous generation, which in turn may mean that only a small group of people obtain the benefits of human capital accumulation.[14]

Likewise, longer life expectancy has a positive influence on human capital formation through an additional channel, one explored by Stark and Wang (2005). According to them, given that parental support is cheaper than market financing, human capital formation will be higher in societies where individuals experience greater longevity, which lengthens the period of parental support in the financing of their children's education. This could be even more important in societies where the state does not provide significant coverage of higher education, which in turn may coincide with low life expectancy.

Sundry authors, such as Viaene and Zilcha (2001), and Blankenau and Simpson (2004), have found that public expenditure on education promotes human capital accumulation; through provision of formal education with the consequence that differences in opportunities among individuals heterogeneous with respect to wealth and parental human capital are eliminated. Hanushek and Kimko (2000) find that the quality of institutions influences how efficiently public resources are used and,

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14 Dessus (1999) highlights the importance of the distribution of human capital of parents in the formation of child human capital, upon discovering/learning about generational externalities, wherein children benefit from their parents' education through learning at home and motivation.

as a consequence, the quality of education offered. According to Hanushek, it is only profitable to increase years of schooling when doing so produces skills, which in turn depends on the quality of the education being offered. On the other hand, institutional arrangements affect education profitability over the medium term, as they either encourage or discourage piracy and productive activities. In the same manner, human capital distribution across activities is important; countries with a considerable number of engineers in proportion to overall workers grow faster and have a higher return on human capital than countries with, say, a higher proportion of lawyers (Murphy et al., 1991). Along that same lines, Easterly (2001) finds that the return on education is lower in countries that have deficient legal systems and/or weak markets.

Based on the above, human capital supply is defined as a function of the salary for skilled workers (*Wh*) and unskilled workers (*Wl*); inequalities in human capital distribution lagged 20 years (*gini KH$_{t-20}$*); life expectancy (*lifeexp*); public expenditures on education (*expenditure*); a variable representative of institutions (*inst*); and the percentage of vaccinated children under two years of age (*vaccinated*), as a measure of healthcare[15]:

$$H_t^o = \beta_0 + \beta_1 w_h + \beta_2 w_l + \beta_3 \exp enditure_t + \beta_4 gini\ KH_{t-20} +$$
$$\beta_5 inst_t + \beta_6 life \exp_t + \beta_7 vaccinated_t \tag{8}$$

B.   HUMAN CAPITAL DEMAND

To estimate the demand for human capital, we assume a representative firm in the economy, one operating in a product and input market under the conditions of perfect competition. The production of the firm combines skilled and unskilled labor and physical capital. All factors are complementary in the production process. Skilled labor refers to the labor of agents with a high level of education, for which there are three definitions: males who have completed higher education; males who have completed an incomplete higher education; and males who have completed higher education multiplied by the average years of schooling of the population. Unskilled labor is the labor performed by agents with a lower level of education.

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15 The variables are in logarithms.

Human capital demand arises from firms' maximization problem, wherein the production function is determined by:

$$Y_{it} = A_{it} K_{it}^{\alpha} H_{it}^{\beta} L_{it}^{1-\alpha-\beta} H_t^{\gamma} \tag{9}$$

As before, Y_{it} is the product (output) of firm i for period t; A_{it} the technology level or total factor productivity; K_{it} is the capital stock; H_{it} is the stock of human capital or skilled labor;and L_{it} is unskilled labor. H^{γ} captures the externality of the abundance of an economy aggregate human capital over firms' individual productions, following Romer's (1986a) statements on physical capital. Furthermore, this production function captures the idea stated by Acemoglu (1996), wherein an individual's human capital marginal productivity increases with the average of the human capital of the labor force. According to the above description, the aggregate production function should be given by the equation:

$$Y_t = A_t K_t^{\alpha} H_t^{\beta+\gamma} L_t^{1-\alpha-\beta} \tag{10}$$

The production function in equation (10), unlike the neoclassical production function, does not show constant returns to scale if γ is other than zero. Additionally, if γ is greater than $1-\beta$, the production function has increasing marginal returns and does not meet Inada's conditions for human capital —that is to say, when human capital tends to zero, its return does not tend to infinity, and when human capital tends to infinity, its return does not tend to zero. These new conditions for the production function will be responsible for stopping the mechanisms leading to a conditional convergence, as with the neoclassical function.

