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A quantitative look at the economic impact of the European Union's educational goals*

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ABSTRACT
This paper quantifies the economic benefits of educational improvement covered by the educational goals of the European Union, providing disaggregated projections for each of the EU countries and comparative economic results for alternative policy goals. Increased student achievement by 25 PISA points across the EU would be expected to add €71 trillion in present value to EU GDP over the status quo. By contrast, the more limited EU goal of reducing low achievement to 15 percent by country would have an impact of only €5 trillion. Central to the analysis is careful attention to the dynamics of educational reform.

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Introduction

The changing conditions of the global economy raise concerns among citizens about their future prosperity and that of their societies. New challenges are emerging, including technological changes such as automation and digital transformation, shifting trade patterns and increasing tensions in the global economy, political polarization and rising populism, and increasing concerns about inequality, especially inequality of opportunity. In facing these challenges, the education of the population is a seen as a critical component not only for the economic prosperity of individuals and societies but also for social cohesion. Research supports these views, showing that the educational achievement of students provides the foundation for the skills of the future labor force and that this determines long-term economic growth and future economic wellbeing (Hanushek and Woessmann 2015a). Nonetheless, quantitative assessments of the economic implications of improvements in the educational system are often missing when plans and policies are being formulated and evaluated, raising the possibility of serious distortions in political decision making.

Europe provides an interesting laboratory to investigate broad political goals for education alongside substantial heterogeneity in current performance and in potential economic gains. Serious deficiencies are found in the educational achievement of students across the European Union with substantial variation in how EU Member States perform in terms of the math, science, and reading achievement of their students. These differences are directly related to differences in skills of the future workforce. The lack of convergence in average performance points to increasing economic disparities over time.

In the debate about the future of Europe, the European Commission (2018a) has expressed strong policy interest in strengthening education in Europe. Its Communication 'Building a stronger Europe:

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the role of youth, education and culture policies' emphasizes the role of investments in education and training in empowering Europe's citizens to benefit from the potential offered by new global trends and emerging technologies. However, the generally positive support for more education does not adequately link policies (and the related expenditures) to economic results. Additionally, even when the full economic gains are large, the slow evolution of benefits may work against improvement policies because upfront costs are not appropriately compared to the dynamic stream of benefits.

Overall, the European Union seriously lags behind its own benchmark of reducing the share of low achievers below 15 percent by 2020. In fact, the results of OECD's Programme for International Student Assessment (PISA) in 2015 indicate a step backward compared to the previous PISA wave (European Commission 2016). The share of 15-year-olds who fail to reach PISA level 2 has increased to 20–22 percent in the three domains.[1] These low achievers lack the most basic skills necessary to participate in modern societies.

This paper quantifies the potential consequences of this underachievement for the future prosperity of the European Union and its constituent states. As a quantification of the economic rationale for investing in education and raising standards of educational achievement, it provides up-to-date estimates of how much the European Union would gain, in economic terms, from educational reforms that improve student achievement. Based on the observed historical relationship between educational achievement and growth in gross domestic product (GDP), it projects the future evolution of GDP of EU Member States with improved educational achievement of varying forms and magnitudes. The GDP difference between a projection with the status quo and that with improved educational outcomes provides an estimate of the economic benefits of improved educational achievement.

Extending the methods and potential policies employed in earlier work (Hanushek and Woessmann 2011b), we provide calculations of the cost of low educational achievement in the European Union for the most recently available economic and educational data. We refine previous projection methods to take into account that policies targeted at a student group below (above) a certain achievement threshold are likely to spill over to students just above (below) the threshold. Using estimates of Member States' GDP in 2020 and student achievement in the 2015 PISA test, we provide projections of the economic benefits of improving educational achievement in the European Union over the next 80 years, the expected lifetime of a child born today.

Our projections indicate that insufficient education imparts heavy costs on society and that raising educational achievement will have huge economic benefits for society. We consider alternative scenarios of educational improvement that correspond to current EU policy goals, each of which would be achieved over a period of 15 years:

- Each country would increase the average achievement of its students by 25 PISA points;
- All students achieve minimal skill levels (level 2 on in the OECD's PISA math and science tests), or alternatively the goal of the Strategic Framework for European cooperation in education and training (ET 2020) that only 15 percent fail to reach minimal skills;
- All current early leavers from education improve skills by 25 PISA points (roughly one year of schooling), or alternatively the ET 2020 goals that only 10 percent remain early leavers;
- Top educational performers are expanded to at least 15 percent at level 5 or above on the PISA test in each country.

The calculated aggregate economic benefits of improved educational achievement under the different reform scenarios in terms of gained future GDP growth are truly significant. While not considered here, the enhanced education has commensurate improvements in the economic wellbeing of individuals who now have more skills valued in the labor market (see Hanushek et al. (2015)). Moreover, if economic growth accelerates, these individual rewards are likely to increase (Hanushek et al. 2017).

As background for the projection analysis, the next section provides an overview of macroeconomic research that shows the importance of educational achievement for economic growth.

Next, we describe our simulation model and the parameter choices. In the subsequent sections, we report the results on the economic benefits of increasing educational achievement under the four reform scenarios. The final section concludes.

Background: knowledge capital and economic growth

Education has long been viewed as an important determinant of economic well-being.[2] While early analysis of the role of education emphasized labor market gains to individuals, work over the past quarter-century has brought in the implications of education and skills for national economic growth. The theoretical literature on macroeconomic growth emphasizes at least three mechanisms through which education may affect economic growth.[3] First, education can be viewed as a component of the labor force and as a factor of production that in the aggregate is combined with physical capital to produce a society's GDP. Added human capital for the labor force increases aggregate economic inputs, and the economy would move to a new higher level of output. The economy thus grows as the GDP moves to the higher level implied by increased inputs (as in augmented neoclassical growth theories, e.g. Mankiw, Romer, and Weil (1992)). Second, education can increase the innovative capacity of the economy, and the development of new technologies, products and processes promotes faster growth (as in theories of endogenous growth, e.g. Lucas (1988), Romer (1990), Aghion and Howitt (1998)). Third, education can facilitate the diffusion and transmission of knowledge needed to understand and process new information and to implement successfully new technologies devised by others, which again promotes economic growth (e.g. Nelson and Phelps (1966)).

Empirical growth models

Following the seminal contributions by Barro (1991) and Mankiw, Romer, and Weil (1992), a vast empirical literature focused on schooling quantity in cross-country growth regressions, albeit with mixed results (see, e.g. Krueger and Lindahl (2001) and Pritchett (2006) for reviews). However, using average years of schooling as an education measure implicitly assumes that a year of schooling delivers the same increase in knowledge and skills regardless of the education system. It also assumes that all skills and human capital come from formal schooling, even though extensive evidence on knowledge development and cognitive skills indicates that a variety of factors outside of school – family, peers, and others – have a direct and powerful influence.

Hanushek and Kimko (2000) first incorporated measures of cognitive skills based on the international tests of student performance preceding PISA into growth analysis and showed that this dramatically alters the assessment of the role of education in economic development. The evidence from an increasing number of studies suggests that the quality of education, measured by the knowledge that students gain on tests of cognitive skills, is substantially more important for economic growth than the mere quantity of schooling (see Hanushek and Woessmann (2008) for a review).

