Knowledge and Growth in a panel and cross-section analysis of nations*

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Abstract

In this paper we investigate the impact of knowledge as measured by PISA and TIMSS average achievements of nations on growth. We do so by using a standard growth model of human capital. The result is that improving average achievements in the international tests increases the level of GDP per worker (short term growth rate), but it does not affect the long run growth rate. This is a different interpretation to the important contribution of Hanushek and Woessmann (2015), who find that those tests are better than schooling as measures of the impact of knowledge on economic growth. In particular, while they find that a one standard deviation in knowledge as measure by international tests generates an increase of GDP per capita of 26% after 90 years, we find a more moderate effect of 11% for the same period.

JEL Clasification: I25, O47, O15, I20

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1 Introduction

In this paper we investigate the impact of knowledge as measured by PISA and TIMSS average achievements of nations on growth. We do so by implementing the methodology of Hanushek and Woessmann (2015, HW) on a panel of thirteen advanced economies for the period of 1970-2010, as well as a cross section of countries for 1960-2010. The panel enables us to better identify the short run determinants of

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growth (level effect), and the long run determinants of growth (growth effect). We show that improving the average achievements of a nation in the international tests impacts the short run growth trajectory, but not the long run growth rate. Thus, we provide a different interpretation to the important contribution of HW, who showed very convincingly that a quality-based measure of knowledge is better than quantity-based measures in estimating the relation between knowledge and growth.

We start from a standard production function, conduct a growth accounting estimation, *á la* Benhabib and Spiegel (1994). In such a model, if human capital impacts the long run growth, then its *level* should be positively correlated with the growth of GDP per capita, while if it affects the short run growth, then its *change* should be correlated with the growth rate of GDP per capita. To test the model, we construct a series of the measure of human capital, based on HW. Thus, our first contribution is to build series of quality based measures of knowledge. We discover that none of the countries in the sample has experienced a sharp increase in the average achievements of its students in the international tests. We also use data from Penn World Tables (Feenstra et al., 2013, PWT) on GDP per worker and capital stocks to estimate the short run and long run effects of knowledge on growth.

We first measure the model assuming that human capital has a growth effect alone. The coefficient of the level of human capital on GDP per worker growth rate is not statistically significant. We then test the hypothesis of the level effect alone (assuming that there is no growth effect of human capital on growth), and indeed the coefficient of the change in human capital is positive and statistically significant. Finally, we do not restrict the model, and allow both level effect and growth effect play a role. Consistent with our previous results, the level of human capital is not correlated with the growth rate of output per worker, whereas the change in the level of human capital (which captures the level effect) is positive and statistically significant. We conclude from this analysis that consistent with the cross country analysis, the panel data support the level effect hypothesis, rather than the growth effect hypothesis. Summary of cross section

Interpretation

To test for robustness we extend the analysis to a larger sample of countries. Due to data restrictions, this is only possible if we move to a cross section analysis. Thus we lose the advantages of panel data, but gain a larger sample of countries, which are less similar to one another as in the previous panel of thirteen advanced economies. We construct a variant of the neoclassical model in which human capital affects the growth rate of output per worker. In this model, each country converges to a globally stable steady state. Yet unlike the basic neoclassical model, in this model, even in the steady state countries may differ in their growth rates, since the growth rate of each economy depends on its level of human capital. We estimate the model for a cross section of countries, and find no evidence that the data support the hypothesis that the level of human capital positively affects per capita growth.

So how different is the impact of an educational reform if we interpret it as a level effect and not a growth rate effect? To answer this question, we conduct a simulation of the impact of an educational reform on GDP per capita, and take the simulations of HW as a benchmark for a growth rate effect. HW show that 90 years after an educational reform, output per capita will be 26% higher than its no-reform counterpart. Our estimations suggest that after 90 years, output per capita will exceed its no-reform level by about 4.8%. Furthermore, the difference between the results of HW and ours increases over time. These results call for revising the pro-and-con debates on educational reforms throughout the world.

2 Knowledge and Growth Using Panel Data

In this section we construct a simple model that will enable us to identify the growth and level effects in panel data. Thus, the model is similar in the spirit to Islam (1995). Note, however, that it is also different from the latter: most previous studies, which used panel data, attempted to estimate a neoclassical growth model and its convergence rate. As such, they used the level of output per worker as the dependent variable. We, on the other hand, try to identify the growth and level effects. Consequently, we use the growth rate of output per worker as our dependent variable.

2.1 The Model

Consider economy i in which production takes place using a production function as given in (1). In this case, output per worker is given by:

$$\ln y_{i,t} = \alpha \ln k_{i,t} + \beta \ln h_{i,t} + (1 - \alpha - \beta) \ln A_{i,t}, \tag{1}$$

where $y_{i,t}$ is output per worker produced in country i at time t, $k_{i,t}$ is the capital per worker employed in production at country i at time t, $A_{i,t}$ is TFP in country i at time t, $0 < \alpha, \beta, \alpha + \beta < 1$. This Cobb-Douglas production function is very common in the literature. Assume also that the TFP growth rate depends on the level of human capital:

$$g_{A_{i,t}} = \phi + \chi \cdot h_{i,t}, \tag{2}$$

where $g_{A_{i,t}}$ is the growth rate of TFP in country i at period t, which depends on two elements: an exogenous element, denoted by ϕ, and the level of human capital in country i at time t. We assume that the relation between the level of human capital and the growth rate of TFP is linear and captured by χ. This equation is a reduced form of two economic forces that may generate a growth effect: a higher level of human capital implies a higher level of both inventing and absorbing new technologies (We below attempt to estimate the two effects separately).[1]

