
Education and Economic Growth

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Summary

Economic growth determines the future well-being of society, but finding ways to influence it has eluded many nations. Empirical analysis of differences in growth rates reaches a simple conclusion: long-run growth in gross domestic product (GDP) is largely determined by the skills of a nation's population. Moreover, the relevant skills can be readily gauged by standardized tests of cognitive achievement. Over the period 1960–2000, three-quarters of the variation in growth of GDP per capita across countries can be accounted for by international measures of math and science skills. The relationship between aggregate cognitive skills, called the knowledge capital of a nation, and the long-run growth rate is extraordinarily strong.

There are natural questions about whether the knowledge capital–growth relationship is causal. While it is impossible to provide conclusive proof of causality, the existing evidence makes a strong *prima facie* case that changing the skills of the population will lead to higher growth rates.

If future GDP is projected based on the historical growth relationship, the results indicate that modest efforts to bring all students to minimal levels will produce huge economic gains. Improvements in the quality of schools have strong long-term benefits.

The best way to improve the quality of schools is unclear from existing research. On the other hand, a number of developed and developing countries have shown that improvement is possible.

Keywords: economic growth, education, cognitive skills, knowledge capital, human capital, economic development, international tests of math and science

Subjects: Economic Development, Labor and Demographic Economics, Macroeconomics and Monetary Economics

Introduction

Economic growth determines the well-being of society over time, but the source of differences in growth rates of countries are continuously debated. Intensive analysis over the past three decades of differences in growth has, however, produced a much clearer picture of the underlying causes. In simplest terms, long-term economic growth is largely determined by the skills of the population in each country. In turn, the relevant skills can be gauged by international assessments of mathematics and science achievement.

The extensive theoretical and empirical analysis of economic growth, almost regardless of its overall focus, includes human capital as a central element. This partly incorporates insights from the work of Theodore Schultz (1961), Edward Denison (1962), Gary Becker (1964), Jacob Mincer (1974), and others since the late 1950s that human capital is important for individual productivity and earnings. Building on that, innovation and productivity improvements, while possibly differing in the underlying details, are seen as being fundamentally guided by underlying invention, and invention flows from the knowledge and skills of the population.

Empirical testing of different determinants of differences in economic growth across countries began in earnest around 1990. From the outset, attention was focused on the role of education and human capital in determining growth, although these early modeling efforts went in a variety of directions in looking for consistent explanations of growth differences. Initial enthusiasm for this empirical growth work faded, however, when the estimated models appeared to be very sensitive to the set of factors considered, to the estimation approach, and to a variety of measurement issues.

Many of these problems appear to be closely related to the measurement of human capital and the skills of a country's population. The evidence surveyed in this article highlights the importance of measuring human capital in ways that are consistent with general analyses of the educational production process. When direct skill measures for a country's population are introduced, the pattern of long-run growth differences across countries becomes much clearer.

Measurement issues are compounded by confusion in the terminology used. The early writers coined the term *human capital* in parallel to physical capital to correspond to skills in which individuals invested and from which they received economic value. As empirical analysis progressed, this concept was most frequently measured by years of school attainment. Subsequently, human capital became virtually synonymous with school attainment—even as research demonstrated that school attainment was a flawed measure of the relevant labor market skills of the individual. To distinguish between skill measures based on cognitive test scores and those based on school attainment, the term *knowledge capital* is used here to refer to measured cognitive skills as opposed to school attainment (Hanushek & Woessmann, 2015a).

A Conceptual Framework for Knowledge and Growth

Economists have devoted enormous time and effort to developing and understanding alternative mechanisms that might underlie the growth of nations, writing entire books on models of economic growth and their implications (see, e.g., Acemoglu, 2009; Aghion & Howitt, 1998, 2009; Barro & Sala-i-Martin, 2004; Jones & Vollrath, 2013). Theoretical models of economic growth have emphasized different mechanisms through which education affects economic growth. Three general classes of theoretical models have been applied, and each has received support from the data. At the same time, it has been difficult to compare the alternative models empirically and to choose among them based on the economic growth data because their predictions tend to differ only in the very long run.¹

The most straightforward modeling follows a standard aggregate production function where the output of the macro economy is a direct function of the capital and labor in the economy. The basic growth model of Solow (1956) began with such a description and then added technological change to trace the movement of the economy over time. The determinants of this technological change, although central to understanding economic growth, were not an integral part of that analysis. Augmented neoclassical growth theories developed by Mankiw et al. (1992) extend this analysis to incorporate human capital, stressing the role of education as a factor of production. Education can be accumulated, increasing the human capital of the labor force and thus the steady-state level of aggregate income. The human capital component of growth comes through accumulation of more education. With added education, the economy moves from one steady-state level to another, but, once at the new level, education exerts no further influence on growth in such a model. The common approach to estimating this model focuses on the level of income and relates *changes* in gross domestic product (GDP) per worker to *changes* in education (and in capital). This view implies a fairly limited role of human capital because there are natural constraints on the amount of schooling in which a society will invest. It also fails to explain patterns of education expansion and growth for many developing countries (Pritchett, 2006).

A very different view comes from the endogenous growth literature that has developed over the past quarter century, which partly builds on the early insight of Schumpeter (1912/2006) that growth is ultimately driven by innovation. In this work, several researchers—importantly, Lucas (1988), Romer (1990), and Aghion and Howitt (1998)—stress the role of human capital in increasing the innovative capacity of the economy through developing new ideas and new technologies. In these models, technological change is determined by economic forces within the model. From this perspective, a given level of education can lead to a continuing stream of new ideas, thus making it possible for education to affect long-run growth rates even when no new education is added to the economy. The common way to estimate these models focuses on growth in income and relates *changes* in GDP per worker (or per capita) to the *level* of education.

A final view of human capital in production and growth centers on the diffusion of technologies. If new technologies increase firm productivity, countries can grow by adopting these new technologies more broadly. Theories of technological diffusion such as those developed by Nelson and Phelps (1966), Welch (1970), and Benhabib and Spiegel (2005) stress that education may facilitate the transmission of knowledge needed to implement new

technologies. Benhabib and Spiegel (1994) find a role for educational attainment in both the generation of ideas and in the diffusion of technology, and Hanushek et al. (2017) find that the return to skills is higher in countries with faster growth and thus a greater need to adapt to new demands.

