



HUMAN CAPITAL AND ECONOMIC GROWTH

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The positive relationship between years of education and income at the individual level is a well established empirical relationship. Decades of estimations of Mincerian wage regressions have lead to a plethora of estimates of the elasticity of wages to additional years of educational attainment. At the macroeconomic level, however, finding a robust empirical relationship between measures of educational attainment and long-run economic growth turns out to be an extremely difficult task. This note summarizes the efforts of the recent literature on the macroeconomic relationship between education and long-run economic growth.

Theoretical setting(s)

Human capital as an input of production

Mankiw *et alia* (1992) present a straightforward generalization of the Solow model of economic growth including human capital as an extra production factor, which is able to account for larger cross-country differences in income emanating from differences in investment rates than the basic Solow model. Using a simple Cobb-Douglas production function, total output (Y_t) is assumed to depend on physical capital (K_t), human capital (H_t), labour input (L_t) and technology (A_t),

$$Y_t = K_t^\alpha H_t^\beta (A_t L_t)^{1-\alpha-\beta},$$

where $\alpha + \beta < 1$, $\alpha \in (0, 1)$ and $\beta \in (0, 1)$. Labour input and technology are assumed to grow at constant rates n and g , respectively. Physical and human capital evolve according to

$$\frac{dK_t}{dt} = \dot{K}_t = s_k Y_t - \delta K_t \quad (1)$$

and

$$\frac{dH_t}{dt} = \dot{H}_t = s_h Y_t - \delta H_t, \quad (2)$$

where s_k is the savings rate on physical capital, s_h can be interpreted as the savings rate on human capital or as the proportion of input used in the human capital production function (human capital is assumed to be produced with the same technology as output) and δ is the depreciation rate of physical and human capital. In terms of effective labour, we can write (1) and (2) as

$$\dot{k}_t = s_k y_t - (n + \delta + g)k_t, \quad (3)$$

$$\dot{h}_t = s_h y_t - (n + \delta + g)h_t, \quad (4)$$

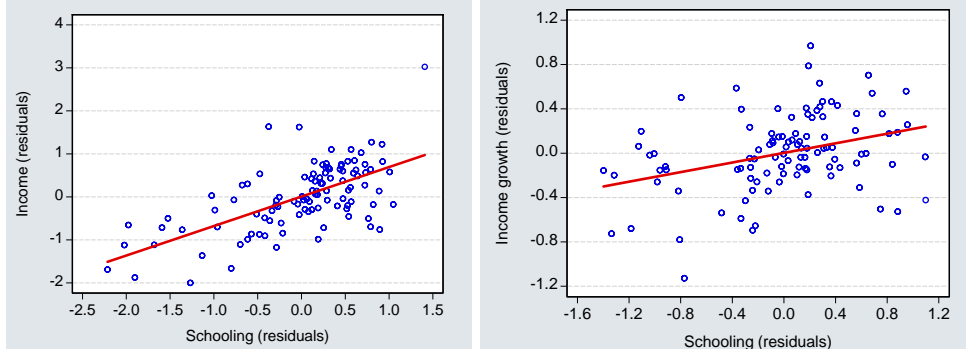
where $h_t = H_t/[A_t L_t]$, $k_t = K_t/[A_t L_t]$ and $y = Y_t/[A_t L_t] = k_t^\alpha h_t^\beta$. This implies that the steady state level of capital and human capital per unit of effective labour is given by the solution to $\dot{k}_t = 0$ and $\dot{h}_t = 0$. Denoting equilibrium variables with an asterisk,

$$\ln y^* = \alpha \ln k^* + \beta \ln h^* = \frac{\alpha}{1 - \alpha - \beta} \ln s_k + \frac{\beta}{1 - \alpha - \beta} \ln s_h - \frac{\alpha + \beta}{1 - \alpha - \beta} \ln(n + \delta + g).$$

This expression nests the results for the standard Solow model (without human capital) for $\beta = 0$. Notice the value of the elasticity of income to (physical capital) savings, $\frac{\alpha}{1-\alpha-\beta} > \frac{\alpha}{1-\alpha}$.

Using the data in Mankiw *et alia* (1992) for 106 countries in the period 1965-1985, Figure 1 presents the scatterplot of per capita income (after controlling for investment and population growth) against schooling rates of the working age population (after controlling for investment and population growth) and income growth and schooling (where initial income is also controlled for), which clearly shows a positive and significant relationship between both variables and the schooling measure.