Fully differentiating with respect to time yields the following equation:

$$g_{y_{i,t}} = \alpha g_{k_{i,t}} + \beta g_{h_{i,t}} + (1-\alpha-\beta) g_A(h_{i,t}) = \alpha g_{k_{i,t}} + \beta g_{h_{i,t}} + (1-\alpha-\beta)(\phi + \chi \cdot h_{i,t}),$$

where $g_{x_{i,t}}$ is the growth rate of varible x in country i at period t. Note that $\chi \cdot h_t^i$ represents the growth rate effect of human capital, and $g_{h_{i,t}}$ represents the level effect. Hence, the panel data provide us a simple specification to assess if human capital has a level effect or a growth effect. Thus, we estimate the following equation:

$$g_{y_{i,t}} = \alpha g_{k_{i,t}} + \beta g_{h_{i,t}} + (1-\alpha-\beta)(\phi + \chi \cdot h_{i,t}) + \Delta_i + \epsilon_{i,t}, \quad (3)$$

where Δ_i is country time-invariant fixed effects and $\epsilon_{i,t}$ is an error term. If human capital has a growth effect, one would find a positive and statistically significant estimator of χ, whereas if human capital has a level effect, one would find a positive and statistically significant estimator of β.

2.2 Data

We would like to use a measure of human capital as similar as possible to HW. However, since their estimation is of a cross section of countries, their data do not allow for panel data estimation. To overcome this problem, we follow the methodology of HW to construct a similar measure for a panel of countries. This measure is based on the average student achievements in international tests in math and sciences. However, unlike the cross section case, for panel data analysis, we can use data only for thirteen countries that participated in the international tests long enough. The international tests were initiated in 1964, and since then they took place several times a decade. Table A.1 presents the thirteen countries

[1] Another channel would be of positive externalities. Nevertheless, the evidence for such externalities are mixed. Acemoglu and Angrist (2001), for instance, find very weak evidence for such externalities.

that participated either in the first tests in 1964, or in the second ones in 1970 and hence construct our sample. The table shows that these countries participated in at least five different tests (the average among these countries is 7.07). Note that all these countries are advanced, suggesting that we cannot analyze in this section different growth patterns of developed and developing countries that may arise, for example, due to threshold externalities (e.g., Azariadis and Drazen (1990)).

We use data from PWT on the real capital and labor stocks, and real output for the countries in our sample for the period 1970-2005.[2] For each country, we calculate the annual level of output per worker. We then divide the entire period of 1970-2005 to 5 year long sub-periods. We calculate for each sub-period the average annual growth rate of output per worker and of the stock of capital per worker. This approach, as well as the length of the sub-periods is very common in the literature (e.g., Islam (1995)).[3]

As discussed above, we use the methodology developed by HW to construct a measure of human capital. Yet unlike HW, we construct for each country a series of this measure.[4] For each of these countries, we calculate the measure for each year the country participated in the international tests. Since most countries did not participate in all the tests that took place, and since the tests did not take place in all the years in our sample, we linearly interpolate the results for these missing years. Figure 1 presents the human capital measure in these countries over time. For most of the countries that participated in 1964, there is a sharp rise in the measure of human capital between 1964 and 1970. However, after 1970 the dynamics are mixed: some countries experience a moderate increase (e.g. Australia); some experience a relative decline (e.g., Israel) and other countries do not have a specific trend (e.g., Sweden and Belgium). Note also that the measure of human capital has not risen sharply for none of these countries. This raises the question whether an increase in human capital much above the range presented in the figure is feasible. Furthermore, it is not clear whether those countries which experienced some increase in their human capital indeed experienced a higher growth than those which did not experience such an increase in the stock of human capital.

The international tests are taken at the ages of 10, 14 and 17. Most of the exams are for the ages of 14 (45%) and 17 (31%).[5] Since we attempt to capture how variations in the test scores affected long run growth, we use the human capital measure with a lag of 5 years, which means that the individuals who

[2] We restrict our analysis until 2005 in order to avoid some biases that may emerge due to the Great Recession. For robustness, we also add to the analysis the period between 2005 and 2010, as described below.

[3] For a thorough survey of the literature using panel data in growth regressions, see Section VI.ii Durlauf et al. (2005).

[4] See Hanushek and Woessmann (2012) for a detailed explanation of the methodology.

[5] Most of the exams for 10 year old students took place towards the end of the 1990's and as such they form a small part in our sample.