All approaches see human capital as being a crucial ingredient for growth, and the latter two stress its impact on long-run growth trajectories.

A Canonical Growth Model

A very simple but convenient growth model relates a country's rate of economic growth (g) to the skills of workers (H) and other factors (X) that include initial levels of income and technology, economic institutions, and other systematic factors (see Hanushek & Woessmann, 2008):

$$g = \gamma H + \beta X + \varepsilon. \tag{1}$$

Worker skills are best thought of simply as the workers' human capital stock. For expositional purposes, H is assumed to be a one-dimensional index and growth rates are linear in these inputs, although the precise form of the relationship is subject to considerable controversy as suggested by the alternative conceptual models.

Human capital is a latent variable that is not directly observed. To be useful and verifiable, it is necessary to specify the measurement of H . The vast majority of existing theoretical and empirical work on growth begins—frequently without discussion—by taking the quantity of schooling of workers (S) as a direct measure of H . This choice was largely based on data availability, but it also had support from the empirical labor economics literature. Mincer (1974), in looking at the determinants of wages, demonstrated that years of schooling in the United States was an informative empirical measure of differences in individual skills. This analysis has been replicated across 139 countries (Psacharopoulos & Patrinos, 2018).

Historically, in the standard empirical growth model, school attainment averaged across the labor force is the measure of aggregate human capital. Early work employing school enrollment rates was followed by measures of average years of schooling (see, importantly, Barro & Lee, 1993).

Following the seminal contributions by Barro (1991, 1997) and Mankiw et al. (1992), a vast early literature of cross-country growth regressions tended to find a significant positive association between quantitative measures of schooling and economic growth. (For extensive reviews of the literature, see, e.g., Krueger & Lindahl, 2001; Sianesi & Van Reenen, 2003; Temple, 2001; Topel, 1999). To give an idea of the reliability of this association, the analysis of 67 explanatory variables in growth regressions on a sample of 88 countries in 1960–1996 by Sala-i-Martin et al. (2004) found that primary schooling is the most robust influence factor (after an East Asian dummy) on growth in GDP per capita.

Figure 1 plots the average annual rate of growth in GDP per capita over the 40-year period of 1960–2000 against years of schooling at the beginning of the period for a sample of 92 countries. Both growth and education are expressed as conditional on the initial level of per capita GDP to account for a significant conditional convergence effect. (For a description of the underlying data sources and the method of producing this figure, see Hanushek & Woessmann, 2015a.)

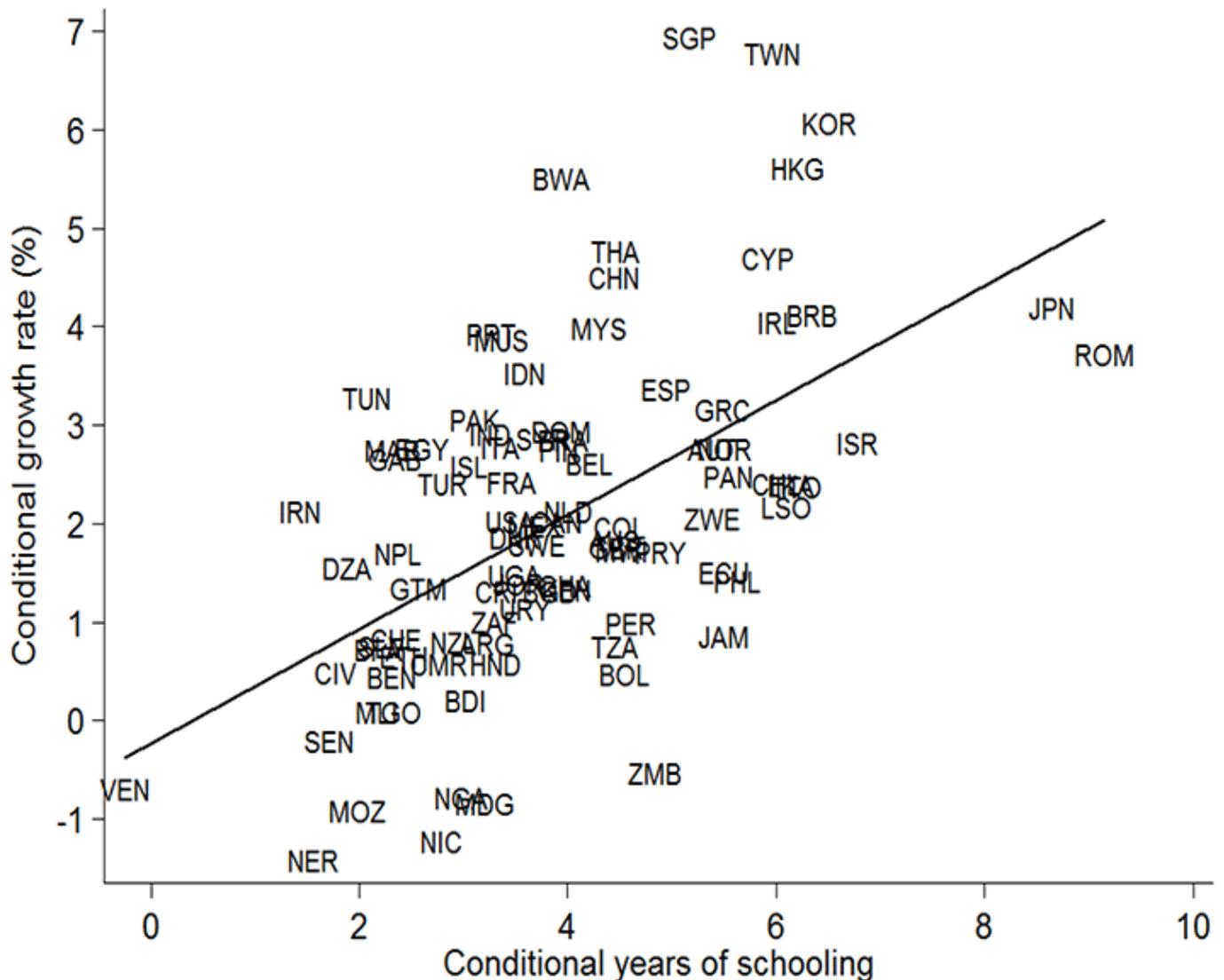


Figure 1. Years of schooling and economic growth rates without considering knowledge capital.

