Knowledge and Growth in a Panel of Nations*

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Abstract

We investigate the impact of knowledge as measured by the average achievements of nations in the international students tests PISA and TIMSS on growth. We do so by using panel data on nations to estimate a standard production function and a measure of knowledge we construct. The result is that improving the average knowledge increases the level of GDP per worker, but not the growth rate. This is a different interpretation to the important contribution of Hanushek and Woessmann (2015), who found that these international tests are better measures than schooling years in estimating the impact of knowledge on GDP. The implication is that an educational reform that increases the average knowledge by one standard deviation will generate an increase in GDP per worker of 6% ninety years after the reform rather than the projected 26% by HW.

JEL Clasification: I25, O47, O15, I20

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1 Introduction

We investigate the impact of knowledge as measured by the average achievements of nations in PISA and TIMSS tests on economic growth. We do so by using panel data on nations to estimate a standard aggregate production function with our measures of human capital. We use data on the average growth rate of GDP per worker and physical capital in the period 1970-2010, and construct a measure of knowledge using the methodology of Hanushek and Woessmann (2015, HW). The panel enables us to distinguish between the short-run level effect, and the long-run growth impact of human capital on growth.

We find that the data strongly support that knowledge has a positive short-run effect, but not a long-run effect. This is a different interpretation to the results obtained by HW, who showed convincingly that the international tests are better measures than schooling years for estimating the effect of human capital on growth. However, we show in a simulation that according to our interpretation of a short-run effect, the effect of an educational reform that increases knowledge by one standard deviation are much more moderate: ninety years after such a reform, GDP per capita will exceed its no-reform counterpart by 6% using our interpretation, and not by 26%, as in the long-run growth interpretation reported by HW.

2 Knowledge and Growth Using Panel Data

We construct a simple model, which with panel data, unlike a cross section, enables us to estimate separately the impact of human capital on the level and growth rate of GDP. The model consists of a Cobb-Douglas production function, and an equation that connects the GDP growth rate to the level of knowledge through TFP.

Production in country i takes place using the following technology:

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

where $y_{i,t}$ is output per worker, $k_{i,t}$ is capital per worker, $A_{i,t}$ is TFP, all at country i in time t, $0 < \alpha, \beta, \alpha + \beta < 1$. TFP growth rate, $g_{A_{i,t}}$, depends on the level of knowledge, $h_{i,t}$:

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

where ϕ is a common constant for all countries. We assume that the relation between knowledge and TFP growth rate is linear and captured by χ. This equation is a reduced form of two economic forces that may generate a growth effect: knowledge may promote both inventing (Ha and Howitt, 2007) and absorbing (Nelson and Phelps, 1966; Rubinstein and Tsiddon, 2004) new technologies. Fully differentiating with respect to time, adding a country time-invariant fixed effect, Δ_i, and an error term, $\epsilon_{i,t}$, generates our estimated equation:

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

where $g_{x_{i,t}}$ is the growth rate of variable x in country i at period t. A long-run growth effect is captured by a positive value of χ, whereas a short-run level effect is captured by a positive value of β. Having a fixed effect is equivalent to allowing each country a different level of constant growth rate that is independent of the level of knowledge. Hence, the panel data provide us a simple specification to estimate the effect of knowledge on short-run and long-run growth.

2.1 Data

Our first contribution is in constructing the series of knowledge measure. We construct these series for a panel of thirteen advanced countries following the methodology of HW. This measure is based on the average achievements in international tests in math and sciences.[1] We use data only for countries that participated in these tests since the first tests (1964), or the second ones (1970).[2]

In constructing the series, we linearly interpolate the results for missing years, either because the tests did not take place in these years, or because the countries did not participate in them. Figure 1 presents the knowledge measure we construct. Clearly, the dynamics are mixed: some countries experience an increase, some a decline and others have no specific trend.