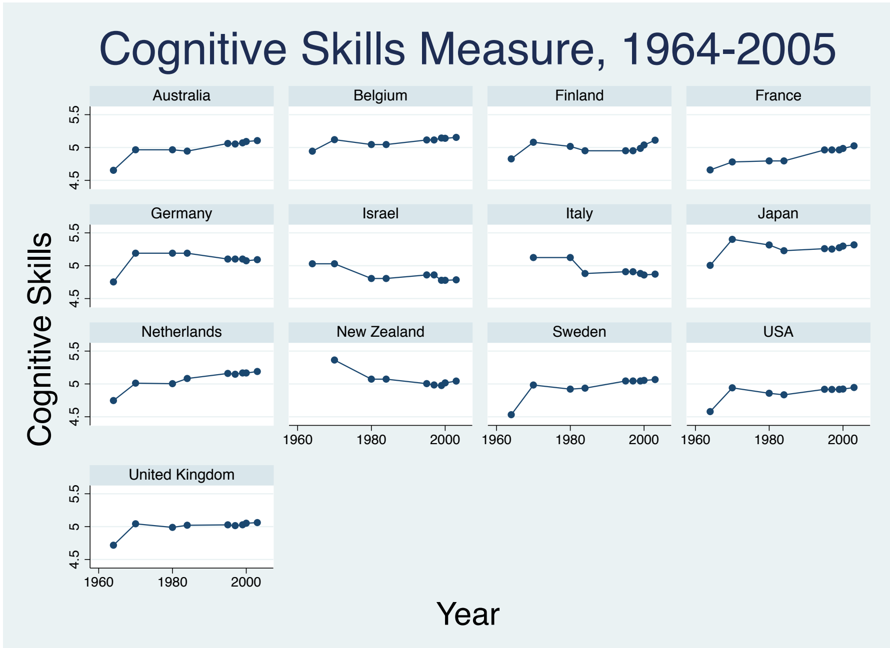

Figure 1: The measure of cognitive skills for countries which participated in international tests since 1964 or 1970

took the exams 5 years earlier are 15, 19 and 22 years old, respectively.

Table A.1 explains why we use a five year lag. For the countries in our sample, the table provides the average years of schooling of the 20-24 year old cohort in 1970 and 1990, as well as the share of this cohort that graduated high school and college (in percentage points). As can be seen in the table, the average schooling years in 1970 for the cohort of 20-24 year olds was 9.5. This suggests that on average, individuals entered the labor force around the age of 17. This means that students who participated in the international tests when they were 14 entered the labor force on average 3 years later. The same methodology reveals that in 1990 the average schooling years of the 20-24 year old cohort was 11.43, suggesting that on average students who took the test when they were 14, entered the labor force 5 years later. Note that a five year lag for all exams that had taken place at the age of 17, implies that the vast majority of the population is already in the labor force.[6] Table B.1 provides the summary statistics of all the variables used in the panel data analysis.

2.3 Results

Our estimated model is a model with country fixed effects, as the Hausman test rejects the random effects model. Table A.6 presents our results for estimating (3) using the data described above. In column (1)

[6] As described above, exams for the 10 year old were not so prevalent during most of the period we analyze. Consequently, we emphasize more on individuals who took the exams when they were either 14 or 17.

we test whether there is a growth rate effect, without any controls (that is, assuming that β and α equal zero). The coefficient of the level of human capital is negative and marginally statistically significant. In column (2) we add the change of physical capital, yet the coefficient of the level of human capital is still negative and not statistically significant. In column (3) we test whether human capital has a level effect, without any controls (that is, assuming that χ and α equal zero). The coefficient is positive and statistically significant at the 5% level. In column (4) we add the controls of the change in stock of capital per worker. The coefficient of the change in human capital increases in magnitude (from 1.2 to 1.3), and is statistically significant at the 1%.

In columns (5) and (6) we include as independent variables both the change in the human capital and its level, and only the change in human capital is statistically significant at the 10% and 5% respectively. In column (6) we add to the analysis back the change in the capital and labor stocks. In column (7) we add initial GDP per worker of the period as a control. This is meant to capture some to overcome a possible problem that the initial level of human capital may capture the effect of initial output per worker instead of the direct effect of human capital on growth. Yet as column (7) shows, our results are equivalent to the results presented in all other columns: The level of human capital is not statistically significant, whereas the change in the level of human capital is positive and statistically significant, as the neoclassical growth model would predict. Yet in none of the columns the coefficient of the level of human capital is significant. We conclude from this table that the data support the level effect hypothesis rather than the growth rate effect.

Robustness One concern with our results are that these are driven by the lag that we chose. Tables A.2, A.3 and A.4 in Appendix A provide evidence that this is not the case. These tables provide the results of estimating (3) with lags of 3, 6 and 10 years for our measure of human capital (and their change), respectively. As can be seen, the level of human capital (χ) is never positive and statistically significant. In fact in Table A.3 it is *negative* and statistically significant at the 5%. The change in the human capital measure is always positive, and statistically significant either at the 1% or the 5% when the lag we use is either 3 or 6 years. It is not statistically significant when we use a 10 year lag. This, however, may be due to the decline in the sample of 13 observations that happens due to the large lag we impose in this table.