The problem first-order conditions for each factor are:

$$H: \beta A K^{\alpha} H^{\beta+\gamma-1} L^{1-\alpha-\beta} = W_h \tag{11}$$

$$L: (1-\alpha-\beta) A K^{\alpha} H^{\beta+\gamma} L^{-\alpha-\beta} = W_l \tag{12}$$

$$K: \alpha A K^{\alpha-1} H^{\beta+\gamma} L^{1-\alpha-\beta} = r \tag{13}$$

Solving the firm's problem, the optimal demands for the three production factors are obtained as follows:

$$H_t^{D*} = \left(\frac{W_{t,h}}{A_t \beta K_t^{\alpha} L_t^{1-\alpha-\beta}} \right)^{\frac{1}{\beta+\gamma-1}} \tag{14}$$

$$K_t^{D*} = \left(\frac{r_t}{A_t \alpha H_t^{\beta+\gamma} L_t^{1-\alpha-\beta}} \right)^{\frac{1}{\alpha-1}} \tag{15}$$

$$L_t^{D*} = \left(\frac{W_{t,l}}{A_t (1-\alpha-\beta) H_t^{\beta+\gamma} K_t^{\alpha}} \right)^{\frac{1}{-\alpha-\beta}} \tag{16}$$

From equation (14), we establish that human capital demand depends positively on salary if $\gamma + \beta$ is greater than one, since we would have increasing marginal returns.

Upon dividing 12 and 13 by 11, and solving for K and L, we get:

$$L = \frac{(1-\alpha-\beta) HW_h}{\beta W_l} \tag{17}$$

$$K = \frac{\alpha HW_h}{\beta r} \tag{18}$$

Replacing these expressions in the human capital first-order condition, we get an expression for the demand on human capital based on exogenous variables. This expression is:

$$H_t^{D*} = \left[\frac{W_{H,t}^{\beta}}{A_t \beta^{\beta} \left(\frac{\alpha}{r_t} \right)^{\alpha} \left(\frac{1-\alpha-\beta}{W_{L,t}} \right)^{1-\alpha-\beta}} \right]^{\frac{1}{\gamma}} \tag{19}$$

Taking the logarithms of the expression inequation (19), we can estimate the demand equation:

$$LnH_t^D = -\frac{1}{\gamma}\ln A_t - \frac{\beta}{\gamma}\ln\beta - \frac{\alpha}{\gamma}\ln\alpha - \frac{1-\alpha-\beta}{\gamma}\ln(1-\alpha-\beta) +$$
$$\frac{\beta}{\gamma}\ln W_{H,t} + \frac{\alpha}{\gamma}\ln r_t + \frac{1-\alpha-\beta}{\gamma}\ln W_{L,t} \tag{20}$$

Rewriting[16] equation (20), we get:

$$H_t^D = \delta_0 + \delta_1 W_{h,t} + \delta_2 r_t + \delta_3 W_{l,t} + \delta_4 A_t + u_t \tag{21}$$

Equations (8) and (21) are estimated using a simultaneous equation system, where the equilibrium equation is[17] $H_t^0 = H_t^D$. This estimation uses independent supply variables as skilled salary instruments. The objective of this exercise is to determine the value of production function parameters and to evaluate the presence of positive externalities and increasing marginal returns in human capital. To know this value, we need to solve the system arising from estimating the interest rate coefficient and the two types of salary from/in equations (20) and (21). The system is as follows:

$$\frac{\beta}{\gamma} = \delta_1 \tag{22}$$

$$\frac{\alpha}{\gamma} = \delta_2 \tag{23}$$

$$\frac{(1-\alpha-\beta)}{\gamma} = \delta_3 \tag{24}$$

Upon solving the equations, the production function parameters become:

$$\alpha = \frac{\delta_2}{\delta_3 + \delta_2 + \delta_1} \tag{25}$$

$$\gamma = \frac{1}{\delta_1 + \delta_2 + \delta_3}\; also\; \gamma = \frac{1}{-\delta_4} \tag{26}$$

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16 This is a statistical optimization that shows only those elements that have permanent effects on demand. An abstraction of the transaction and adjustment costs is made, in such a manner that the levels of the factors actually used are always optimal.