Note: Added-variable plot of a regression of the average annual rate of growth (in percent) of real GDP per capita in 1960–2000 on average years of schooling in 1960 and initial level of real GDP per capita in 1960 (mean of unconditional variables added to each axis).

Source: Hanushek and Woessmann (2015a).

The regression results depicted by the figure imply that each year of schooling is statistically significantly associated with a long-run growth rate that is 0.6 percentage points higher. The association is somewhat lower (at 0.3) but still significant when regional dummies are added to the regression. The positive association is substantially larger in the sample of countries that are not members of the Organisation for Economic Co-operation and Development

(OECD) (at 0.6) than in the sample of OECD member countries (at 0.3). Alternatively, results based on the samples of countries below and above the median of initial output are in line with the pattern of larger returns to education in developing countries.

This basic model with a wide range of extensions has been thoroughly investigated, and considerable skepticism has been raised about it. First, estimates based on this model have been shown to be very sensitive to the specification of the model (Levine & Renelt, 1992; Levine & Zervos, 1993). Bils and Klenow (2000) raise the issue of causality, suggesting that reverse causation running from higher economic growth to additional education may be at least as important as the causal effect of education on growth in the cross-country association. Finally, one of the conclusions that Pritchett (2001, 2006) draws from the fragility of the evidence linking changes in education to economic growth is that it is important for economic growth to get other things right as well, in particular the institutional framework of the economy. This general theme is reinforced by Easterly (2001).

A simple summary of this work, which is amplified in the next section, is that while human capital is closely related to economic growth, the measurement of human capital poses serious problems that are not dealt with in the early literature.

The Measurement of Human Capital

Measuring human capital by average years of schooling as the education measure implicitly assumes that a year of schooling delivers the same increase in knowledge and skills regardless of the education system. For example, a year of schooling in Brazil is assumed to create the same increase in productive human capital as a year of schooling in Portugal. Additionally, this measure assumes that formal schooling is the primary (sole) source of skills and that variations in nonschool factors have a negligible effect on education outcomes. The neglect of cross-country differences in the quality of education and in the strength of family, health, and other influences is a major drawback of using a quantitative measure of school attainment to proxy for skills of the labor force in cross-country analyses.

The larger issues can be better understood if the source of the skills (H) is considered. As discussed in the extensive educational production function literature (Hanushek, 2002), these skills are presumed to be affected by a range of factors, including family inputs (F), the quantity and quality of inputs provided by schools (qS), individual ability (A), and other relevant factors (Z), which include labor-market experience, health, and so forth; as in:

$$H = \lambda F + \phi(qS) + \eta A + \alpha Z + \nu. \quad (2)$$

The schooling term combines school attainment (S) and its quality (q). Indeed, there is a broad research base that documents each of these components.

If equation 2 describes the formation of skills, simply relying on school attainment in the growth modeling will not provide reasonable estimates of the role of human capital. Such estimates will undoubtedly be biased and will be sensitive to the exact model specification and to the inclusion of other country measures—exactly the case in early growth modeling.

A compelling alternative is to focus on the cognitive skills component of human capital and to measure H with test-score measures of mathematics, science, and reading achievement. The use of measures of educational achievement, which builds on prior research into both educational production functions and models of economic returns, has a number of potential advantages. First, achievement captures variations in the knowledge and skills that schools strive to produce and thus relates the putative outputs of schooling to subsequent economic success. Second, by emphasizing total outcomes of education, such measures incorporate skills from various sources—families, schools, and ability. Third, by allowing for differences in performance among students with differing quality of schooling (but possibly the same quantity of schooling), they open the investigation of the importance of different policies designed to affect the quality aspects of schools.

International assessments of student achievement provide a consistent measure of skills in math, science, and reading across countries and present some analytical challenges (see Hanushek & Woessmann, 2011). International testing began with a series of meetings in the late 1950s and early 1960s with a group of academics. An exploratory study in testing mathematics, reading comprehension, geography, science, and nonverbal ability was conducted in 1959–1962 (see Foshay, 1962). This led to the first major international test in 1964, the First International Mathematics Study, in which 12 countries participated. This and a series of subsequent assessments were conducted in a set of nations voluntarily participating in a cooperative venture developed by the International Association for the Evaluation of Educational Achievement (IEA). The continuing IEA efforts have been complemented by ongoing Programme for International Student Assessment (PISA) that the OECD began in 2000.

The major IEA and OECD testing programs have expanded dramatically in terms of participating countries. While only 29 countries participated in these testing programs through 1990, a total of 102 countries had participated by 2012. Only the United States participated in all 19 testing occasions, but an additional 32 countries participated in 10 or more different assessments.

Between 1964 and 2003, 12 different international tests of math, science, or reading were administered. These include 36 different possible scores for year-age-test combinations (e.g., science for 8th-grade students in 1972 as part of the First International Science Study or math for 15-year-olds in the 2000 PISA cycle). The assessments are designed to identify a common set of expected skills, which are tested in the local language. It is easier to do this in math and science than in reading, and a majority of the international testing has focused on math and science.

These international testing programs involve a group of voluntarily participating countries that have differed across time and even across subparts of specific testing occasions. Before 1999, little effort was made to equate scores across time. Furthermore, the testing has been almost exclusively cross-sectional in nature, not following individual students' changes in achievement. Each of these issues enters into using them for cross-country comparisons.

Hanushek and Kimko (2000) developed methods for aggregating the observed individual test scores to a single country-level measure, an approach refined by Hanushek and Woessmann (2012a, 2015a). This permits comparison of performance across countries, even when all

countries did not participate in a common assessment, as well as tracking performance over time. These aggregate assessment scores are measures of the knowledge capital of nations, and they permit direct analysis of how education and skills affect economic growth.

Knowledge Capital and Growth

The investigation of the role of skills (measured in international tests) in growth was initiated by Hanushek and Kimko (2000), who related a measure of cognitive skills derived from the international student achievement tests through 1991 to economic growth in 1960–1990 in a sample of 31 countries with available data. They found that the association of economic growth with cognitive skills dwarfs its association with years of schooling and substantially raises the explanatory power of growth models. Their general pattern of results was duplicated by a series of other studies that pursued different tests and specifications along with different variations of skills measurement (see, e.g., Angrist et al., 2021; Barro, 2001; Barro & Lee, 2015; Bosworth & Collins, 2003; Ciccone & Papaioannou, 2009; Filmer et al., 2020; Kaarsen, 2014; Lee & Lee, 2021; Patel & Sandefur, 2019; Woessmann, 2003).