Another potential concern with a fixed effects model in panel data may arise due to the relatively small number of observations in each country. In such a case, since the variation between countries is

Table 1: Growth Rate vs. Level Effect Analysis

	Annual GDP per Worker Growth						
	Growth Effect Alone		Level Effect Alone		Both Effects		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
HC Level (5 year lag)	-0.04*	-0.03			-0.02	-0.01	-0.01
	(0.02)	(0.02)			(0.02)	(0.02)	(0.02)
HC Growth (5 year lag)			1.20**	1.30***	0.95*	1.15**	0.84*
			(0.42)	(0.42)	(0.45)	(0.43)	(0.40)
Capital Growth		0.08**		0.10***		0.10**	0.11**
		(0.04)		(0.03)		(0.03)	(0.04)
Labor Growth							
Initial GDP per Worker							-0.01
							(0.01)
Adjusted-R^2	0.05	0.10	0.07	0.16	0.08	0.16	0.17
Observations	104	104	104	104	104	104	104

Notes: Both levels and changes in cognitive skills are calculated with a 5 year lag. Standard error estimates clustered at the level of the country fixed effects are reported in parentheses; *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level, all for two-sided hypothesis tests; All regressions include a constat.

not used for estimating the coefficients, the standard errors of the coefficients may be large.[7] In order to overcome this problem, we estimate a random effects model. Its results are presented in Table A.5. As can be seen in the table, our result are unaffected by the random effect model, and their significance is higher.

Last but not least, one may argue that the results are driven by the fact that we stop at the peak of growth during the first decade of the second millennium. To overcome this problem, we add another observation to the analysis of the sub-period between 2005 and 2010. As can be seen in Table **??**, the results obtained for the entire period of 1970-2010 are very similar to the results presented in Table A.6, which analyzes the period 1970-2005.

3 Knowledge and Growth in a Cross Section

Our previous results rely on a panel of thirteen advanced economies. One caveat of this approach is that it limits the analysis to a small sample of countries. As a robustness check, we would like to extend the sample of countries, at the expense of using a cross section. Unfortunately, in the basic MRW model, human capital has a level effect by assumption, and thus it is not suitable to identify the two effects. To

[7]For a deep discussion of this problem, see Section VI.ii in Durlauf et al. (2005).

overcome this problem, we extend the basic MRW model in a way that it would distinguish between the growth and level effects. Specifically, in this section we assume (similarly to the panel analysis described above) that the technological growth rate is a linear function of the level of human capital in the economy, as in (2). This assumption, which suggests that the higher the average level of human capital, the higher the rate of technical change, is consistent with the endogenous growth literature (e.g., Ha and Howitt (2007)),[8] and is similar to the assumption in Benhabib and Spiegel (1994). The rest of our model does not change. It turns out that in the steady state, output per worker equals:

$$\ln y_{i,t} = \frac{\alpha}{1-\alpha-\beta}\ln s_{K_i} + \frac{\beta}{1-\alpha-\beta}\ln s_{H_i} - \frac{\alpha+\beta}{1-\alpha-\beta}\ln[n_i + \lambda(h_i^*) + \delta] + \ln A_{i,t}, \tag{4}$$

where, h_i^* is the steady state level of human capital. It is straightforward that since in the steady state the level of human capital is constant, so is the growth rate of technology. As a result, the term in the squared brackets is constant. This implies that in the steady state output per worker grows at a constant rate, $\phi + \chi \cdot h_i^*$. The level of human capital, on the other hand, may differ from one country to the other, as the investment rate in human capital may differ between countries. As a result, the *level* of human capital may yield different growth rates in different countries. To test this specification, we take logs from both sides of (6) and subtract from both sides $\log y_{i,0}$. Finally, we subtract and add to the right hand side of (6) $\log A_{i,0}$. This yields the following equation:

$$\begin{aligned}\ln y_{i,t} - \ln y_{i,0} = \frac{\alpha}{1-\alpha-\beta}\ln s_{K_i} + \frac{\beta}{1-\alpha-\beta}\ln s_{H_i} - \frac{\alpha+\beta}{1-\alpha-\beta}\ln[n_i + \lambda(h_i^*) + \delta] \\ + \ln A_{i,t} - \ln A_{i,0} - \ln y_{i,0} + \ln A_{i,0}.\end{aligned} \tag{5}$$

Note that along the steady state, the technological level grows at a constant rate, which is a function of the steady state level of human capital. Close to the steady state, the technological level grows also from the accumulation of human capital. As a result, in (7), $\ln A_{i,t}^* - \ln A_{i,0} \cong \phi + \chi \cdot (h_i^* + \Delta h_{i,0})$, where $\Delta h_{i,0} \equiv h_i^* - h_{i,0}$. Hence, the growth effect of the level of human capital is captured in two elements of this equation. First, in the expression in the squared brackets, $n_i + (\phi + \chi \cdot h_i^*) + \delta$, and second, in the expression of convergence toward the steady state, $\phi + \chi \cdot (h_i^* + \Delta h_{i,0})$.

In order to estimate this last equation, we assume (following MRW) that $\ln A_{i,0} = \ln \overline{A}_0 + \epsilon_i$, where

[8] Note that the endogenous growth theory does *not* rule out convergence. See, for instance, Howitt (2000).