17 Two types of estimations are made. In one, supply is equal to demand; in the alternative one, demand is affected by the unemployment level for the population with a higher education.

$$\beta = \frac{\delta_1}{\delta_1 + \delta_2 + \delta_3} \tag{27}$$

$$1 - \alpha - \beta = \frac{\delta_3}{\delta_1 + \delta_2 + \delta_3} \tag{28}$$

The individual statistical significance of α, β, γ, $1 - \alpha - \beta$, is tested using the delta method.

IV.   RESULTS

This section shows the results from the equation (14) estimation using different approaches with fixed effects[18] and instrumental variables.[19] Each table shows various results, as we have different human capital measures: males who completed higher education; males who completed and did not complete higher education; and the population's years of schooling multiplied by the number of males with a higher education. Human capital data is used just for males because Freeman and Oostendorp's (2005) wage standardization only applies to this gender. As an additional exercise, the abovementioned human capital variables are multiplied by one less the unemployment rate of the population with a higher education, with the objective of including a variable representing the labor market structure in the estimation. This exercise appears in the last three columns in Tables 6-8.

The problems of the statistical significance of the estimations with human capital variables are well documented in the literature (Benhabib and Spiegel, 1994; Ciccone and Papaioannou, 2005; De la Fuente, 2004; Pritchett, 2008). In the first place, errors in the measurements —frequent with different measures of human capital— increase estimator variance and decrease its size.[20] In the second place, the multi-

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18 According to the Hausman test, there are systematic differences between fixed effect estimators and random effect estimators; therefore, fixed effects are used in order to obtain a consistent estimation.

19 The instruments or variables used in the first stage of the regressions corresponded to the supply side determinants (see equation 7).

20 According to De la Fuente (2004, p. 7), "Let's suppose that the productivity level, Q, is a linear function of the human capital stock, H, in such a manner that $Q = bH + u$, where u is a random disturbance. Given this relation, variances in human capital stock, H, will induce to changes in the productivity level, Q, and the examination of the relative variance magnitude of both variables will

collinearity present in this type of works magnifies the problem, as countries with high levels of human capital tend to have good institutions, a high level of physical capital, high salaries, and so forth. In this vein, it is important to take into account that collinearity —represented by the two salary measures in the equation and the sample size— may make estimators statistically insignificant, even where they are economically significant.

Given these measurement problems, the results included herein must be interpreted cautiously. According to Table 5, where equation (21) is estimated using instrumental variables for skilled-activity salaries —that is for all specifications of human capital demand— the traditional coefficients of the production function are those previously found by the theory. These are α, physical capital participation with a value of around one third, and β, the human capital coefficient, with a value lower than one third. According to the estimation, α is statistically significant for all exercises, and one less α less β is statistically different from zero in various estimations. However, the β results are only significant for one specification.

The results show that the size of the externality is greater than 0.68 and is statistically different from zero for all specifications. This value corresponds not only to solving γ from the equation system, but also to the negative inverse of the A coefficient (see equation 26). According to these two definitions there are positive externalities in human capital that are statistically significant. Consequently, the production function has increasing returns to scale and human capital has increasing marginal returns.[21]

The above exercise supposes, as do most growth theories, that the production function coefficients are constant in time and independent of a country's development level. However, Caselli and Feyrer (2000), Sturguill (2008), and Zuleta (2009) have found evidence to the contrary. With available data on salaries and factor abundance, the ratio $\dfrac{1-\alpha-\beta}{\beta} = \dfrac{LW_l}{HW_H}$ (see equations (12) and (13)) may be calculated. Graph

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enable us estimating the value of coefficient *b*. So, if *H* is measured with error, in such a manner that what we observe is not really *H* but a *noisy proxy*, $P = H + e$, where *e* is a random measurement error, part of the apparent variance of human capital stock (in time or among countries) will be due to the measurement error (i.e., it will be *noise* instead of real *signal*). As such variances do not logically induce any response in *Q*, this variable will seem less sensitive to human capital stock than to what it actually is in reality, which will cause downward bias on the estimated value of *b*." This problem is stressed with the use of fixed effects in a panel.

