Skills, Mobility, and Growth

Eric A. Hanushek[*] and Ludger Woessmann[†]

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Abstract

The simple perspective in this analysis is that the long run economic outcomes for the United States are directly related to the skills of society. And, enhanced economic mobility and improved distribution of income depend crucially on the level and distribution of skills. The primary impact comes from the relationship of skills to economic growth, although it is important to measure skills appropriately. When skills are measured in terms of knowledge capital – the aggregate cognitive skills of the population – the importance of high quality schooling becomes clear. In order to provide direct evidence of the importance of knowledge capital, this analysis projects the economic benefits of an overall increase in achievement and of a move toward universal minimal skills. The results of these projections show dramatically the dependence of the economy on improvement of schools.

[*] Hoover Institution, Stanford University
[†] Ifo Institute and University of Munich

Introduction

Human capital investment has been seen as a primary tool for producing inclusive growth. But the research support for this has not been entirely clear. Countries that have expanded their schooling have not necessarily seen the positive economic gains they had hoped for. Similarly the beneficial distributional effects are difficult to document. The central explanation for both appears directly related to measurement issues. When skills are properly measured, many of the issues of growth, development, and distribution become much clearer.

Empirical growth analysis has focused on why some nations have grown faster than others. Propelled by the initial studies of Barro (1991), Romer (1990b), and others, hundreds of subsequent studies searched for the key ingredients of growth. After initial enthusiasm, however, there was growing skepticism about how to interpret cross-sectional growth models. Specifically, many have argued that the existing analyses have not adequately identified the role of human capital and thus that the estimated relationships are heavily influenced by specification issues, by reverse causality, and by mismeasured other elements of country differences.

We argue that most of the prior problems emanate from bad measures of skill differences across countries. When properly measured by the knowledge capital of nations – i.e. the aggregate cognitive skills of the workforce – we see a clear and well-identified impact of skills on growth.

We exploit the measured skill differences across countries to estimate robust models of economic growth. We then use these models to analyze how improvement in the skills of U.S. students/workers would impact on aggregate economic outcomes.

The simple idea behind this is that improving mobility in society and the distribution of income in the United States – issues of considerable current debate – depends importantly on improving the skills of the population. Skills at the bottom end of the distribution are particularly important for economic outcomes, and we project how improving skills at the bottom end of the distribution would affect both individual outcomes and aggregate economic well-being.

Basic Relationship of Knowledge Capital and Economic Growth

The existing empirical analysis of growth is now quite extensive, but this work has not always been convincing or successful, as extracting the fundamental factors underlying growth differences has proven difficult. Here we build on our prior analysis, which we believe resolves the most important uncertainties in understanding long run growth.[3] Specifically, growth is directly and significantly related to the skills of the population.

We conclude that by far the most important determinant of economic growth is the knowledge capital, or the collective cognitive skills, of a country. Virtually all past economic analyses of the long run growth of countries have highlighted a role for human capital, but the validity and reliability of the empirical analysis has been open to question.[4] There have been concerns introduced by the instability of any estimates, which has been taken as evidence of misspecified relationships where omitted influences of other factors appear likely. Moreover, there is concern about reversal causality; i.e., growth causing schooling rather than the opposite. As laid out in detail in Hanushek and Woessmann (2015a), we believe that these prior concerns can now be satisfactorily answered – once skills are correctly measured – and that the basic growth relationships can support a detailed analysis of the economic implications of improving on a nation's knowledge capital. While the complete analysis of these statistical and modeling issues can be quite complicated, we summarize the analysis below and provide appropriate references for those desiring more depth.

A. Baseline Estimates

Prior theoretical and empirical work has pursued a variety of specifications of the underlying growth process.[5] Here we begin with a very general view and then provide some details of how skills relate to growth. Because the subsequent economic analysis relies heavily on the estimates of growth models, it is useful to have an overview of these.

[3] Hanushek and Woessmann (2015a).
[4] Pritchett (2006).
[5] See the reviews in Hanushek and Woessmann (2008, (2010).

We think of a country's growth rate as a function of the skills of workers and other factors that include initial levels of income and technology, economic institutions, and other systematic factors. Skills are frequently referred to simply as the workers' human capital stock.

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

This formulation suggests that nations with more human capital tend to continue to make greater productivity gains than nations with less human capital, although we consider the possibility that the induced growth in productivity disappears over time.[6]

The empirical macroeconomic literature focusing on cross-country differences in economic growth has overwhelmingly employed measures related to school attainment, or years of schooling, to test the human capital aspects of growth models. While it has tended to find a significant positive association between quantitative measures of schooling and economic growth, we believe that these formulations introduce substantial bias into the picture of economic growth.[7] Average years of schooling is a particularly incomplete and potentially misleading measure of education for comparing the impacts of human capital on the economies of different countries. It 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 Korea. Additionally, formulations relying on this measure assume that formal schooling is the only source of education and that variations in non-school factors have negligible effects on education

[6] A major difference of perspective in modeling economic growth is whether education should be thought of as an input to overall production, affecting the level of income in a country but not the growth rate in the long run (augmented neoclassical models as in Mankiw, Romer, and Weil (1992)) or whether education directly affects the long-run growth rate (endogenous growth models as, importantly, in Lucas (1988), Romer (1990a), and Aghion and Howitt (1998)). See Acemoglu (2009), Aghion and Howitt (2009), Barro and Sala-i-Martin (2004), and Jones and Vollrath (2013) for textbook introductions. In terms of these major theoretical distinctions, our formulations combine key elements of both competing models. The fact that the rate of technological change and productivity improvement is directly related to the stock of human capital of the nation makes it an endogenous growth model. At the same time, by including the initial level of income among the control variables, our model does allow for conditional convergence, a leading feature of the augmented neoclassical approach. We return to these alternatives below in the projections of economic outcomes.

[7] To give an idea of the robustness of this association, an extensive empirical analysis by Sala-i-Martin, Doppelhofer, and Miller (2004) of 67 explanatory variables in growth regressions on a sample of 88 countries found that primary schooling was the most robust influence factor (after an East Asian dummy) on growth in GDP per capita in 1960-1996.

outcomes and skills. This neglect of cross-country differences in the quality of schools and in the strength of family, health, and other influences is probably the major drawback of such a quantitative measure of schooling.