$\ln \overline{A}_0$ is the average level of $\ln A_{i,0}$. Consequently, (7) can be written as:

$$\ln y_{i,t} - \ln y_{i,0} = \frac{\alpha}{1-\alpha-\beta} \ln s_{K_i} + \frac{\beta}{1-\alpha-\beta} \ln s_{H_i} - \frac{\alpha+\beta}{1-\alpha-\beta} \ln(n_i + \lambda(h_i^*) + \delta) \\ + \phi + \chi \cdot (h_i^* + \Delta h_{i,0}) - \ln y_{i,0} + \ln \overline{A}_0 + \epsilon_i. \tag{6}$$

Note that this specification is similar to a specification analyzed in previous studies, such as HW. Specifically, it is similar to a recent study by Sunde and Vischer (2015). They also attempt to measure the levels vs. growth effect. However, they estimate both human capital (and its change over time) using data on the average schooling years. We, on the other hand, attempt to use a quality based measure of human capital, and thus use a measure constructed by HW.

3.1 Data

We use data on GDP per capita and population size from 1960 to 2010 for 51 countries from Penn World Tables version 8.1 (Feenstra et al., 2013, PWT). All these countries did not belong previously to the Soviet bloc. We calculate the real GDP (on aggregate level) for these countries in these years, and then use data on the number of workers in these years from PWT as well to calculate output per worker in each year in the period 1960-2010, and its growth rate. We use data also from PWT to compute the average investment rate in physical capital for this period by calculating the investment as a percentage of GDP. We assume that the depreciation rate is 4% (as suggested in Inklaar and Timmer (2013)). We also compute for each country its average annual growth rate of the labor force, n_i. Finally, we use the measure of human capital from HW as our human capital measure, as it was shown previously that its correlation with growth is much more consistent than other measures of human capital. Table B.2 summarizes the statistics of the variables we use for our estimations. All variables except the human capital measure level are in percentage points.

Estimating Δh_0^i

The measure of human capital developed by HW is calculated as an average score of each country in the international tests it had participated in. Unfortunately, only 13 countries participated in these tests long enough to allow us to investigate its dynamics. In order to overcome this problem, we calculate the difference in the level of human capital under different assumptions regarding the average schooling years, as reported in Barro and Lee (2013). First, for each country we estimate $\Delta h_{i,0}$ by the difference in average schooling years. Second, we extrapolate the results in the international tests by using the growth rate of the average schooling years.

3.2 Results

Table 3 summarizes the results from estimating these two specifications, along with a replication of the results obtained by HW, used mainly as a benchmark. Column (1) replicates the main result in HW, and indeed the quality based measure of human capital is positive and statistically and economically significant. In particular, this estimation suggests that a one standard deviation increase in the quality based measure of human capital is associated with a 1.38% increase in GDP per worker growth. This result is similar to the ones reported in HW, where the quantitive difference stems from the fact that we use the growth rate of GDP per worker, whereas they use the growth rate of GDP per capita. Column (2) includes in addition the average investment rate in physical capital and the average growth rate of labor as independent variables. Their coefficients are positive and negative, respectively, exactly like theory suggests. Note that once these variables are taken into account, the coefficient of investment in human capital declines from 1.38 to 0.81, reducing the direct effect of investment in human capital on economic growth. This suggests also that the coefficients reported in HW include also the complementarity between investment in physical capital and investment in human capital, and the interaction between population growth and investment in human capital.[9]

We now turn to estimate the model that attempts to identify the growth effect and the level effect separately. Columns (3) and (4) present the results of the estimations with our first and second specifications, respectively. The average investment rate in physical capital is positive and close to 0.08; The coefficient of the initial level of output per worker in 1960 is negative, significant, and close to its level in the column (2). Furthermore, recall that this level of human capital is the *level* effect, and not the *growth* effect.

The coefficients at stake are the coefficient of $n_i + \lambda(h_i^*) + \delta$ and the coefficient of the change in human capital. The first coefficient is negative and statistically significant. In order to test whether this indeed suggests of the existence of a level effect, we run two more regressions, reported in columns (3) and (4), where we omit $\lambda(h_i^*)$ from the expression $n_i + \lambda(h_i^*) + \delta$. If indeed the level effect is in force, then one would expect to have a different coefficient when measuring the model with and without $\lambda(h_i^*)$, as

[9] Different theories explain the observed correlation between investment in human capital, fertility decisions and thus population growth rate and investment in human capital, and causality may stem from each one of these three variables to the other. Consequently, we do not argue that the coefficient obtained in column (2) is the overall effect of investment in human capital on growth, but merely its direct effect.

different countries with different levels of human capital may also grow at a different rate. Nevertheless, comparing the coefficients of $n_i + \delta$ in columns (5) and (6) to the ones of $n_i + \lambda(h^*) + \delta$ in columns (3) and (4) respectively, reveals that these coefficients are identical. This suggests that $\lambda(h)$ is a constant. If this is the case, then the regressions in columns (3) and (4) do not provide any evidence that human capital indeed have a growth effect.

Finally, in none of the estimations reported, the effect of human capital on the growth rate of TFP (the coefficient of the change in human capital) is statistically significant. We conclude from all these results that we find no evidence in the data for the assumption that the level of human capital has a growth effect.