21 This happens for all of the exercises except for one (See column 6 in Table 5).

6 shows the behavior of the/this ratio (left panel) and the human capital coefficient resulting from solving β from $\dfrac{1-\alpha-\beta}{\beta} = \dfrac{LW_l}{HW_H}$, and supposing the $\alpha = 0.33$[22] (right panel), in both cases, with regard to per capita GDP. According to the graph, human capital participation increases with the income level, this fact motivates us to make an estimation that allows for the inclusion of this source of variance, although a coefficient corresponding to the average of this coefficient continues to be estimated.

Table 5
Estimation of Equations (8) and (21) Using Instrumental Variables with Fixed Effects[23]

Dependent variables	Log males with complete higher education	Log males with complete and incomplete higher education	Log males with complete higher education by number of years of populations' education	Log males with complete higher education by the percentage of employees with higher education	Log males with complete and incomplete higher education by the percentage of employees with higher education	Log males with complete higher education by the number of years of population's education by the percentage of employees with higher education
A Solow residual	-1.03***	-1.03***	-1.19***	-0.95***	-0.86***	-1.06***
Wage H(instr.)	0.39	0.38	0.38	0.08	0.25	0.22
Wage L	0.34	0.33	0.55	0.53**	0.47	0.41
Interest rate	0.46***	0.46***	0.52***	0.30***	0.41***	0.42***
implict α	0.39***	0.39***	0.35***	0.33***	0.36***	0.40***
implicit β	0.33	0.33	0.26	0.08	0.22	0.21
implicit $\gamma 1$	0.84***	0.85***	0.68***	1.1***	0.89***	0.94***
implicit $\gamma 2$	0.96***	0.97***	0.84***	1.05***	1.16***	0.94***
$1-\alpha-\beta$	0.28	0.28	0.38	0.58***	0.42	0.39
Obs.	118	118	118	149	129	126
R2 first stage	0.56	0.56	0.56	0.41	0.49	0.42
R2 Second stage	0.61	0.61	0.59	0.61	0.58	0.55

Asterisks refer to statistical significance: *** at 1%, ** at 5% and * at 10%. $\gamma 1$ refers to the γ resulting from solving the system, and $\gamma 2$ to the negative inverse of the A coefficient.
Source: Author calculations.

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22 We found the value close to what appears in the literature.

23 These results are robust to changes in the instruments set, particularly to the exclusion of all variables, one at a time.

Graph 6
The Production Function Coefficients versus Per Capita GDP
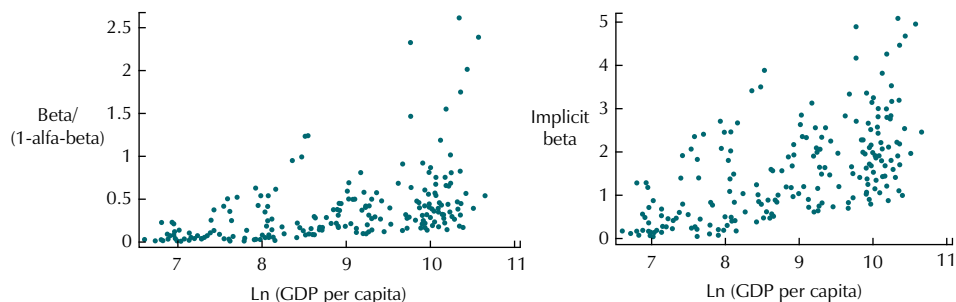
Source: WDI, Barro and Lee (2000), Oostendorp and Freeman (2005), and the author's calculations.

However, in the above estimation, γ is over-identified and the new restriction suggested by data enables us to estimate more precisely the production function parameters.

From equation (20), we get:

$$LnH_t^D = -\frac{1}{\gamma}\ln A_t - \frac{\beta}{\gamma}\ln\beta - \frac{\alpha}{\gamma}\ln\alpha - \frac{1-\alpha-\beta}{\gamma}\ln(1-\alpha-\beta) + \\ \frac{\beta}{\gamma}\ln W_{H,t} + \frac{\alpha}{\gamma}\ln r_t + \frac{1-\alpha-\beta}{\gamma}\ln W_{L,t}$$

(20)

