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Will more higher education improve economic growth?

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Abstract: Calls for expanded university education are frequently based on arguments that more graduates will lead to faster growth. Empirical analysis does not, however, support this general proposition. Differences in cognitive skills—the knowledge capital of countries—can explain most of the differences in growth rates across countries, but just adding more years of schooling without increasing cognitive skills historically has had little systematic influence on growth.

Keywords: economic growth, higher education, cognitive skills, knowledge capital

JEL classification: O4, I2

I. Introduction

For the past quarter century, economists have shown renewed interest in long-run economic growth. The investigations of growth have evolved in both theoretical and empirical realms. And, while there are many competing views of the determinants of economic growth, virtually all of the growth studies see a key role for the human capital of the nation. This in turn motivates a variety of human capital policy initiatives throughout the world. This article assesses what has been learned about the human capital–growth linkages, with special reference to the measurement of human capital and to the role of college and university training.

Interest in long-run economic growth is appropriate. Differences in growth rates have a huge impact on the economic wellbeing of the nation—indeed much larger impacts than those of even the deepest recessions. For example, annual growth between 1960 and 2000 in GDP *per capita* in East Asia was 4.5 per cent, while it was less than 2 per cent in Latin America. As a result, the average East Asian was seven times better off at the end of this period, while the average Latin American was less than twice better off (Hanushek and Woessmann, 2015).

Around the world, countries have been pushing to expand education. This is particularly true at the tertiary level. The underlying view is clearly that improving the skills of the country will improve the economic position of both individuals and the nation. Higher education is seen as the source of innovation that will drive productivity

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improvements and thus economic growth. And, expansion of higher education is frequently put forth as an attractive government policy because of its potential impact on economic growth (e.g. Browne Report, 2010).

This article considers how human capital differences link to differences in growth rates. An important element of this is consideration of how to measure human capital. It then presents evidence on the impact of human capital differences across countries on economic growth.

II. Conceptual background

Modern growth theory has taken a variety of perspectives on what fundamentally determines economic growth. This field has gone in a variety of directions (Hanushek and Woessmann, 2008). It has stressed different underlying models of how resources and institutions affect growth. And, in the empirical analysis, there has been a quest to see how various factors from politics to geography enter into growth differences across countries. But for the purposes of this discussion it is important to note that virtually all developments maintain a key role for the skills of workers—i.e. for human capital.

In the late 1980s and early 1990s, macroeconomists turned to attempts to explain differences in growth rates around the world. A variety of different issues have consumed much of the theoretical growth analysis that developed with the resurgence of growth analysis. At the top of the list is whether growth should be modelled in the form of growth rates of income, or whether it should be modelled in terms of the level of income. The former is generally identified as endogenous growth models (e.g. Lucas, 1988; Romer, 1990), while the latter is typically thought of as a neoclassical growth model (e.g. Mankiw *et al.*, 1992).

The two different perspectives have significantly different implications for the long-run growth and income of an economy. In terms of human capital, the focus of this paper, an increase in human capital would raise the level of income but would not change the steady-state rate of growth in the neoclassical model. On the other hand, increased human capital in the endogenous growth model will lead to increases in the long-run growth rate. The theoretical distinctions have received a substantial amount of theoretical attention, although relatively little empirical work has attempted to provide evidence on the specific form (see Benhabib and Spiegel, 1994; Hanushek and Woessmann, 2008; Holmes, 2013).

Fundamentally, however, these theoretical issues appear much less important than how human capital should be measured. While there have been distinct differences in how skills are seen as affecting the economy, little of the broad theoretical work has focused on the measurement of relevant skills. We argue that measurement issues—particularly as we consider the role of higher education—become central to any empirical considerations of human capital and growth.