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 analysis below is based on the empirical growth model previously developed and presented in Hanushek and Woessmann (2015a). In this, an aggregate measure of cognitive skills is developed from international tests of math and science between 1964 and 2003 and scaled like PISA today (see also Hanushek and Woessmann (2016)). This measure of the cognitive skills of a country – which in the aggregate we refer to as the 'knowledge capital' of nations – relies on the average standardized test scores from each country's historical participation in the tests, interpreted as a proxy for the average skills of the whole labor force. The growth model combines these skill measures with the average years of school attainment and the initial level of GDP in each country in order to explain the average annual growth rate in real per-capita GDP between 1960 and 2000 for 50 countries.[4]

We interpret the test scores as an index of the human capital of the populations (and workforce) of each country. This interpretation of 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.[5]

Cognitive skills are strongly associated with economic growth. The estimated growth model that is the basis of the economic projections is presented in Appendix Table A1 (see Supplementary material), column 3. 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.[6] However, once the test measure of human capital is included (columns 2 and 3), cognitive skills are highly significant while years of schooling become statistically insignificant and the estimated schooling 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 human capital is measured by cognitive skills rather than years of schooling.

Figure 1 depicts the fundamental association graphically, plotting the long-run growth rates in per-capita GDP against average test scores, after allowing for differences in initial per-capita GDP and average years of schooling. Countries align closely along the regression line that depicts the positive association between cognitive skills and economic growth.

This historical experience suggests a very powerful response to improvements in education outcomes. The estimated coefficient on cognitive skills implies that an increase of one standard deviation in educational achievement (i.e. 100 score points on the PISA scale) yields an average annual growth rate over the 40 years of observation that is 1.98 percentage points higher. This parameter estimate forms the basis of our projections of the benefits of improved schooling.

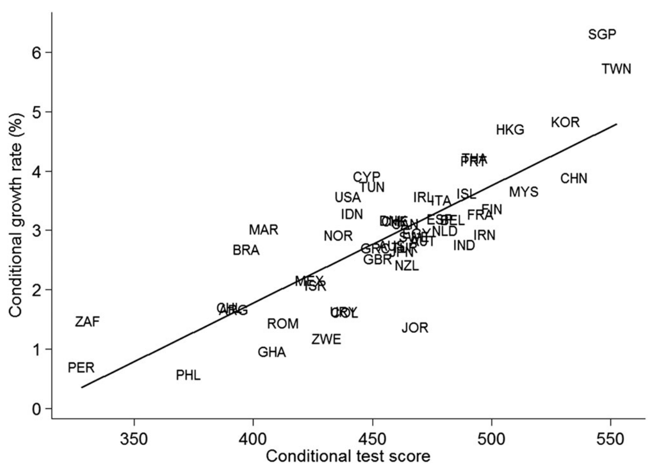

Figure 1. Knowledge capital and economic growth rates across countries, 1960–2000. Notes: Added-variable plot of the regression of the average annual rate of growth (in percent) of real GDP per capita in 1960–2000 on average test scores on international student achievement tests, average years of schooling in 1960, and initial level of real GDP per capita in 1960 shown in column 3 of Appendix Table A1 (see Supplementary material) (mean of unconditional variables added to each axis). Source: Hanushek and Woessmann (2015a).

Causality

It is, of course, essential to understand whether these estimates can be interpreted as representing a causal relationship. If policies are to be based on the results, it is essential that one can reasonably assume that growth rates will improve when student achievement is improved. A major concern with empirical growth modeling is that the estimated relationships may not measure causal influences but instead reflect reverse causation, omitted variables, cultural differences, and the like. This concern has been central to the interpretation of much of the prior work in empirical growth analysis, and indeed some have rejected the entire body of work on the basis of concerns about causation. Fully considering these issues goes beyond what can be presented here (see Hanushek and Woessmann (2012a, 2015a)), but it is possible to give some sense of the issues and their resolution.

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

It is possible to address the main causation concerns with a series of additional analyses, even if none of the tests is completely conclusive. To rule out simple reverse causation, Hanushek and Woessmann (2012a) estimate the effect of scores from tests conducted until the early 1980s on economic growth in 1980–2000, finding an even larger effect of knowledge capital.

Additional analysis finds that the international test scores of US immigrants' home country significantly explain their earnings on the US labor market, but only for those immigrants educated in their home country and not for those educated in the US. This finding addresses issues of cultural differences, because immigrants from the same country (but educated differently) are directly compared. By observing impacts within a single labor market, it also addresses possible concerns that countries with well-functioning economies also have good schools without the good schools driving growth.

Another analysis shows that changes in test scores over time are systematically related to changes in growth rates over time. In other words, it implicitly holds the country constant while looking at whether changing scores have the hypothesized impact on changing growth rates.

Finally, it is possible to exploit institutional features of school systems as instrumental variables for test performance. By employing only the variation in test outcomes emanating from country differences because of the use of central exams, decentralized decision making, and shares of privately operated schools, this instrumental variable approach both increases confidence in the possibility of a causal interpretation and suggests that schooling can be a policy instrument contributing to economic outcomes.

While concerns about issues of causation still remain, the tests that have been done provide a *prima facie* case that improving the knowledge capital of a country can be expected to improve economic growth. Each of the causation tests points to the plausibility of a causal interpretation of the basic models. As a consequence of this causality analysis, we believe that it is reasonable to move to an analysis of the economic implications of improving a nation's knowledge capital. Moreover, 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 also 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 simulation model

Discussions of education policy frequently neglect consideration of the dynamics of educational improvement and of the impact on economic outcomes. Improving schools takes time, and the results of policy changes do not appear instantly. Further, it takes time until the more skilled people coming out of the improved schools have a significant impact on the economy. Without fully considering the dynamics, substantial decision errors can be introduced to policy development. Some people expect educational changes to lead immediately to improved economic outcomes, an expectation surely to be dashed quickly after any reform is begun. Other people just see the delays and assume that the impact of any policies is so far in the future that the economic value of gains is very small. That too is an inappropriate view.

The projections here are designed to portray the time to improvement and the time to impact more accurately. The important result of this analytical treatment of the dynamics is that the long-run impact of schools on the economic wellbeing of countries comes through strongly. While not instantaneous, the results of school improvement are startlingly large.

The estimate of the empirical growth model discussed above suggests that each standard deviation in educational achievement relates to 1.98 percent higher annual growth in GDP. This estimate allows us to simulate how future growth rates of the economy would develop after an increase in educational achievement.[7] In doing so, we assume that the marginal growth effect of improved achievement is independent of the initial average achievement level of a country and of the part of a country's overall skill distribution in which it is achieved.

For each of the 28 EU Member States, we measure student achievement on the most recent PISA test of 2015 (OECD 2016).[8] We use the underlying micro database to model the different reform scenarios that depict how students improve due to alternative policy reforms. As the underlying growth research uses average math and science skills, the projections are also based on average achievement in these two subjects.[9]

The base year of the projections is 2020. Estimates of countries' GDP in 2020 are provided by the International Monetary Fund (2019). The GDP figures are based on purchasing power parity (PPP) calculations in current international dollars and are converted into euros using the reference exchange rate over the past half-year provided by the European Central Bank (1 EUR = 1.1391 USD). The time horizon of the projections is taken as the life expectancy of a child born today, i.e. an 80-year period. Accordingly, the projections span from 2020 to 2100. We will also report results of shorter projections over a 40-year period.

We project how the GDP of each EU country would develop without and with improved educational achievement. In the status quo situation (without policy change), the future growth rate of the economies at current skill levels is projected to be 1.5 percent, which is roughly the average growth of GDP per capita for OECD countries over the past two decades. Future GDP values and future gains in GDP are discounted to the present with a 3 percent discount rate.[10] All projected values of future GDP and GDP gains are reported in present value terms and are thus directly comparable to the current levels of GDP.