The tests are taken at the ages of 10, 14 and 17. Most of the exams are for the ages of 14 and 17 (76%).[3] Since we attempt to capture how variations in the test scores affected growth, we use the knowledge measure with a lag of 5 years, which means that the individuals who took the exams 5 years earlier are 15, 19 and 22 years old, respectively.[4]

We use data from PWT to compute real capital and labor stocks, and real output per worker for the

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

[2] Table A.1 presents the countries in our sample.

[3] 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.

[4] For robustness, we use other lags as well.

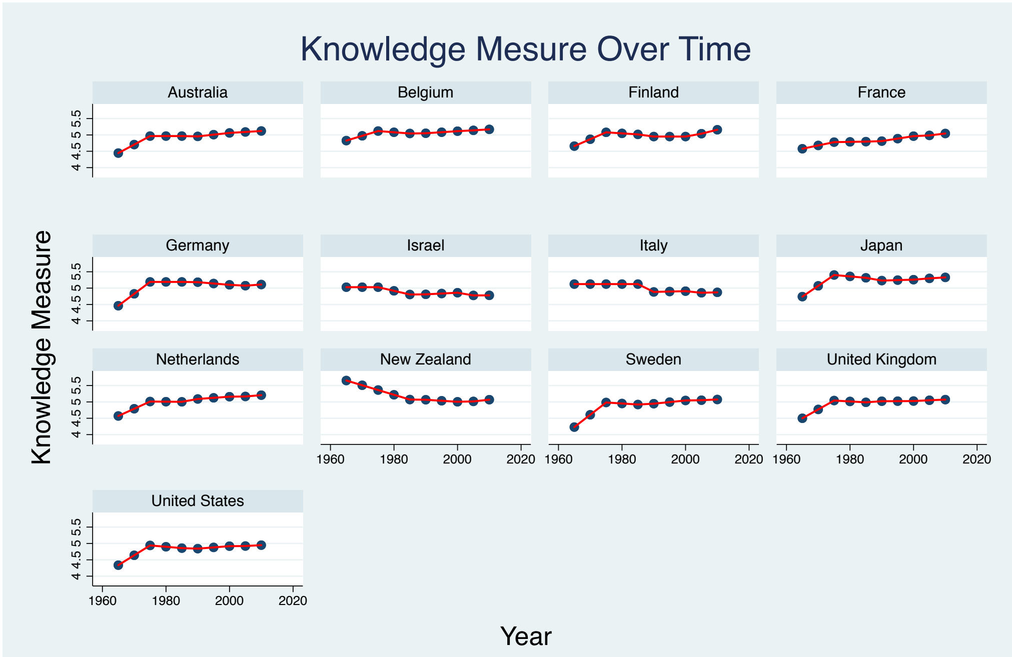

Figure 1: The knowledge measure for the countries in our sample

period 1970-2010. We divide this period to 5 year-long sub-periods. We calculate for each sub-period the average annual growth rate of output per worker and of capital per worker stock. This approach is very common in the literature.[5] [6]

2.2 Results

Table 1 presents our results. In columns (1) and (2) we test whether knowledge has a growth effect alone. The coefficient of the level of knowledge, χ, is negative and marginally statistically significant. In columns (3) and (4) we test whether knowledge has a level effect alone. The coefficient is positive and statistically significant at the 5% and 1% level, respectively.

In columns (5) and (6) we test simultaneously the growth and level effects, and only the level effect becomes statistically significant at the 10% and 5% respectively. In column (7) we add initial GDP per worker of the sub-period as a control, to overcome a possible problem that the initial level of knowledge captures the effect of initial output per worker and not its direct effect on growth. Yet our results are similar to the results in all other columns. We conclude from this table that the data support the existence of a short-run effect but not a long-run effect.

These results differ from previous papers (Sunde and Vischer, 2015) for several reasons:First, we use

[5] For a thorough survey of the literature using panel data in growth regressions, see Section VI.ii Durlauf et al. (2005).
[6] Table C.1 provides the summary statistics of all the variables used in the panel data analysis.