The importance of skills for growth can be seen from estimates of the basic growth model of equation 1 for the 50 countries with both cognitive-skill and economic data over the period 1960–2000 (Hanushek & Woessmann, 2015a). Knowledge capital (aggregate cognitive skills) is measured by the simple average of all observed math and science scores between 1964 and 2003 for each country, the income data come from version 6.1 of the Penn World Tables (Heston et al., 2002), and the data on years of schooling are an extended version of the Cohen and Soto (2007) data.

The central finding of the statistical analysis in Hanushek and Woessmann (2015a) is that cognitive skills are a significant factor in explaining international differences in long-run growth rates. The simple growth model with school attainment—as portrayed in Figure 1—accounts for a quarter of the variance in growth rates across countries, while adding knowledge capital increases this to three-quarters of the variance. As Figure 2 shows, the test score is strongly significant in explaining growth, and Hanushek and Woessmann (2015a) show that its magnitude is unchanged by including school attainment in 1960. Countries are now seen lying quite close to the overall line, indicating a very close relationship between educational achievement and economic growth.

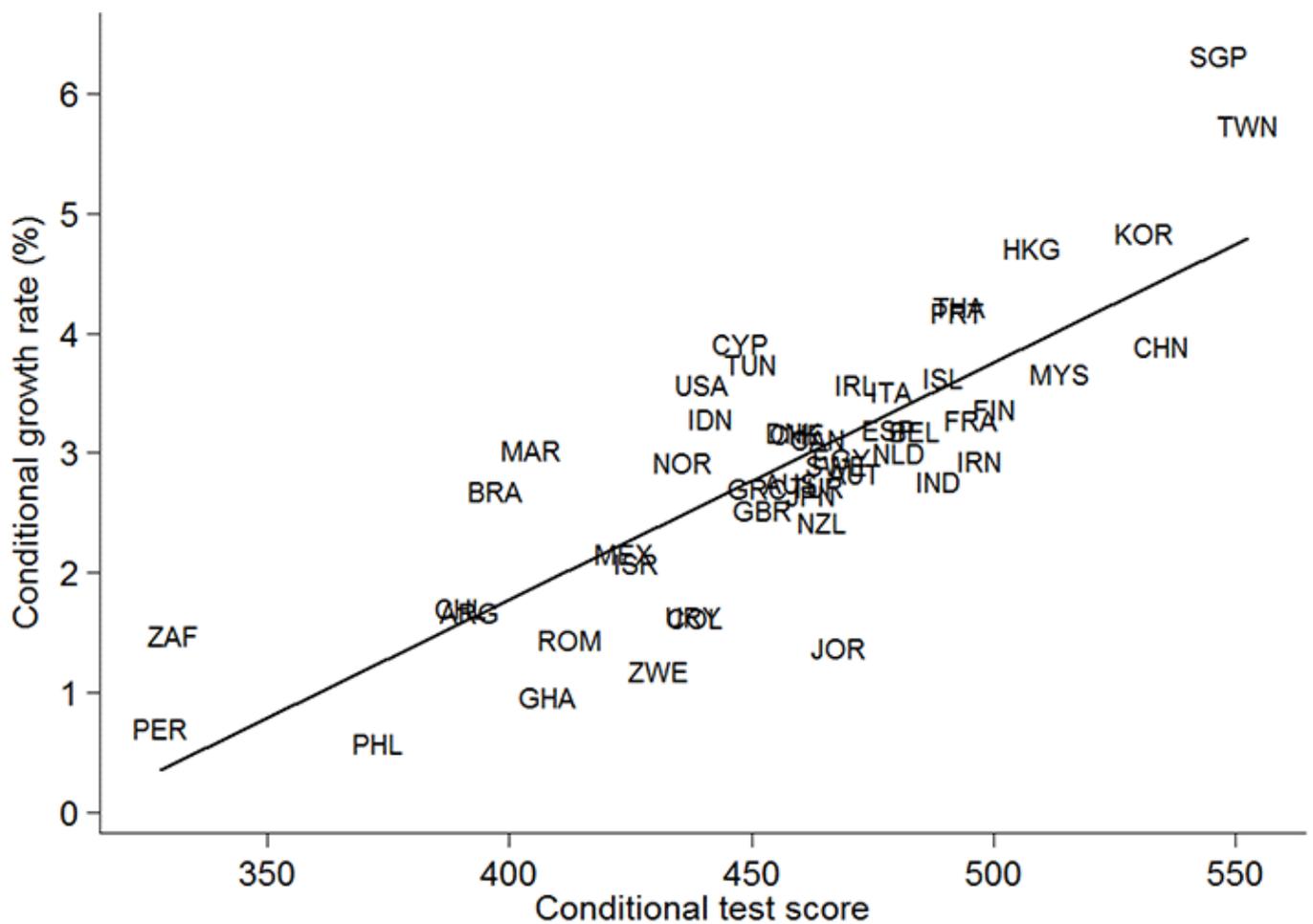


Figure 2. Knowledge capital and economic growth rates across countries.

Note: Added-variable plot of a regression of the average annual rate of growth (in percent) of real GDP per capita in 1960–2000 on average test scores on international student achievement tests, average years of schooling in 1960, and initial level of real GDP per capita in 1960 (mean of unconditional variables added to each axis).

Source: Hanushek and Woessmann (2015a), table 1, column 3.

It is also instructive to plot the impact of school attainment on growth *after considering cognitive skills*. As seen in Figure 3, the relationship is now flat; that is, school attainment is not statistically significant in the presence of the direct cognitive-skill measure of human capital.

