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Convergence in Human Capital and Income

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Abstract
Followed by a long period of divergence of income levels, new evidence shows that poorer countries are converging to the income levels of richer economies. In a model where human capital is the engine of growth, our results indicate that human capital is a very significant variable in explaining the accumulation of physical capital and employment rates, and that its effects on GDP per capita have been increasing from 1960 to 2015. We also show that the total variance of human capital can explain a considerable part of the variance in per capita income across countries. While the residual variance remains relatively constant across the sample, the variance of GDP per capita and the total variance of human capital exhibit similar dynamics. According to our results, the total variance of human capital explains 88% of the increase in the variance of GDP per capita between 1960 and 2000, and 56% of its decrease between 2000 and 2015.

Keywords: Convergence, GDP per capita, human capital, returns to education.
JEL Classification: I26, O11, O15, O47.

1. Introduction

Whether poorer countries are converging to the income levels of richer countries has captured the attention of researchers for a long time. For many years, no evidence was found of unconditional convergence (Pritchett, 1997). However, new evidence is found from the 2000s (e.g., Kremer et al., 2021). The standard deviation of GDP per capita, which has been increasing for a long period of time, shows a reduction in the dispersion from the 2000s. In this paper, we analyze whether human capital has played a role in this process. Our results indicate that the divergence of income levels

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across countries and the convergence in recent years can be accounted for by the counterbalancing effects of the convergence in the years of schooling and the divergence of the aggregate returns to education.

O'Neill (1995) found that from 1967 to 1985 human capital convergence explained income convergence among developed countries. However, despite the convergence in educational levels, the increase in the skill premium led to divergence in income levels in the least developed countries and in the world. We use data from the Penn World Table 10 and Barro and Lee (2013) and extend the analysis to include the recent period that shows convergence in income levels in a broad sample of countries. However, the dispersion of human capital is so small that it cannot explain the variation in income per capita.

Early studies also found relative little contribution of human capital to cross-country income differences (e.g. Hall and Jones, 1999; Klenow and Rodriguez-Clare, 1997). Improvements in the measurement of production inputs gave human capital a larger role (Schoellman, 2012; Lagakos et al, 2018).[2] In this literature the parameters of the production function are calibrated based on micro evidence.

Motivated by the work of Lucas (1988, 1990), we move to an endogenous growth model in which human capital is the main engine of growth. Human capital not only influences income directly, but also can have an indirect effect through the accumulation of other factors of production.[3] Instead of calibrating the parameters, we estimate them in a standard production function and compute the decomposition of variances and their evolution over time. In this framework, we decompose the variation in income into the total variation in human capital, the direct and indirect effects, and the variation in the orthogonal components of the other factors of production that are not due to human capital. Interestingly, in this case, the variation in human capital can account for most of the evolution of the variation in per capita GDP. [4]

From 1960 to 1995, the increase in the variance in the returns to education out-

[2] Recent contributions that assume imperfect substitution between skilled and unskilled workers display a large role of human capital if relative efficiency reflects the human capital and attributes of workers (Jones, 2014, 2019) or a small role, if relative efficiency reflects differences in institutions, technology and other environmental factors (Caselli and Ciccone, 2019)

[3] Human capital can also have indirect effects on economic development through fertility rates, social capital, industrial production or foreign trade (Guisan and Neira, 2006). Texeira and Quirós (2016) also point to the interaction of human capital with the productive structure of countries as an alternative indirect effect of human capital on economic growth.

[4] Gennaioli et al (2013) present a Lucas-Lucas model that incorporates the allocation of talent between entrepreneurship and work (Lucas, 1978), and also human capital externalities (Lucas, 1988). In this framework, they find that human capital is an essential determinant of regional development.

weighs the reduction in the variation in the quantity of schooling, so that the dispersion of total human capital increases and can account for the divergence pattern observed in income levels. By the end of the 1990s and beginning of the 2000s, the process reverses, and the reduction in the variation of schooling is larger than the increase in the variation in the returns. As a result, the variation in total human capital decreases and can also account for part of the reduction in the dispersion of per capita GDP across countries from 2000 onward.

The paper is related to the literature on income convergence across countries. For many years, there was no evidence that poor countries unconditionally catch up to the income levels of rich economies (Barro, 1991; Pritchett, 1997; Rodrik, 2013). New evidence shows a change in the trend from the 2000s onward (Kremer et al., 2021; Patel et al., 2021), suggesting that a process of unconditional convergence might have started.[5] Kremer et al. (2021) focuses mainly on unconditional beta convergence in per capita GDP and its correlates. In our paper, we focus on sigma convergence in per capita GDP and analyze the role of human capital in this process.