The projections of future GDP trajectories with improved educational achievement after educational reforms rely on a simple description of how skills enter the labor market and have an impact on the economy. As educational reforms cannot improve schools overnight, the analysis assumes that improvements occur linearly from today's schooling situation to attainment of the respective policy scenario in 15 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 individuals who retire. The analysis assumes that a worker remains in the labor force for 40 years, implying that the labor force will not be made up of fully skilled workers until 55 years have passed (15 years of reform and 40 years of replacing less-skilled workers as they retire).

The growth rate of the economy is calculated each year into the future based on the average skills of workers (which change as new, more skilled workers enter), multiplied by the historic estimate of how skills affect annual growth. The difference between the projected future GDPs with status-quo skills and those with the improved workforce, i.e. the gain in GDP due to the reform, then provides an estimate of the economic value of the reform, or the economic benefit of improved educational achievement.

In what follows, we provide results of projections of the economic benefits of four different policy reform scenarios. Scenario 1 increases the average achievement of all students. Scenario 2 focuses on improvements among particularly low achievers. Scenario 3 reduces early school leaving. Scenario 4 focuses on improvements among top-performing students.

Scenario 1: the economic benefits of increasing average achievement

The first policy scenario considers an improvement of the educational achievement that is obtained on average across all 15-year-old students. The size of the improvement, achieved gradually over a 15-year period (i.e. by 2035), amounts to 25 PISA points, or a quarter of a standard deviation. As a rule of thumb, one-quarter to one-third of a standard deviation is roughly equivalent to what an average student learns during one school year. Accomplishing such an improvement on average across all 15-year-old students is clearly an achievement, but one that Portugal, Poland, and Germany in fact realized in math over comparable periods of time from 2000 to 2015. A 25-point increase is roughly equivalent to the average achievement difference between the United Kingdom (501) and top-performing Estonia (527), between bottom-performing Cyprus (435) or Romania (439) and Slovakia (468), or between Croatia (470) and Austria or Portugal (496) (see Appendix Table A2, Supplementary material). While improving by 25 points might seem particularly challenging for countries that are already performing at a very high level, even Estonia's current achievement level is still 33 points below the score achieved in Singapore, the top performer outside of Europe.

Table 1 shows the results of how this improvement would affect the GDP trajectories of EU countries. The value of the reform for the EU 28 amounts to € 71 trillion over the 80-year period.[11] Note that this improvement of 25 points has a uniform effect on all countries when viewed relative to their respective GDP. The present value of added GDP would be 340 percent of a country's current GDP, or 7.3 percent higher average GDP over the entire 80 years of the projection. By 2100, GDP would be 30 percent higher than that expected with today's skill levels, representing the result of an annual growth rate that, in the end, is 0.5 percentage points higher.

Of course, the total value of the added GDP differs by the size of the economy (see also Figure 2). For instance, the largest economy, Germany, would see a present value of gains of over € 14 trillion, while smaller countries such as Greece, Hungary, Ireland, and Portugal would see gains just above € 1 trillion.

The analysis of economic effects of education requires a long-run perspective, as impacts will not be evident until the presence of higher-achieving students starts becoming significant in the labor market. Therefore, the baseline projections take an 80-year perspective, the lifetime of a child born today. Initial impacts are very small, and the effects keep increasing over the period. Still, taking a 40-year period, scenario 1 would already yield over € 11 trillion (present value) of added GDP in the EU by 2060 (see Appendix Table A3, Supplementary material). While reflecting substantial gains, this value over the first half of the entire period is only 16 percent of the ultimate entire gain. But, as should be obvious, getting these future gains requires beginning reforms now. It is not possible to wait until sometime in the future to start and still get these improvements. There will always be a slow initial period while the schools improve and while the future labor force is being developed.

Scenario 2: the economic benefits of achieving universal basic skills

While the first scenario refers to average achievement levels, the second scenario analyses compensatory policies that target improvement at the bottom of the achievement distribution. Many EU countries still have a very large share of 15-year-olds who are 'low achievers' in basic skills, defined as those who scored below proficiency level 2 on the PISA tests (European Commission

Table 1. Effect on GDP of Scenario 1: Increasing average performance by 25 PISA points.

	Value of reform (bn €)	In % of current GDP	In % of discounted future GDP	GDP increase in year 2100	Long-run growth increase	Increase in PISA score
Austria	1494	340%	7.3%	30%	0.50	25.0
Belgium	1758	340%	7.3%	30%	0.50	25.0
Bulgaria	535	340%	7.3%	30%	0.50	25.0
Croatia	350	340%	7.3%	30%	0.50	25.0
Cyprus	113	340%	7.3%	30%	0.50	25.0
Czechia	1300	340%	7.3%	30%	0.50	25.0
Denmark	967	340%	7.3%	30%	0.50	25.0
Estonia	146	340%	7.3%	30%	0.50	25.0
Finland	825	340%	7.3%	30%	0.50	25.0
France	9511	340%	7.3%	30%	0.50	25.0
Germany	14,064	340%	7.3%	30%	0.50	25.0
Greece	1014	340%	7.3%	30%	0.50	25.0
Hungary	1014	340%	7.3%	30%	0.50	25.0
Ireland	1264	340%	7.3%	30%	0.50	25.0
Italy	7585	340%	7.3%	30%	0.50	25.0
Latvia	190	340%	7.3%	30%	0.50	25.0
Lithuania	318	340%	7.3%	30%	0.50	25.0
Luxembourg	219	340%	7.3%	30%	0.50	25.0
Malta	70	340%	7.3%	30%	0.50	25.0
Netherlands	3167	340%	7.3%	30%	0.50	25.0
Poland	3977	340%	7.3%	30%	0.50	25.0
Portugal	1055	340%	7.3%	30%	0.50	25.0
Romania	1704	340%	7.3%	30%	0.50	25.0
Slovakia	641	340%	7.3%	30%	0.50	25.0
Slovenia	251	340%	7.3%	30%	0.50	25.0
Spain	6035	340%	7.3%	30%	0.50	25.0
Sweden	1757	340%	7.3%	30%	0.50	25.0
United Kingdom	9701	340%	7.3%	30%	0.50	25.0
EU 27 (w/o UK)	61,326	340%	7.3%	30%	0.50	25.0
EU 28	71,027	340%	7.3%	30%	0.50	25.0

Notes: Discounted value of future increases in GDP until 2100 due to the reform, expressed in billion Euro (PPP), as a percentage of current GDP, and as a percentage of discounted future GDP. 'GDP increase in year 2100' indicates by how much GDP in 2100 is higher due to the reform (in %). 'Long-run growth increase' refers to increase in annual growth rate (in percentage points) once the whole labor force has reached higher level of educational achievement. 'Increase in PISA score' refers to the ultimate increase in educational achievement due to the reform. See text for reform parameters.