To see this, consider a standard version of an education production function as employed in a very extensive literature,[8] where skills are expressed as a function of a range of factors:

$$human\ capital = \beta_1 schools + \beta_2\ families + \beta_3 ability + \beta_4 health + \beta_5 other\ \ factors + \upsilon \qquad (2)$$

In general, human capital combines both school attainment and its quality with the other relevant factors including education in the family, labor market experience, health, and so forth.

Thus, while school attainment has been convenient in empirical work because of its ready availability across countries, its use ignores differences in school quality in addition to other important determinants of people's skills. A more satisfying alternative is to incorporate variations in cognitive skills, which can be determined through international assessments of mathematics, science, and reading achievement, as a direct measure of the human capital input into empirical analyses of economic growth.

The focus on cognitive skills has a number of potential advantages. First, it captures variations in the knowledge and ability that schools strive to produce and thus relates the putative outputs of schooling to subsequent economic success. Second, by emphasizing total outcomes of education, it incorporates skills from any source – including schools, families, and ability. Third, by allowing for differences in performance among students with differing quality of schooling (but possibly the same quantity of schooling), it opens the investigation of the importance of different policies designed to affect the quality aspects of schools. Fourth, it is practical because of the extensive development of consistent and reliable cross-country assessments.

Our growth analysis relies on the measures of cognitive skills developed in Hanushek and Woessmann (2015a). Between 1964 and 2003, twelve different international tests of math,

[8] See Hanushek (1986, (2002) for reviews.

science, or reading were administered to a voluntarily participating group of countries.[9] These include 36 different possible scores for year-age-test combinations (e.g., science for students of grade 8 in 1972 as part of the First International Science Study or math of 15-year-olds in 2000 as a part of the first PISA test). The assessments are designed to identify a common set of expected skills, which were then tested in the local language. Each test is newly constructed, until recently with no effort to link to any of the other tests. Hanushek and Woessmann (2015a) describe the construction of consistent measures at the national level across countries through empirical calibration of the different tests.[10] These measures of knowledge capital for nations rely on the average (standardized) test scores for each country's historical participation in the tests. The aggregate scores are scaled (like PISA today) to have a mean of 500 and a standard deviation at the individual level of 100 across OECD countries.

We interpret the test scores as an index of the human capital of the populations (and workforce) of each country. This interpretation of our averages over different cohorts is reasonable if a country's scores have been stable across time, implying that estimates from recent school-aged populations provide an estimate of the older working population. If scores (and skills) do in fact change over time, some measurement error is clearly introduced. We know that scores have changed some, but within our period of observations differences in levels across countries dominate any intertemporal score changes.[11]

Using the aggregate test scores for each country – its knowledge capital – we directly estimate equation 1, using this more refined measure of human capital.[12] Table 1 presents the basic results on the association between educational outcomes and long-run economic growth in

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[9] See Hanushek and Woessmann (2011a) for a review. Note that there have been five major international assessments since 2003. We emphasize the early assessments because they fit into our analysis of long run growth. In the analysis of economic impacts for countries, we rely on the subsequent testing.

[10] By transforming the means and variances of the original country scores (partly based on external longitudinal test score information available for the United States), each is placed into a common distribution of outcomes. Each age group and subject is normalized to the PISA standard of mean 500 and individual standard deviation of 100 across OECD countries, and then all available test scores are averaged at the country level.

[11] For the 50 countries in our growth analysis, 73 percent of the variance in scores lies between countries (Hanushek and Woessmann (2012a)). The remaining 27 percent includes both true score changes and any measurement error in the tests. Any measurement error in this case will tend to bias downward the estimates of the impact of cognitive skills on growth, so that our estimates of economic implications will be conservative.

[12] The data on GDP per capita and its growth for our analyses come from the Penn World Tables (Heston, Summers, and Aten (2002)). Data on quantitative educational attainment are an extended version of the Cohen and Soto (2007) data. Results are very similar when using the latest Barro and Lee (2013) data on educational attainment; see Hanushek and Woessmann (2015a), Appendix 3A.

the sample of 50 countries for which we have both economic growth data and our measure of knowledge capital.[13] The inclusion of initial GDP per capita in all specifications simply reflects the fact that it is easier to grow when one is farther from the technology frontier, because one just must imitate others rather than invent new things.

When knowledge capital is ignored (column 1), years of schooling in 1960 are significantly associated with average annual growth rates in real GDP per capita in 1960-2000.[14] However, once our test measure of knowledge capital is included (columns 2 and 3), we see that cognitive skills are highly significant while years of schooling become statistically insignificant and the estimated coefficient drops to close to zero. Furthermore, the variation in cross-country growth explained by the model increases from 25 percent to 73 percent when measuring human capital by cognitive skills rather than years of schooling. Note that the bivariate association with initial per-capita GDP already accounts for 7 percent of the variance in subsequent growth, making the relative increase in understanding growth through cognitive skills as opposed to just the natural convergence of growth from less developed to more developed countries remarkable.

The estimated coefficient on cognitive skills implies that an increase of one standard deviation in educational achievement (i.e., 100 test-score points on the PISA scale) yields an average annual growth rate over 40 years of observation that is two percentage points higher. This historical experience suggests a very powerful response to improvements in educational outcomes, particularly when compared to the average 2.3 percent annual growth within our sampled countries over the past two decades.

Perhaps the easiest way to see the relationship is to plot the marginal impact of knowledge capital on long run growth. Figure 1 depicts the fundamental association graphically, plotting growth in real per-capita GDP between 1960 and 2000 against average test scores after allowing for differences in initial GDP per capita and initial average years of schooling. Countries align closely along the regression line that depicts the positive association between cognitive skills and economic growth.

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[13] See Hanushek and Woessmann (2012a, (2015a) for a more complete description of both the data and the estimation, which extends previous work by Hanushek and Kimko (2000).

[14] To avoid the 2008 global recession, its aftermath, and any potential bubbles building up beforehand, the growth analysis stops in 2000, but results are very similar when extending the growth period to 2007 or 2009; see Hanushek and Woessmann (2015a), Appendix 3A.

This basic relationship underlies the subsequent consideration of what skill improvement would mean for the U.S. economy. Before going to that, however, we provide a discussion of the plausibility of using these estimates as the basis of projections into the future.