If we group together the coefficients from $lnW_{H,t}$ and $lnW_{L,t}$, we get:

$$LnH_t^D = -\frac{1}{\gamma}\ln A_t - \frac{\beta}{\gamma}\ln\beta - \frac{\alpha}{\gamma}\ln\alpha - \frac{1-\alpha-\beta}{\gamma}\ln(1-\alpha-\beta) + \\ \frac{\alpha}{\gamma}\ln r_t + \frac{\beta}{\gamma}\left(\ln W_{H,t} + \frac{1-\alpha-\beta}{\beta}\ln W_{L,t}\right)$$

(29)

Lastly, dividing equation (12) by equation (13), we get:

$$\frac{1-\alpha-\beta}{\beta} = \frac{LW_L}{HW_H}$$

(30)

If we plug equation (30) into equation (29), we get the equation estimated in Table 6:

$$LnH_t^D = -\frac{1}{\gamma}\ln A_t - \frac{\beta}{\gamma}\ln\beta - \frac{\alpha}{\gamma}\ln\alpha - \frac{1-\alpha-\beta}{\gamma}\ln(1-\alpha-\beta) +$$
$$\frac{\alpha}{\gamma}\ln r_t + \frac{\beta}{\gamma}\left(\ln W_{H,t} + \frac{LW_l}{HW_H}\ln W_{L,t}\right) \tag{31}$$

Table 6
Equation (31) Two-Stage Least Square with Fixed Effects

Dependent variables	Log males with Complete higher education	Log males with complete and incompleta higher education	Log males with complete higher education by number of years of populatlons' education	Log males with complete higher education by the percentage of employees with higher education	Log males with complete and incomplete higher education by the percentage of employees with higher education	Log males with complete higher education by the number of years of population's education by the percentage of employees with higher education
implict α	0.28***	0.29***	0.36***	0.31***	0.33***	0.34***
implicit β	0.50***	0.50***	0.53***	0.44***	0.44***	0.54***
implicit γ	1.15***	1.17***	0.93***	1.29***	1.31***	1.15***
$1-\alpha-\beta$	0.22	0.21	0.11	0.25	0.23	0.12
Obs.	166	166	140	149	149	149
R2	0.78	0.78	0.70	0.66	0.76	0.72

Note: $1-\alpha-\beta$ is not estimated in the regression. That is why it does not have statistical significance. Asterisks refer to statistical significance:
*** at 1%, ** at 5% and * at 10% levels.
Source: Author calculations.

According to the estimations in Table 6, all of the calculated production function coefficients are statistically significant at 1%. Alpha is around one third, and β around one half. Furthermore, the externality maintains its statistical significance and its size increases a little bit. In all of the exercises, there are increasing returns to scale and human capital is accumulated with increasing marginal returns. Additionally, the model's of fit improves.

The next estimation is also the result of an algebraic transformation of equation (20), and solves a problem of the estimation in Table 6. For that particular estimation, we introduced the fact that the human capital coefficient can vary; however, that exercise required the estimation of a coefficient that even though it predicts the average behavior, does not meet the initial assumption —that we should not estimate this

coefficient. To solve this, the following estimation groups variables in such a way that γ is the only coefficient to be estimated, α and β are left free.

Grouping together all of the variables other than the constant variable, we get[24]:

$$
LnH_t^D = -\frac{\beta}{\gamma}\ln\beta - \frac{\alpha}{\gamma}\ln\alpha - \frac{1-\alpha-\beta}{\gamma}\ln(1-\alpha-\beta) +
$$
$$
\frac{1}{\gamma}\left(\beta\left(\ln W_{H,t} + \frac{LW_l}{HW_H}\ln W_{L,t}\right) - \ln A_t + \alpha\ln r_t\right) \tag{32}
$$

Table 7
Equation (32) Two-stage Least Squares With Fixed Effects

Dependent variables	Log males with Complete higher education	Log males with complete and incomplete higher education	Log males with complete higher education by number of years of populations' education	Log males with complete higher education by the percentage of employees with higher education	Log males with complete and incomplete higher education by the percentage of employees with higher education	Log males with complete higher education by the number of years of population's education by the percentage of employees with higher education
implicit γ	1.08***	1.09***	0.91***	1.21***	1.23***	1.04***
Obs.	137	137	137	149	149	137
R2	0.53	0.53	0.49	0.42	0.42	0.47

Asterisks refer to statistical significance: *** at 1%, ** at 5% and * at 10%. γ 1 refers to the γ resulting from solving the system, and γ 2 to the negative inverse of the A coefficient.
Source: Author calculations.