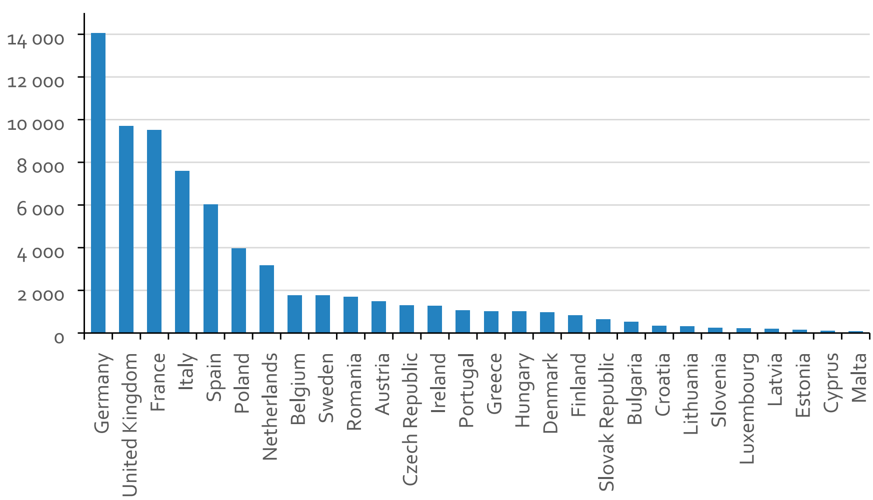

Figure 2. Effect on GDP of Scenario 1: Increasing average performance by 25 PISA points (in billion Euro). Notes: Discounted value of future increases in GDP until 2100 due to the reform, expressed in billion Euro (PPP). See Table 1 for details.

2017b).[12] This skill level is assumed to represent the minimal skills necessary for participating productively in modern economies. Students who do not reach it will most likely face serious difficulties in their educational career, in the labor market, and in everyday life. Under scenario 2, all children would achieve at least these baseline skills by 2035, making it equivalent to achieving 'universal basic skills' (Hanushek and Woessmann 2015b).

With a policy targeted at a specific subpopulation of students, it is difficult to think of the reform program precisely reaching just those below level 2 while not affecting anybody at level 2. Almost certainly any realistic policy would also spill over to other students. Thus, in contrast to ignoring such spillovers as in previous simulation models, we propose a methodological refinement to account for reform effects on other marginal students. While somewhat arbitrary, we assume that some students starting just above the level 2 boundary receive half of the impact that those starting below level 2 received. We allow for this spillover to affect half the number of students directly affected by the basic compensatory policy in each country – assuming implicitly that the smaller the group needing compensatory policies, the easier it is to target them.

Table 2 presents the projected gains for each country under scenario 2. Aggregated for the entire EU 28, the value of the reform amounts to € 38 trillion. The added GDP is equivalent to 181 percent of current EU GDP, or 3.9 percent of the discounted GDP over the entire projection period. By the end of the period, annual EU GDP would be 16 percent higher due to the reform.

For each country, the value of the reform is not just determined by the size of its economy but also by the share of under-achieving students and their distance from the basic-skill level. France and Germany still see the largest present value of gains because of the size of their economies (see Figure 3, panel A). But relative to their current GDP, the largest gains are obtained by currently low-achieving countries. For example, the value of the reform is at least three times the current GDP in Cyprus (where currently 42 percent of students fail to reach level 2), Bulgaria (40 percent), Malta (31 percent), Romania (39 percent), Greece (34 percent), and the Slovakia (29 percent) (see Figure 3, panel B). In these six countries, as well as in Hungary and Croatia, the reform would increase the projected GDP over the entire 80-year period by more than 5 percent on average (see Figure 3, panel C).

This compensatory policy does go beyond EU goals which call for reducing those without basic skills to less than 15 percent of students (ET 2020 target, European Commission (2018b)). Clearly, this more limited policy would have less impact on country economies. We consider a modified compensatory policy that ensures at most 15 percent of students remains below level 2 on a country-by-country basis by 2035. (Note that three countries – Denmark, Estonia, and Finland – currently already have less than 15 percent of their students below level 2, and Ireland and Slovenia have just over 15 percent). Again, feasible policies would undoubtedly spill over both to those just above the level 2 cut-off and to those in the bottom 15 percent. For illustrative purposes, we assume that there are spillovers in the educational improvement to all of the bottom group below the 15th percentile and to a group at the low end of the level 2 students equal to half the size of the low achievers moving above the level 2 boundary. The achievement spillovers are assumed equal to half of the impact on the target population, i.e. they are proportional to the size of the compensatory education reform program. This modified compensatory policy yields gains of € 5 trillion (see Appendix Table A5, Supplementary material).

Scenario 3: the economic benefits of enhancing skills of early school leavers

The third scenario refers to another official EU target, which is to reduce early school leaving. The European Commission (2017a) defines early school leavers as

> people aged 18 to 24 fulfilling two conditions: (1) the highest level of education or training they have attained is ISCED 0, 1, or 2 [i.e. do not obtain a certificate of upper secondary education]; (2) they did not receive any education or training in the 4 weeks before the survey.

In most countries, school dropout happens only after age 15, when students are tested in PISA.[13]

Table 2. Effect on GDP of Scenario 2: Achieving universal basic skills.

	Value of reform (bn €)	In % of current GDP	In % of discounted future GDP	GDP increase in year 2100	Long-run growth increase	Increase in PISA score
Austria	823	187%	4.0%	16%	0.28	14.2
Belgium	923	178%	3.8%	15%	0.27	13.6
Bulgaria	771	489%	10.5%	44%	0.69	34.9
Croatia	253	245%	5.2%	21%	0.36	18.4
Cyprus	165	496%	10.6%	44%	0.70	35.3
Czechia	673	176%	3.8%	15%	0.27	13.4
Denmark	302	106%	2.3%	9%	0.16	8.2
Estonia	26	61%	1.3%	5%	0.09	4.8
Finland	228	94%	2.0%	8%	0.14	7.3
France	6052	216%	4.6%	19%	0.32	16.3
Germany	5734	139%	3.0%	12%	0.21	10.7
Greece	1047	351%	7.5%	31%	0.51	25.7
Hungary	779	261%	5.6%	23%	0.39	19.5
Ireland	398	107%	2.3%	9%	0.16	8.3
Italy	4587	205%	4.4%	18%	0.31	15.6
Latvia	76	136%	2.9%	12%	0.21	10.5
Lithuania	198	211%	4.5%	18%	0.32	16.0
Luxembourg	147	227%	4.9%	20%	0.34	17.2
Malta	85	408%	8.7%	36%	0.59	29.6
Netherlands	1327	142%	3.0%	12%	0.22	10.9
Poland	1427	122%	2.6%	10%	0.19	9.4
Portugal	539	174%	3.7%	15%	0.26	13.3
Romania	1910	381%	8.1%	34%	0.55	27.8
Slovakia	598	317%	6.8%	28%	0.46	23.4
Slovenia	85	116%	2.5%	10%	0.18	8.9
Spain	2927	165%	3.5%	14%	0.25	12.6
Sweden	1001	193%	4.1%	17%	0.29	14.7
United Kingdom	4818	169%	3.6%	14%	0.26	12.9
EU 27 (w/o UK)	33,080	183%	3.9%	16%	0.32	16.3
EU 28	37,898	181%	3.9%	16%	0.32	16.2

Notes: Discounted value of future increases in GDP until 2100 due to the reform, expressed in billion Euro (PPP), as a percentage of current GDP, and as a percentage of discounted future GDP. 'GDP increase in year 2100' indicates by how much GDP in 2100 is higher due to the reform (in %). 'Long-run growth increase' refers to increase in annual growth rate (in percentage points) once the whole labor force has reached higher level of educational achievement. 'Increase in PISA score' refers to the ultimate increase in educational achievement due to the reform. See text for reform parameters.

Scenario 3 models a reform that helps a share of students equal to the current extent of early school leaving in each country, lifting the achievement of these potential early school leavers by 25 PISA points. This projection relates directly to an average increase in schooling for potential school leavers of approximately one year, affecting as many students as the current number of early school leavers and going far beyond the ET 2020 goal. Data on the number of early school leavers (see Appendix Table A2, Supplementary material) is taken from the European Commission (2017a).