The structure of the paper is as follows. Section 2 computes the decomposition of the variance of income levels into different components. Section 3 presents a reduced version of the Lucas (1988) model and computes the variation in human capital taking into account the direct and indirect effects on income levels. Section 4 summarizes the conclusions reached.

2. Variance Decomposition

Following O'Neill (1995), we start with a log-linearization of a standard production function of the form:

$$ln(Y_{it}) = \phi_t + \alpha_t \ln(K_{it}) + \beta_t \ln(L_{it}) + \gamma_t \ln(H_{it}) + e_{it} \tag{1}$$

where aggregate GDP per capita (Y) in country i and year t depends on three factors of production: human capital (H), physical capital per capita (K) and the number of persons employed over total population (L). To differentiate between the role of the quantity and the returns to education, we allow factor prices to vary over time. We estimate equation (1) from 1960 to 2015 over a 5-year span and get the estimates

[5] Acemoglu and Molina (2021) argue that Kremer et al. (2021) findings could be biased due to the omission of country fixed effects that account for unobserved determinants of per capita GDP across countries.

of the elasticities in each period.[6] Using these estimates, we follow O´Neill's (1995) decomposition and compute how much of the variation in aggregate output can be accounted for by the variation in the quantity and the returns to education.

The variation in total human capital (VT_t) across countries in year t is computed as follows:

$$VT_t = var_t(\overline{\phi} + \gamma_t \ln(H_{it}) + \overline{\alpha}\ln(\overline{K}) + \overline{\beta}\ln(\overline{L})) \tag{2}$$

where the estimates of the returns to education and the average years of schooling are allowed to vary, while the other components of the production function remain constant. $\overline{K}$ and $\overline{L}$ are the averages of physical capital and the employment rate across countries over time, and $\overline{\phi}$, $\overline{\alpha}$, $\overline{\beta}$ are the average of the estimated parameters over time.

We calculate the variance of the quantity of education (VH_t) in year t by keeping the returns to education constant and only allowing H_i to vary across countries:

$$VH_t = var_t(\overline{\phi} + \overline{\gamma}\ln(H_{it}) + \overline{\alpha}\ln(\overline{K}) + \overline{\beta}\ln(\overline{L}) \tag{3}$$

Then, the variance of the returns to education (VP_t) can be computed as the difference between the variance in total human capital and the variance in the quantity of education:

[6] We use the average years of schooling of the population aged 15-64 as a measure of the quantity of education (H), taken from Barro and Lee (2013). Aggregate output (Y), measured with real GDP per capita at constant 2017 national prices, the stock of physical capital (K), proxied by the capital stock per capita at constant 2017 national prices, and the employment rate (L), measured as the number of persons employed divided by total population, are taken from the Penn World Table 10. Panel causality tests show that causality runs from $\ln H_{it}$ to $\ln Y_{it}$. In particular, in the first stage we have estimated the long-run relationship between both variables (t-ratios in parenthesis):

$$ec_{it} = \ln Y_{it} - \alpha_t - \underset{(36.2)}{1.495} \ln H_{it}$$

In the second stage, as in Granger (1988), we test the exclusion of ec_{it-5} in two error correction models:

$$\Delta \ln Y_{it} = \delta_{1t} - \underset{(4.94)}{0.028} ec_{it-5} + \underset{(11.8)}{0.373} \Delta \ln Y_{it-5} - \underset{(1.57)}{0.080} \Delta \ln H_{it-5} + u_{it}^{y}$$

where the exogeneity of $\ln Y_{it}$ is rejected at the 0.1% significance level, and

$$\Delta \ln H_{it} = \delta_{2t} + \underset{(1.36)}{0.004} ec_{it-5} + \underset{(0.64)}{0.011} \Delta \ln Y_{it-5} + \underset{(20.0)}{0.560} \Delta \ln H_{it-5} + u_{it}^{h}$$

where the exogeneity of $\ln Y_{it}$ is accepted at the 17.3% significance level. This result is robust to the inclusion of additional lags and is consistent with the evidence that $\ln H_{it-j}$ is statistically significant in explaining $\ln Y_{it}$ for $j = 5, ..., 55$, whereas the opposite is not the case, that is, lagged human capital is more predictive of actual GDP per capita than lagged income of current human capital.

$$VP_t = VT_t - VH_t \quad (4)$$

The residual variance, which includes the variance of the other factors of production and the unobserved variation, is calculated as the difference between the variance of the aggregate output (VY_t) and the variance of total human capital:

$$VR_t = VY_t - VT_t \quad (5)$$

We find that in 1960, the variance of the average years of schooling (VT) accounted for about 60% of the variation in VY. Since then, the dispersion of the years of schooling has reduced over time, and its variance has tended to zero in recent years. The decreasing trend in the variance of the average years of schooling cannot explain the increasing trend in the dispersion of per capita income from 1960 to 2000. We use the estimates of the returns to education from equation (1) and compute the decomposition of the variation in income levels into the components in equations (2)-(5). We find the variance of the quantity (VH) and the price (VP) of education follow different trends. Evidence also shows that both variances are small in quantitative terms and cannot account for the variation in per capita income (VY) over the years.