Finally, Table 7 reaffirms γ's statistical significance and magnitude, as found in the above exercises. These results suggest the existence of increasing returns and a violation of the Inada conditions in human capital. As a consequence of the foregoing, an economy's aggregate production function does not show constant returns to scale, but, contrarily, increasing returns ranging from 1.7 and 2.2.

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24 For this estimation, it is supposed/assumed that alpha equals 0.33, which is a value close to that found in previous estimations and which is coherent with the data in the literature.

As a result, our estimations support the hypothesis of a production function of the following type: $Y = AK^{\alpha}H^{\beta}L^{1-\alpha-\beta}H^{\gamma}$, where the sum of all coefficients is greater than one, and $\beta + \gamma$ adds up to more than one. This means that the marginal productivity of human capital is increasing in its entire domain.[25] Human capital accumulation is always useful/profitable in generating product —that is, capital marginal productivity does not tend to zero when human capital tends to infinity. Even more so —unlike the case of neoclassical function— the marginal productivity of human capital does not tend to infinity when this factor stock tends to zero. Accordingly, economies with human capital scarcity do not attract human capital flows. As a consequence of the production function proposed herein, the mechanisms through which the conditional convergence in human capital takes place are eliminated. Additionally, movements of physical capital are limited, since returns to that factor depend on human capital levels.

This paper finds human capital externalities greater than those found in previous work using different approaches, particularly those papers based on individual data and which mostly analyze local-level externalities (Acemoglu and Angrist, 1999; Psacharopoulos and Patrinos, 2004 —this paper analyses global level return to education—; Ccicone and Peri, 2006; see also Davies, 2003). These authors find that education externalities could amount to something quantitatively of similar importance as private returns, which means that these authors do not find evidence of human capital externalities.

It is important to clarify that, in this paper, it was assumed that education was homogenous across countries. That is to say, a year of education, in both secondary and higher education generates the same skills and knowledge anywhere throughout the world. However, this is a very strong assumption. Hanushek and Kimko (2000) found that quality of education differs considerably across countries. In this vein, if omitting differences in quality, the results for γ may show an upwards bias if countries with higher indices of education coverage also have better quality of education. Consequently, the externality of human capital, in addition to measuring the benefits of an increase in education, implicitly measures the effects of education improvement.

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25 The first and the second derived from the production function with respect to human capital are positive.

V.   CONCLUSIONS

The neoclassical growth theory proposes a model that obtains as one of its main conclusions the conditional convergence hypothesis. However, the evidence of divergent development in the twentieth century —and more generally speaking, a lower than predicted speed of convergence— encourages us to examine the causes of this behavior. To do so, it is necessary to know the theoretical sequence required in order to reach such a conclusion —diminishing marginal returns must exist in the factors for such a convergence to occur. We evaluate the validity of this assumption for human capital and document that the data does not show evidence of such behavior. This paper is supported by the literature dealing with the reasons for human capital externalities. With this evidence at hand, the process is completed estimating the return on human capital, which we suggest is increasing. To reach convergence, it is necessary to make a great amount on investment in tertiary education.

This paper documents various stylized facts: i) remuneration to human capital does not diminish where this factor is abundant; ii) the relative return on human capital with respect to unskilled labor becomes greater the poorer the country, although not to the extent predicted by theory; iii) in particular for low income and medium-low income countries, the neoclassical theory fails to explain the dynamics of marginal productivity and human capital return; and iv) the relationship between human capital and per capita GDP, unlike the relationship between physical capital and per capita GDP, is not linear.[26]

In summary, our results support a production function that shows increasing returns to scale and increasing marginal returns for human capital —that is to say, human capital is better remunerated the more abundant it is. The existence of externalities for human capital discourages its accumulation in economies where this factor is scarce (the Inada conditions); this, in turn, diminishes the efficiency of the use of physical capital (Caselli and Feyrer, 2007 Lucas, 1990), limits factor flows, and prevents conditional convergence.