Figure 1: Income and income growth versus schooling: Mankiw *et alia* (1992) data



Human capital as a determinant of technology adoption

The model with human capital as an input of production hypothesizes *level effects* of human capital on GDP per capita. Education, however, has long been considered a determinant of technology adoption/innovation (the so-called Nelson-Phelps hypothesis, Nelson and Phelps, 1966). This can be modelled by including a specification for technology such as (Benhabib and Spiegel, 1994),

$$\frac{\dot{A}_t}{A_t} = g(H_t) + c(H_t) \left(\frac{A_{ft}}{A_t} - 1 \right),$$

where A_{ft} is the level of technology of the leading country (technology frontier) and $g(\cdot)$ and $c(\cdot)$ are assumed to be linear functions proxying the innovation and diffusion process of technology, respectively. Benhabib and Spiegel (1994) consider two alternative production functions, one where human capital is a standard production input,

$$Y_t = A_t K_t^\alpha H_t^\beta L_t^\gamma,$$

and one where human capital determines technology diffusion,

$$Y_t = A_t K_t^\alpha L_t^\gamma, \quad \frac{\dot{A}_t}{A_t} = g(H_t) + c(H_t) \left(\frac{A_{ft}}{A_t} - 1 \right),$$

which imply the following models for the growth rate of GDP:

$$\frac{\dot{Y}_t}{Y_t} = \frac{\dot{A}_t}{A_t} + \alpha \frac{\dot{K}_t}{K_t} + \beta \frac{\dot{H}_t}{H_t} + \gamma \frac{\dot{L}_t}{L_t},$$

and

$$\frac{\dot{Y}_t}{Y_t} = g(H_t) + c(H_t) \left(\frac{A_{ft}}{A_t} - 1 \right) + \alpha \frac{\dot{K}_t}{K_t} + \gamma \frac{\dot{L}_t}{L_t}.$$

Table 1 presents OLS estimates of alternative models (including the two above) for the data of Benhabib and Spiegel (1994), which uses the data on *average years of schooling* by Kyriacou

(1991) as a proxy for human capital. The results in Table 1 show that, in this dataset, changes in averages years of schooling are not positively related to economic growth, while there is evidence of human capital affecting technology diffusion and innovation.

Table 1: Model estimates: Benhabib and Spiegel (1994) data

	(1)	(2)	(3)	(4)	(5)	(6)
\dot{K}_t/K_t	0.46 (5.36)	0.50 (5.01)	0.54 (8.31)	0.50 (5.01)	0.49 (6.50)	0.44 (4.23)
\dot{H}_t/H_t	0.06 (0.80)		-0.06 (-1.02)			
\dot{L}_t/L_t	0.21 (1.01)	0.11 (0.52)	0.13 (0.79)	0.11 (0.52)	0.27 (1.62)	0.17 (0.77)
H_t		-0.10 (-1.48)		-0.10 (-1.48)	0.16 (2.32)	0.38 (2.91)
$H_t(A_{ft}/A_t - 1)$						0.04 (3.31)
$(A_{ft}/A_t - 1)$			0.19 (5.26)		0.24 (5.43)	
$R^2/\text{Obs.}$	0.52/78	0.53/78	0.68/78	0.53/78	0.69/78	0.62/78

Robust t-statistics in parenthesis.

Education data: Problems and solutions

The striking lack of empirical relationship between changes in years of education and subsequent economic growth has led to a number of studies trying to assess the problem by improving the available data on education measures. While Temple (1999) claims that the lack of relationship may be due to outliers, most of the literature attributes the existence of the puzzle to deficiencies in the human capital data (see Krueger and Lindahl 2001, De la Fuente and Domenech, 2006, or Cohen and Soto 2007).

Crespo Cuaresma (2005) analyzes the evolution of (the second moment of) the distribution of educational attainment across OECD countries and finds enormous differences depending on the dataset used. In particular, the three datasets analyzed (Barro-Lee, Cohen-Soto and De la Fuente-Domenech) provide contradictory conclusions on the existence and evolution of convergence of educational attainment across industrialized countries. The issue is of special relevance, since convergence in schooling levels has been usually claimed to be partly responsible for the convergence process in labour productivity across OECD countries.

Recently, Lutz *et alia* (2008) present a new dataset of educational attainment by five-year age groups for 120 countries for the period 1970-2000 (see also Lutz *et alia*, 2007, for a technical discussion of the reconstruction exercise). The dataset is reconstructed using demographic methods to back-project the population by four levels of educational attainment and sex along cohort lines. Unlike earlier reconstruction efforts, these data also incorporate the fact that people with different levels of education tend to have different mortality rates. While some studies show evidence of significant effects of the demographic structure of the working age population on economic growth (see for example Lindh and Malmberg, 1999), the existing data was not able to disentangle quantity effects (from non-education related productivity differentials across age groups) from quality effects (from education-related differences affecting productivity and technology adoption/innovation). Lutz *et alia* (2008) show that considering differences in human capital across age groups is highly important in order to assess the effect of education on economic growth. In particular, Lutz *et alia* (2008) show that secondary education of the older age groups and tertiary education of younger age groups tend to be important for technology adoption and innovation.

Education quality and economic growth

The quality of schooling can be considered as important as the quantity, measured, for instance, by years of attainment. Although comparable cross-country data on international test scores are only available for a limited number of countries, some studies have been able to establish a positive relationship between quality of schooling and income growth. Hanushek and Kimko (2000) and Barro (2001) find that scores on international examinations have quantitatively bigger effects on economic growth than years of attainment. This effect is more relevant for scores in science examinations.

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