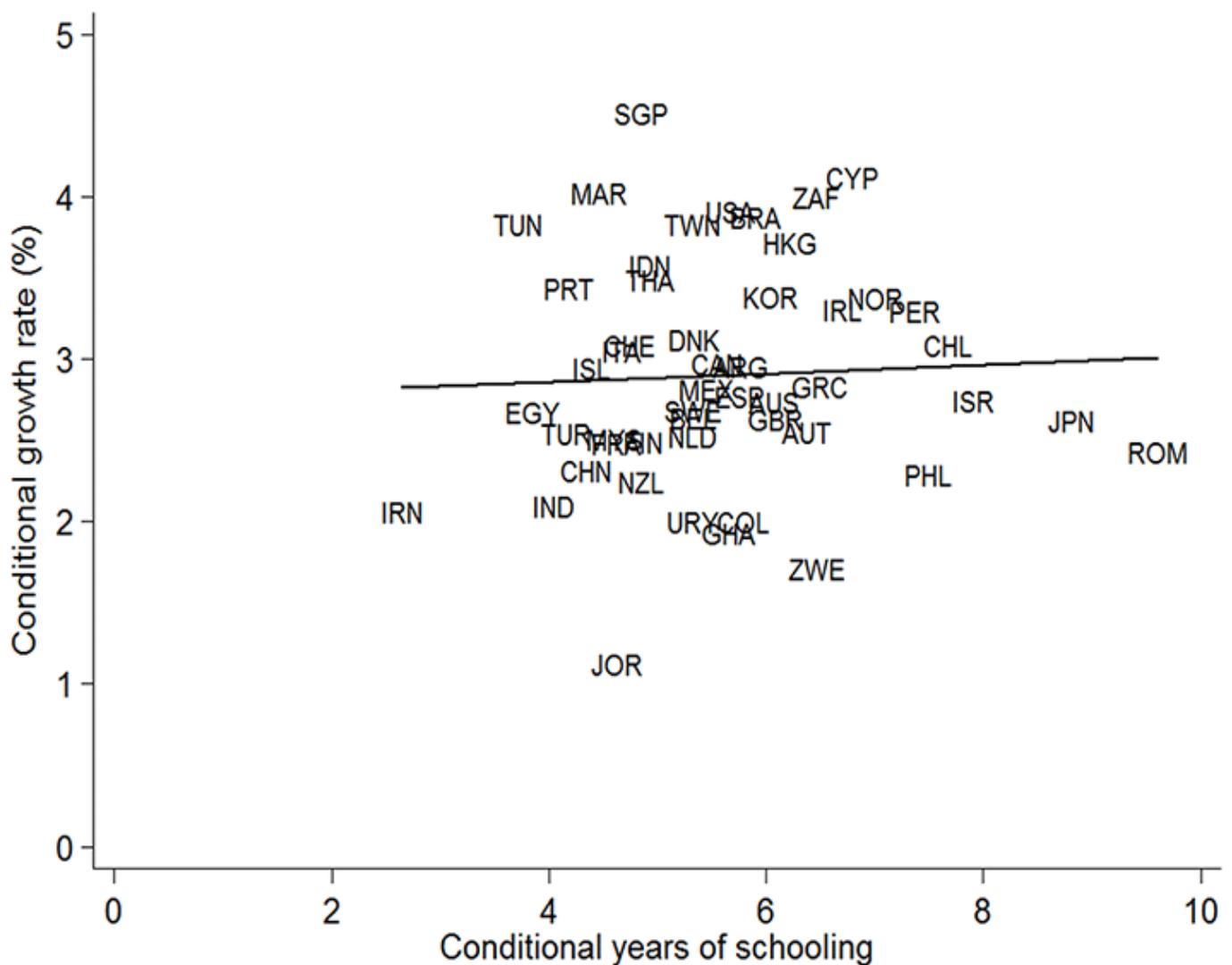


Figure 3. Years of schooling and economic growth rates after considering knowledge capital.

Note: Added-variable plot of a regression of the average annual rate of growth (in percent) of real GDP per capita in 1960–2000 on average years of schooling in 1960, average test scores on international student achievement tests, and initial level of real GDP per capita in 1960 (mean of unconditional variables added to each axis).

Source: Hanushek and Woessmann (2015a), table 1, column 3.

The insignificance of school attainment does not mean that schooling is irrelevant. Measured skills are closely related to schooling, and life-cycle skill accumulation depends on the learning that takes place earlier in life. Achievement is measured at various points during primary and secondary education, but knowledge at earlier points in education will strongly influence the ultimate skill accumulation when students enter the labor force. As James Heckman and his colleagues have emphasized, there is a dynamic complementarity of investments such that further schooling has a larger impact on skills if it builds on a larger base developed earlier (Cunha & Heckman, 2007). The simple point is that “skill begets skill through a multiplier process” (Cunha et al., 2006, p. 698). The insignificance of school attainment suggests that simply investing in further schooling without ensuring commensurate improvements in cognitive skills does not lead to economic returns.

With respect to magnitude, one standard deviation in test scores (measured at the OECD student level) is associated with a two-percentage-point higher average annual growth rate in GDP per capita over the 40 years where growth is measured. (One standard deviation of test scores is typically estimated to be equivalent to 3–4 years of schooling.) As indicated in the section on the impact of education reform, the magnitude of this relationship is such that feasible changes in cognitive skills, such as through improved schools, would yield enormous economic impact (see, e.g., Hanushek et al., 2013; Hanushek & Woessmann, 2015b).

This basic estimation emphasizes the importance of measuring the knowledge capital of nations reliably. Once this is done, variations in growth around the world fall into a clear pattern.

There are a number of natural extensions to these basic models. One important line of inquiry emphasizes the role of economic institutions as the fundamental cause of differences in economic development. In one influential body of research, Acemoglu et al. (2001, 2002, 2005, 2014) argue that major societal institutions have created the fundamental building blocks for modern development. They particularly fixed on the central notion of strong property rights. This is not, however, without controversy. Glaeser et al. (2004) argue it is more likely that better human capital led both to the development of good institutions and higher economic growth.

Societal institutions are almost certainly a component of differences in economic growth, and it is important to understand how they interact with the knowledge capital of nations. All of the early investigations of the interaction between institutions and human capital across countries were analyzed in terms of school attainment, something seen to be problematic. Hanushek and Woessmann (2015a) introduce two common institutional measures into their growth estimates. The measures of openness of the economy and security of property rights are jointly significant in explaining growth, but the results also show that cognitive skills exert a positive and highly significant effect on economic growth independent of these measures of the quality of institutions. Interestingly, an interaction term between cognitive skills and each of the institutional measures suggests that openness and cognitive skills not only have significant individual effects on economic growth but also have a significant positive interaction. The effect of cognitive skills on economic growth is indeed significantly higher in countries that have been fully open to international trade than in countries that have been fully closed.