The historical development of human capital modelling and measurement provides important background for understanding the development of modern empirical growth analysis. The importance of skills of the workforce entered into some of the earliest economic analysis, and the history helps to explain a number of the issues that are pertinent to today's analysis of economic growth. Sir William Petty (1676 [1899]), an early public finance economist, assessed the economics of war and of immigration in terms of skills (and wages) of individuals. Adam Smith (1776[1979]) incorporated the ideas of different skills of workers having pay-offs in the labour market in *The Wealth of Nations*, although other ideas about specialization of labour came to dominate his ideas about human capital. Alfred Marshall (1898), however, effectively froze any development because he thought the concept of human capital lacked empirical usefulness, in part because of the severe measurement issues involved.

After languishing for over a half century, the concept of human capital was resurrected by the systematic and influential work of Theodore Schultz (1961), Gary Becker (1964), and Jacob Mincer (1970, 1974), among others. Their work spawned a rapid growth in both the theoretical and empirical application of the concept of human capital to a wide range of issues.

The contributions of Jacob Mincer were especially important in setting the course of future empirical work. A central critique of early human capital ideas was that human capital was inherently an elusive concept that lacked any satisfactory measurement. Arguing that differences in earnings, for example, were caused by skill or human capital differences suggested that measurement of human capital could come from observed wage differences—an entirely tautological statement. Mincer, in a simple but elegant model, pursued an individual investment model. He argued that a primary motivation for schooling was developing the general skills of individuals and, therefore, individuals could be thought of as going to school to invest in skills that ultimately paid off in the labour market. From this, it made sense to measure human capital by the amount of schooling completed by individuals. Mincer followed this with statistical analysis of how wage differentials could be significantly explained by school attainment and, in a more nuanced form, by on-the-job training investments (Mincer, 1974). This insight was widely accepted and has dictated the empirical approach of a vast majority of empirical analyses in labour economics through today. Importantly, school attainment was something that was frequently measured in censuses and surveys, supporting empirical analysis. For example, the Mincer earnings function has become the generic model of wage determination and has been replicated in over 100 separate countries (Psacharopoulos and Patrinos, 2004).

III. Growth modelling

Owing in part to the power of the analysis of Mincer *and* in part to the ready availability of data, schooling became virtually synonymous with the measurement of human capital. Thus, as growth modelling looked for a measure of human capital, it was natural to think of measures of school attainment.

As the labour market perspective was carried over to growth modelling, the early international growth modelling efforts, nonetheless, still confronted severe data issues. Measures of school attainment that were comparable across countries did not exist during the initial modelling efforts, although readily available measures of enrolment rates in schools across countries could be related to changes in school attainment over time. This general data shortcoming was remedied by the early data construction of Barro and Lee (1993) that provided the necessary data on school attainment, and the international growth work could proceed to look at the implications of human capital in earnest. There were some concerns about accuracy of the data series, leading to alternative developments (Cohen and Soto, 2007) and to further refinements by Barro and Lee (2010), but the availability of a suitable measure of human capital has seemed clear over the past two decades. (See some lingering measurement concerns, however, in Krueger and Lindahl (2001).)

With this human capital history, we can return to growth modelling itself. A generic form of an empirical growth model is:

$$growth = \alpha_1 human\ capital + \alpha_2 other\ \ factors + \varepsilon. \tag{1}$$

By this, a country's growth rate can be considered as a function of workers' skills along with other systemic factors, including economic institutions and initial levels of income and technology. And, here, in the initial growth work that was consistent with the prior development, human capital was simply measured by school attainment, or S. Thus, equation (1) could be estimated by substituting S for human capital and estimating the growth relationship directly. (Note that modelling growth rates as a function of the level of human capital is the general form of endogenous growth models, while modelling growth rates as a function of changes in human capital over time is the general form of neoclassical growth models. These differences are discussed below in the context of the empirical analysis.)

Using school attainment as a measure of human capital has been almost standard and provokes little mention. Indeed, schooling is often used essentially as a synonym for human capital. But in an international setting this presents huge difficulties. In comparing human capital across countries, it is necessary to assume that the schools across diverse countries are imparting the same amount of learning per year in all countries. In other words, a year of school in Japan has the same value in terms of skills as a year of school in South Africa. In general, this is implausible.