3. Direct and Indirect Effects of Human capital

Following Lucas (1988, 1990), we move to an endogenous growth model in which the main driver of growth is human capital, which also determines the accumulation of physical capital.

Consider the following production function in per capita terms,

$$y = k^{\alpha}(eh)^{1-\alpha} \quad (6)$$

where $0 < \alpha < 1$, y, k and h are, respectively, output, physical and human capital per capita, and e is time devoted to producing goods and services. Human capital is accumulated according to the following equation:

$$\Delta h = (1 - e)\psi h \quad (7)$$

where ψ represents the efficiency in the accumulation of human capital. The accumulation of physical capital is determined by

$$\Delta k = sy - (n + \delta)k \quad (8)$$

where s is the saving rate, n population growth and δ the depreciation rate. We assume that these rates are exogenous and constant.

In the balanced growth path (denoted by an asterisk) in which y^*/k^* is constant and both variables grow at the same rate, it is clear that

$$\frac{\Delta y^*}{y^*} = \frac{\Delta k^*}{k^*} = \frac{\Delta h}{h} = (1-e)\psi \tag{9}$$

Now assume that there is perfect mobility of physical capital and that economies a and b are identical except in their levels of human capital. These assumptions imply that the returns to physical capital must be the same in both countries, that is,

$$r_a = \alpha \left(\frac{eh_a}{k_a}\right)^{1-\alpha} = r_b = \alpha \left(\frac{eh_b}{k_b}\right)^{1-\alpha} \tag{10}$$

Therefore, the level of physical capital will be higher in the country with the higher human capital. According to this result, human capital has a direct effect on output per capita, given by its elasticity in the production function, and an indirect effect, through the accumulation of physical capital. We have tested this hypothesis in our sample of countries and the results broadly confirm it. In all 5-year periods from 1960 to 2019 the elasticity of physical capital to human capital is greater than 1.0 and statistically significant at 1%, and the share of the variance of k explained by h ranges from 51% in 1960-64 to 66% in 2010-14.

In order to estimate the direct and indirect effects of human capital through the elasticity of H (γ) in the production function, we follow two steps. First, we regress each factor of production on $\ln(H_{it})$. Then, we use the residuals from these regressions to estimate equation (1), that is, in the second step we use the variations in the factors of production that are not explained by the variation in human capital. The left-hand side of Figure 1 plots the estimates of γ in equation (1), using the orthogonal components of physical capital and the employment rate. The figure shows that γ displays an increasing trend over the years. The estimate is three times higher in 2015 than in 1960, increasing from 0.91 in 1960 to 2.81 in 2015.

The right hand side of the figure shows the evolution of the variances in equations (2)-(5). When the direct and indirect effects of human capital are taken into account, the total variance of human capital (VT) can explain a considerable part of the variation in income per capita across countries (VY). Whereas the residual variance (VR) remains relatively constant, VT and VY exhibit similar dynamics. From 1965 to 1995, the increase in the variance of VT (due to the higher contribution of the variance of the returns to education, VP) explains the rise of VY. From 1995 onward, the situation