The results are remarkably similar when comparing the sample of OECD countries to the sample of non-OECD countries, with the point estimate of the effect of test scores slightly larger in non-OECD countries. When the sample is separated based on whether a country was below or above the median of GDP per capita in 1960, the effect of test scores is statistically significantly larger in low-income countries than in high-income countries (Hanushek & Woessmann, 2015a). Specific analyses focusing on Latin America (Hanushek & Woessmann, 2012b) and on East Asia (Hanushek & Woessmann, 2016) confirm and extend the basic results. More recently, the importance of knowledge capital for long-run economic growth has also been shown in within-country analyses across U.S. states (Hanushek et al., 2017a, 2017b).

In another important line of inquiry, Hanushek and Woessmann (2015a) consider one potentially important issue of overall policy—whether to concentrate attention on the lowest or the highest achievers. Some argue in favor of elitist school systems that focus on the top

performers as potential future managers of the economy and drivers of innovation. Others favor more egalitarian school systems to ensure well-educated masses that will be capable of implementing established technologies. In other words, should education policy focus on forming a small group of “rocket scientists” or are approaches such as the Education for All initiative (United Nations Educational, Scientific and Cultural Organization [UNESCO], 2014) more promising in spurring growth?

Hanushek and Woessmann (2015a) investigate these issues by introducing measures of the share in the top and in the bottom of the test score distribution into the growth estimation in place of the country mean score. They find that both distributional measures of the nation’s cognitive skills are significantly related to economic growth, either when entered individually or jointly. It is difficult to directly compare the impacts of the two performance measures. For example, it may be much more feasible to increase the basic-literacy share than to increase the top-performing share by the same amount.

The effect of the basic-literacy share does not vary significantly with the initial level of development, but the effect of the top-performing share is significantly larger in countries that have more scope to catch up to the initially most productive countries. These results appear consistent with a mixture of the basic models of human capital and growth mentioned earlier. The accumulation of skills as a standard production factor, emphasized by augmented neoclassical growth models (e.g., Mankiw et al., 1992), is probably best captured by the basic-literacy term, which has positive effects that are similar in size across all countries. However, the larger growth effect of high-level skills in countries farther from the technological frontier is most consistent with technological diffusion models (e.g., Nelson & Phelps, 1966). From this perspective, countries need high-skilled human capital for an imitation strategy, and the process of economic convergence is accelerated in countries with larger shares of high-performing students. An informative extension considers the interaction of the top-performing and basic-literacy shares: The complementarity between basic skills and top-level skills suggests that countries need a workforce with at least basic skills to implement the imitation and innovation strategies developed by scientists.

Causation

The fundamental question is this: Should the tight relationship between cognitive skills and economic growth be interpreted as a causal one that can support direct policy actions? In other words, if achievement were raised, would growth rates be expected to go up by a commensurate amount?

Work on differences in growth among countries, while extensive over the past two decades, has been plagued by legitimate questions about whether any truly causal effects have been identified or whether the estimated statistical analyses simply pick up a correlation that emerges for other reasons.

Knowing that the relationship is causal, and not simply a by-product of some other factors, is very important from a policy standpoint. It is essential to be confident that, if a country manages to improve its achievement in some manner, it will see a corresponding improvement

in its long-run growth rate. Said differently, if the relationship between test scores and growth rates simply reflects other factors that are correlated with both test scores and growth rates, changes in test scores may have little or no impact on the economy.

The early studies that found positive effects of years of schooling on economic growth quite plausibly suffered from reverse causality; that is, improved growth was leading to more schooling rather than the reverse (see, e.g., Bils & Klenow, 2000). If a country gets richer, it tends to buy more of many things, including more years of schooling for its population.

There is less reason to think that higher student achievement is caused by economic growth. For one thing, scholars have found little impact of additional education spending on achievement outcomes, so it is unlikely that the relationship comes from growth-induced resources lifting student achievement (Hanushek & Woessmann, 2011).

It is difficult to develop conclusive tests of causality with the limited sample of countries available for analysis. To deal with causation issues, Hanushek and Woessmann (2012a, 2015a) consider alternative explanations to determine whether one can rule out major factors that could confound the results and lead to incorrect conclusions about causal relationships. Although no single approach can address all of the important issues, they argue that a combination of approaches, if it provides support for a causal relationship between achievement and growth, offers some assurance that the issues most likely to be problematic are not affecting the results. This section summarizes Hanushek and Woessmann's investigations into the potential problems with the prior estimation and their likely severity.

First, the estimated relationship is little affected by including other possible determinants of economic growth. In an extensive investigation of alternative model specifications, Hanushek and Woessmann (2015a) employ different measures of cognitive skills, various groupings of countries (including some that eliminate regional differences), and specific subperiods of economic growth. These efforts show a consistency in the alternative estimates, in both quantitative impacts and statistical significance, that is uncommon in cross-country growth modeling. Moreover, measures of geographical location, political stability, capital stock, and population growth do not significantly affect the estimated impact of cognitive skills. These specification tests rule out some basic problems attributable to omitted causal factors that have been noted in prior growth work.

Second, the most obvious reverse-causality issues arise because their analysis relates growth rates over the period 1960–2000 to test scores for roughly the same period. To address this directly, Hanushek and Woessmann (2015a) separate the timing of the analysis by estimating the effect of scores on tests conducted only until 1984 on economic growth in the period since 1985 (and until 2009). In this analysis, available for a sample of 25 countries, test scores strictly predate the growth period, making it clear that increased growth could not be causing the higher test scores of the prior period. This estimation shows a positive effect of early test scores on subsequent growth rates that is almost twice as large as that as that found in their base model (Figure 2). Indeed, this fact itself may be significant, because it is consistent with the possibility that skills have become even more important for the economy in recent periods.

Third, even if reverse causality were not an issue, important international differences in test scores do not necessarily reflect school policies. After all, achievement may arise because of health and nutrition differences in the population or simply because of cultural differences

regarding learning and testing. Hanushek and Woessmann (2012a) focus attention on variations in achievement that arise directly from institutional characteristics of each country's school system (exit examinations, autonomy, relative teacher salaries, and private schooling). This estimation of the growth relationship, using instrumental variables, yields essentially the same results as previously presented, lending support both to the causal interpretation of the effect of cognitive skills and to the conclusion that schooling policies can have direct economic returns. Nonetheless, countries that have good economic institutions may have good schooling institutions, so this approach, while guarding against simple reverse causality, cannot eliminate a variety of issues related to omitted factors in the growth regressions.