A second problem with this measurement of human capital is that it presumes schooling is the only source of human capital and skills. Yet, a variety of policies promoted by national governments and by international development agencies emphasize not only school quality but also the role of families and the importance of improving health and nutrition as a way of developing human capital. These factors are typically considered in the very large literature on education production functions (Hanushek, 2002), where it is common to focus on models such as:

$$human\ capital = \beta_1 schools + \beta_2 families + \beta_3 ability + \beta_4 health + \beta_5 other\ factors + \upsilon. \tag{2}$$

In light of equation (2), it makes little sense to estimate growth models that simply substitute school attainment into equation (1). Unless families, health, and school quality are unrelated to school attainment, this approach will yield biased estimates of how human capital affects growth. Indeed, this observation is consistent with the early findings about the sensitivity of empirical growth models to model specification and the range of alternative factors considered (Levine and Renelt, 1992).

IV. Knowledge capital and growth

An alternative approach is to measure human capital directly. An obvious choice for this is to use standardized achievement tests of students as measuring the relevant skills of individuals. Student achievement is both a primary putative output of schools and the measure of human capital used in substantial parts of the education production function literature. This proves to be a very productive way to proceed in considering empirical growth models.

The analysis of cross-country skill differences has been made possible by the development of international assessments of mathematics and science (see the description in Hanushek and Woessmann (2011*a*)). These assessments, conducted over the past half century, can be used to construct a common metric for measuring cognitive skill differences across countries. We label this aggregate measure of a country's skills *knowledge capital*, in order to distinguish it from school attainment. This metric provides a method for testing directly the fundamental role of human capital in growth, as found in equation (1). This approach to modelling growth as a function of international assessments of skill differences was introduced in Hanushek and Kimko (2000) and has been extended in Hanushek and Woessmann (2007, 2015).

The fundamental idea is that skills as measured by achievement, A, can be used as a direct indicator of the knowledge capital of a country in equation (1). And, as described in equation (2), schooling is just one component of the skills of individuals in different countries. Note, however, that the test scores at a given age or point in time are interpreted as an index of the skills of individuals. It is not the specifically tested information that is important, but instead the indication of relative learning levels that can be applied across the schooling spectrum.

The impact of alternative measures of human capital can be seen in the basic long-run growth models displayed in Table 1. The table presents simple models of long-run growth over the period 1960–2000 for the set of 50 countries with required data on growth, school attainment, and achievement. Growth is measured by increases in real GDP *per capita*. The inclusion of initial income levels for countries is quite standard in this literature. The typical interpretation is that this permits convergence of incomes, reflecting the fact that countries starting behind can grow rapidly simply by copying the

Table 1: Alternative estimates of long-run growth models with knowledge capital

	(1)	(2)	(3)
Cognitive skills (A)		2.015	1.980
		(10.68)	*(9.12)*
Years of schooling 1960 (S)	0.369		0.026
	(3.23)		*(0.34)*
GDP *per capita* 1960	–0.379	–0.287	–0.302
	(4.24)	*(9.15)*	*(5.54)*
No. of countries	50	50	50
R^2 (adj.)	0.252	0.733	0.728

Notes: Dependent variable: average annual growth rate in GDP *per capita*, 1960–2000. Regressions include a constant. *t*-statistics in parentheses.
Source: Hanushek and Woessmann (2012).

existing technologies in other countries, while more advanced countries must develop new technologies (see Hanushek and Woessmann, 2012).

The estimates in column (1), which mirror the most common historical approach, rely just on years of schooling to measure human capital and show a significant relationship between school attainment and growth. It explains one-quarter of the international variation in growth rates. Much of the early empirical analysis was then designed to go beyond this and to explain a portion of the remaining variation in growth.