Table 1: The Effect of Knowledge on Growth

	Annual GDP per Worker Growth, 1970-2010						
	long-run effect		short-run effect		Both		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$(1-\alpha-\beta)\chi$	-0.04*	-0.03*			-0.03	-0.02	-0.02
	(0.02)	(0.02)			(0.02)	(0.02)	(0.02)
β			1.22**	1.31***	0.93*	1.07**	1.07**
			(0.40)	(0.41)	(0.45)	(0.45)	(0.45)
α		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

knowledge rather than schooling as a measure for human capital. This measure is better, as was shown convincingly by HW, but also because it suffers less from endogeneity problems, as it is not affected by labor market responses to changes in growth.[7] Second, estimating fixed effects in a panel enables us to eliminate any bias generated by country unobserved characteristics.

Robustness We run several robustness checks. First, in columns (1), (3) and (5) we omit physical capital investment, to overcome a potential endogeneity problem because physical capital is pro-cyclical. Second, Tables B.1 and B.2 show similar results to Table 1 when we use a lag of 3 and 6 years, respectively, instead of 5 years. Next, Table B.3 shows that very similar results are obtained by using a random effects model. Moreover, Table B.4 shows that our results do not change if we omit the Great Recession and stop our estimation in 2005.

Finally, in another study (Eckstein et al., 2018) we construct a neoclassical growth model, *á la* Mankiw et al. (1992), and add an assumption similar to (2). We linearize around the steady state and estimate the short-run and long-run effects in a cross-section of countries. We obtain close estimates to the results here: the long-run growth impact was not significantly different from zero and the short-run level impact was significant and close in value to what we report in Table 1. Thus, our results are also robust to a larger set of countries and a different empirical approach.

[7]In Eckstein et al. (2018) we replicate the result that HW measure of knowledge better measure empirically the impact of human capital on GDP than years of schooling.

3 Discussion

We simulate the quantitative differences between interpreting the effect of knowledge as a short-run or a long-run effect. We build the simulations by following the methodology of HW.[8] Figure 2 presents the impact of an educational reform, which increases knowledge by one standard deviation, with both 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%.

For the long-run growth interpretation we use the results of HW. Our simulation is based on the results above, and they differ from the simulation of HW in two aspects. First, the coefficient of the impact of such a reform on the change in the (short-run) growth is 1.07, rather than 2, as in HW. Second, the growth rate of GDP per capita converges towards 1.5% at a rate of 2%, consistent with Barro and Sala-i Martin (1992) and Mankiw et al. (1992). We add another simulation – the "short-run effect only" – that uses the coefficient of HW, but with the interpretation of a short-run effect. Hence, this simulation can be seen as an upper bound for the impact of such a reform according to the short-run interpretation.

Immediately after the reform, there are no big differences between the three simulations, but over time the differences increase: Ninety years after the reform, in the long-run interpretation, output per capita exceeds its no-reform level by about 26%. In our simulations we get a much more moderate impact of 6% only. Furthermore, using the "short-run effect only", the simulation predicts a long-run increase of only 10%.

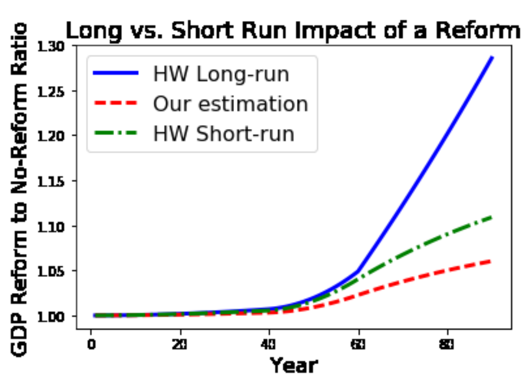

Figure 2: Growth vs. level effect of an educational reform

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

4 Conclusions

Most economic experts predict that GDP per capita growth is reduced to about 1 to 1.5 percent. An allegedly suggested remedy is to invest in an educational reform, which will increase human capital. We show that such a reform will affect the level of GDP per capita and growth in the short-run. This result is based on a standard estimated aggregate production function, using panel data of advanced economies on knowledge measured by international tests.