Table 3 reports the results of the projections under scenario 3. The economic gain from such a reform would amount to € 7 trillion. This is equivalent to about a third of the EU's current GDP, or 0.7 percent of the discounted future GDP over the entire projection period.

In absolute values, the gains are particularly large for large Member States with shares of early school leavers larger than 10 percent – Germany, Spain, the United Kingdom, and Italy – where gains are about € 1 trillion each (see Figure 4, panel A). Relative to GDP, gains are particularly large for the three countries with shares of early school leavers close to 20 percent – Malta, Spain, and Romania (see Figure 4, panel B).

While scenario 3 models improvements for all early school leavers, this overstates the ET 2020 benchmark that is to reduce the share of early school leavers to less than 10 percent. Appendix Table A6 (see Supplementary material) reports results of a variant of this scenario that would leave up to 10 percent of early school leavers unaffected in each country. Only the 11 EU countries with shares of early school leavers exceeding 10 percent would be affected by this reform at all, and

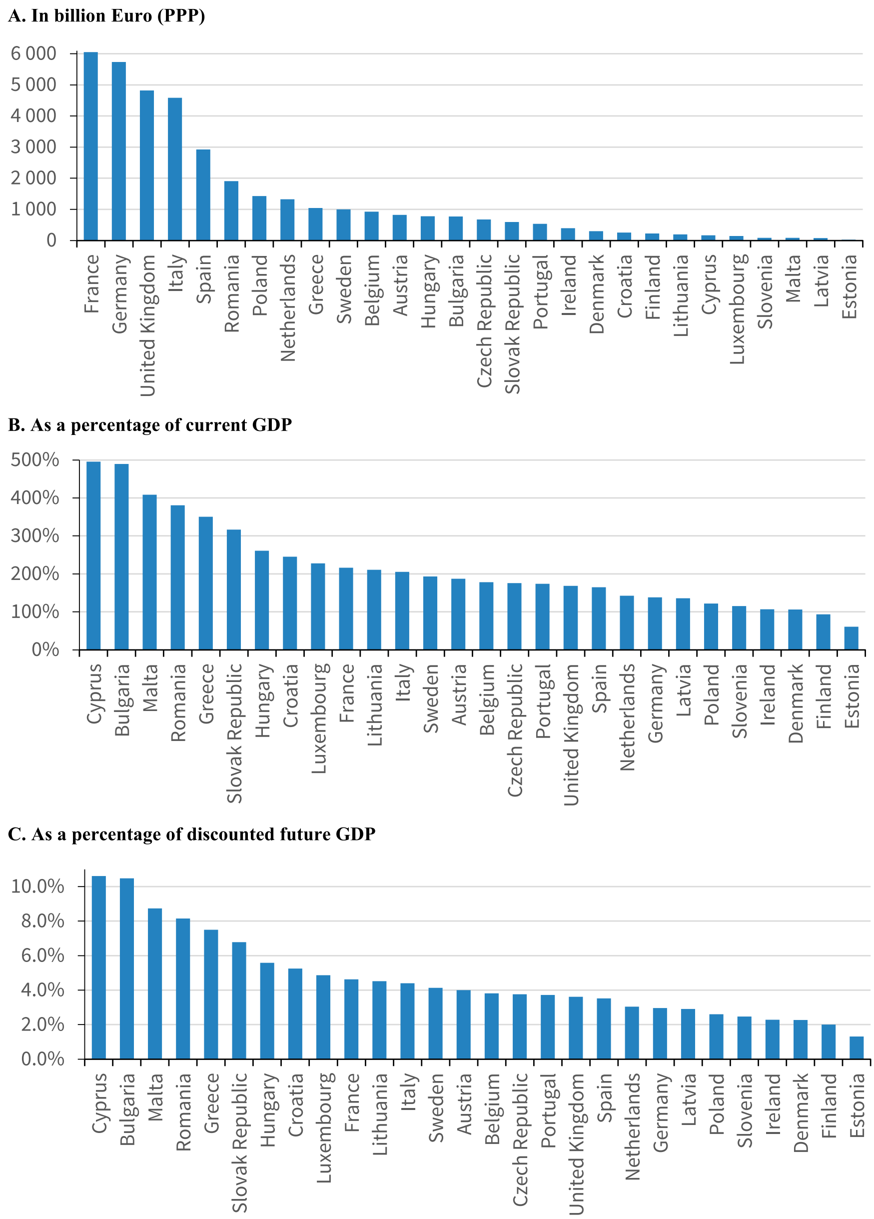

Figure 3. Effect on GDP of Scenario 2: Achieving universal basic skills. A. In billion Euro (PPP), B. As a percentage of current GDP, C. As a percentage of discounted future GDP. Notes: Discounted value of future increases in GDP until 2100 due to the reform, expressed in billion Euro (PPP), as a percentage of current GDP, and as a percentage of discounted future GDP. See Table 2 for details.

most of them to only a relatively small extent. Accordingly, the value of such a more limited reform would amount to € 1 trillion in the entire EU.

Scenario 4: the economic benefits of increasing top performance

Previous analysis has shown that economic growth is improved both by ensuring that all students have basic skills and by increasing the top portion of the achievement distribution. Gains from

Table 3. Effect on GDP of Scenario 3: Enhancing skills of early school leavers.

	Value of reform (bn €)	In % of current GDP	In % of discounted future GDP	GDP increase in year 2100	Long-run growth increase	Increase in PISA score
Austria	96	22%	0.5%	2%	0.03	1.7
Belgium	144	28%	0.6%	2%	0.04	2.2
Bulgaria	69	44%	0.9%	4%	0.07	3.5
Croatia	9	9%	0.2%	1%	0.01	0.7
Cyprus	8	24%	0.5%	2%	0.04	1.9
Czechia	80	21%	0.4%	2%	0.03	1.7
Denmark	65	23%	0.5%	2%	0.04	1.8
Estonia	15	35%	0.7%	3%	0.05	2.7
Finland	61	25%	0.5%	2%	0.04	2.0
France	780	28%	0.6%	2%	0.04	2.2
Germany	1352	33%	0.7%	3%	0.05	2.6
Greece	59	20%	0.4%	2%	0.03	1.6
Hungary	118	39%	0.8%	3%	0.06	3.1
Ireland	74	20%	0.4%	2%	0.03	1.6
Italy	980	44%	0.9%	4%	0.07	3.5
Latvia	18	32%	0.7%	3%	0.05	2.5
Lithuania	14	15%	0.3%	1%	0.02	1.2
Luxembourg	11	17%	0.4%	1%	0.03	1.4
Malta	13	63%	1.3%	5%	0.10	4.9
Netherlands	236	25%	0.5%	2%	0.04	2.0
Poland	192	16%	0.4%	1%	0.03	1.3
Portugal	138	45%	1.0%	4%	0.07	3.5
Romania	296	59%	1.3%	5%	0.09	4.6
Slovakia	44	23%	0.5%	2%	0.04	1.9
Slovenia	11	15%	0.3%	1%	0.02	1.2
Spain	1077	61%	1.3%	5%	0.09	4.8
Sweden	121	23%	0.5%	2%	0.04	1.9
United Kingdom	1015	36%	0.8%	3%	0.06	2.8
EU 27 (w/o UK)	6082	34%	0.7%	3%	0.05	2.7
EU 28	7097	34%	0.7%	3%	0.05	2.7

Notes: Discounted value of future increases in GDP until 2100 due to the reform, expressed in billion Euro (PPP), as a percentage of current GDP, and as a percentage of discounted future GDP. 'GDP increase in year 2100' indicates by how much GDP in 2100 is higher due to the reform (in %). 'Long-run growth increase' refers to increase in annual growth rate (in percentage points) once the whole labor force has reached higher level of educational achievement. 'Increase in PISA score' refers to the ultimate increase in educational achievement due to the reform. See text for reform parameters.

improving top performers reflect the importance of scientific and intellectual leadership in each country.