The second column substitutes the direct measure of skills derived from international mathematics and science tests for school attainment. Not only is there a significant relationship of knowledge capital with growth but also this simple model now explains three-quarters of the variance in growth rates. The final column includes both measures of human capital, i.e. knowledge capital and school attainment. Importantly, once direct assessments of skills are included, school attainment is not significantly related to growth, and the coefficient on school attainment is very close to zero.

These models of course do not say that schooling is worthless. They do say, however, that it is the portion of schooling directly related to skills that has a significant and consistent impact on cross-country differences in growth. The importance of skills and conversely the unimportance of just extending schooling that does not produce higher levels of skills has a direct bearing on human capital policies for both developed and developing countries.

Two aspects of these estimates are relevant for policy consideration. First, it is the case that countries with higher skill levels also invest more in years of schooling. This holds for both developed and developing countries. Second, and very important for thinking about these results, education is a cumulative process, and later learning always builds on earlier learning. James Heckman and his colleagues describe it as dynamic complementarities, such that 'skill begets skill' (Cunha *et al.*, 2006; Cunha and Heckman, 2007). The idea is very simple—schools not only build upon early learning, but the path of performance (i.e. skills) follows a multiplicative function. We return to these issues below.

The estimated impacts of knowledge capital on growth in Table 1 are very large. The cognitive skills measure is scaled in standard deviations of achievement. The results imply that a one standard deviation difference in performance equates to 2 per cent per year in average annual growth of GDP *per capita*. This difference in growth rates is close to the observed differences between East Asia and Latin America mentioned earlier.

Finally, estimating models in this form with a convergence term permits some assessment of the differences between the endogenous and neoclassical growth models, although full discussion is beyond this essay. In the neoclassical model, the cumulative increases in GDP that emanate from increased human capital are approximately one-third less over a 75-year period than those from the endogenous growth model, but they are still very substantial; see Hanushek and Woessmann (2011*b*). It remains difficult, however, to distinguish between the two models with existing data, because insufficient data about changes in knowledge capital over time are not available and because the impacts on growth are seen only in the distant future (see Holmes, 2013).

V. Issues of causation

Before extending this discussion of knowledge capital and growth, it is important to touch on one of the key features of it. An analytical concern is that the growth relationships discussed do not measure causal influences but instead reflect reverse causation, omitted variables, cultural differences, and the like. This concern has been central to the interpretation of much of the prior work in empirical growth analysis, and, indeed, some have rejected the entire body of work on the basis of concerns about causation. The analysis of these issues goes beyond what can be fully presented here (see Hanushek and Woessmann, 2012, 2015), but it is possible to give some sense of the issues and their resolution.

An obvious issue is that countries that grow faster have added resources that can be invested in schools, so that growth could cause higher scores. However, the lack of relationship across countries in the amount spent on schools and the observed test scores that has been generally found provides evidence against this (Hanushek and Woessmann, 2011*a*). Moreover, a variety of sensitivity analyses show the stability of these results when the estimated models come from varying country and time samples, varying specific measures of cognitive skills, and alternative other factors that might affect growth (Hanushek and Woessmann, 2012).

None of the set of tests of causation is completely conclusive, but it is possible to address the main concerns with a series of alternative analyses. To rule out simple reverse causation, Hanushek and Woessmann (2012) separate the timing of the analysis by estimating the effect of scores on tests conducted until the early 1980s on economic growth in 1980–2000, finding an even larger effect of knowledge capital in the later period. Additional analysis considers the earnings of immigrants to the US and our measures of cognitive skills in order to address the idea that cognitive skills are unimportant and that knowledge capital is just correlated with other causal factors. This analysis finds that the international test scores for their home country significantly explain US earnings but only for those educated in their home country and not for those educated in the US. This finding addresses possible concerns that countries with well-functioning economies also have good schools, leading to the observed correlations without causal impacts. It also addresses simple issues of cultural differences, because immigrants from the same country (but educated differently) are directly compared.

Another analysis takes out level considerations and shows that changes in test scores over time are systematically related to changes in growth rates over time. In other words, it implicitly holds the country constant, while looking at whether changing scores have the impact on changing growth rates that is predicted in Table 1.