B. Causality in Brief

The fundamental question is: should we interpret this tight relationship between cognitive skills and economic growth as a causal one that can support direct policy actions?[15] In other words, if achievement were raised, would we really expect growth rates 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 byproduct of some other factors, is very important from a policy standpoint. It is essential to be confident that, if a country managed to improve its achievement in some manner, it would 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, a change 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 may have, indeed, been suffering from what is known as reverse causality, that is, improved growth was leading to more schooling rather than the reverse.[16] 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

[15] This section summarizes the detailed analysis found in Hanushek and Woessmann (2012a, (2015a).
[16] See, for example, Bils and Klenow (2000).

resources lifting student achievement.[17] Still, it remains difficult to develop conclusive tests of causality with the limited sample of countries included in our analysis.

The best course is to 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, 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. We summarize here our investigations into the potential problems with the prior estimation and their likely severity. These have been more fully reported elsewhere.[18]

First, the estimated relationship is little affected by including other possible determinants of economic growth. In an extensive investigation of alternative model specifications, we employ different measures of cognitive skills, various groupings of countries (including some that eliminate regional differences), and specific sub-periods 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. Of course, there are other possible omitted factors, leading us to go further into the details of international differences.

Second, the most obvious reverse-causality issues arise because our analysis relates growth rates over the period 1960 to 2000 to test scores for roughly the same period. To address this directly, we 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 only, test scores strictly pre-date 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 displayed above. Indeed, this fact itself may be

[17] See the review in Hanushek and Woessmann (2011a).
[18] See the extended discussion in Hanushek and Woessmann (2015a).

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, we cannot be sure that the important international differences in test scores 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. We can nevertheless focus attention just 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).[19] This estimation of the growth relationship 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 that this approach, while guarding against simple reverse causality, cannot eliminate a variety of issues related to omitted factors in the growth regressions.

Fourth, a 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 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 U.S. who have been educated in their home countries and who can be compared to those immigrants educated just in the U.S. 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 schooled in the U.S. see no economic return to home-country test scores, thus pinpointing the value of better schools. These

[19] The formal approach is called "instrumental variables." In order for this to be a valid approach, it must be the case that the institutions are not themselves related to differences in growth beyond their relation with test scores. For a fuller discussion, see Hanushek and Woessmann (2012a).

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 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, we can observe whether or not students seem to be getting better or worse over time. (For more recent periods, we look at changes over time in detail in the concluding section). 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. For 12 OECD countries, we can relate the magnitude of trends in educational performance to the magnitude of trends in growth rates over time.[20] 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.[21] 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 school children 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

[20] Only 12 OECD countries have participated in international tests over a long enough period to provide the possibility of looking at trends in test performance over more than 30 years. The analysis simply considers a bivariate regression of test scores on time for countries with multiple observations. The trends in growth rates are determined in a similar manner: Annual growth rates are regressed on a time trend. The analysis relates the slopes in the test regression to the slopes in the growth rate regression. Hanushek and Woessmann (2012a) consider more complicated statistical relationships, but the overall results hold. They also hold when the sample of countries is expanded to include the non-OECD countries.

[21] It is very unlikely that the changes in growth rates suffer the same reverse causality concerns suggested previously, because a change in growth rate can occur at varying income levels and varying rates of growth.

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.

C. Bad Economic Institutions

There has been an increasing emphasis on the role of economic institutions as the fundamental cause of differences in economic development. But also, for a decade, the roles of societal institutions and of human capital have been much debated in discussions of economic growth and development.[22] Here we consider how attention to various economic institutions affects our picture of the pattern of growth across nations.

Our analysis is not designed to resolve either the debate about the predominance of institutions or other related debates about precise measurement of institutions. Our view is simply that 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. Our concerns at this point again relate to the measurement of human capital in these prior analyses. All of the prior investigations of the interaction between institutions and human capital across countries are analyzed in terms of school attainment, something that we have demonstrated to be a very incomplete measure of the relevant skills of nations.

We have addressed the estimation of how growth is affected by institutions elsewhere and just summarize the results and implications here.[23] Specifically, we consider alternative

[22] In one influential line of research, Acemoglu, Johnson, and Robinson (2001, (2005) have argued that major societal institutions created the fundamental building blocks for modern development (see also Acemoglu, Gallego, and Robinson (2014)). They particularly fixed on the central notion of strong property rights, arguing that the causal role of these institutions could be seen analytically by tracing back to the different colonial paths of countries. On the other hand, Glaeser et al. (2004) have argued that the colonists brought human capital in addition to knowledge of good societal institutions and that it is more likely that better human capital led both to the development of good institutions and higher economic growth.
[23] Hanushek and Woessmann (2015a).

measures of economic institutions within the context of our basic growth models above. Our approach is simply to add two common (and powerful) institutional measures related to the quality of the underlying economic environment to our baseline models: openness of the economy and security of property rights.[24] These measures are jointly significant in explaining growth, and the property rights measure is individually significant.[25] At the same time, though, the results show that cognitive skills continue to exert a positive and highly significant effect on economic growth independent of these measures of the quality of institutions, albeit the estimated impact of cognitive skills is reduced from 2.0 to around 1.3 on average.

The overall interpretation in our context must be nuanced, since the developed nations almost uniformly show no variation in either property rights or openness to international trade. This suggests that developing countries (with restrictive institutions) have room for improving their economic performance by moving toward better institutions. But once they have in fact corrected the imperfect economic institutions, they too must return to relying on knowledge capital for any further improvements in growth.

Importantly, while these macro institutions cannot explain variations in growth among the developed countries, knowledge capital can. Within the OECD, the wide variation in long run growth rates are very closely related to cognitive skills, and the growth coefficient estimated for just OECD countries is very close to that presented in Table 1.[26] Thus, we feel confident in using our previous growth models to project the impact of improvements in achievement in the United States.

What Improved Achievement Means for the U.S.

The main thrust of this paper is showing the impact that improved student achievement would have on the long run operations of the U.S. economy and on the distribution of economic

[24] The measure of openness is the Sachs and Warner (1995) index reflecting the fraction of years between 1960 and 1998 that a country was classified as having an economy open to international trade, based on five factors including tariffs, quotas, exchange rate controls, export controls, and whether or not a socialist economy. Following Acemoglu, Johnson, and Robinson (2001), the measure of security of property rights is an index of the protection against expropriation risk, averaged over 1985-1995, from Political Risk Services, a private company which assesses the risk that investments will be expropriated in different countries. Note that data limitations reduce the sample from 50 countries to 47.