To capture the role of increased leadership, we project the economic impact of ensuring that each country has at least 15 percent of its students reaching level 5 or above in math and science by 2035.[14] In 2015, 9.2 percent of the EU student population reached this advanced level (on average across math and science), ranging from 2.0 percent in Romania to 13.9 percent in Estonia. For simulation purposes, we again assume that any program to expand top performers has broader impacts past the group starting lower and lifted up to level 5 and that the spillovers are proportional to the size of the program needed to achieve the basic level 5 goal. We assume that half of those already at level 5, as well as a group below the treated group and equal to half the size of the treated group, will get an improvement with half the score impact.

Table 4 shows the economic impact of policies aimed at boosting the top achieving group. Note that these policies again have limited impact on the highest performing EU countries, since they are already at or close to having 15 percent at level 5. The aggregate impact is € 4.6 trillion, 22 percent of current EU GDP.

Across countries, the absolute value of the reform is highest in Italy, Romania, and Spain at more than € 600 million each (see Figure 5, panel A). Relative to the current size the economy, Romania, Cyprus, Greece, and Bulgaria would gain the most (see Figure 5, panel B). These are the countries where currently less than 4 percent of students reach level 5. The relative effect is lowest in

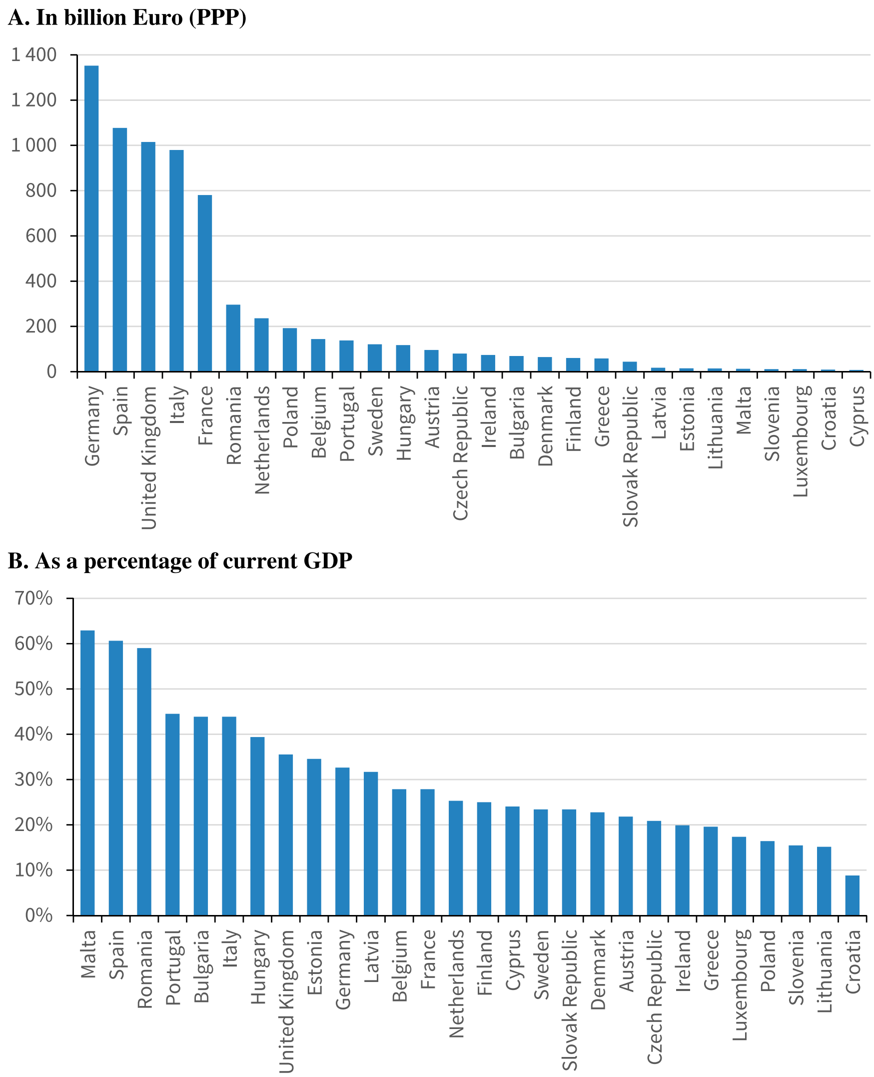

Figure 4. Effect on GDP of Scenario 3: Enhancing skills of early school leavers. A. In billion Euro (PPP), B. As a percentage of current GDP. Notes: Discounted value of future increases in GDP until 2100 due to the reform, expressed in billion Euro (PPP) and as a percentage of current GDP. See Table 3 for details.

Estonia, Finland, and the Netherlands, where already more than 13 percent reach level 5 (on average across math and science).

When considering programs for the top of the distribution, it is important to note that the current performance of the top EU countries does not equal the top from other parts of the world. Currently, Singapore and Taiwan have greater than 20 percent at level 5 or above, and Japan, Hong Kong, Korea, and Macao have greater than 15 percent, implying that there is room for feasible improvement even in the top EU countries.

Summary and policy conclusions

The overarching conclusion of our analysis is that improvement of schools that boosts student achievement can have enormous impacts on the future economic wellbeing of EU countries. While the results of improvement take time before they are fully realized, the present value of

Table 4. Effect on GDP of Scenario 4: Increasing top performance.

	Value of reform (bn €)	In % of current GDP	In % of discounted future GDP	GDP increase in year 2100	Long-run growth increase	Increase in PISA score
Austria	71	16%	0.3%	1%	0.03	1.3
Belgium	61	12%	0.3%	1%	0.02	0.9
Bulgaria	124	79%	1.7%	7%	0.12	6.2
Croatia	58	56%	1.2%	5%	0.09	4.4
Cyprus	37	111%	2.4%	9%	0.17	8.6
Czechia	80	21%	0.4%	2%	0.03	1.6
Denmark	54	19%	0.4%	2%	0.03	1.5
Estonia	1	1%	0.0%	0%	0.00	0.1
Finland	9	4%	0.1%	0%	0.01	0.3
France	402	14%	0.3%	1%	0.02	1.1
Germany	307	7%	0.2%	1%	0.01	0.6
Greece	247	83%	1.8%	7%	0.13	6.4
Hungary	115	38%	0.8%	3%	0.06	3.0
Ireland	78	21%	0.4%	2%	0.03	1.6
Italy	801	36%	0.8%	3%	0.06	2.8
Latvia	29	52%	1.1%	4%	0.08	4.1
Lithuania	43	46%	1.0%	4%	0.07	3.6
Luxembourg	15	23%	0.5%	2%	0.04	1.9
Malta	4	20%	0.4%	2%	0.03	1.6
Netherlands	59	6%	0.1%	1%	0.01	0.5
Poland	206	18%	0.4%	1%	0.03	1.4
Portugal	53	17%	0.4%	1%	0.03	1.4
Romania	665	133%	2.8%	11%	0.20	10.2
Slovakia	95	50%	1.1%	4%	0.08	3.9
Slovenia	5	7%	0.2%	1%	0.01	0.6
Spain	652	37%	0.8%	3%	0.06	2.9
Sweden	82	16%	0.3%	1%	0.02	1.3
United Kingdom	263	9%	0.2%	1%	0.01	0.7
EU 27 (w/o UK)	4352	24%	0.5%	2%	0.04	1.9
EU 28	4615	22%	0.5%	2%	0.04	1.9

Notes: Discounted value of future increases in GDP until 2100 due to the reform, expressed in billion Euro (PPP), as a percentage of current GDP, and as a percentage of discounted future GDP. 'GDP increase in year 2100' indicates by how much GDP in 2100 is higher due to the reform (in %). 'Long-run growth increase' refers to increase in annual growth rate (in percentage points) once the whole labor force has reached higher level of educational achievement. 'Increase in PISA score' refers to the ultimate increase in educational achievement due to the reform. See text for reform parameters.

gains shows that educational improvement could dramatically change the path of European economic development.