Finally, it is possible to exploit institutional features of school systems as instrumental variables for test performance, thereby employing only that part of the variation in test outcomes emanating from such country differences as use of central examinations, decentralized decision-making, and the share of privately operated schools. These results support a causal interpretation and also suggest that schooling can be a policy instrument contributing to economic outcomes.

Again, while there could still possibly be concerns about issues of causation, the tests that have been done provide a *prima facie* case that improving cognitive skills and the knowledge capital of a country can be expected to improve economic growth. Each of the analyses points to the plausibility of a causal interpretation of the basic models.

But, even if the true causal impact of cognitive skills is less than suggested in Table 1, the overall finding of the importance of such skills is unlikely to be overturned.

VI. High skills, higher education, and growth

With this overview of empirical growth and the importance of knowledge capital, it is possible to delve deeper into the growth relationships. A key question is whether the linear models of Table 1 hold across different countries, across different skill distributions, and across different levels of school attainment. It is possible to approach these issues from several vantage points.

The issue is especially relevant for consideration of higher education. Historically, without any direct measures of skills such as our knowledge capital, schooling was taken as synonymous with human capital. Moreover, college was taken as a clear indicator of high skills of the type needed for innovation, making more college- and university-educated workers an important engine of growth. Thus, by these presumptions, expanded higher education may have a different impact on growth than earlier education. Additionally, and reinforcing this idea, the achievement data used previously is all measured prior to attendance in higher education, so that time in tertiary education may make up for lower scores (measured earlier).

In order to address the role of higher education along with a series of other possible issues, we consider a series of alternative specifications that elaborate on the prior estimates. To begin with, simply because of the different technologies that are being employed, the overall relationship between skills and growth may be more important to OECD (Organization for Economic Cooperation and Development) countries than in developing countries. Moreover, given the more basic and less technologically advanced technologies in developing countries, there may a stronger demand for basic skills and a weaker demand for high-level skills in developing countries.

These issues are consistent with some of the developments of theoretical growth models. One major thread of theoretical growth models is the importance of developing new ideas, which in turn affects improvements in productivity. The idea formulation suggests a greater importance of human capital in developed countries and perhaps added demand there for higher education—a major source of ideas. A variety of models such as those of Vandenbussche *et al.* (2006) or Aghion and Howitt (2009) focus directly on movements of the technological frontier, suggesting that tertiary education is particularly important for countries near the technological frontier where growth requires new inventions and innovations.

Table 2 expands on the modelling of long-run growth contained in Table 1. The first column provides a direct test about whether cognitive skills are more important in developed as opposed to developing countries. The point estimate on the interaction of cognitive skills and OECD countries is slightly negative—indicating that skills are *more* important in developing countries. Nonetheless, the differences are not statistically significant.

In another variant, the previous growth models uniformly considered just country-average skills. But, particularly in developing countries there is often a large variance in performance with some very high performers and many very low performers (see

Table 2: Extensions of basic models of long-run growth

	(1)	(2)	(3)	(4)
Cognitive skills	1.978			1.923
	(7.98)			*(9.12)*
Share of students reaching basic literacy		2.644	2.146	
		(3.51)	*(2.58)*	
Share of top-performing students		12.602	16.536	
		(4.35)	*(4.90)*	
OECD	0.859		–0.659	
	(0.32)		*(0.44)*	
OECD x cognitive skills	–0.203			
	(0.36)			
OECD x basic literacy			2.074	
			(0.94)	
OECD x top-performing			–13.422	
			(2.08)	
Years of non-tertiary schooling				0.076
				(0.94)
Years of tertiary schooling				0.198
				(0.16)
Initial years of schooling	0.080	0.066	0.070	
	(1.07)	*(0.87)*	*(0.94)*	
Initial GDP *per capita*	–0.313	–0.305	–0.317	–0.325
	(5.61)	*(6.43)*	*(5.63)*	*(6.81)*
No. of countries	50	50	50	50
F (OECD and interaction)	0.10		1.62	
R^2 (adj.)	0.723	0.724	0.734	0.728

Notes: Dependent variable: average annual growth rate in GDP *per capita*, 1960–2000. Regressions include a constant. *t*-statistics in parentheses. Basic literacy is a score of 400 or above on the PISA scale, which is one standard deviation below the OECD mean. Top-performing is a score of 600 or above on the PISA scale, which is one standard deviation above the OECD mean.
Source: Hanushek and Woessmann (2015).