Fourth, a potentially major concern is that countries with good economies also have good school systems, implying that those that grow faster because of the basic economic factors also have high achievement. In this case, achievement is simply a reflection of other important aspects of the society and economy and not the driving force in growth. One simple approach is to consider the implications of differences in measured skills within a single economy, thus eliminating institutional or cultural factors that may make the economies of different countries grow faster. This can readily be done for immigrants to the United States who have been educated in their home countries and who can be compared to immigrants educated solely in the United States. Since the two groups are within the single labor market of the United States, any differences in labor-market returns associated with cognitive skills cannot arise because of differences in the economy or culture of their home country. Looking at labor-market returns, the cognitive skills seen in the immigrant's home country lead to higher incomes, but only if the immigrant was in fact educated in the home country. Immigrants from the same home country but schooled in the United States see no economic return to home-country test scores, thus pinpointing the value of better schools. These results hold when Mexicans (the largest U.S. immigrant group) are excluded and when only immigrants from English-speaking countries are included. While not free from problems, this comparative analysis using "difference-in-differences" rules out the possibility that test scores simply reflect cultural factors or economic institutions of the home country. It also lends further support to the potential role of schools in changing the cognitive skills of citizens in economically meaningful ways.

Finally, for those countries that have participated in testing at different points over the past half century, it is possible to observe whether or not students seem to be getting better or worse over time. Building on this, perhaps the toughest test of causality is relating *changes* in test scores over time to *changes* in growth rates. If test-score improvements actually increase growth rates, it should show up in such a relationship. This approach implicitly eliminates country-specific economic and cultural factors because it looks at what happens over time within each country. While only 12 OECD countries participated in testing over 30 years, Hanushek and Woessmann (2012a) can relate the magnitude of trends in educational performance to the magnitude of trends in growth rates over time. This investigation provides more evidence of the causal influence of cognitive skills (although the small number of countries is obviously problematic). The gains in test scores over time are very closely related to the gains in growth rates over time. As with the other approaches, this analysis must presume that the pattern of achievement changes has been occurring over a long time,

because it is not the achievement of schoolchildren but the skills of workers that count. Nonetheless, the consistency of the patterns and the similarity in magnitude of the estimates to the basic growth models are striking.

Again, each approach to determining causation is subject to its own uncertainty. Nonetheless, the combined evidence consistently points to the conclusion that differences in cognitive skills lead to significant differences in economic growth. Moreover, even if issues related to omitted factors or reverse causation remain, it seems very unlikely that these cause *all* of the estimated effects.

Since the causality tests concentrate on the impact of schools, the evidence suggests that school policy can, if effective in raising cognitive skills, be an important force in economic development. While other factors—culture, health, and so forth—may affect the level of cognitive skills in an economy, schools clearly contribute to the development of human capital. More years of schooling in a system that is not well designed to enhance learning, however, will have little effect.

The Impact of Education Reform on Economic Growth

Development strategies invariably include education and human capital improvement as important components. Until recently these have focused on quantitative goals, such as achieving certain levels of educational enrollment or attainment. For example, the two Millennium Development Goals related to education that the United Nations adopted in 2000—universal primary education and gender parity by 2015—are solely phrased in terms of educational quantity (United Nations, 2009). Similarly, while UNESCO's Education for All initiative mentioned quality, its explicit goals mostly focused on school quantity (UNESCO, 2008).

Unfortunately, development strategies built just on schooling have generally been a disappointment because expansion of school attainment has not guaranteed improved economic conditions (Easterly, 2001). Thus, when the United Nations revisited its development goals in 2015 in the Sustainable Development Goals (SDGs), the education component included explicit mention of quality. It did acknowledge that lower-income countries still have generally incomplete enrollment in lower secondary schools, but it still raises the possibility of overemphasis of attainment at the cost of lower quality. In general, the SDGs highlight the long-standing tension between goals framed in terms of school completion (which is readily and routinely measured) and quality (which is less frequently measured).

In showing the value of improved quality of schooling, Hanushek and Woessmann (2015b) project the economic impacts of countries' changes to access and quality of schooling. Three improvements in student performance are considered. In the first, each country moves to full access to lower secondary schooling at the 2012 quality level. In the second, all students currently in school with insufficient skills are brought up to at least to a basic skill level. In the third, both moves simultaneously occur.

Hanushek and Woessmann's (2015b) projections rely on a simple description of how skills enter the labor market and have an impact on the economy. Improvement is assumed to progress linearly from the schooling situation in 2015 for each country to reaching the goal in

15 years. Assuming that a worker remains in the labor force for 40 years implies that the labor force is progressively made up of increasingly more skilled workers for 55 years (15 years of reform and 40 years of replacement of retiring, less-skilled workers), after which all workers are at the new improved quality level. The difference in GDP is then estimated based on historic growth (Figure 2) with an improved workforce versus the existing workforce skills over 80 years, roughly the life expectancy of somebody in a developed country born today. Future gains in GDP are discounted from the present with a 3% discount rate. The resulting present value of additions to GDP is thus directly comparable to the current levels of GDP.

Hanushek and Woessmann (2015b) define basic skills by a simple PISA test standard, whereas the OECD defines fully achieving Level 1 on the PISA test as representing the skills necessary to participate productively in modern economies.

Figure 4 displays projections for four groupings of countries (according to World Bank categories): lower middle income, upper middle income, high income non-OECD, and high-income OECD. Lower middle income countries include Ghana, Honduras, Indonesia, and Morocco. Examples of upper middle income countries are Argentina, Bulgaria, South Africa, and Turkey. The high income non-OECD countries include Hong Kong, Lithuania, and several Arab oil-producing countries. The 76 countries included in the overall projections are restricted to those that have recently participated in testing through PISA or Trends in International Mathematics and Science Study (TIMSS) so that a measure of quality is available.