Europe has rightfully highlighted the importance of improving education across the EU. As the European Commission has emphasized, 'A crucial part of the Europe 2020 agenda for smart, sustainable and inclusive growth is bolstering education and training.'[15] With this in mind, the European Commission has set a variety of goals – goals that can be analyzed directly. This study has taken scientific evidence about the relationship between achievement and economic growth to provide quantitative estimates of economic impacts from various feasible educational improvements.

Using the historical relationship of growth and educational achievement, we project the aggregate economic results of improvements in achievement. We consider a range of possible changes that implicitly reflect more or less ambitious reform programs. As is obvious, broad-based reforms have larger economic impacts compared to reforms affecting relatively small portions of the student population. Of course, the more limited improvements targeted only at sub-groups of the overall student population may also be achieved at a lower cost and political effort compared to system-wide improvements of all students and schools.

The projections incorporate the dynamics of educational reform – that it takes time to adjust educational policies and programs, that student outcomes take added time to appear, and that the economy will only adjust when the new, highly-skilled workers become a noticeable proportion of the workforce. These dynamics imply that the economic gains of improvement take some time to

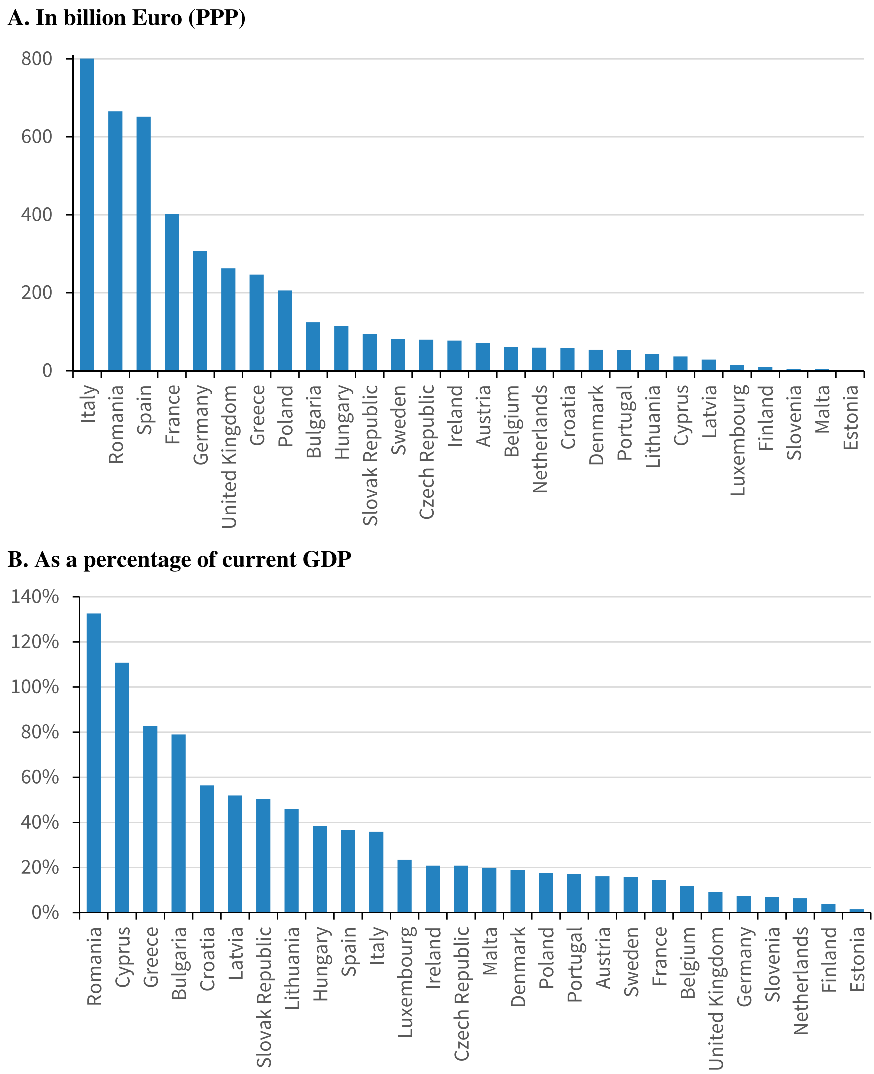

Figure 5. Effect on GDP of Scenario 4: Increasing top performance. A. In billion Euro (PPP); B. As a percentage of current GDP. Notes: Discounted value of future increases in GDP until 2100 due to the reform, expressed in billion Euro (PPP) and as a percentage of current GDP. See Table 4 for details.

be realized. To allow for the timing of growth effects, all estimates are calculated in present value terms that give today's monetary equivalent of future economic gains across the remainder of the century. In doing this, gains in the near term are weighted more heavily than gains later on using a three percent discount rate.

Table 5 summarizes the results of projections of four educational improvement scenarios. The first scenario considers an increase in student achievement of 25 points on the PISA scale (one-quarter of a standard deviation). While challenging, Portugal, Poland, and Germany have already demonstrated that such gains are feasible. If all EU countries met this goal within 15 years, the aggregate impact on the EU would be faster economic growth (by 0.5 percent annually) in the long run, and this would add GDP over the status quo of €71 trillion. This amounts to an aggregate EU gain of almost 3½ times current levels of GDP and an average GDP that is seven percent higher for the remainder of the century.

Table 5. The economic benefits of improving educational achievement in the European Union.

Policy scenarios	Present value of reform (bn €)	In % of current GDP	In % of discounted future GDP
1. Increasing average performance (25 points)	71,027	340%	7.3%
2. Achieving universal basic skills	37,898	188%	3.9%
At most 15 percent low achievers	*5223*	*25%*	*0.5%*
3. Enhancing skills of early school leavers	7097	34%	0.7%
At most 10 percent early leavers	*1144*	*6%*	*0.1%*
4. Increasing top performance	4615	22%	0.5%

Notes: Present value of future increases in GDP of EU 28 countries until 2100 due to respective reforms, expressed in billion Euro (PPP), as a percentage of current GDP, and as a percentage of discounted future GDP. See text for reform parameters.

The other scenarios reflect varying policy approaches. The second scenario brings all low-performing students up to the basic skill requirements for competing in today's economy (taken to be level 2 on the PISA tests). Achieving this goal would boost average GDP over the twenty-first Century by nearly four percent with countries facing more low-skilled students obtaining proportionately larger improvements in their future economic outcomes. A policy that would not bring all students up to basic skills, but only reduce low achievement to 15 percent in each country (mirroring the ET 2020 goal), would have only about one-seventh the aggregate impact.

The third scenario is derived from the goal of ET 2020 calling for a reduction in early school leaving to no more than 10 percent in each EU country. Enhancing the skills of all potential early school leavers is projected to raise average GDP by 0.7 percent. But just reaching the 10 percent benchmark would have considerably less impact (0.1 percent) since only 11 Member States currently have more than 10 percent early school leavers.