Hanushek and Woessmann, 2008). In fact, given resource constraints, both developed and developing countries frequently feel it is necessary to make decisions about whether to spread resources broadly across their population to provide as great a coverage as possible for its schools or to concentrate resources on those students identified as the best.

To judge the efficacy of these alternative strategies, it is possible to measure the proportion of high performers and the proportion with basic literacy as assessed by the cognitive skills tests. (Basic literacy for this purpose is a score one standard deviation below the OECD mean. Top-performing is a score one standard deviation above the OECD mean.) Column (2) of Table 2 provides an estimate of the impact on long-run growth of having a broad basic education versus having more high achievers. Importantly, both broad basic skills ('education for all' in terms of achievement) and high achievers have a separate and statistically significant impact on long-term growth. Interestingly, column (3), which allows for different impacts in the OECD and non-OECD countries, indicates that high performers are more important for growth in developing countries than in the OECD countries. This somewhat surprising result suggests the importance of high skills for adapting more advanced technologies to developing countries, particularly when the overall proportion of high performers is small.

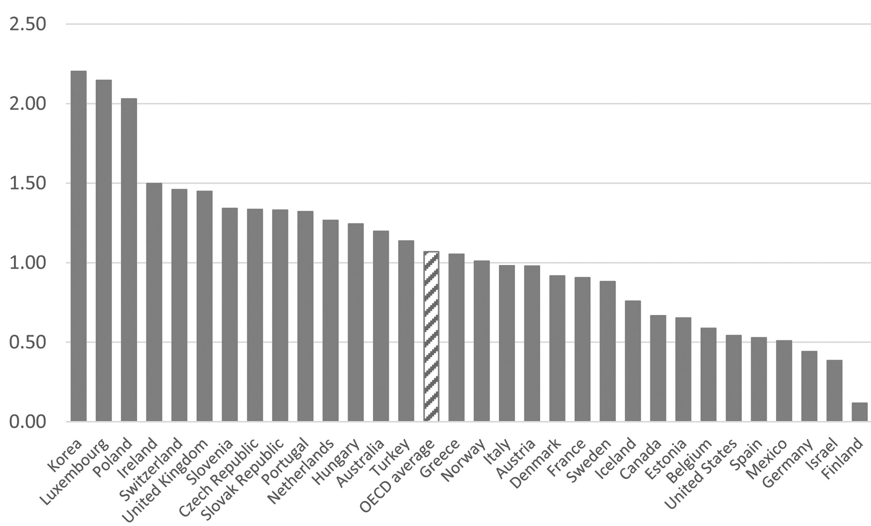
These estimates of the varied impact of basic literacy and of top-performers, while suggestive, do not answer the overall policy question about where to invest resources. To address that question, it is necessary to know more about the relative costs of producing more basic and more high-performers. In fact, no analysis is available to describe the costs of producing varying amounts of skills.

We now return to the overall question about the role of higher education. A variety of countries have contemplated expanding their systems of higher education, both in terms of broad-access institutions (generally 2-year colleges) and higher-level institutions. In fact, Figure 1 shows the annual increase in the percentage of the population aged 25–34 with tertiary schooling over 2000–14 across OECD countries. The OECD average has increased by more than 1 percentage point per year for the last decade and a half. Korea, Luxemburg, and Poland have each expanded at a rate above 2 percentage points per year. This substantial increase reflects a common view that expanding higher education is a way to promote better economic outcomes.