[25] Note that protection against expropriation and openness are strongly correlated, with a simple correlation of 0.71.

[26] Hanushek and Woessmann (2011b)

wellbeing. The growth models provide a clear means of projecting the aggregate economic implications of improvements in schooling. The next section looks at the direct impact on individual earnings.

To set the stage, it is useful to consider where the U.S. falls in terms the world achievement distribution. Figure 2 shows the rankings of countries on the combined mathematics and science scores of PISA for 2009 and 2012.[27] The U.S. was 30th in the world, tied with Latvia and behind a range of countries that the U.S. generally does not view itself as competing with. The figure identifies the position of the U.S. along with the position of Germany, to which we return below.

Our valuation of the economic impact of improved achievement explicitly recognizes the dynamics of schools and of the economy. In particular, we allow time to improve student achievement and time to have students enter the labor market. We then employ the previous growth models to analyze how different the economy having workers with higher skills would be compared to one with workers of current skills.

We consider two improvements in student performance. In the first, the U.S. raises its achievement to that of Germany. In the second, all students with insufficient skills are brought up to at least to a minimal skill level. This later is essential an international analog to No Child Left Behind goals of all students reaching proficiency levels.

A. Projection Model and Parameter Choices

Our projections rely on a simple description of how skills enter the labor market and have an impact on the economy.[28] We consider achievement goals of U.S. students framed as the standard that should be met by 2030, leading us to assume that improvement occurs linearly from today's schooling situation to reaching the goal in fifteen years. But of course the labor force itself will only become more skilled as increasing numbers of new, better trained people enter the labor market and replace the less skilled who retire. We assume that a worker remains in the

[27] A more complete analysis of the U.S. scores along with the rankings of individual U.S. states can be found in Hanushek, Peterson, and Woessmann (2013).

[28] The details of the projection methodology, in somewhat different circumstances, can be found in Hanushek and Woessmann (2010, (2011b, (2015a), where we focused on different policy scenarios (that do not take non-universal enrollment into account) just for OECD countries. Hanushek and Woessmann (2012b) provided projections for European Union countries.

labor force for forty years, implying that the labor force will not be made up of fully skilled workers for 55 years (15 years of reform and 40 years of replacement of retiring, less-skilled workers).

We calculate the growth rate of the economy (according to the estimate of 1.98 percent higher annual growth rate per standard deviation in educational achievement in column 3, Table 1) each year into the future based on the average skill of workers (which changes as new, more skilled workers enter). We then estimate the difference in GDP with an improved workforce versus the existing workforce skills beginning in 2015 until 2095.[29] The projection for 80 years is meant to correspond to the life expectancy of somebody born in 2015.

Future gains in GDP are discounted from the present with a 3 percent discount rate. The resulting present value of additions to GDP is thus directly comparable to the current levels of GDP. We can also compare the gains to the discounted value of projected future GDP without reform to arrive at the average increase in GDP over the 80 years.

B. Two Improvements of U.S. Achievement

We consider the implications of two very straightforward policies. In the first, we look at the long run implications of increasing average U.S. achievement by 25 PISA points by 2030. In the second, we bring all students up to at least a level of minimal skills – a level required to fully participate in today's internationally competitive world.

Table 2 displays what, according to the historical growth relationships, the outcomes of improving the school would be. Bringing U.S. students up by 25 points – almost exactly to the current levels of German students – would have a present value of $62 trillion, or some 3.4 times the value of current U.S. GDP. This increase corresponds to a GDP that is on average for the next 80 years over seven percent above the no-change levels of GDP. Much of this gain comes in the future, with GDP in 2095 being 30 percent higher – but all of the calculations consider present values and weight long future gains less than immediate gains.

[29] The growth of the economy with the current level of skills is projected to be 1.5 percent, or the rough average of OECD growth over the past two decades.

The second row of the table considers bringing all U.S. students to a minimal level of skills.[30] To define this, we use the OECD categories of and define these as skills of youth at age fifteen, or roughly the ninth year of schooling. We assume that fully achieving Level 1 skills represents the minimal skills necessary in order to participate productively in modern economies. The border line between Levels 1 and 2 is 420 points on the PISA mathematics scale.[31] With the mean of 500 and standard deviation of 100 for the OECD countries, this implies performance at the twenty-third percentile of the overall OECD distribution. The U.S. average in math for 2012 was only slightly under the OECD average, leaving 23.5 percent of U.S. 15-year-olds without minimal skills.

The designation of levels of performance correspond to distinct skills of individuals (OECD (2013b)). The descriptions of this performance (for math) are:

> At Level 1, students can answer questions involving familiar contexts where all relevant information is present and the questions are clearly defined. They are able to identify information and to carry out routine procedures according to direct instructions in explicit situations. They can perform actions that are almost always obvious and follow immediately from the given stimuli.

The impact of raising the bottom quarter of the distribution up to a minimal level would be to increase the average U.S. PISA score by 11.7 points.[32] This would yield a present value of $28 trillion, or some 1.5 times the value of our current GDP.

C. Endogenous versus Neoclassical Growth

One of the enduring debates in growth literature is how skills affect the long run development of the economy. At the risk of over-simplifying, one view is that added skills of a society (knowledge capital) leads to enhanced innovation and can support a higher growth rate in the future. The other view is that expanded education and skills enter into economic outcomes

[30] The development of the idea of minimal skills relates directly to our analysis of alternative development goals for world economies. Added details can be found in Hanushek and Woessmann (2015b).

[31] Note that the border between Levels 1 and 2 in science is slightly lower at 407 points (OECD (2013b)). Nonetheless, we use 420 PISA points for both science and math.

[32] For these calculations, we look at the scores that would be required to bring everybody with a score below 420 up to 420, and we assume that no other students were affected.

just as capital and raw labor do.[33] While we cannot distinguish between these views empirically, we can see how much difference adopting one or the other would mean for future economic outcomes.

With a small modification in our basic growth models, it is possible to estimate models consistent with neoclassical growth.[34] When this is done, the impact of differences in knowledge capital is not measurably affected, but the growth path is different. Table 3 shows a direct comparison. Indeed, the present value of improved schooling is lowered when schooling no longer has an impact on the rate of productivity improvement (as in the endogenous growth version). Nonetheless, the long run impact on economic wellbeing remains large and important.