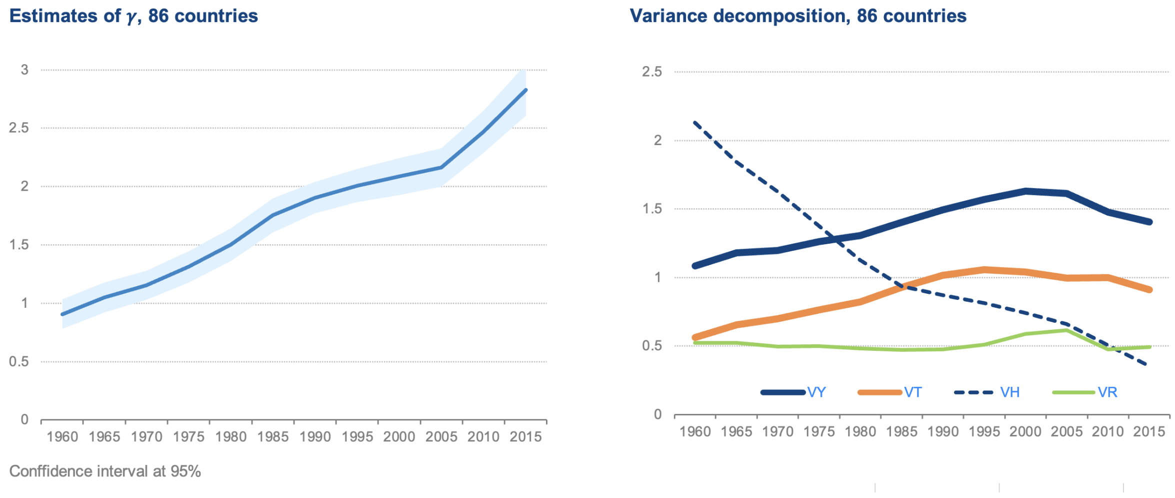

Figure 1: *Estimates of gamma and variance decomposition, direct and indirect effects.*

reverses.

To evaluate the relationship in quantitative terms, Table 1 displays the values of the changes in the variances in two distinct periods: the period when the dispersion of income levels increases, from 1960 to 2000; and the one in which the variance decreases, from 2000 to 2015. We compute the difference between the variances in the last year and in the first year (e.g., $VY_{2000} - VY_{1960}$).

During the first period, the variance of the returns to education (VP) in column (4) increases markedly (1.865) and is even larger in absolute terms than the reduction in the variance of the quantity of education (-1.389) in column (3), so that the total variation in human capital (0.476 in column (2)) can mostly explain the increase in the variance of per capita income across countries (0.544). VT explains about 88% of the variation in VY.

During the period 2000-2015, the process reverses. The increase in the variance of the returns to education slows down (0.261 in column (4)) and is lower than the reduction in the variance of the quantity of education (-0.388 in column (3)). As a result, the total variance of human capital decreases (-0.127) and can explain about 56% of the reduction in the dispersion of income levels (-0.226).

The results are robust to alternative measures of education. De la Fuente and Domenech (2006) and Cohen and Soto (2007) point that Barro and Lee´s data on years of schooling are noisy and are subject to some breaks over time and measurement errors. We check the robustness of the results with the years of schooling estimated by Cohen and Leker (2014) and our findings hold. We have also checked that the results are not driven by atypical observations. Following Temple (1998) we have used

Table 1: Change in the variances in different periods

	ΔVY	ΔVT	ΔVH	ΔVP	ΔVR
	(1)	(2)	(3)	(4)	(5)
1960-2000	0.544	0.476	-1.389	1.865	0.067
2000-2015	-0.226	-0.127	-0.388	0.261	-0.098

Note: The change is computed as the difference between the corresponding variance in the last and in the first year in each period.

Iterated Weighted Least Squares, which weights the observations based on outliers with residuals 2.5 times the standard deviation. The findings reveal the results are robust to the presence of outliers.

4. Conclusions

Based on the endogenous growth model of Lucas (1988 and 1990), in this paper we have proposed a method to decompose the variance of GDP per capita in a large sample of countries from 1960 to 2015 between the contribution of human capital (taking also into account its indirect effects on the accumulation of physical capital and the employment rate) and the contribution of the orthogonal components to human capital. Our results show that the total variance of human capital can explain a considerable part of the variance in per capita income across countries. While the residual variance remains relatively constant across the sample, the variance of GDP per capita and the total variance of human capital exhibit similar dynamics. According to our results, the total variance of human capital explains 88% of the increase in the variance of GDP per capita between 1960 and 2000, and 56% of its decrease between 2000 and 2015.

The evidence found in this paper suggests that the efforts in the less developed countries to raise education levels are a necessary condition and should be a priority, not only to increase the growth rates of these economies, but also to accelerate the convergence process in income levels towards the richer countries. Our results indicate that human capital is a very significant variable in explaining the accumulation of physical capital and employment rates, and that its effects on GDP per capita have been increasing from 1960 to 2015.

We leave for future work two extensions of our analysis. First, in this paper, we consider the quantity but not the quality of human capital, which could be more appropriate as an explanatory variable in our empirical analysis, as shown by de la

Fuente and Domenech (2024). Second, the analysis is made in a broad sample of countries with different levels of development. However, the role of human capital in the convergence process might differ between poorer and richer economies. A further analysis of these issues will be addressed in future research.

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