Column (4) of Table 2 provides estimates of the separate impact of tertiary education on long-run growth. Consistent with the prior analysis, once the level of cognitive skills is considered, years of tertiary schooling in the population—like years of earlier schooling—has no independent effect on growth. (Holmes (2013) also shows that neither the level nor the change in tertiary schooling for a larger group of countries is positively related to growth even in the absence of knowledge capital measures.)

This result about tertiary education is slightly different for just OECD countries. In the presence of knowledge capital, years of tertiary schooling has a positive effect (significant at the 10 per cent level) for the 24 OECD countries in the sample (not shown). But this effect is entirely driven by the United States. If the US is dropped, the estimated impact of higher education falls and is statistically insignificant.

Figure 1: Annual percentage increase in tertiary education in OECD countries: 25–34-year-olds, 2000–14



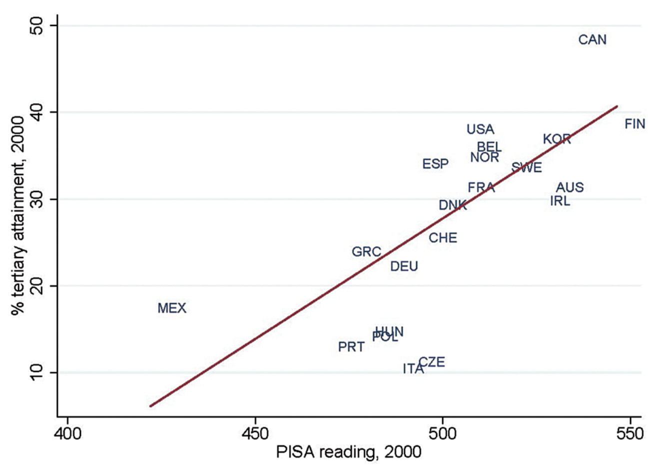
Source: OECD (2015).

How should this apparent impact in the US be considered? It turns out that the US has grown faster than would be predicted by the basic growth models with knowledge capital (i.e. the US has a positive residual in the regression models of Table 1). The candidates for factors to explain this are several. First, the US has had generally the strongest economic institutions for growth—free and open labour and capital markets, limited government regulation, secure property rights, openness to trade. These institutions could explain the added growth. Second, the US has historically had more years of schooling than the rest of the world, suggesting that the quantity of schooling can make up for lower cognitive skills. However, the Holmes (2013) analysis that includes the expansion of schooling in other countries over recent decades does not support this interpretation. Third, the US is generally regarded as having the best universities, and this quality may make the difference. And, fourth, the US has been able to attract highly skilled immigrants. The latter argument is quite consistent with the previous growth results, because a measure of achievement of US students would not capture the skills of the immigrants. Hanson and Slaughter (2015) find that 55 per cent of PhD workers in the US in STEM fields (science, technology, engineering and mathematics) were foreign born. In other words, the US is able to bring in highly skilled individuals, who frequently get PhDs at US universities and then remain to work in the US. In short, it is difficult to attribute the faster than expected growth in the US just to the impact of higher education in the US.

These overall results for cross-country growth are quite dramatic. In the absence of improved knowledge capital, the strong push toward more tertiary schooling does not look like it will consistently show up in added economic growth.

To get some idea of the patterns of tertiary schooling and knowledge capital, Figure 2 plots higher education percentages for the 25–34-year-old population in 2000 against the level of PISA (Programme for International Student Assessment) reading scores in 2000. The figure shows the strong positive relationship between achievement levels and overall tertiary schooling for the young age group. But the skills that can be expected at the end of university in different countries will almost certainly differ strongly. Unless the value-added of colleges is inversely related to incoming skills (measured by these

Figure 2: Tertiary schooling by PISA scores, 2000



PISA test scores), the education in college is likely to follow the earlier differences in skills. Indeed, the gap would expand under the Heckman hypothesis of dynamic complementarity, although it would remain constant if value-added of college were constant and linear across countries. In other words, the skills of college graduates are endogenous and depend directly on skills at entry to college.