Direct Distributional Issues

Economic growth does not, however, imply that all in society gain. It is possible to have economic gains that do not in particular bring up the bottom of the distribution.

This section begins with a discussion of how changing the skill distribution affects the income distribution. It then considers a broader issue of whether focusing on minimal skills is better than focusing on just the people with the highest level of skills.

A. Skill Variance and Income Variance

In any country, many things enter into the distribution of income that is observed. The character of the labor market, the taxes of the government, the level of welfare and social security programs, and the returns to investments all enter into the distribution of income. But in a modern competitive economy, a fundamental factor in the determination of incomes is the productivity of individuals that will be rewarded in the labor market. Analyzing the full distribution of income is clearly beyond this discussion, but it is possible to use the prior data on the skill distributions to understand how the distribution of productivity and individual earnings might change with obtaining the minimal skills goal.

[33] In empirical application, the endogenous growth view indicates that growth rates should be related to the level of human capital. The neoclassical view is that growth rates are related to the change in human capital.
[34] Empirically this amounts to estimated models with the log of initial GDP instead of the level of GDP. See Hanushek and Woessmann (2015a).

The simple idea is that the distribution of skills is an important ingredient in the distribution of productivity in modern economies, and in competitive economies the distribution of productivity directly affects the earnings of workers. The distribution of labor earnings in turn enters significantly into the distribution of income in society. We consider how the earnings distribution would change if all society members have minimal skills. We consider changes in the skill distribution brought about by our previous policy of ensuring that all youth have minimal skills.

The most direct way to see the impact comes from information about the rewards to skills in the labor market. Information on the labor market earnings is directly available for a number of OECD economies. In its Programme for the International Assessment of Adult Competencies (PIAAC), the OECD sampled a random selection of adults in 24 separate countries in 2011/12 and gave them a series of tests covering cognitive skills in three domains: literacy, numeracy, and problem solving in technology-rich environments. The tasks respondents had to solve were often framed as real-world problems, such as maintaining a driver's logbook (numeracy domain) or reserving a meeting room on a particular date using a reservation system (problem-solving domain). The domains, described more completely in OECD (2013a), refer to key information-processing competencies that are demanded in modern economies.

Using the PIAAC data, it is possible to estimate how different skills affect individual earnings in different countries. It turns out that there is considerable variation across countries.[35] The largest return to skills is, however, found in the United States. The U.S. labor market data indicate that one standard deviation of mathematics achievement yields on average 28 percent higher earnings each and every year of a career.[36] In other words, somebody at the 84th percentile of the mathematics distribution would earn 28 percent more than an average person over the work life. Similarly, and important for this analysis, somebody at the 16th percentile of the mathematics distribution would earn 28 percent less than an average person.

Viewing the changes arising from reaching the goal of universal minimal skills in earnings terms, we can estimate the achievement-induced changes in the earnings distribution.

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[35] See the analysis in Hanushek et al. (2015).

[36] The analysis of the PIAAC data indicates a wide range of returns to math skills – from 28 percent in the U.S. to 12 percent in Sweden.

The increase in average earnings from reaching minimal skills amounts to some 3.3 percent for the United States.[37] Importantly, this is accompanied by a 4.5 percent average reduction in the standard deviation of earnings.[38]

This analysis points to the fact that achieving the goal of universal minimal skills has a complementary impact on reducing gaps in earnings that will filter into income differences in the societies. But it does so while also expanding the size of the economy, as opposed to any simple tax and redistribution scheme that might change the ultimate distribution of income but would not add to societal output. For this reason, knowledge capital policies are desirable in terms of inclusion and achieving a more equitable income distribution.

B. Minimal Skills for All vs. Top Achievers

One aspect of the previous calculations is quite artificial. We consider policies that affect only those youth who would obtain less than minimal skills. The policies are analyzed as if all others were unaffected, and this surely is a very improbable outcome from any school policy. Thus, in this regard the policy scenarios would represent lower bounds on the achievement and economic impacts of policies designed to ensure that all youth reach at least 420 points on the achievement scale, or at least minimal skills.

A second part about the wider performance distribution also deserves attention. Many countries are torn between providing minimal skills and cultivating the very highest achievers. Visually different countries make varying choices about where to focus the attention of their educational systems.[39]

The impact on economic growth of greater proportions of superior achievers compared to that of minimal skills as seen here has been considered in Hanushek and Woessmann (2015a). Instead of relying on just mean skills, that analysis incorporates the share of top achievers (greater than 600 point) and the share of bottom achievers (400 points in that analysis) into the

[37] The earnings gains come from relating the change in skills to earnings through the estimated U.S. earnings parameter of 28 percent per standard deviation.

[38] In calculating the standard deviation of the post-reform distribution, we assign a score of 420 to everybody previously below this level. In reality, instead of all of the people stacked at 420, there would almost certainly be a distribution of scores with a portion of the affected distribution scoring above 420. This would produce an even larger reduction in the standard deviation than calculated here.

[39] See the depictions of distributions of cognitive skills across countries in Hanushek and Woessmann (2015a).

growth modeling. It turns out that both ends of the distribution of a nation's cognitive skills are significantly related to economic growth, either when entered individually or jointly.[40] Both the basic-skill and the top-performing dimensions of educational performance appear separately important for growth. A ten percentage point increase in the share of students reaching basic literacy is associated with 0.3 percentage points higher annual growth, and a ten percentage point increase in the share of top-performing students is associated with 1.3 percentage points higher annual growth.

It is difficult to compare directly 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, as suggested by the fact that the international standard deviations of these two shares are 0.215 and 0.054, respectively. Thus, increasing each share by roughly half a standard deviation (10 percentage points basic-literacy share and 2.5 percentage points top-performing share) yields a similar growth effect of roughly 0.3 percentage points.

The impact of the minimal skills share does not vary significantly with the initial level of development, but the impact of the top-performing share is significantly larger in countries that have more scope to catch up to the initially most productive countries.[41] This appears to reflect the fact that 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. Obvious cases are East Asian countries such as Taiwan, Singapore, and Korea that all have particularly large shares of high-performers, started from relatively low levels, and have shown outstanding growth performances. By looking at the interaction of the top-performing and basic-literacy shares in growth models, it also appears that there is a complementarity between basic skills and top-level skills: in order to be able to implement the imitation and innovation strategies developed by scientists, countries need a workforce with at least basic skills.