The fourth scenario considers expanding the top end of the performance distribution. It ensures that at least 15 percent of students in each country achieve level 5 on the PISA test. While this takes limited adjustment for the top-performing countries, it represents a substantial increase in EU countries that are starting at a performance deficit. In aggregate, average GDP would be 0.5 percent higher over the remainder of the century.

These projections are done one country at a time. Of course, with the significant mobility of individuals across EU labor markets, these policies can have immediate spillovers to other countries.

A sidelight of these projections is that apparently modest acknowledgement contained in the EU goals of current challenges to reaching all disadvantaged students – ones allowing some incomplete education of the population – have very large economic costs. The gains in well-being are obviously significantly reduced for the individuals who are no longer covered in the skill improvement. But the costs also extend to the overall economy through the reduction in skills of the future workforce that follow allowing discretion in the form of partial fulfillment of educational goals.

Addressing exactly how any country should go about improving their schools goes beyond what we can do here. These questions have been extensively investigated elsewhere – and are the subject of continuing study.[16] There are, however, a few top-level conclusions that we draw from the existing analyses.

First, while the discussion of education policy is invariably couched in terms of 'investing in education,' successful improvement requires much more than just putting added resources into the schools. While this issue has received an enormous amount of research attention, a simple look at increases in spending on schools and changes in student achievement shows that there is essentially no relationship between resource investments and changes in student achievement across countries (e.g. Hanushek and Woessmann (2015a)). This does not say that money never has an impact on student achievement. Nor does it say that money cannot have an impact. It does say that money alone does not lead consistently to higher performance. It matters how any resources are used.

Second, while there have been extensive discussions of proposals to adopt the programs and policies of some subset of countries that are doing well on international tests, there is limited evidence that this approach will be successful. It is extraordinarily difficult to pinpoint exactly why individual countries do as well as they do, because there are many country policies simultaneously at play; because the separate country policies are imbedded in a variety of historical, societal, and cultural differences; and because both the demands and capacities of educational systems differ across countries.

Third, while more limited in application, the use of incentives linked to student outcomes appears to be a more universally successful approach. By rewarding people and programs that demonstrate successful improvements in learning, resources can be channeled to places where they are demonstrably productive. This concept seems particularly appropriate for the interactions between finance ministries – which control much of educational funding – and education ministries – which control much of what happens in schools.

Education reform is challenging, because it takes time to see results and because it almost certainly requires changes from current policies and programs. While there may well be costs involved in reaching the achievement gains modeled here, the large benefits of improved achievement that we find constitute a strong incentive to find actions that work at a reasonable cost. Given the time necessary to change policies and programs and the time that passes before results are clearly seen, it is often compelling to delay actions – recognizing that outcome changes may considerably lag the actual costs of change. Our results underscore the societal costs of delay.

Notes

1. We use reaching level 2 of PISA as a threshold of low achievement. Appendix Table A4 (see Supplementary material) provides a description of the skills that define the various levels.
2. This section draws on Hanushek and Woessmann (2015b, 2020).
3. See Aghion and Howitt (2009) for a textbook introduction.
4. Initial GDP is included to allow for 'catch-up growth,' where individual countries that start behind have an opportunity to employ the technologies and production processes introduced by the leading economies. Thus, countries starting behind can growth faster than those who start ahead, because the leaders must invent new, more productive ways to proceed.
5. 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.
6. 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.
7. Earlier studies using a similar model framework applied to other policy scenarios include Hanushek and Woessmann (2011b, 2012b, 2015b). Hanushek, Ruhose, and Woessmann (2017a, 2017b) provide similar growth analyses and projections for US states. Hanushek and Woessmann (2011b) also provide projections with alternative parameter assumptions for the achievement-growth nexus. These projections provide evidence on the range of estimates obtained when assuming alternative growth relationships.
8. Appendix Table A2 (see Supplementary material) shows each country's performance on the PISA test, as well as other descriptive statistics on achievement, early school leaving, and GDP. While there are alternatives to the PISA test, PISA is the only test covering all EU Member States. Furthermore, performance on PISA is very closely correlated with performance on the Trends in International Mathematics and Science Study (TIMSS) across the 28 countries participating in both tests (correlation of 0.944 in math and 0.930 in science, see Woessmann (2016)). This is reassuring because TIMSS takes a substantially different perspective for its test construction.
9. Some recent investigations of scores on international assessments have focused on the reliability of these low-stakes tests, in particular highlighting differential effort levels of students across countries (see, for example, Borghans and Schils (2012); Balart, Oosterveen, and Webbink (2018); Akyol, Krishna, and Wang (2018); Zamarro, Hitt, and Mendez (2019); Gneezy et al. (2019)). The growth analyses described above indicate that these tests do indeed capture meaningful skill aspects of the student populations in different countries. To the extent that they partly reflect effort differences, the analyses of the international tests should be interpreted as reduced-form effects of the measured cognitive skills combined with the correlated noncognitive skills (see Hanushek and Woessmann (2008)). Note also that other analysis that experimentally investigated test motivation effects in a short form of the PISA test did not find significant effects of informational feedback, grading, or

performance-contingent financial rewards on intended effort, actual effort, or test performance (Baumert and Demmrich 2001). Another potentially biasing effect on international comparisons is non-response (Durrant and Schnepf 2018). However, Hanushek and Woessmann (2011c) show that differences in non-response across countries, while relevant for the international rankings, do not affect the results of the growth regressions underlying our projections.

10. A standard value of the social discount rate used in long-term projections on the sustainability of pension systems and public finance is 3 percent (e.g. Börsch-Supan (2000); Hagist et al. (2005)), a precedent that is followed here. As a practical value for the social discount rate in cost-benefit analysis (derived from an optimal growth rate model), Moore et al. (2004) suggest using a time-declining scale of discount rates for intergenerational projects that do not crowd out private investment, starting with 3.5 percent for years 0–50, 2.5 percent for years 50–100, 1.5 percent for years 100–200, 0.5 percent for years 200–300, and 0 percent years over 300. (The proper starting value is actually 3.3 percent based on the parameter values they assume for the growth rate in per capita consumption (2.3 percent), the social marginal utility of consumption with respect to per capita consumption (1), and the utility discount rate (1 percent)). By contrast, the influential Stern Review report that estimates the cost of climate change uses a discount rate of only 1.4 percent, thereby giving a much higher value to future costs and benefits (Stern 2007).
11. All tables also report aggregate values for the EU 27 without the United Kingdom.
12. The OECD (2016) sets level 2 to reaching at least 420 PISA points in math and 410 points in science. The conceptual differences in what students should know at different proficiency levels for mathematics is found in Appendix Table A4 (see Supplementary material).
13. Note that this is different modeling students who are not enrolled in school at age 14–15 – an issue particularly relevant in many developing countries. The difference is that students can be enrolled at age 15 but not successfully graduate from high school. In fact, in all EU 28 countries except one, the early school leaving rate as measured by the EU is larger than the share of non-enrolled 15-year-olds as measured in the PISA population (OECD 2016, Table A2.1). Enrollment at age 15 is necessary for PISA participation, and thus comes into the analysis of growth and of projected changes.
14. The boundary for level 5 is set at 607 in math and 633 in science (OECD 2016). See Appendix Table A4 (Supplementary material) for a description of the skills involved in level 5 for math.
15. https://ec.europa.eu/education/policy/strategic-framework/et-monitor_en [accessed 9/6/2019].
16. See, e.g. Hanushek (2002), Hanushek and Woessmann (2011a, 2015a), and Woessmann (2003, 2016).

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