Future research that stems from our knowledge measure may indicate that human capital is bounded from above. If so, policies that attempt to raise the average level of knowledge by increasing the knowledge of all students might overshoot their target. Instead, targeting education policies to reduce the dispersion of students' achievements in the international tests may be better, as they may increase the average level of knowledge – and hence stimulate economic prosperity – by helping more the less abled students.

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Appendix

A The Countries in the Sample, and Their Participation in International Tests

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

B Robustness Checks for the Panel Data Analysis

Table B.1: Growth Rate vs. Level Effect Analysis Using a 3 Yead Lag

	Annual GDP per Worker Growth, 1970-2010					
	Growth Effect Alone		Level Effect Alone		Both Effects	
	(1)	(2)	(3)	(4)	(5)	(6)
$\chi(1-\alpha-\beta)$	-0.03	-0.03			-0.01	-0.01
	(0.03)	(0.03)			(0.03)	(0.03)
β			1.86***	1.80***	1.72**	1.66**
			(0.58)	(0.53)	(0.76)	(0.73)
α		0.08*		0.07*		0.07*
		(0.04)		(0.04)		(0.04)
Adjusted-R^2	0.03	0.08	0.10	0.15	0.10	0.14
Observations	117	117	117	117	117	117

Table B.2: Growth Rate vs. Level Effect Analysis Using a 6 Year Lag

	Annual GDP per Worker Growth, 1970-2010					
	Growth Effect Alone		Level Effect Alone		Both Effects	
	(1)	(2)	(3)	(4)	(5)	(6)
$\chi(1-\alpha-\beta)$	-0.04**	-0.04**			-0.03	-0.02
	(0.02)	(0.02)			(0.02)	(0.02)
β)			1.18***	1.25***	0.77*	0.90**
			(0.38)	(0.40)	(0.41)	(0.41)
α		0.07*		0.08**		0.08*
		(0.04)		(0.04)		(0.04)
Adjusted-R^2	0.07	0.11	0.07	0.13	0.09	0.14
Observations	117	117	117	117	117	117

Table B.3: Growth Rate vs. Level Effect Analysis: Random Effects Model

	Annual GDP per Worker Growth, 1970-2010						
	Growth Effect Alone		Level Effect Alone		Both Effects		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$\chi(1-\alpha-\beta)$	-0.01	-0.01			-0.00	0.00	-0.00
	(0.01)	(0.01)			(0.01)	(0.01)	(0.01)
β			1.22**	1.34***	1.26***	1.36***	0.96*
			(0.40)	(0.44)	(0.45)	(0.45)	(0.53)
α		0.08*		0.09**		0.09**	0.10***
		(0.04)		(0.04)		(0.04)	(0.04)
y_0							-0.01**
							(0.01)
Adjusted-R^2	0.07	0.08	0.07	0.14	0.08	0.14	0.21
Observations	117	117	117	117	117	117	117

Table B.4: Growth Rate vs. Level Effect Analysis Excluding The Great Recession

	Annual GDP per Worker Growth, 1970-2005						
	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)
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

C Summary Statistics

Table C.1: Summary Statistics

Variable		Mean	Std. Dev.	Min.	Max.	Observations	
GDP per capita growth	overall	0.019	0.017	-0.23	0.076	N=	117
	between		0.007	0.006	0.029	n=	13
	within		0.016	-0.024	0.066	T=	9
knowledge	overall	5.01	0.16	4.607	5.509	N=	117
	between		0.124	4.836	5.273	n=	13
	within		0.108	4.68	5.359	T=	9
knowledge change	overall	0.001	0.004	-0.007	0.014	N=	117
	between		0.002	-0.002	0.004	n=	13
	within		0.004	-0.005	0.011	T=	9
Physical capital change	overall	-0.007	0.049	=0.122	0.106	N=	117
	between		0.011	-0.022	0.015	n=	13
	within		0.048	-0.108	0.1	T=	9