But the expansion of tertiary schooling since 2000 shows a somewhat different picture than that in Figure 2. Figure 3 plots the increase in tertiary schooling for the young cohort against the PISA performance levels in 2000. When looking at the expansion of higher education, there is no relationship with PISA 2000 scores. This suggests some potential for disappointment, since the prior growth analyses indicated that simply expanding tertiary schooling at the current quality levels is unlikely to spur new long-run growth.

As an offset, it could be the case that countries that have expanded their tertiary schooling have also moved to increase the cognitive skills of their youth. To describe the patterns, Figure 4 plots the improvements in PISA reading scores between 2000 and 2012 against the expansion rate of tertiary schooling. There is a positive relationship between the two schooling changes (r = 0.3) but this is statistically insignificant in this cross-country comparison. The expansion of knowledge capital does not appear to be a generally important element of the expansion of higher education.

These results suggest the possibility that a number of countries are following a misplaced investment strategy if their goal is to improve economic growth. They might be better off spending on the margin to improve basic skills in earlier schooling (where they can be subsequently built upon in university) than simply expanding colleges and universities with existing basic skills.

The policy discussion often appears to assume that the skills of college graduates are exogenous and fixed, implying that expansion of higher education will lead to proportionate increases in knowledge capital. Indeed, debates about standards for primary and secondary education in the US have called for making students 'college-ready', implicitly attempting to take notions of the admissions standards for colleges and universities and to use them to define what students should know at the end of secondary

Figure 3: Tertiary expansion by PISA scores, 2000

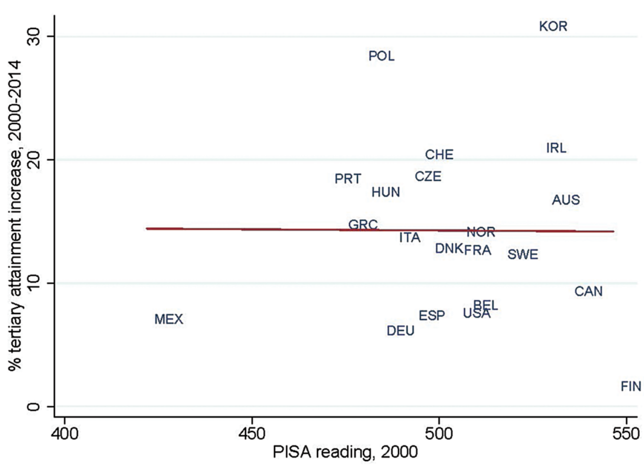


Figure 4: Tertiary expansion by PISA improvements

schooling. But the marginal skills of admitted students are clearly below the average skills, and expansion of students attending tertiary education is likely to lower the skills of the average graduate. In other words, the output of higher education should be thought of as endogenous rather than the more common view that it is exogenous to admissions.

VII. Conclusions

Higher education has yielded substantial rewards to individuals in terms of individual earnings. Partly for this reason, but perhaps more for the potential impact on productivity and economic growth, governments have pushed for the expansion of higher education. This broad movement toward expanding schooling must confront the record of economic growth.

Growth is highly related to the knowledge capital of the country. Moreover, once knowledge capital as measured by international mathematics and science tests is taken into account, school attainment (or years of schooling) *per se* is unrelated to economic growth. In this, adding years of university provide no greater impact than added years of earlier schooling.

To be sure, one does not get electrical engineers and computer scientists without investing in higher education. But, one gets better engineers if universities start with students with stronger skills. And, looking across countries, the better engineers produced in countries with greater knowledge capital appear to have a distinct impact on growth differences.

Part of this lack of impact of attainment of higher education in our growth models is probably that there are no good measures of university quality, so that very different outcomes are treated the same. But the achievement levels of students at an earlier age appears to provide an index of the aggregate skills of the students at the end of their schooling when each level of schooling builds on earlier knowledge.

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