Many countries have focused on either basic skills or engineers and scientists. In terms of growth, our estimates suggest that developing basic skills and highly talented people reinforce each other. Moreover, achieving basic literacy for all may well be a precondition for identifying

[40] In the joint model, the two measures are separately significant even though they are highly correlated across countries with a simple correlation of 0.73.

[41] 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 and Phelps (1966)).

those who can reach “rocket scientist” status. In other words, tournaments among a large pool of students with basic skills may be an efficient way to obtain a large share of high performers.

Why has the U.S. done so well?

But is it really all that important to boost student achievement? Does long-term growth in economic productivity within the United States really depend on the quality of the human capital of the next generation? It may be true that economic growth is greater in countries that have higher levels of human capital, as indicated by student achievement, as we showed in chapter two. But is the United States not exempt from the human capital law that ties learning and growth together?

The United States has never done well on international assessments of student achievement. Instead, as described, its level of cognitive skills is only about average among the developed countries. Yet the country’s GDP growth rate has been higher than average over the past century. If cognitive skills are so important to economic growth, how can we explain the puzzling case of the United States? Indeed, in Figure 1, the U.S. lies above the line – getting faster growth than suggested by its achievement levels.

Part of the answer is that the United States comes from other economic advantages that are quite separate and apart from the quality of its schooling. Overall, the United States has generally less intrusion of government in the operation of the economy, including lower tax rates and minimal government production through nationalized industries. The United States maintains generally freer labor and product markets than most countries in the world, there is less government regulation of firms, and trade unions are less powerful than in many other countries. Taken together, these characteristics of the U.S. economy encourage investment, permit the rapid development of new products and activities by firms, reward individuals for invention, and allow U.S. workers to adjust to new opportunities. These features of the U.S. economy are generally viewed as the best economic institutions in the world, something that many other nations are attempting to copy.

It is also the case that, over the 20^{th} century, the expansion of the U.S. education system outpaced the rest of the world. The United States pushed to open secondary schools to all citizens. Higher education also expanded with the development of land grant universities, the G.I. bill, and direct grants and loans to students. The extraordinary U.S. higher-education system is a powerful engine of technological progress and economic growth in the United States not accounted for in our analysis. By most evaluations, U.S. colleges and universities rank at the very top in the world.

Although the strengths of the U.S. economy and its higher-education system offer continuing hope for the future, the situation at the K–12 level has an obvious impact on the higher-education system as well. The U. S. higher-education system will likely be challenged both by the quality of incoming students and by improvements in higher education across the world.

Other countries are working to secure property rights and open their economies, which will enable them to make better use of their human capital. Most obviously, the historic advantage of the U.S. in school attainment has come to an end, as half of the OECD countries now exceed the United States in the average number of years of education their citizens receive. Those trends could easily accelerate in the coming decades.

We have been able to import skilled immigrants from abroad—immigrants who have better skills than our own workers. These immigrants also increasingly populate our colleges and universities and have frequently been induced to stay in the U.S. after their post-secondary schooling. However, our ability to continue with this depends directly both on U. S. immigration policies and its ability to offer better opportunities than other countries. Neither is assured into the future.

In fact, all of the historical advantages over our economic competitors—our commitment to universal secondary school attainment; our strong and well-developed economic system; our secure property rights and free movement of labor and capital; our world's best universities; and our use of skilled immigrants--are likely to go away as many other countries have made great strides in emulating and even surpassing these strengths of the U.S. In the future, we will simply have to rely just on our skills if we are to sustain our current economic standing. In other words, we think that the best projection is that the U.S. falls back to the growth-achievement line in Figure 1, leaving us with the same human capital challenges as other countries.

The advantages of the U.S. economy will not disappear immediately. But that does not mean that we cannot benefit from an improved K-12 schooling system. As we demonstrated in chapter five, the gains that could be expected from improvement are striking. Moreover, these projections, which build on the worldwide experience, may understate the potential advantage of greater human capital to the United States, because the value of added skills is made even greater by its strong political and economic institutions.

Conclusions

One thing stands out from this analysis. Skills govern economic outcomes in the long run, and improvements in skills of U.S. society could effectively solve all of the current fiscal and distributional concerns that are so much in debate today.

This is not the place to consider reform approaches and the many obstacles and arguments against reform proposals.[42] It is useful to point out, however, that reforms of the magnitude that we consider here are possible. Figure 3 shows the average annual gains in scores on the international tests that have been seen in various countries. Fully 20 countries achieved sufficient gains over the period 1995-2009 to obtain 25 point gains on the tests.[43] Of course this is not easy, as indicated by the fact that a number of countries actually regressed in performance over this period.

Our summary perspective is very simple. Both overall economic outcomes and distributional/mobility aspects of these depend crucially on upgrading the skills of U.S. society.

[42] See the discussion in Hanushek, Peterson, and Woessmann (2013).
[43] This figure provides data on score changes for all countries that had participated sufficiently over time.

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Table 1: Basic Growth Regressions, Long Run Growth in Per Capita GDP 1960-2000

	(1)	(2)	(3)
Cognitive skills		2.015***	1.980***
		-10.68	*-9.12*
Initial years of schooling (1960)	0.369***		0.026
	-3.23		*-0.34*
Initial GDP per capita (1960)	-0.379***	-0.287***	-0.302***
	-4.24	*-9.15*	*-5.54*
Constant	2.785***	-4.827***	-4.737***
	-7.41	*-6*	*-5.54*
R^2 (adj.)	0.25	0.73	0.733

Notes: Dependent variable: average annual growth rate in GDP per capita, 1960 to 2000. Cognitive skill measure refers to average score on all international tests 1964 to 2003 in math and science, primary through end of secondary school. t-Statistics in parentheses: statistical significance at *** 1 percent. Source: Hanushek and Woessmann (2015

Table 2. Economic benefits from Improved School

School improvement by 2030	Present value ($bn)	Present value Compared to:		GDP in 2905 compared to no reform	Long-run growth increase	Increase in PISA scores
		Current GDP	Discounted future GDP			
25 point improvement	62,120	340%	7.3%	30%	0.5	25
Universal minimal skills	27,929	153%	3.3%	13%	0.23	11.7