Table 2: Output per Worker Growth in a Model of Endogenous Growth

	Output per Worker Growth, 1960-2007					
	HW Replication		$n + \lambda(h^*) + \delta$		$n + \delta$ alone	
	(1)	(2)	(3)	(4)	(5)	(6)
Cognitive Skills level	1.38***	0.83***	1.20***	1.12***	0.74**	0.67*
	(0.19)	(0.27)	(0.23)	(0.29)	(0.30)	(0.36)
GDP per worker, 1960	-0.69**	-0.71***	-0.69***	-0.66***	-0.69***	-0.66***
	(0.29)	(0.19)	(0.19)	(0.20)	(0.19)	(0.20)
Investment Rate		0.09**	0.08**	0.08**	0.08**	0.08**
		(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
$n + \lambda + \delta$		-0.42**				
		(0.17)				
$n + \lambda(h^*) + \delta$			-0.45***	-0.46***		
			(0.17)	(0.17)		
HC change, first spec			0.07		0.07	
			(0.07)		(0.07)	
HC change, second spec				0.13		0.13
				(0.16)		(0.16)
$n + \delta$					-0.45***	-0.46***
					(0.17)	(0.17)
Adjusted-R^2	0.41	0.60	0.59	0.59	0.59	0.59
Observations	49	49	49	49	49	49

Notes: Standard error estimates are reported in parentheses; All regressions include a constant; *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level, all for two-sided hypothesis tests.

Note that the results obtained in our research differ from Sunde and Vischer (2015), who find evidence for the existence of both the level and growth effects. The difference lies, in our opinion, in the different measures of human capital: as mentioned above, Sunde and Vischer (2015) use a quantity measure of human capital, whereas we use a quality based measure of human capital. Indeed, it might be that each one of the measures captures a different aspect of human capital. The average schooling years may include also effects of the labor market on the incentives to pursue higher education, and thus this measure may be more vulnerable to reverse causality, as output growth rate may generate more incentives to private investment in higher education.[10] On the other hand, a quality based measure, which is based on the average achievements of school students in tests is not affected by their future decision whether to acquire higher education, and thus this measure may capture better the effect of investment in education on growth.[11]

4 Discussion

In this section we highlight the quantitative differences between our results, namely that knowledge has a short run effect on growth, and other results, which suggest that knowledge affects the long run growth. For the latter we use the simulation presented in HW. Figure 2 presents the impact of an educational reform with the two interpretations. The horizontal axis represents time from the beginning of the educational reform, while the vertical axis represents the ratio of GDP per capita after the reform, relative to a scenario of no reform, in which we assume that the economy grows at a constant rate of 1.5%.

In building the simulations, we follow the methodology of HW.[12] As a benchmark, we use the results of HW, who interpret the impact of an educational reform as affecting the long run growth. their simulation is depicted by the upper curve. Our simulation is based on the results above in the second column of Table 3, and they differ from the simulation of the results of HW in two aspects. First, the coefficient of the impact of such a reform on the change in the (short-run) growth rate is 0.84, rather than 2, as used by HW. Second, unlike HW, we assume that the growth rate of GDP per capita converges towards 1.5%. Furthermore, we assume that the convergence rate is 2%, as we calculate the convergence rate from Table 3.[13] This convergence rate is similar to the one reported in Barro and Sala-i Martin (1992) and Mankiw et al. (1992).

In order to distinguish between the effects of the two differences between the growth effect interpretation and the level effect interpretation, we add another simulation, which uses the coefficients of HW, but

[10]See, for example, Bils and Klenow (2000).

[11]Clearly, this measure is still not immune to endogeneity problems. However, HW employ several IV strategies to show that indeed the relation between quality based measures of human capital and growth is causal.

[12]For more information, see Chapter 7 in HW.

[13]Since the convergence rate is given by $\gamma = (n + \lambda + \delta)(1 - \alpha - \beta)$, we can compute the convergence rate from the results in the Table 3.

experiences convergence back to the previous steady state growth rate of 1.5%. Hence, this simulation does not partial out the effects of physical capital accumulation and population growth rate on human capital accumulation, but highlights the importance of understanding if human capital has a level effect or a growth effect.

During the first years following the reform, there are no big differences between the three simulations. However, as the second stage of the reform initiates, differences between the three simulations emerge, and the growth rate simulation curve becomes steeper than the two level effect simulations. Note that as the years go by, while the simulation of HW becomes steeper, the other two become flatter. This is due to the forces of convergence, which are absent in the case of a growth rate effect. Finally, HW calculate that 90 years after the reform, output per capita will be higher than its level without such a reform by about 26%. Our simulations do not support this viewpoint; they imply a much more moderate impact: after 90 years from the educational reform output per capita is only 4.76% higher than its level without a reform. Furthermore, the "level effect only" simulation predicts also a minor effect on output per capita 90 years of the reform of slightly over 10%.