The policy implications of these results are aimed at promoting human capital accumulation, especially for poor and developing countries that have low stocks of this particular factor. High levels of human capital generate aggregate externalities that

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26 Taking the variables in logarithms.

favor higher levels of per capita GDP. However, the mechanics of the returns on human capital do not encourage accumulation of human capital at low stock levels. Government efforts therefore, should concentrate on pulling the economy to a higher stock level of human capital, and then take advantage of the increasing marginal returns on this factor. The financial and opportunity costs of human capital accumulation were not examined in this paper, so we cannot posit an optimal level of accumulation. This paper provides evidence of the existence of human capital externalities, however, other types of externalities and complementarities between factors could also be present such as would foster growth, and using resources to invest in human capital has the potential cost of their being used to boost other factors.

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APPENDIX

1. Skilled and unskilled wage classification.

Occupations considered low skilled.
Field crop farm worker
Plantation worker
Forestry worker
Logger
Inshore (coastal) maritime fisherman
Underground helper
Quarryman
Butcher
Packer
Thread and yarn spinner
Cloth weaver (machine)
Laborer
Garment cutter
Tanner
Clicker cutter (machine)
Laster
Sawmill sawyer
Plywood press operator
Furniture upholsterer
Wood grinder
Paper-making-machine operator (wet end)
Laborer
Mixing- and blending-machine operator
Laborer
Mixing- and blending-machine operator
Packer
Laborer
Laborer
Welder
Bench molder (metal)
Machinery fitter-assembler
Laborer
Power-generating machinery operator
Laborer
Building painter
Bricklayer (construction)
Reinforced concreter
Cement finisher
Plasterer
Laborer
Room attendant or chambermaid
Railway vehicle loader
Railway engine-driver
Railway steam-engine fireman
Motor bus driver
Urban motor truck driver
Dock worker
Aircraft loader
Postman
Refuse collector
Pattern makers (wood)
Permanent way laborers
Laborers (unskilled, public parks and gardens)

OCCUPATIONS CONSIDERED TO BE HIGH SKILLED.

Coalmining engineer
Petroleum and natural gas engineer
Journalist
Chemical engineer
Power distribution and transmission engineer
Ship's chief engineer
Air transport pilot
Flight operations officer
Accountant
Computer programmer

Insurance agent

Computer programmer

Government executive official:

Mathematics teacher (third level)

Teacher in languages and literature (third
    level)

Teacher in languages and literature (sec-
    ond level)

Mathematics teacher (second level)

General physician

Dentist (general)

2. Countries in the database[27]:

Algeria

Angola

Antigua

Argentina

Australia

Austria

Azerbaijan

Bangladesh

Barbados

Belarus

Belgium

Belize

Benin

Bermuda

Bolivia

Botswana

Brazil

Brunei

Bulgaria

Burkina Faso

Burundi

Canada

Cambodia

Cameroon

Cape Verde

Central African Republic

Chad

China

Chile

Colombia

Comoros

Costa Rica

Cote d`Ivoire

Croatia

Cuba

Cyprus

Czech Republic

Denmark

Djibouti

Dominican Republic

Equatorial Guinea

Estonia

Ethiopia

Fiji

Finland

France

Gabon

Ghana

Guyana

Honduras

Hong Kong

Hungary

Iceland

India

Iran

Ireland

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27 These are all of the countries for which
information is available for at least one of the
years studied. However, since the econometric
estimation needs more than one year of data, a
smaller group of countries is considered.

Italy	Slovenia
Japan	South Africa
Kyrgyzstan	Sri Lanka
Latvia	St. Kitts and Nevis
Liberia	St. Lucia
Lithuania	St.Vincent & the Grenadines
Luxembourg	Sudan
Macao	Suriname
Madagascar	Swaziland
Malawi	Sweden
Mali	Syria
Mauritius	Thailand
Mexico	Togo
Moldova	Trinidad &Tobago
Mongolia	Tunisia
Mozambique	Turkey
Netherlands	Uganda
Netherlands Antilles	Ukraine
New Zealand	United Kingdom
Nicaragua	United States
Niger	Uruguay
Nigeria	Venezuela
Norway	Zambia
Papua New Guinea	
Peru	
Philippines	
Poland	
Portugal	
Puerto Rico	
Romania	
Russia	
Rwanda	
Samoa	
Senegal	
Seychelles	
Sierra Leone	
Singapore	
Slovak Republic	