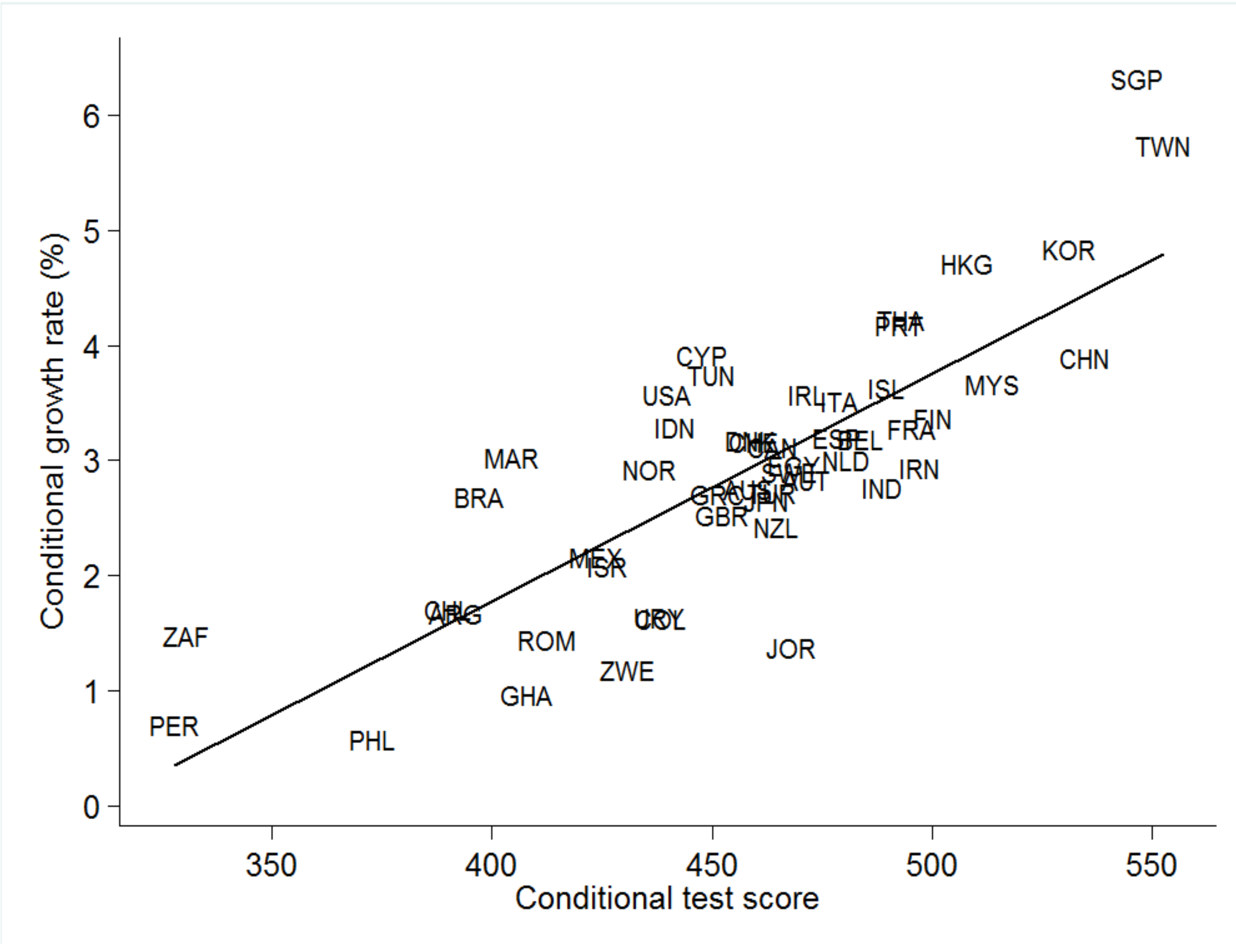
Source: Hanushek and Woessmann (2015b)

Table 3. Economic benefits from Improved School by Projection Model

School improvement by 2030	Endogenous Growth			Neoclassical Growth		
	Present value ($bn)	Present value Compared to:		Present value ($bn)	Present value Compared to:	
		Current GDP	Discounted future GDP		Current GDP	Discounted future GDP
25 point improvement	62,120	340%	7.3%	45,048	246%	5.9%
Universal minimal skills	27,929	153%	3.3%	15,419	84%	2.0%

Source: Hanushek and Woessmann (2015b)

Figure 1: Knowledge capital and economic growth rates across countries



Notes: 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 (2015).