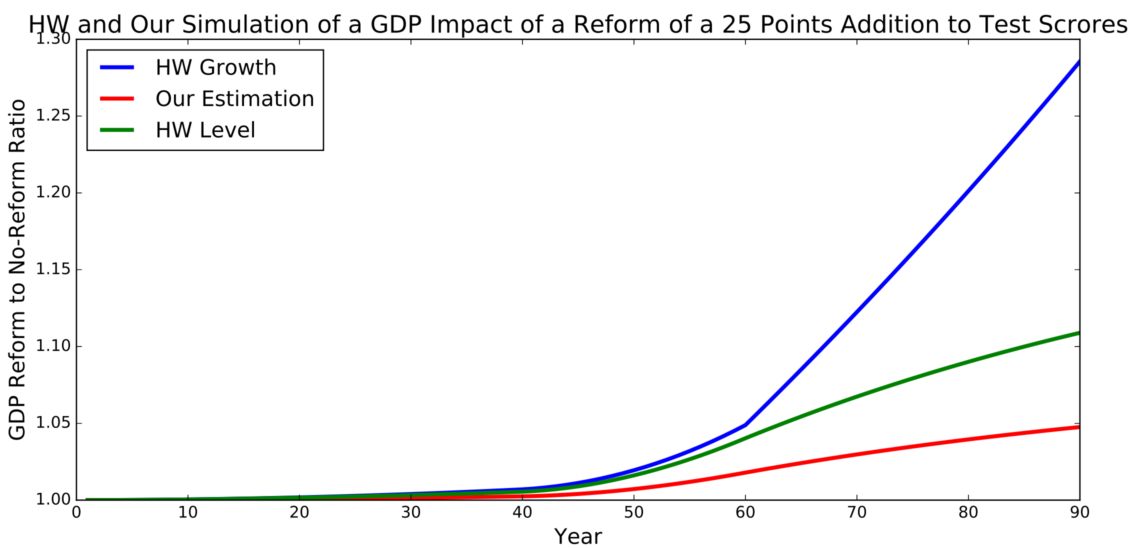

Figure 2: The ratio between GDP per capita after reform and without reform for our results and previous results.

5 Conclusions

The recent macroeconomic developments in the last decade have raised a concern on the future growth of different economies in the world, perhaps due to secular stagnation. A potential remedy, it was argued, is to invest in an educational reform, which will provide a more skilled labor force. This study asks whether such a reform has a growth effect or a level effect. To answer this question, we use a simple neoclassical growth model, in which human capital only has a level effect by assumption. We estimate our baseline model using data from PWT and HW, and show that the data support the level effect hypothesis. Furthermore, we show that the data do not fit an extended model in which we assume that the level of human capital has a growth effect.

We also use panel data based on 13 OECD countries to answer this question. The data reveal that the level of human capital among these countries had mixed dynamics, and in all of the countries the level of human capital is close to a certain level (of 5). This raises the question whether the level of human capital, as measured in terms of the average achievements of students in international tests such as the PISA tests, is bounded from above.

Using the panel data, we test a model that incorporates both the level and the growth effects. We show that the data support only the level effect, and not the growth effect. Furthermore, we show that the data do not support neither one of the theoretical justifications of a growth effect of absorbing or inventing new technologies. We conclude from this analysis that there is no evidence that the quality of human capital affects the long run growth rate of output per worker. As a result, we show quantitatively that the impact of human capital on output per worker is much smaller that under the assumption that it has a growth effect.

This study raises several questions for future research that have some policy implications. First, it highlights the possibility that human capital is bounded from above. If this is the case, policies that attempt to raise the average level of human capital by increasing the level of all the students might overshoot their target. Instead, it may be better to target education policies to reduce the dispersion of students' achievements in the international tests. This may increase the average level of human capital – and hence stimulate economic prosperity – by helping more the less abled students. This is also consistent with some of the causes raised of the decline in the participation rate of unskilled workers in the labor force.

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Appendix

A Robustness Checks for the Panel Data Analysis

Table A.1: Countries with Early Participation in International Tests & Average Years of Schooling, 1970, 1990

Country	Year of First Participation	No. of Times Participated	Avg. Years of Schooling, 1970	Avg. Years of Schooling, 1990
Australia	1964	8	11.44	11.97
Belgium	1964	7	9.5	11.57
United Kingdom	1964	9	8.48	9.05
Finland	1964	7	8.66	10.15
France	1964	6	7.41	10.03
Germany	1964	5	4.2	11.35
Israel	1964	5	10.39	12.31
Italy	1970	6	7.38	10.74
Japan	1964	9	10.72	12.41
Netherlands	1964	8	9.1	11.43
New Zealand	1970	7	13.13	12.55
Sweden	1964	6	9.9	12.16
United States	1964	9	12.53	12.89

Table A.2: Growth Rate vs. Level Effect Analysis Using a 3 Year Lag

	Annual GDP per Worker Growth					
	Growth Effect Alone		Level Effect Alone		Both Effects	
	(1)	(2)	(3)	(4)	(5)	(6)
HC level (3 year lag)	-0.03	-0.02			-0.00	0.00
	(0.03)	(0.03)			(0.03)	(0.03)
HC Growth (3 year lag)			1.85***	1.76***	1.80**	1.77**
			(0.59)	(0.54)	(0.75)	(0.71)
Capital Growth		0.09**		0.09**		0.09**
		(0.04)		(0.03)		(0.03)
Adjusted-R^2	0.02	0.08	0.11	0.17	0.10	0.17
Observations	104	104	104	104	104	104

Notes: Both levels and changes in cognitive skills are calculated with a 5 year lag. Standard error estimates clustered at the level of the country fixed effects are reported in parentheses; *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level, all for two-sided hypothesis tests; All regressions include a constat.