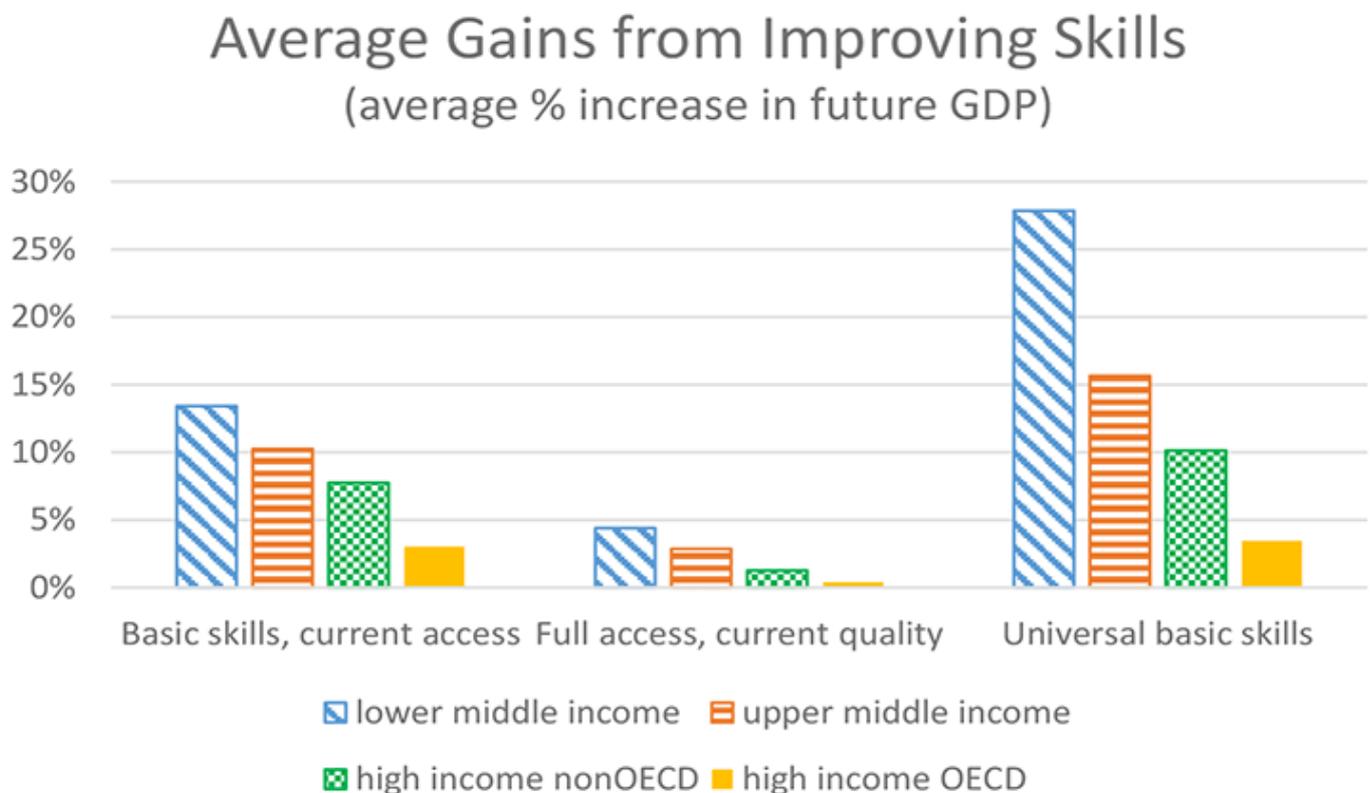


Figure 4. Average gains for countries at different income levels from improving skills.

Source: Hanushek and Woessmann (2020b).

The first grouping of bars in Figure 4 shows the gains from improving quality for existing access levels to schools. The lower middle income countries on average would see gains in the average level of GDP over the next 80 years of 13%, but even high income OECD countries would on average gain 3% percent in GDP from bringing all students up to basic skills (PISA Level 1).

The second set of columns shows the economic impact of ensuring access for all children through lower secondary but maintaining existing country quality levels. While this has essentially no impact on high income OECD countries where access is almost complete now, it has noticeable impact for the other sets of countries. For lower middle income countries, which currently average about 80% completion of lower secondary schooling, the gains would on average lift future GDP levels by 4.4%.

These two sets of projections show the tension that has existed in setting international goals for schooling. Full access clearly has value, but the value is significantly less than seen through quality improvements.

The final columns in Figure 4 show the result of achieving simultaneous improvements in access and quality. Lower middle income countries gain on average 28% higher GDP, and upper middle income countries gain 16% in the level of future GDP. This broader quality dimension is also relevant to upper income countries since they have students who do not achieve basic skill levels. For example, in the United States 23% of 15-year-olds do not get to Level 1 in mathematics; getting them to Level 1 implies a future GDP that would be 3.3% higher on average.

The simulations in Hanushek and Woessmann (2015b) show that the previous estimates of the effects of education quality on growth have large impacts on national economies. They also suggest that directly focusing on school quality is important for economic development.

There are, of course, many uncertainties in these estimates, including whether the growth experiences of 1960–2000 will hold for the remainder of the 21st century. Perhaps more important, there is not an obvious set of policy changes that would lead to the gains considered in the simulations. While there are countries that have shown this kind of gain, there are others that have tried and failed. A full discussion of what the research indicates is beyond the scope of this article, but some of the possibilities from historical experience can be found elsewhere (Hanushek & Woessmann, 2015a).

Conclusions

Economic growth determines the future economic well-being of a country, making understanding the determinants of growth a high-priority area of economic research. The analysis of how education affects growth makes a strong case that the skills of the population are by far the most important factor. There is also strong evidence that these skills can be reliably measured by international tests of cognitive achievement. Knowledge capital, the aggregate cognitive skills of the population, can account for three-fourths of the variation across countries in long-term growth rates.

Schools rightfully receive attention by policy makers, because they offer a direct path to improving the economic outcomes of nations. Just expanding access to schooling, however, is insufficient. Further, not all school policies pursued in the past have proved successful in raising student outcomes. Schools are also subject to adverse forces such as the reactions around the world to the COVID-19 pandemic. Countries cannot ignore the learning losses from such school disruption. Historical growth relationships indicate an increased likelihood of large economic losses if school quality is not improved after disruptions occur (Hanushek & Woessmann, 2020a).

The overwhelming conclusion is that the magnitude of the impact of knowledge capital on growth appears to be so large that nations cannot afford to neglect the quality of their schools. Doing so would impair their economic future.

Further Reading

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Notes

1. The depiction here draws on Hanushek and Woessmann (2015a, 2015b, 2020b).

Related Articles

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The Economics of Gender and Educational Achievement: Stylized Facts and Causal Evidence

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