Figure 2. PISA Mathematics plus Science: 2009 and 2012

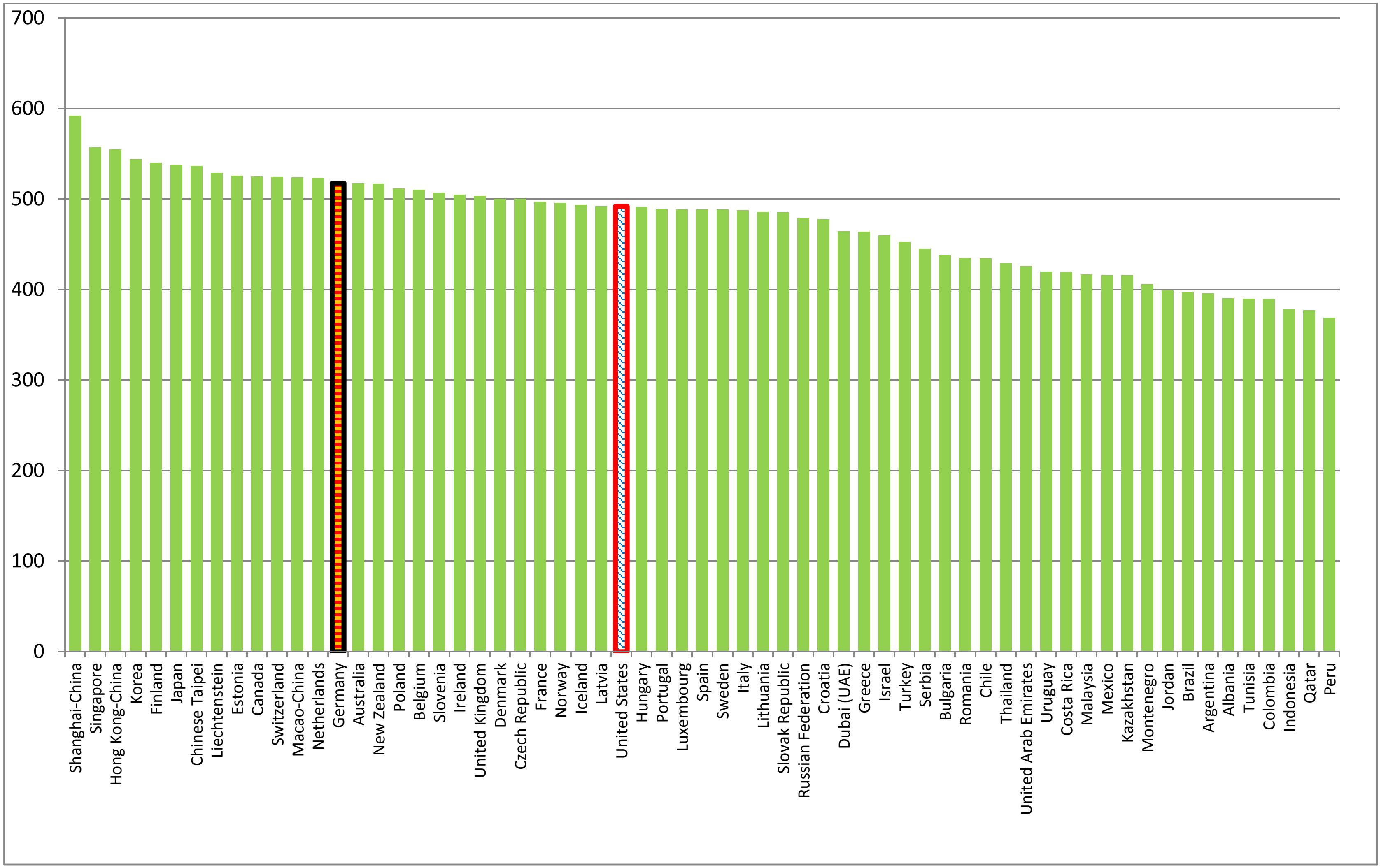
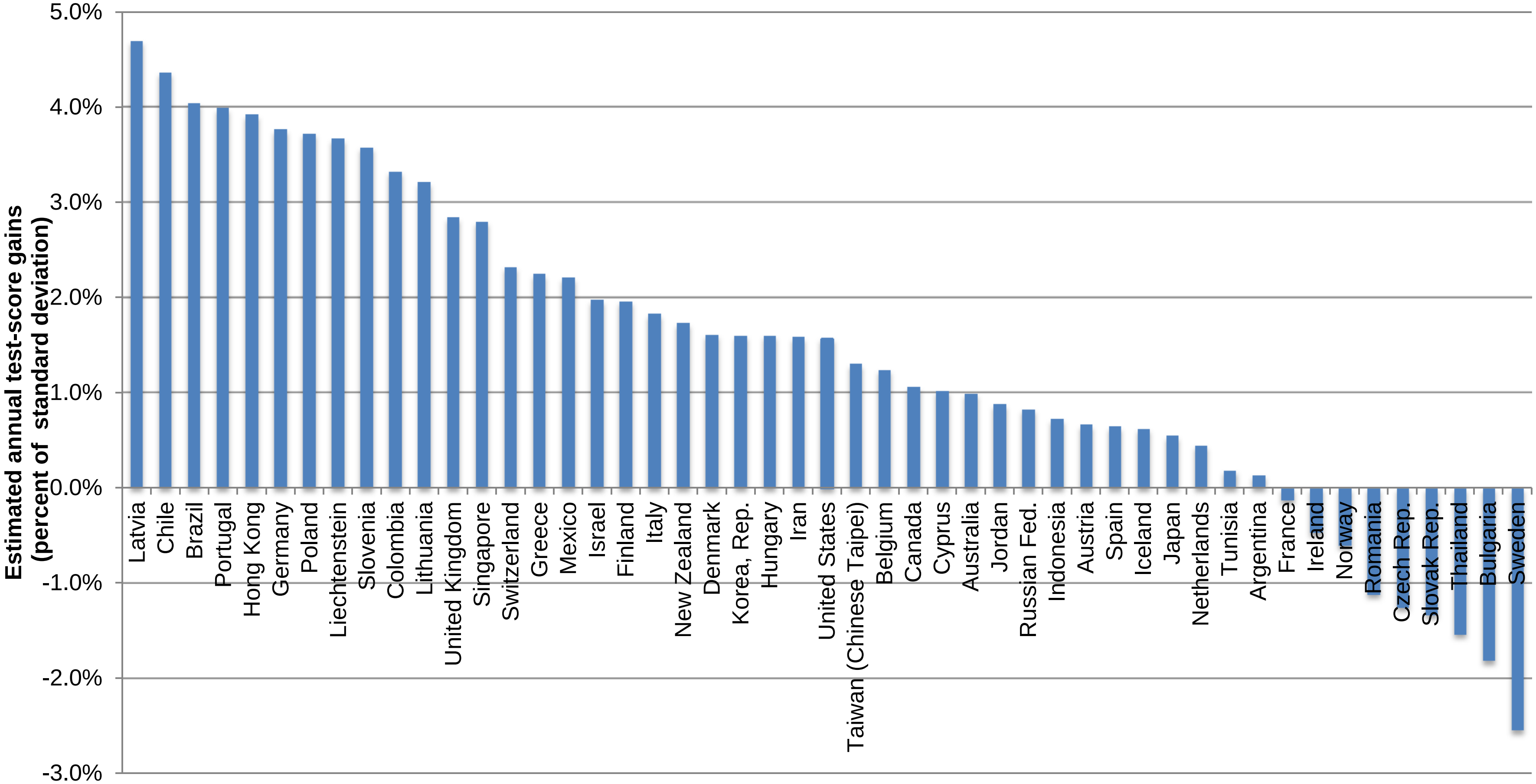


Figure 3: Annual growth in student achievement, 1995-2009



Notes: Estimtaed annual test score change as percent of a standard deviation, based on NAEP, PISA, TIMSS, and PIRLS achievement tests.
Source: Hanushek, Peterson, and Woessmann (2012), Table B.1.