Table A.3: Growth Rate vs. Level Effect Analysis

	Annual GDP per Worker Growth					
	Growth Effect Alone		Level Effect Alone		Both Effects	
	(1)	(2)	(3)	(4)	(5)	(6)
HC Level (6 year lag)	-0.04**	-0.03*			-0.02	-0.01
	(0.01)	(0.02)			(0.01)	(0.01)
HC Growth (6 year lag)			1.18**	1.25***	0.83*	1.02**
			(0.40)	(0.41)	(0.41)	(0.39)
Capital Growth		0.09**		0.10***		0.10**
		(0.03)		(0.03)		(0.03)
Adjusted-R^2	0.06	0.12	0.07	0.16	0.08	0.16
Observations	104	104	104	104	104	104

Notes: Both levels and changes in cognitive skills are calculated with a 5 year lag. Standard error estimates clustered at the level of the country fixed effects are reported in parentheses; *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level, all for two-sided hypothesis tests; All regressions include a constat.

Table A.4: Growth Rate vs. Level Effect Analysis

	Annual GDP per Worker Growth					
	Growth Effect Alone		Level Effect Alone		Both Effects	
	(1)	(2)	(3)	(4)	(5)	(6)
HC Level (10 year lag)	-0.01	-0.02			-0.02	-0.02
	(0.01)	(0.01)			(0.01)	(0.01)
HC Growth (10 year lag)			-0.15	0.28	-0.30	0.13
			(0.32)	(0.37)	(0.36)	(0.40)
Capital Growth		0.07**		0.07*		0.07**
		(0.03)		(0.03)		(0.03)
Adjusted-R^2	-0.00	0.04	-0.01	0.03	-0.01	0.03
Observations	91	91	91	91	91	91

Notes: Both levels and changes in cognitive skills are calculated with a 5 year lag. Standard error estimates clustered at the level of the country fixed effects are reported in parentheses; *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level, all for two-sided hypothesis tests; All regressions include a constat.

Table A.5: Growth Rate vs. Level Effect Analysis: Random Effects Model

	Annual GDP per Worker Growth					
	Growth Effect Alone		Level Effect Alone		Both Effects	
	(1)	(2)	(3)	(4)	(5)	(6)
HC Level (5 year lag)	-0.01	-0.01			0.00	0.00
	(0.01)	(0.01)			(0.01)	(0.01)
HC Growth (5 year lag)			1.23***	1.32***	1.24***	1.36***
			(0.45)	(0.45)	(0.45)	(0.43)
Capital Growth		0.09**		0.10***		0.10***
		(0.04)		(0.03)		(0.04)
Adjusted-R^2						
Observations	104	104	104	104	104	104

Notes: Both levels and changes in cognitive skills are calculated with a 5 year lag. Standard error estimates clustered at the level of the country fixed effects are reported in parentheses; *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level, all for two-sided hypothesis tests; All regressions include a constat.

Table A.6: Growth Rate vs. Level Effect Analysis, FE Model

	Annual GDP per Worker Growth						
	Growth Effect Alone		Level Effect Alone		Both Effects		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
HC Level (5 year lag)	-0.04*	-0.03*			-0.03	-0.02	-0.02
	(0.02)	(0.02)			(0.02)	(0.02)	(0.02)
HC Growth (5 year lag)			1.22**	1.31***	0.93*	1.07**	1.07**
			(0.40)	(0.41)	(0.45)	(0.45)	(0.45)
Capital Growth		0.07*		0.09**		0.08*	0.08*
		(0.04)		(0.04)		(0.04)	(0.04)
Adjusted-R^2	0.06	0.10	0.07	0.13	0.09	0.14	0.14
Observations	117	117	117	117	117	117	117

Notes: Both levels and changes in cognitive skills are calculated with a 5 year lag. Standard error estimates clustered at the level of the country fixed effects are reported in parentheses; *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level, all for two-sided hypothesis tests; All regressions include a constat.

B Summary Statistics

B.1 Summary Statistics for Panel Data Analysis

Table B.1: Panel data summary statistics

Variable		Mean	Std. Dev.	Min.	Max.	Observations	
GDP per capita growth	overall	0.019	0.017	-0.23	0.076	N=	104
	between		0.007	0.006	0.029	n=	13
	within		0.016	-0.024	0.066	T=	8
Human capital	overall	5.01	0.16	4.607	5.509	N=	104
	between		0.124	4.836	5.273	n=	13
	within		0.108	4.68	5.359	T=	8
Human capital change	overall	0.001	0.004	-0.007	0.014	N=	104
	between		0.002	-0.002	0.004	n=	13
	within		0.004	-0.005	0.011	T=	8
Physical capital change	overall	-0.007	0.049	=0.122	0.106	N=	104
	between		0.011	-0.022	0.015	n=	13
	within		0.048	-0.108	0.1	T=	8

B.2 Variables Used in the Cross Section Analysis

Table B.2: Summary statistics

Variable	Mean	Std. Dev.	Min.	Max.	N
Output per Worker Growth Rate, 1960-2007	2.321	1.247	-0.721	5.165	51
Cognitive Skills Level	4.523	0.594	3.089	5.338	51
Initial Output per Worker, 1960	1.624	1.184	0.074	4.189	51
$n + \lambda + \delta$	7.694	0.967	6.338	10.262	51
Investment Rate	24.997	6.728	3.784	39.401	51